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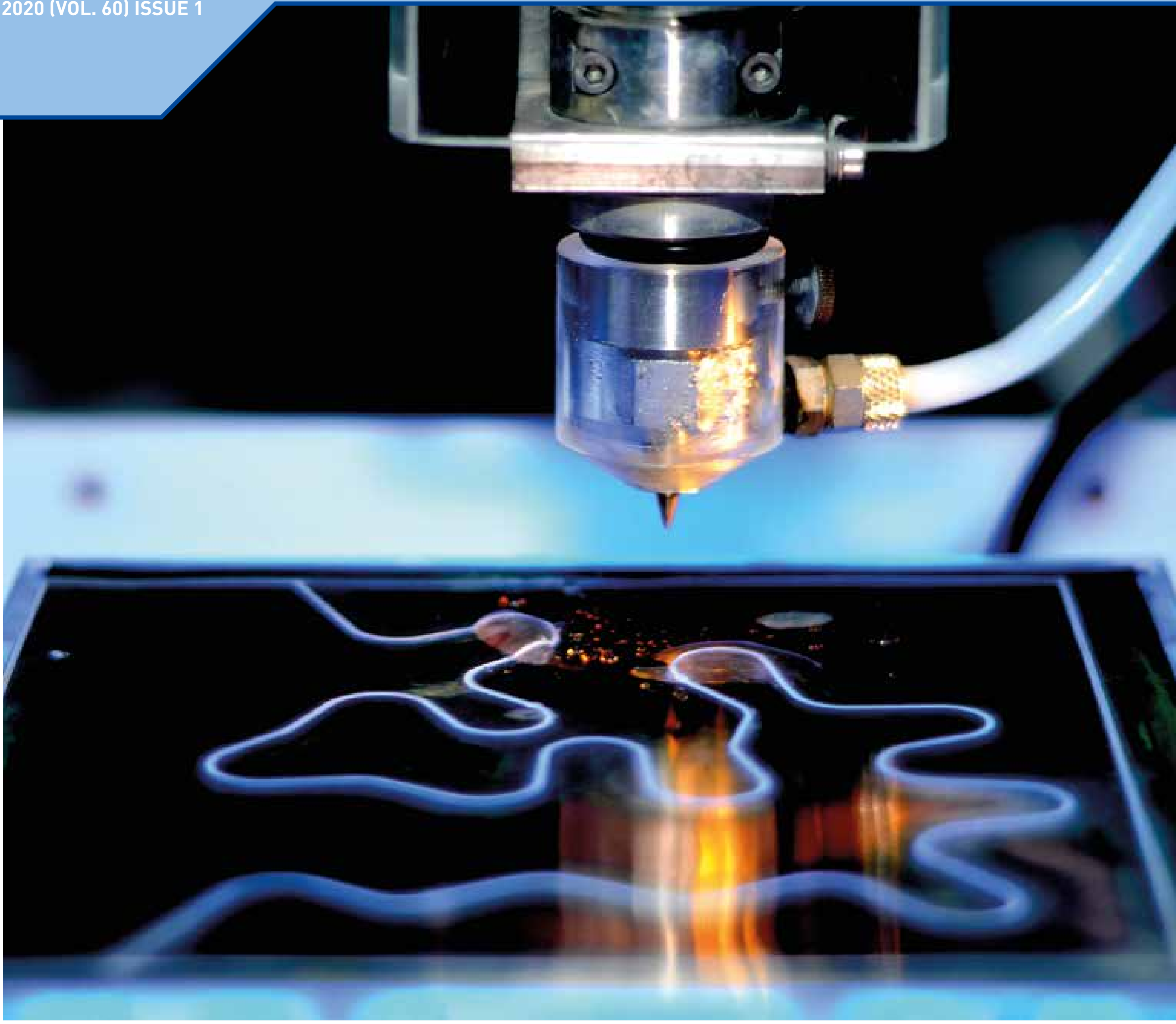

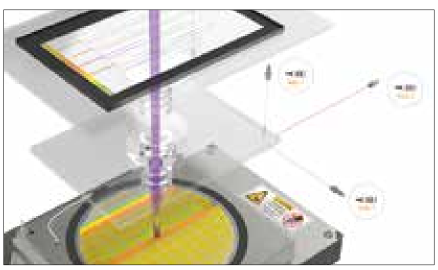

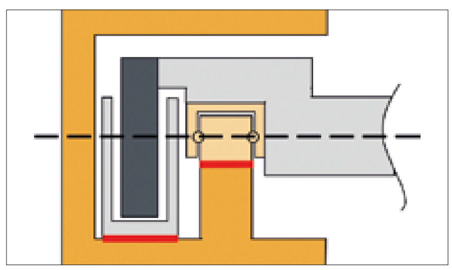

- HIGH-TECH SYSTEMS
- DESIGN OF HIGH-THROUGHPUT WAFER INSPECTION STAGE
- 2019 RIEN KOSTER AWARD WINNER; HANS VAN DE RIJDT
- EINDHOVEN ENGINE UPDATE

DSPE

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YOUR PRECISION PORTAL

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The main cover photo (featuring a free-jet electrochemical machining set-up) is courtesy of TU Chemnitz. Read the article on page 19 ff.

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FEATURES

EINDHOVEN ENGINE: NATLAB+ TO BE?

In 1891, the newly established company Philips decided to base itself in Eindhoven (NL), as its owners were able to purchase a factory there, including machinery (this factory is now the Philips Museum in the centre of Eindhoven). The initial growth of the company was facilitated by the automation of cigar making by cam-driven machines, which meant that Philips had access to a larger workforce. A second boost came from applying the experience of the cigar making automation to light-bulb manufacturing automation. Following light bulbs, radio tubes were made, which helped radios conquer the world. Televisions were the next breakthrough, followed by solid-state transistors, which enabled the development of consumer products. Philips had become a big company.

In the decades after the Second World War, Philips drove innovation through the NatLab (*Natuurkundig Laboratorium*, Philips Research) and CFT (*Centrum voor Fabricage Technologie*, Philips Centre of Manufacturing Technology). One could say that the NatLab did the fundamental research and CFT did the applied science.
High-tech companies like ASML, Thermo Fisher, Philips Healthcare, VDL ETG, NTS, Frencken, Prodrive, Neways, Raith and others started to flourish based on the ideas and competences developed by Philips Research and CFT. Communication between precision engineers within Philips (*Ontwikkeling en Bedrijfsmechanisatie*, Research and Factory Automation) was not limited by NDAs or confidentiality agreements. This knowledge sharing was essential for innovation and there are many examples where companies collaboratively built up experience and used their shared experience.

Nowadays, the arena has changed and it is filled with independent companies, where IP departments frustrate collaboration, which is not good at all. One good thing, however, is that researchers and engineers from different companies still like to share knowledge. DSPE strives to support this knowledge sharing, as you know. Recently, I spoke with some people in our community. The high-tech systems' supply chain is strong, we agreed, and the equivalent competence of the former CFT is developing in the relevant supply chain companies. Within two years they will have reached a level above that of the former CFT.

But what has been missing is the NatLab part, i.e. the capability of our region to do research on new technologies, new products and new business ideas, in a typical NatLab fashion: open doors, co-location of all disciplines, outside-the-box thinking, and a high refresh rate of talent and projects.

Marc Hendrikse, CEO of NTS-Group and executive chairman of Holland High Tech, recently requested my help in this matter. He asked me, as a professor at Fontys University of Applied Sciences, to become an ambassador of High Tech Systems & Materials. We agreed to ask the new generation (students) to participate in thinking outside the box. I told him this is a great idea, as students are not yet in a box, so by nature they think outside the box.
It is not easy to come up with ideas for starting new OEMs that can grow big, or to obtain funding for great high-tech ideas. Hence, it is not easy to create a successful new OEM. But history teaches us that we need perseverance to create a new high-tech future for our region.

At the Eindhoven University of Technology (TU/e), the initiative has been taken to create Eindhoven Engine: "connecting innovative minds". Eindhoven Engine aims to accelerate innovation in the Brainport Region through challenge-based research in its public-private research facility at the TU/e campus. Teams of our region's most talented researchers from industry and the knowledge institutes TU/e, Fontys and TNO will collaborate with students in Eindhoven Engine research programmes to deliver breakthrough technological solutions.

Will the Eindhoven Engine be our new NatLab, or even NatLab+, the + deriving from the involvement of students and of other knowledge institutes and high-tech supply chain partners? Hope so.
To be continued.

Hans Krikhaar
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VEGA MOTION PLATFORM DESIGN OVERVIEW

PM, a company well known for its precision linear bearings, has also gained experience in the development and production of custom motion systems. Recently, PM launched a stage that was completely developed and assembled in-house. The motion platform – designated as 'Vega' – was developed to set new standards for optical wafer inspection speed and accuracy. The central design concept was to position all driving dynamics in one plane, in order to prevent undesired reaction torques on the sensitive parts of the system.

MATHYS TE WIERIK AND JAN WILLEM RIDDERINKHOF

For more than 50 years, PM has been developing and producing very precise linear and rotating bearings. The Dutch family company focuses on bearings for the precision industry, where strict requirements are set for straightness, smoothness and stiffness. As well as these bearings, PM also develops high-end mechatronic motion solutions.

The development and production of these motion stages is often not the core competency of PM's customers and therefore it is something that they prefer to outsource. Typically, these customers are responsible for realising complex production process steps in the semiconductor, medical, optical or analytical industry. For PM, developing motion systems is a perfect addition to its bearing business, as the knowledge of making precision bearings can conveniently be used for developing stages, and vice versa.

PM normally builds motion platforms that are dedicated for customer projects. A year and a half ago, however, the company started to develop its own motion platform. PM engineers visited a number of customers to see what developments are taking place in their markets and what products they need to be competitive in five years' time. From all these discussions, PM derived a set of requirements that a next-generation motion system would need to meet.

The Vega motion platform had to be a fast, accurate stage, focused on back-end wafer inspection. This represents a particularly demanding market. Once having proven its competitiveness in that market, PM should be able to extend platform application to, for example, the medical market.

AUTHORS' NOTE

Mathys te Wierik (lead system engineer) and Jan Willem Ridderinkhof (manager R&D and engineering) both work at PM in Dedemsvaart (NL). This article is based in part on PM's presentation at the Precision Fair 2019, held last November in Veldhoven (NL).

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High throughput required

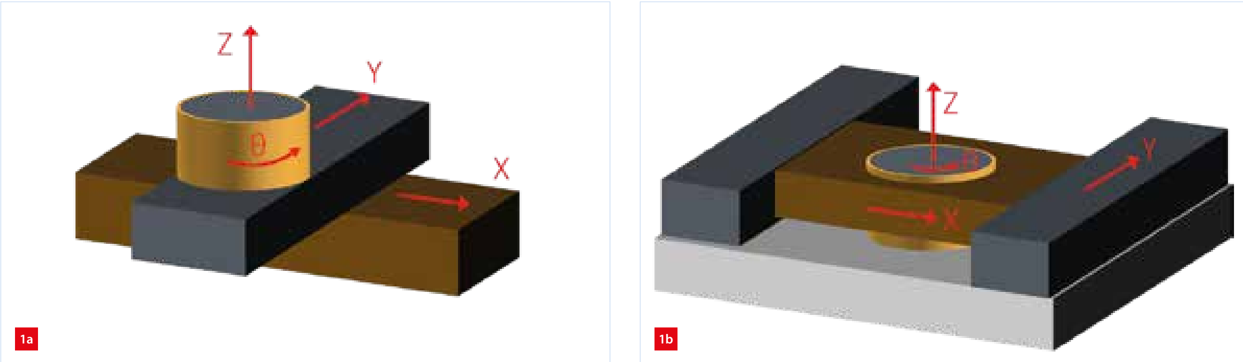
The bar was set high with the following critical performance requirements:

- Over a stroke of more than 300 mm, the mechanical accuracy in the X- and Y-direction must be better than 1 µm.
- Motion profiles include accelerations of 2 g and speeds of up to 2 m/s in the horizontal plane.
- Vibrations in the horizontal plane must remain below 25 nm, assuming the machine is operated on a cleanroom floor that vibrates at a VC-C specification.
- Vibrations in the vertical direction – the direction used to move the wafer into the optics' focal point – may not even exceed 10 nm.

Achieving high accelerations and short settling times are crucial in a wafer inspection application, where a high wafer throughput is key. Along with the technical demands, the timing of the project was also challenging: the complete design and production phase of the project needed to be performed within 12 months. Moreover, the stage had to be cost effective and robust, which was achieved by minimising the use of exotic materials and by manufacturing almost all components in-house at PM.

The starting point for the design was that all of the driving dynamics need to be in one plane. As a result, the motors do not cause any undesired reaction torques on the sensitive parts of the system. This was achieved by properly aligning the centres of mass for all moving bodies, the position of the motor forces and the position of the bearings. An additional advantage of keeping all the dynamics in one plane is that the out-of-plane loads on the bearings will also remain minimal – a lower bearing load adds to a longer lifespan with less wear and thus fewer bearing-induced inaccuracies.

Designing all of the dynamic components in one plane is relatively easy for a single-axis system. Normally, a second axis would be put on top of the first to realise the movement orthogonal to the first direction. Also, if needed, a third axis could be stacked on top. By stacking axes like this, however,



XYZθ-architecture alternatives
(a) Conventional low-speed.
(b) High-throughput-optimised, with all COGs in one single plane.

the centre of gravity (COG) of the moving mass is no longer ideal for each of the axes and, as a result, reaction torques occur when accelerating or decelerating the axes. These reaction torques create yaw, pitch and roll errors.

PM found a different solution, as can be seen in Figure 1. The construction consists of a horizontal box frame supported by a linear bearing on each side. In this square frame, the second axis is mounted, coplanar with the first axis. Then, the Zθ-module is integrated in this second axis, which is responsible for rotations and vertical movements. Only short-stroke vertical movements are made, so the centres of mass and actuation remain mostly in one plane. This means that the moving masses cannot exhibit lever arm behaviour, resulting in a much better positioning accuracy. Recirculating ball bearings were found to be accurate enough for optical wafer inspection when they are mounted correctly and the proper design principles have been applied.

Topology optimisation

After establishing the global layout, PM entered the detailed engineering phase. The dynamic requirements for such a wafer inspection stage meant that the box frame should be given a high structural stiffness at a minimum of moving mass. For accomplishing this, aluminium is an obvious material of choice. To shape the aluminium frame, PM developed its own topology optimisation program in Matlab.

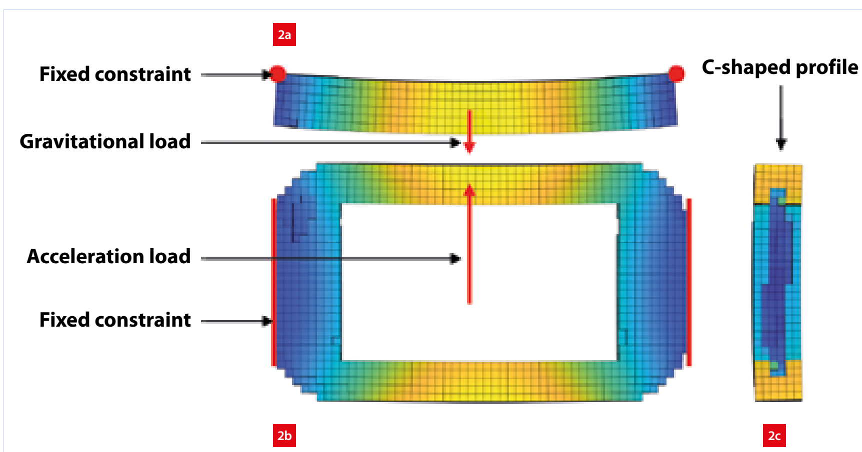
In the topology (shape) optimisation study, manufacturability was also considered. One of the constraints was having a constant material thickness for the cross members, allowing cost-effective and accurate manufacturing. The software eventually iterated to produce relatively large C-shaped profiles for the main cross members (see Figure 2). The C-shaped profile offers a good stiffness-to-weight value as well as a good base for installing bearings.

Actuators

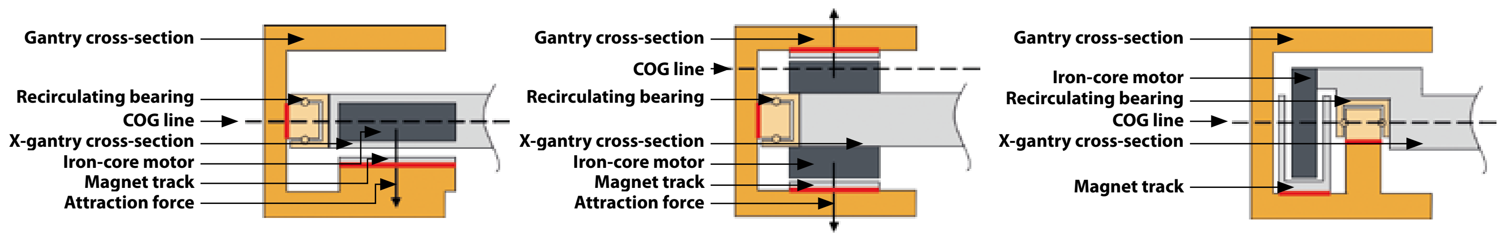
The next question was how the motion platform should be driven. Various concepts were discussed and evaluated (Figure 3). The concepts in Figure 3a and 3b do not make optimal use of the bearing stiffness and require expensive grinding tolerances on two separate components (indicated in red), whereas the concept in Figure 3c only requires tight grinding tolerances on a single component.
Eventually, PM selected this third concept (Figure 3c); a solution based on an ironless motor with moving coils. This choice resulted in a somewhat complex construction, but this way the motor, the bearing and the encoder can all be mounted on the lower part of the C-profile. This choice helped to minimise the number of surfaces that needed very tight grinding tolerances to reach the accuracy requirements. Therefore, this design is cost effective, as it minimises manufacturing cost.

Settling-time simulations

To get a good understanding of what kind of settling times can be achieved, the frequency response functions of the



The optimum topology for the X-axis cross members has C-shaped cross sections placed near the outside of the box. The colour coding indicates displacement under gravitational and acceleration loading, from small (blue) to large (yellow) displacements.
(a) Side view.
(b) Top view.
(c) Cross section (the middle part showing a box frame member in the background).



Three conceptual layouts (X-axis perpendicular to the drawing plane) that have been evaluated, each featuring the C-shaped profile that emerged from the topology optimisation. The surfaces that require expensive grinding tolerances are indicated in red.
(a) Iron-core motor force aligning with bearing and COG; attraction force loads the bearing.
(b) Dual-iron-core combined motor forces aligning with bearings and COG; attraction forces cancel each other out.
(c) Motor force aligning with bearing and COG; no attraction force.

stage needed to be accurately predicted. The stage structure consists of a rigid base plate and a number of machined metal cross members, while in between each axis the bearings are located. See Figure 4 for an impression of the resulting stage.

The difficulty in getting accurate transfer function predictions was mostly in the bearing dynamics. Conventional bearing stiffness models based on ideal Hertzian contact theory significantly overestimate the stiffness of bearings in practice. PM therefore used a combination of Hertzian contact theory and component-based testing, where experimental modal analysis was applied to a bearing with a rigid dummy load (see Figure 5). Extensive testing revealed that the enriched bearing models are much more realistic than conventional idealised Hertzian contact theory models.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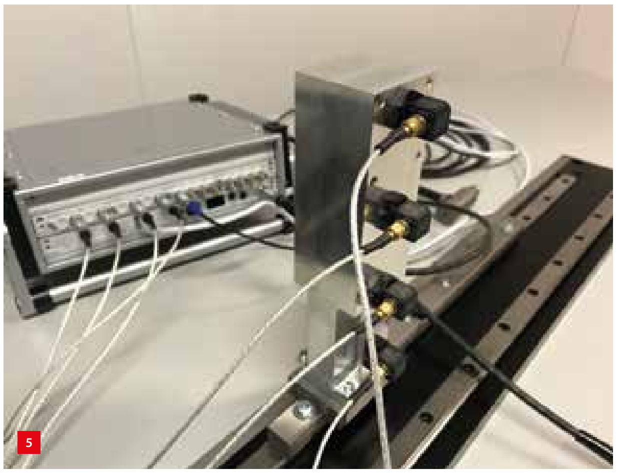
The resulting design: a stage featuring a rigid granite base plate, linear motors and linear bearings for each axis, and a Zθ-module in the centre of the XY-axes. Wafers can be placed on the black circular plate on top of the Zθ-module.

Based on FEM (finite-element method) simulations of the stage assembly (including the aforementioned bearing stiffnesses), the open-loop transfer functions were determined, revealing that the first observable eigenmode was comfortably above the target bandwidth of the stage. A feedback control loop was modelled around these transfer functions, so that the settling times of the stage, including its control, can be predicted. As well as the settling-time prediction, the complete motion profile, based on a wafer inspection cycle, can be simulated to evaluate the maximum throughput of the machine.

Active vibration isolation

In view of the tight residual vibration requirements, a vibration isolation system is an absolute necessity. With high acceleration requirements in particular, the granite is loaded by high lateral forces and therefore the vibration isolation system needs to be active (see Figure 6); the alternative of eliminating vibrations by using a balance mass was discarded because of the tight footprint requirements. The requirements for the vibration isolation systems were conflicting. The settling times would benefit from a stiff set-up, whereas the low residual vibration requirement can be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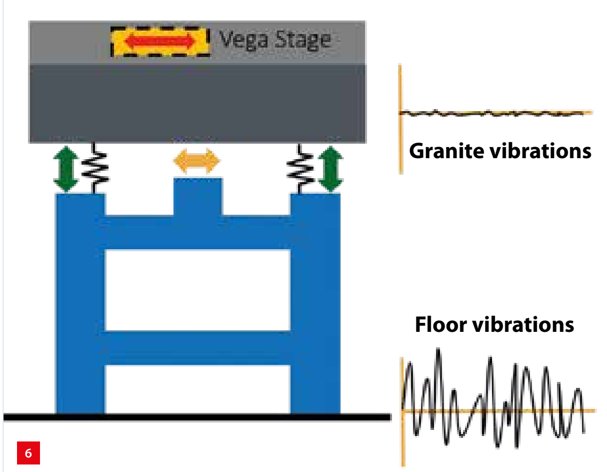
Hammer impact testing was applied to the bearings to identify their stiffness in the relevant degrees of freedom.



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Schematic representation of the Vega stage mounted on an active vibration isolation platform. Compliant springs prevent transfer of floor vibrations to the stage. In addition, skyhook damping is applied as well as an advanced floor feedforward algorithm (green arrows). The forces applied by the stage (red arrow) on the granite are counteracted by feedforward control (orange arrow).

reached by using a compliant vibration isolation system; the transmissibility of floor vibrations to the stage would quickly diminish above the first eigenfrequency of the isolation system.

As the vibration isolation system has a strong influence on the stage settling times, its dynamics were also incorporated into the aforementioned settling-time simulations.

Thermal management

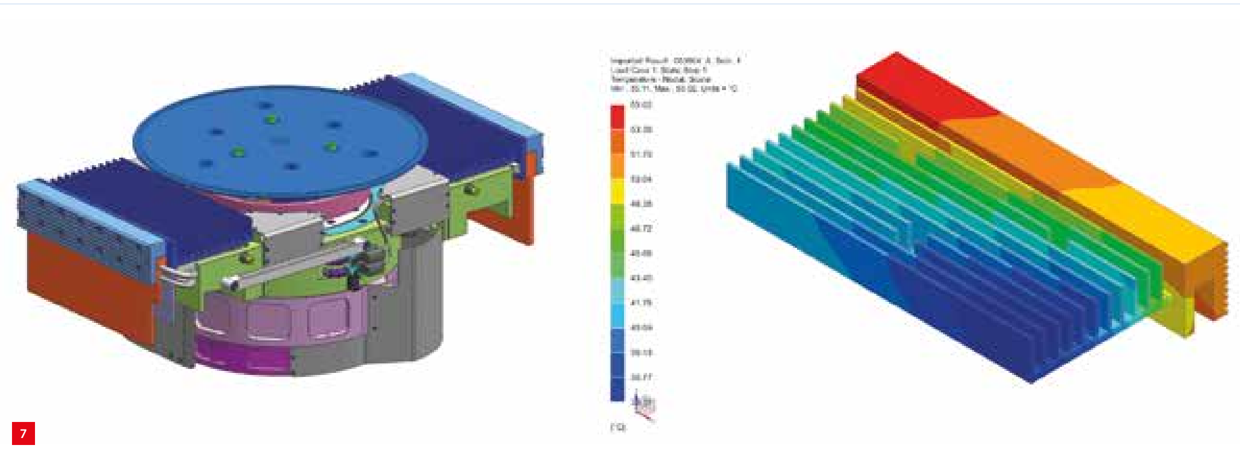
Also, thermal management was a topic that deserved special attention because of the stringent accuracy requirements. The location of the tool point – the point of interest on the wafer – must be known with an accuracy of a single micrometer, even when the system is operating at its maximum throughput cycle and the actuators are generating a considerable amount of heat.

During the concept phase, a comprehensive thermal network model was built to understand the implications of conceptual choices on thermal management. Based on the requirements of PM's customers, the use of any form of liquid cooling was strictly forbidden, as this would pose a major risk in terms of potential coolant leakages that could damage the expensive payload or could cause expensive stops in critical production steps. Also, the use of cooling fans was not preferred, as a forced airflow could induce vibrations on the stage or on the sensitive payload.

With active cooling not being allowed, the design was pushed towards passive cooling, which posed a significant design constraint. To get rid of the heat of the actuators, relatively large heatsinks were designed to keep the temperature, and therefore the thermal expansion, relatively low. The heat sinks are structurally connected but thermally isolated from the rest of the system by means of thermal barriers. This way, the heat sinks contribute to the stiffness of the stage without affecting its accuracy.

FEM analyses revealed that the thermal barriers functioned well, but further improvements were necessary to minimise the thermal deformation of the stage. One option was that some structural components would be made of invar, a nickel-iron alloy with a low coefficient of thermal expansion. This would not be very cost effective, however, given the high price of this material. In addition, the stiffness-to-weight ratio of invar is not as high as that of alternative materials.

Instead of making use of expensive materials throughout, PM decided to employ strategically placed aluminium flexures that allow the stage structure to expand freely. In addition, a small number of stiff invar components were attached to the centres of thermal expansion, keeping the centres of the components position-independent of



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Zθ-module with heat sinks (dark and light blue) on each side. A convective heat transfer study was performed on this assembly to get an impression of the temperatures of the heat sinks. In this analysis, the assembly was assumed to move at a uniform speed. On the right, the temperature ranges from 35 °C (blue) to 55 °C (red).

temperature variations. This way, the use of expensive materials could be limited to only a few components.

The last step in the thermal management study was to optimise the shape of the heatsink for maximum effectiveness. A conjugate heat transfer model was made in which air flows through the heatsink. In this way, the thickness, the height and the spacing of the cooling fins were determined. Figure 7 gives an impression of the convective heat transfer analysis.

Thermal (as well as dynamic) stability was also an issue in determining optimal encoder positions.

Outlook

One prototype stage has been built, which was demonstrated at the Precision Fair in November 2019. Construction of a second stage, including a vibration isolation system, is currently ongoing. This second prototype will be used to validate that all design requirements have been met and to further quantify specifications, using for example external interferometers, grid encoders and application-oriented equipment. Meanwhile, several potential customers have already shown their interest in the Vega stage, which could lead to a further evolution of the current design approach.

VIDEO

- *www.youtube.com/watch?v=sO3hUWLTco8*

VALIDATING INTERFEROMETER PERFORMANCE

Keeping up with Moore's law requires ultraprecise interferometry in semiconductor production and measurement. Attocube's IDS3010 (Interferometric Displacement Sensor) has the capability of measuring any kind of displacements and vibrations with nanometer accuracy, even under extreme environmental conditions. The validation that the IDS' displacement measurement performs in accordance to the International Length Standard is physically rooted in its technical design and certified by National Metrology Institutes participating in the CIPM-MRA (CIPM Mutual Recognition Arrangement).

FELIX SCHEINKÖNIG

Introduction

Based on Moore's law, the capability of technology should every year increase at least two times. As this evolution fast-forwarded itself with better materials and developments in their application, it presented the challenge of achieving greater precision in any kind of measurement. As the abilities of semiconductor technologies increased, this progress pushed the development of new production technologies. Based on sensitive materials and exactness at precision, production and measurements demand idealistic environmental conditions such as ultrahigh vacuum (UHV), cleanroom conditions, and high temperatures. Modern production processes and devices need to keep pace with these demands and deliver the highest precision, without compromising quality and output.

Attocube's IDS3010 (Interferometric Displacement Sensor), an ultraprecise interferometer, has the capability of measuring any kind of displacements and vibrations with nanometer accuracy, even under extreme environmental conditions. The IDS has three inputs and its modular design makes it easy to select different fibres and/or sensor heads for each of the three measurement axes, tailored to the specific application. With its compact size, the IDS3010 (Figure 1) can be directly integrated into machines and – for even more confined applications – its sensor heads can be remotely operated and interconnected via glass fibres. Therefore, the IDS is the product of choice for sophisticated precision engineering, space, synchrotron and semiconductor applications.

1

The IDS3010 laser interferometer.

AUTHOR'S NOTE

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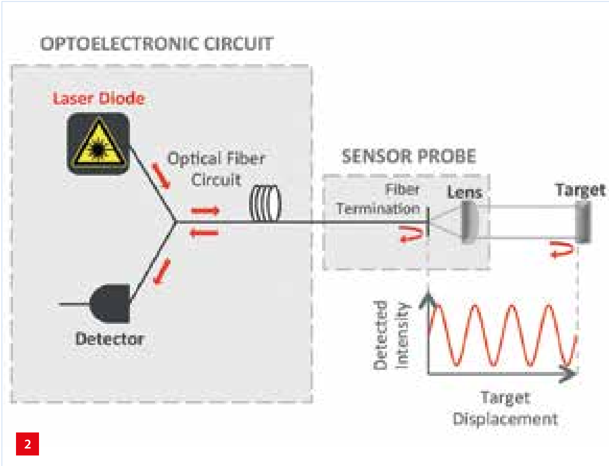
Work principle

Interferometers work by merging two or more sources of light to create an interference pattern, which can be measured and analysed. The interference patterns generated by interferometers contain information about the object or phenomenon being studied. They are often used to make the most accurate measurements that are not achievable any other way. This is why they are so powerful for the detection of, for example, gravitational waves.

The measuring principle of the IDS is also based on interferometry; see Figure 2. To measure displacements of a target, the IDS emits a laser beam of a certain wavelength. This laser beam gets coupled into an optical fibre and reaches a sensor head, in which the ferrule of the fibre ends. At the end of the ferrule, a small share of the beam is reflected back into the fibre. The remaining light travels to a reflective target and is also coupled back into the fibre where both beams interfere. The displacement of the target only influences the emitted beam. Therefore, the movement of the target causes a phase shift between the interfering signals that have been created, which leads to changes in the intensity of the interference signal.



Working principle of the IDS3010.

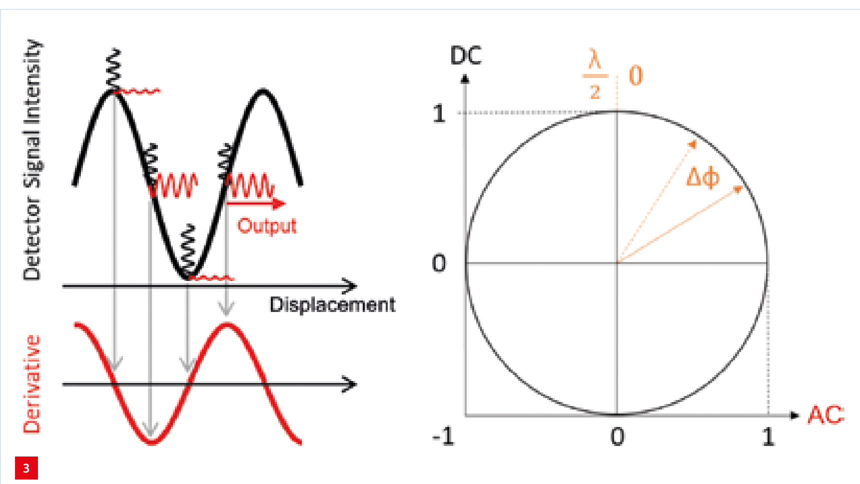
The interference signal is detected and processed by the IDS. Based on theory, it should contain all required information regarding the amount of displacement.
Two issues still remain, however:

1. The direction of the displacement cannot be determined.
2. At the peaks and lows of the signal, higher displacement is required to cause a detectable change in intensity

To overcome these challenges, the laser is modulated to create a second, 90°-phase-shifted, interference signal. The signals can be represented in a Lissajous figure (Figure 3), in which a full 360° shift is equal to a displacement of 0.5·λ. The target displacement Δx is measured by analysing the phase change $\Delta\phi$ of the Lissajous figure, which is proportional to the laser wavelength λ:

$$\Delta x = \lambda / 4\pi \cdot \Delta\phi$$

The direction of movement can be determined based on the sign of $\Delta\phi$.



The normalised Lissajous figure, which is based on two 90°-phase-shifted sinusoidal interference signals (AC and DC).

Environmental compensation unit

If an accurate interferometric measurement is performed in ambient conditions, the refractive index n of the medium must be taken into account. The refractive index of air depends on environmental parameters. A variation in the refractive index causes a phase shift of the laser light and leads to a systematic error in the displacement measurement. To ensure the accurate measurement of the displacement under ambient conditions, attocube offers an environmental compensation unit (ECU) as an additional device for the IDS3010. The ECU precisely measures the key parameters of the air and calculates the refractive index based on the Ciddor equation [1].

The refractive index at T = 20 °C, p = 1,013 mbar, 50% relative humidity and a CO_2 content of 400 ppm for a wavelength of 1,530 nm is n = 1.000268091.
The dependence of the refractive index on temperature, pressure, wavelength, humidity and CO_2 content around these conditions is defined in Table 1.

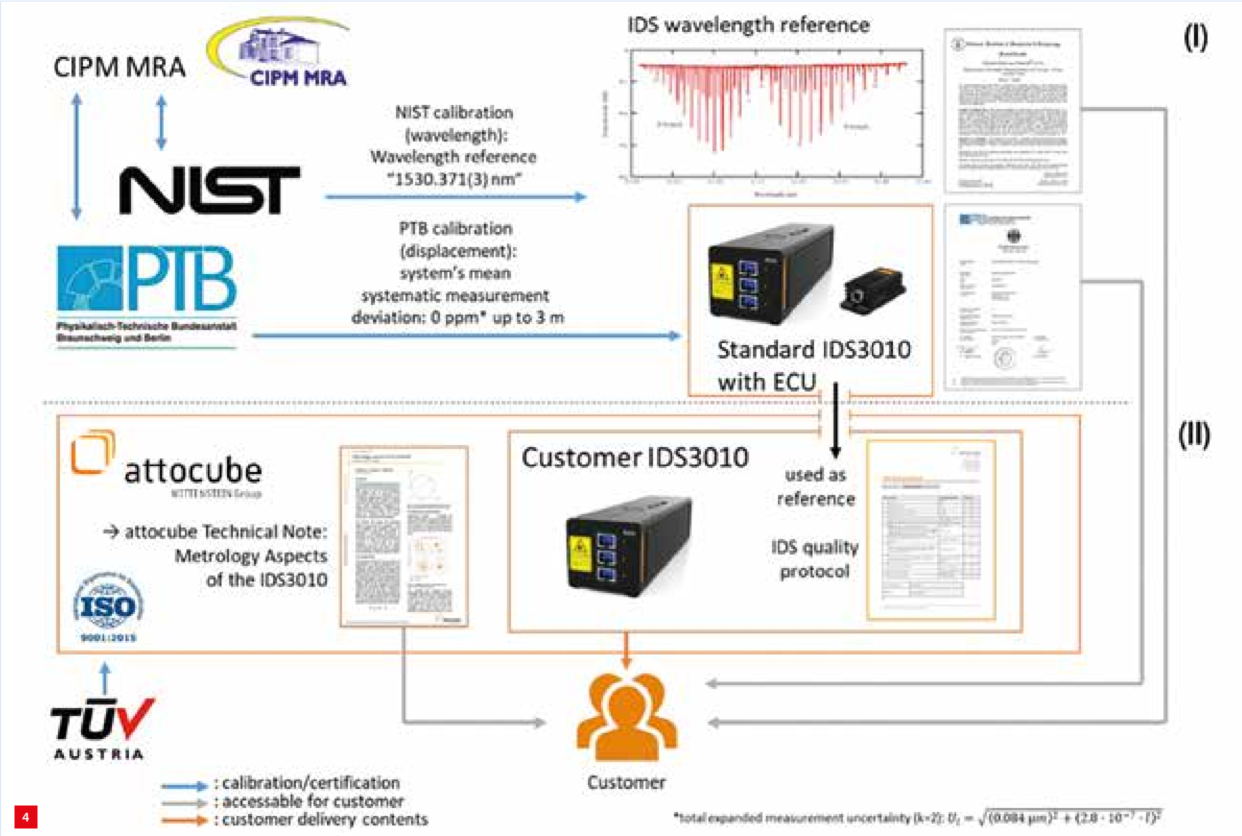
CO_2 content can be neglected, as its influence is extremely small. Therefore, by measuring parameters such as temperature, pressure, and humidity, the ECU provides measurement accuracy of 1 ppm, even at ambient conditions.

Metrology aspects

In applications with the highest demand for accuracy, the measuring device must be compared to and traced in line with international standards (Figure 4). The validation that the IDS displacement measurement performs in accordance with the International Length Standard is physically rooted in its technical design and certified by National Metrology Institutes participating in the CIPM-MRA (International Committee for Weights and Measures (CIPM) - Mutual Recognition Arrangement [2]). Furthermore, performance is quality-checked during the production process. This provides assurance that the specification of a customer system is validated with full traceability.

Table 1
Dependence of the refractive index n of air on temperature T, pressure p, humidity h , CO_2 content x_c, and wavelength λ, around T = 20 °C, p = 101.325 kPa, h = 50%, x_c = 400 ppm, and λ = 1,530 nm.

Temperature T	dn/dT (K^{-1})	$-9.32 \cdot 10^{-7}$
Pressure p	dn/dp (mbar^{-1})	$2.70 \cdot 10^{-7}$
Humidity h	dn/dh (%$^{-1}$)	$-8.72 \cdot 10^{-9}$
CO_2 content x_c	dn/dx_c (ppm^{-1})	$1.42 \cdot 10^{-10}$
Wavelength λ	$dn/d\lambda$ (nm^{-1})	$-8.59 \cdot 10^{-10}$



IDS traceability chart.
(I) National Metrology Institute calibration certificates that are available.
(II) The attocube internal aspects that ensure highest quality of the product.

Calibration methods

Laser wavelength (NIST-traceable)

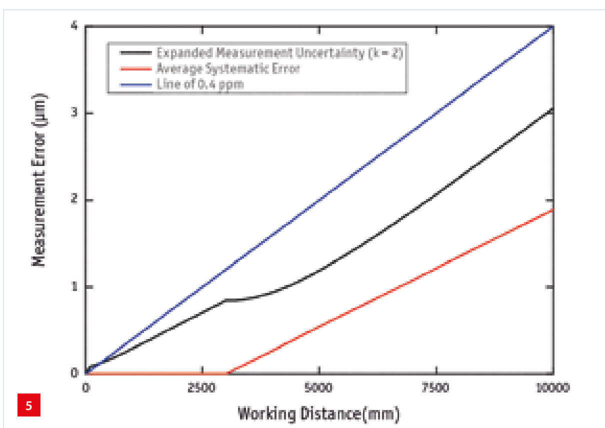
The laser wavelength is assumed to be constant and its value is internally stored in the IDS. A deviation of the stored value from the true laser wavelength value would directly result in a systematic measurement error that sums up with additional displacement. Therefore, it is crucial that the absolute laser wavelength is known and adjusted very precisely.

To reference the laser wavelength, a gas cell is integrated into the IDS. This gas cell is filled with acetylene gas, which features stable absorption peaks at certain wavelengths. A control loop is implemented to adjust the laser wavelength to an absorption peak at 1530.3711 nm. The position of the absorption peak is known with an expanded uncertainty (k = 2) of ±0.3 pm. This is certified by NIST, the United States' National Institute for Standards and Technology [3].

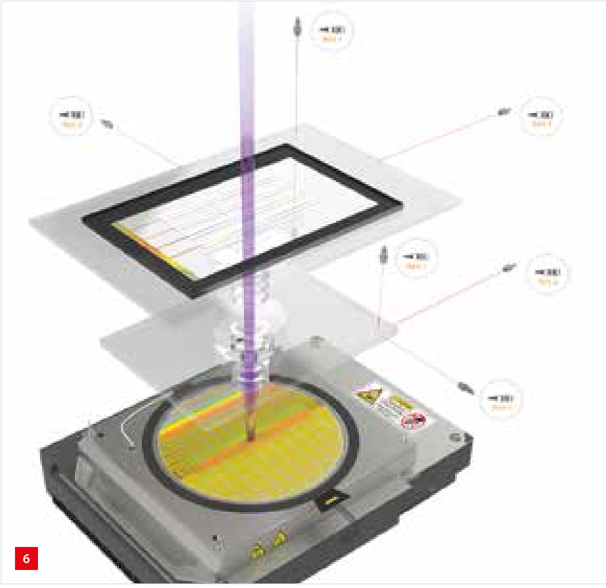
IDS displacement measurement (PTB-traceable)

The validity of the laser wavelength and the index compensation by the ECU are the main systematic errors within the displacement measurement that can sum up. To ensure the accuracy of the system's displacement measurement, attocube verified the IDS sensor characteristic curve by calibrating a standard IDS system including the ECU at the PTB, Germany's National Metrology Institute. The accuracy of the IDS system's displacement measurement was calibrated over a working distance of 10 m (see Figure 5). As a result, a systematic error of the IDS displacement measurement has been quantified to be lower than 0.0 ± 0.4 ppm (k = 2) within a working distance of 0 to 10 m [4].

Based on this result, attocube is able to guarantee the accuracy of more than 1 ppm at IDS measurements even in case of ECU compensation of larger displacements. This accuracy level is even anticipated to be close to 0 ppm up to 3 m travel range. The discrepancy starting in the travel range above 3 m, as observed in Figure 5, is an effect of the complex coherence between the DC-signal intensity and the working distance.



Systematic measurement error of the IDS certified by the PTB [4].



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Representation of applying the IDS3010 in a photolithography process.

Lithography application example

During the photolithography process, circuit patterns of a few nanometers in size are transferred from a photomask onto the semiconductor wafer via various lenses. After the photomask pattern has been projected to one piece of the wafer, the wafer stage is moved and the lithography process is repeated until the whole wafer is covered with the respective patterns. This process takes place under cleanroom conditions and, depending on the technology, even in extreme environments such as UHV. The ultraprecise position tracking and alignment of measurement frame, optics and wafer stage is a key condition to ensure the highest quality throughout the lithography process.

Attocube's laser interferometer IDS3010 enables real-time detection of any movement in the photolithography process (Figure 6), down to the nanometer range. With 10 MHz bandwidth and target velocities up to 2 m/s, the sensor ensures the best alignment among the key components involved in the lithography process. Small sensor heads with a diameter of only 1.2 mm are available and all sensor heads can be used under extreme environmental conditions, such as UHV and high temperatures.

REFERENCES

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[2] CIPM-MRA, *Mutual recognition of national measurement standards and of calibration and measurement certificates issued by national metrology institutes*, 1999.

[3] IDS laser wavelength NIST calibration certificate: *www.nist.gov/system/files/documents/srm/SP260-133.PDF*

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DESIGNING COMPLEX HIGH-TECH SYSTEMS FROM SCRATCH

During the 2019 Precision Fair, the Rien Koster Award was presented to ing. Hans van de Rijdt, owner of Van de Rijdt Innovatie, based in Gemert (NL). The jury honoured him for his merits as a developer of multidisciplinary and straightforward concepts for high-tech systems that score well on manufacturability and cost. His work is a superb example of the Dutch design principles school founded by Wim van der Hoek and extended by Rien Koster and his successors.

Van de Rijdt (Figure 1) studied mechanical engineering at the HTS Eindhoven, now Fontys Engineering University of Applied Sciences in Eindhoven (NL). "At first, I couldn't choose between engineering and mechanical engineering, but eventually I decided that moving parts fascinated me more than static building constructions. However, I didn't like the way the construction design course was taught; messing about with ink pens when drawing. Nevertheless, due to a miscommunication, I was given a construction assignment during my internship. That turned out to be a lot of fun; coming up with the design of a machine yourself and building it together with a supplier. It was supercool."

1

Hans van de Rijdt. (Photo: Mikrocentrum)

Philips CFT

So, Van de Rijdt opted for graduating on a construction assignment and he ended up at Philips CFT (*Philips Centrum voor Fabricage Technologie*, Philips Centre of Manufacturing Technology) in Eindhoven. There he designed a feeder for a placement machine for electrical components. "It was also built later, and then less than ten years ago I saw it still running at Philips Drachten, in the assembly of pcb's (printed circuit boards) for shavers." The graduation assignment went so well that within a couple of weeks Van de Rijdt was offered a job. He accepted and after graduating he joined CFT in August 1989 as a young constructor (he was nearly 21). "The focus at the time was on production mechanisation and the motto was speed: 'Thinking for one hour equals milling for two hours, so please don't think about a design for too long'. In the beginning, I worked on, among other things, the laser tracking mechanism for CD players and the mechanisation of the production of video recorders and audio cassette tapes for Philips factories."

Fast Component Mounter

However, in 1991 the large-scale reorganisation operation Centurion started and Philips quickly disbanded its factories. CFT therefore switched from production mechanisation to OEM products. Van de Rijdt started working on the Fast Component Mounter (FCM, Figure 2) for EMT (Philips Electronic Manufacturing Technology, later renamed Assembléon, then divested and since 2014 part of Kulicke & Soffa). "With a relatively small team, we developed a new machine in a year. I designed the transport system for the pcb's and for other modules I did the calculations, as I was quite skilled at that. When the FCM was introduced at a trade fair, we got a phone call one night from security; they had pulled Japanese attendees with sketchbooks in their hands out from under the machine. That made me really proud."

2

In the 1980s, Philips CFT started developing machines for mounting smd's (surface mounted devices) on pcb's. The revolutionary FCM-II (Fast Component Mounter) by Philips EMT featured 16 placement robots working in parallel. Hans van de Rijdt's contribution was the design of the pcb transport module, among other things. More than 1,000 of these machines were produced.

Van de Rijdt enjoyed the project so much that he decided to help finish machine development and construction. "That's why I moved over from CFT to EMT with the project. I then became the lead designer for the entire system, so all issues ended up on my plate. It was a deliberate choice to not only make prototypes but also to help solve all the problems that come up in the field. I did that for five years and learned a lot about how a system really works in practice."

Medical systems

Van de Rijdt then wanted to design new, different machines again and thus returned to CFT. "There I worked a lot on systems for Philips Medical Systems, for cardiovascular diagnostics, nuclear magnetic resonance and radiotherapy. I became a prototype development group leader, but when the economy, and also CFT, slowed down in around 2000, I was appointed account manager for Philips Healthcare. However, I didn't really like that work, so when Assembléon's request came to lead their mechatronics development, I started doing that, in the period from 2005 to 2008. I mainly worked on technology roadmaps there, but because Philips was already preparing Assembléon for divestment, the focus was on the short term."

Self-employed

Van de Rijdt then followed his heart and started his own company in 2008, Van de Rijdt Innovatie. With this he stays close to his first love, technology, handling the technical management of development teams and also coaching team members. "I have always held a 3D CAD license, so that I can present designs myself and elaborate new concepts. ASML was a customer from day one, and I worked for Philips on their new digital pathology scanner for ten years and now I also serve companies such as VDL ETG and Nexperia. It often starts with the need for a technical innovation, a system that has to function more quickly and accurately. With a small team we look for a solution and if the customer says yes, then the development team grows and I have to keep it on the right engineering track, by testing concepts and looking for technical solutions to mostly multidisciplinary issues."

Mechatronics gurus

It's a role that suits Van de Rijdt perfectly and he is happy with his professional life as a self-employed entrepreneur. He acknowledges the foundation that was laid at Philips CFT. "At that time, the discipline of mechatronics developed and the gurus in that field were found at CFT: Rien Koster, Jan van Eijk, Piet van Rens, John Compter, and the like. From those world-class experts, CFT people like me learned a lot. I was also lucky to arrive just before Operation Centurion. In those days, young constructors used to start with a full-time, three-month production mechanisation course; I was in the last class. There you were taught from all kinds of fields, including precision mechanics by Wim van der Hoek or Rien Koster, but also industrial design, learning how to sketch and present. You got to know young people, at a higher vocational education and academic level, from the various Philips divisions."

Manufacturability

Part of that course was also visiting various Philips factories, from display tubes to radar systems. "By taking a good look around, you got a feel for the manufacturability of your designs." In that respect, it was also important for Van de Rijdt's development as a designer that CFT had its own workplace. "I looked around there to learn from other projects and to consult with the machine operators. And within CFT my group also had a small workshop, where now and then I made something myself. It was nice being able to make things yourself and not having to put everything on paper, then ordering it and waiting for three weeks, like today. It was also easy to walk into a factory; for designers nowadays that threshold is much higher."

Van de Rijdt is grateful for the training and the opportunity to develop himself that Philips offered. In return, he later contributed to the master class, which replaced the production mechanisation course. "I wrote lecture notes for that, full of things worth knowing for the young constructor: things they don't learn at school, but are super useful in practice, about manufacturability, bearings, lifetime calculations, accounting for accurate measures, and so on."

System architect

Drawing upon the design principles of Van der Hoek, Koster et al., Van de Rijdt acts as a system architect for the hardware in development projects. "My talent, if I may say so, is that I can oversee a lot of things in my head. The tricky thing about designing, when there is nothing yet, is to determine which lines to put on paper first. You can only do initial analyses if you already have a design in mind. If the customer has a question, I can quickly develop in my mind what the system offering a solution to that need would look like. I can already analyse many aspects in that early phase, with simple calculations, on the proverbial beer mat."

Van de Rijdt often makes these calculations in Excel. "I defined standard sheets for myself in Excel for calculating set points, natural frequencies, thermal behaviour, and so on. This way I can transfer insights to the customer very quickly, using a first design in 3D CAD accompanied with basic sums. Customers need that, but many engineers lack that skill, because they are too monodisciplinary or as a mechatronic engineer have no mechanical background for making a 3D model."

It is what Van de Rijdt enjoys the most, working simultaneously for various clients on technical projects. Mostly for the large OEMs in the Eindhoven region, on projects such as the architecture for various NXP production systems and the concept for a new ASML planar wafer stage (the so-called 'flying carpet'), but sometimes also in smaller projects, such as the asparagus harvester by Cerescon. "It's about understanding the customer's need for a process that has to achieve something and translating this into a machine. You always have to master the application before you can build a good machine for it and come up with the necessary technical solutions. I am mostly involved in the preliminary phase. That is where my strength lies: translating an application into the design for a machine."

Image quality

Sometimes Van de Rijdt also guides a new machine to the field. As already stated, he did this for the FCM and he was involved with the aforementioned Philips Digital Pathology Scanner (Figure 3) for ten years. "Philips had asked me to take up the role of mechatronics architect. It was a unique project, with an application that was new to everyone involved from Philips, CCM, Frencken and Prodrive." By digitising the images of the samples that pathologists normally view through a microscope, Philips wanted to offer integrated solutions that help to enhance the operational efficiency and productivity of pathology departments. "We really immersed ourselves in this application and that has helped in making the right system choices. At the beginning of 2009 we started the development, in April 2010 the system was at a trade show

The Philips Ultra-Fast Digital Pathology Scanner, combining exceptional image quality with high speed and throughput. All sample slides are scanned at high resolution, providing visibility to cellular detail, using multi-sensor technology and parallel processing.

for the first time. Upon introduction, the scanner was immediately awarded a prize for the best image quality in pathology scanning, so that was a success."

Patient table

The scanner is one of the many projects that Van de Rijdt is proud of. Another appealing project was the design for a patient table for radiotherapy, an excellent example of applying the design principles of the school of Van der Hoek and Koster. "It was mainly about exactly constrained construction and the clever use of material properties in the right direction, in particular for sheet metal constructions."

As the X-ray beam cannot be focused and only has one degree of freedom, the tumour must be irradiated consecutively from different directions in order to limit radiation damage to healthy tissue as much as possible. For this, the patient table had to be provided with several degrees of freedom. For example, a vertical stroke of no less than 1.2 m was required in order to get rid of the large hole in the floor that the previous system required – which of course was a disadvantage for the customer and therefore for Philips. In the other two translation directions, too, the table had to be able to achieve a considerable stroke. In addition, rotations of 360° around the vertical axis and of 200° around a point in the floor had to be designed.

"A British engineering firm failed to make a design that met all the requirements. At CFT, together with my team, I made a proposal and visualised it for the customer using Meccano. After realising a functional model and a prototype, we transferred the design to a supplier and later the production went to China. The table has now been produced for more than 20 years, without many changes in the design."

Modesty

As an architect, Van de Rijdt plays a leading role in development projects, but by nature he is a modest person.

In the presence of his family at the Precision Fair 2019, Hans van de Rijdt expresses his thanks after receiving the Rien Koster Award. (Photo: Mikrocentrum)

However, if necessary, he can become ‘functionally angry’. “Once I was invited for a design review in the final phase of a design project. That got me angry: ‘You want to review the details, but I already told you a year ago that the concept was wrong’. The development director then gave me four weeks to come up with a new concept. I did that, in another building and with the help of two designers. We succeeded and after detail engineering of the design it was the first module of the machine concerned that passed the project milestones. By making the right choices in the concept phase you can make pace and not waste time taking a wrong ‘turn’.”

Appreciation

The jury of the Rien Koster Award noted Van de Rijdt’s modesty. “He is often the guiding factor in a design team of five to 20 people, yet he remains relatively modest as a person.” Of course, he is pleased with the jury’s appreciation, summarised as: “He makes careful use of mechanics, electrical engineering, metrology and control technology to arrive at an optimum design. At the same time, he considers the manufacturability and the cost price, and he often manages to achieve significant cost-price reductions with his design approach. He creates no-nonsense solutions and usually comes with multiple options, so that clients have something to choose from, and his designs are often remarkably simple.”

But above all, Van de Rijdt (Figure 4) is very happy with the reactions he has been receiving from colleagues and, in particular, personal acquaintances. “They generally don’t know what I am doing and it’s difficult to explain what kind of work I do. Thanks to the prize, people can understand at what level I am operating.” All the more reason to carry on in the same way. “I have no ambition to start doing something completely different. However, I do want to work more with my hands. Five days a week in the office working on the computer or in meetings; that’s not what man was made for. Therefore, I am taking a part-time sabbatical this year to build a new home, which will include a small workshop, where I can make things for customers, such as test cells.”

Te Lintelo Systems – the connection to the world's leading photonics suppliers

Te Lintelo Systems, based in Zevenaar (NL), is a privately owned distributor that focuses on the photonics industry in the Benelux region. Its mission is to find the best business solution in the field of optics and photonics for all customers, from research to industry. Over the years, Te Lintelo has become a specialist in the field of lasers products, laser beam characterisation and positioning, optics, imaging, opto-electronic equipment, light metrology (from interferometry to spectroscopy), and much more….

Te Lintelo Systems was founded in 1985 by Ben te Lintelo, with ownership moving in 2015 to Roland Kuijvenhoven. Since the subsequent reorganisation, the company has improved its value proposition and expanded its number of contracted high-end partners. Together with them, Te Lintelo Systems provides the answers to customers' photonics questions.

Te Lintelo Systems is a regular exhibitor at events such as the Precision Fair.

Portfolio

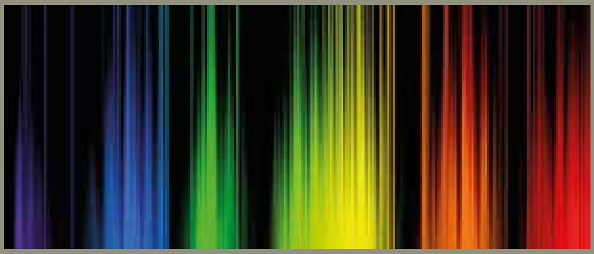
Te Lintelo Systems' product offering covers the categories of emitting light, manipulating light and detecting light. A brief summary of this portfolio:

- lasers;
- fibre optics;
- optical components;
- spectroscopy;
- hyperspectral imaging;
- imaging;
- interferometry;
- opto-electronic equipment;
- light metrology;
- laser safety;
- and much more.

OEM business

Te Lintelo Systems can act as a long-term partner for a customer's OEM business, over the complete lifetime of its product, offering flexible volume and stock possibilities, expert knowledge, a competitive pricing structure, and cooperation with well-established suppliers. This OEM business includes spectroscopic and optoelectronic solutions as well as custom optical components.

For instance, with one of its partners, Piezosystem Jena, Te Lintelo Systems can quickly develop closed-loop microstages and other motion modules for OEM applications. Building on miniature piezoelectric motor and position sensor technology, this design platform yields complete closed-loop motion modules that feature high precision and a tiny footprint. Combining mechanical and electrical functions in one optimised, easy-to-integrate device speeds up the design process and ensure smallest system size. These 'all in-one' smart modules require no separate electronics and are ready to be integrated 'plug & play' with the overall system's processor and power supply. This smart module offer helps customers to achieve the fastest time-to-market with the lowest total cost.



The portfolio of Te Lintelo Systems covers the broad spectrum of emitting light, manipulating light and detecting light.

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ULTRAFINE JET FOR ULTRAHARD METALS

The precision machining of metals nearly as hard as diamond has been challenging as long as precision engineering has existed. These days, accurately focused lasers are the most widely applied tools to meet such challenges. Researchers from the Technische Universität Chemnitz (Germany) have succeeded in applying another precision tool: an extremely fine electrolyte jet. Intelligent process control helped to apply this tool for the making of microchannels on flat surfaces as well as microgrooves on rotating workpieces.

FRANS ZUURVEEN

Electrochemical machining (ECM) is characterised by a high direct current passing between an electrode and the workpiece through an electrolytic fluid. The electrode acts as a cathode and the electrically conductive workpiece is the anode. Material from the workpiece is dissolved due to the high current density and subsequently removed by pumping the electrolyte through the gap between electrode and workpiece. Compared to the spark-erosion machining technology, there is no wear on the electrode with ECM.

The electrolyte jet set-up

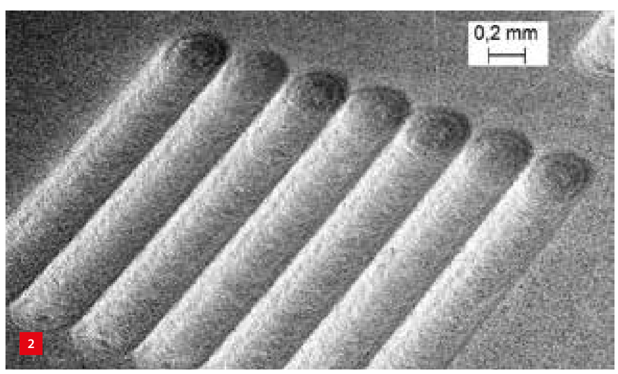
The TU Chemnitz jet electrode is fixed to a milling machine structure, whereas the workpiece is mounted on an XYZ-stage with a displacement repeatability for each coordinate of ±1 µm (see Figure 1). The electrode is represented by a nozzle with a diameter between 50 and 500 µm. The electrolyte commonly used for stainless steels is a water-based fluid with a 30% weight content of $NaNO_3$. It is pumped through the nozzle with a high speed of 20 m/s. The electrolyte jet hits the workpiece surface perpendicularly. With decreasing jet diameter, the current density on the workpiece is more locally confined. Microchannels machined with a free electrolyte jet might be applied in microfluidic chips of stainless steel. In that case the removal width is approximately equal to between 1.5 and 2 times the nozzle diameter and the channels can be machined with a workpiece speed of 9 mm/min. The making of such channels does not require the application of masks, because the X- and Y-movements are controllable with computer software.

The TU Chemnitz high-direct-current free-jet technology provides higher local material removal rates than conventional ECM with pulsed currents. Since the free-jet technology is independent of the mechanical characteristics of the workpiece material, even extremely hard cemented carbides can be machined, as shown in Figure 2.

Electrolytic free-jet applications

Besides the already mentioned application in microfluidic structures, TU Chemnitz researchers investigated the structuring of tribologically optimised surfaces. For that purpose, tiny half-spherically shaped micro-excavations with a diameter of about 180 µm were made without electrode movement for single excavations. Such excavations might be able to create a better retention of lubricants. The creation of a series of a few hundred up to ten thousand cavities with a depth of 60 µm required

1 *The TU Chemnitz free-jet ECM set-up with a fixed electrode and a movable workpiece on a high-precision XYZ-stage.*



2 *Free-jet-machined micro-channels in the surface of a WC/Co6 hard-metal workpiece.*

AUTHOR'S NOTE

Frans Zuurveen, former editor of Philips Technical Review, is a freelance writer who lives in Vlissingen (NL).

The support of Matin Yahyavi Zanjani, research assistant at TU Chemnitz, is acknowledged.

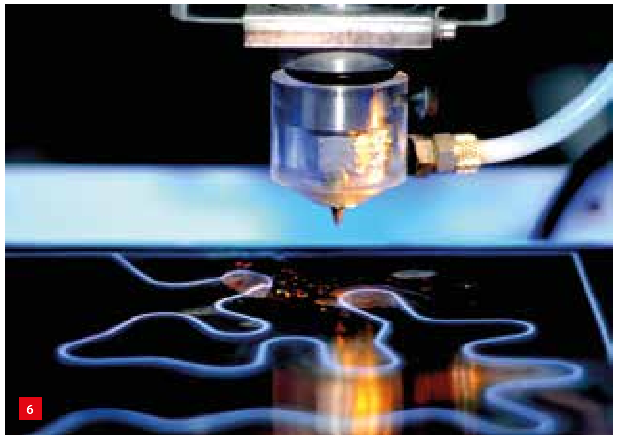
Electrochemical free-jet turning.

A cylindrical workpiece with recessions machined with free-jet ECM technology.

processing times from a few minutes to several hours. Working gap width, nozzle diameter, electrolyte conductivity and electric potential were the parameters for optimising material removal.

A further development of the free-jet technology offered electrochemical turning (see Figure 3). For this purpose, a cylindrical workpiece was clamped in a high-precision six-jaw chuck, resulting in a rotational deviation of only 10 μm. Figure 4 shows the recessions that could be machined from stainless steel in such a workpiece by supplying energy through a sliding contact.

Figure 5 illustrates the different procedures that could be followed when machining a cylindrical object with a diameter of 3 mm. Figure 5a shows the machining of 75-μm-wide grooves without axial movement of the free jet. Figure 5b shows the result when the jet moved axially with a speed of 0.12 mm/min across a lateral trajectory of 1 mm. Figure 5c shows free-jet machining with different axial speeds ranging from 6 to 0.15 mm/min. The result of this was a gradually increasing removal depth from 0 to 63 μm. The realised roughness value R_a amounted to 0.25 μm. Another application to be mentioned here is the local removal of a metallic coating from a non-conductive workpiece, for example from plastic (see Figure 6). The bulk material remains unaffected because the removal process stops when the electrolyte jet reaches the electrical insulation.



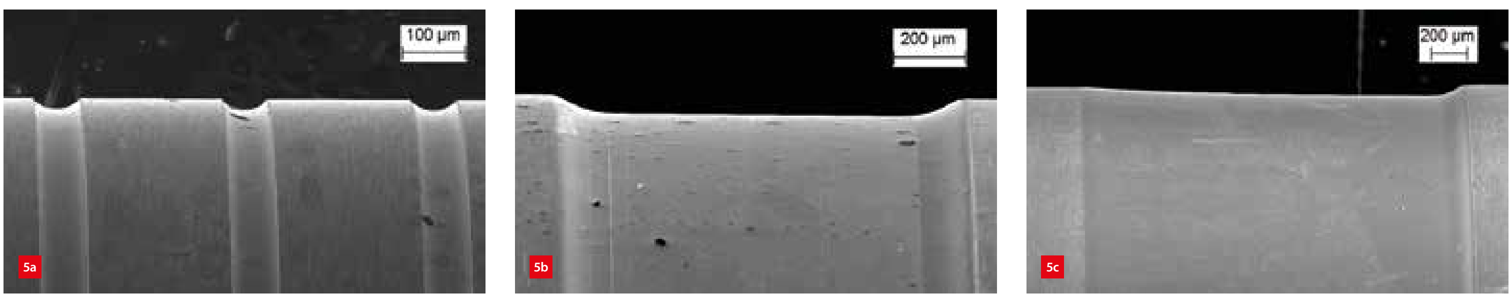
The local removal of a metallic coating from a non-conductive workpiece.

Prospects

TU Chemnitz is continuing its research on this promising technology for the machining of ultrahard metals with high accuracies. One of the aims is the application of free-jet machining for micro-injection moulding tooling. TU Chemnitz is in search of partners to bring this micromachining technology to the shopfloor with commercially available equipment.

Source

- Schubert, A. Martin, M. Yahyavi Zanjani, and M. Hackert-Oschätzchen, “ECM with closed electrolytic free jet”, *Microproduction* 01/19, pp. 44-49, 2019.



Different strategies to machine cylindrical objects.
(a) Without axial jet movement;
(b) With constant axial movement;
(c) With varying axial movement, resulting in removal depths up to 63 μm.

INFORMATION
WWW.TU-CHEMNITZ.DE/MB

Weiss Technik – specialist in testing, heating and cooling

Weiss Technik specialises in environmental simulation, cleanroom technology, oven technology and containment solutions. Its solutions are deployed around the world in research, development, production and quality assurance of numerous products. Experts from 22 companies in 15 countries provide service and support to ensure high operational reliability of the customers' systems. The Dutch branch is based in Tiel.

Environmental simulation

Weiss Technik is one of the most innovative and prominent manufacturers of environmental simulation systems. With these testing systems, all climatic conditions around the globe and beyond can be simulated, under accelerated conditions. Solutions include temperature, climate, corrosion, dust and combined shock testing. Weiss supplies systems in all sizes and versions, from standard products up to customised, process-integrated facilities – for high reproducibility and precise test results.

A Weiss Technik cleanroom solution for the preparation of cytostatics, drugs that inhibit cancer cell growth.

Cleanroom technology

Weiss Technik also offers reliable climate solutions wherever people and machinery are challenged: in industrial precision production processes, hospitals, mobile operating tents or in the area of IT and telecommunications technology. As a leading provider of professional cleanroom and climate solutions, Weiss Technik delivers effective and energy-saving solutions, from planning to the implementation of projects.

Industrial oven technology

Under the brand of Vötsch, Weiss Technik offers a wide product portfolio of high-quality, reliable heating technology systems for virtually any field of application.

A climate test chamber from Weiss Technik's portfolio of environmental simulation systems.

The product portfolio includes heating/drying ovens, cleanroom drying ovens, hot-air sterilisers, microwave systems and industrial ovens – from technologically sophisticated standard versions to customised solutions for individual production operations.

Pharmaceutical technology

In addition, Weiss Technik is a competent provider of sophisticated cleanroom and containment solutions for the pharmaceutical industry. The product range includes barrier systems, laminar flow facilities, security workbenches, isolators and double-door systems.

Service

The quality systems supplied by Weiss Technik require regular testing and maintenance. Service teams are available around the clock for customer reassurance. Weiss Technik offers a service network with excellent geographic coverage, to minimise reaction times and thus maximise system availability.

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UPCOMING **EVENTS**

4-5 March 2020, Veldhoven (NL)
RapidPro 2020
The annual event showcasing solutions for prototyping, product development, customisation and rapid, low-volume & on-demand production.

WWW.RAPIDPRO.NL

17-20 March 2020, Utrecht (NL)
ESEF / TechiShow 2020
The premier exhibitions in the Benelux area in the field of supply, subcontracting, product development and engineering (ESEF), and industrial production technology and processing of metals and plastics (TechniShow), respectively.

WWW.ESEF.NL
WWW.TECHNISHOW.NL

2 April 2020, Eindhoven (NL)
DSPE Knowledge Day
DSPE event on Engineering for Particle Contamination Control. See also page 27.

WWW.DSPE.NL/EVENTS/AGENDA

21-22 April 2020, Aachen (DE)
Aachen Polymer Optics Days 2020
Conference devoted to innovations and trends in optical plastics production. The topics range from classical injection moulding to material-related issues and aspects of digitalisation in production.

AACHEN.POLYMEROPTICS.DE

6-8 May 2020, Cambridge (USA)
ASPE 2020 Spring Topical Meeting
ASPE's sixth topical meeting on the design and control of precision mechatronic systems includes tutorial sessions on the pre-conference day (6 May), presentations, a student poster session and walking tours of MIT laboratories.

WWW.ASPE.NET

14-15 May 2020, Aachen (DE)
30th Aachen Machine Tool Colloquium
The general topic of AWK 2020 (*Aachener Werkzeugmaschinen-Kolloquium*) is "Internet of Production – Turning Data into Value". The focus is on the added value of comprehensive production networking, from data acquisition to machine learning to the fast and error-free implementation of changes in series production.

WWW.AWK-AACHEN.DE

3-4 June 2020, Veldhoven (NL)
Materials+Eurofinish+Surface 2020
At this new event, a combination of three trade fairs, product developers, product designers, engineers, R&D professionals, production staff, material specialists and researchers can meet the entire materials value chain.

WWW.MATERIALS-EUROFINISH-SURFACE.COM

4 June 2020, Eindhoven (NL)
Martin van den Brink Award
The Martin van den Brink Award, for the best system architect in precision engineering, will be handed out for the fourth time. See page 25.

WWW.DSPE.NL

8-12 June 2020, Geneva (CH)
Euspen's 20th International Conference & Exhibition
The event features latest advances in traditional precision engineering fields such as metrology, ultra-precision machining, additive and replication processes, precision mechatronic systems & control, and precision cutting processes. This 20th edition will be a landmark event at CERN, the largest particle physics laboratory in the world.

WWW.EUSPEN.EU

10-11 June 2020, Veldhoven (NL)
Vision, Robotics & Motion 2020
This trade fair & congress presents the future of human-robot collaboration within the manufacturing industry.

WWW.VISION-ROBOTICS.NL

17 June 2020, Den Bosch (NL)
Dutch System Architecting Conference
The third edition of this conference features system architecting as a distinguishing discipline in the development and commercialisation of complex systems, products and machines.

WWW.SYSARCH.NL

8-9 September 2020, Sint-Michielsgestel (NL)
DSPE Conference on Precision Mechatronics 2020
Fifth edition of the conference on precision mechatronics, organised by DSPE. This year's theme is "Uncovering the Essence".

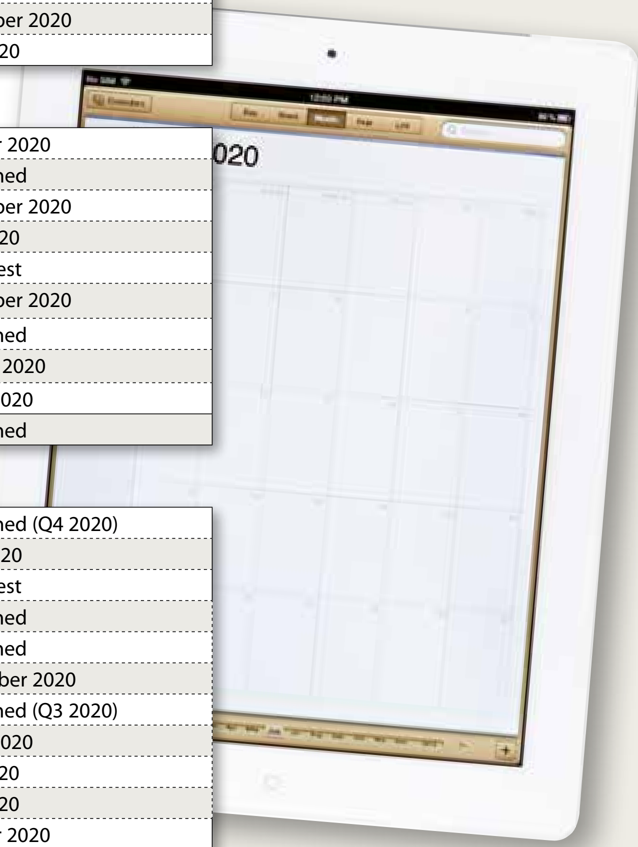
WWW.DSPE-CONFERENCE.NL

14-18 September 2020, Ilmenau (DE)
60th Ilmenau Scientific Colloquium
Flagship event of the Technische Universität Ilmenau, organised by the Department of Mechanical Engineering, reflecting both the broadness and depth of modern engineering as well as the increasing integration of engineering disciplines. See also page 27.

WWW.TU-ILMENAU.DE/60-IWK

ECP² COURSE CALENDAR

COURSE (content partner)	ECP² points	Provider	Starting date
FOUNDATION			
Mechatronics System Design - part 1 (MA)	5	HTI	28 September 2020
Mechatronics System Design - part 2 (MA)	5	HTI	5 October 2020
Fundamentals of Metrology	4	NPL	to be planned
Design Principles	3	MC	11 March 2020
System Architecting (S&SA)	5	HTI	23 March 2020
Design Principles for Precision Engineering (MA)	5	HTI	23 November 2020
Motion Control Tuning (MA)	6	HTI	22 June 2020
ADVANCED			
Metrology and Calibration of Mechatronic Systems (MA)	3	HTI	27 October 2020
Surface Metrology; Instrumentation and Characterisation	3	HUD	to be planned
Actuation and Power Electronics (MA)	3	HTI	16 November 2020
Thermal Effects in Mechatronic Systems (MA)	3	HTI	23 June 2020
Summer school Opto-Mechatronics (DSPE/MA)	5	HTI	upon request
Dynamics and Modelling (MA)	3	HTI	23 November 2020
Manufacturability	5	LiS	to be planned
Green Belt Design for Six Sigma	4	HI	3 February 2020
RF1 Life Data Analysis and Reliability Testing	3	HI	30 March 2020
Ultra-Precision Manufacturing and Metrology	5	CRANF	to be planned
SPECIFIC			
Applied Optics (T2Prof)	6.5	HTI	to be planned (Q4 2020)
Advanced Optics	6.5	MC	5 March 2020
Machine Vision for Mechatronic Systems (MA)	2	HTI	upon request
Electronics for Non-Electronic Engineers – Analog (T2Prof)	6	HTI	to be planned
Electronics for Non-Electronic Engineers – Digital (T2Prof)	4	HTI	to be planned
Modern Optics for Optical Designers (T2Prof) - part 1	7.5	HTI	18 September 2020
Modern Optics for Optical Designers (T2Prof) - part 2	7.5	HTI	to be planned (Q3 2020)
Tribology	4	MC	10 March 2020
Basics & Design Principles for Ultra-Clean Vacuum (MA)	4	HTI	15 June 2020
Experimental Techniques in Mechatronics (MA)	3	HTI	23 June 2020
Advanced Motion Control (MA)	5	HTI	26 October 2020
Advanced Feedforward Control (MA)	2	HTI	30 September 2020
Advanced Mechatronic System Design (MA)	6	HTI	to be planned (2020)
Passive Damping for High Tech Systems (MA)	3	HTI	26 May 2020
Finite Element Method	5	MC	in-company
Design for Manufacturing (Schout DfM)	3	HTI	5 March 2020



ECP² program powered by euspen

The European Certified Precision Engineering Course Program (ECP²) 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 ECP² certificate is an industrial standard for professional recognition and acknowledgement of precision engineering-related knowledge and skills, and allows the use of the ECP² title.

WWW.ECP2.EU

Course providers

- High Tech Institute (HTI)
  WWW.HIGHTECHINSTITUTE.NL
- Mikrocentrum (MC)
  WWW.MIKROCENTRUM.NL
- LiS Academy (LiS)
  WWW.LISACADEMY.NL
- Holland Innovative (HI)
  WWW.HOLLANDINNOVATIVE.NL
- Cranfield University (CRANF)
  WWW.CRANFIELD.AC.UK
- Univ. of Huddersfield (HUD)
  WWW.HUD.AC.UK
- National Physical Lab. (NPL)
  WWW.NPL.CO.UK

Content partners

- DSPE
  WWW.DSPE.NL
- Mechatronics Academy (MA)
  WWW.MECHATRONICS-ACADEMY.NL
- Technical Training for Prof. (T2Prof)
  WWW.T2PROF.NL
- Schout DfM
  WWW.SCHOUT.EU
- Systems & Software Academy (S&SA)

Call for Martin van den Brink Award candidates and sponsors

This year, the Martin van den Brink Award will be presented for the fourth time. The award, named after ASML's current president and CTO, reflects the importance of system architecture in the development of high-tech equipment and underlines the role that system architecture plays in the success of the Dutch high-tech systems industry.

A long list of criteria annex qualifications and competences has been drawn up for Martin van den Brink Award candidates:

- The best contribution in precision engineering from both a system architecture and business development perspective.
- Unorthodox thinker.
- Contributor to innovation and new business creation.
- Highly experienced in interdisciplinary collaboration and a master in using soft skills to achieve results.
- Open to unconventional solutions and ready to go places where others think the limit has been reached.
- Taking practical realisation into account.
- A complete system overview for well-founded decisions on module implementation in either hardware, electronics or software.
- A thorough overview of all system modules and their connections and interfaces, keeping future developments in mind for easy reuse.

In 2012, the first Martin van den Brink Award was bestowed upon Erik Loopstra, program system engineer at ASML (now fellow at Carl Zeiss), in 2016 to Jan van Eijk, former CTO of Mechatronics at Philips Applied Technologies and emeritus professor of Advanced Mechatronics at Delft University of Technology, and in 2018 to Marco Wieland, co-founder of Mapper Lithography. The 2020 jury is composed of Jos Benschop (ASML), Martin van den Brink (ASML), Pieter Kappelhof (DSPE, Hittech Group), Hans Krikhaar (DSPE, Fontys) and Adrian Rankers (DSPE, Mechatronics Academy). Suitable candidates can be recommended to the jury, via DSPE.

The award ceremony will be held on Thursday 4 June 2020, at a gala dinner held in the Evoluon in Eindhoven (NL). Preceding the ceremony, Ph.D. students from Dutch universities of technology will present their work. For details on the presentation opportunities, DSPE can be contacted.

Companies that want to partner with the Martin van den Brink Award organisation can sponsor a dinner table in the Evoluon, to which they can invite guests. For information and reservations, please contact DSPE.

MARTIN VAN DEN BRINK AWARD

INFO@DSPE.NL

Eindhoven Engine update

Last year, Eindhoven Engine was established at the initiative of Maarten Steinbuch, distinguished university professor in systems and control at Eindhoven University of Technology (TU/e). Eindhoven Engine was set-up to accelerate innovation in the Brainport region through challenge-based research in its public-private research facility at the TU/e campus. Teams of talented researchers from industry and knowledge institutes and students cooperate in Eindhoven Engine research programmes to deliver breakthrough technological solutions.

The Eindhoven Engine's kick-off last April was an inspiring event attracting over 500 attendees and in the meantime ten projects with iconic applications in high-tech, energy, mobility and health have started. The Engine Academy has held the first seminars for project partners and the blueprint for the coming years is ready to be rolled out, focusing on transformation, the unlocking of collective intelligence and the revolutionising of innovation.

Open calls

In 2019, the Engine's open call was very successful, resulting in four new projects which represent a value of more than 10 million euros and the involvement of more than 100 researchers and students in total. An independent jury performed a high-quality assessment of the proposals, also providing improvement suggestions for the next call. This 2020 call will be opened shortly and the selection of projects will be finished before the summer, with special attention to SME participation. The ambition of Eindhoven Engine for 2020 is to grow in terms of cooperation, energy and the involvement of all parties through co-location. This should generate a novel way of working and hopefully lead to more iconic projects in the region.

Some ongoing projects

Advanced piezo-electric wafer stage

The project "Advanced piezo-electric wafer stage for next generation lithography and metrology application" aims to demonstrate feasibility of an ultrashort-stroke stage using lightweight and compact piezo-electric actuators instead of current electromagnetic actuators. As opposed to these 'force' actuators, which provide good isolation for environmental disturbances from the long-stroke mover, piezo-electric actuators are stiff and nonlinear, which requires breakthroughs in terms of materials, electronics, control, mechatronic implementation, and sensor systems.

Eindhoven Engine initiator Maarten Steinbuch at the kick-off last April. Behind him, the slide displays the names of industrial participants, including ASML, NXP, Philips and VDL. In the middle, the knowledge partners: TU/e, TNO and Fontys University of Applied Sciences. (Photo: Bart van Overbeeke)

Relevant use cases are next-generation lithography systems, where mass reduction is pursued, and e-beam metrology systems, where electromagnetic fields at close proximity to the e-beam process are not allowed and even small electromagnetic fields need to be shielded. The main goal is a proof-of-concept in hardware of a relatively large-range (> 10 µm) piezo-electric stage with integrated measurement system with an uncertainty of < 100 pm. The consortium for this project comprises ASML and TU/e.

Smart Mobility

This project of NXP and TU/e (the consortium intends to attract more partners) includes two subprojects. The first one is devoted to deep learning for embedded automotive platforms and covers research into semi-supervised training methods and inference methods. Semi-supervised training methods should help to make neural networks more resilient to adverse imaging conditions, so that the performance drop (with respect to nominal imaging conditions) decreases with one order of magnitude. Inference methods can exploit spatio-temporal coherency in video streams, to increase computational efficiency by one order of magnitude. Research results will be validated in real-world conditions using TU/e's Highly Automated Driving research vehicle. NXP will make available its Bluebox automotive computation platform.

The second subproject is concerned with 'smart radar': Spread-spectrum Modulated And interfeRence resilienT RADAR. The aim is to develop novel nm CMOS 77-81GHz radar front-ends that generate ultrafast arbitrary radar waveforms that alleviate radar interference through spread-spectrum techniques. Concepts will be demonstrated on NXP's modulated radar demonstration platforms that will be made compatible and available for the test chips.

MEDICAID

This e/MTIC (Eindhoven MedTech Innovation Center) mini-programme seeks to leverage technological advances in unobtrusive sensing, monitoring and data analysis to enable earlier recognition, mitigate progression and improve treatment of cardiovascular disease. It targets three priorities of the Dutch *Hartstichting*: earlier recognition, cardiovascular disease in women, and better treatment of heart failure and arrhythmias. Consortium partners are Philips, Maxíma Medical Centre, Catharina Hospital, Kempenhaeghe (centre of expertise for epilepsy, sleep disorders and neurological learning and developmental disorders) and TU/e.

WWW.EINDHOVENENGINE.NL

DSPE Knowledge Day on Engineering for Contamination Control

On Thursday 2 April 2020, the second edition of the DSPE Knowledge Day on Engineering for Contamination Control will be held. This afternoon event is devoted to design aspects aimed at dealing with contamination or minimising the implications of contamination. In addition, information will be shared regarding tools that support the design (and test) phase of a project. The first edition of the event, last summer, attracted some 30 attendees and featured a number of highly interesting presentations.

The event is highly relevant for precision engineers involved in designing advanced mechatronics systems. Presentations will be given by Paul Blom (senior system engineer at VDL ETG), Sven Pekelder (CTO at Settels Savenije), Cees van Duijn (contamination control expert at Omneo Systems), and Rob Lansbergen (senior system engineer at Lans Engineering/Fast Micro). More information and registration on the DSPE website.

The DSPE Knowledge Day on Engineering for Contamination Control is organised by DSPE in collaboration with VCCN (Association of Contamination Control Netherlands), VDL ETG, Settels Savenije, Omneo Systems, and Lans Engineering/Fast Micro, and will be hosted by Settels Savenije in Eindhoven (NL).

WWW.DSPE.NL

60th Ilmenau Scientific Colloquium

This flagship event of the Technische Universität Ilmenau (Germany), organised by its Department of Mechanical Engineering, will be held on 14-18 September 2020. It reflects both the broadness and depth of modern engineering as well as the increasing integration of engineering disciplines. As always in this conference series, there will be a balanced combination of contributions from both academia and industry. The programme is still being developed. The previous, 59th edition covered Precision Engineering and Metrology; Industry 4.0 and Digitalisation in Mechanical Engineering; Mechatronics, Biomechatronics and Mechanism Technology; Systems Engineering; and Innovative Metallic Materials.

WWW.TU-ILMENAU.DE/60-IWK

EMC for motion systems

Challenges with electromagnetic compatibility (EMC) in motion systems are not new but are substantially growing due to the increasing use of pulse-width-modulated (PWM) power conversion techniques (even with spread-spectrum techniques or self-oscillating) in power supply systems and motion drive systems. The power conversion efficiency is constantly increased by reducing the power losses, thus faster switching at higher frequencies in compacter volume.

While making motion-based systems like production machines, robotic systems, automotive applications, etc., more compact, with a higher density of sensor systems, the likelihood of cables running together over longer distances increases, up to the integration of motion drivers into the motor housings. PWM drives and sensor systems are often using the same operational frequency bands in the 'Eldorado' band: 2-150 kHz.

Modern motion drive systems must satisfy the IEC/EN 61800-x: Adjustable speed electrical power drive systems – Parts 1 through 9: General requirements - Rating specifications for low-voltage adjustable speed AC and DC power drive systems. Fulfilling these requirements does not guarantee that EMC issues will not occur with practical installations. This is where the "EMC for motion systems" training of the High Tech Institute comes in. After a successful debut last year, this April, starting on the 6th, a new edition of this 3-day EMC course will be organised. It is targeted at engineers who are confronted with low-frequent disturbances (from DC to approx. 150 kHz) generated by:

- the mains-frequency-related current and voltages and their harmonics, power factor corrections, mains-filter applications and leakage current flowing everywhere;
- linear and rotation motion frequencies and their accompanying fluxes of motors;
- pulse-width modulation (PWM);
- utility and internet via the mains.

These typical EMC-like phenomena are not fully covered by international standards and regulations. The disturbances and their consequences will be discussed and analysed. Solutions are based on a high level of 'good engineering practices'. This course is also important for mechanical engineers, since their work has a big impact on the creation and transport of the resulting disturbance currents and they may have problems to understand certain concepts from the physical and electrical domain. In a forthcoming issue of Mikroniek more on EMC challenges and solutions.

WWW.HIGHTECHINSTITUTE.NL/EMC-MS

Official launch of Breda Robotics

On 12 March 2020, Breda Robotics will officially be opened. In this Smart Industry field and skills lab in Breda (NL), companies and students together will experiment with robotics and automation in, for example, industrial production and maintenance. Breda Robotics aims to offer an inspiring environment where companies and students work on new applications, prototypes and demonstrators.

Breda Robotics was initiated by regional tech companies (Ex Robotics, WWA and Synchron) together with Avans University of Applied Sciences, the municipality of Breda and regional development agency Rewin. In the Breda Robotics lab, professionals, companies and organisations can become acquainted with Industry 4.0 and students can gain hands-on experience.

The main goals of Breda Robotics are:

1. Strengthening West-Brabant as an attractive region for students and robotic companies by improving the connection between the education of students and the needs of companies.
2. Building and maintaining an active network of robotics companies, in order to increase the employment opportunities in the robotics and automation sector with innovative and Industry 4.0 jobs for (young) professionals.
3. Making companies in the region West-Brabant aware of the opportunities and the urgency to implement robotics in their companies. On one hand, because of the shortage of well-educated professionals and, on the other hand, to remain competitive in the future.

Breda Robotics is the place where students and companies can innovate, in a Smart Industry field and skills lab with a focus on applied research and knowledge. In this way the innovation strength of the manufacturing and maintenance industry increases and tech students can link theoretical knowledge to practice. Avans has been ranked the leading major university of applied sciences in the Netherlands; Dr. Daniël Telgen's Robotization & Sensoring research group works closely together with Breda Robotics.

On 12 March 2020, Breda Robotics will officially be opened. Director Chantal van Spaendonck is available for more information or registration for the opening event.

CHANTAL@BREDA-ROBOTICS.NL
WWW.BREDA-ROBOTICS.NL

"If you want more, you will need a robot"

On 24 April 2020, Dr. Daniël Telgen, professor of Robotization & Sensoring at Avans University of Applied Sciences in Breda (NL), will present his inaugural lecture, entitled: "If you want more, you will need a robot".

Technology becomes more important to fulfil our primary needs, Telgen states. "From drinking water to our self-driving car; technology gives us more possibilities. However, it also makes us more dependent. These are exciting times, where challenges like quality of life, sustainability and security are important topics. Many transitions are quickly becoming more and more relevant, e.g. the energy and the materials transition. For an individual it might be hard to make the right choices and adopt new habits. Hence, we will need technology to support us in the coming transitions.

The summum of integration of technology is the robot. A machine with a brain, that becomes smarter and autonomous and starts to move without us, adapting to become more flexible. Many technical systems start to comply with these characteristics and as such we see a rapid robotisation of the world."

In his inaugural speech, Telgen will explore the current state of affairs and the opportunities that robots provide. "We will look for the balance, between humans, nature and the robot, and present the way of working of a research group, in order to show how we want to help society."

REDEDANIELTELGEN.AVANS-EVENEMENTEN.NL (REGISTRATION)

WWW.AVANS.NL/LECTOREN/ROBOTISERING-EN-SENSORING/DANIEL-TELGEN

Daniël Telgen, professor of Robotization & Sensoring at Avans University of Applied Sciences: "We see a rapid robotisation of the world."

Third edition of the high-performance mechatronics text/reference book

This month, the third revised edition of "The Design of High Performance Mechatronics" was published by IOS Press. This book by mechatronics veterans Robert Munnig Schmidt, Georg Schitter, Adrian Rankers and Jan van Eijk deals with the special class of mechatronics that has enabled the exceptional levels of accuracy and speed of high-tech equipment applied in the semiconductor industry, realising the continuous shrink in detailing of micro-electronics and MEMS. The book was published in 2011 and first revised in 2014. Now, the new edition contains updates concerning motion control, dB scales in Bode plots, and the SI redefinition.

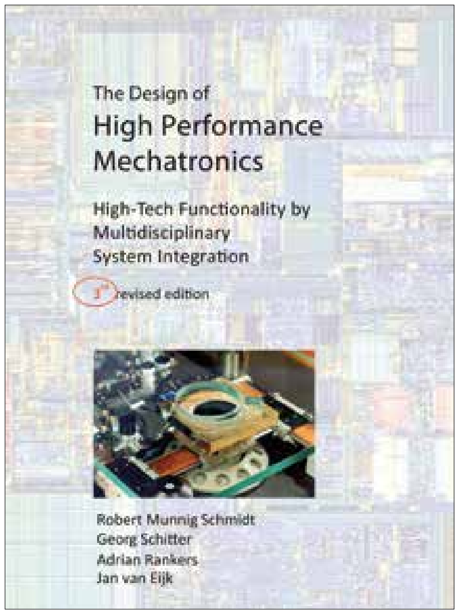
In addition to the 'standard' mechatronics subjects of dynamics, motion control, electronics and electromechanics, this book includes an overview of systems engineering, optics and precision measurement systems, in an attempt to establish a connection between these fields under one umbrella. The book distinguishes itself from other textbooks on mechatronics in several ways. First of all, it is a combination of a reference book for engineers working in the high-tech industry and a university textbook, due to the mixed industrial and academic background of the authors.

The industry-oriented part is based on extensive experience in designing the most sophisticated motion systems presently available, the stages of wafer scanners, which are used in the semiconductor industry. The academic part is based on advanced research on precision motion systems, including ultra-precision metrology equipment with fast scanning probe microscopy and optical measurement systems with sub-nanometer accuracy.

From its high-tech industrial background, the book focuses on high-precision positioning at very high velocity and acceleration levels. With this focus, the book does not include examples from other important application areas like robotics, machining centres and vehicle mechatronics, though the theory is also applicable to those areas of mechatronics. The presented material is aimed at obtaining maximum understanding of all dynamic aspects of a motion system, which is the reason for the term 'High Performance' in the title. It covers all relevant fields of expertise that support the focus area, including optics and measurement technology.

Most changes to the previous edition have been made in Chapter 4 on motion control, where the focus in feedback control has been shifted from pursuing a target bandwidth to a targeted low sensitivity for disturbances in combination with high-accuracy feedforward control using a solid trajectory planning, which is more in line with industrial practice. For this reason, the PID guidelines have been replaced by design steps that also include optimisation with loop shaping.

The presentation of 'poles and zeros' and the different kinds of impedances has moved to the physics chapter, as they are applied in various chapters. Another change is the addition of a dB scale next to the absolute magnitude scale in the Bode plots of the motion control chapter, because it has often been mentioned that the use of dB is as common in the control community as it is in the electronics community.
The redefinition of the SI base units in May 2019 required slight changes in some numbers and it further appeared useful to mention the units with the equations to avoid confusion.



Robert Munnig Schmidt, Georg Schitter, Adrian Rankers and Jan van Eijk, "The Design of High Performance Mechatronics – High-Tech Functionality by Multidisciplinary System Integration", 3rd revised edition, hardcover, 948 pages, ISBN 978-1-64368-050-7 (print), ISBN 978-1-64368-051-4 (online), €135 / US$166 / £122 excl. VAT, IOS Press.

Due to the addition of several subjects also some pruning of 'ancient' technology has been done. Especially the large part on linear power amplifiers has been reduced to the bare minimum, because at present almost all power amplifiers apply switched-mode technology. Finally, the "Main Design Rules for Precision" section, which was omitted from the second edition, returns at the end of the book after a complaint of an enthusiastic reader who worked with both the first and second edition, stating that he really used these design rules.

Authors

Robert Munnig Schmidt is emeritus professor in Mechatronic System Design at Delft University of Technology (NL) with industrial experience at Philips and ASML in r&d of consumer and high-tech systems. He is also director of RMS Acoustics & Mechatronics, doing r&d on actively-controlled low-frequency sound systems. Georg Schitter is professor in the Automation and Control Institute (ACIN) at Vienna University of Technology (Austria) with a standing track record in research on the control and mechatronic design of extremely fast precision motion systems such as video-rate AFM systems. Adrian Rankers is managing partner of Mechatronics Academy, developing and delivering high-level courses to the industrial community, based on industrial experience at Philips. He also teaches mechatronics at the Eindhoven University of Technology (NL). Jan van Eijk is emeritus professor in Advanced Mechatronics at Delft University of Technology. He is also director of MICE and partner at Mechatronics Academy, acting as industrial r&d advisor and teacher with experience in r&d at Philips.

WWW.IOSPRESS.NL

First prototype of autonomous and modular drone with robot arm

At the end of last year, Saxion University of Applied Sciences in Enschede (NL) received 1 million Euro from the RAAK-PRO scheme and the business community for its MARS4Earth project. The goal of MARS4Earth (Modular Aerial Robotic Systems for Sustainable Living on Earth) is the development of the world's first autonomous and modular flying drone with robot arm that can physically interact with the environment.

Current drone applications are limited to the use of drones for non-interactive remote sensing, 'eyes and noses in the sky'. The next breakthrough will be tele-interaction, 'hands in the air'. The MARS4Earth project aims to develop the first autonomous and modular air manipulator that works physically in a safe, autonomous, efficient and cost-effective way with the environment. The applicability of this technology will be demonstrated in three selected application domains: inspection & maintenance (maintenance of offshore wind turbines and cleaning of solar panels), agriculture (selective treatment of plants and sample picking) and safety & security (active firefighting).

The modular aerial manipulator consists of four basic building blocks:
- mission-specific interaction module(s);
- intelligent surface exploration;
- adaptive interaction control algorithm(s);
- advanced perception and decision module(s) on board.

MARS4Earth is a four-year collaboration project between knowledge institutes (Saxion, NHL Stenden, University of Twente, Wageningen University & Research), fieldlabs (Space53, TValley, Zephyros) and public-private partners (DRONExpert Nederland, Drone4Agro, Brandweer Twente, AmperaPark, Groningen Seaports). RAAK-PRO (RAAK stands for Regional Attention and Action for Knowledge circulation) is a programme by the Taskforce for Applied Research (*Nationaal Regieorgaan Praktijkgericht Onderzoek SIA*) that financially supports research by universities of applied sciences.

WWW.SAXION.NL
WWW.REGIEORGAAN-SIA.NL

Collaboration in 3D-printing technologies moves to BIC

AM-Flow, Additive Center and Marketiger, three young companies active in the world of 3D printing (or additive manufacturing) technology, are going to intensify their collaboration and will move to Brainport Industries Campus (BIC), a development and production location (near Eindhoven Airport, NL) for companies and knowledge institutions in the high-tech sector. AM-Flow, based in Amsterdam (NL), will open a second branch in Eindhoven (NL). Marketiger and Additive Center – both already located in Eindhoven – will move all of their activities to BIC. Together they will build a 3D innovation centre on BIC.

With this step, the three companies not only expect to further intensify their mutual cooperation, but also to benefit from the presence of the other tenants within BIC, both companies and educational institutions. In addition to the collaboration benefits, AM-Flow, an Industry 4.0 (automation) technology provider for the additive manufacturing market, expects to gain from the existing expertise in the field of robotics, vision software and other elements of Industry 4.0 at BIC.

For Additive Center, which wants to make 3D technologies accessible to the industry through consultancy and product development, the challenge lies in being more accessible for partners and clients. The company also sees the new collaboration as an opportunity to bring 3D-printing raw materials such as polymers, which are now mainly used, and metals closer together. Marketiger, a provider of full-colour 3D printing solutions, will be given space for further development at BIC.

WWW.AM-FLOW.COM
WWW.ADDITIVECENTER.COM
WWW.MARKETIGER.NL
WWW.BRAINPORTINDUSTRIESCAMPUS.COM

DfM in HTI

The Design for Manufacturing (DfM) training, provided by Schout DfM, has been incorporated in the comprehensive range of courses offered by High Tech Institute. DfM is a method to achieve successful designs by optimally aligning product design with production methods. In practice, the required production process development is often strongly underestimated in the design phase, resulting in delays and financial setbacks. In most cases, more attention to production methods in the design phase leads to immediate cost and time savings.

DfM should help to ensure a smooth production take-off and therefore starts in the concept phase: manufacturing processes are selected conscientiously and the design is tailored to these manufacturing processes and vice versa. Success factors include functionality, total lead time and integral cost price (costs up to and including a few years of production).

Schout DfM used to give the 3-day DfM training (ECP2-certified, see page 24) on an in-company basis. On 5 March 2020, the first open-enrollment edition will start.

WWW.HIGHTECHINSTITUTE.NL
WWW.SCHOUT.EU

A new era for freeform micro-optics

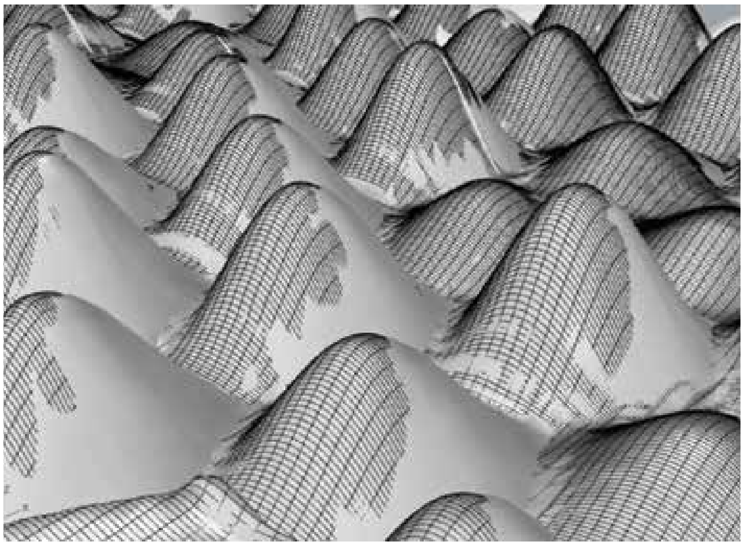
Led by CSEM, the PHABULOuS consortium is unifying Europe's leading companies and research & technology organisations (RTOs), through the creation of a self-sustainable pilot line for the design and manufacturing of freeform micro-optical solutions. These solutions will be integrated into high-added-value devices, spanning from microdisplays for augmented reality, to innovative systems for professional, automotive and transportation lighting, to optical effects for luxury.

There is an urgent need to provide miniaturised optical components due to the exponential growth of the micro-optics market over the last decade. This is in tandem with an increasing need for freeform micro-optics that can address the challenges set by the photonics market over the next five to ten years. However, the high access barriers to pre-commercial production capabilities in Europe prevent companies, especially SMEs, from commercially exploiting this technology.

Objectives of the PHABULOuS project:

- the general increase of the current technology and manufacturing readiness levels of freeform micro-optics;
- the implementation of six industrial user cases demonstrating pilot manufacturing in operational environments for applications spanning from augmented reality, to professional, automotive and transportation lighting, to luxury;
- the establishment of an open-access, sustainable, distributed pilot-line infrastructure with a single entry point;
- the validation of the pilot-line services through the implementation of 20 industrial pilot cases in various fields, such as solid-state & day-lighting, photovoltaics, displays & imagers, consumer electronics & wearables, anti-counterfeiting & branding.

The EU project PHABULOuS (Pilot-line providing highly advanced & robust manufacturing technology for optical free-form μ-structures) was launched last month at CSEM, a Swiss research and development centre (public-private partnership) specialising in microtechnology, nanotechnology, microelectronics, system engineering, photovoltaics and communications technologies, in Neuchâtel.



Sketch of a freeform micro-optics component.

PHABULOuS has received funding in the order of 15 million euros in the framework of the European Horizon 2020 Work Programme in public-private partnership with Photonics 21. The consortium comprises 19 companies and RTOs along the whole manufacturing value chain, including CSEM as coordinator, Fraunhofer Gesellschaft, Lasea, SUSS MicroOptics, Swarovski, Hella and EPIC (European Photonics Industry Consortium).

WWW.PHABULOUS.EU
EC.EUROPA.EU/PROGRAMMES/HORIZON2020
WWW.PHOTONICS21.ORG

Vacuum in the LHC

Pfeiffer Vacuum, a leading provider of vacuum solutions, has received yet another major order for leak detectors from CERN, the world's largest centre for particle physics research. CERN's particle accelerator LHC (Large Hadron Collider), with a circumference of some 27 kilometers, is the world's largest vacuum installation, with thousands of welds, flanges, feedthroughs and complex internal circuits. For the accelerated particles to travel in beam lines, ultrahigh vacuum is essential. To maintain such a very low pressure it is crucial to keep the leak rates as low as possible. The most advanced leak detector technology from Pfeiffer Vacuum has been chosen by CERN.

This concerns the ASM 340 leak detector, an easy-to-operate device that can detect leaks down to $5 \cdot 10^{-13}$ $Pa \cdot m^3/s$. With a built-in backing pump of 15 m^3/h small as well as big volumes can be leak-tested. The patent-pending functionality makes it possible to start at 100 hPa, which can be very convenient for such a big installation like the LHC. Furthermore, the leak detector is so compact that it can be easily maneuvered underneath the cryostats and beam lines of the LHC.
Nowadays, helium leak detectors are based on a patented design from Pfeiffer Vacuum, involving a turbopump as a kind of filter and safety element in front of a mass spectrometer. At the time, CERN was one of the first customers to buy this innovative technology.

WWW.PFEIFFER-VACUUM.COM

CMM manufacturer launches portable measuring arms

For the first time, LK Metrology has diversified into the supply of 3D articulating arm metrology systems, otherwise known as portable arms, with the launch of a range of 24 machines called Freedom arms. The company has been manufacturing static coordinate measuring machines (CMMs) in the UK since 1963 and was relaunched, in 2018, as an independent CMM manufacturer after several years as a division of Nikon Metrology.

The Freedom arm comes as a 6-axis model for touch probing and a 7-axis version for multi-sensor metrology including laser scanning. Both are available in two accuracy levels and the four products come in six sizes with a reach of up to 5 m. Their portability suits them to line-side measuring and inspection in factories, while their compactness facilitates their use on machine tools for in-process quality control. The platform is also particularly appropriate for reverse engineering applications, virtual assembly design environments and 3D modelling. If very high precision tolerances do not have to be measured, a portable arm is a cost-effective way to progress from manual to CNC metrology.

Carbon fibre tubular construction ensures stability under challenging conditions. Infinite rotation and a proprietary counter balance make manual movements light, Wi-Fi connectivity and battery power allow completely portable wireless touch probing. A notable feature of the arms is the inclusion of absolute rather than incremental rotary encoders to feed back the angular position of every joint to the control software. The equipment may therefore be used immediately on start-up, avoiding the need to calibrate the probe before use every time.

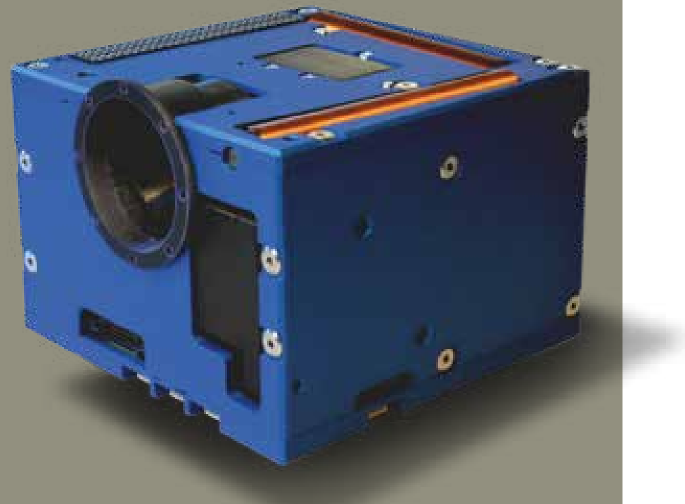
WWW.LKMETROLOGY.COM

Hyperion – smart satellite components engineered for performance

Space is a hostile environment. To explore it, you have only one chance to do it right. Or do you? What if you could spread the risk by launching more satellites? Lower the cost per satellite by making them smaller? Or increasing the performance of your application because you have a swarm of satellites sending data, rather than only one? This is the heart of Hyperion's activity.

Hyperion Technologies is an independent Dutch space company located in Delft. Ever since 2013, the company has been following one core philosophy: to scratch at the limits of the physically possible, in the interest of smaller and lighter components for satellites. The appealing result: miniaturised, high-performance and smart products, satellite platforms for complete missions, ranging from hardware to software. Today, Hyperion serves clients around the globe, enabling their missions to be more profitable, more performant and more efficient.

To achieve all this, Hyperion focuses on research, design and development with a particular expertise in electronics. The manufacturing is outsourced to trusted partners. This allows Hyperion to look beyond the status quo of available commercial off-the-shelf products and initiate technology transfers and innovations. Increasing the reliability of such new components is equally important: Hyperion gives high importance to testing and gathering flight heritage. This is why the company has been investing in its in-house test facilities and is continuously working on improving its products.



Knowing your direction and being able to rotate your satellite is crucial for mission success. Hyperion's compact ADCS (Attitude Determination and Control System) unit provides all that – and makes space for the king of the satellite: the main payload.

An inside view of the jointly developed laser communication unit for small satellites. Hyperion and TNO contributed with their expertise in electronics and optical systems, respectively.

This is possible thanks to numerous collaborations with other organisations. The company's Star Tracker is a co-development between Hyperion and Berlin Space Technologies; the chemical propulsion system for small satellites is the result of a collaboration with Delft start-up Dawn Aerospace, providing expertise in mechanical systems. Another innovative project is being developed together with TNO and a consortium of Dutch companies: a small and powerful laser communication terminal for small satellites.

Hyperion believes that the future of mankind's data sourcing and communication will depend to a large extent on space, be it for streaming services, risk assessments or climate monitoring. Enabling the transition to a society where space is a commodity, that's Hyperion's goal.

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