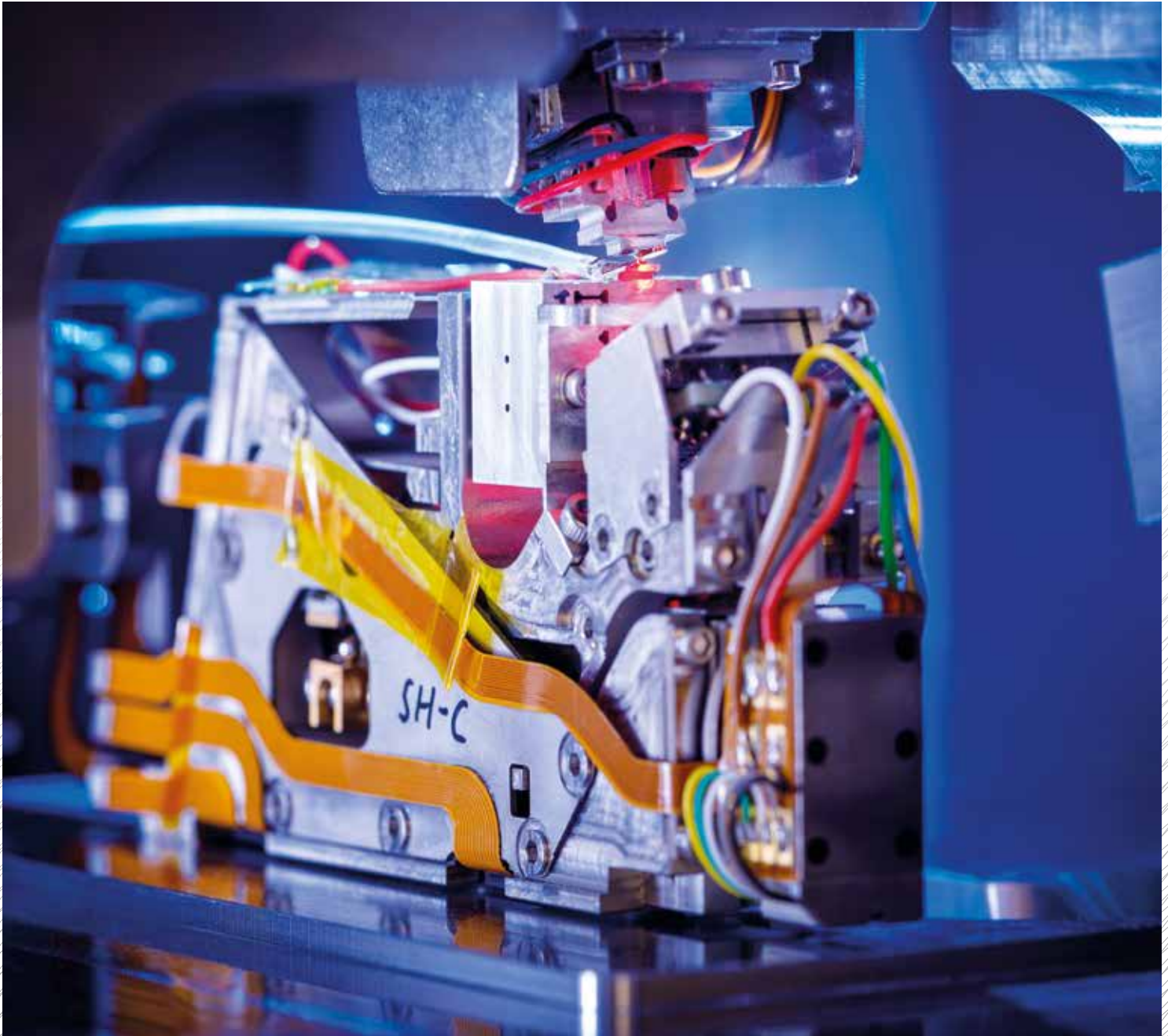


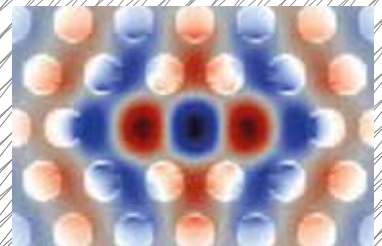
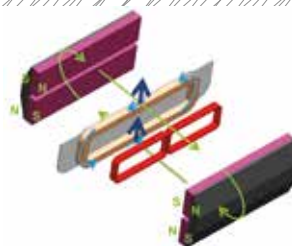
# DSPE MIKRONIEK

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PROFESSIONAL JOURNAL ON **PRECISION ENGINEERING**



- **THEME: PRECISION MECHATRONICS** ■ **DSPE CONFERENCE 2018 CATALOGUE**
- **EUSPEN CONFERENCE REPORT** ■ **SYSTEMS ENGINEERING FOR HIGH-END R&D**



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The main cover photo (featuring a miniaturised AFM scan head below a cantilever exchange unit) is courtesy of Rogier Bos/TNO. See the abstract for the DSPE Conference 2018 (page 16 ff) on page 27.

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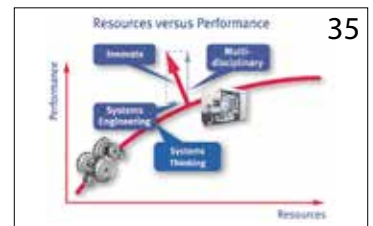
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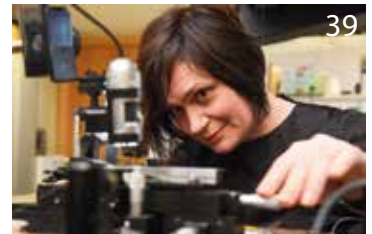
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# STATUS QUO VS **BIG DREAMS**

After our well-deserved summer holidays it will be high time for the 4th edition of the DSPE Conference on Precision Mechatronics. During two days with an overnight stay we share insights and strengthen our network. For our precision engineering community, accustomed to close collaboration and open communication, it may seem a 'normal' thing to continue what was once started by Philips CFT – the conference being just one fine example of this – and perhaps we are no longer even aware of the special biotope we live in and the position we have in the international scene.

When at a conference, such as euspen's annual event, international colleagues make you aware of this by expressing a mix of respect and jealousy when talking about the achievements of our small country in the field of precision engineering and the special characteristics of our community. Many times I have heard comments like:

- "Netherlands Inc."
- "Acting together and granting each other part of the success."
- "What a huge Dutch representation at the euspen Conference."
- "How come you Dutch guys take care of three of the five tutorials?"
- "You all seem to know one another."

To be honest, I think that in part this is just perception (fed by presentation), but to some extent these observations are justified. Here Philips has played an enormous role, not only emanating from all of its industrial activities, which nowadays still flourish under the Philips and other brand names, but also from the mindset of cooperation and sharing insights it has nurtured over the years. The DSPE Conference is an exponent of this mindset: sharing insights, strengthening our network and in this way contributing to a wider utilisation of the community's capabilities and competences and their better positioning in the global market.

However, pride comes before the fall. Should we be content with the status quo, i.e. doing well within Europe and hearing people say they envy our precision engineering community, or should we rather look at what is happening in China? Because once an item, e.g. self-reliance regarding core technologies, has been put on the Chinese agenda, they start working on it with great speed, and especially huge numbers of people and resources. Is that not the real standard we have to compete against? Therefore, should we next time maybe not register for a conference in an ancient European city but travel to China instead?

On the other hand, the size of a country is not the only yardstick. As Darwin already observed, survival of the fittest is not about size or strength, but about adaptability. Translated into the industrial economic setting, this means that we must cherish the enormous successes of ASML, Philips, NXP, VDL and others, and at the same time pursue our own big dreams to realise new successes.

Fortunately, we can boast of many examples of enterprising precision engineers. At Eindhoven Medical Robotics, under the leadership of Maarten Steinbuch, a new medical robot industry with hundreds of millions of sales is being dreamed up. Dutch United Instruments (a TNO-Demcon joint venture) is working on a state-of-the-art measuring machine for absolute form metrology of aspherical and freeform optical surfaces. Additive Industries, started just six years ago, has grown to be an established equipment manufacturer for industrial metal additive manufacturing systems. And Luxexcel, the only company in the world capable of 3D printing ophthalmic specialty lenses, has already reached the size of a scale-up. These are just a few examples and I am convinced our community holds all the ingredients for a bright future: knowledge, cooperation and entrepreneurship.

*Adrian Rankers*

*Managing director Mechatronics Academy, DSPE board member (in charge of the DSPE Conference)*  
*adrian.rankers@mechatronics-academy.nl*

P.S. My advice would be to be active in the DSPE community, maintain the euspen and ASPE networks and on top of that do some technology scouting in Asia.





# A PARTICULAR PICK & PLACE PLATFORM

In close cooperation with NXP Semiconductors and Sioux CCM, Nexperia ITEC has developed a high-speed RFID die bonder with unrivalled quality and speed, enabling low-cost RFID label production. The high-speed and accurate web handling module and the optics modules for quality and alignment inspections are the result of an intensive collaboration, focused on choosing the right design principles at the right cost.

THIJS KNIKNIE, RAYMOND ROSMALEN, PATRICK HOUBEN AND RONALD PLAK

The RFID (radio frequency identification) market is a particularly interesting growth market for semiconductor assembly. Several sources [1] [2] indicate that the RFID market is growing with double digit percentages in the coming decade, especially in passive UHF RFID tags for retail, tickets and logistics. Market analysts [1] [2] estimate the RFID market to grow beyond 47 B\$ in 2027, while in 2017 12 B\$ has been reported.

## RFID technology

A passive UHF RFID tag consists of a plastic or paper substrate (in industry called the 'web'), laminated with an antenna, and a semiconductor device (the 'die') that carries product information and connects to a reader. The die is glued on the web in a 'die-bonding' process, where glue is applied and the die is pressed onto the antenna. Although highly depending on the type of glue, generally a thermo-compression step follows to cure the glue and ensure a good conductive bond with the antenna. The antennas are laminated into a wide variety of products by so-called converter equipment. Examples of RFID tags and labels are shown in Figure 1.

## Platform

Competing with printed barcode labels and QR codes means that the operational and material costs for passive RFID tags must be extremely low. The fully functional RFID tag or label consists of a semiconductor device, adhesive, plastic and paper, so the drive of low-cost manufacturing is evident. A combination of the smallest semiconductor in the market with low-cost antenna designs and the lowest cost of ownership for assembly of the product has resulted in the cost breakthrough that enables the RFID market growth. The challenge for die bonding is that the small contact pitch in combination with the inaccurate paper or plastic antenna material requires accurate alignment and placement.

Recently, Nexperia ITEC has released its Die Bond Web Glue (DBWG) platform for RFID production. The DBWG model is a specially developed pick & place platform that is integrated in the BW Bielomatik TagLiner RFID by BW Papersystems, a division of Barry-Wehmiller, which is a global leader in packaging, labeling and converting equipment. The highlights of the design will be presented below, as far as confidentiality allows.

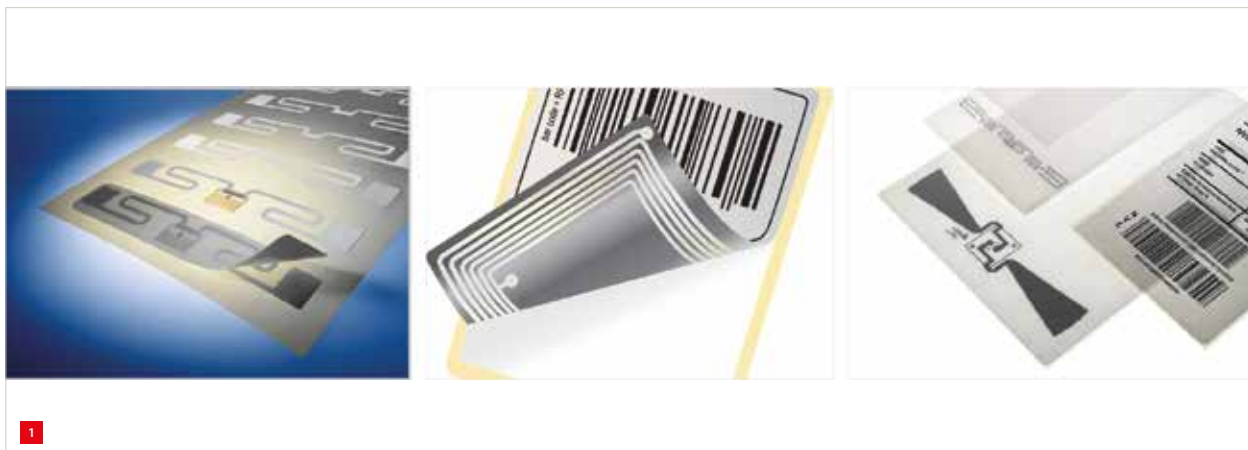
1 Typical RFID tag designs. (Source: Barry-Wehmiller)

## AUTHORS' NOTE

Thijs Kniknie (principal mechatronics engineer), Raymond Rosmalen (principal software engineer) and Patrick Houben (principal mechanical engineer) all work at Nexperia ITEC in Nijmegen, the Netherlands. Ronald Plak is a system architect mechanics at Sioux CCM in Nuenen, the Netherlands.

Part of the work described here will be presented at the DSPE Conference on Precision Mechatronics 2018 (see the programme on page 16 ff).

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1

The system is capable of handling the low-cost web designs with extremely high output speeds and with 100% quality control. In consecutive steps, the web is fed through the:

- Unwinding station;
- Glue station for dispensing adhesive;
- Bond station for attaching the die (or chip) to the adhesive;
- Thermocompression station for ultrafast curing of the adhesive;
- Winding station.

See Figure 2 for an overview of the process steps.

Production tolerances on the web material are too large for 'blind' placement of adhesive and die. It is required to align the web to each process position within tenths of microns, while web tolerances can go up to a few hundred micrometers. Because each process position requires its own alignment step, they all take place on a separate module. This modular approach also has the advantage that changes in the processes do not affect each other, so future technologies can be integrated in dedicated development projects.

Yield and quality requirements demand 100% quality control at each process step. A functional test with a high-speed RFID reader before winding the web ensures ppm (parts-per-million) level quality for the customer. Figure 3 shows a schematic overview of the DBWG system realised by Nexperia ITEC. The dispensing, chip placing (die-attach) and curing (thermocompression) processes require (as shown in Figure 2) are performed on separate web-handling modules, each with their own camera systems.

### Web handling module

Experience of Sioux CCM in web (e.g. foil and paper substrate) handling in the solar and printing industry provided a good technological base for handling flexible substrate in a continuous flow. One of the main limiting factors of positioning accuracy in web-handling systems is

the relatively low stiffness of the web materials. Sioux CCM previously tackled this challenge by creating a transport system called Vexar in which the web is temporarily fixated with vacuum to a steel belt making it possible to position webs within  $\pm 5 \mu\text{m}$  over several meters. Another system developed by Sioux CCM with similar technology is the Generic Substrate Carrier [3].

With this system high accuracies can be achieved because the web temporarily gains the relatively high stiffness of the steel carrier making it robust for force variations on the web. Such a steel belt transport system however is not suitable in the RFID case, because synchronised motion is required for the die-bonding process. In addition, the web in this application is not moving in a straight line as in common web-handling systems but must be aligned in transport and lateral direction each production step to compensate for the position variations of the antennas on the web.

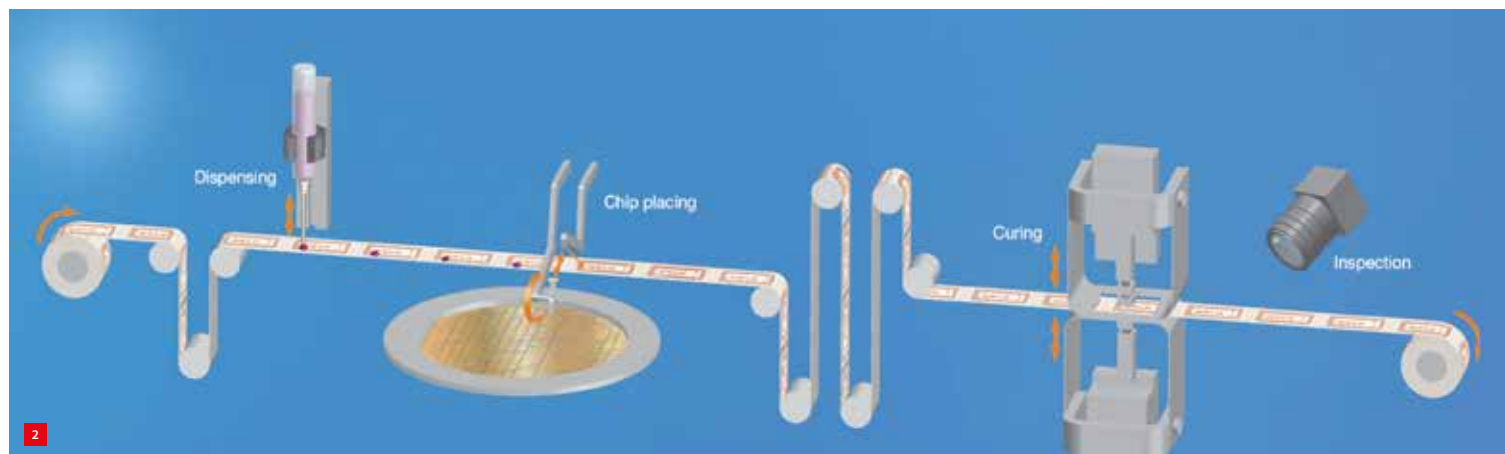
The solution was to design a rotating drum combined with axial motion capability. Automatic alignment of the web relative to the process positions is done with optical inspection of markers on the web. The result of each inspection is a dedicated setpoint for the X and Y position of the web. Figure 4 shows the global design of the web-handling module.

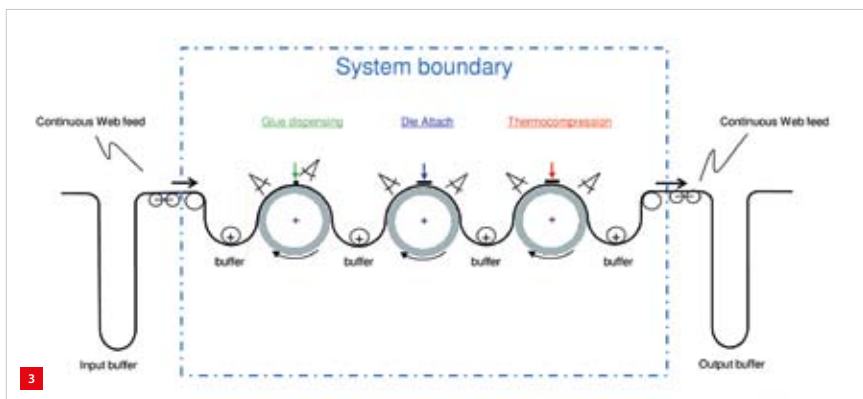
The web-handling module consists of three elements:

1. Rotational ('X') drive for positioning the web in feed direction;
2. Axial ('Y') drive for aligning the web in axial direction;
3. Web-steering unit that keeps the web on tension and on track.

The web is transported and aligned to the next product position for dispense, die-attach and thermocompression processes. During the process, movement of the web is not allowed. The output requirements demand web acceleration up to  $100 \text{ m/s}^2$  and a velocity up to  $2 \text{ m/s}$ . The optimal drum design has sufficient structural and dynamic stiffness to enable position accuracy and minimised mass and inertia to comply with the limits of the motion control electronics.

**2** Schematic overview of the RFID die-bonding process. (Source: DELO Industrial Adhesives)





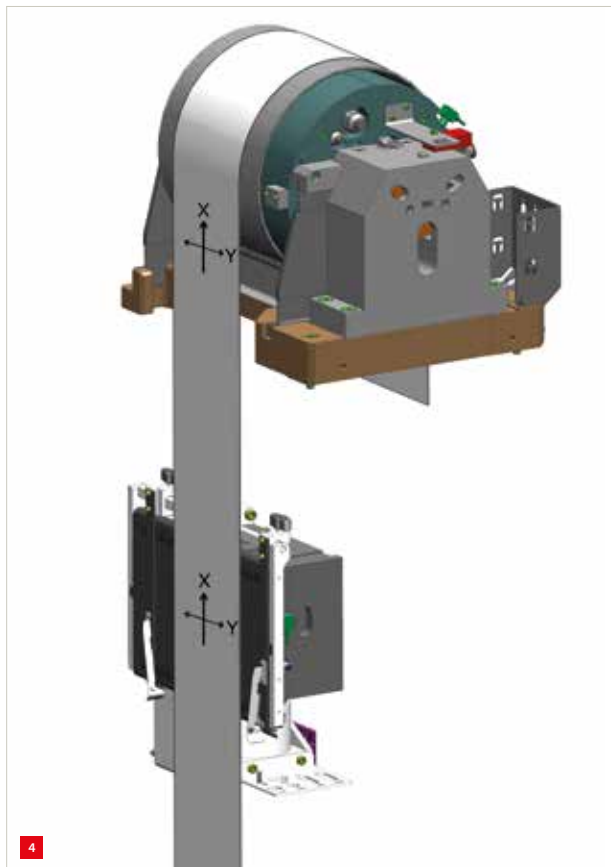
### Web steering

Web has the natural tendency to spiral off from drums due to small imperfections in roll-to-roll alignment, eccentricity and roundness. This effect must be countered with a web-steering mechanism. Since the web is fully constrained on the drum, the web steering must use the in-plane flexibility (i.e. bending) of the web before entering the drum surface. This gives the following risks:

- Lagging on the inside of the web curve → web moving off the drum.
- Overtensioning on the outside of the web curve → web rupture.
- Web wrinkle (buckling of web due to sheer stresses) → web damage.

3 Schematic layout of the DBWG die-bonder system. Each process has an inspection before and after the process position, each indicated schematically as 'eye'.

4 Drawing of the web-handling module. The X and Y drive (upper part) align the web, and the web-steering unit (lower part) realises a constant tension and tracking force of the web infeed.



## Partners

Nexperia is a dedicated global leader in Discretes, Logic and MOSFETs devices, with 11,000 employees across Asia, Europe and the US. Originally part of Philips and then a business unit of NXP Semiconductors, Nexperia became an independent company in the beginning of 2017. The focus remains on efficiency, producing consistently reliable semiconductor components at high volume: 85 billion annually. Nexperia is a specialist in ultra-compact packages and a leader in the automotive industry.

At Nexperia, the Industrial Technology & Engineering Center (ITEC) develops and realises semiconductor assembly, test, inspection and automation solutions. While situated in Nexperia headquarters in Nijmegen, the Netherlands, ITEC cooperates with knowledge partners around the country to innovate in the fields of design & control, imaging, data intelligence and process technology. In close cooperation with the package innovation departments of Nexperia, ITEC can tailor the equipment to the lowest cost of ownership for semiconductor assembly and test.

Sioux CCM (part of Sioux Group) has all the expertise in-house to contribute to high-tech products and production systems. Sioux's strength lies in the combination of high-quality competences in software, mechanics, optics, physics, mechatronics, electronics, mathematics and final assembly & testing. With more than 600 engineers Sioux supports or forms the R&D department of leading high-tech companies and can take responsibility from the concept phase to serial production. Sioux wants to build innovative solutions that can contribute to a society that is smarter, safer, healthier, more enjoyable and more sustainable.

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Web steering only works properly if there is continuous traction between web and drum. Therefore, the web supplied to the drum must be continuously tensioned. If a part of the web is tensionless then the web will not align perpendicular to the rotation axis but will keep having a non-zero angle relative to the roll, making the web track off the roller. In most web-handling systems web steering and tensioning is done with steering rolls, but these are not suitable in this application. Each roll would require its own drive system, otherwise the force required to accelerate the rolls would rupture the web. This would result in a very complex and costly system that is difficult to control.



The theory of web steering dates back to 1968, when John Jarvis Shelton derived basic equations for stress and forces on webs in his thesis [4]. Basically, when a web is under tension, Euler beam theory can be applied with varying boundary conditions, depending on the steering method (see Figure 5).

In case of using a steering roll, web rotation is constrained, introducing a bending moment on the web at the steering roll. The equations for stress and pretension force can be derived from a beam that is fixed at one end and has a simple support at the other end. When steering is done with a friction brake, the equations follow cantilever beam theory (one end fixed, the other end free). The stress and required pretension force are significantly lower for this situation. See Figure 6 for the model and the equations.

The web-steering unit that has been developed, is placed just before the position where the web enters the drum. It consists of a vacuum friction plate to tension the web combined with leafspring elements that press against the web edges. The leafspring elements create lateral steering forces when the web tends to move away, resulting in the required bending moment to guide the web back to the centre position on the drum. The risk of web wrinkling is minimised since the web is constrained onto the friction

5 Equations for deflection and stress in a beam for two boundary conditions. With beam deflection  $f$ , load force  $F$  at the beam end, beam length  $L$ , Young's modulus  $E$ , area moment of inertia  $I$ , stress  $\sigma$  in the beam, bending moment  $M$  and distance from the neutral line  $e$ .

6 Model of web steering based on Euler beam theory for a steering roll (left) and a friction plate (right). With web displacement  $u$ , Young's modulus  $E$ , web width  $W$ , web length between steering elements  $L$ , web thickness  $t$  and web entry angle  $\theta$ .

7 Simplified Stribeck curve. Nonlinear friction occurs at relatively low speeds, depending on material properties and surface finish.

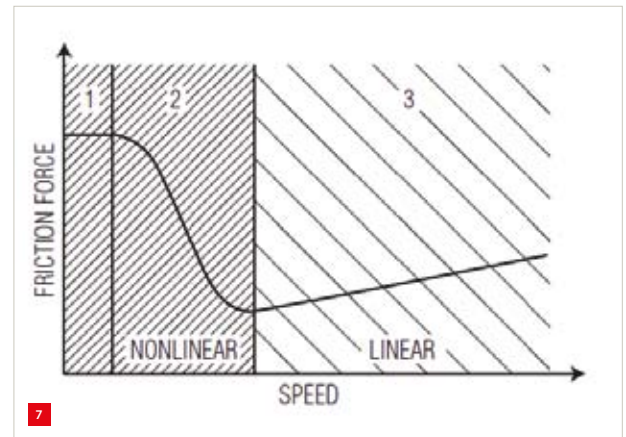


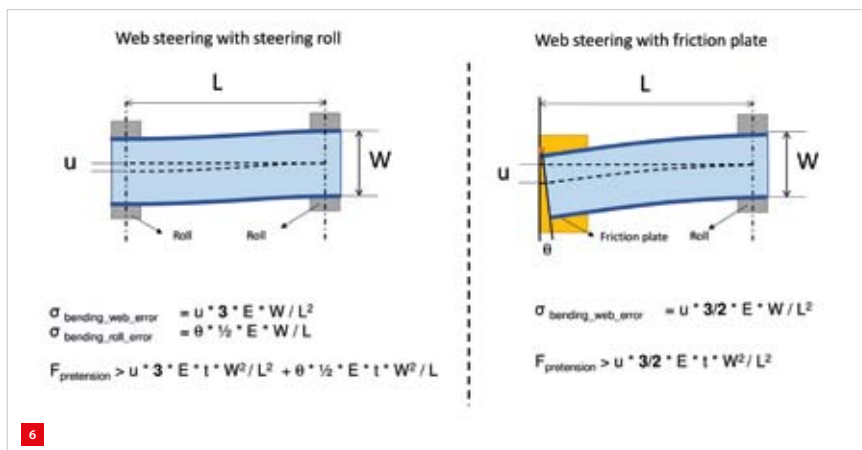
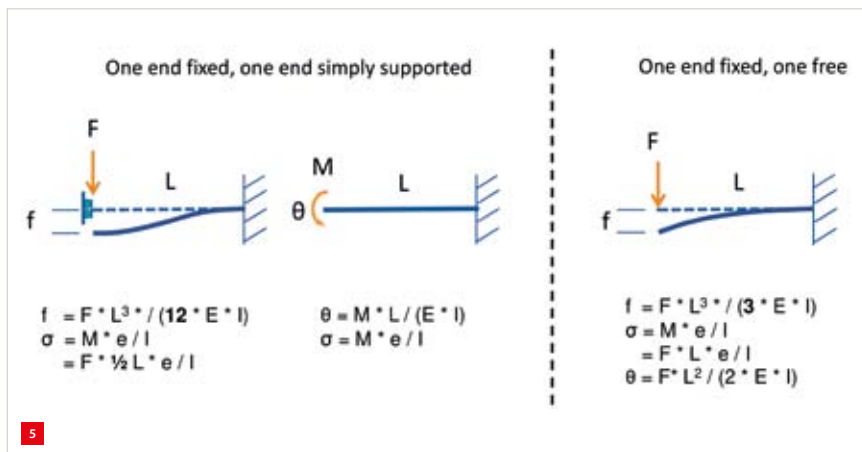
plate. Micrometer positioning performance is secured by keeping the friction force of the web on the vacuum plate constant. This is achieved by always having a sufficiently high relative movement with a constant speed of the friction plate compared to the web, creating an air film between the web and the plate. The friction force is always in the linear area (see Figure 7), making the disturbances towards the X and Y drives of the web handler constant and predictable.

## High-speed vision for alignment and quality

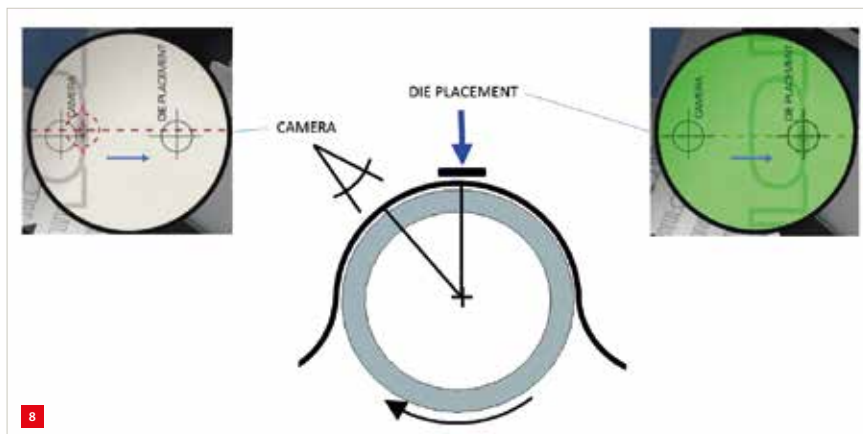
Once the web is fixed on the drum, alignment can be controlled accurately. The antennas on the web have a fixed pitch and with the chosen concept it is assured that more than one antenna is constrained to the drum. This enables web alignment in parallel with the process (glue, bond or cure). Figure 8 shows an example of alignment during the die-placement (die-bond) process.

A camera inspects the web antenna on a fixed position before the die-bond position. The position measurement is done based on the circularly shaped fiducials on the web. Reliable performance is achieved by applying basic blob analysis algorithms. When the antenna is transported to the die-bond position, the measured offsets can be corrected in the setpoint, thus avoiding a separate correction setpoint, which would result in speed loss.

To enable high throughput of the web bonder, the machine vision must be operating at high speed as well. The speed of a vision task can be divided into shutter time, image data transfer time and image processing time. A fast shutter time can be achieved via fast optics (high numerical aperture) and high-intensity illumination. The camera selection is based on sensor sensitivity and read-out speed including AOI (area of interest) support. The inspection algorithms run on a basic Windows PC motherboard and have been developed in house for high performance and speed, a.o. by minimising overhead (e.g. avoiding redundant interface layers or algorithm functionality).





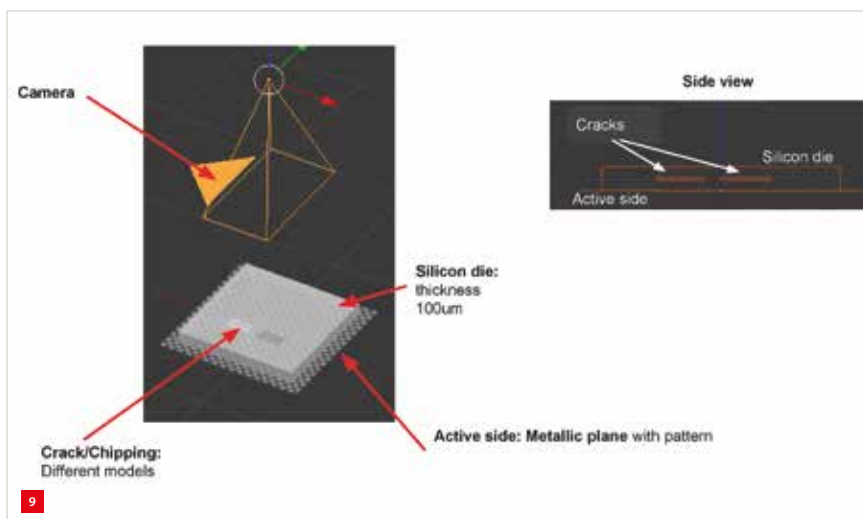


Quality inspections verify the input and output material (dies and lead frame) and the result of every executed process step (die pickup, glue dispense, die bond, glue cure). The optical systems are positioned after or directly at the process position. Inspection results are stored real time and are available online for easy monitoring of the system performance. In the RFID die bonder, available quality inspections on the silicon include frontside (pick-up), backside (attach) and sidewall inspections. Delamination, cracks and chip-outs can appear at every side of the silicon, so 100% inline '6-sided' inspection without speed loss is a crucial step forward in quality control.

## Near Infrared (NIR) inspection

A particularly interesting way to improve output quality even further is to look for defects inside the silicon, using near-infrared (NIR) technology. To define the optimal set-up for inline integration of the NIR inspection, an explorative study has been performed by Sioux CCM, mathematical engineering firm Sioux LIME and Nexperia. This study included a simulation based on a 3D model for semiconductor materials and crack definition. The

- 8 Web alignment strategy. The product position is inspected before moving to the process position, making it possible to generate a dedicated setpoint to directly move the web to an accurate position.
- 9 NIR ray-tracing model. On a metallic plane, a silicon body is modelled with cracks inside the material. A camera above the model gathers reflected rays of a NIR source.
- 10 NIR test results on FIB cuts inside the silicon. The upper image made with scanning electron microscopy (SEM) shows the cuts, the lower image shows the results of NIR inspection. The area below has been covered for confidentiality reasons.



3D model was created using Blender, an open-source software package. The simulation was performed using LuxCoreRender, a physical ray-tracer program. LuxCoreRender simulates the flow of light according to physical equations, thus producing realistic images of photographic quality. See Figure 9 for an overview of the ray-tracing model.

Sensitivity for silicon thickness, coatings, roughness, wavelength and doping were studied, as well as illumination sources and angle of incidence (direct and indirect). Using the results of the study the camera sensor could be selected.

The model results show the most important parameters for crack detection in different semiconductor materials, including applied coatings and laser marking. Based on the simulation results the hardware components for the NIR inspection set-up were selected. The realised set-up contains a NIR light source illuminating the backside of a die. Figure 10 shows test measurement results. Using focused ion beam (FIB) techniques, ‘cracks’ as small as 10  $\mu\text{m}$  width were created inside the silicon. With the NIR set-up these cracks were clearly visible as dark spots with sufficient contrast for automatic detection of defects using vision software. Seamless integration of the NIR option in the standard optics module of the TagLiner makes it possible to enable the next step in quality inspections.

## Conclusion

The BW Bielomatik TagLiner RFID has been successfully introduced at the launching customer. Figure 11 and 12 show two of the realised process stations.





**11** The Thermocompression station in the BW Bielomatik TagLiner RFID. Two sets of optics modules are placed before and after the thermocompression modules in the middle of the drum.



**12** Detail of the Bond (die-attach) station in the BW Bielomatik Tagliner RFID. A bond head places the silicon die on a plastic web with aluminium antenna pattern. In the front, the optics for quality inspection can be distinguished.

In a joint program with NXP Semiconductors, Sioux CCM and Sioux LIME, Nexperia has developed a breakthrough web-bonding technology with high output while complying with the semiconductor quality standards. Combining the experience in the printing industry for flexible webs with high-speed die-bonding technology has resulted in a cost-effective system to fuel the growth in RFID tags and labels for the coming years. ■

### REFERENCES

- [1] [www.futuremarketinsights.com/reports/rfid-market](http://www.futuremarketinsights.com/reports/rfid-market)
- [2] [www.idtechex.com/research/reports/rfid-forecasts-players-and-opportunities-2017-2027-000546.asp](http://www.idtechex.com/research/reports/rfid-forecasts-players-and-opportunities-2017-2027-000546.asp)
- [3] A.-J. Beltman, et al., "Improved ink registration through advanced steel belt steering", *Mikroniek* 53 (3), pp. 12-16, 2013.
- [4] J.J. Shelton, *Lateral dynamics of a moving web*, Oklahoma State University, 1968.





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# LIGHTWEIGHT LIFTING

## AUTHOR'S NOTE

Max van Lith graduated on the subject of this article at Eindhoven University of Technology (TU/e), the Netherlands. For this work he received a nomination for the 2017 Wim van der Hoek Award. As a Master of Science in mechanical engineering he currently works at Nobleo Technology in Eindhoven.

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A z-mechanism that achieves high cleanliness and highly reproducible motion is proposed for use in the wrist assembly of an in-vacuum wafer handler robot. The required 10 mm stroke is made by an elastic straight guide and contactless actuation. The proposed design has no friction, is backlash-free, and requires no lubrication. A Lorentz duo-motor has been designed for actuation of z and Rx. The application of a buckled leafspring to compensate for weight and stiffness, significantly decreases static actuation forces and heat production.

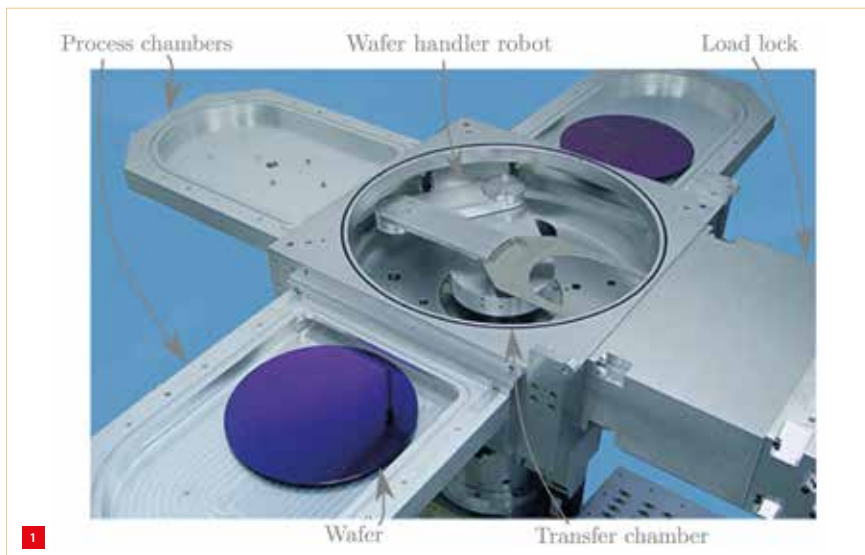
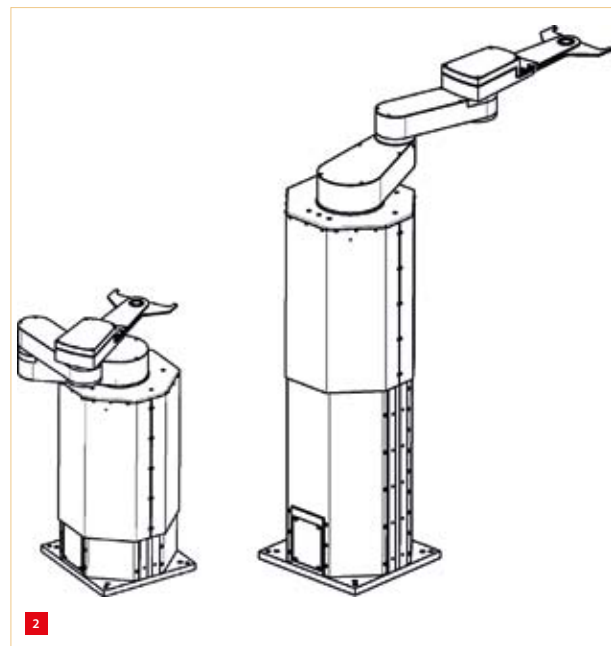
MAX VAN LITH

1 Photo of a typical cluster tool with a wafer handler robot in the central transfer chamber. (Adapted from [www.designworldonline.com/advanced-motion-controls-boost-wafer-handling-efficiency/](http://www.designworldonline.com/advanced-motion-controls-boost-wafer-handling-efficiency/), accessed 19-04-2017)

2 Example of a typical wafer handler robot, shown in two different orientations. The base column provides vertical (z) translation. On top of the base, three serial Rz joints called the shoulder, the elbow and the wrist provide radial and Rz movement. (Source: K. Mathia, Robotics for Electronics Manufacturing, Cambridge University Press, 2010)

Integrated circuits are manufactured in a layer-by-layer fashion on substrates such as silicon wafers. Multiple production steps require a clean environment and are often performed under vacuum conditions. Examples include layer deposition, etching, and photolithography. Cluster tools can provide the clean vacuum environment where these production steps can be carried out in separate process chambers. An example of a cluster tool is given in Figure 1.

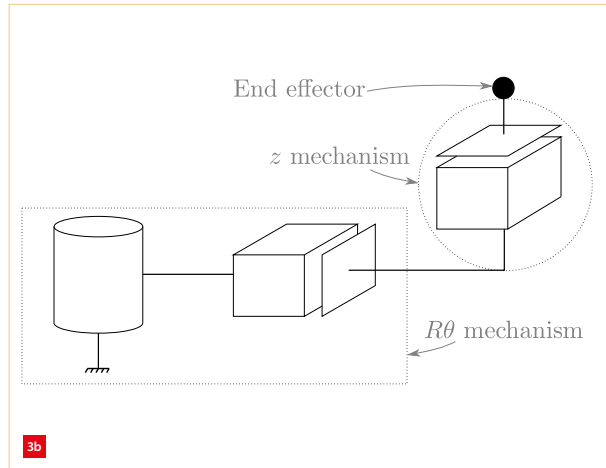
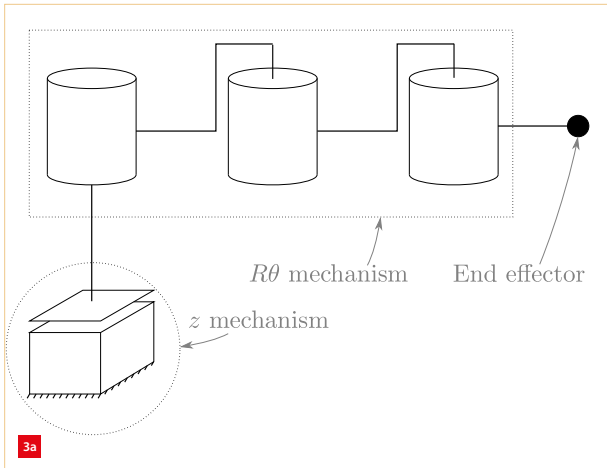
In Figure 1, a wafer handler robot is placed centrally in a transfer chamber. This robot transports wafers throughout the cluster tool. A typical kinematic design of a wafer handler robot has a z-mechanism as a base. The z-mechanism serves two purposes: indexing of a 'foup' (front opening unified pod, i.e., a 'wafer box'), and picking up and putting down wafers. Note that the proposed z-mechanism only takes care of the latter function. On top of the base z-mechanism, a SCARA-type robot takes care of radial and Rz movement, as depicted in Figure 2.



The robotic arm typically has three serial Rz joints, called the shoulder, the elbow and the wrist (Figure 3a). A wafer is transported by moving the SCARA underneath the wafer and subsequently lifting the entire SCARA 10 mm. The z-mechanism therefore has to carry a weight that is significantly larger than the weight of a wafer.

The TU/e Control Systems Technology group is currently collaborating with VDL ETG to improve on the design of wafer handler robots. Key requirements are high cleanliness (both particle and molecular) and minimising the amount of moving mass.



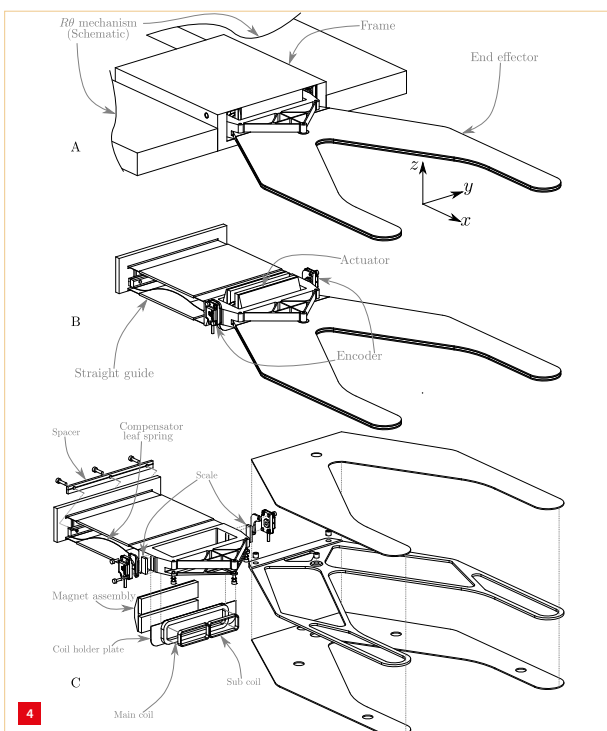


- 3 Schematics of the robot arm.
  - (a) Conventional design with three serial  $R\theta$  joints on top of a z-mechanism.
  - (b) New design with a z-mechanism on top of an  $R\theta (= R\theta)$  joint.
- 4 Overview of the proposed design, depicting the main components.
- 5 Cross-section along the X-Z plane of the z-mechanism, depicting the mechanism within the design volume (in red).

The purpose of this graduation project was to propose a design for a z-mechanism in the wrist assembly of the manipulator. This will decrease the z-mechanism's load from tens of kilogrammes to a few tenths of a kilogramme, allowing for better dynamic behaviour. A volume claim of  $150 \times 150 \times 36 \text{ mm}^3$  (x, y, z) was available for the z-mechanism.

### Design overview

The proposed design (Figure 3b shows a schematic) consists of the following components. A closed box-style frame provides the interface between the wafer handler robot and the z-mechanism. The frame also acts as the 'fixed world' for the magnet assembly of the actuator and the encoders, i.e. the magnet assembly and encoder are attached to the robot side.

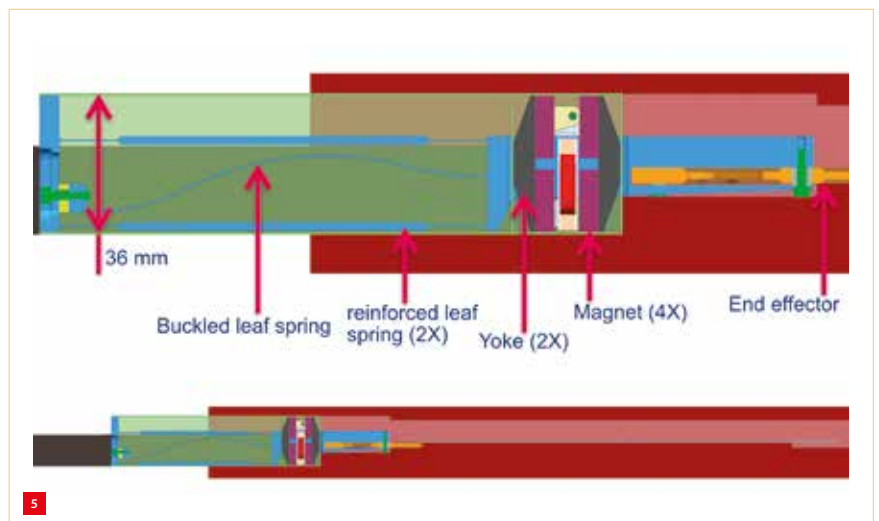


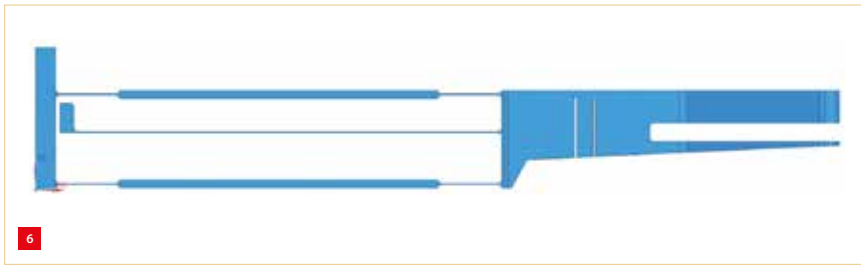
At the heart of the z-mechanism is a flexure-based parallelogram straight guide with stiffness and weight compensation. It is directly driven by a Lorentz duo-motor with moving coils and fixed magnets. Two encoders measure the z-position and the torsion along the x-axis of the straight guide. A two-pronged end-effector is attached to the front of the z-mechanism. This end-effector is made by gluing three pieces of aluminium oxide together. The result is a stiff and lightweight sandwich construction. An overview of the proposed design is displayed in Figure 4. A centre cross-section is presented in Figure 5.

### Straight guide:

#### Passively constraining degrees of freedom

A flexure-based parallelogram is used as a straight guide for both the motion of the coils and for the motion of the end-effector. The straight guide is made from a single block of Ti-6Al-4V by wire-EDM. This titanium alloy has a favourable combination of fatigue properties, high elastic modulus and low density. The elastic straight guide exhibits no backlash and no friction. This simplifies controller design and improves motion reproducibility.



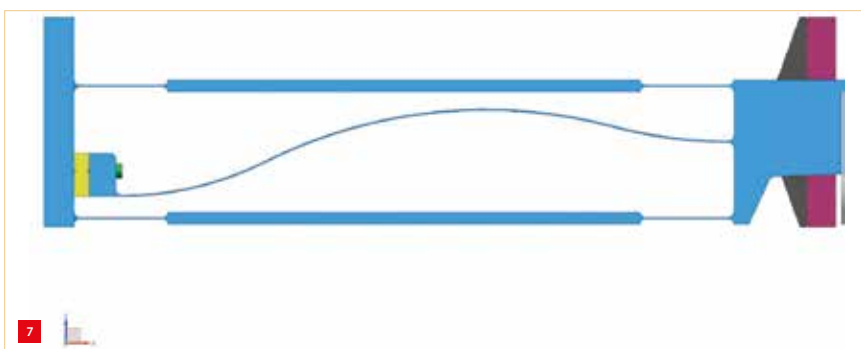


Moreover, flexures do not require lubrication and make no rolling, sliding or colliding contacts. These properties result in high cleanliness. A leafspring, called the compensator, will be cut from the same block of material, such that there is a monolithic connection to the moving part of the straight guide. By buckling this compensator, weight and stiffness in the guidance direction can be compensated for. A side view of the straight guide is given in Figure 6.

### Stiffness and weight compensation: Passively reducing control effort

A disadvantage of the flexure-based straight guide is the stiffness in the direction of motion. Moreover, the direct-drive Lorentz motor implies that the weight must be carried by the actuator as well. To minimise thermal issues in the vacuum environment, the actuation forces need to be as low as possible. A linear negative-stiffness spring is used to achieve this. The negative stiffness is chosen close to the parasitic (positive, linear) stiffness of the elastic parallelogram. The negative-stiffness spring is given a preload to function as weight compensation. To achieve the required negative stiffness, and the preload, a leafspring is buckled axially and placed within the parallelogram straight guide. Out-of-plane deflection of the buckled leafspring results in the desired properties.

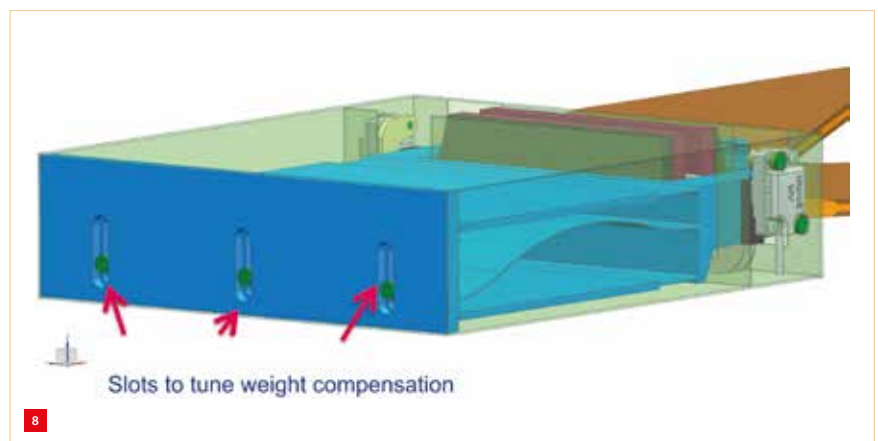
As previously mentioned, the buckled leafspring can be cut in one set-up from the same material as the parallelogram using wire-EDM. This is presented in Figure 7. Slots in the backplate of the straight guide can be used to adjust the preload of the negative-stiffness spring. This allows for the weight compensation to be tuned, thereby allowing for larger manufacturing tolerances of the flexures. The slots are shown in Figure 8.



6 Side view of the parallelogram straight guide and the central compensator spring. The coil holder plates of the actuator fit in the two vertical slots. The end-effector is attached in the horizontal slot.

7 Side view of the flexure-based parallelogram (reinforced leafsprings) with stiffness and weight compensator (buckled leafspring). The result is a straight guide with very low parasitic stiffness.

8 Backplate of the compensator, showing the slots that allow for adjustment of the negative-stiffness spring preload. The negative-stiffness spring preload functions as weight compensation.



### Actuation:

#### Actively controlling degrees of freedom

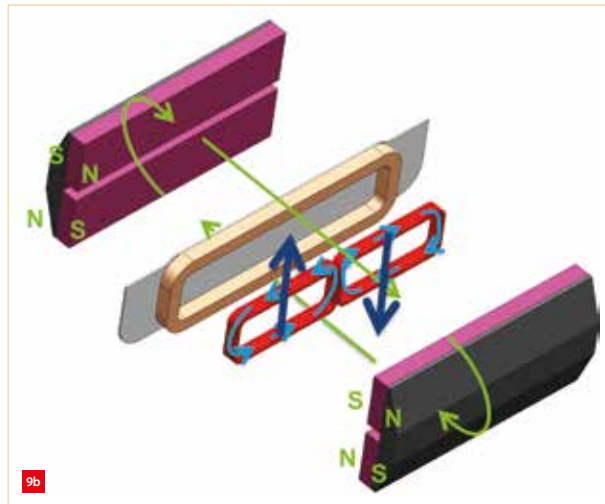
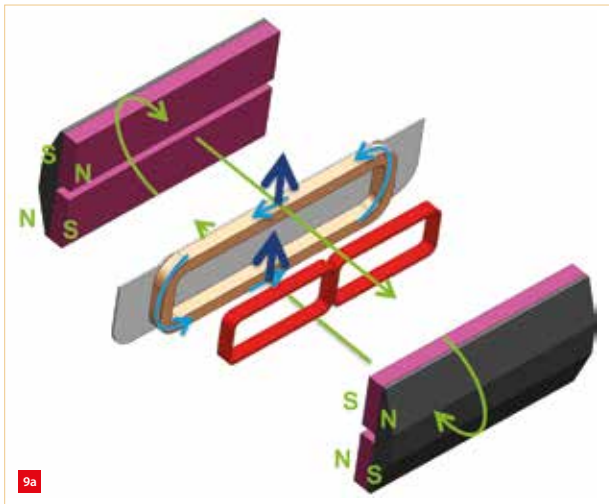
Actuation is achieved with a moving-coil Lorentz motor. This motor features two coils which are glued to ceramic coil holder plates. These plates are in turn glued in slots in the straight guide. The main coil actuates the z-position of the end effector. The sub coil is wound in a figure-of-8 shape, and fits in the main coil. With this figure-of-8 winding, a torque can be produced. This torque may be used to suppress torsional eigenmodes, along the length of the robotic arm (Rx). Figure 9 depicts the working principles of the actuator. By using two encoders, both z-position and Rx can be measured and actively controlled.

Vacuum environments are notorious for causing thermal problems. Therefore, the actuator was optimised towards efficiency. The Lorentz force produced in the coils scales with the product of magnetic flux density, current flowing through the coil and number of wires in a coil cross-section. The first step was to optimise the magnet and yoke thicknesses for maximum flux density through the coil cross-section within a given design volume. The coil was subsequently designed using commercially available, vacuum-compatible wires. For these wires, the maximum allowed current, flowing through a coil, in a vacuum, was retrieved from a catalogue. Together with the wire diameter and a given design volume for the coil cross-section, this made it possible to characterise the actuator specifications.

### Conclusion

Generally, wafer handler robots have SCARA-like kinematics where the z-translation is driven from the base of the robot. In a collaboration between VDL ETG and TU/e, new technologies for wafer handler robots are being researched. One new concept features a z-mechanism in the wrist assembly of the robot arm for the picking and placing of wafers. The z-mechanism has been designed to achieve high levels of cleanliness. Moreover, high stiffness and low mass allow for good dynamic behaviour and reproducible motion.





9 Exploded view of the Lorentz actuator. Magnets in purple, yoke in black, main coil in orange, sub coil in red, and coil holder plates in white. Green arrows indicate magnetic flux direction, light blue arrows indicate current flow direction and dark blue arrows indicate resulting Lorentz forces. (a) Main coil produces a net force in z-direction. (b) Sub coil produces a net torque in Rx-direction.

The bending stresses of the straight guide and the buckled leafspring remain well below the fatigue strength to achieve a life span of  $10^8$  cycles without intermittent maintenance. Within the constraints of this project no prototype was completed for validation. The ambition is to validate the

design in a follow-up project. Design topics for further consideration include the planning of the wire-EDM process for this challenging design including negative-stiffness leafsprings and the addition of range limiters to protect the fragile part during transport. ■

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# DSPE CONFERENCE 2018 – PROGRAMME

## “Precision Imagineering”

The fourth edition of the DSPE Conference on Precision Mechatronics will be held in Sint Michielsgestel, the Netherlands, on 4-5 September 2018. This year's theme 'Precision Imagineering' represents the combination of precision, imagination and engineering. An enterprise may start with a dream or 'imagination', but it takes 'engineering' skills in the broadest sense to actually transform an initial idea into a successful product, service or business.



When it comes to precision products, it is evident that mastery in great depth of the various aspects of precision engineering (design principles, dynamics, control, thermomechanics, contamination, ...) is required. But the development of modern mechatronic devices, such as IC equipment, electron microscopes, harvesting machines or surgical robots, also requires mastering the art of managing complexity by adopting a systems engineering approach and having a keen eye on the growing importance of software and the possibilities and challenges that new developments, such as artificial intelligence and deep learning, offer to the precision engineering community.

Hence, DSPE strives to extend the traditional core topics of the conference with a session about software and systems engineering aspects in the development of precision equipment. The conference will therefore be open to members of the SASG (System Architecture Study Group), besides the original target group, which



includes technologists, designers and architects in precision mechatronics, who, through their respective organisations, are connected to DSPE, the mechatronics contact groups MCG and MSKE, or selected companies and research/educational institutes.

In addition to paper and poster presentations and demos, the conference will provide the ideal setting for networking, technical discussion and sharing the enthusiasm of working in this challenging field. The programme is outlined on the next page and the following pages feature the abstracts of the papers and an overview of the posters and demos.

**1** The DSPE Conference 2018 venue, conference hotel De Ruwenberg in Sint Michielsgestel.

**2** Impressions of the 2016 conference, packed with demos, posters and papers. (Photos: Iris Wuijster)



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## Tuesday 4 September 2018

### Invited speakers

Precision Engineering in Art

*Joris Dik (Antonie van Leeuwenhoek Professor, Delft University of Technology)*

Advancing Precision in Additive Manufacturing

*John Taylor (Adjunct Professor Center for Precision Metrology, University of North Carolina at Charlotte)*

### SESSION 1: SYSTEM DESIGN 1

Unravelling the James Webb Space Telescope

*G. Aitink-Kroes, et al. (NOVA Optical Infrared Instrumentation Group)*

ASML Wafer Stage: The power of Mechatronics & Imagination

*Harry Cox (ASML)*

The Virtual Printer – Virtualization to the Extreme

*Eugen Schindler (Océ-Technologies)*

### SESSION 2: MODELLING & CONTROL

Impulsive control: High-precision positioning of systems with friction

*Dennis Bruijnen, et al. (Philips Innovation Services)*

Milli-Kelvin Temperature Control using a Local Fluid Stream Heater

*Björn Bukkems, et al. (MI-Partners, ASML, Thermo Fisher Scientific)*

Multi-body Modelling of High-Tech Mechatronic Systems with Flexible and Nonlinear Dynamics

*Dragan Kostić, et al. (ASM Center of Competency, Eindhoven University of Technology, University of Minnesota)*

### SESSION 3: NOVEL SYSTEMS

DigiScanner, a 3D scanner for orthodontists

*Hans Kuppens (Sioux CCM)*

Nano-precision multi-agent Maglev positioning platform

*Lukas Kramer, et al. (TNO, Department of Optomechatronics)*

In-vacuum linear stage with 30G acceleration capacity

*Jan Huang, et al. (ASML, Demcon)*

## Wednesday 5 September 2018

### Invited speaker

Printing of lenses – from imagination to imagineering

*Joost van Abeelen (COO, Luxexcel)*

### SESSION 4: MECHANICAL DESIGN

Self-alignment of kinematic couplings: effects of deformations

*Francesco Patti, et al. (VDL ETG)*

The characterization of recirculating ball bearings and their effect on mechatronic system performance

*Tim Groothuysen, et al. (MI-Partners)*

Improving Optical Performance of Multicomponent Optomechanical Systems through Topology Optimization

*Stijn Koppen, et al. (Delft University of Technology, TNO)*

### SESSION 5: DYNAMICS

Tackle pm vibration in a cryogenic application on an Electron Microscope

*Ab Visscher (Thermo Fisher Scientific)*

Vibration damping for X-ray systems

*Rob van Loon, et al. (Philips – Image Guided Therapy Systems)*

Hybrid Design Approach of Constrained Layer Dampers for Discontinuous Surfaces

*Kees Verbaan, et al. (NTS-Group, DUI)*

### SESSION 6: MEASURING & MONITORING

Precision life estimation: a case of predictive condition monitoring in the rail sector

*Henk Mol, et al. (SKF Research and Technology Development, Delft University of Technology)*

High resolution magnetoresistive sensor systems for precise positioning tasks

*Uwe Stock, et al. (Sensitec)*

Sensor based adaptive laser micromachining

*Albert Borreman, et al. (Demcon, Lightmotif, IPT Fraunhofer, Sill Optics)*

### SESSION 7: SYSTEM DESIGN 2

Design of an optimized fixation drum

*Bert van Beek, et al. (Océ-Technologies)*

Automatic exchange and alignment of AFM cantilevers

*Rodolf Herfst, et al. (TNO, Department of Optomechatronics)*

High speed motion and high speed imaging for RFID tag production

*Thijs Kniknie, et al. (Nexperia, Sioux CCM)*

### Both days

### POSTER SESSIONS AND DEMONSTRATIONS

# DSPE CONFERENCE – PAPERS (abstracts)

## SESSION 1: SYSTEM DESIGN 1 - 1

### Unravelling the James Webb Space Telescope

G. Aitink-Kroes, et al. (NOVA Optical Infrared Instrumentation Group)

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Since Galileo's time (around the 17th century), astronomy has made great strides, as he was the first to use 'technology' for sky observations. In recent times huge scientific instruments reveal more and more the diversity of the distant universe. The James Webb Space Telescope (JWST), an infrared space observatory, will help to reveal the answers to some of the biggest mysteries of astronomy with its specific location in space, longer-wavelength coverage and greatly improved sensitivity. JWST is a joint international NASA/ESA/CSA mission involving scientists and engineers from over 14 countries.

Only through imagination several technological advances made it possible to create this innovative observatory which folds up inside a rocket for launch and is deployed when nearing its observing environment, far from any heat sources, 1 million miles from Earth. Its 6.5-meter primary mirror is built from 18 adjustable ultra-lightweight beryllium segments. In addition a tennis-court-sized five-layer sunshield keeps the observatory cool to 40 K. The four science instruments (cameras and spectrometers) have detectors that are able to record extremely faint signals. Programmable microshutters enable near-infrared observation up to 100 objects simultaneously and a cryocooler brings the mid-infrared detector to its operational temperature of 7 K. In the Netherlands, NOVA, together with TNO and SRON, has been involved in the design,

development and realisation of the Mid Infra-Red Instrument (MIRI), providing the Spectrometer Main Optics (SMO). Together with the Spectrometer Pre Optics it functions as a mid-infrared spectrometer providing the full high-resolution spectrum in just three exposures. A true proof of cross (discipline) border research and development through an integrated design approach, and an advocate for simple solutions to complex problems. ■



*The Mid Infra-Red Instrument for JWST. (Source: STFC/RAL Space)*

## SESSION 1: SYSTEM DESIGN 1 - 2

### ASML Wafer Stage: The power of Mechatronics & Imagination

Harry Cox (ASML)

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ASML, manufacturer of lithography equipment, launched the first wafer stepper in 1984. Since then, the imaging resolution has improved from 1200 nm down to 13 nm in 2018, meanwhile increasing productivity from 20 wafers per hour to more than 275 wafers per hour. This evolution was driven by a persisting belief in the success of the wafer scanner realised by the combination of optical knowledge of lens design, mechatronic stage design and a strong imagination in the engineering process.

This paper describes the critical design choices, the evolutionary and revolutionary

changes and the need of engineering imagination of how to realise such a wafer stage with subnanometer positioning accuracy. It starts with translating system requirements into module design specifications. Critical elements include the two-stage long stroke/short stroke design, material selection for the chuck (regarding, in particular, thermo-mechanical stability), position measurement using interferometers or optical encoders, actuator design and servo-dynamics. Recent advancements in mechanical design and control that will be addressed are visco-elastic damping (enabling a higher servo bandwidth) and advanced compliance compensation resulting in a fast servo settling.

The conclusion will be that wafer stage design is state-of-the-art mechatronics combined with craftsmanship and

imagination. This is illustrated by the evolution of ASML atmospheric (DUV) and vacuum stages (EUV). Over time, the stage acceleration or productivity has been steadily increasing in combination with a significant increase in positioning accuracy. An integrated mechatronic design may overcome initial hardware limits, resulting in chuck dynamics with high eigenfrequency and high servo bandwidth thus enabling subnanometer positioning accuracy at high productivity. ■



## SESSION 1: SYSTEM DESIGN 1 - 3

### The Virtual Printer – Virtualization to the Extreme

Eugen Schindler (Océ-Technologies)

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[WWW.OCE.COM](http://WWW.OCE.COM)

As the demand for modelling and simulation as well as domain-specific modelling has increased dramatically over the last few years, the demand for serious model (lifecycle) management solutions also increases. This trend is highly visible within Océ, which has to deal with an increasing number of product lines and models when supporting the design, construction, and maintenance of the products within these product lines.

Although modelling can always be improved to add more research and design power, existing models within Océ are numerous. Some (inherently multi-disciplinary)

examples for single-print system modelling are physics simulations (to determine various effects of media movement through the printer, chemical aspects of ink-media interaction, mechanical design, etc.), model-based control (for designing the mechatronics), media handling systems models (describing the cross-cutting functionality of transporting media), and others.

While there are technological aspects to model interoperability and model lifecycle management, there are equally important organisational (and cultural) aspects to the topic. All of these aspects need to be taken into account in order to make model lifecycle management in a company such as Océ into a success.

This paper explains why one would want to make a virtual version of their product and gives an outline for the Virtual Printer, which at Océ is used to shape the direction of model-based development. ■

## SESSION 2: MODELLING & CONTROL 1

### Impulsive control: High-precision positioning of systems with friction

Dennis Bruijnen, Jeroen Dekkers (Philips Innovation Services)

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Accurate control of systems with static friction can be very challenging due to its non-linear behaviour. For some applications, low-friction options like elastic elements, air-bearings and magnetic levitation are prohibited because of range, application-specific and/or cost limitations. As a consequence, rolling or sliding solutions have to be applied resulting in increased friction forces. Dependent on the solution, the behaviour could be resembled by a Coulomb friction model up to a generalised Maxwell slip (GMS) friction model. Due to the static friction, a static error remains when controlling such a system with a PD-type

of controller. On the other hand, adding an integrator to remove the static error could give limit-cycling problems.

For point-to-point applications, a way to obtain accurate positioning in the presence of static friction is a technique called impulsive control. Impulsive control applies a sequence of force pulses where the pulse shape is linked to the servo error. By applying a pulse with an amplitude higher than the static friction, the system will slide a short distance depending on the pulse length. By adapting the pulse shape in a smart way, the servo error will converge to a small value after a number of pulses. A pulse-width approach has been adopted and besides simulations, also experiments have been carried out.

It was learned how to apply impulsive control and for which class of systems this

is a feasible solution. In some cases, other solutions are preferred. When, e.g., the friction surface decouples at a relatively low frequency, impulsive control works less effectively because the force pulses are being filtered. Fortunately, for such systems, having a low stiffness from actuator to the friction surface, an integrator can be used without obtaining limit-cycling behaviour. ■

# DSPE CONFERENCE – PAPERS (abstracts)

## SESSION 2: MODELLING & CONTROL 2

### Milli-Kelvin Temperature Control using a Local Fluid Stream Heater

Björn Bukkems (MI-Partners), Michael Ronde (ASML), Ronald Lamers (Thermo Fisher Scientific), Theo Ruijl (MI-Partners)

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Temperature fluctuations occur due to varying heat loads in high-precision systems. These fluctuations cause deformation of critical system parts, which results in undesired loss of accuracy and/or drift. The conventional solution is to supply machines with water from a chiller, which has a few disadvantages. Firstly, the temperature stability of commercial chillers (tens of mK) is often insufficient. Moreover, the chiller is typically placed far away from the system, which limits the response time to

disturbances. Finally, only one temperature setpoint can be given, making it impossible to act on local disturbances.

For high-end systems it is desirable to have local thermal control to anticipate on local heat loads and their cooling requirements. Therefore, multiple controlled local heaters can be added in the water channels, which enables individual temperature control in each channel. These local heater devices can be small (low thermal mass), such that the dynamics can be optimised for a higher bandwidth and better disturbance rejection. To control the temperature of the overall system, three sensors are used. A feedforward and feedback sensor inside the local heater device are used to generate water with mK temperature stability. In order to achieve the desired temperature stability, the dynamics and transport delays of the local heater

device are characterised. An additional sensor near/on the system is used to correct for offsets and slow variations.

Both ambient and active machine heat load variations cause temperature fluctuations of the cooling water. Although these disturbances are typically very slow, they can cause relevant deformations or drift in the system. To achieve stability in the mK range at the system, an additional feedback loop is employed, which utilises the third sensor. This results in a system with mK temperature stability, which can compensate offsets and slow temperature variations at a location relevant for the accuracy of the system. ■

## SESSION 2: MODELLING & CONTROL 3

### Multi-body Modelling of High-Tech Mechatronic Systems with Flexible and Nonlinear Dynamics

Dragan Kostić (ASM Center of Competency), R. van Es, L. Zwaans, Tim Fethke, Rob Fey (Eindhoven University of Technology (TU/e)), Nathan van de Wouw (TU/e, University of Minnesota), Henk Nijmeijer (TU/e), Guido Knippels (ASM)

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To enable further performance improvements for semiconductor machines under constraints on the costs, more effective strategies to product development become necessary. An appealing solution is multi-domain model-based product development, which enables analysis and optimisation of the integral machine electromechanical dynamics, including communication and software,

right from the earliest development stages. The existing mechatronics approach is characterised by system design optimisation at a limited number of operating points (e.g. motion or temperature). To achieve high system performance, the mechatronics design aims at dominantly linear input-output behaviour of the resulting system in close neighbourhoods of these setpoints. The linear approach greatly facilitates understanding of the machine dynamics and control design for high performance and disturbance rejection. However, semicon machines have wide operating ranges and exhibit variations in their dynamics including non-negligible nonlinear effects. Direct compensation for the changing and nonlinear machine dynamics is not common in classical mechatronics, whereas it appears inevitable for achieving advanced performance and high robustness against

disturbances. By theoretically sound and explicit treatment of the integral system dynamics, including structural deformations and nonlinearities, many principles of the mechatronics system design approach can still be used for advanced design of new and improvement of the existing semiconductor machines.

This paper describes a software framework for multi-body modelling and simulation of semicon machines. It is demonstrated by dynamical and control simulations of a wire bonder. Thanks to a high level of automation of the model building, this framework significantly simplifies and speeds up the modelling and analysis of the integral machine dynamics, together with control simulations. Such automation also minimises occurrences of modelling errors and gives non-specialists access to this methodology. ■



## SESSION 3: NOVEL SYSTEMS 1

### DigiScanner, a 3D scanner for orthodontists

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Nowadays, orthodontists use plaster models for creating appliances, which has some disadvantages. The clay bite used for creating the plaster models is quite unpleasant to the client. Then, various process steps in an orthodontic laboratory are required, followed by manual manufacturing. This workflow is not very efficient. So what if a scanner could create a digital 3D model of the jaw directly, a treatment could be designed using the computer and the appliance could be manufactured with 3D-printing technology?

This requires many 'precision' competences. Focusing on the 3D scanner, first of all,

an optical principle is needed capable of measuring the shape of the teeth with sufficient accuracy. Spatial constraints and specular surface reflections are complicating factors. Then, precision mechanics is needed to adjust and hold the optical components, within a volume of only a few cm<sup>3</sup>. Low-power electronics should be able to handle the high-bandwidth data streams. Efficient mathematical software algorithms must process the data and construct the 3D model in real time. Finally, the scanner must have a modern, slim look-and-feel, and manufacture should be cost-effective.

The Sioux group, to which Sioux CCM belongs, has all these competences under one roof. Systems engineering is applied over the entire duration of the project, from the beginning (theoretical exploration and simulation) via functional models and

prototypes to the final product. Each project phase has its own engineering challenges, where critical risks have to be mitigated continuously by balancing and selecting the options that the various disciplines offer. But even after selecting the best solution or compromise, the inherent system complexity will still result in some unpredictability and uncertainty about how the composite system will eventually behave, e.g. due to shaking by the user. This complexity has been managed with a structured and agile approach by the project team. By applying an adequate PLC (Project Life Cycle) and SDLC (System Development Life Cycle), the Sioux team was able to efficiently realise the system requirements in a final product. ■

## SESSION 3: NOVEL SYSTEMS 2

### Nano-precision multi-agent Maglev positioning platform

Lukas Kramer, Teun van den Dool, Rik Kruidhof, Aukje Kastelij, A. Dekker, Evert Nieuwkoop, Johan Lugtenburg (TNO, Department of Optomechatronics)

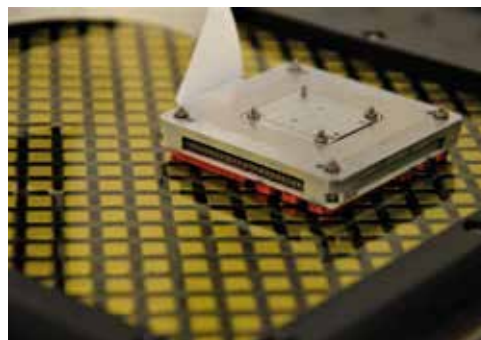
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The low throughput of 'slow' AFM metrology (Atomic Force Microscopy) prevents widespread application in semiconductor fabs. One way to increase throughput is to operate many metrology devices in parallel. TNO's parallel arm AFM inspection system is an example, but the arms in that system limit the amount of devices and flexible application.

As a next step in parallelisation, TNO develops more flexible positioning systems. One of them consists of independent, free-

flying carriers based on magnetic levitation. Each carrier supports an agent, which is like a 'lab-on-instrument', to perform various tasks at the nanoscale, e.g. inspection, deposition, repair or cleaning. Electromagnetic actuation and control in six degrees of freedom (DoFs) is selected because of its potential to combine large x- and y-motion with subnanometer resolution.



Realised 50 x 50 mm<sup>2</sup> carrier with moving coils on a Hallbach array of magnets.

As a first step, a demonstrator carrier with a size of 50 x 50 mm<sup>2</sup> has been successfully designed, built and tested. The six-DoF controlled carrier has a maximum acceleration of 1.5 g in x- and y-direction. The coarse metrology system is based on Hall sensing and achieves a position resolution below 1 µm. Next steps involve integration of miniaturised subnanometer sensors, on-board control, wireless communication and wireless power transfer. ■

# DSPE CONFERENCE – PAPERS (abstracts)

## SESSION 3: NOVEL SYSTEMS 3

### In-vacuum linear stage with 30G acceleration capacity

Jan Huang (ASML), Rob Reilink, Pieter de Jager, Jasper Scholten (Demcon), Sjoerd Huiberts (ASML)

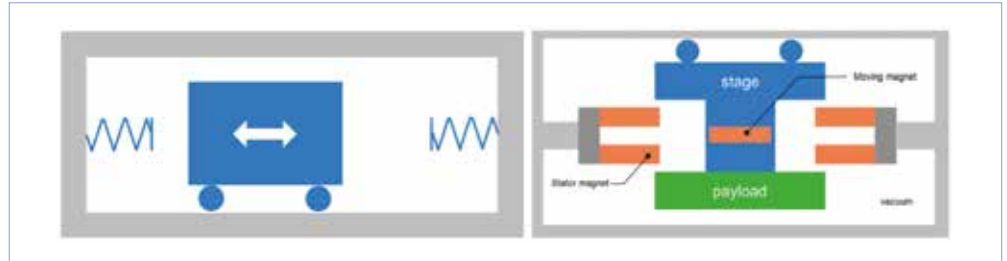
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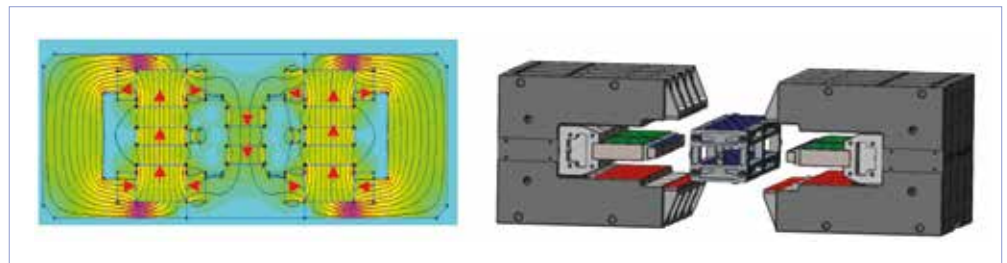
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ASML is continuously pursuing faster and more reliable stage designs. With the high acceleration and vacuum application in mind, an exploratory test set-up has been built to address the following key challenges:

1. Actuator with high force output and minimum moving mass.
2. Long-range in-vacuum linear guiding. ■



Left: A concept of an energy-efficient stage features two springs to convert the kinetic energy to potential energy. Right: the design has two magnetic springs.



Magnet spring arrangement for high force output. Left: simulated magnetic field; the red arrows denote the magnetisation direction. Right: 3D view of the two E-core stator magnets and the moving magnet.

## SESSION 4: MECHANICAL DESIGN 1

### Self-alignment of kinematic couplings: effects of deformations

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A kinematic coupling has the ability to self-align; if it is positioned in an off-centred configuration, it will spontaneously move to its centred position. Friction is one of the main factors in the phenomenon of self-alignment. The direction of the friction forces is among the unknown parameters of the problem: this issue is normally overcome by assuming friction forces oriented as if they were actually relative to the motion.

During the study, it was found that this assumption, although in many cases a good approximation, is not correct and might lead to errors. In particular:

- friction forces are oriented in directions unrelated with the possible relative motion of the coupling, but they are strictly related to the way the involved bodies deform;
- there are cases where assuming friction oriented against the possible relative motion leads to underestimation of the friction ability to prevent self-alignment, thus stating that a specific kinematic coupling is self-aligning when in reality it is not.

Therefore, to perform an accurate study of the self-aligning properties of the interface, knowledge about the elastic behaviour of the involved bodies is needed. Such information is normally not available at the moment of concept definition, so a mathematical model has been developed and implemented in a computer algebra system, to find the worst-case scenario with respect to self-alignment.

The coefficient of friction is expressed as a function of the friction forces orientations, which are considered not related anymore to the motion; such a function is then minimised.

This method was used to analyse a standard kinematic coupling and compare the results with the ones of the previous approach. It was concluded that in order to find the limiting coefficient of friction for a kinematic coupling, deformations of the involved bodies should be taken into account. If this is not (yet) possible, a worst-case approach can be followed, preventing overestimation of the self-aligning property. ■



## SESSION 4: MECHANICAL DESIGN 2

### The characterization of recirculating ball bearings and their effect on mechatronic system performance

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For the development of high-accuracy positioning systems, highly predictable bearing components such as air bearings and magnetic bearings are preferred when designing for systems with long strokes. Due to their relatively low cost, the use of linear ball and roller bearings can nonetheless be an attractive alternative even for positioning at submicrometer level.

These components, however, have downsides such as friction forces and overdetermined design. For predicting the performance of a mechatronic system that uses such bearings, measurement and modelling methods are

found in literature. MI-Partners integrates these measured parameters at element level into models for system level behaviour. The focus of this paper is on the recirculating type of linear ball bearings, also known as profile rail guides or linear motion guides. Several linear guide measurement set-ups have been developed to identify parameters that are relevant for dynamic system modelling. The capabilities of these set-ups include measurement of Stribeck curves, Dahl curves, ball passage vibrations and dynamic stiffness in both constrained and free directions.

As an example, a customer required to position a stage on linear guideways at submicrometer level by making small steps at low velocities ( $< 100$  mm/s). From the measurements on two guideway types, it was found that type 2 requires less force at higher

velocities. However, these measurements also showed that type 1 outperforms type 2 at low velocities, which is most relevant for stepping applications. The Dahl curve measurements revealed that the pre-rolling behaviour (motion  $< 100$   $\mu$ m in this case) of the two guideway types is quite similar, even though the Stribeck curves exhibit a strong difference. This demonstrates how these measurements help to obtain relevant parameter values. The paper will show the effects of small displacement bearing stiffness (Dahl curves) on dynamics and the stability of control loops for a stage using these types of bearings. ■

## SESSION 4: MECHANICAL DESIGN 3

### Improving Optical Performance of Multicomponent Optomechanical Systems through Topology Optimization

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Optomechanical instruments generally have to meet very stringent optical, mechanical and thermal requirements. The challenge lies in maintaining the position and shape of optical components such that the image quality is guaranteed under all working environments, while satisfying multiple conflicting requirements such as costs, mass and eigenfrequency. In the state-of-the-art system engineering thermomechanical design process, the

optical performance is not considered directly. Instead, each component is designed and optimised separately to meet a priori defined deformation limits. There is room for improvement when multicomponent systems are optimised in a coupled fashion, as this allows for error compensation between components.

This paper focuses on the reduction of optical performance errors of multicomponent reflective optical systems induced by (quasi)-static thermal loads. The thermomechanical design and structural topology optimisation of all components is driven by system-level optical performance metrics using a full structural-thermal-optical performance (STOP) analysis. Topology optimisation is a systematic, bottom-up structural optimisation approach that provides maximum design freedom without any prior

knowledge of the design to optimise the material layout within given design domains.

To demonstrate the benefit of our approach, a two-mirror case study under thermomechanical disturbances is presented. The integrated STOP design optimisation procedure taking into account all system components is compared to individual component optimisation, while subjected to the same (or equivalent) design constraints. In this case study, the proposed approach resulted in a 95% spot size error reduction.

The key to satisfying next-generation optomechanical system requirements is to not distribute error budgets over components a priori, but to consider and optimise the system as a whole. This allows for focus where it matters, without overconstraining the system unnecessarily. ■

# DSPE CONFERENCE – PAPERS (abstracts)

## SESSION 5: DYNAMICS 1

### Tackle pm vibration in a cryogenic application on an Electron Microscope

Ab Visscher (Thermo Fisher Scientific)

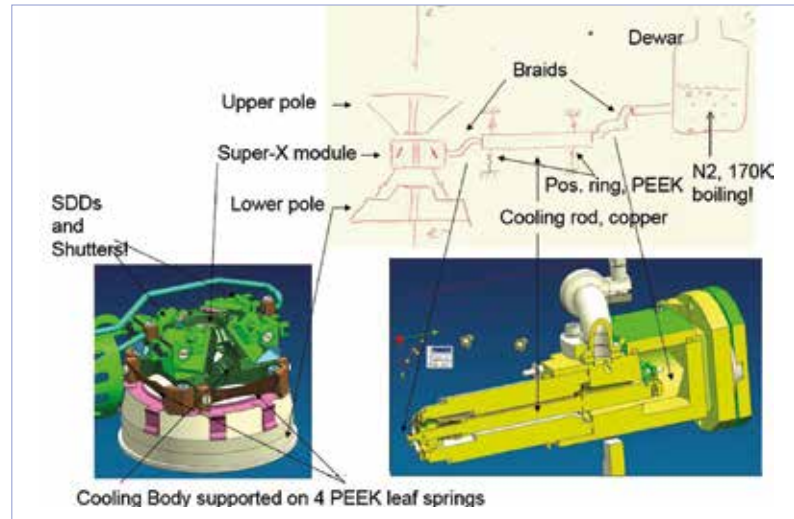
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The technique of energy dispersive X-ray spectrometry (EDS) on an electron microscope makes it possible to do very local identification of material atomic number, down to individual atoms of one material embedded in the atomic structure of another material. The technique requires X-ray detectors that must be cooled down to cryogenic temperatures. Liquid nitrogen close to the microscope is used for this. The nitrogen is always boiling to some extent, causing small vibrations of the sample. The disturbance is only 10 pm around 270 Hz. How can vibrations that are even a mere fraction of typical atomic distances still be problematic? How can we even measure sub-atomic vibrations?

A tough and attractive quest will be presented to trace the cause and transmission path of this tiny vibration. It involves a good interaction of the several familiar dynamics

analysis techniques, as well as special and charming methods that only an electron microscope can facilitate. ■



*Schematic construction of the EDS application.*

## SESSION 5: DYNAMICS 2

### Vibration damping for X-ray systems

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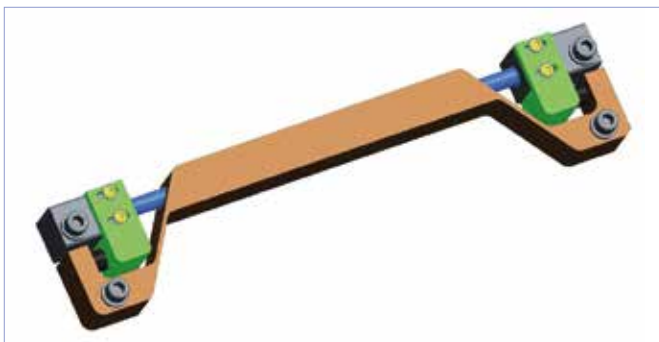
Dynamics play a more important role in the development of imaging systems as clinical outcome improves at higher speed, with less X-ray radiation and less

bulky systems. In this paper two vibration problems, each with their own solution, are discussed: damping a poorly damped eigenmode using a tuned-mass damper; and isolating a vibration source from the main system using a vibration isolation suspension.

A new system prototype contains a low-frequency eigenmode with little damping (3.3 Hz & 0.3%). This mode can be excited by system movements or floor vibrations resulting in poor 2D image quality. Moreover, it also affects the aesthetic look and feel of the system. To deal with this problem a tuned-mass damper has been developed that adds

damping to the eigenmode. The damper is tuned for robustness. A comparison with other solutions such as active damping, vibration isolation, etc., will be provided.

Trends in the design of X-ray sources are to increase rotation speed of the anode disc that is used to generate the photons. However, frequencies above 100 Hz combined with a small unbalance in the anode disc generate a high-frequency disturbance energy that impacts the system dynamics. To deal with this, the design has been optimised to reduce the effects of this vibration. An innovative interface has been created such that it isolates high frequencies and at the same time increases stiffness in other directions. ■



*The interface between X-ray source and system containing stiffness and damping in defined directions.*



## SESSION 5: DYNAMICS 3

### Hybrid Design Approach of Constrained Layer Dampers for Discontinuous Surfaces

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**T**his paper describes a design approach to improve the damping behaviour for relatively thin wafer stages with a discontinuous surface area. A constrained layer damper (CLD) with limited thickness has been designed to improve the dynamic performance at the first resonance frequency. Design equations for continuous CLD layers have been applied which are compensated for the discontinuities.

Firstly, the undamped characteristics of the stage design have been studied by means of FEM-based undamped modal analysis

resulting in mode shapes with corresponding natural frequencies. The second step is the approximation of these undamped modal results by analytical equations in order to be able to study variations in modal damping afterwards.

The theory for CLD layers, known as the RKU equations, provides estimates for the modal damping of the stage with a continuous CLD layer added. Inputs for these equations are the material properties of the linear viscoelastic (LVE) layer.

Finally, the resulting modal damping value has to be compensated for discontinuities in the CLD. This shear efficiency factor (SEF) was estimated by calculating the effectiveness of the discontinuous CLD layer with respect to an equal-sized continuous CLD layer. The basis for this estimate lies in the shear displacement, which is known as

function of the mode shape and the spatial coordinates on the motion stage.

The result is a theoretical modal damping value of 1.3% at the first resonance frequency around 100 Hz. Experimental modal analysis (EMA) on the motion stage to measure the modal damping of the first flexible modes yielded 1.19% damping at a frequency of 97.7 Hz. It appears that the hybrid design approach as described results in a quite accurate estimate for the modal damping value of CLD layers on discontinuous surfaces and enables a fast iteration during the design process due to the simplicity of the methodology. ■

## SESSION 6: MEASURING & MONITORING 1

### Precision life estimation: a case of predictive condition monitoring in the rail sector

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**T**U Delft has worked for several years on rail wear and rail defect detection and created a condition-based maintenance for rails. The use of a test vehicle with axle box bearing acceleration measurements was a vital part of the work. The end result is a method to detect and quantify the level of wear of the rails, in much higher detail levels than have been achieved by other systems. This data can be used to identify beforehand the defects that might become problematic over time, and allow simple condition based maintenance such as, e.g., grinding the rails.

Overall, the trend is that rail quality is going up, and is inevitably leading to less wear of the wheels, so the fixed wheel replacement intervals can become longer. When stretching the interval there will be more bearings failing and this could limit the extent of the interval and overall the efficiency of maintenance. Measurement of the condition of the wheelset solves this problem. This makes sense as bearings wear slowly: when they develop a defect this is not growing to disastrous level overnight. Rolling bearing maker SKF has developed the know-how of this death path and the ability to act upon it. SKF has introduced its first generation of Industrial Internet of Things devices that monitor bearing and wheel quality in the field with acceleration and temperature. They are mounted on the bearing axle box and measure several times per day.

The R&D department of SKF has cooperated with the TU Delft through the use of their test vehicle in order to assess how well algorithms could work. The test-vehicle-based measurements are the signal for TU Delft, while they were the 'background' vibration for the bearing condition. The bearing and wheel vibration is a 'background' for TU Delft. The principles of the defects in rails, wheels and bearing are similar, but the condition is derived by different features in the same data. ■

# DSPE CONFERENCE – PAPERS (abstracts)

## SESSION 6: MEASURING & MONITORING 2

### High resolution magnetoresistive sensor systems for precise positioning tasks

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**M**agnetic position measuring systems are extremely robust compared to optical systems and often cheaper in the overall system design, but do not achieve their high accuracy. However, the potential of magnetic metrology is largely untapped. For example, new, improved sensor designs, new magnetoresistive effects, and new materials and manufacturing technologies are enabling magnetic solutions to expand into other areas of high accuracy and resolution and to open up new application fields.

Optical encoders offer the highest resolution and accuracy but are vulnerable to critical

environmental conditions, contamination and mechanical influences. For the alternative of magnetic encoders, users have to accept reductions in terms of resolution and accuracy. Magnetic measuring systems can also convince with their compact design and very flexible use of the technology. Thus, these advantages are fully in line with the trend in machine manufacturing of higher integration of components and function, driven by digitisation and higher networking of information and data (Industry 4.0).

Therefore, it is an objective to further reduce the size of the magnetic components and, above all, to significantly improve their accuracy and resolution in order to meet the requirements of the market. Results will be presented for magnetic scales produced with the highly accurate photolithographic possibilities, as well as for tunnel

magnetoresistive (TMR) sensors, which can be made very small and still have a very high sensitivity.

Additionally, options for absolute measuring are explored, so that a measuring system provides an absolute position information directly after switching on – without referencing. This requirement is typically realised with multiple coded tracks on the measuring scale. The consistent implementation of the individual components with a focus on accuracy, both in the design and manufacture of the measuring scale and sensor element, enabled the realisation of a measuring system with position errors of less than 1 µm. ■

## SESSION 6: MEASURING & MONITORING 3

### Sensor based adaptive laser micromachining

Albert Borreman, Léon Woldering, Erik-Jan de Hoon, Ger Folkersma (Demcon), Max Groenendijk (Lightmotif), Rouwen Kunze (IPT Fraunhofer), Manuel Zenz (Sill Optics)

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**W**ithin the Horizon 2020 project ADALAM, a novel depth sensor was successfully integrated in a laser micromilling machine. This new sensor allows the milling system to get proper feedback while processing microstructures, resulting in an accurate and fast micromilling process. This paper describes the novel depth sensor, the integration of this sensor in an existing laser milling machine, and the first results when

using this adaptive laser micromachining system.

The sensor is based on the spectral-domain low-coherence interferometer principle. By using a measurement and reference path, an interference pattern is generated which can be used to derive the optical path difference between these arms. An automatic reference path has been developed, which allows the sensor to deal with different reflectivity values of the material that is being processed by adapting the reference path to the intensity coming back from the measurement path.

For integration of the sensor in the milling machine additional measurement devices have been developed: i) a coaxial sensor head for the alignment of the sensor beam, ii) a beam measurement system that can

measure both the laser milling beam and the sensor beam to allow proper alignment and overlap, and iii) a spot measurement system to measure and compensate for changes over the entire scan field.

An interesting application is to measure the microstructure of ceramic plates and subsequently using the laser milling system to reshape such a microstructure. First experiments show a very good correlation between measurements with a confocal microscope and the integrated depth sensor, which proves that it measures with sufficient precision: 1 µm over a range of 1 mm. The next step will be a volume calculation and determine the required laser ablation process to reshape the microstructure. ■



## SESSION 7: SYSTEM DESIGN 2 - 1

### Design of an optimized fixation drum

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The Canon VP i300 is a high-volume colour inkjet press. It can print up to 300 images per minute on A4/A3 sheets and aims to replace conventional offset presses. Key features of this system are efficient short runs, high media flexibility, and the ability to print on standard offset paper.

It has an innovative drying system suppressing media waviness and delivering high-quality stacked output. This consists of a suction transport drum surrounded by different heating and enhanced convection (air impingement) modules. A system with a significant cost price reduction was imagined.

The approach was to focus on the main cost price drivers:

- Reduce module volume.
- Reduce pressure (drop) and flow.
- Remove/reduce/integrate functionality.
- Reduce power consumption.

This resulted in two innovations:

#### 1. Air impingement integration

By integrating IR heaters and air impingement, not only the volume was reduced, but also a form of localised heating was realised – thus promoting drum and paper temperature uniformity.

#### 2. Vacuum drum

A new concept of a vacuum drum was developed with a large centralised airflow channel instead of the multiple small channels. The air channels are now switched inside the drum. This reduced

the pressure drop in the system by 50% and enabled a compact design with a 30% smaller footprint.

The switching of the channels is done using a pressure box that connects to the air channels in the drum mantle. To reduce the leakage of this device a contactless seal was developed using the labyrinth seal principle. This concept enabled positioning of the air connections to the centre of the drum tubes. This creates a symmetric airflow, which improves the flow and temperature uniformity, especially combined with air impingement integration. ■

## SESSION 7: SYSTEM DESIGN 2 - 2

### Automatic exchange and alignment of AFM cantilevers

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Most Atomic Force Microscopes (AFMs) require a manual exchange of the AFM cantilever and manual alignment of the optical beam and position-sensitive detector (PSD). While this can be a cumbersome task when operating a traditional, single-cantilever laboratory instrument, it can become a prohibitive bottleneck for achieving high throughput in an industrial setting. To this end, an instrument for automatic exchange and optical alignment of AFM cantilevers has been developed. It is compatible with TNO's high-throughput, parallel atomic force microscope. Using the



*Miniaturised AFM scan head below cantilever exchange unit. (Photo: Rogier Bos/TNO)*

developed instrument a cantilever can be exchanged and aligned in 6 seconds with an accuracy of better than 2 µm. This was done consistently over ten thousand continuous

exchange and alignment cycles that were performed without failure. This paper presents the concept, design and hardware that makes this possible.

In the cantilever exchange instrument, the central functionality is realised by the chip manipulator: a manipulator with two vacuum nozzles that can pick up an AFM cantilever chip, precisely position it above a miniaturised AFM scan head, and align the cantilever before transferring it to the scan head. The chip manipulator is small enough to allow parallel use of tip exchange units. It is used in the demonstrator set-up and can reliably exchange cantilevers. Repeatedly exchanging the same chip does not degrade imaging performance. ■



# DSPE CONFERENCE – PAPERS (abstracts)

## SESSION 7: SYSTEM DESIGN 2 - 3

### High speed motion and high speed imaging for RFID tag production

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At Nexperia, ITEC develops and realises semiconductor assembly, test, inspection and automation solutions. A particularly interesting growth market for semiconductor assembly is the RFID (radio frequency identification) market. An RFID tag consists of a plastic or paper substrate (the 'web') with an antenna and a semiconductor device (the 'die') that carries product information and connects to a reader. The die is glued on the web in a die-bonding process, where glue is applied and the die is pressed onto the antenna.

In cooperation with NXP Semiconductors and Sioux CCM, Nexperia ITEC has developed a high-speed RFID die bonder with unrivalled quality and speed, enabling low-cost RFID label production. A key module in the RFID die bonder is a high-speed indexing drum that transports and aligns the web through

several process steps. Experience of Sioux CCM in foil and paper handling in the solar and printing industry provided a good technological base for handling flexible substrate in a continuous flow.

The paper presents the global RFID die-bonder platform layout, zooming in on the drum indexer module and optics modules, from specification, concept design and integration to release.

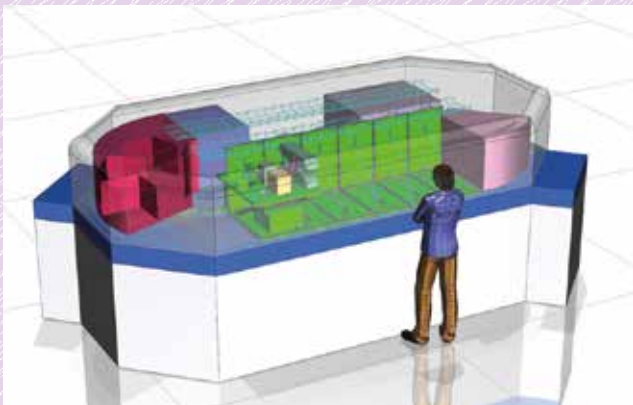
See also the article on page 5 ff. ■



*A close-up of the die-bonder platform.*

## DSPE CONFERENCE 2018 – POSTERS AND DEMOS

- **Next generation additive manufacturing**  
Jeroen Smeltink, et al. (AMSystems – TNO and TU/e HTSC)
- **Predict Manufacturing Defect Rate**  
Dick van Hees (ASML)
- **Active EMI Noise Cancellation**  
Mart Coenen, et al. (EMCMCC)
- **Particle contamination reduction to improve substrate manufacturing**  
Kasper van den Broek (VDL ETG)

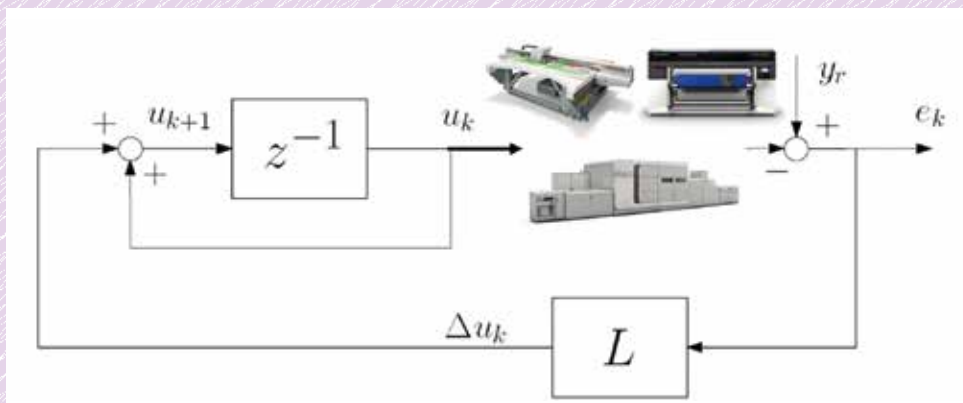


*AMSystems is developing continuous AM platforms to demonstrate elements of next-generation AM. (From the poster by Jeroen Smeltink, et al. (AMSystems – TNO and TU/e HTSC), "Next generation additive manufacturing")*



# DSPE CONFERENCE 2018 – POSTERS AND DEMOS

- **Collision Free Interventional Environments**  
Rishi Mohan, et al. (Eindhoven University of Technology (TU/e), Philips Healthcare)
- **Hybrid integrators for nonlinear motion control**  
Ron Verstappen, et al. (ASML, TU/e)
- **Multirate control for high accuracy and low cost: dual-stage experiments**  
Jurgen van Zundert (TU/e, ASML)
- **Novel mechatronic concepts for interventional X-ray systems**  
Jeffrey van Pinxteren, et al. (TU/e, Philips IGTS)
- **Lumped parameter model of vacuum flow, using 20-sim**  
Jaap Brand, et al. (VDL ETG)
- **Filtered Split-Path Nonlinear Integrator for Improved Transient Performance**  
Annemiek van der Maas, et al. (TU/e)
- **Practical Thermal Control by Thermo-Electric Coolers**  
Rob van Gils (Philips Innovation Services)
- **Design and dynamic performance of the primary mirror supports for the Extremely Large Telescope**  
Gert Witvoet, et al. (TNO)
- **Measure non-linear stiffness of a rubber membrane in an air isolator for an Electron Microscope**  
Ab Visscher, et al. (Thermo Fisher Scientific)
- **Mask Profilometry - High-throughput AFM for Metrology in Semiconductor applications**  
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Edwin van den Tillaart, et al. (Settels Savenije)
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Juan Pérez Muñoz (Océ-Technologies)
- **Critical misalignments of an overconstrained compliant mechanism**  
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Silvan Viëtor, et al. (TUD)
- **Design of a low-cost climate control system for consumer 3D printers**  
Senthan Mathaven (Nobleo Technology)



Application of advanced learning control structures to actual industrial systems for product development.  
(From the poster by Sjirk Koekebakker, et al. (Océ-Technologies, TU/e), "Learning and Repetitive Control in Printing – Cooperation Océ-TU/e CST 2010-2018")



# TOWARDS 'LAB-IN-THE-PHONE' AND 'INTERNET OF THINGS' APPLICATIONS

Spectrometer applications can be greatly extended if such instruments become consumer items in everyday applications as testing food quality and nutritional values or medical self-diagnosis. This will require the devices to be smaller, cheaper, easier to use and fit for operation with existing consumer devices like the smartphone or as 'Internet of Things' (IoT) sensors. An approach potentially satisfying these requirements is to integrate spectrometers on semiconductor chips. It is based on tuneable resonant photonic structures with nanomechanical electrostatic actuation and built-in photocurrent sensors.

ROB VAN DER HEIJDEN, ŽARKO ZOBENICA AND ANDREA FIORE

Employing mechanical motion to control light is an elementary function for steering free-space light beams with movable mirrors. Nowadays, this is already well established in advanced micro-electromechanical systems (MEMS) fabricated on a chip to form large arrays of individually adjustable tiny mirrors. In the last decade or so, with the advancement of nanotechnology, new avenues for the interaction between light and mechanical displacement at the nanoscale have been opened.

Methods to confine and control light at the (sub)micrometer scale have been developed, motivated by the need of downscaling photonic devices and circuits to achieve higher integration densities. At these scales, subnanometer displacements of tiny moving parts produce significant effects on the light beam, while in turn photons produce measurable forces on the mechanics. The interplay between light and mechanical motion at the nanoscale forms the currently very active research area, known as nano-optomechanics [1].

The strong interaction between light and mechanics in nanophotonic structures can in particular be used to control light confinement and flow. When light propagates in a dielectric slab ('waveguide'), the movement of a part of this slab produces a phase change two to three orders of magnitude larger than changes achieved by traditional methods, employing temperature or electric fields. Exploiting tuning by mechanical motion is a relatively unexplored avenue, which gives rise to a new class of nano-opto-electromechanical systems (NOEMS), with new functionalities [2].

Recently, building on this tuning concept in NOEMS, an integrated spectrometer has been designed and realised with a footprint of only about  $15 \times 15 \mu\text{m}^2$  [3]. A spectrometer can be used to observe the optical reflection, transmission, or emission spectrum of a material, which acts as a fingerprint and thereby betrays its nature or composition [4]. In the hands of individual consumers, it would be a highly useful device, e.g., for verifying the status of food, whether fresh, tainted, ripe, etc., at home or in the supermarket, aiding initial health self-diagnosis by characterising affected skin parts and measuring the air quality.

Typically, a spectrometer with a high spectral resolution is a bulky device, as it is based on spatially separating wavelength components by gratings or prisms [4]. Therefore, it is not easily miniaturised to a cost-effective consumer instrument. A small-size, mass-produced, and therefore cost-effective chip spectrometer would change the case. Using the connectivity and processing power of ubiquitous smartphones, the spectral information can be compared to a database in the cloud for identification. At present, a number of companies are already offering handheld devices in conjunction with apps to the consumer [5] [6]. It can be well conceived that these devices will ultimately be incorporated in a next generation of ever smarter smartphones, providing a new functionality [7].

Already one Chinese company announced a smartphone with built-in spectrometer, including a light source [8]. These devices are functional, but are based on a relatively small ( $\sim 10$ ) set of filters and therefore have a low wavelength resolution. The device described in detail below has a single, but tuneable,

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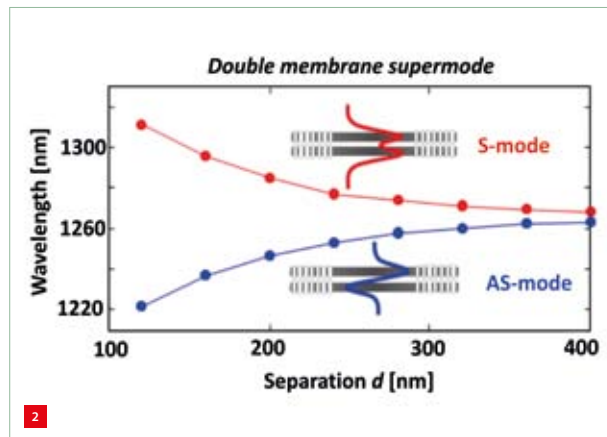
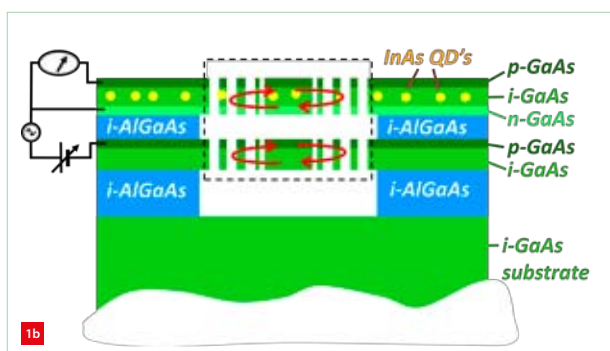
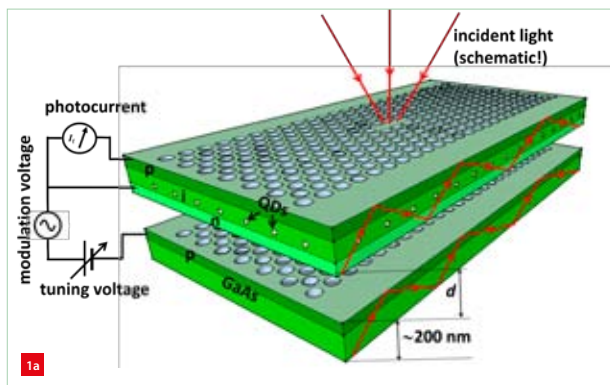
very narrow-band filter with wavelength width of  $\sim 0.1$  nm, and therefore excels in size and resolution.

### NOEMS spectrometer

As a starting point, consider a single, planar dielectric waveguide, roughly half a wavelength thick ( $\sim 200$  nm), one of the slabs shown in Figure 1a. The light is restricted to propagate in the slab by total internal reflection (TIR), but nonetheless a fraction of the electromagnetic field extends for a small distance ( $\geq 100$  nm) outside the slab, the 'evanescent field'.

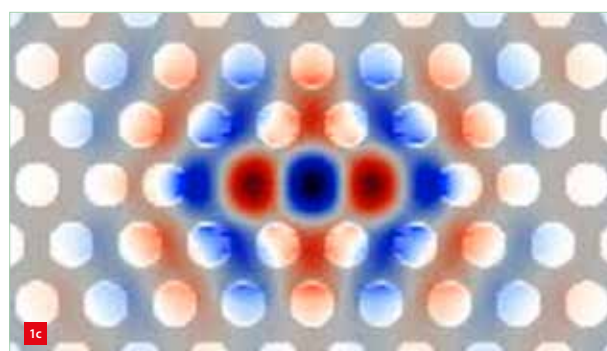
As a next step, the light is further confined to a small, wavelength-sized ( $\sim 1$   $\mu$ m) region within the slab, schematically near the centre of Figure 1a. This is accomplished by surrounding the small region by a so-called photonic crystal (PhC), i.e., a regular array of tiny holes, on a pitch of roughly half a wavelength. For a range of wavelengths around the design wavelength, the array of holes reflect and diffract light in a coherent way, such that by interference effects the array works as a perfect reflector.

The mechanism is just a two-dimensional analogue of a multilayer optical coating, as found on optical filters or (expensive) sunglasses. The light bounces back and forth between the PhC mirrors, as schematically illustrated by the red curved arrows in a cross-sectional view of (a double set of) slabs in Figure 1b. Because the thus created 'PhC cavity' is wavelength-sized, it can only confine light at a small number of discrete wavelengths, the resonant wavelengths, or 'resonant modes'.



The physical phenomenon is analogous to the discrete tones of a vibrating string. A typical calculated standing wave pattern of a resonant mode is shown in Figure 1c. Hence, the cavity acts as a filter, and provides the wavelength selectivity which is needed for measuring the spectrum. The spatial extent of the PhC mirror need not be more than 5 to 10  $\mu$ m, to achieve linewidths of  $\sim 0.1$  nm. This linewidth determines the resolution and is strongly dependent on a clever design of the open central region in the PhC.

Having realised the basic filter of the spectrometer, it now needs to be made tuneable. For this function, a second, nominally identical slab with cavity is brought in close proximity to the first one, at a distance where their 'evanescent fields' overlap ( $\leq 200$  nm), as in the sketch of Figure 1a. The two identical cavities obviously have the same resonant wavelengths at large separations. When the separation is reduced, each of the two cavity's original modes becomes shared by both slabs, leading to two so-called supermodes (sketched in the insets of Figure 2). They have a different intensity distribution over the dielectric slabs and the surrounding air and therefore their resonant wavelengths are different from the original one. The simulation result in Figure 2 shows the splitting of the resonant wavelengths becoming gradually larger as the separation gets smaller, with one wavelength getting larger ('S-mode'), the other smaller ('AS-mode').



- 1 Schematic representation of the spectrometer device.
  - (a) The double slab with photonic crystal (PhC). The green layers are GaAs, the colour variations correspond to the different dopings p-i-n. The red arrows symbolise the light propagating in the slab waveguide or incident from free space. The white dots represent the Quantum Dots (QDs). In the centre of the slabs, some holes are omitted or modified to create the cavity.
  - (b) Cross-section of the device through the cavity showing the layer stack and illustrating the mirror operation of the PhC (curved arrows in the cavity). Also the electrical contacts to the electrically conducting doped semiconductor layers are shown schematically. Only the freestanding slabs, where the AlGaAs is etched away, within the dashed box, are represented in more detail in (a).
  - (c) Typical calculated standing wave pattern of the electromagnetic field strength in the cavity.
- 2 Resonant wavelengths (from simulations) of the lowest double-slab supermodes as a function of the slab separation. The insets depict the field distribution of the two modes, with the electric fields in the two slabs being in phase, labelled as Symmetric (S) or in antiphase, labelled as Antisymmetric (AS).

The phenomenon is an example of a very general physical principle, also found, e.g., in the binding between identical atoms, or in the coupling between identical mechanical oscillators. As will be outlined further on, the two slabs will be configured so that their separation can be changed with an external voltage based on electrostatic attraction and elastic restoring, similar to the actuation in common MEMS devices.

As a final step, light at the resonant wavelength must be detected. For this purpose, the slabs are made from a semiconductor with a precisely controlled layer structure, visible in the cross-section of Figure 1b. With electrically positive (p) and negative (n) doping layers, one slab is configured as a standard p-i-n photodiode light sensor, where i stands for ‘intrinsic’, i.e. not intentionally doped. To have a controlled light absorption, a small amount of another semiconductor (indicated as Quantum Dots (QDs) in Figure 1a and 1b) is incorporated, also distributed across the entire middle i-layer.

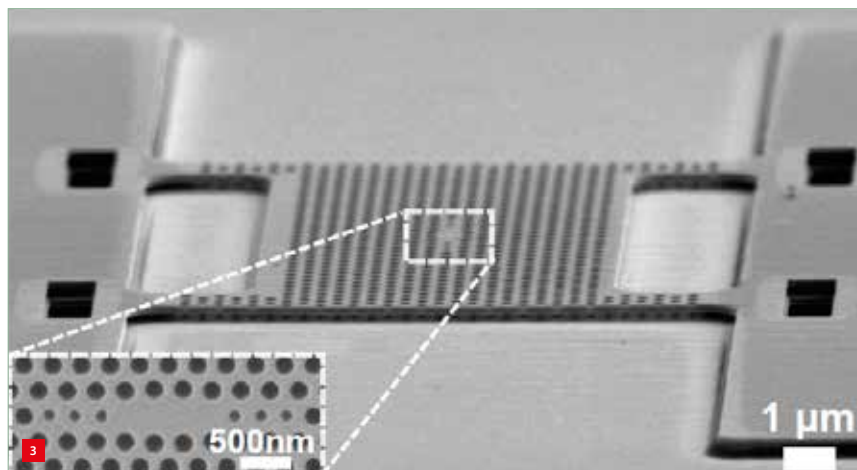
The light in the cavity is absorbed by the QDs and produces a photocurrent which can be measured between the p and n terminals of the upper slab, as schematically indicated in Figure 1a and 1b. Only light at the resonant wavelength can couple into the cavity, and therefore give rise to a photocurrent. By measuring the photocurrent at each slab separation, we can effectively measure the light intensity as a function of wavelength, and therefore the spectrum, because slab separation translates to wavelength changing according to Figure 2.

### Nanofabrication and spectrometer operation

The entire device is based on the semiconductor system Gallium Arsenide (GaAs), Aluminium Gallium Arsenide (AlGaAs) and Indium Arsenide (InAs). They belong to the class of opto-electronic semiconductors, well suited for light absorption (and emission) in the relevant near-infrared (NIR) wavelength spectral range from approximately 1 to 1.8  $\mu\text{m}$ . They can be grown with atomic layer precision by molecular beam epitaxy with different Al or In compositions and doping levels.

The stack layer is grown on a GaAs substrate and is shown in Figure 1b. It consists of the target GaAs device slab layers with p, i and n doping, sacrificial AlGaAs layers and a layer of InAs QDs. The upper membrane is configured as a p-i-n diode which acts as detector. Another p-i-n diode is made between the upper and lower GaAs slab, with the AlGaAs in between as i layer, the n-layer being common to both diodes.

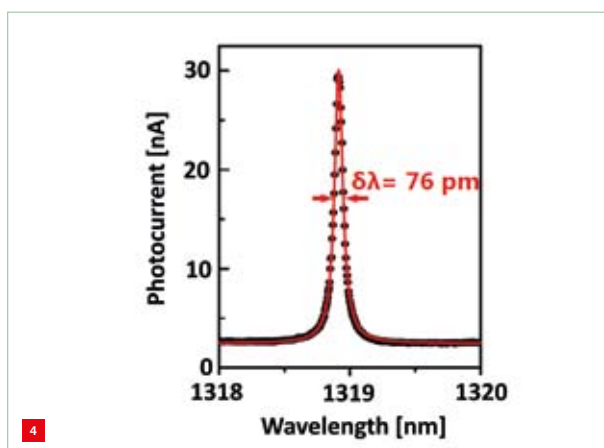
The PhC pattern is defined by electron beam lithography and anisotropically etched by a combination of physical and chemical processes using reactive ion etching. The upper slab is suspended by lithographically defined tethers that provide a



restoring force with adjustable spring constant. The etched PhC holes give access to the underlying AlGaAs, so that, as a final step, the AlGaAs layers can be selectively wet-etched locally to leave the GaAs slabs free.

A scanning electron microscope image of a typical fabricated device is shown in Figure 3. Applying a reverse voltage to the tuning diode formed between the slabs provides a substantial electrostatic force, with only a very small current flowing, which allows changing the slab separation and by this tuning the cavity. The inset of Figure 3 shows a close-up of the designed PhC arrangement that optimises the resonance linewidth. The electrical contact pads for both diodes adjacent to the device are not shown in Figure 3, but the electrical connections have been schematically indicated in Figure 1b.

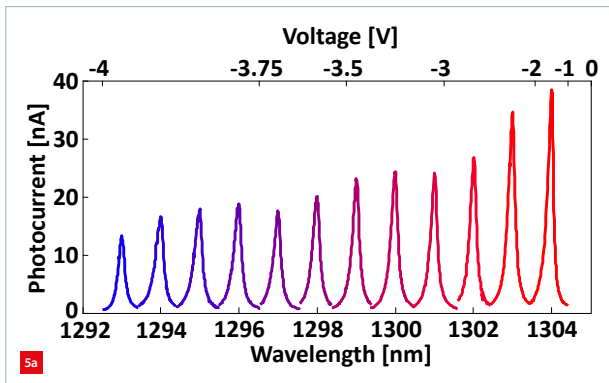
An experimental result is shown in Figure 4, where the photocurrent is plotted as a function of the laser wavelength. The sharp peak corresponds to the situation when the laser light is resonant with the cavity and its width will ultimately determine the wavelength resolution of the spectrometer. Note that a flat background is present, because of residual absorption by the QDs outside of the resonance and even further away from the cavity.



3 Scanning electron microscope image of the suspended upper membrane (the lower one is present, but not visible). The inset is a magnification of the photonic crystal cavity, designed to have a very narrow linewidth of around 0.1 nm measured.

4 Photocurrent as a function of laser wavelength for a fixed tuning voltage.





The operation and calibration of the spectrometer is shown in Figure 5a, which consists of a compilation of 12 traces. For each trace, the laser wavelength is fixed and the tuning voltage, displayed on the top-scale, varied. The photocurrent peaks when the electrostatic force tunes the slab separation such that the cavity is resonant with the laser. Repeating this procedure for 12 different laser wavelengths gives the calibration of tuning voltage against wavelength, displayed in Figure 5b.

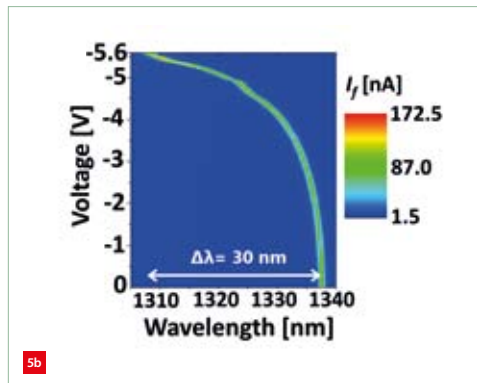
The wavelength resolution of the spectrometer is better than 0.1 nm as follows from Figure 4. This is remarkably good in view of its extremely small size. Such a resolution is typically found only in table-top spectrometers and is much better than in existing handheld spectrometers.

The major limitation of the current design is the limited wavelength span of the spectrometer of about 30 nm around a design wavelength. This range is limited on one hand by the free spectral range (FSR) of the cavity, i.e. the separation of different resonant modes. If two modes are present in the measured wavelength range, a peak cannot be unequivocally attributed to a specific cavity resonance. On the other hand, the tuning range of a single mode is limited by the pull-in (PI) effect. This is the well-known fundamental property of MEMS that the electrostatic force overtakes the elastic restoring force when the distance between the slab is reduced to 2/3 the original distance [9].

With the original membrane separation of ~210 nm, the displacement is limited to ~70 nm which in turn leads to a spectral tuning of 35 nm for a typical optimised tuning rate of 0.5 nm wavelength per nm displacement. Efforts are underway to use smaller separations, different cavity designs and exploiting multiple cavity modes to increase the wavelength span.

### Resonance modulation spectroscopy

While the resonantly enhanced photocurrent clearly dominates the photocurrent for a narrowband source as seen in Figure 4, the nonresonant background could be detrimental in case the source is broadband with only a small fraction in the cavity resonance band. To mitigate this effect, a sinusoidally time-



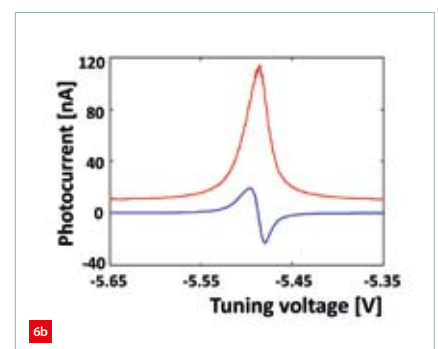
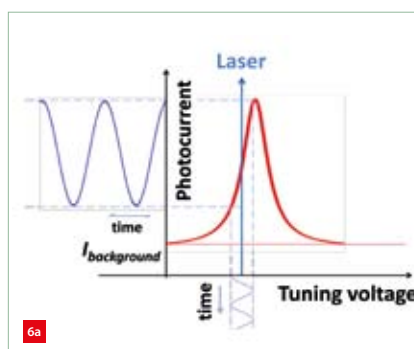
varying (‘AC’) voltage can be superimposed on the tuning voltage, so that the slab separation is modulated. This results in a temporal modulation of the resonant wavelength.

As schematically indicated in Figure 6a, with a source having a wavelength close to the resonance, the photocurrent has an AC-component at the modulation frequency, which can be very accurately measured using lock-in detection techniques. From the sketch in Figure 6a, it can be seen that the amplitude of the AC current follows the derivative of the resonance curve when the tuning voltage (or laser wavelength) is varied. The derivative feature is nicely reproduced in the experimental trace of Figure 6b.

As a consequence, the background is also suppressed by several orders of magnitude. Moreover, the original peak position in the derivative feature corresponds to a zero-crossing, which can be much more accurately determined than a peak. As a peak wavelength detector therefore, the resolution of the spectrometer is actually a few orders of magnitude better than the linewidth and therefore below a pm for an integration time of 1 s. The sign-changing feature of the derivative curve is also very useful for feedback and wavelength-locking applications.

### Wavemeter operation demonstration

Despite the still narrow tuning range of the present spectrometer, an important real-life application as a wavemeter can be demonstrated. For this, the accurate peak detection capability, enabled by the resonance modulation technique, is exploited.



- 5 Operation and calibration of the spectrometer.
  - (a) Compilation of photocurrent traces at fixed laser wavelength (lower scale) as a function of voltage (upper scale).
  - (b) Typical nonlinear calibration curve of voltage vs wavelength, on a different device than in (a).
- 6 Resonance modulation technique.
  - (a) By modulating the tuning voltage the resonance peak oscillates back and forth on the horizontal axis, resulting in a time-varying photocurrent signal.
  - (b) Red: the photocurrent as a function of tuning voltage. Blue: Phase-sensitively detected amplitude of the time-varying (AC) photocurrent as a function of tuning voltage.

7 Application as a wavemeter for a fibre bragg grating (FBG) peak-shift detector.

(a) The FBG is illuminated by a broadband source (SLED) via a fibre beam splitter (BS). Using a free-space path, the backreflected narrow peak is coupled into the voltage-modulated sensor, from which the time-varying (AC) photocurrent is measured.

(b) Portion of the AC photocurrent amplitude near the zero-crossing, from which the current-to-wavelength conversion can be obtained.

(c) Initially, the tuning voltage was adjusted to the zero-crossing. A heater pulse induces a peak shift and a corresponding photocurrent signal excursion from zero.

A widely used fibre-optic sensor is the fibre bragg grating, which reflects a narrow peak from a broadband source, the peak position being a measure for the sensed parameter such as temperature or strain. The sensor therefore needs an interrogating device able to determine the peak wavelength, typically requiring a sophisticated spectrometer or tuneable laser.

Figure 7a shows the experimental arrangement of a commercial FBG sensor, interrogated by the new spectrometer in resonance modulation mode. A fibre-optic beam splitter is used to expose the FBG to the superluminescent light emitting diode (SLED) broadband source and receive the reflected narrow peak in another fibre (a redundant arm of the 2x2 splitter is not used). The reflected signal is focused to the PhC cavity by a microscope objective.

Figure 7b shows the measured AC-current amplitude as a function of tuning voltage. The zero-crossing at approximately  $-1.3$  V indicates the peak wavelength of the FBG reflection, corresponding to 1314.9 nm wavelength. For sensing variations of the FBG peak due to the environmental conditions, it is noted that around the zero-crossing the current varies linearly with voltage. Because the calibration relates tuning voltage to wavelength, also the current can be converted to wavelength.

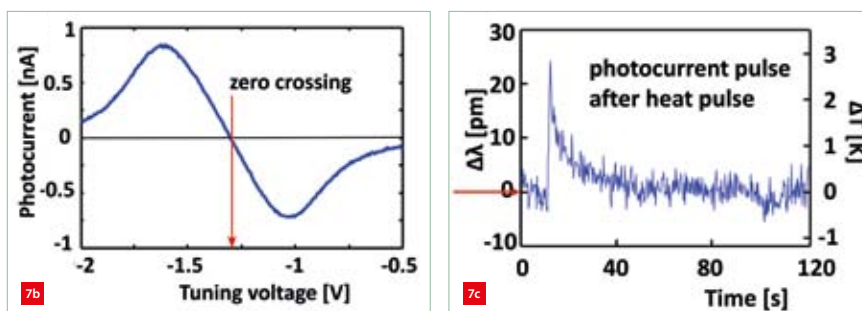
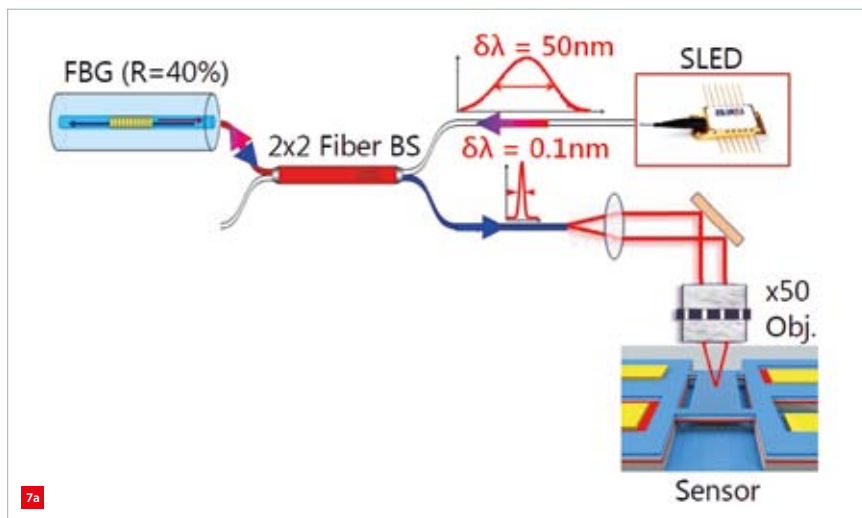
The tuning voltage is adjusted so that the AC photocurrent is zero. Using a short heater pulse, the temperature of the FBG is briefly increased. This results in an increase in photocurrent, as shown in Figure 7c, where on the left scale the current is already converted to wavelength shift. The right scale provides the corresponding temperature change according to the calibration data of the FBG manufacturer. It can be noted that the wavelength resolution is of the order of 1 pm, which is already comparable to or better than that of the best commercial FBG interrogators, and two to three orders of magnitude below the cavity linewidth.

## Conclusion

An ultracompact NIR spectrometer on a chip with a footprint of only about  $15 \times 15 \mu\text{m}^2$  based on a nano-opto-electro-mechanical system has been realised with resolution of  $\leq 0.1$  nm for broadband spectra comparable to benchtop laboratory instruments. Efforts are ongoing to extend the wavelength span to at least several hundred nanometers. The low-cost and small size associated with chip-scale manufacturing will allow this type of sensors to be integrated with next-generation smart consumer devices that eventually may lead to future 'lab-in-the-phone' applications or 'Internet of Things' sensors. ■

## REFERENCES

- [1] F. Marquardt and S.M. Girvin, "Trend: Optomechanics", *Physics* 2, 40, [physics.aps.org/articles/v2/40](http://physics.aps.org/articles/v2/40), 2009.
- [2] L. Midolo, A. Schliesser and Fiore, "Nano-Opto-Electro-Mechanical Systems", *Nat. Nanotech.* 13, 11-18, doi:10.1038/s41565-017-0039-1, 2018.
- [3] Ž. Zobenica, R.W. van der Heijden, M. Petruzzella, F. Pagliano, R. Leijssen, T. Xia, L. Midolo, M. Cotrufo, Y. J. Cho, F.W.M. van Otten, E. Verhagen and A. Fiore, "Integrated nano-opto-electro-mechanical sensor for spectrometry and nanometrology", *Nat. Commun.* 8, 2216, doi: 10.1038/s41467-017-02392-5, 2018.
- [4] A. Hind, "Agilent 101: An Introduction to Optical Spectroscopy", [www.agilent.nl/labs/features/2011\\_101\\_spectroscopy.pdf](http://www.agilent.nl/labs/features/2011_101_spectroscopy.pdf)
- [5] [www.consumerphysics.com](http://www.consumerphysics.com)
- [6] [www.bayspec.com/newly-released/breeze-smart-palm-spectrometer/breeze-smart-palm-spectrometer/](http://www.bayspec.com/newly-released/breeze-smart-palm-spectrometer/breeze-smart-palm-spectrometer/)
- [7] A.J.S. McGonigle, T.C. Wilkes, T.D. Pering, J.R. Willmott, J.M. Cook, F.M. Mims and A.V. Parisi, "Smartphone Spectrometers", *Sensors* 18, 223, doi:10.3390/s18010223, 2018.
- [8] [www.phone.consumerphysics.com](http://www.phone.consumerphysics.com)
- [9] [www.kaajakari.net/~ville/research/tutorials/pull\\_in\\_tutorial.pdf](http://www.kaajakari.net/~ville/research/tutorials/pull_in_tutorial.pdf)





# REFLECTIONS FROM THE HIGH TECH SYSTEMS CENTER

## AUTHOR'S NOTE

Ton Peijnenburg received his M.Sc. in Electrical Engineering from Eindhoven University of Technology (TU/e) in 1992. He started his career in the mechatronics department of Philips's Centre for Industrial Technology (Philips CFT). He worked for five years as an expat in the US for Philips, then at FEI and, since 2010, for VDL Enabling Technologies Group. Since 2015, he has been a part-time fellow at TU/e High-Tech Systems Center.

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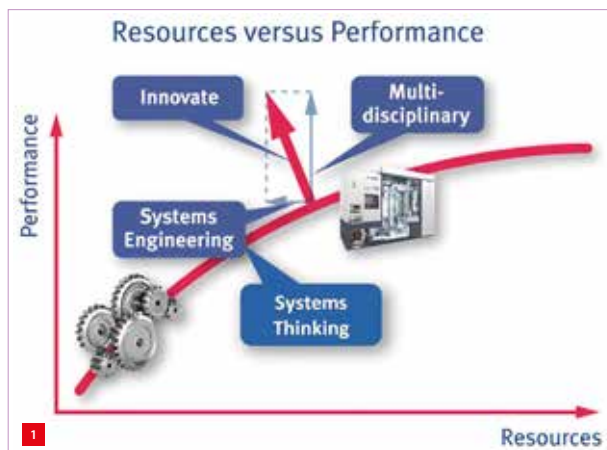
The High Tech Systems Center (HTSC) at Eindhoven University of Technology (TU/e) employs in-depth understanding of the classical engineering fields, together with model-based systems engineering to conceive, predict and verify cutting-edge system functionalities and architecture. However, with the increasing complexity of high-end systems – driven for example by the evolution of precision mechatronics – the performance of development & engineering is decreasing. Hence, innovation is required; enter systems engineering.

## TON PEIJENBURG

**T**he TU/e HTSC is a multidisciplinary research centre with the ambition to understand, teach and innovate system synthesis and design of complex equipment, instruments, robotic and manufacturing systems and systems-of-systems.

It employs in-depth understanding of the classical engineering fields, together with model-based systems engineering to conceive, predict and verify cutting-edge system functionalities and architecture. With high-end systems becoming more complex, the performance of development & engineering is suffering. Output per person decreases due to the increased overhead of growing team sizes. Innovation is required, and HTSC [1] explicitly looks to multidisciplinary teams and the use of systems engineering to achieve this innovation, see Figure 1.

The S in HTSC is rather important; on the one hand it designates the focus area of the centre (high-tech systems) while on the other it reflects the systems engineering approach the centre proposes taking for its research and design activities on high-tech systems. This focus is rather explicitly spelled out in our vision document. The following two statements from the document convey this:



1 The driving force to innovate with systems engineering. (Source: (TU/e))

- More complex systems call for multidisciplinary fundamental research and proven practices in the synthesis and design of technically advanced systems.
- Systems engineering is the keyword at the HTSC. We will teach and innovate the system design and synthesis of complex equipment, instruments, robotic systems, manufacturing systems and systems-of-systems.

## Our agenda

Now, the fact that systems engineering (SE) is such an explicit part of our strategy does not imply it has already been thought out completely; we will need to develop a tailored interpretation based on current SE practices that is suitable for high-end equipment research & development. Stimulated by our advisory board and by key industry partners, we have put the topic in quite a prominent position on our agenda. Also, the TU/e board has put the topic of 'systems thinking' on their strategic plan for 2030. With such focus, we will see progress. Let's provide an update on some of our current insights. We would like to invite readers to participate as stakeholders in the discussion, to share ideas and experiences.

*"Systems engineering is a consistent, interdisciplinary approach for developing multidisciplinary systems. Not only does it address the system to be developed, but also the associated project.*

*Systems engineering is very multifaceted. It originates from systems theory and has been evolving steadily. The catalyst was always the increased complexity of problems. The current research topics Industry 4.0 and Cyber-Physical Systems are significant driving forces behind systems engineering."* [2]

## Get back training in design

At the moment, much of the training of bachelor, graduate, PDEng and Ph.D. students focuses on the scientific side of engineering, i.e. analysis. This is not specific to TU/e, but has

been recognised more broadly and internationally. For a balanced SE approach, the design side of engineering, i.e. synthesis, is also required. A very nice paper on this topic is based on a lecture by one of NASA's distinguished systems engineers [3]. A first task of HTSC will be to help introduce some balance by promoting greater attention for design training. Given the development of university focus as mentioned above, the involvement of industrial systems engineers and system designers is crucial to achieve this balance.

### Connecting the software discipline

A second important focus area is the connection of the (embedded) software discipline to the other disciplines relevant for machine design. We have seen many disciplines operate under the umbrella of mechatronics (even called mechaphysics by some), but the discipline of embedded software engineering has not always been well connected. This is, however, crucial – and will become even more so. Much of the value-added functionality in high-tech systems already is or will be implemented in (embedded) software. A modern car already contains 100 million lines of code [4]! The complexity of the (embedded) software will increasingly drive the complexity of our engineered systems and we will need an SE approach inclusive of the software discipline in order to manage it.

### Our focus

These two focus areas should be addressed in the context of model-based SE. According to a study by the Heinz Nixdorf Institut and Fraunhofer IPT, we should not expect a unification of engineering models (supporting 'domain-spanning system architecting') to happen any time soon [2]. Nevertheless, we see it as an important dot on the horizon. For now, we will develop ways in which the SE approach can handle multiple, significantly different models, such as event-based descriptions for supervisory control and state-space descriptions for motion control. Training of students in both the general principles as well as the various flavours of system modelling, is a necessary ingredient.

At HTSC, we are now focusing on translating these three aspects into a practical implementation at the centre and the university. Experienced engineers from industry work at HTSC as fellows and programme managers, to support the definition and execution of research programmes. As one of the fellows, I have picked up the responsibility for SE.

### Towards multidisciplinary development & research

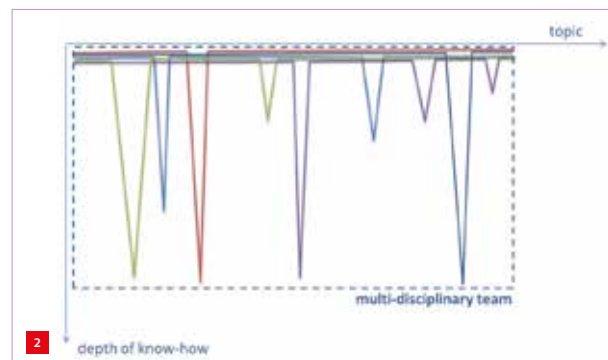
So, the need for SE has been explained and the focus has been put on two aspects: the analysis-synthesis balance and the incorporation of embedded software development. Now, I will shift the focus to the need for multidisciplinary research and development. The design of new technological systems has to address various technological disciplines at the same time, and requires teams that have been set up to effectively and efficiently do this.

When I started my career at Philips CFT back in 1992, I joined the mechatronics department of Jan van Eijk et al. and was quickly trained in what mechatronics was about. Essentially, it was about collaboration between specialists who were familiar with one another's existence, and who respected one another's competences as being equally relevant for the design of mechatronic systems of the future.

A mechatronics course programme was developed at the time, with each specialist teaching newcomers about their specific field of activity. Understanding one another's field and language is the basis for respect, which in turn forms the basis for successful collaboration. Figure 2 sketches such a multidisciplinary team, where each engineer has a different colour, and depth of knowledge is plotted for each engineer against an arbitrary set of topics. In some cases, misunderstanding has developed about what a multidisciplinary team is. Figure 3 shows another type of team, where each of the members has a broad understanding but lacks in-depth knowledge of one (or more) specific areas of expertise. Although the team covers the required topics, it lacks thorough understanding and is therefore not as effective as the previous team. It either has to consult with specialists on specific topics, which sacrifices the team's efficiency, or it is blind to their lack of knowledge, which also compromises effectiveness.

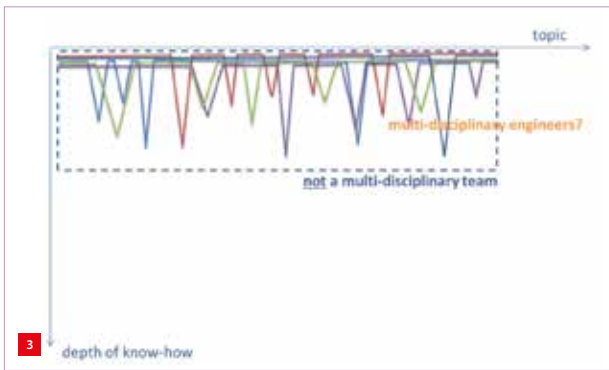
A key notion is that multidisciplinary teams are actually groups of specialists; the fact that a team operates on multiple disciplines does not sacrifice the depth of understanding of single topics, or the excellence with respect to such topics. This notion is the basis under the multidisciplinary working that HTSC promotes; rather than training researchers and designers to become multidisciplinary themselves, we will train them to work in a multidisciplinary manner – as part of a team – but still achieve depth and excellence in their individual topics.

Recently, this combination of depth in a certain field, combined with multidisciplinary awareness and ability to communicate, has been described as a T-shape profile – which may be obvious when looking at the figures displayed here. In addition to the T-shape, the  $\Pi$  shape is also used to



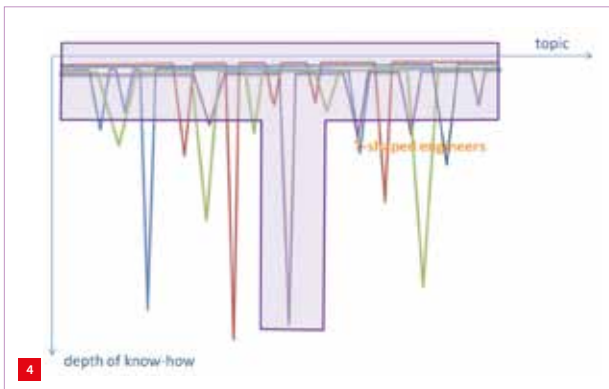
2 Schematic composition of a multidisciplinary team.





indicate that not one, but two in-depth knowledge areas should be part of an engineer's profile. People not familiar with the Greek alphabet can use the M-shape – which makes the connotation to multidisciplinary.

System architects are a good example of specialists with multidisciplinary awareness that have demonstrated the capability of combining oversight with the capability of learning quickly about new fields of expertise. In addition to their specific expertise, they have the ability to act as glue between specialists



of other domains, translate system level requirements to more detailed requirements for each of the specialists involved, make trade-offs and keep all team members on board.

In a discussion with a TU/e colleague, I was made aware of another implication. When taking the perspective of company culture, specialisation is key, not only in mono- but also in multidisciplinary development & engineering activities. Rather than trying to make people work on many topics right from the start of their career, there should be time to develop one's specialism. Like multidisciplinary skills, depth in one's field of expertise should be regarded as a valuable asset. Companies should keep this in mind when motivating and rewarding their employees.

In a forthcoming article, process-related aspects such as V-models and agile development will be discussed. A key challenge is to find a tailored way of working that supports the characteristics of the high-tech equipment industry, and provides a sufficient backbone for structuring and guiding the development projects, but stays away from document-based bureaucratic processes as much as possible. Educating students in using this way of working provides a challenge as well – they will have to be trained before having the opportunity to learn first-hand the need to have these processes in place. ■

#### REFERENCES

- [1] High Tech Systems Center, [www.tue.nl/htsc](http://www.tue.nl/htsc)
- [2] "Systems engineering in industrial practice", Heinz Nixdorf Institut (Universität Paderborn), Fraunhofer IPT and UNITY consulting & innovation, 2015 (retrieved from [www.hni.uni-paderborn.de/en/spe/systemsengineering](http://www.hni.uni-paderborn.de/en/spe/systemsengineering))
- [3] M.D. Griffin (Administrator, NASA), "System Engineering and the 'Two Cultures' of Engineering", Boeing Lecture, Purdue University, 28 March 2007 (retrieved from [www.nasa.gov/pdf/173108main\\_mg\\_purdue\\_20070328.pdf](http://www.nasa.gov/pdf/173108main_mg_purdue_20070328.pdf))
- [4] Infographic on code bases: [www.informationisbeautiful.net/visualizations/million-lines-of-code](http://www.informationisbeautiful.net/visualizations/million-lines-of-code)

3 Without in-depth knowledge of one (or more) specific areas of expertise no true multidisciplinary team can be assembled.

4 The T-shaped engineer.

**Mikroniek is the professional journal on precision engineering and the official organ of the DSPE, The Dutch Society for Precision Engineering.**

Mikroniek provides current information about technical developments in the fields of mechanics, optics and electronics and appears six times a year.

Subscribers are designers, engineers, scientists, researchers, entrepreneurs and managers in the area of precision engineering, precision mechanics, mechatronics and high tech industry. Mikroniek is the only professional journal in Europe that specifically focuses on technicians of all levels who are working in the field of precision technology.

**Publication dates 2018**

| nr: | deadline:  | publication: | theme (with reservation):                       |
|-----|------------|--------------|---|
| 4.  | 03-08-2018 | 07-09-2018   | Precision talent (education, training, HRM)     |
| 5.  | 21-09-2018 | 26-10-2018   | Big Science (incl. preview Precision Fair 2018) |
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EFFICIENCY WINS.



# IN VAN LEEUWENHOEK'S HOMETOWN

The Netherlands is a hot spot for photonics in Europe and a stronghold in optics research and industry, with Delft, home of microscope pioneer Antoni van Leeuwenhoek, as one of the focal points. It makes this city a perfect location for the upcoming European Optical Society Biennial Meeting 2018. The event features intriguing topical meetings, a Grand Challenges in Photonics session, an Autumn Physics School and a number of tutorials.



In Delft, where he was born in 1632 and died in 1723, Antoni van Leeuwenhoek (Figure 1) started making lenses, conducted his pioneering work in microscopy and made his contribution to establishing microbiology as a scientific discipline. Until the present day, Delft has remained a hometown for optics research and industry, spanning areas from space instrumentation to electron beam lithography. Combined with the strong Dutch position in photonics, featuring research at the various universities of technology and companies like Technobis, Effect Photonics and LioniX, it makes

the Netherlands, and Delft in particular, a perfect location for the European Optical Society Biennial Meeting 2018, which will cover optics as well as photonics.

The EOS Biennial Meeting will be held at Delft University of Technology (TU Delft) from 8 to 12 October 2018. The latest results in optics and photonics research will be presented and the meeting includes several topical meetings, an industrial exhibition and special sessions for EU projects and Grand Challenges in Photonics, as well as a conference dinner in the Royal Delft-Koninklijke Porcelейne Fles. Prior to the actual conference programme, both the Autumn Physics School and tutorials will take place.

The event is organised by EOS (European Optical Society) in co-operation with the Dutch Optics Centre, TU Delft, the Netherlands Organisation for Applied Scientific Research (TNO), the PhotonicsNL trade association and the International Commission for Optics (ICO). Dr. Stefan Bäumer (TNO) and Prof. Paul Urbach (TU Delft) act as general chairs (Figure 2) and the venue will be the TU Delft Aula Conference Center.



1 A portrait of Antoni van Leeuwenhoek (1632–1723) by Jan Verkolje. ([www.rijksmuseum.nl](http://www.rijksmuseum.nl))

2 Dr. Stefan Bäumer of TNO (left) and Prof. Paul Urbach of TU Delft act as general chairs of the EOS Biennial Meeting 2018.



## Topical Meetings

- 1 Silicon Photonics and Guided-Wave Optics
- 2 Freeform Optics for Illumination, Augmented Reality and Virtual Reality
- 3 Optical System Design, Tolerancing, and Manufacturing
- 4 Bio-Medical Optics
- 5 Metamaterials, Plasmonics and Resonant Nanophotonics
- 6 Frontiers in Optical Metrology
- 7 Organic & Hybrid Semiconductor Materials and Devices
- 8 Adaptive Optics & Information driven optical systems
- 9 Optical tapered fibres for light manipulation on the nanoscale

### Highlights

The EOS Biennial Meeting 2018 features a total of nine Topical Meetings (TOMs); see the text box. Below the TOMs that are most relevant from the precision engineering and mechatronics perspective will be highlighted.

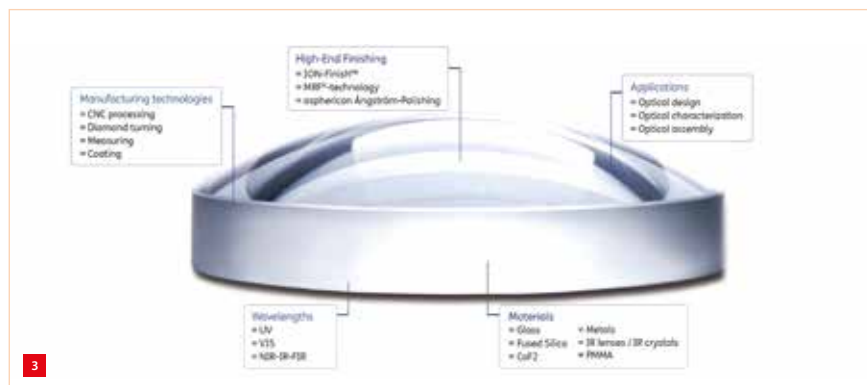
*Contributions can still be submitted as post-deadline papers.*

#### Freeform Optics

TOM 2 will explore and discuss new trends and developments within the rapidly evolving field of optical systems based on freeform optical surfaces as the major component. Refractive as well as reflective freeform optical components offer great opportunities to realise non- or low-symmetry optical systems with new functionalities, high optical performance or reduced complexity. This pertains in particular to illumination systems and to optical systems with very special requirements regarding applications in augmented reality and virtual reality.

On the other hand, manufacturing, characterisation, assembly and optical testing of such systems are still challenging, especially for imaging systems. The meeting will address how new tools and technologies in design, manufacturing, and inspection are enabling next-generation freeform optical systems and will focus on applications in illumination and imaging systems, including augmented and virtual reality systems.

3 Asphericon commands all aspects of the industrial fabrication of aspheres.



Dr. Manuel Flury (INSA Strasbourg, France) will discuss white-light beam shaping with optical elements, manufactured by 3D-printing, containing facets.

#### Optical System Design

TOM 3 will highlight significant technology trends, emerging technologies and associated prospective developments in the field of optics design, tolerancing and fabrication. It will cover all aspects of optical design and fabrication, ranging from micro to large-scale optics and from high-value one-off to mass-produced components, including lessons learned from special design and manufacturing issues. A main goal of the meeting is to provide a better link between the design, manufacturing and characterisation of optical components and systems. Consequently, special attention will be paid to the collaboration between design and fabrication to generate cost-effective and manufacturable optical systems.

Sven Kiontke, CEO and founder of Asphericon (Jena, Germany), will talk about the challenges and myths of industrial fabrication of aspheres (Figure 3).

#### Optical Metrology

TOM 6 will cover application-oriented basic and applied optical metrology techniques. This includes basic methods, fundamental limits, measurement techniques and their applications, foundations of applied metrology as well as future trends and topics. As optical metrology methods are generally non-contact, non-destructive, fast, reliable and high-precision, and can sometimes even be used in a rugged environment, they lend themselves very much to industrial applications such as process development, in-line processing (roll-to-roll, in-process, etc.), and quality control.

However, industrial demands are ever increasing, so evolutionary improvements as well as new ideas and even revolutionary breakthroughs are called for. Besides developing new methods and paradigms, rigorous modelling and simulations also deserve attention, especially in the emerging fields of hybrid and holistic metrology. Finally, an assessment of the absolute performance in terms of resolution and measurement uncertainty stresses the role of traceability in internationally recognised primary metrology standards.

Prof. Alain Diebold (SUNY Polytechnic Institute, Albany, USA) will present the application of Mueller-matrix spectroscopic ellipsometry to scatterometry-based measurement of feature shape and dimension.

#### Light manipulation on the nanoscale

TOM 9 will explore new trends and applications in the field of tapered optical fibres, i.e. fibres with diameters close to or smaller than the optical wavelength. These 1D micro-/





nanoscale waveguides present interesting properties, including light confinement, strong evanescent field, design of dispersion, and enhanced surface effects.

The session will cover the design, simulation, and fabrication of tapered optical fibres. Special issues may include nonlinear optical effects and laser applications in tapered optical fibres using either silica or other materials, such as tellurite or chalcogenide, and tapered fibres embedded in different materials (polymers, metals, ...) for the realisation of complex systems (plasmonic fibres, optomechanics at the nanoscale, etc.).

Prof. Yuliya Semenova (Dublin Institute of Technology, Ireland) is one of the invited speakers (Figure 4). She will talk about whispering gallery modes in optical fibre micro-resonators for sensing applications.

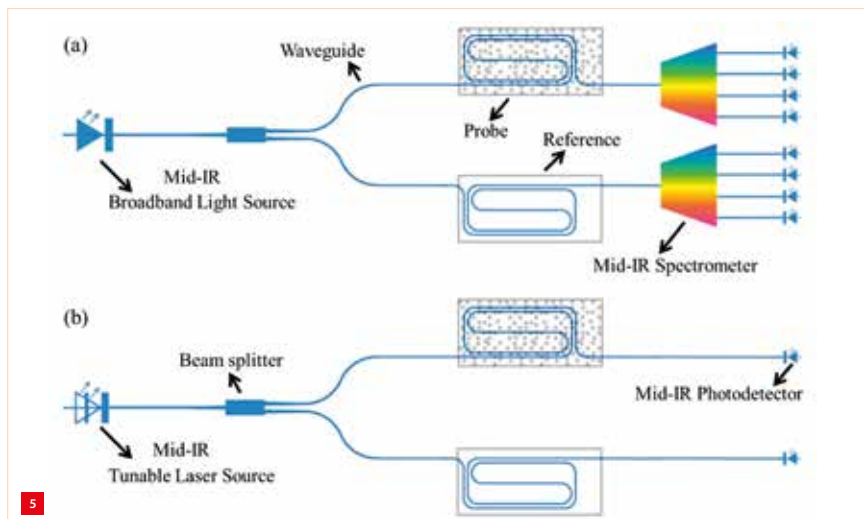
### Grand Challenges in Photonics

A special session will be dedicated to the 'grand challenges of photonics'. World-class speakers will discuss technologies which are revolutionary, uncommon and not realisable to date, but can pave the way for an even brighter future in optics and photonics.

Prof. Yuan Xiaocong (Nanophotonics Research Centre, Shenzhen University, China) will present "Singular optical beam multiplexing communication towards high performance computing applications" and Marc Cayrel, project manager European Extremely Large telescope (ELT) Optomechanics at ESO (European Southern Observatory, Germany), will give an update on the ESO 39-meter ELT.

A 'home game' will be played by Prof. Ronald Hanson (QuTech, TU Delft), talking about "The dawn of quantum networks". Entanglement – the property that particles can share a single quantum state – is arguably the most counterintuitive yet potentially most powerful element in quantum theory. Future quantum networks may harness the unique features of entanglement in a range of exciting applications, such as distributed quantum computation, secure communication and enhanced metrology for astronomy and time-keeping.

To fulfil these promises, a strong worldwide effort is ongoing to gain precise control over the full quantum



dynamics of multi-particle nodes and to wire them up using quantum-photonics channels. Hanson will introduce the field of quantum networks and discuss ongoing work with the specific target of realising the first multi-node network wired by quantum entanglement.

### Autumn Physics School

The Autumn Physics School on Metrology for Thin Film Materials, held on Monday 8 October, is organised as part of the dissemination activities for the European HYMet project: Hybrid metrology for thin films in energy applications. This project addresses the development of hybrid metrology approaches where datasets from multiple measurements are combined to deliver new or better results than the sum of the individual methods; and the development of in-situ metrology methods, improvement of measurement sensitivity and identification of key parameters that can be used to monitor or predict ageing of thin-film energy materials and devices.

### Tutorials

The tutorials on Monday 8 October will be targeted at students new to the field, but others are also welcome to attend. The programme lists a total of six speakers. Among them, Prof. Roel Baets (Ghent University, Belgium) will present sensing applications enabled by silicon photonics (Figure 5) and Dr. Oliver Föhnle (Fisba, Switzerland) will discuss optimisation in optics fabrication.

Particularly interesting will be the presentation by renowned expert in optical and EUV (extreme ultraviolet) lithography, Andreas Erdmann (Fraunhofer IISB, Germany), about optical and material-driven resolution enhancements for semiconductor lithography. Erdmann's fields of research include simulation of optical lithography, computational imaging, computational electrodynamics, microelectronic process technology, and modern optics. ■

4 Prof. Yuliya Semenova (Dublin Institute of Technology, Ireland) is one of the invited speakers of the Topical Meeting on light manipulation on the nanoscale. (Source: [www.dit.ie](http://www.dit.ie))

5 An example of the research of Prof. Roel Baets and collaborators on sensing applications enabled by silicon photonics. (Source: R. Wang et al., "III-V-on-Silicon Photonic Integrated Circuits for Spectroscopic Sensing in the 2–4  $\mu\text{m}$  Wavelength Range", *Sensors* 17(8), 1788, doi.org/10.3390/s17081788, 2017)

(a) Schematic of two silicon photonic configurations to realise an integrated on-chip mid-infrared absorption spectroscopy sensor. Broadband source and spectrometer, best suited for liquid and solid analytes.

(b) Tunable single-mode laser source for trace gas detection.

### INFORMATION

[WWW.MYEOS.ORG/EVENTS/EOSAM2018](http://WWW.MYEOS.ORG/EVENTS/EOSAM2018)

[WWW.HYMET.PTB.EU](http://WWW.HYMET.PTB.EU)

# PRECISION IN VENICE

This year, euspen's International Conference & Exhibition was held in Venice, Italy, at the Venice Terminal Passeggeri (VTP). The venue in arguably one of Italy's most iconic cities afforded striking views of the Venice lagoon, and the beautiful weather and scenery provided the backdrop for what many have described as the most successful euspen annual event ever to be held.

CHRIS YOUNG

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## About euspen

The European Society for Precision Engineering and Nanotechnology (euspen) is an influential community linking industrialists, researchers, respected authorities, and new and established players worldwide. It provides an entrepreneurial platform that enables companies and research institutes to promote their latest technology developments, products, and services and keep up to date with those in the field. euspen's defined mission is to advance the arts, sciences and technology of precision engineering, micro-engineering and nanotechnology; to promote its dissemination through education and training; and to facilitate its exploitation by science and industry.

[WWW.EUSPEN.EU](http://WWW.EUSPEN.EU)

The 18th euspen International Conference & Exhibition in Venice (Figure 1) attracted nearly 400 delegates from across the world and 34 exhibitors. Overall the event hosted 206 organisations, from 22 countries, the content of the event consisting of 235 submissions from 167 organisations.

The key to the euspen annual event is networking. This is a gathering of leading academics, researchers, and industrialists all with an acute focus on advancing the discipline of precision engineering and micro/nano-scale manufacturing. The event has over the years become synonymous with alerting attendees to the latest cutting-edge developments and next-generation solutions that exist in the precision engineering environment.

The five days of the event catered for all levels of understanding and involvement in the precision engineering sector, and this year the event kicked off on day one with some lively workshops and tutorials that focused on the key

1 The 18th euspen International Conference & Exhibition was held in Venice, Italy. Here, the Canal Grande and Rialto Bridge are depicted. (Photo: Martin Falbisoner/Wikipedia)







issues of concern to all working in the micro- and nano-manufacturing environments. Topics covered included the fundamentals of precision design, optical measuring technology, dynamics and control of mechatronic systems, design in ultra-high vacuum, flexure design in mechatronics, cutting tools, and the EU dissemination project “Geometrical Product Specification & Verification Toolbox” (GPS&V).

## Conference

The basic structure of the conference covered the key areas of critical concern to the precision engineering community, the first day this year being kicked off with two keynote addresses.

Professor Piero Martin (Figure 2a) from the University of Padua, Italy, focused on the status, challenges and perspectives of the research on magnetic confinement nuclear fusion, i.e. that approach to fusion where the fuel in the plasma state is confined in a toroidal vacuum chamber by a magnetic field. In the quest for sustainable global energy scenarios controlled thermonuclear fusion represents an important option. Fusion, the process that drives the sun and the stars, is clean, carbon-free, safe, does not contribute to nuclear proliferation and uses fuel, which is abundant and ubiquitous like water and lithium. The magnetic confinement nuclear fusion flagship project is ITER, an experiment which is designed to demonstrate the scientific feasibility of this type of fusion and is under construction in France.

The second keynote address, entitled “Mechatronics disrupted?”, was delivered by Professor Maarten Steinbuch (Figure 2b) from Eindhoven University of Technology, the Netherlands. In next-generation high-tech and mechatronic systems, extreme functionalities and performance requirements demand a multi-physics systems approach. The control systems will become adaptive, auto-tuned, will be implemented in optimised hardware and software architectures, and will employ effective (wireless) communication. The field of robotics could be treated as a separate research area, next to mechatronics, but for

instance the speed requirements of industrial robots or the accuracy requirements of surgical robots necessitate the inclusion of the description of dynamical behaviour of the robots. Where does mechatronics end and robotics start?

Steinbuch: “Overseeing the developments we could question what mechatronics actually is or will be. Is mechatronics being disrupted? Has it evaporated already into systems engineering, is it part of the supporting disciplines, does it enlarge to be the backbone of cyber physics? Moreover, if biological systems are also going to have technical devices implemented (internet of humans), what is then the role of the mechatronics discipline?”

The conference sessions over the course of the three-day event looked at advances in precision engineering, design and performance of measuring instruments and machine tools, mechatronics and control, replication and additive manufacturing, mechanical manufacturing processes, non-mechanical manufacturing processes, and metrology.

This year, prominent among the high-calibre presentations was the one by Patrick Bointon from the University of Nottingham, UK, which precipitated a lot of interest as he discussed the effects of vibration on fringe projection systems, and a paper by Jun Qian from KU Leuven in Belgium that looked in-depth at ultrasonic assisted drilling of composites.

## Exhibition

There was a real buzz around this year’s exhibition, and there were a number of new faces and new technologies on display. Notable among these were Ultrason, Cytosurge, Kinetic Ceramics, and a company returning to the event after a while away, Alio Industries.

Ultrason was showcasing its ultrasonic micro-moulding technology. To date, technology providers in the area of precision moulding have attempted to focus on adapting large-scale moulding technologies to micro-moulding applications. However, the inherent problems associated with moulding in general (and exacerbated at the micro-scale) have not been addressed. Moulding using the traditional screw, barrel, and heater band configuration means the preheating of materials in advance of injection into the mould. This means that the material degrades before injection, and this has huge repercussions when moulding on a micro-level.

The Ultrason process eliminates residence time and hence material degradation by dosing only the amount of material needed per shot, which is melted via an ultrasonic horn right by the gate, reducing the thermal window to milliseconds. In addition, ultrasonics reduces the viscosity of the

- 2** Keynote speakers:  
 (a) Prof. Piero Martin, University of Padua, on magnetic confinement nuclear fusion.  
 (b) Prof. Maarten Steinbuch, Eindhoven University of Technology, on the current status of mechatronics.

## 'euspen inside'

What is being discussed at the annual euspen conference is pushing the boundaries of what is already possible and is being achieved in industry today, and is incorporated in things that we take for granted every day. The organisers are working hard to ensure the link between the technical conference presentations and real world applications is reinforced. This is not an event where researchers are discussing issues concerning non-practical applications. Each and every paper is actually pushing advances in technologies and techniques that have real-world uses, and this link is being promoted through a new initiative that euspen is in the process of launching, called 'euspen inside'.

The idea of 'euspen inside' is to make clear the link between the work that euspen undertakes day-to-day as a society promoting the art of precision engineering, the presentations at its annual events and other seminars and workshops throughout the year, and the commercial use of micro- and nano-scale engineering in countless industry sectors. We are surrounded by real-time applications of the art of precision engineering in every walk of life, be it a trip to a hospital, a drive in a car, a flight in an aeroplane, or using our mobile phones. You name it, and micro- and nano-scale manufacturing is there, and the link between what may seem like rarefied discussion and research, and the real world is one that euspen will continually seek to demonstrate. In this way its events and initiatives will become more and more inclusive and pragmatic over time.

melted plastic, meaning that longer, thinner, flatter parts can be manufactured than ever before, stimulating innovation by knocking down design and manufacturing constraints.

Cytosurge was presenting its FluidFM  $\mu$ 3Dprinter, which is the world's first 3D printer capable of delivering submicron resolution in direct metal printing. Pinpoint additive manufacturing provides the possibility to print complex

metallic 3D  $\mu$ -structures on existing objects and surfaces. The FluidFM technology allows a variety of materials to be combined within one object, and can be used to print micron-wide solid metal structures directly into or onto individual objects, as well as for the repair of tiny structures or electrically linking minute objects.

Kinetic Ceramics, one of the world's leading multi-industry precision technology companies was showcasing its range of piezo actuators used across numerous industrial applications. Details were also available of the company's proprietary Piezomotor®, made from PZWT-100 powder, and according to Kinetic Ceramics the highest performing piezoelectric actuator available on the market today. Over 20 years of research and development have been invested to create a material that provides up to 28,000 Newtons of force, 10 to 200 microns of displacement, and precision movement at nanometer resolution.

Alio Industries used the euspen Venice event to announce the introduction of its Hybrid Hexapod® (Figure 3) in response to the demand from industry for more and more versatile and accurate motion control systems. The Hybrid Hexapod® technology which Alio claims outperforms any other hexapod solution in the market could be a game-changer in the field of motion control, and may stimulate innovation as an enabler of next-generation manufacturing processes.

Other exhibitors included regular euspen supporters attocube, Huber, Cranfield Precision, Sensofar Metrology, Taylor Hobson, Zygo, and Precitech among many more. It is interesting to get first-hand feedback from exhibitors about how the event works for them. This is not an exhibition that exhibitors attend expecting a thousand new leads, but is rather a place where strategic, meaningful, and long-term alliances are forged.

William Meiklejohn from first-time exhibitor Kinetic Ceramics said, "We were very happy with the event, and we met a good number of new contacts which we will work with into the future." Marianne Janssen (Figure 4) from Janssen Precision Engineering (JPE) endorsed this view, and explained that the event was an annual fixture for them as it afforded the opportunity to have long and meaningful interaction with influential players in the precision engineering space, and to forge and mature long-term relationships. For Janssen, the euspen event is "less a place to sell products, and more a place to embed with companies' research projects".

This is an important aspect of the euspen event. In the area of precision engineering, technology and service providers like to forge relationships where they are seen as strategic



3 Alio used the euspen event to announce the introduction of its Hybrid Hexapod.





partners in product development, and the ability to integrate themselves with companies at the research stage of product development is obviously advantageous.

In many ways this is the reason that another seasoned euspen exhibitor, MI-Partners, keeps coming back. MI-Partners is an engineering consultancy company that creates new design concepts and delivers prototypes and one-of-a-kind equipment. The company is a development partner maturing measurement systems and precision equipment, and Ronald Timmermans, sales director, sees exhibiting at the euspen annual event as “a great opportunity to keep in touch with the engineering and science community that deals with these types of systems”.

Atsuko Nose from Mitaka Kohki also endorsed the value of the euspen event as a way of embedding with companies that were at the early stage of research with their analysis equipment, and Clive Warren, strategic business development manager from Renishaw (another regular exhibitor) highlighted another key value of conference and exhibition, namely that it was a great recruiting ground for prospective employees as it attracted the cream of Ph.D. students fronting research in precision engineering.

## Posters

A key feature of the euspen annual event is the extremely vibrant and busy poster area. This year, the winner of the poster award was “Manufacturing uncertainty: How reproducible is the depth of cut during diamond turning of OFHC copper?” by Junguo Zhao, Claudiu Giusca and Saurav Goel from the School of Aerospace, Transport and Manufacturing, Cranfield University, UK.

In second place was “Experimental qualification of the strength enhancement of coated concrete parts” by C. Hahm, R. Theska, and D. Raab from Technische Universität Ilmenau, Germany, Department of Mechanical Engineering, Precision Engineering Group, A. Fehrer from Egbert Reitz Natursteintechnik, Germany, and A. Kästner from ETC-Products, Germany.

Third came “Accuracy of surface topography measurements performed by X-ray computed tomography on additively manufactured metal parts” from F. Zanini, E. Sbettega, and S. Carmignato from the Department of Management and Engineering, University of Padua, Vicenza, Italy and M. Sorgato from the Department of Industrial Engineering, University of Padua, Padua, Italy.

## To conclude

The week was rounded off on the final day with a series of tours, this year to Consorzio RFX (a research organisation that performs scientific and technological research activities in the field of controlled thermonuclear fusion as a possible energy source), the Laboratory for Micro and Precision Manufacturing at the University of Padua, and Marposs, a leader in precision equipment for measurement and control in the production environment.

Finally, each year euspen hosts the Heidenhain Scholarships. The Heidenhain group has been associated with the euspen annual event for over ten years, and has provided over 100 scholarships to date, and was brought into a philanthropic foundation over 40 years ago with a philosophy to invest in research, development, social, and scientific projects. Scholarships are available for students or researchers registered for Masters/Ph.D. or equivalent courses at a recognised international higher education institution. Figure 5 shows the 2018 scholarship winners.

Next year, the euspen annual event will be held on 3-7 June in Bilbao, Spain. ■

4 According to Marianne Janssen (JPE) the euspen event is “less a place to sell products, and more a place to embed with companies’ research projects.”

5 The recipients of the 2018 Heidenhain Scholarship.



# AWARD FOR 'TECHNICAL CONSCIENCE' OF ELECTRON BEAM LITHOGRAPHY

Marco Wieland (Mapper Lithography) received the Martin van den Brink Award on Thursday 7 June. This system architecture award was presented at a gala dinner held at the Evoluon in Eindhoven, the Netherlands, as part of the Dutch Technology Week. The event was organised by DSPE in collaboration with Brainport Industries. Marco Wieland is the CTO and co-founder of Mapper Lithography in Delft. He serves as the 'technical conscience' in the development of electron beam lithography into a full-blown supplement to optical lithography. This conventional lithography is the technology with which Martin van den Brink's ASML has grown to become world market leader.

### System architecture

The success of the Dutch high-tech industry is partly thanks to thinking in terms of system architecture. At a high level of abstraction, system architecture describes the design for a complex machine that is usually made up of multiple modules. The system architect is responsible for the main design and coordinates the contributions of all the disciplines involved. He ensures that the different modules, which are mostly built and nowadays also co-developed by suppliers, are combined to create one optimally functioning machine.

### Martin van den Brink

The most successful exponent of system architecture thinking is the Veldhoven-based company ASML, which was spun off from Philips in 1984 and is now the global leader in lithography machines.

Lithography is the crucial production step that determines the performance of semiconductor chips. It is partly thanks to ASML's machines that we have tablets, smartphones and other high-tech electronic products today. Since ASML's start in 1984, Martin van den Brink, its current President and chief technology officer, has played an important role in the development of optical lithography.

### Award

To highlight the importance of system architecture, the Martin van den Brink Award was established in 2012 thanks to an initiative from DSPE, TNO, Brainport Industries, High Tech Systems Platform, Point-One and High Tech Campus Eindhoven. The first award was presented that same year to Erik Loopstra, system architect at ASML. In 2016, Jan van Eijk, former CTO of Mechatronics at Philips Applied Technologies and Emeritus Professor of Advanced Mechatronics at Delft University of Technology (TU Delft), received the award.

For the third edition of the award, DSPE, in collaboration with Brainport Industries, organised a gala dinner at the Evoluon in Eindhoven as part of the Dutch Technology Week. No less than



■ Martin van den Brink (ASML) handing over a litho, as a symbolical representation of the award, to Marco Wieland (Mapper Lithography). On the left, DSPE president, Hans Krikhaar, and on the right, Prof. Pieter Kruit (Delft University of Technology). (Photo: Max Franken)



180 guests from high-tech companies and universities of technology attended the dinner and the award presentation on the evening of Thursday 7 June. Martin van den Brink, after whom the award was named, presented the award to Marco Mieland, M.Sc., for his crucial role in the development of e-beam lithography.

### Marco Wieland

Marco Wieland studied Applied Physics at TU Delft from 1993 to 1999 and performed his graduation assignment in the group of Prof. Pieter Kruit, professor in the optics of charged particles. After graduating in 2000, Wieland founded a company, Mapper Lithography, together with his fellow student Bert Jan Kampherbeek and Professor Kruit. When ideas for improvement of mask-based optical lithography did not reach a successful conclusion, they focused on maskless e-beam lithography.

This alternative technique directly 'writes' structures on semiconductor wafers using tens of thousands of parallel electron beams. This makes the expensive optics and masks of optical lithography superfluous, but itself has completely different challenges, such as the super-fast control and magnetic shielding of the electron beams, in addition to known issues such as vibration isolation, advanced metrology and heat dissipation control.

Mapper has now demonstrated nanometer accuracy for both wafer table positioning and electron beam control, and a first alpha machine is running in the cleanroom of the French LETI. For the commercialisation of the technique, the further increase of the wafer throughput and cost reduction are additional challenges.

As CTO, Wieland, together with COO Guido de Boer, is ultimately responsible for the architecture of the Mapper machine, the development roadmap of the company and the development of the various technical solutions. His contributions to this have been laid down in dozens of patents. In short, every reason for the judging panel to distinguish Marco Wieland on behalf of DSPE with the Martin van den Brink Award 2018.

The judging panel consisted of Jos Benschop (ASML), Pieter Kappelhof (Hittech Group), Adrian Rankers (Mechatronics Academy), Hans Krikhaar (DSPE) and Martin van den Brink (ASML).

[WWW.MAPPERLITHOGRAPHY.COM](http://WWW.MAPPERLITHOGRAPHY.COM)

## Readers' survey: an update



To gain insight into the reception of Mikroniek and further align Mikroniek's editorial focus and standard to the information needs and wishes of its (potential) readership, the editorial board decided to conduct a readers' survey. The survey was launched last month and is still open. All Mikroniek readers who did not yet participate in this brief survey are kindly invited to do so. It can be found on the DSPE website.

At the same time a restyling of Mikroniek's design and layout has been commissioned. Results on both fronts – content and presentation – will be reported in a forthcoming issue.

[WWW.DSPE.NL/CENTRAAL/NEWS/MIKRONIEK-READERS--SURVEY](http://WWW.DSPE.NL/CENTRAAL/NEWS/MIKRONIEK-READERS--SURVEY)

Dutch Society for Precision Engineering

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If you are interested in a button or banner on the website [www.dspe.nl](http://www.dspe.nl), or in advertising in Mikroniek, please contact Gerrit Kulsdom at Sales & Services.



60th anniversary  
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# ROBOTS AND US

This year, the leading event on robotics in Europe took place in Tampere, Finland. Over 900 people from industry, academia, not-for-profit and government gathered, exchanged opinions and shared technical developments in more than 50 workshops spread over eight parallel sessions in three days. Central theme of the event was ‘Robots and Us’, reflecting the rise of robots collaborating with humans and their societal acceptance.

HENK KORTIER

## euRobotics

The European Robotics Forum (ERF) is the annual meeting of euRobotics AISBL. This is a European network organisation with members from academia and industry working together to develop and exchange knowledge on robotic technology and applications. It aims to bridge the well-known gap between academic research and the needs of both the robotic industry and the increasing diversity of sectors in society where robotic devices are used.

EuRobotics runs four kinds of topic groups:

- Sector groups, such as: industrial robotics, professional service robotics, domestic service robotics, security robotics, space robotics, medical and healthcare robotics, agricultural robotics.
- Groups covering the supply chain, such as: component suppliers, system integrators, service providers.
- End-user groups covering existing and new markets for robotic systems.
- Technology-related groups as identified in strategic documents and roadmaps.

[WWW.ERF2018.EU](http://WWW.ERF2018.EU)  
[WWW.EU-ROBOTICS.NET](http://WWW.EU-ROBOTICS.NET)

### AUTHOR'S NOTE

Henk Kortier is mechatronics researcher and lecturer at Saxion University of Applied Sciences in Enschede, the Netherlands. This year, he obtained his Ph.D. on “Assessment of hand kinematics and interactions with the environment” at Twente University of Technology, the Netherlands.

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[www.saxion.nl/mechatronica](http://www.saxion.nl/mechatronica)

In snowy Tampere (Figure 1), euRobotics president, Berndt Liepert, chief innovation officer of KUKA, kicked off the event by addressing the safety aspects of ‘cobots’, i.e. robots collaborating with humans. We are currently facing a digitisation and robotisation revolution. Robots get out of their cages and increasingly become a co-worker. Liepert highlighted the societal aspects and need for greater acceptance, which is currently the main concern hampering the adoption of robots in society.



Next, Anne Berger, minister of Transport and Communications of Finland, discussed the importance of open data and data content enrichment such that it is of value to a wider audience and application range. Tomas Hedenborg, president of Orgalime (EU engineering industry branch organisation) and CEO of Fastems, again emphasised that we live in an era of digitisation and robotisation. The potential of successful innovations does not only require technical aspects but, more important, the engagement of societal challenges.

Subsequently, the keynote of Thomas Pilz, managing partner of Pilz, divided the timeline of service robots into three periods. Starting more than 40 years ago we were introduced to robots as they appeared in science fiction movies (e.g. Star Wars’ C-3PO). He expressed his concern about the contrast between the advances in technology, basically domain-independent, versus the regulations, about to be redefined for each specific domain over and over again. Pilz argued for uniform safety standards with a focus on safe human-robot interactions. Europe should look to Japan with regard to the societal acceptance of robots. Engaging young children with robots removes fear and results in the adoption of robots in all domains, e.g. personal care, health, construction and agriculture.

The opening ceremony ended with a panel discussion on how society should prepare for the rapid robotic developments and how we can find a balance between safety and innovations. The longest discussion was about regulations. Some panel members felt there is a need for regulation because of the rapid technological developments, whereas others argued that time should be spent on the enhancement of a positive attitude towards robots in society. An important step towards such an attitude is open data; hence regulations should actually focus on data.

### Interesting workshops

The video [V1] provides an overview of the conference, which also included demonstrations by industry and academia, showcasing their robotic products and state-of-the-

1 Venue of ERF 2018 in snowy Tampere, Finland.





art developments; see Figure 2 for an impression. The main body of the event was the extensive workshop programme. A few interesting workshops are briefly highlighted below.

#### *Hybrid production systems*

The applications of robotic co-workers are rapidly growing. Various Horizon 2020 projects were presented, addressing important issues regarding a safe, dynamic, intuitive and cost-effective working environment between human workers and robots, while maintaining the flexibility to reconfigure configurations.

#### *Robotics for inspection and maintenance of civil structures*

Different UAV (unmanned autonomous vehicle) application projects were showcased. Advanced slamming (slam = simultaneous localisation and mapping) techniques enable, e.g., performing autonomous chimney inspection or thickness measurements in hazardous and hardly accessible environments. Drone delivery and cinematography systems showed the potential of using UAV swarms in non-industrial environments.

#### *Wearable robotics in industry*

The first experiences with exoskeletons to support workers were presented. From a user perspective some lessons have been learned. Simplicity, weight, adaptiveness and usability are the most important criteria to success in adopting exoskeleton technology. In addition, today's systems can only assist in single tasks whereas typical human workers perform a variety of tasks every day.

#### *Adapting robotics for SMEs*

Today's rapid changes in market demands result in frequent launches of more product variants. SMEs compete on costs, quality and delivery time. In order to stay competitive, SME suppliers are forced to continuously automate and streamline their production set-up. A solution can be found in flexible industrial robots. Various industrial use cases (metal welding/food production lines/furniture assembly) were presented and experiences were shared regarding the use of easily configurable robots in the production line. In addition, a tool was presented to easily modify a workcell.

#### *Innovations in Horizon 2020*

Innovative H2020 projects involving robots, ranging from

inspection and maintenance using a UAV with multiple arms ([aeroarms-project.eu](http://aeroarms-project.eu)), cleaning of nuclear waste ([h2020romans.eu](http://h2020romans.eu)) to an advanced vision module to perform pose estimation ([roboception.com](http://roboception.com)) were presented. A discussion revealed that such innovations cannot be realised without basic scientific research. Future European projects should therefore not only focus on innovations.

#### *Education in the digital transformation / Teaching with ROS*

Various academic institutes discussed their experience using robots in class. In general, a positive engagement of students is visible when experimental work is incorporated in interactive activities. Industrial companies are key partners to provide authentic problems. The Robotic Operating System (ROS) can be of a great value given the number of successes presented.

#### *Artificial Intelligence / Teaching collaborative robotics to non-experts*

A general question is how to easily program robots. Artificial Intelligence (AI) and deep learning (DL) are the enabling technologies. Nevertheless, challenges remain. Keeping track of a reference system, trajectory versus position thinking, the ambiguity of natural language, and lack of domain knowledge are some of the topics that are currently being researched and were addressed in this workshop. A second aspect is the training that every employee should follow. This ranges from a management level for understanding, to an operator level for the implementation of robotic activities.

#### *Robot companions*

Europe has a long history in the development of robotics, from core scientific discoveries to their applications in our industries and homes. In this context, the FET (Future and Emerging Technologies) Robotics Flagship ([roboticsflagship.eu](http://roboticsflagship.eu)) was introduced: it aims to improve the European Robotics ecosystem; using the technology potential to improve the economy and our daily lives. A third wave of robotics is coming.

Key words for this era are: bio-inspired systems, advanced and new materials, cognitive science, self-organisation, energy efficiency, worldwide connectivity. This 10-year initiative strives for a proactive Europe such that key industrial companies maintain the competitiveness. Within

**2** 'Robots and Us' was the central theme of ERF 2018. (Credits: Visual Outcasts, Uwe Hass, Matti Nenonen)



3 Finnish school kids meeting with robots. (Credits: Visual Outcasts, Uwe Hass, Matti Nenonen)

the Flagship, cost-effective energy-efficient mobile robots are created that are able to operate and interact for a whole day, safely, socially, intelligently and physically with people and the environment using a self-contained energy supply.

### Engaging youth

Every day, groups of school kids from Tampere (Figure 3) attended the conference, albeit in a defined area. Being in the close vicinity of robotic experts may have contributed to the societal acceptance of robots and encouraged the school kids to consider pursuing an engineering degree. Many set-ups and applications were available and could be used to become acquainted with robotics in a playful and intuitive manner.

Next year, ERF will be hosted in Bucharest, Romania, on 20-22 March. ■

### Video

[V1] [www.youtube.com/watch?v=d4c3oL\\_ozu4&index=2&list=PLyHQG8zj\\_84a32TP2XFsic32pf1NeDe4r&t=0s](http://www.youtube.com/watch?v=d4c3oL_ozu4&index=2&list=PLyHQG8zj_84a32TP2XFsic32pf1NeDe4r&t=0s)



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# UPCOMING EVENTS

## 22-25 July 2018, Berkely (CA, USA) 2018 Summer Topical Meeting: Advancing Precision in Additive Manufacturing

The 5th in a series of joint Special Interest Group meetings between ASPE and euspen on dimensional accuracy and surface finish in additive manufacturing.

[WWW.EUSPEN.EU](http://WWW.EUSPEN.EU)

## 4-5 September 2018, Sint-Michielsgestel (NL) DSPE Conference on Precision Mechatronics 2018

This year's theme is "Precision Imagineering", inspired by the notion that every enterprise starts with a dream or 'imagination', but that it takes 'engineering' to actually transform the initial idea into a successful product, service or business. See the programme on page 16 ff.



[WWW.DSPE-CONFERENCE.NL](http://WWW.DSPE-CONFERENCE.NL)

## 23-26 September 2018, The Hague (NL) ISCC'18

This year, the Netherlands Contamination Control Society VCCN will host the International Symposium on Contamination Control (ISCC), comprising a 2-day conference, workshops, tutorials and technical tours.

[WWW.ISCC2018.COM](http://WWW.ISCC2018.COM)

## 2-5 October 2018, Utrecht (NL) World Of Technology & Science 2018

Four 'worlds' (Automation, Laboratory, Motion & Drives and Electronics) and Industrial Processing will be exhibiting in the Jaarbeurs Utrecht.



[WWW.WOTS.NL](http://WWW.WOTS.NL)

## 8-12 October 2018, Delft (NL) European Optical Society Biennial Meeting 2018

Conference featuring nine topical meetings, including Freeform Optics for Illumination, AR and VR; Optical System Design, Tolerancing, and Manufacturing; Frontiers in Optical Metrology; and Adaptive Optics & Information-driven optical systems. See the preview on page 39 ff.

[WWW.MYEOS.ORG/EVENTS/EOSAM2018](http://WWW.MYEOS.ORG/EVENTS/EOSAM2018)

## 10 October 2018, Eindhoven (NL) Software-Centric Systems Conference

Conference devoted to complex software development.

[WWW.SOFTWARECENTRICSYSTEMS.COM](http://WWW.SOFTWARECENTRICSYSTEMS.COM)

## 11 October 2018, Eindhoven (NL) Smart Systems Summit 2018

A combination of Bits&Chips Smart Systems and DSP Valley's Smart Industry Summit.



[WWW.SMARTSYSTEMSSUMMIT.COM](http://WWW.SMARTSYSTEMSSUMMIT.COM)

## 23-25 October 2018, Stuttgart (DE) Parts2clean 2018

International trade fair for industrial parts and surface cleaning.

[WWW.PARTS2CLEAN.COM](http://WWW.PARTS2CLEAN.COM)

## 4-9 November 2018, Las Vegas (NV, USA) 33th ASPE Annual Meeting

Meeting of the American Society for Precision Engineering, introducing new concepts, processes, equipment, and products while highlighting recent advances in precision measurement, design, control, and fabrication.

[WWW.ASPE.NET](http://WWW.ASPE.NET)

## 12-16 November 2018, Kamakura (JAP) 17th International Conference on Precision Engineering

Topics of the conference, organised by the Japan Society for Precision Engineering, include digital design and manufacturing systems, non-traditional machining and additive manufacturing, robotics and mechatronics, ultra-precision control, nano-scale measurement and calibration, and precision manufacturing education.

[WWW.SCOOP-JAPAN.COM/KAIGI/ICPE2018](http://WWW.SCOOP-JAPAN.COM/KAIGI/ICPE2018)

## 14-15 November 2018, Veldhoven (NL) Precision Fair 2018

Eighteenth edition of the Benelux premier trade fair and conference on precision engineering, organised by Mikrocentrum.



[WWW.PRECISIEBEURS.NL](http://WWW.PRECISIEBEURS.NL)

## 21 November 2018, Utrecht (NL) Dutch Industrial Suppliers & Customer Awards 2018

Event organised by Link Magazine, with awards for best knowledge supplier and best logistics supplier, and the Best Customer Award.

[WWW.LINKMAGAZINE.NL](http://WWW.LINKMAGAZINE.NL)

## 27-29 November 2018, Paris-Saclay (FR) Special Interest Group Meeting: Structured & Freeform Surfaces

A special focus will be given to research fields in the following topics: replication techniques, structured surfaces to effect function, precision freeform surfaces, large-scale surface structuring, and surfaces for nano-manufacturing and metrology.

[WWW.EUSPEN.EU](http://WWW.EUSPEN.EU)

## 11-12 December 2018, Amsterdam (NL) International MicroNanoConference 2018

Organ-on-chip, microfluidics, biosensing, and functional surfaces and interfaces are main topics of this industry- and application-oriented conference, exhibition and demo event.

[WWW.MICRONANOCONFERENCE.ORG](http://WWW.MICRONANOCONFERENCE.ORG)

| COURSE<br>(content partner)                                 | ECP <sup>2</sup> points | Provider | Starting date           |
|---|-------------------------|----------|-------------------------|
| <b>FOUNDATION</b>   |                         |          |                         |
| Mechatronics System Design - part 1 (MA)                    | 5                       | HTI      | 8 October 2018          |
| Fundamentals of Metrology                                   | 4                       | NPL      | to be planned           |
| Mechatronics System Design - part 2 (MA)                    | 5                       | HTI      | 29 October 2018         |
| Design Principles   | 3                       | MC       | 26 September 2018       |
| System Architecting (S&SA)                                  | 5                       | HTI      | 24 September 2018       |
| Design Principles for Precision Engineering (MA)            | 5                       | HTI      | 26 November 2018        |
| Motion Control Tuning (MA)                                  | 6                       | HTI      | 6 February 2019         |
| <b>ADVANCED</b>   |                         |          |                         |
| Metrology and Calibration of Mechatronic Systems (MA)       | 3                       | HTI      | 6 November 2018         |
| Surface Metrology; Instrumentation and Characterisation     | 3                       | HUD      | to be planned           |
| Actuation and Power Electronics (MA)                        | 3                       | HTI      | 20 November 2018        |
| Thermal Effects in Mechatronic Systems (MA)                 | 3                       | HTI      | to be planned (Q2 2019) |
| Summer school Opto-Mechatronics (DSPE/MA)                   | 5                       | HTI      | -                       |
| Dynamics and Modelling (MA)                                 | 3                       | HTI      | 26 November 2018        |
| Manufacturability   | 5                       | LiS      | to be planned           |
| Green Belt Design for Six Sigma                             | 4                       | HI       | 3 September 2018        |
| RF1 Life Data Analysis and Reliability Testing              | 3                       | HI       | 5 November 2018         |
| <b>SPECIFIC</b>   |                         |          |                         |
| Applied Optics (T2Prof)                                     | 6.5                     | HTI      | 30 October 2018         |
| Applied Optics  | 6.5                     | MC       | 20 September 2018       |
| Machine Vision for Mechatronic Systems (MA)                 | 2                       | HTI      | 3 July 2018             |
| Electronics for Non-Electronic Engineers – Analog (T2Prof)  | 6                       | HTI      | 8 October 2018          |
| Electronics for Non-Electronic Engineers – Digital (T2Prof) | 4                       | HTI      | 4 February 2019         |
| Modern Optics for Optical Designers (T2Prof)                | 10                      | HTI      | 14 September 2018       |
| Tribology   | 4                       | MC       | 30 October 2018         |
| Basics & Design Principles for Ultra-Clean Vacuum (MA)      | 4                       | HTI      | 20 November 2018        |
| Experimental Techniques in Mechatronics (MA)                | 3                       | HTI      | to be planned (Q2 2019) |
| Advanced Motion Control (MA)                                | 5                       | HTI      | 5 November 2018         |
| Advanced Feedforward Control (MA)                           | 2                       | HTI      | 10 October 2018         |
| Advanced Mechatronic System Design (MA)                     | 6                       | HTI      | 26 September 2018       |
| Finite Element Method                                       | 5                       | ENG      | in-company              |
| Design for Manufacturing – Design Decision Method           | 3                       | SCHOUT   | in-company              |
| Precision Engineering Industrial Short Course               | 5                       | CRANF    | to be planned           |

## ECP<sup>2</sup> program powered by euspen

The European Certified Precision Engineering Course Program (ECP<sup>2</sup>) has been developed to meet the demands in the market for continuous professional development and training of post-academic engineers (B.Sc. or M.Sc. with 2-10 years of work experience) within the fields of precision engineering and nanotechnology. They can earn certification points by following selected courses. Once participants have earned a total of 45 points, they will be certified. The ECP<sup>2</sup> certificate is an industrial standard for professional recognition and acknowledgement of precision engineering-related knowledge and skills, and allows the use of the ECP<sup>2</sup> title.

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- Engenia (ENG)  
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- The High Tech Institute (HTI)  
[WWW.HIGHTECHINSTITUTE.NL](http://WWW.HIGHTECHINSTITUTE.NL)
- Mikrocentrum (MC)  
[WWW.MIKROCENTRUM.NL](http://WWW.MIKROCENTRUM.NL)
- LiS Academy (LiS)  
[WWW.LISACADEMY.NL](http://WWW.LISACADEMY.NL)
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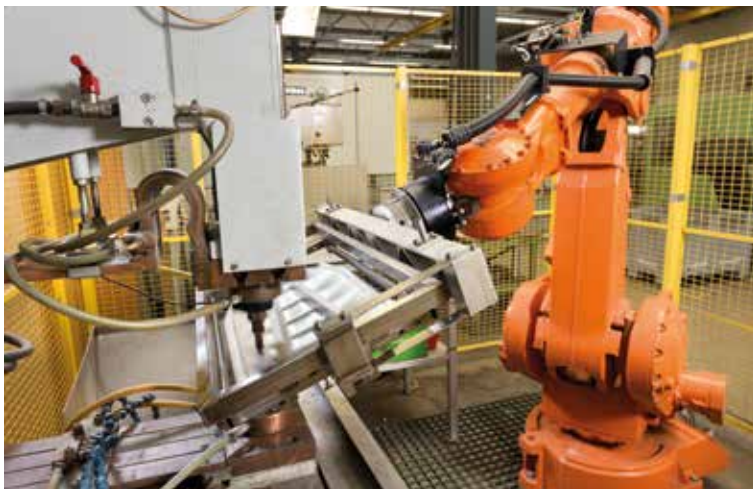
## NEWS

### Pratt & Whitney and KMWE Group sign long-term agreement for F135 nozzle

Aircraft engine manufacturer Pratt & Whitney has awarded a new contract to KMWE Group to manufacture F135 engine nozzle fabrications. The F135 engine is the propulsion system for the fifth generation F-35 Lightning II aircraft. As one of the original nine partner nations for the F-35 (Joint Strike Fighter), the Netherlands is a key contributor to the development, production, and sustainment of the F-35 programme.

Located in Eindhoven, the Netherlands, engine components specialist DutchAero, part of KMWE Group since 2014, has received a 10-year procurement agreement for engine nozzle fabrications. DutchAero is specialist in exhaust nozzles since 1976. "This long-term arrangement confirms the excellent, world-class competences we have in DutchAero and ensures growth of local highly-skilled jobs", said Edward Voncken, CEO of KMWE Group. "This contract complements our existing agreement signed in January 2016 with Pratt & Whitney for complex machined parts."

KMWE Group is a supplier and partner for the high-tech equipment and aerospace industry. The group employs over 550 highly skilled staff in its facilities worldwide, with its head-office in Eindhoven. Core aerospace capabilities include manufacturing of aero-engine and airframe machined parts and complex fabrications. KMWE Group has the next generation of fully automated production cells for complex machining and also offers a one-stop-shop capability for complex sheet metal fabrications with an extensive capability in thermal spray coatings, supported by a fully equipped metallurgical laboratory and experience in additive manufacturing.



■ Automated spot welding of joining titanium steel or super alloy sheets and castings for parts of the exhaust nozzle.

[WWW.KMWE.COM](http://WWW.KMWE.COM)

[WWW.PRATT-WHITNEY.COM](http://WWW.PRATT-WHITNEY.COM)



## HIGH TECH INSTITUTE



#### MECHATRONICS

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Data: 26 - 28 September +  
1 - 3 October 2018 (6 days in 2 weeks)

Location: Eindhoven

Investment: € 4,495.00 excl. VAT

[hightechinstitute.nl/AMSD](http://hightechinstitute.nl/AMSD)

## Stepping to Mars

**F**aulhaber PRECIstep produces precise and small stepper motors and focuses on the development, manufacture and marketing of its renowned stepper motor technology. The company (previously ARSAPE), based in La Chaux-de-Fonds, Switzerland, was established in 1988 and has been a globally active part of the Faulhaber group since 2001.

Faulhaber PRECIstep now produces 2-phase permanent-magnet stepper motors with diameters from 6 to 22 mm. These micro-drives with a high performance-volume ratio are contributing to the trend towards miniaturisation in many sectors. In conjunction with the zero-backlash gearheads from Faulhaber Drive Systems they allow to reach a level of operation that remains unmatched by the other solutions available on the market, according to a Faulhaber press release.

An innovative technological motor design and specially developed manufacturing processes allow the drives to be quickly adapted to customer-specific requirements. The application possibilities are accordingly broad: from optics and photonics, especially in the medical sector, to aerospace, which require, in addition to performance, absolute reliability well beyond ten years. No wonder then that stepper motors from Faulhaber PRECIstep will be part of the next rover expedition on Mars in 2020.



[WWW.FAULHABER.COM](http://WWW.FAULHABER.COM)

## New robot for skull base surgery

**D**rilling out a hole in the skull base – for example to treat an infection or cancer, or to place a cochlear hearing implant – has to be done with great precision and often takes many hours. It is an intervention that requires the maximum from a surgeon. Researchers from Eindhoven University of Technology (TU/e) have therefore developed a surgery robot to take over this task. With sub-millimeter precision, the robot can automatically and safely mill a cavity of the desired shape and dimensions. Jordan Bos received his Ph.D. last April for the robot he designed and built in the TU/e group of Maarten Steinbuch, professor of Control Systems Technology. (See also: J. Bos, "RoBoSculpt: microsurgical drilling and milling with a robot", *Mikroniek* 57 (2), pp.5-8, 2017)

At the request of skull base surgeon Dirk Kunst of the Radboud University Medical Centre in Nijmegen, the Netherlands, Jordan Bos developed a robot to take over at least part of these kinds of operations. The robot, called RoBoSculpt, works on the basis of precise instructions from the surgeon who accurately indicates which piece of bone the robot has to remove on CT images of the patient's skull. The robot is in fact a very advanced arm, which holds an existing surgical drilling tool. Before the operation, the head is accurately fixed in position and then the robot mills the desired cavity. Because the robot works faster in principle, the duration of an operation can be shorter. It is expected that the robot will make more accurate procedures possible, with shorter recovery times, and will result in fewer complications and recovery operations.

The robot is actually an advanced computer-controlled (CNC) milling machine, with seven axes of motion to enable all possible angles. Despite the high number of axes, the device is very accurate, thanks to the compactness, the high level of stiffness, the low weight and the minimal backlash on the axes. The robot can be covered with a sterile cover, which is important in the operating room.

The first pre-clinical tests with the robot will start this year, at the Radboud UMC. The first operation on people could take place in two to three years. A possible first step in the introduction is that the robot does the preparatory work, and the surgeon himself the crucial final part, in order to gain experience safely with the robot. The company Eindhoven Medical Robotics plans to commercialise the technology, in a partnership with TU/e.



■ The robot of Jordan Bos with a phantom piece of skull base. The rest of the skull is added virtually to show where the piece is located in the body. (Photo: Bart van Overbeeke)



## European Inventor Award for ASML inventions

This month, the European Patent Office (EPO) announced the winners of the European Inventor Award 2018. The annual Award honours individuals and teams who with their inventions have helped to advance technology, further social and economic development, and generate employment. The winners in the Popular Prize category were Dutch engineer Erik Loopstra and Dutch-Russian scientist Vadim Banine, both working with ASML, for their key inventions regarding extreme ultraviolet lithography (EUVL).

ASML's advanced EUVL platform has helped to strengthen Europe's technology foothold, according to an EPO press release. Thanks to Loopstra and Banine and their research and engineering teams, the next generation of microprocessors is being produced with European high-tech. Patented and brought to market by chip equipment manufacturer ASML, their technology uses high-energy lasers to achieve nanoscale details, thereby producing smaller, faster and more powerful semiconductors.

In recent years, the microchip industry has been approaching a plateau. The wavelength of laser light that is used to etch detailed transistor patterns onto silicon chips has been reaching its physical limit – portending an end to Moore's law. Enter Banine and Loopstra at ASML. Over the course of 20 years, the two used their skills as physicist and system architect respectively to break the wavelength barrier. Their patented inventions in EUVL reduce radiation wavelength by a factor of 14 to only 13.5 nm, well below the one-time 'wall' of 193 nm. EUVL will be the enabling technology behind next-generation chips that feature details at a scale of 7 and 5 nm.



■ The winners of the European Inventor Award 2018 in the Popular Prize category, Erik Loopstra (left) and Vadim Banine. (Photo: EPO)

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## NTS-Group names new COO

Rob Karsmakers will join the executive board of NTS-Group as the new chief operations officer from 1 August onwards. NTS, headquartered in Eindhoven, the Netherlands, develops, produces, assembles and tests complex (opto) mechatronic systems and mechanical modules for large, high-tech machine manufacturers (OEMs).

Karsmakers has an impressive record of service with Philips. He has led factories in Western Europe, Eastern Europe and Asia. From 2009 to 2016, he was general manager of the Philips factory in Drachten, the Netherlands, and turned it into one of the company's most efficient production plants. His expertise forms an important addition for expanding the quality of NTS service and for giving more attention and direction to a constructive cooperation between the various operating companies at NTS, according to NTS CEO, Marc Hendrikse.

Hendrikse: "Our company is continuing to develop, both in size and in our role as supplier to the world's leading high-tech machine builders. Our success brings increasing pressure to perform consistently at the highest level. This is true for each unit, but also for cooperation between the units. The expansion of the executive board with the position of COO is therefore a logical step in our ambition to continuously keep expanding our performance to our clients."



■ The new COO of NTS-Group, Rob Karsmakers.

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## VDL works on building “the world’s biggest eye on the sky”

**V**DL ETG Projects, part of VDL Groep, will build the supporting structure for the main mirror of the Extremely Large Telescope (ELT) in northern Chile. At an elevation of over 3 km, this is where the ESO (European Southern Observatory) will build the world’s largest telescope. The supporting structure consists of 798 individual support structures for mirror segments, which together form the telescope’s main mirror (with a diameter of over 39 m). The order, which VDL ETG Projects will deliver over the course of five years, is worth several tens of millions of euros.

VDL Groep President and CEO, Willem van der Leegte, comments: “It is wonderful that ESO has awarded us this prestigious order. It’s the first time an astronomy-related contract of this size has gone to a Dutch party. This project will further boost VDL Groep’s reputation as a high-tech player and will be a springboard for our involvement in more new telescopes that ESO is building around the world.”

It is impossible to make the 39-meter main mirror as a single element, so the mirror will be constructed from 798 hexagonal mirror segments, each approximately 1.4 m wide and 5 cm thick. Each mirror segment has its own support structure and will be driven by multiple electric motors, allowing the mirror to be positioned very precisely. The continuous correction is achieved by nine electric motors on each frame and three electric motors under each frame. The mirrors will have to be swapped out on a regular basis to have a new reflective layer applied. Therefore, nearly 950 mirror segments and supporting structures are being built.

The hexagonal, mechatronic supporting structure holds the primary ELT mirror in the desired shape with nanometer precision. VDL ETG Projects will take responsibility for the construction of these structures. The design was created in collaboration with the Netherlands Organisation for Applied Scientific Research (TNO), with support from the Netherlands Research School for Astronomy (NOVA).



■ VDL ETG Projects will build 950 copies of this supporting structure for the main mirror of the Extremely Large Telescope.

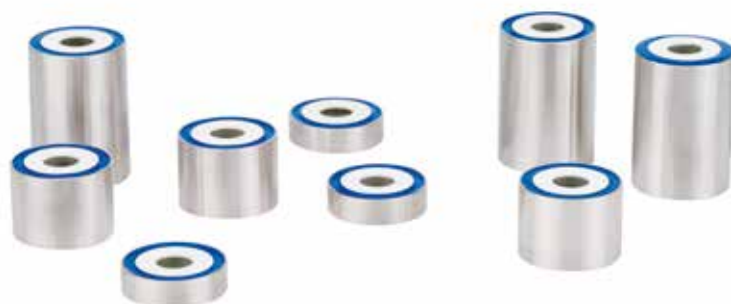
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## Active shims for nanometer resolution and long-term stability

**I**f a target or an actual dimension between two components inside a precision machine changes, readjustment may be necessary. An example of this would be when the machine is started up at the user’s location, and initial settings need to be changed or drifting and changes in tolerances have to be compensated for after installation. The disadvantage of classical shims that are ground exactly to the required dimension, is that they need to be inserted mechanically. Furthermore, unlimited fine adjustment is not always possible and once the dimension has been fixed, it is often very difficult to change it afterwards.

To provide a solution, PI (Physik Instrumente) has developed the PIRest piezo-based ‘shims’. Once they have been installed into the machine, the active shims not only make it possible to readjust the gap between two components at any time, but also achieve this with nanometer precision. The piezo-based shims are built into the machine during its construction; they are available in virtually any shape and size. The static gap at the actuator can be set by applying voltage. After adjusting, the desired position remains stable without power and the power supply can then be disconnected.

In the case of standard products, the maximum displacement is 35 µm; skillful combination of the active shims makes it possible to adjust in up to six axes. If required, active shims can be combined with classical piezo actuators, e.g. for dynamic vibration compensation.



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## LabVIEW 2018 release

**N**I (National Instruments), the provider of a software-defined platform for automated test and automated measurement systems, has issued the 2018 release of the LabVIEW platform software for test workflows. New tools simplify system integration and grant more control through hardware accessibility. Industry trends such as 5G, the Industrial Internet of Things and autonomous vehicles continue to increase system and device complexity. Consequently, the challenge of testing these devices to ensure reliability, quality and safety introduces new demands and test configurations.

Engineers can use LabVIEW 2018 to address these challenges. They can, for example, integrate more third-party IP from tools like Python to make the most of the strengths of each package or existing IP from their stakeholders. Test engineers can use new functionality in LabVIEW 2018 to strengthen code reliability by automating the building and execution of software through integration with open-interface tools like Jenkins for continuous delivery. For test engineers using FPGAs for high-performance processing, new deep learning functions and improved floating-point operations can reduce time to market.

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## "Robotize your Future" – Official start T-Valley

**B**y delivering his inaugural speech, entitled "Robotize your Future", in mid-June, Dirk Bekke, professor in Mechatronics at Saxion University of Applied Sciences, gave the official starting signal for T-Valley in Enschede, the Netherlands. Under the name T-Valley, Mechatronica Valley Twente (MVT) is reviving itself with an ambitious goal. In addition to mechatronics education and profiling of the high-tech industry in the east of the Netherlands, the agenda also includes knowledge exchange and specific projects on robotics and smart industry.

Seventeen years ago, MVT started with the main aim of guaranteeing the continuity of education in mechatronic design at the University of Twente (UT). Since then, the UT has trained a large number of mechatronic engineers and MVT has put Twente and its surroundings on the map as a leading mechatronics region. Last year, MVT made a new start under the name T-Valley on the initiative of Dirk Bekke.

The Saxion Mechatronics lectorate and research group was set up in 2011, partly on the initiative of various companies from the current T-Valley board. Bekke: "During the construction phase, my predecessor Rini Zwikker worked on mechatronic building blocks for various applications, including medical robotics. Examples of these are robotic arms, grippers, navigation, computer vision and an exoskeleton. A demonstrator has also been built. As a successor to Rini, I started to build on this basis and gauge the research needs in the region. As a lectorate we are demand-driven and, through cooperation with industry, we can increase our impact for the region."

T-Valley will now structurally organise the cooperation between industry and Saxion education/research in the east of the Netherlands. In anticipation of the official start of T-Valley, Saxion and the various companies have already engaged in a large number of joint small and large projects, including the application of computer vision in high-end machines, the use of cobots (collaborative robots) for the assembly of high-tech products and the development of drones, for applications including agriculture, firefighting and defence.

In his inaugural speech Bekke outlined the developments in mechatronics and robotics as part of the so-called fourth industrial revolution. His research group focuses mainly on unmanned robotic systems, smart industrial systems, modular robotics and systems engineering and avails over a Mechatronics Lab and soon also a large Drone Dome for the indoor testing of drones. With a RoboTechLibrary to be established, Bekke wants to give companies, knowledge institutions and interested individuals access to state-of-the-art robotics technology in order to make his motto "Robotize your Future" accessible to everyone.

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# HEIDENHAIN



## Exposed Linear Encoders for Permanently Stable Measured Values

Machines in electronics manufacturing, in high-level automation, or medical technology need to position finely, quickly and exactly. Exposed linear encoders from HEIDENHAIN are used exactly wherever there is a need for positioning with extremely high accuracy or for precisely defined movements. Even if the encoder is subjected to contamination, the scanning signals stay lastingly stable. This is ensured by the new HEIDENHAIN signal processing ASIC, which almost completely compensates signal changes caused by contamination and maintains the encoder's original signal quality. And this without any significant increase in the noise component or interpolation error of the scanning signals, so the control loop receives highly accurate absolute or incremental position information permanently and reliably.

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