Mikroniek

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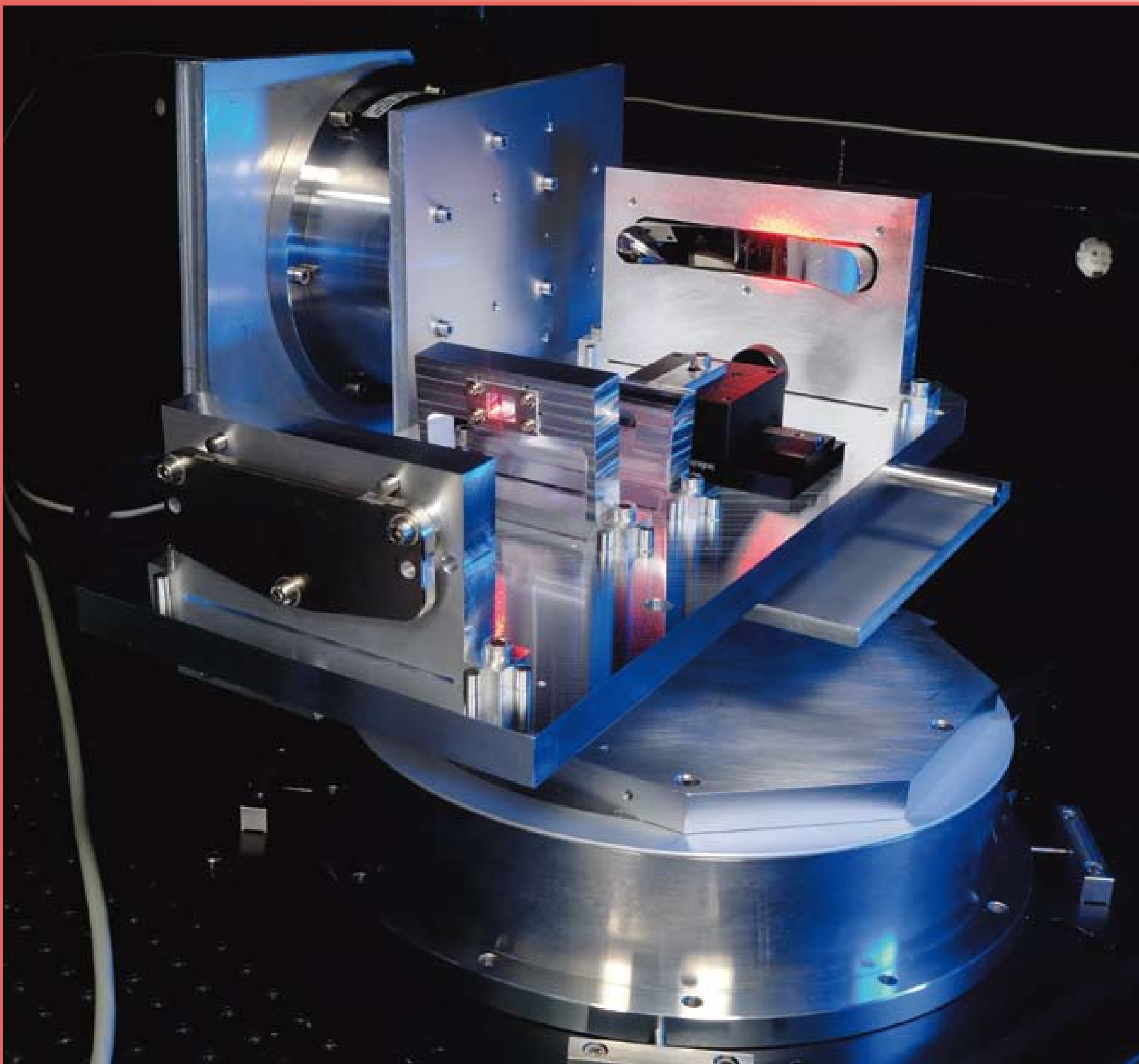

DSPE Conference Special Issue

Meeting intra-system PI, SI and EMC requirements in modular mechatronic designs
Organic and optical, devices and metrology (euspen) • Shrink and growth (ASPE)
Dance of the photons • Measurement of 3D surface metrology, wear and friction
Complex systems, simple models • Dutch astronomical instrumentation innovation

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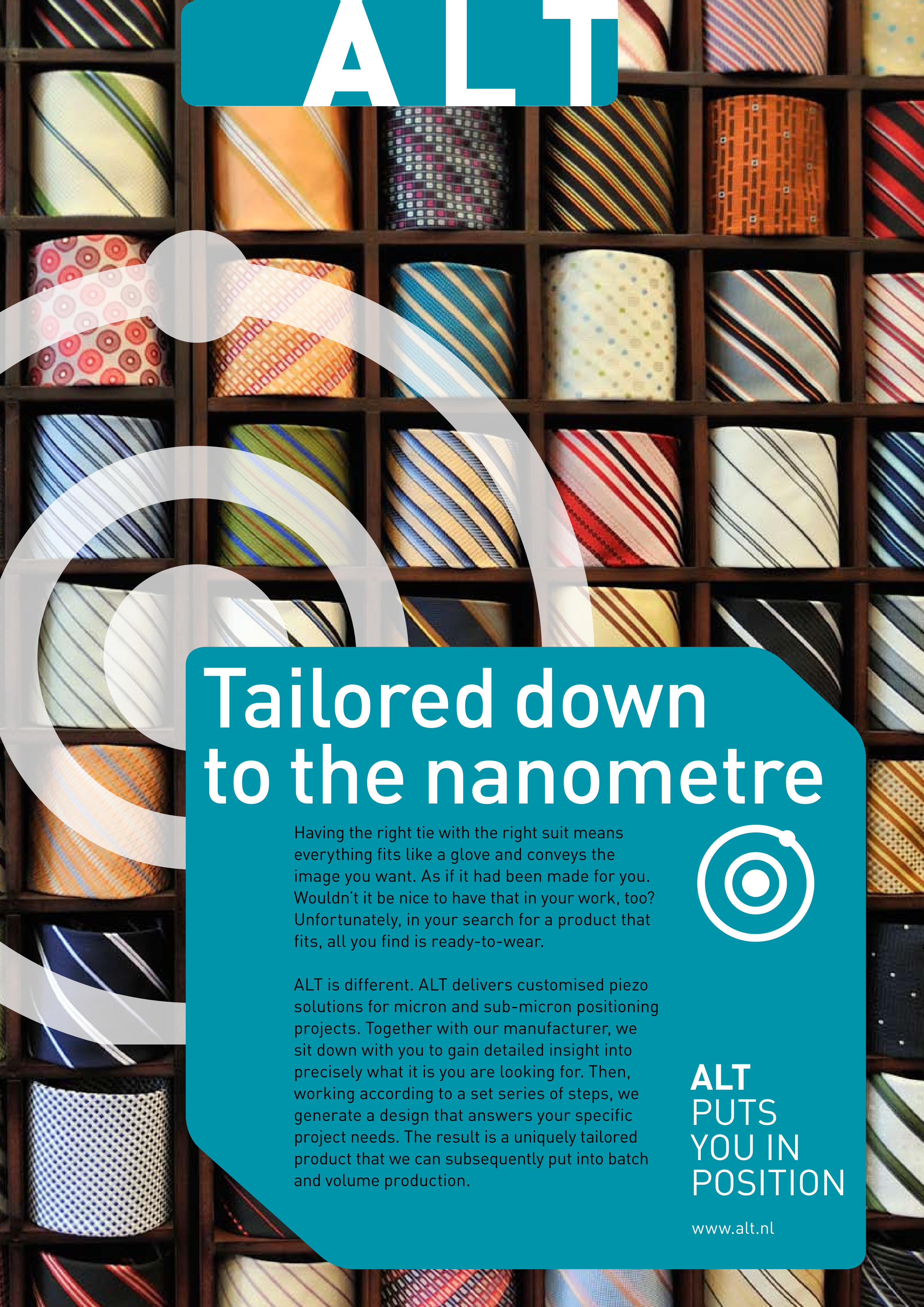
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Mikroniek - 2012

In this issue

Publication information

Objective
Professional journal on precision engineering and the official organ of DSPE, the Dutch Society for Precision Engineering. Mikroniek provides current information about scientific, technical and business developments in the fields of precision engineering, mechatronics and optics.
The journal is read by researchers and professionals in charge of the development and realisation of advanced precision machinery.

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DSPE
PO Box 359, 5600 AJ Eindhoven (NL)
+31 (0)40 – 296 99 15 / 26 (tel/fax)
info@dspe.nl, www.dspe.nl

Editor
Hans van Eerden, hans.vaneerden@dspe.nl

Advertising canvasser
Sales & Services
PO Box 2317, 1620 EH Hoorn (NL)
+31 (0)229 – 211 211, gerrit@salesandservices.nl

Design and realisation
Twin Media bv
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+31 (0)345 – 470 500, info@twinmediabv.nl

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The cover photo (TROPOMI telescope breadboard) is courtesy of TNO/Fred Kamphues.

editorial

Share to multiply

The technical performance of many of today's mechatronic and precision engineering systems is close to pure magic. We can position a 25 kg body to nm accuracy within milliseconds, pile up a wall of minute 01005 form factor devices with a robot, find and fix a 10 nm flaw on a 300 mm wafer, print with picoliter dose, create parts by additive manufacturing in titanium, etc. So the question is: what's the secret? How does the magic happen? And more so, how do we perpetuate it prosperously?
Attempts to analyse and fully explain the industrial success of Dutch High Tech – many have been made – are in principle impossible to validate, and I don't believe any one person has the sure-fire recipe. But the main ingredients can be pinpointed. Here's my list:

Magic = Rhineland model + craftsmanship & skills + creativity + passion + guts + vision + sharing

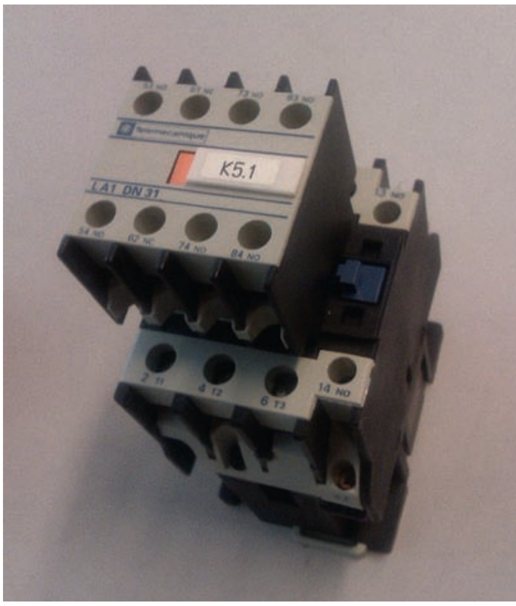
Although they are all equally important, there are two that I choose to dwell on shortly here, starting with the Rhineland model of capitalism. In the Eindhoven area Philips's DNA stemming from its history as a Rhineland business, is surely the one largest ingredient for the technological achievements and economic success of the Brainport area. It's Philips's policy to actively encourage learning and to invest in training people and skills. These are true long-term investments and the culture is such that educating people is considered a value. In effect this has resulted in a population of highly-skilled and motivated technical professionals, a true asset to the region.
And of course sharing: teaching and training, as mentioned above is a form of sharing, but there's more. A true 'sharing paradigm' is emerging nowadays in the form of shared innovation as exercised in the Holst Center or the Open Source initiatives found in software (the best Backgammon PC games I know are from GNU)

In Dutch the verb for sharing, 'delen', is synonymous with dividing, which is not so strange since sharing usually implies dividing what you have and giving parts away, hopefully to receive something of greater value in return, now or in the future. So in order to increase value, to multiply, you need to share. It's a concept that has led me to pursue my role in the mechatronics contact group MSKE, where professionals across businesses share their technical insights, and it fuels my belief in the innovation of our labour market. So share to excel in your craft/art, be it software, structural mechanics, power electronics, signal processing or feedback control, and benefit from the upcoming DSPE conference on precision mechatronics to share, because if we want to continue to make the technological magic happen, we need to share in order to multiply.

Frank Sperling, Director Nobleo Technology

Extending PI, SI and EMC requirements

The amount of electronics involved in mechatronic systems is constantly increasing. The required precision, speed and stability of such systems are co-determined by the reliability of all kinds of sensors with electronics, embedded controllers and pulse-width-modulated (PWM) motion drives with increasing performance and bandwidth. To ensure a correct and safe operation of the electronics involved, parameters like power integrity (PI), signal integrity (SI) and electromagnetic compatibility (EMC) need to be addressed. When building modular mechatronic designs, 'inter-system' EMC is usually specified but PI and SI are commonly ignored, as explicit requirements fail. However, when building modular mechatronic sub-systems, intra-system PI, SI and EMC requirements have to be met to ensure reliable operation at the required performance level.



• ***Mart Coenen*** •

When mechatronic systems are built in such a way that their AC or DC supplies are situated far away from their loads, PI and SI will be affected quite easily. An example is the on-switching of 'green' (energy-efficient) electronically driven power relays (see Figure 1), which draws an instant current of tens of Ampères over tens of microseconds (see Figure 2). Though the charge required ($Q = \int I_{(t)}\, dt$) is limited, the local supply will collapse shortly due to a voltage drop over the wire inductance: $L \cdot dI/dt$.

Author's note

Mart Coenen (B.Sc., 1979) has over 33 years of experience in EMC in various fields. He has published books and many (inter)national papers and is actively involved in international EMC standardisation since 1988. He is co-founder of the Dutch EMC/ESD Society and part-time lecturer in post-academic EMC courses. Since 1994 he owns the private consulting company EMCMCC, focusing on PI, SI, EMC and system integration issues in e-hardware. EMCMCC is based in Eindhoven, the Netherlands.
Mart Coenen had contributed a poster presentation to the DSPE Conference (see page 45 ff.).

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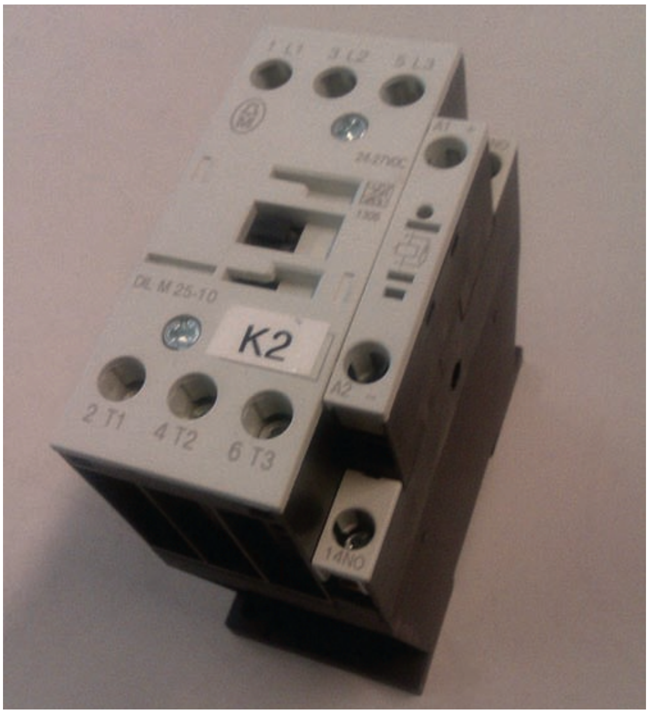

Figure 1. Example of an electronically driven power relay.

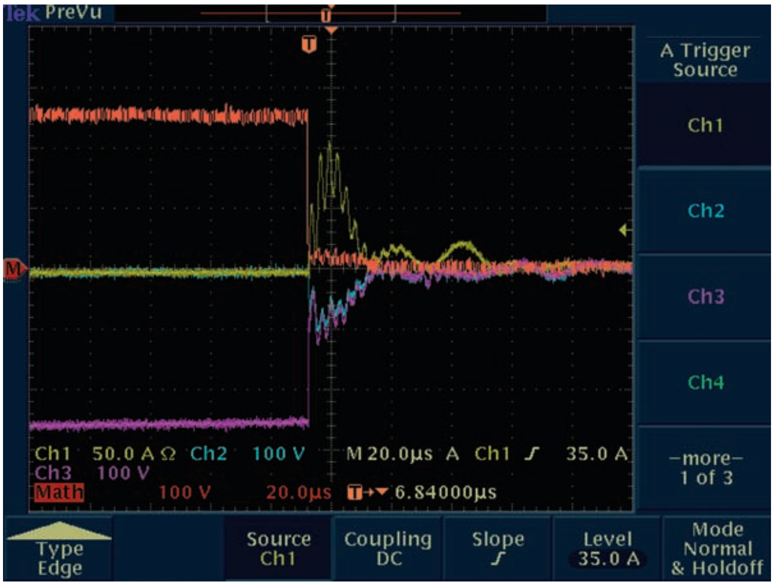

Figure 2. Peak start-up current of an electronically driven power relay (yellow curve).

To sustain the relay in its closed position, a hold current of just a few tens to a hundred mA is drawn and less energy is consumed. In operation, the relay contacts are switched much faster (thus resulting in less arcing on the contacts) but leading to much higher voltage and current transients (d*V*/d*t*, d*I*/d*t*), at the load side [1, 2]. With conventional electro-mechanical relays, the current through the relay coil inductance builds up smoothly when it is connected to its supply. A freewheel diode, transient voltage suppressor (TVS) or snubber (RC-network) is used to clamp the coil's

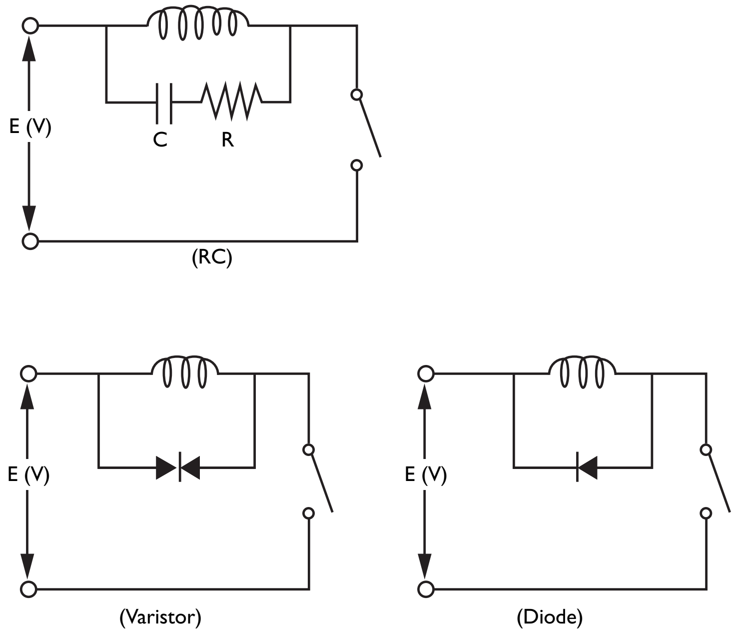

Figure 3. Different voltage clamping techniques.

reverse voltage when switched off (see Figure 3). Similar measures are also applied inside the electronically driven power relays. Mechatronic relays are preferred over solid-state relays as they can handle higher currents and they suit electrical safety with respect to the required insulation over open contacts.

Transients

Instant transients occurring on an AC distribution system couple onto the DC distribution network that supplies active sensors, embedded controllers and motion drives. Depending on the AC/DC converter(s) used for supplying these active sensors, the noise suppression, i.e. attenuation from AC-input to DC-output, is unspecified by the AC/DC converter supplier (as there is no international standard describing the required test methods and their requirements yet). With most electrical safety Class II (= double or reinforced insulated *without* PE, protective earth, connection) AC/DC converters or poorly grounded Class I converters (= basic insulation *with* PE connection), these transients are nearly 1:1 coupled from the AC input onto the DC output, due to the internal filtering components used (necessary to satisfy inter-system compliance of the converter itself). From well-designed AC/DC converters, either Class I or II, an RF attenuation of 60 dB (a factor of 1,000) or more between input and output can be expected. But even in these design cases, transients of 1,000 Volt on the AC mains are still passed onto the DC output at a level of 1 Volt. In accordance with the specification of an AC/DC converter manufacturer only an AC ripple in the order of 10-200 mV is specified [7], when measured in a 20 MHz bandwidth. Voltage and current measurements with less bandwidth will not show these transients at all.

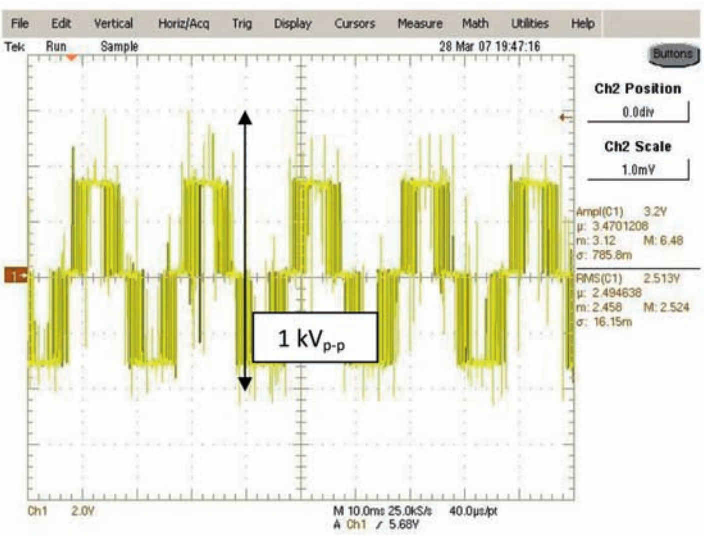

Figure 4. Example of voltages occurring on a PWM driven motor, measured against PE using an external 1:100 differential probe [9].

Figure 5. Example of bearing corrosion as a result of transient arcing.

When a sensor system receives these 1 Volt transients on its supply, differentially or in common-mode, its reaction will be determined by the power supply rejection ratio (PSRR) and the inner front-end design of the sensor (where often µVolts or less are obtained from a physical transducer, which requires 10^6-10^9 (120-180 dB) or more attenuation from signals occurring elsewhere in the system). If it is a single switching event, filtering by hardware and/or software can help to suppress the false data that is coming out of the sensor system. When using PWM driven applications, either at low-voltage DC or driven from the AC mains level, the resulting noise induced on the low-voltage DC supply distribution network will be repetitive (see Figure 4). When non-shielded or falsely applied shielded cables are partly routed in the same cable trays, the induced voltages will be higher. At the motor, i.e. load, side, often non-filtered PWM switching voltages and currents occur. With a single-phase AC-supplied PWM drive system, the internal DC bus voltage becomes 360 Volt and the peak-peak voltage at the load may exceed 1,000 Volt by cable reflections that occur (see Figure 4). These repetitive PWM signals also couple onto the rotor shaft, rotating in its grease-insulated bearings, which then couple into an encoder. One of the mechanical aspects of these high-voltage transients is bearing corrosion due to arcing through the grease film in the bearings (see Figure 5).

The impact of transients on sensor systems may be twofold:

- Communication gets corrupted; unintended index pulses on I/Q-sensor signalling occur (by which the system loses its reference position).
- The sensitivity of the sensor (in particular with high-input-impedance front-ends) goes down by some orders of magnitude, such that e.g. distance measurement resolution derates from sub-nanometer to micrometers or even millimeters.

Cables

The coupling from cables onto other cables is determined by the electrical and magnetic fields stemming from these cables. Solutions to reduce coupling can serve both ways, as cables are passive networks and as such reciprocal. When the sum of all signal currents is confined to the inner wires of a shielded cable, the resulting external magnetic fields will be low. Fulfilment of this condition can be easily measured, as the common-mode current on the inner wires of such cables as a whole will be 'zero'. Electrical fields can easily be minimised by connecting the cable shield to the reference terminal belonging to the circuit, which often is not the ground or protective earth (PE) terminal of the (sub-)system's enclosure.

Outer cable screens should be electrically connected through their connector shells to the enclosure. This electrical connectivity is determined by the various surface treatments of the metals used. Powder coatings, anodised aluminum, commonly used from a mechanical and/or an aesthetic point of view, are providing one of the best electrical insulators. Using stainless steel thread inserts, which are glued into an aluminum frame, extends this non-conductivity.

Disturbance levels

The industrial mains disturbance levels given in Figure 6 reveal that power line communication (PLC) [1] needs to use higher signal levels (to enable communication) than those resulting from industrial systems [3] (solid green line). The active infeed converters (AIC), used with

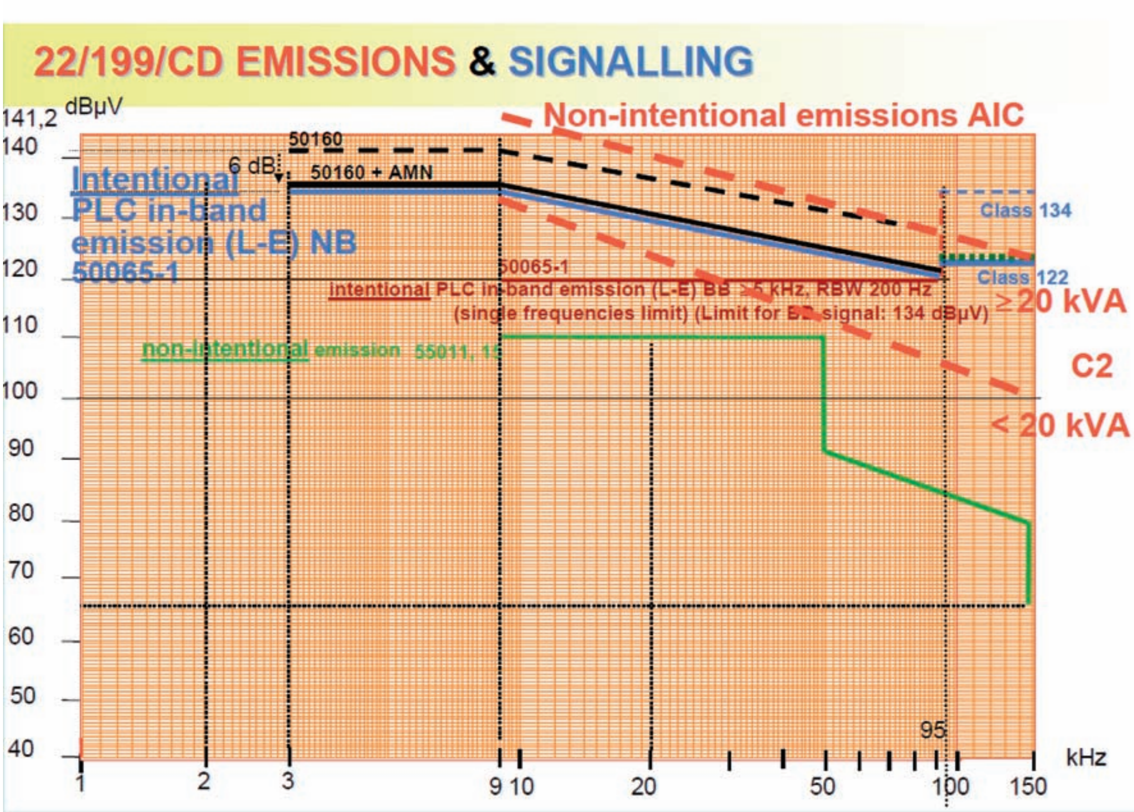

Figure 6. Summary of observed LF differential voltages on mains wires in industrial installations (excerpt from a working group document IEC 22/199/cd).

windmills and photovoltaic systems to convert the harvested energy onto the mains distribution system, exceed these disturbance levels even further [11-16].

Unintended interaction

Most, if not all, AC/DC, DC/AC and AC/AC converters, and PWM motion drive systems are switching in the frequency range of 2-150 kHz as being a free zone for RF emission in EMC legislation. Most active inductive or capacitive sensors operate in the same frequency domain, also to avoid any formal legislative EMC immunity requirements. Even temperature and strain gauge sensors have a front-end sensor bandwidth over 20 kHz and often suffer intra-system immunity issues, though being inter-system EMC compliant. The likelihood of having unintended interaction in a modular mechatronic system design is increasing progressively. Unintended coupling may occur through air (E/H-fields), via mechanical frames (common-impedances) or result from cables running in parallel (crosstalk), which can not be resolved by simply adding an opto-coupler somewhere along the signal path. It is unpleasant when your car’s motor management system does not recognise the contactless key anymore when the roof of your convertible is closing while driving.

Closing the gap

All this requires an extended conceptual approach, with additional specifications, to anticipate such interaction by ‘selection’ and/or ‘design’. A CE-mark on a sensor system or PWM drive product does not add anything to the avoidance of intra-system issues. These considerations should be extended beyond the boundaries of the sub-system, in particular when the sub-system is part of an even larger system which adds additional constraints, and should be made clear to all parties/suppliers involved.

International standardisation work is progressing to close the non-regulated gap between 2 and 150 kHz. The mains harmonic disturbances up to 2 kHz are legally covered [5] (up to 16 A/phase), [6] (up to 75 A/phase). Recently, an inventory document was written with respect to the many signals that appear most severely in this frequency band, see Figure 6 [4]. In parallel, work is already progressing in CENELEC’s sub-committee 205 and IEC TC77A on new proposals regarding how to perform and apply immunity tests uniformly, see Figure 7 [8, 9, 10]. The levels are taken again with some margin over those given in Figure 6. Care should however be taken with these documents as again only inter-system issues are being addressed while intra-system effects are being ignored and left over to the modular mechatronic system designers. To enable modular

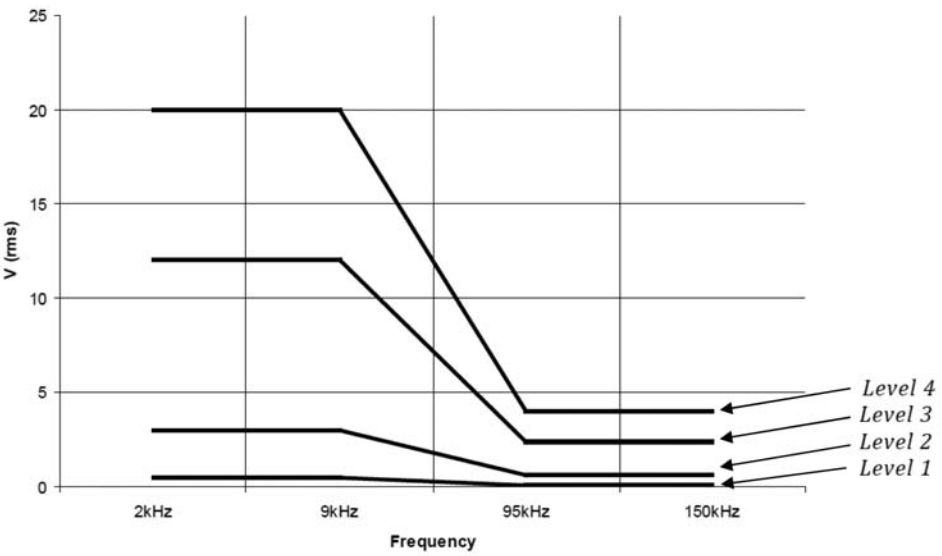

Figure 7. Proposed LF immunity requirements on conducted, differential mode disturbances in the frequency range of 2-150 kHz to be superimposed on the mains voltage at AC mains ports [7].

mechatronic system design, unified intra-system PI, SI and EMC requirements should be defined to reduce time-to-market at limited costs.

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Organic and optical, devices and metrology

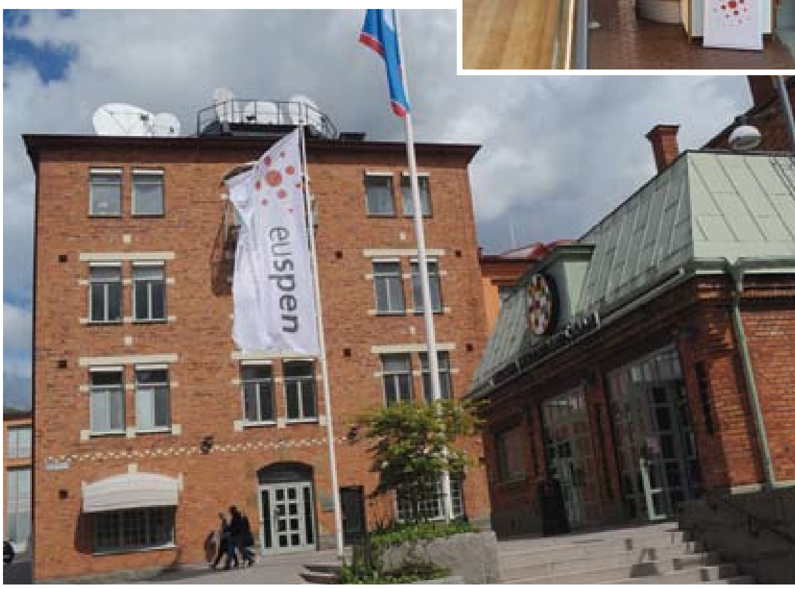
From 4 to 8 June 2012, the 12th International Conference of the European Society for Precision Engineering & Nanotechnology (euspen) was held in Nacka Strand near Stockholm, Sweden. The three conference keynotes focused on optical and organic devices and optical metrology. Besides the usual precision- and mechatronics-oriented topics, special sessions were devoted to Precision Engineering of Plastics Based Electronics and Optronics, and to Nordic Countries Precision Engineering and Nanotechnology.

• *Raymond Knaapen* •

Now in its 12th year, the euspen International Conference attracted over 400 attendees and 30 exhibitors, representing some 26 countries worldwide. The conference was held in the Nacka Strandsmässan conference centre near Stockholm. It comprised a mix of presentations, poster sessions, technical workshops and an exhibition where companies could present themselves and their products and services.

Author's note

Raymond Knaapen works as a systems architect at TNO in Eindhoven, the Netherlands.



The euspen 2012 Conference was held in the Nacka Strandsmässan conference centre near Stockholm. (Photo on the left courtesy of euspen)

This year's conference topics included:

- Precision Engineering of Plastics Based Electronics and Optronics
- Nordic Countries Precision Engineering and Nanotechnology
- Nano & Micro Metrology
- Ultra Precision Machines & Control
- High Precision Mechatronics
- Ultra Precision Manufacturing & Assembly Processes
- Important/Novel Advances in Precision Engineering & Nano Technologies

The mix of research and industry is one of euspen's strengths, as reflected by the wide range of participants.

Euspen

Founded in 1999 with funding from the European Community, euspen is a leading professional body in the field of ultra-precision/nano-manufacturing technologies. Linking leading industrialists and researchers worldwide, it has representatives in more than thirty countries. Euspen strives to enable companies, research institutes and universities to more effectively develop and exploit leading-edge precision, micro and nano technologies, to promote their products and services, and to keep up to date with important developments.

Today, euspen is a self-sustaining non-profit organisation whose members include individual as well as corporate members from industry and academia, and it collaborates with the American (ASPE) and Japanese (JSPE) societies for precision engineering. Euspen, ASPE and JSPE jointly publish the Precision Engineering journal. Euspen has its headquarters at Cranfield University in the UK. The largest annual euspen event is the International euspen Conference. The past conferences were in Bremen (1999), Copenhagen (2000), Eindhoven (2002), Glasgow (2004), Montpellier (2005), Baden (2006), Bremen (2007), Zürich (2008), San Sebastian (2009), Delft (2010), Lake Como (2011) and Stockholm (2012). The thirteenth conference will be held in Berlin from 27 to 30 May 2013.

www.stockholm2012.euspen.eu
www.euspen.eu

Tutorials

On 4 June, there was a programme of tutorials in the morning and workshops in the afternoon. The tutorial topics were "Metrology of Precision-engineered Surfaces using Interferometry: Principles & Applications" by Prof. Chris Evans (UNC Charlotte, USA) and Dr Peter de Groot (Zygo Corporation, USA), and "Geometric Testing of 5-axis Machine Tools" by Dr Wolfgang Knapp (IWF/ETH Zürich, Switzerland). Whereas the tutorials covered conceptual theories through best-practice applications, the workshops were more focused on reviewing technologies currently available on the market. The workshop topics were "Precision Bearing Advancements" by Drew Devitt (New Way Air Bearings, USA), Mike Wellstead (Westwind, UK) and Askar Gubaidullin (S2M-SKF Group, France), and "Cutting Tool Advancements" by Andrew Cox (Contour Fine Tooling, UK), Sean Kitson (Element Six, UK) and Gustav Grenmyr (Sandvik, Sweden).

In the evening, a reception was held at the Restaurang Stortorgskällaren in Stockholm's historic city centre. On the second day of the conference, there was a networking dinner in the evening at the banqueting hall of the Vasa Museum. This gave the participants a spectacular view of the Vasa, the world's only well-preserved seventeenth-century ship.

Optical devices

On 5 June, the conference was opened by euspen President Prof. Paul Shore of Cranfield University in the UK. The first conference keynote, "Production Incubator for Optical Devices: Technology and Industrialization", was held by Dr Hans Hentzell, Managing Director of Swedish ICT Research. This institute and its daughter institute Acreo evaluate innovative research worldwide and deliver the results to their Swedish and international clients. Two of the key technology areas are fibre optics and imaging sensors and systems for wavelengths that are not visible to the human eye.

Fibre optic technology development is organised around the Acreo Fiber Optic Center (AFOC), which develops optical fibre technology for medical, energy, laser and sensor markets. One example are processes for producing optical fibres for use in harsh environments, such as those developed by the recently launched company Fibertronix.

The development of imaging systems for non-visible wavelengths has been taken on by IMAGIC. Research is based on the institute's traditional background in thermal infrared imaging, but newer fields such as UV imaging are explored as well. All innovations are realised in partnership with industry and academia.

Organic devices

The second conference keynote, "Roll-to-Roll Fabricated Organic Devices", was delivered by Prof. Paul Blom, Scientific Director of the Holst Centre in the Netherlands. Roll-to-roll production processes, comparable to what is now being used in the graphics printing industry, will enable large-scale and low-cost production of numerous types of plastic electronic devices, such as ultra-light, ultra-thin, flexible, wearable electronics products, lighting and signage devices, reusable and disposable sensor devices and foldable solar panels and displays.

Examples include an organic light emitting diode (OLED) for lighting and signage applications or an organic solar cell. On top of a flexible substrate a transparent barrier is deposited, followed by an anode including a metallic grid for current distribution. Then an active layer is printed, followed by thermal evaporation of the cathode. The device is finished with the deposition of an encapsulation layer to protect the device from oxygen and water.

There are many challenges in manufacturing large-area devices on such thin plastic foils, such as lack of dimensional stability of polymer substrates, protection of the OLED cathode against moisture and oxygen, and electrode transparency versus electrical conductivity. In terms of dimensional stability, polycrystalline polymers are generally considered suitable for use as a flexible substrate. Polyethylene Naphtalate (PEN) is one of the most stable polymer films and it can be thermally stabilised. Because of the sensitivity of the OLED cathode to moisture and oxygen, the quality of the encapsulation layer is one of the determining factors in the OLED lifecycle. Every pinhole in the layer is a possible point of entry for water to reach the cathode, which results in black spots. An encapsulation stack has been developed consisting of SiN – OCP – SiN (in which OCP stands for Organic Coating for Planarisation). This stack is able to achieve water vapour transmission rates (WVTR) below 10^{-6} g/m^2/day, which is needed to achieve the required OLED lifetime.

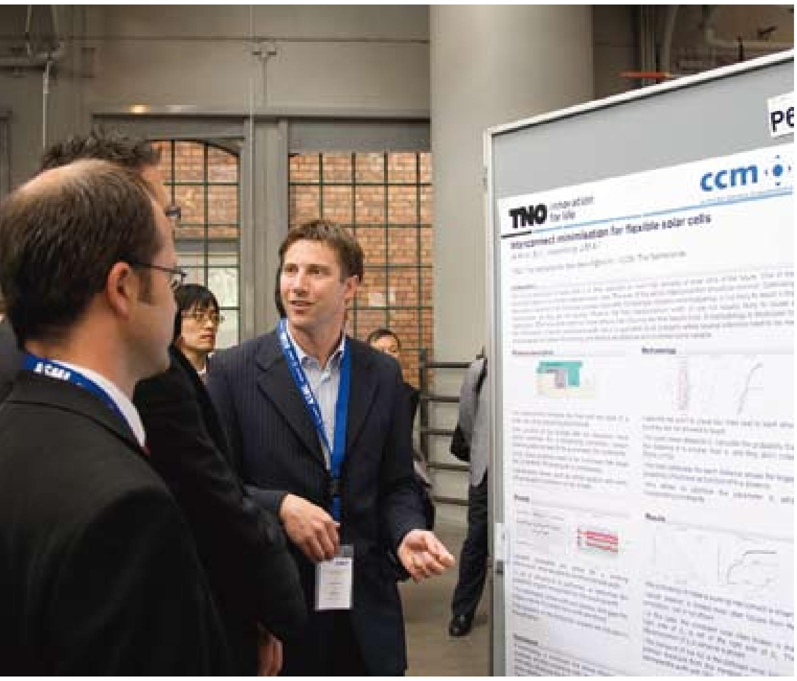
Impression of a plenary session. (Photo courtesy of euspen)

In OLEDs at least one of the electrodes must be both transparent and electrically conductive. The most common choice for this electrode is indium-tin-oxide (ITO). ITO, however, has relatively limited conductivity, which is a problem for lighting applications because of the large surface area. At the Holst Centre, ITO-free anodes have been developed, based on metallic shunt lines combined with a low-cost layer of poly(3,4-ethylenedioxythiophene): poly(styrenesulphonic acid) (PEDOT:PSS), which acts as both the anode and hole injector layer.

Optical metrology

On 6 June, Dr Peter de Groot, Director of R&D at Zygo Corporation (USA), delivered the third conference keynote: "The Expanding Role of Optical Metrology in Precision Engineering". He gave an overview of the history of the application of optical metrology. Many early examples of interferometric optical metrology relate to length standards, which fall in the category of calibration and validation. As a validating technology for process development and yield enhancement, optical methods play a complementary role to mechanical and electrical metrology. "Optics measures optical parts, and machines measure machined parts."

There have been breakthroughs in optical metrology in the fields of lasers, machine tool calibration, stage metrology using lasers, coordinate measuring machines (CMM) using lasers, and the transition from 'interferogram by hand' to analysis by computers. A major breakthrough in interferometric micrometrology is white-light interferometry, which is capable of analysing the surface shape, texture and dimensions of highly varied and complex shapes.
The extension of optical metrology into areas traditionally considered the domain of stylus gauging has highlighted the need to bridge the gap between these techniques.



Impression of a poster session.

Plastics Based Electronics & Optronics

The topic of plastic electronics from the second keynote was continued in the first oral session. The author (Raymond Knaapen, TNO, the Netherlands) gave a presentation on equipment to perform spatial atomic layer deposition (ALD) in a continuous roll-to-roll process. This can be used, for example, to apply barrier layers for OLEDs. In spatial atomic layer deposition, the reactive gases for deposition that are conventionally applied separated in time, are now supplied continuously but separated spatially by using gas bearings with an inert gas. The use of spatial ALD in a rapidly rotating drum with a flexible substrate slowly moving over the drum, without making contact, using gas bearings, enables high-throughput, low-cost layer deposition with high ALD quality.

The next presentation, by Uwe Hübner (Institute of Photonic Technology, Germany), highlighted a method to make low-cost SERS (Surface Enhanced Raman Spectroscopy) substrates, using PMMA (polymethyl-methacrylate) resist on a fused silica substrate. The final presentation by Torbjörn Eriksson (Obducat Technologies, Sweden) discussed the application of nano-imprint lithography for high-volume manufacturing.

Nordic Region

In the second oral session, a number of developments in precision engineering in the Nordic region were presented. Jacek Kaminksi (SKF, Sweden) talked about the manufacturing of dimpled surfaces using hard turning with an oscillating tool and a subsequent honing operation. Julius Denafas (Technical University of Denmark) presented an evaluation of machined surfaces on sintered porous stainless steel samples. The goal was to find out how much the surface open-pore fraction is reduced by different machining techniques. Peter Ekberg (Micronic Mydata and KTH Royal Institute of Technology, Sweden) discussed the development of a state-of-the-art nm-measurement system for square-meter-sized lithography masks. Measurement repeatability of 10 nm (3σ) and an absolute accuracy of better than 100 nm (3σ) on a scale of over 1.5 m^2 are required.

Ultra Precision Machines and Control

The session on Ultra Precision Machines and Control featured a wide range of topics:

- An integrated control approach for machine control of fast-tool assisted ultra-precision machining.
- The design of a precision measurement system using moving linear scales, in order to comply with Abbe's principle and to avoid the use of laser interferometers.
- Ultra-precision positioning with sub-nanometer resolution using a ball screw and aerostatic guideway.
- Nanometer performance of a 6-DoF Maglev system based on Heidenhain 1Dplus encoders.
- Aspects of thermal design and dimensional drift.

High Precision Mechatronics

The session on High Precision Mechatronics, another highly interesting topic, was opened by Herman Soemers of Philips Innovation Services and the University of Twente in the Netherlands. He presented two design cases of high-accuracy rotor bearings: one is the Philips Brilliance iCT (intelligent Computer Tomography) diagnostic imaging system, the other is an E-beam wafer lithography system, which is being researched by KLA-Tencor. Takeshi Morishima (Delft University of Technology) talked about the use of thermal modal analysis for the reduction of transient thermal deformation in a thin plate under a moving heat load. Eugenio Brusa (Politecnico di Torino, Italy) presented cantilevered piezoelectric harvesters for converting kinematic energy into electrical storage to supply wireless vibration sensors. Gorka Aguirre (IK4-Ideko, Spain) discussed the use of Dynamic Error Budgeting for performance analysis and optimisation of active aerostatic bearings. W.J. Chen (Singapore Institute of Manufacturing Technology) demonstrated a two-scale force sensor for a power device wire-pull test.

The exhibition had over 30 participating companies and knowledge institutes. (Photo courtesy of euspen)

In conclusion

During the first conference day, Prof. Jan van Eijk received the euspen Lifetime Achievement Award 2012 for his exceptional contribution to the field of precision mechatronics (see page 22 ff.). The conference was closed by euspen Vice President Dr Wolfgang Knapp. The next day a tour was organised to Micronic Mydata in Täby near Stockholm. This Swedish high-tech company develops, manufactures and markets production equipment for the electronics industry. The next euspen International Conference will be held in Berlin at the end of May 2013.

Dance of the

Conventional wisdom states that a gap width of 0.2 millimeters is the upper limit for remote laser welding. However, Volkswagen has now developed a solution that makes this rule of thumb a thing of the past. Remote welding works by using two mirrors inside the scan head to rapidly focus the laser beam on the workpiece with a high degree of precision. The automaker has taken this method one step further by making the laser beam oscillate, or 'dance', along the gap, thanks to Trumpf's next generation of scanner optics that can release the focus spot from the working plane. This new technique is called laser stir welding, and Volkswagen has already integrated the process into its production lines.

Thorge Hammer, who is responsible for technology planning and development, body shop planning, and tool and die operations at Volkswagen, explains that the mirrors in the process manipulate the beam in a circular motion as they guide it along the gap: "We call this the 'wobble effect', and it causes the laser to stir the melt pool, which increases the volume of molten material. As a result, we can now bridge larger gaps than we could before." It also means that the laser is even capable of processing components designed for MIG and MAG welding, without need for modifications. "We weld mounting blocks with gaps of up to 0.5 millimeters", says Hammer.

There is no doubt that scanner welding using robot-guided optics has become firmly established in car body manufacturing and is increasingly pushing production engineers towards ever more exciting innovations, but there has always been one major limitation – the Z axis.

3D scanner optics

The scanner mirrors could make the focus spot dance and jump across the workpiece along the X and Y axes. To bring the Z axis into the equation, the only option was to move either the entire scan head or the lens inside the scanner optics. Now, however, new 3D scanner optics have given the focus spot a whole new freedom of movement (see Figure 1). Equipped with a highly dynamic drive unit, the movable lens quickly positions the spot in a precise location on the Z axis without moving the optics. To find out where the focus lies, the laser beam is calibrated with a sensor (see Figure 2). The control unit can then calculate the spatial coordinates of the beam focus at any given time (see Figure 3). This procedure allows the laser to move around in a third dimension, eliminating the problem of working in different planes and enabling the beam to quickly reach small weld spots in previously inaccessible locations.

Editor's note

This article is based on a previous publication in Laser Community, 02:2011, the laser magazine from Trumpf. Trumpf is a high-tech company, with its headquarters in Ditzingen (Germany), that focuses on manufacturing technology, laser technology and medical technology.

www.trumpf.com

photons

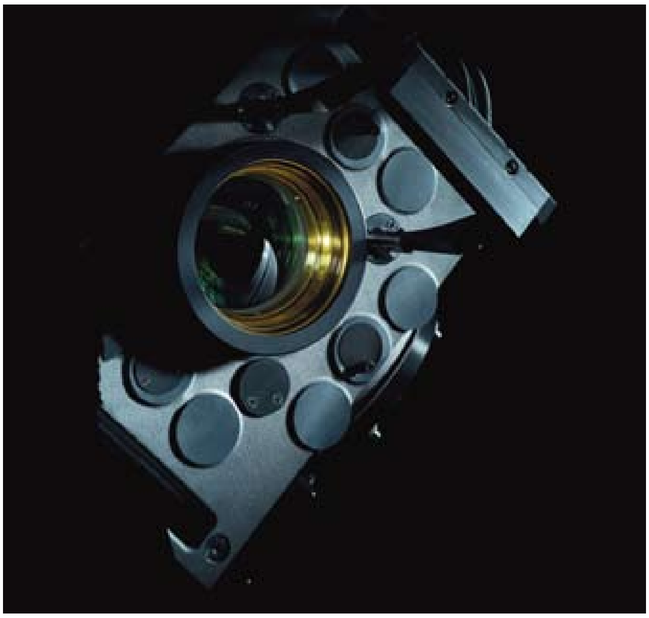
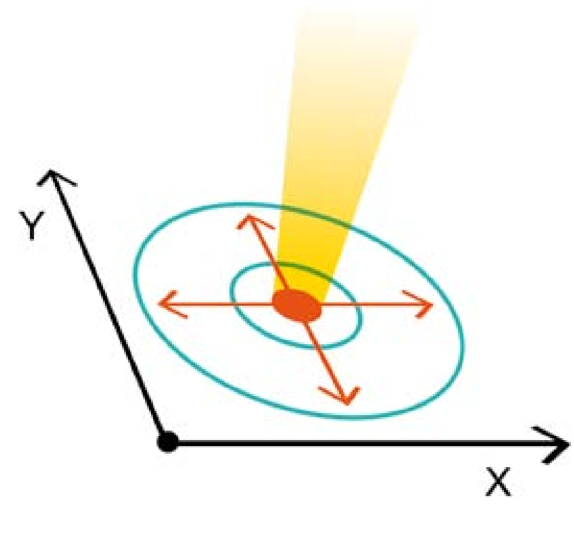
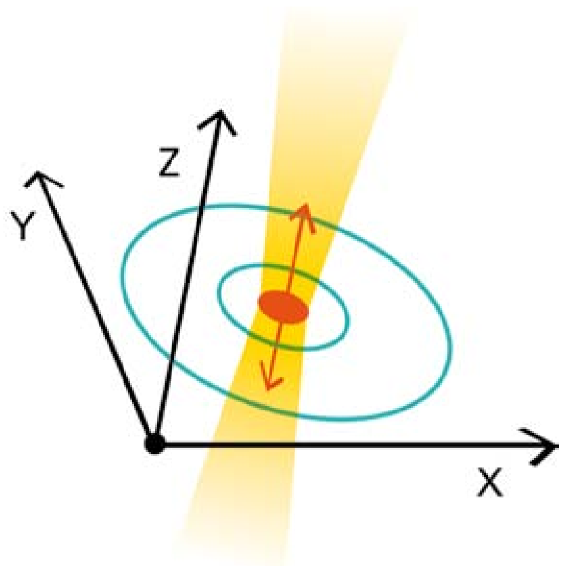


Figure 1. 3D scanner optics add the Z motion of a focusing lens to the X-Y motion of the mirror. This allows the focus spot to move freely and smoothly over the part.

Figure 2. The focus sensor.



X-Y Axis: The PFO unit scans the area around the tiny central hole in the sensor. The photodiode detects the maximum power level when the light is beamed precisely into the hole.



Z Axis: The PFO 3D focuses on the hole and displaces the focus spot along the Z axis. The Z coordinate is determined by measuring the change in laser power.

Figure 3. Determining the beam focus.

Volkswagen

Returning to the example at Volkswagen, the company has incorporated this technology in the laser stir welding process it uses to join sub-assemblies for the Golf VII, which are subsequently integrated in a platform. The front seats are held in place on the four seat supports, while the two mounting blocks referred to by Hammer are used to secure the engine and the power train.
The seat supports are made from deep-drawn, medium-strength sheet steel, 0.7 mm thick. To fix the mounting blocks, Volkswagen welds a 3 mm flow-formed sheet into a shell 3 mm thick. "The ability to move in a third dimension allows us to laser weld components with undercuts", says Hammer.

Volkswagen uses six remote welding systems equipped with 4,000-watt disk lasers to process the Golf VII sub-assemblies, including the laser welding system for welding on the fly. This is the minimum setup to achieve the cycle time required to turn out 4,500 pieces a day. "The laser has 7.5 seconds to carry out a total of 19 weld seams per part", says Hammer. "But at a laser power of 4,000 watts, the robot should not take more then 1.2 seconds to move between two welding spots." A newly developed robot-based control system re-calculates the position of the scanner every millisecond and corrects the position as necessary to create the welding structures specified.

Faurecia

This new-found freedom of movement means the laser system can also be employed in the passenger compartment. OEM supplier Faurecia uses this process to manufacture its seating products. Remote welding already plays a key role in the company's production operations – the technique is used to weld the frames for the seat backs of the front and rear seats, the recliners and seat tracks.

The laser beam is used to process the materials in packages 0.7 to 6 mm thick and comprising multiple layers. For materials up to four millimeters thick, the laser uses remote welding technology. Each year, Faurecia uses this technique to manufacture 18 million frames for front and rear seats and 115 million seat recliners and tracks. Geert Verhaeghe, senior expert for welding at Faurecia, adds: "There is a clear trend toward lightweight construction – materials that are thin yet stable – and consequently toward high-strength steels." This material can only be welded using a laser. Faurecia now has more than 20 systems in operation worldwide, equipped with robot-guided and fixed scanner optics, and the third dimension gives them more freedom of movement.

"The PFO 3D focusing optics from Trumpf enlarges the working area without requiring us to move the optics over the workpiece", says Uwe Viehmann, joining technology manager at Faurecia. "The seat backs come in different heights. The PFO 3D programmable focusing optics do a better job with them because we can now position the laser beam in the Z axis using the same dynamic system we use for the X and Y directions."

Verhaeghe already has one eye on the next technological innovation – he wants to use the PFO 3D for welding on the fly. "Some of the components we process are very large, and the combination of robots and 3D optics would give us an even bigger working area", he says. By gradually making a transition from CO_2 to solid-state lasers, the company is gaining important benefits: "Disk lasers are far more efficient – which has helped us significantly reduce our costs", says Verhaeghe.
Optimising the design of the joints and connections improved the situation for the laser and led to a positive side-effect. Laser-welded joints are up to 30 times smaller and thinner than their MAG-welded counterparts. That saves resources and cuts down weight: the laser-welded spots take up just 0.6 millimeters of space compared to the 10 millimeters required in resistance spot welding.

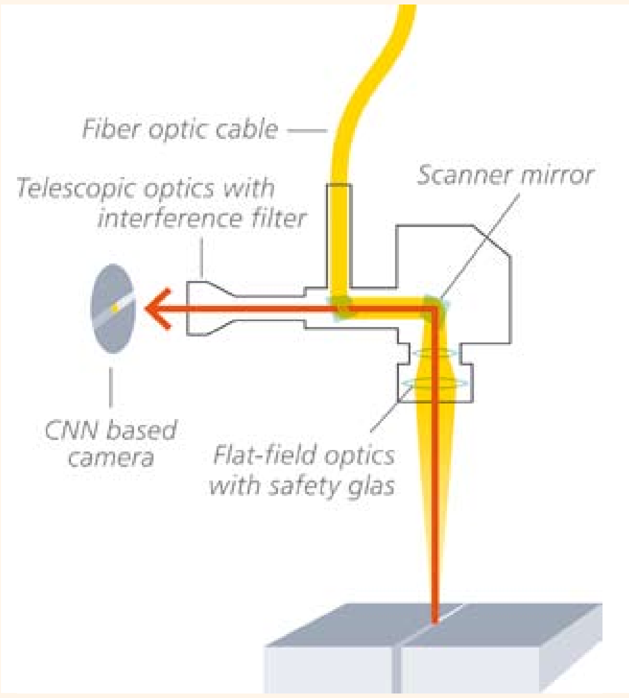
Battery housings

Lasers are making their mark deep inside the cars of today and tomorrow, with the vast flexibility of the third dimension finally making it possible to weld housings for high-voltage batteries. Each battery module consists of individual cells in rectangular aluminum enclosures. By the time it reaches the laser processing stage, the battery is already inside the housing and fully charged. That means a laser can only be used if heat input is kept to a minimum and if welding depth is precisely controlled – penetration would damage the battery, which could have fatal consequences with a battery that is already charged. Spatter is unacceptable and the seam must be fully sealed. Welding performed using TruDisk disk lasers with an output power of between one and five kilowatts, on battery housings ranging in thickness from 0.8 to 1.5 millimeters, has

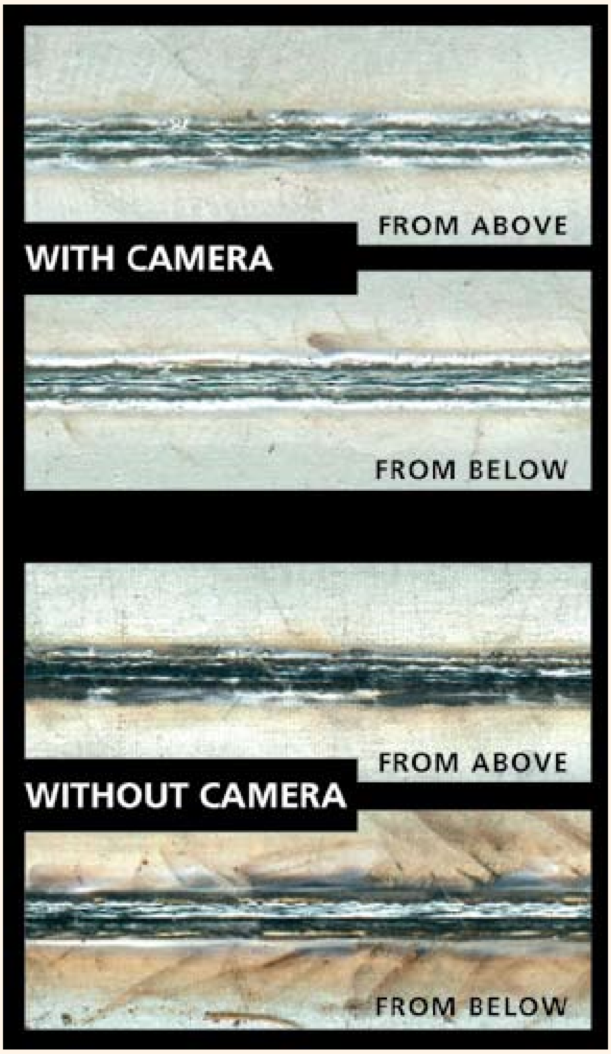
Quality assurance

A CNN-based camera (CNN = Cellular Neural Network) follows the focus spot from a distance and analyses up to 10,000 images per second. The camera, according to the single-lens reflex principle, constantly "looks through" the scanner mirrors to the exact point at which the laser is aimed (see the figure below). The system monitors the penetration hole and adjusts the laser power if the hole deviates from the specifications. The figure on the right demonstrates the benefits of using the camera-based system.

This apparently simple, yet highly sophisticated concept is currently being developed in Germany by Fraunhofer IPM (Institut für Physikalische Messtechnik) in Freiburg, the IFSW (Institut für Strahlwerkzeuge) at Stuttgart University, and the IEE (Institut für Grundlagen der Elektrotechnik und Elektronik) at TU Dresden.



The camera is constantly "looking through" the scanner mirrors to the exact point at which the laser is aimed.



Using the camera-based system improves laser welding quality.

confirmed that the laser lives up to its promises: the weld seams were fully sealed and the battery sustained no damage.

In addition to welding housings, lasers are finding other novel applications in batteries, including welding thin battery contacts and joining individual battery cells into complete modules. Since at the moment battery cells have to be changed, the current practice is to screw the modules together. But once these teething problems have been ironed out, the laser could become the preferred solution for holding the modules firmly together.

New developments

At the moment, these new applications are at an early stage, and manufacturers are only just starting to consider what form of automation would work best in each case. Nowadays, lasers supported by modern scanner optics play a crucial role in the production of car body parts and seating components. The laser is already playing a key part in the development of electro-mobility, and it will continue to help light the way toward ever more cost-effective vehicle production, driven by the developments in quality assurance (see the box).

250 Exhibitors at Precision Fair 2012

The twelfth edition of the Benelux premier trade fair on precision engineering will be held on 28 and 29 November 2012 at the NH Conference Centre Koningshof in Veldhoven, the Netherlands. Specialised companies and knowledge institutions will be exhibiting in a wide array of fields, including optics, photonics, calibration, linear technology, materials, measuring equipment, micro-assembly, micro-connection, motion control, surface treatment, packaging, piezo technology, precision tools, precision processing, sensor technology, software and vision systems.

To accommodate the growing interest, from exhibitors and visitors alike, Mikrocentrum decided – after considering alternative venues – to expand at the existing venue. This proved difficult but was successfully done thanks to the concerted efforts of Koningshof and Mikrocentrum. Koningshof is investing in modifications to the infrastructure and Mikrocentrum is investing in a new, semi-permanent hall that will provide space for approximately 40 further exhibitors. For these additional stands, priority will be given to companies that have previously shown an interest.

Impression of last year's Precision Fair. (Photo courtesy of Jan Pasman, Mikrocentrum)

Therefore, this year no less than 250 exhibitors will be present in Veldhoven. The Precision Fair also features a highly relevant lecture programme, the Technology Hotspot, with over twenty knowledge institutes from the Netherlands, Germany and Belgium, and an international Brokerage Event.

www.precisiebeurs.nl

New, green, light, smart

The 14th edition of the Plastics Fair will be held on 26 and 27 September 2012 in Veldhoven, the Netherlands. At this leading fair for the plastic industry in the Benelux specialised companies from the Netherlands, Belgium, Germany and other countries will be exhibiting, such as product developers, raw materials suppliers, injection moulding and extrusion companies, toolmakers, software and machinery companies. The theme of this year's edition is "No future without plastics – new, green, light, smart". Topics in the lecture programme – with over 40 contributions covering materials, processes and products – include smart polymers, nanotechnology, additives, bio-plastics, lightweight constructions, sustainability and membrane technology. On the first fair day, the Dutch Federation of Rubber and Plastics Industry NRK will present the "PRIMA Ondernemen Award 2013" to a company that has proven itself outstanding in the area of sustainability.

www.kunststoffenbeurs.nl

Kunststoffen 2012

Complex systems,

At the 12th International Conference of the European Society for Precision Engineering & Nanotechnology in Stockholm, Jan van Eijk was awarded the euspen Lifetime Achievement Award 2012. According to euspen, Prof. Dr. Ir. Jan van Eijk is a leading authority worldwide in the field of high-precision mechatronics. His unique skills and expertise are based on the knowledge and experience gained at Philips in Eindhoven, the Netherlands, where he became Chief Technical Officer of Mechatronics, and on his 12 years as part-time professor at the Delft University of Technology.

According to euspen, Jan van Eijk has made outstanding contributions to national and international societies for mechatronics and high-precision engineering. He served on the euspen Council and the Board of ASPE (American Society for Precision Engineering) for several years. He has made a huge contribution towards the enrichment, development and growth of euspen and its international network. The euspen Lifetime Achievement Award 2012 was presented to Jan van Eijk (right) by euspen president Paul Shore.

Jan van Eijk (born 1951) attained his Ph.D. at Delft in 1985, after which he was invited to join the Philips Centre for Manufacturing Technology (Philips CFT). The invitation came from Prof. Wim van der Hoek, who at the time was a leading specialist and had also led the way in establishing the large community of technical specialists chiefly responsible for the success of Philips's industrial activities from 1955 to 1985. Jan van Eijk found this strong technical community based on the open exchange of knowledge and continuous learning to be fertile ground for his own development.

In 2007, Van Eijk ended his work at the Philips division then called Applied Technologies, where he was Vice President and CTO of Mechatronics. Meanwhile, in 2000, he had been appointed part-time professor of Advanced Mechatronics at the Delft University of Technology. Early this year, he retired as professor, but he continues to be an advisor to the Delft department of Precision and Microsystems Engineering. Today, he provides consultancy expertise to world-renowned precision equipment manufacturers through his own company MICE, not only on technical concepts and designs for systems but also on how to develop key competences necessary for the successful growth of advanced technology organisations.

The Philips years

During his years at Philips, Jan van Eijk was driven by the need to always thoroughly understand technical issues in

simple models

every detail. He urged his staff to translate complex science into simple descriptions, so that broader groups of individuals could contribute to the development of engineering solutions. One example is the representation of Modal Decomposition that has helped many engineers improve the critical interaction of machine dynamics and control. “When I introduced this method at Philips, at first it was not accepted. People did not believe in this method, using the concept of eigenfrequencies. Now, everybody has adopted this way of thinking, and I occasionally have to talk people out of using it.”

At Philips he contributed extensively to the conceptual design of a multitude of advanced technical systems, including Compact Disc modules using actively controlled motion systems to achieve micrometer accuracy. Arguably the most important contribution made by Jan van Eijk, with the assistance of many colleagues, was the architecture of the mechatronic elements of ASML’s world-leading lithography tools. Here, achieving nanometer performance at accelerations of up to 100 m/s^2 had to be combined with an acute focus on fully integral system optimisation. A crucial module in this respect was the magnetic-levitation motor

Patents

Van Eijk is particularly proud of two patents relating to his work for ASML. The first one is a patent he holds with ASML’s first and foremost technology officer, Martin van den Brink, and which relates to the principle of dual alignment of the wafer in a stepper lithography machine: “A method and an arrangement for aligning relative to each other a mask pattern and a substrate that are both provided with two alignment marks, using two separate alignment systems…..” (van den Brink, Martinus A, van Eijk, Jan; US Philips, Oct 18, 1988: US 4778275). Van Eijk: “It is the basis for the head start that ASML achieved in its first ten years of existence, when the competition still used die-by-die alignment, which was much slower than ASML’s global (wafer-scale) alignment.” The second patent describes a mechanism for compensating the motion of a lithography machine due to the internal movements of the wafer and reticle stages. “This solution came to me when I was doing the dishes at home. When your mind is set free, you can escape from the tunnel of focused thinking you’re usually in at work and you can adopt a bird’s eye view.”

Publications

“The Design of High Performance Mechatronics – High-Tech Functionality by Multidisciplinary System Integration”, with co-authors Robert Munnig Schmidt and Georg Schitter, embodies a large part of Jan van Eijk’s legacy.

The focus on patents is typical of Jan van Eijk’s approach to publishing. He never gave priority to compiling an extensive publications list. Both at Philips and Delft University, patents came first. Scientific publications mainly came in the form of Ph.D. theses, published by Van Eijk himself as well as his Ph.D. students. The crowning glory of his publications list is the book he published last year with Robert Munnig Schmidt (Delft University of Technology) and Georg Schitter (Vienna University of Technology, Austria): “The Design of High Performance Mechatronics – High-Tech Functionality by Multidisciplinary System Integration” (Delft University Press, ISBN 978-1-60750-825-0 (print), ISBN 978-1-60750-826-7 (online)). Written especially for mechatronic designers and architects, it gives an extensive overview of all technical subjects needed for conceiving and creating a mechatronic high-precision motion system.

Learning

This comprehensive handbook exemplifies that Van Eijk’s main interest is not in publication points and citation scores, but in learning. He is also passionate about protecting and developing the existing community and network of world-renowned mechatronics and precision engineering specialists that form the basis of the highly competitive industrial activities in the Eindhoven region. Van Eijk was heavily involved in the activities of the Philips Centre for Technical Training (CTT). For example, he developed a 12-day intensive industrial mechatronics training course which has trained more than 1,000 engineers in the interactive skills needed for effective mechatronic systems development. When CTT was terminated by Philips three years ago, Van Eijk and others put a great effort into continuing the technical training programmes, resulting in the launch of The High Tech Institute.

Van Eijk has strong opinions on training and education. For example, he applauds the recent initiatives to introduce full-blown mechatronics courses at Dutch institutes of higher vocational education. But he warns that the aim of these courses should not be to develop a so-called "homo mechatronicus". "You cannot teach mechatronics by mixing equal parts of electrical engineering, mechanical engineering, software and physics. I believe in thorough disciplinary educational programmes that include learning to communicate with adjacent disciplines." To participate in a mechatronic project on a senior level, you have to have at least ten years of experience in one of the constituent disciplines, Van Eijk claims.

More than maths

The emphasis Van Eijk places on education dates back to his formative years as a student under professors De Jong (fine mechanics) and Van der Hoek (design principles). "Dedde de Jong taught me to keep a distance in order to be able to adopt a bird's eye view. Wim van der Hoek shared his obsession with understanding things." Thanks to these two professors, Jan van Eijk developed into a system architect who oversees the overall system design, including the balance and connections between submodules. "Basically, I'm an engineer, eager to create and realise new designs." Naturally, nowadays that involves a lot of mathematics, and Van Eijk has made his contributions to augmenting the mathematical toolbox for engineers, including the formalisms of Modal Decomposition and Dynamic Error Budgeting. This last method, originating from Philips CFT, was further developed at Delft University under his supervision. It involves analysing the performance of a system by using power spectrum density models of the disturbances acting on or originating from the system.

But Van Eijk will never let mathematics take over. "You always have to be able to make a simple representation, a model, of the complex system you're studying. Wim van der Hoek was very good at that. For example, when discussing a recirculating ball screw, he would say: 'Imagine you are one of the balls that are being pushed forward within the screw; what resistance would you encounter, causing you to vibrate?' You should not just do the maths, but try to gain insight. When I'm involved in a complex project, I do not always fully understand the maths, but usually I can see whether it makes sense by checking the consistency of the output with the input."

Jan van Eijk at the Award ceremony, delivering his presentation, entitled "A Lifetime?? How did I get here??"

As an example of his 'complex system, simple model' approach, Van Eijk describes the subject picked up by his Ph.D. student Ron van Ostayen: using an air flow to position a wafer with sub-nanometer precision at 30 m/s^2 accelerations. "First we did model calculations on the proverbial back of a cigar box. Now, an initial system has been realised and it performs amazingly well. It's fun to find out whether such a simple model makes sense in practice."

Challenges

One of Jan van Eijk's current interests is the integral optimisation of mechanics and control. At present, in designing complex systems this optimisation takes places in a reiterative, time-consuming manner. Using the concept of topology optimisation for the mechanical design, Van

Eijk has taken up the challenge, together with Delft professor Fred van Keulen, of simultaneously optimising topology and control. “This may seem impossible, but that will not stop us. We will just start tackling the problem by restricting ourselves to a specific class of systems.” Another current line of research at Delft involves thermal effects in precision systems. “Now that we have mastered the dynamics of complex systems, thermal effects are becoming the dominant factor in system performance. Analogously to dynamic mode shapes, thermal mode shapes can be used to study these effects. The results can be used to compensate for inhomogeneous thermal loads of systems, or alternatively to induce required distortions of an object.” Companies like ASML, Zeiss and Océ are involved in this research, focusing on applications such as optical elements used in lithography or printheads in inkjet printers.

Receiving the euspen Lifetime Achievement Award 2012 (“Now you’re officially declared old”, one of his colleagues commented) will not keep Jan van Eijk from taking up new challenges and trying to understand complex systems. It’s the story of a lifetime.

Information

www.micebv.nl
www.euspen.eu

Insights into

Interacting surface applications in the automotive, aerospace, electronic manufacturing and other industries depend upon the fit between the surfaces as well as the friction and wear characteristics of these surfaces. A new generation of measurement methods provides the ability to accurately, repeatably and reproducibly provide data for computation of three-dimensional areal surface parameters. Tribology measurement tools provide additional insights by accurately measuring the friction and wear characteristics of interacting surfaces. The result is that manufacturers can extend the service and reliability of vehicles, aircraft, electrical equipment and other engineered systems.

• *Matt Novak and Patrick Markus* •

The average automobile, for example, has over 80 dynamic seals whose failure costs tens of millions of dollars per year in warranty costs, recalls and fines. Advances in seal/shaft design and materials have provided smoother shafts and superior wear characteristics to the point that traditional measurement methods are unable to keep pace.

Limitations

With traditional, two-dimensional surface metrology, a tool such as a stylus profilometer is used to measure the height (z) of every point (x) along a straight line and two-dimensional R parameters are used to define surface roughness. The most widely used of these parameters is Ra, which is the arithmetic mean value of all the z values relative to the average z value, i.e., the average deviation, up and down, from the mean x axis line sampled by the instrument. All these R parameters are two-dimensional in nature, that is, a measure of z relative to x. However, structural, and more importantly, functional properties of machined surfaces are three-dimensional functions. The limitations of using Ra can be seen in Figure 1.

Authors' note

Matt Novak is Surfaces Market Applications Development Manager with Bruker Nano Surfaces. Patrick Markus is Bruker Nano Surfaces Sales and Applications Engineer with Bruker Netherlands. Bruker Nano Surfaces (Tucson, AZ, USA) is a leading manufacturer of analytical instrumentation for analysis at high spatial resolution.

patrick.markus@bruker-nano.com
www.bruker-nano.com

interacting surfaces

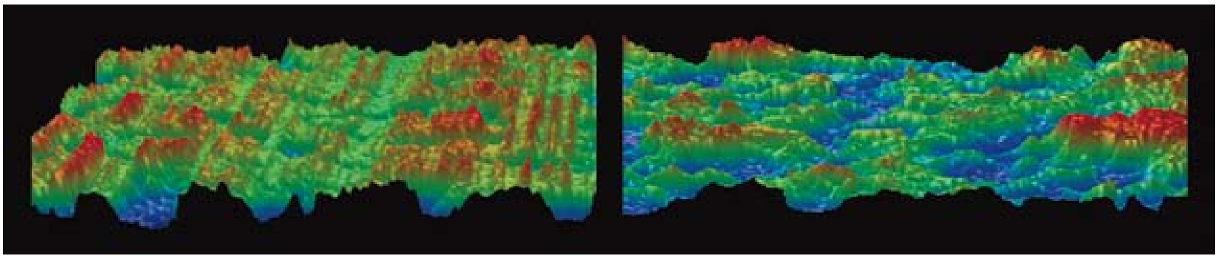


Figure 1. 3D optical microscope images of two surfaces with different qualities and functional performance but the same *Ra* measurement.

As an example of the limitations of two-dimensional measurements, shaft surface texture and machine lead are critical to maintaining minimum fluid leakage and friction for interacting surface applications. For optimal performance, elastomeric radial lip seals require a precise shaft surface texture and zero machine lead angle. When initially run, the primary lip of a new seal contacts the shaft and begins to wear. If the surface texture of the shaft is too rough the seal is quickly worn away, leading to a leak. On the other hand, if the shaft is too smooth, the seal will not bed correctly, which will also lead to leakage.

Even if the surface texture of the shaft meets specifications, the presence of a lead angle can generate leakage. The introduction of a lead angle on a shaft is inherent to all shaft manufacturing operations. Fine helical-shaped grooves are inadvertently machined into the shaft due to the feed rate of the cutting tool and the part orientation during turning or grinding. This helical pattern leads to a wicking out of lubricant or ingestion of contaminants through the shaft-seal interface. A left hand lead moves the oil in the direction of the source, causing the seal to dry out. A right hand lead pulls lubricant away from the seal, causing the seal to leak.

Furthermore, many mechanical and electromechanical systems depend on friction, wear and lubrication. It has been estimated that about 30-50% of all energy goes to overcoming friction. Friction also generates wear and a substantial portion of production goes to replacing wear surfaces and equipment because wear surfaces have failed. The challenge of saving energy, increasing product life and reducing warranty costs demands accurate measurement of friction and wear.

3D surface measurement parameters

The limitations of two-dimensional measurements can now be addressed using ISO-defined 3D parameters, which can be measured and computed using the latest metrology instruments, such as the 3D optical microscope. Specifically, ISO 25178-2 defines several amplitude-based areal parameters based on overall heights, such as *Sa*, *Sdq*, *Sku* and *Ssk*, as well as spatial parameters based on frequencies of features, such as *Std*.

Amplitude parameters (based on overall heights):
- *Sa* – The mean roughness of the surface
- *Sq* – The root-mean-square deviation (rms of height distribution)
- *Ssk* – Skewness, the degree of asymmetry of a surface height distribution
- *Sku* – Kurtosis, the frequency of the distribution of peak points across a surface
- *Sz* – Average of ten highest and lowest points

Spatial parameters (based on frequencies of features):
- *Sds* – Density of summits
- *Str* – Texture aspect ratio
- *Sal* – Fastest decay autocorrelation length
- *Std* – Texture direction of surface

Hybrid parameters (based on a combination of height and frequency):
- *Sdq* – Root-mean-square surface slope
- *Ssc* – Mean summit curvature
- *Sdr* – Developed surface area ratio

Figure 2. The Bruker ContourGT-X system is an example of a 3D optical microscope.

Figure 3. Measurement of shaft lead angle with a 3D optical microscope.

Functional parameters (based on applicability for particular functions):
- *Sbi* – Surface bearing index
- *Sci* – Core fluid retention index
- *Svi* – Valley fluid retention index

The 3D optical microscope (see Figure 2) captures 3D surface measurements based on a technique called white-light interferometry. Parts are analysed by placing them on the microscope stage (in lab settings) or by bringing larger parts and machined surfaces to the focal plane using off-the-shelf, applications-specific hardware. Light approaching the sample is split and directed partly at the sample and partly at a high-quality reference surface. The light reflected from these two surfaces is then recombined. Where the sample is near focus, the light interacts to form a pattern of bright and dark lines that track the surface shape.

The microscope is scanned vertically with respect to the surface so that each point of the test surface passes through focus. The location of the maximum contrast in the bright and dark lines indicates the best focus position for each pixel. This allows the microscope's computer to obtain a full 3D profile over the entire field of view of the camera as the sample is quickly and automatically stepped through focus. The entire data acquisition and analysis is completed in just a few seconds.

Lead angle calculation

The latest generation of optical profilometers goes one step further by calculating the lead angle based on the surface profile (see Figure 3). Calculation of the lead angle to an accuracy of +/-0.05º requires compensation for any off-axis variation associated with the mounting of the part. The operator loads the shaft in a chuck and specifies the locations to measure. At each location the system measures a best fit to true cylinder and lead angle with reference to a charge-coupled device (CCD) camera. This is accomplished by a best-fit nominal arc calculation to independently determine the orientation of the shaft.

New generation of tribological testers

A new generation of tribological testers (see Figure 4) is addressing the challenges of determining friction and wear characteristics of interacting surfaces. The testers perform multiple tests on nano, micro and macro scales including:
- Static and dynamic friction;
- Ultra-low-speed (0.1 micron/s) stick-slip;
- Adhesive, abrasive and scratching wear;
- Pull-off adhesion/striction;
- Scratch-adhesion and delamination;
- Indentation, hardness and elastic modulus;
- Multi-cycle, multi-axis fatigue;
- Strain, elasticity, plasticity and creep;
- Compression, tension and torsion;
- Three-point bending.

Figure 4: One of Bruker's tribological testers.

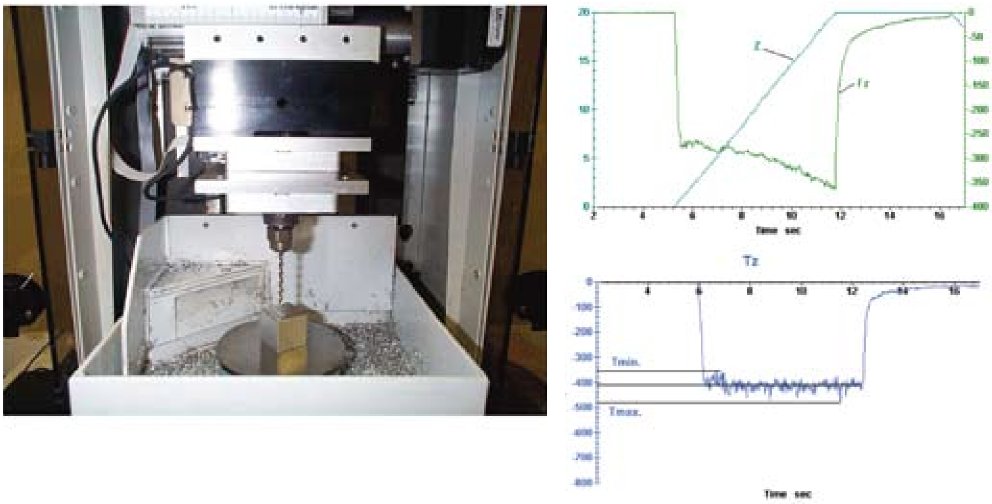


Figure 5: Drill bit mechanical test. On the right, top plot shows z force (green) and z depth (blue) for drilling into metal; bottom plot charts torque vs. z depth, showing constant torque.

The new generation of instruments can accommodate ideal friction pairs such as disc-on-disc, pin-on-disc, ball-on-disc, 4-balls, ring-on-block, etc., as well as real-world industrial assemblies such as screw-in-nut, pin-in-chain, sliding and rolling bearings. They can provide any rotational or linear motions to the parts, in both vertical and horizontal directions, and thus simulate their dynamics in the real machines. All mechanical tests on the tribological test equipment are performed according to ASTM and DIN standard specifications, and numerous tribological parameters can be simultaneously captured, including: friction force, torque and coefficient, in-situ wear and wear rate, contact acoustic emission, and contact electrical resistance or capacitance. See the box for an overview of tribological and mechanical tester applications. One example is the drill bit mechanical test (see Figure 5).

Conclusion

3D areal parameters provide structural and performance data not obtainable from roughness measurements alone. The 3D optical microscope provides a turnkey tool to rapidly and objectively obtain 3D areal parameters, enabling correlation to product performance in a fully gage-capable manner. 3D optical microscopes offer the additional advantage of being able to simultaneously measure both lead angle and surface roughness at a considerably higher level of accuracy. Tribological testers add the capability to accurately measure friction and wear. By taking advantage of this new generation of measurement tools, manufacturers in the automotive, aerospace, electrical equipment and other industries can deliver products with reduced energy consumption, longer life and higher reliability.

Tribological and mechanical tester applications

- Automotive (brake testing, bearings, piston liners, etc.);
- Aerospace (nano-indentation, microhardness, etc.);
- Biomaterials (cosmetics, synovial fluids, drug delivery, etc.);
- Coatings & thin films (adhesions, optical components, solar cells, etc.);
- Elastomers (plastics, nail varnishes, etc.);
- Electric contacts (durability of electrical components, materials, etc.);
- Optimisation of fastener materials;
- High-temperature materials (friction, fatigue, tension, etc.);
- Lubricants (oils, greases, cutting fluids, additives, etc.);
- Macro-indentation & common hardness measurements;
- Magnetic & optical drives (reliability testing, heads, ramps, etc.);
- Paper (friction force, coefficient of kinetic friction, tear resistance, etc.);
- Semiconductor materials (hard disk overcoats, scratch adhesion, etc.);
- Skin tests;
- …and many others.

Dutch innovation in

SPIE Astronomical Telescopes + Instrumentation 2012 was held from 1 to 6 July in Amsterdam, the Netherlands, and attracted some 2,300 participants. Presented by SPIE, the international society for optics and photonics, as a "fantastic showcase of the world's ideas and technologies for enabling astronomical research". The Dutch astronomical and instrumentation institutions TNO, ASTRON, SRON and NOVA seized the opportunity and joined forces to showcase their latest innovations and technologies in the field of instrumentation for astronomy, in the Dutch Eyes on the Skies pavilion. A snapshot of the TNO presentations.

For example, TNO developed and built the silicon carbide Basic Angle Monitoring (BAM) system. This is a metrological system that measures the relative movement of the telescopes of the ESA GAIA satellite with an accuracy of 0.5 microarcseconds, precisely recording slight variations in the position of stars, important for such things as the detection of exoplanets. GAIA will provide unprecedented positional and radial velocity measurements with the accuracies needed to produce a stereoscopic and kinematic census of about one billion stars in our galaxy (see Figure 1). GAIA will enhance our understanding of the early formation – and subsequent dynamical, chemical and star formation – of the Milky Way galaxy and will also detect tens of thousands of extrasolar planetary systems as well as potentially dangerous asteroids in our own solar system.

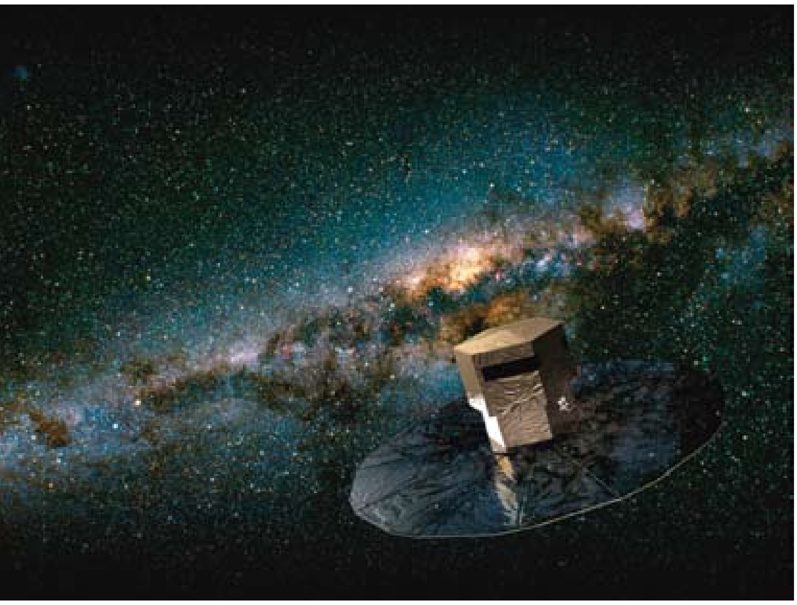


Figure 1. GAIA scanning our galaxy. (Photo courtesy of ESA/ Medialab)

ESO (European Southern Observatory) is equipping one of its Very Large Telescopes (VLT), located in the Atacama Desert in Chile, with an adaptive optics (AO) system. This system will correct for atmospheric turbulence which degrades the telescope performance. To determine the wavefront distortion, a bright star nearby the faint object

Information

spie.org/x89022.xml
www.tno.nl

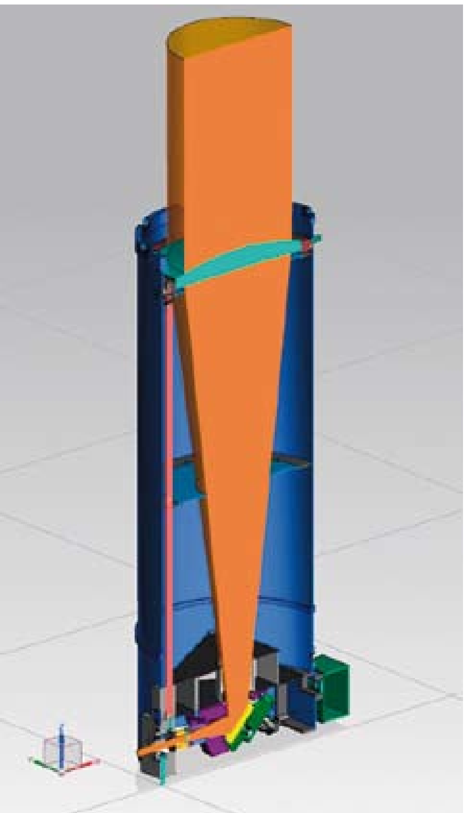


Figure 2. OTA cross-section view.

under study is normally used. This approach however limits sky coverage to about 1%. Therefore, ESO is equipping one of its telescopes with the Four Laser Guide Star system, which creates four artificial stars. To that end, four 25W 589nm lasers are pointed to the sky, where they excite sodium atoms in the atmosphere between 90 and 100 km up, which in turn start emitting light, thus creating an artificial star.
For this ESO VLT Laser Guide Star Facility (4LGSF) TNO developed the Optical Tube Assembly (OTA, see Figure 2). TNO recently tested four OTAs successfully, showing that the challenging demands on the quality of the output wavefront, etc., are being fulfilled. This has the potential to significantly improve the image quality of ground-based telescopes.

Other presentations by TNO and partners included:

- Ultra stable isostatic bonded optical mount designs for high performance astronomical telescopes.
  An overview of the design principles used and the achievable performance, with special attention to the use of adhesives – in combination with an isostatic design this allows for the mounting of optical components in a small volume with limited deformation of the optical surfaces due to thermal and mechanical loads.
- Extremely stable piezo mechanisms for the New Gravitational wave Observatory (NGO).
  Detection and observation of gravitational waves requires extreme stability in the frequency range 10^{-4} Hz to 1 Hz. NGO will attain this by creating a giant interferometer in space, based on free-floating proof masses in three spacecrafts. To operate NGO, various piezo mechanisms were designed: stack, sliding and stepping.
- Deformable mirror for next generation solar telescopes.
  Thermal load handling on a high-density array of linear actuators.
- Manufacturing of high precision aspherical and freeform optics.
  Aspherical and freeform optical elements have a large potential for reducing optical aberrations as well as the number of elements in complex high-performance optical systems. However, manufacturing a single piece or a small series of aspherical and freeform optics has for long been limited by the lack of flexible metrology tools. With the NANOMEFOS metrology tool (see Figure 3) the form of aspheres and freeforms up to 500 mm in diameter can be measured with an accuracy better than 10 nm rms.

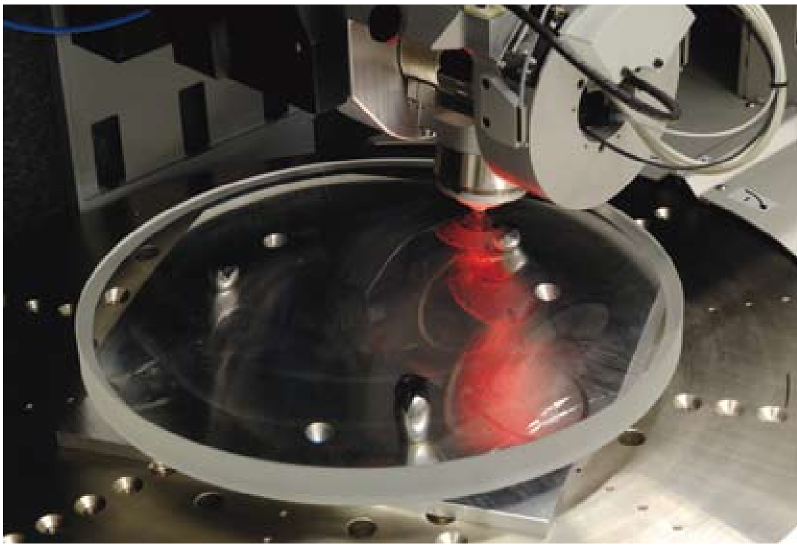


Figure 3. Asphere metrology on NANOMEFOS.

'Shrink and growth'

***The semiconductor equipment industry is in an ongoing process of 'shrink and growth'. The critical dimensions are now below 25 nm, while silicon wafers will grow to a size of 450 mm in diameter. The ASPE 2012 Summer Topical Meeting was devoted to some of the interesting challenges involved, featuring as its central theme* "Precision Engineering and Mechatronics Supporting the Semiconductor Industry". The programme covered eight technical sessions on the latest developments in the semiconductor industry, emerging lithography technologies, metrology, stage design strategies and robust control strategies. The programme included a full-day tutorial with focus on system dynamics and thermal challenges in precision system design. A commercial session and poster sessions were also on the agenda.**

• ***Maurice Bogers*** •

The ASPE 2012 Summer Topical Meeting was held at Lawrence Berkeley National Laboratory in Berkeley, California, USA, from 24 June to 26 June (see Figure 1). Berkeley Lab is a multidisciplinary national laboratory supported by the U.S. Department of Energy and conducts unclassified research across a wide range of scientific disciplines. Berkeley Lab was founded in 1931 by Ernest Orlando Lawrence, a UC (University of California) Berkeley physicist who won the 1939 Nobel Prize in physics for his invention of the cyclotron, a circular particle accelerator that opened the door to high-energy physics. Berkeley Lab employs approximately 4,200 scientists, engineers, support staff and students.

After the pre-conference tutorial and a welcome reception on Sunday, the conference was officially opened on Monday, 25 June, by Co-Chairman John S. Taylor of Lawrence Livermore National Laboratory. He welcomed – also on behalf of Co-Chairman Jan van Eijk, director of MICE and former professor at Delft University of Technology, the Netherlands – more than 100 participants from America (76), Europe (24, including 12 Dutch

Author's note

Maurice Bogers works as a Mechatronic System Architect at MI-Partners in Eindhoven, the Netherlands. The feedback provided by Theo Ruijl is gratefully acknowledged.

ww.mi-partners.nl

in semiconductor equipment

Participants of the ASPE 2012 Summer Topical Meeting at Lawrence Berkeley National Laboratory, located on a 200-acre site in the hills above the UC Berkeley campus, overlooking the San Francisco Bay. (Photo courtesy of ASPE)

participants) and Asia (7). The summer topical conference in Berkeley was a follow-up to the highly successful meeting held in the spring of 2008 on "Precision Mechanical Design and Mechatronics for Sub-50nm Semiconductor Equipment".

Semiconductor industry drivers

Janice Golda, Director Lithography Capital Equipment Development at Intel Corporation, started the first technical session. In her presentation "Pico(meters) to the People", Golda discussed the International Technology Roadmap for Semiconductors (ITRS). As computing technology will be further extended and simultaneously created for a worldwide population in this decade, there is a strong driver for increasing device density, shrinking cost per function and increasing speed of business.

The semicon roadmap describes device scaling trends from the 22nm logic node in production today towards single-digit nanometers this decade. This requires, according to Golda, major enhancement of lithography techniques such as multiple patterning, EUV lithography, complex masks, advanced materials and computational lithography. For sub-10nm nodes, this will lead to error budgets of sub-nanometers or less at subsystem or component level. Besides achieving sub-nanometer precision, increasing productivity will be the next driver for decreasing the cost per function. Wafer size scaling towards 450 mm is the key for producing more dies per hour that pass inspection. Both these developments will need to occur in parallel, and in addition will have to result in flexible equipment solutions to adapt to frequently changing customer demands. Moore's Law was frequently mentioned, so parties involved in research and development for the semiconductor industries are well aware of these challenges, and are eager and enthusiastic to make it happen. This enthusiasm was also apparent in the following sessions of the conference.

Figure 2. The synchrotron-based SHARP EUV mask microscope isolates the critical mask and zoneplate-lens stages inside a vacuum test chamber.

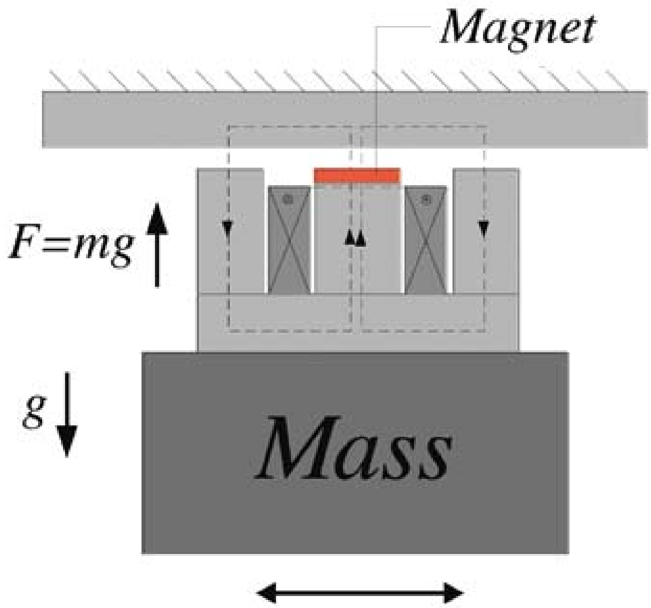


Figure 3. The bidirectional reluctance type of actuator with integrated gravity compensation.

Microscopy

Kenneth A. Goldberg of Lawrence Berkeley National Lab demonstrated that the challenges are not only in the field of imaging but will also influence inspection and metrology equipment. When talking about “Creating an EUV Mask Microscope for Lithography Generations Reaching 8 nm”, he described the concept and working principles of a synchrotron-based extreme ultraviolet (EUV) microscope. This microscope, called SHARP (the SEMATECH High-NA Actinic Reticle review Project), will be dedicated to serve EUV photolithography generations to the year 2020 and beyond (see Figure 2). SHARP incorporates several refinements as compared to its predecessor, such as a new high-efficiency illuminator with customisable coherence control, and a large variety of zone plate objective lenses for different magnifications, numerical apertures, and azimuthal angles of incidence, emulating the optical properties of current and future lithography tools. Mechanically, the key challenge is to achieve sub-5nm stability between mask and the objective lens during 1-5 seconds exposures, a level that is required for accurate pattern measurements.

Lithography tools

Next, Mike Binnard from Nikon Research Corporation of America gave an inside view on which lithography tools offer performance improvements in his presentation on “Semiconductor Lithography: Enabling Production Beyond 22 nm”. These tools offer performance improvements in several key areas: image quality including resolution and critical dimension uniformity, focus control, overlay control, throughput, and productivity. As his final conclusion, Binnard stated that the industry will most likely adopt a combination of ArF (argon fluoride) immersion and other technologies, such as EUVL, Directed Self Assembly (DSA), 3D semiconductors and 450mm wafers, to extend lithography towards 10nm half-pitch around the year 2020. Finally, Binnard had a bit of comfort for all of us working in the semiconductor industry: “We are not running out of precision engineering problems to solve.”

More sessions

The theme of the second session was “Emerging Lithographic Technologies”, with interesting presentations covering various lithographic imaging processes such as reflective electron beam lithography, plasmonic imaging and Jet and Flash Imprint (J-Fil TM) lithography. Sessions three and four focused on stage development, covering “Stage Design Strategies” and “Stage Characterization and Metrology”.

The first day’s programme ended with the Summer Topical Meeting Dinner at the Pyramid Alehouse in Berkeley, giving the participants the opportunity to catch up on existing contacts and make new ones while enjoying some craft beers and good food.

Dutch contributions

Sessions covering “Mechatronic Actuators and Motors”, “Mechanical Lithography”, “Robust Control Strategies” and “Enabling Mechatronic Technologies” were on the agenda for the second day. In his presentation on “Recent Developments and Comparative Evaluation of Lorentz and Reluctance Actuators for High Precision Semiconductor Equipment Stages”, Adrian Toma of Philips Innovation Services (Eindhoven, the Netherlands) provided a comparative analysis of two types of electromagnetic actuators, Lorentz and reluctance. He compared the two as applied to semiconductor equipment. Although the reluctance actuator shows better performance regarding force density and power dissipation, effects such as parasitic stiffness and damping and actuator sensitivity to movements need to be taken into account when considering these actuators for high-precision positioning systems. The disadvantage of the standard configuration of a reluctance actuator is that it only generates an attracting force and no repelling force. However, for position control bidirectional force generation is desirable. A solution is shown in Figure 3.

The last presentation of the conference was given by Rudolf Saathof of Delft University of Technology: "Closed Loop Control of a Lithographic Optical Component". Saathof showed how thermally induced aberrations in a mirror surface, suitable for EUV lithography, can be controlled via a spatially controllable heat source, by applying an inverse heat source profile to the mirror surface (see Figure 4). High levels of accuracy can be achieved by closing the control loop, including feedback control. Besides realising homogeneous surface temperatures, a specific thermal distribution can also be achieved.

Tutorial

During a full-day, pre-conference tutorial on Sunday, June 24, participants were given the opportunity to become acquainted with both basics and recent developments in the field of semiconductor equipment. The focus was on system dynamics and control as well as thermal challenges in the design of precision systems. A total of 45 people participated in these tutorials. The session on "Precision Motion Control: Theory and Practice" was co-hosted by Pradeep K. Subrahmanyan of KLA-Tencor, and Stephen J. Ludwick of Aerotech. The session on "Thermal Effects in Precision Systems" was hosted by Theo A.M. Ruijl of MI-Partners, who gave an introduction on design considerations and state-of-the art modelling, compensation and validation techniques.

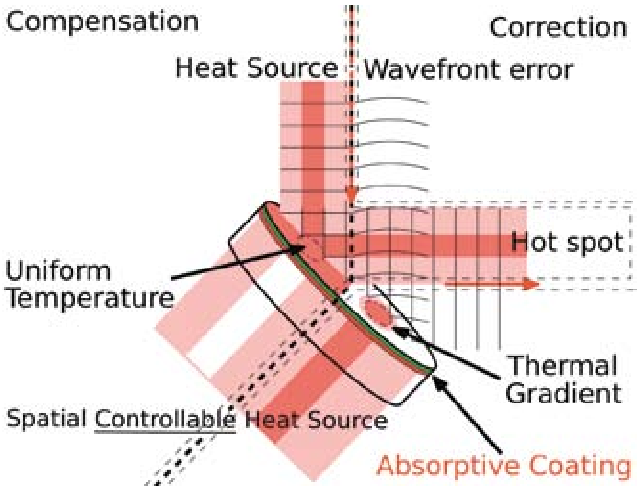


Figure 4. Realising a uniform temperature (left) or inducing a deformation by achieving a specific thermal distribution (right).

Inspiring

The ASPE conference brought together system engineers and scientists from the semiconductor industry to exchange results and ideas, and hear about the latest developments regarding precision mechanics and control. The author returned home from this conference inspired and enriched by what he heard and the people he met. He would happily recommend this conference to anyone wanting to increase their knowledge in this field.

American Society for Precision Engineering

ASPE, a non-profit organisation founded in 1986, promotes the future of manufacturing in America by advancing precision engineering. It does this by supporting education, encouraging the development and application of precision principles, and organising various meetings. The 27th ASPE conference will be held in San Diego, California, USA, from 21 to 26 October 2012.

www.aspe.net/technical-meetings

4-5 September 2012, Deurne (NL)
DSPE Conference

DSPE and Brainport Industries organise this first conference on precision mechatronics. The target group includes technologists, designers and architects in precision mechatronics, who (through their respective organisations) are connected to DSPE, Brainport Industries, the mechatronics contact groups MCG/MSKE or selected companies or educational institutes. See also the extensive Conference programme on page 45 ff.

www.dspe-conference.nl

25-28 September 2012, Besançon (FR)
Micronora 2012

The biennial microtechnology and precision trade fair features multiple activities – from assembly, engineering and machining to metrology and nanotechnology – for markets with high technological value, including aerospace, (bio)medical, microelectronics and telecommunications. The event includes conferences and a European technology brokerage event on micro- and nanotechnology. Micronora 2010 attracted over 14,000 visitors and 565 direct exhibitors (200 from abroad), with a further 300 firms or brands represented.

www.micronora.com

25-28 September 2012, Amsterdam (NL)
HET Instrument 2012

Technology trade show, covering industrial electronics, industrial automation and laboratory technology, organised by FHI, Federation of Technology Branches. The conference programme includes Tomorrow's Electronics (on 26 September), Design Automation & Embedded Systems and High Tech Equipment Engineering (both on 28 September). The previous edition, in 2010, attracted over 450 exhibitors and 17,000 visitors.

www.hetinstrument.nl

10 October 2012, Bussum (NL)
11th National Cleanroom Day

Event for cleanroom technology users and suppliers in the fields of micro/nano electronics, healthcare, pharma and food, organised by the Dutch Contamination Control Society.

www.vccn.nl

31 October 2012, Utrecht (NL)
RoboNED Seminar

Since the Dutch Robotics Strategic Agenda has been received very positively, the next step of RoboNED is to implement the plans. This seminar will be the kick-off for creating consortia around four societal problems where robotics may contribute to a solution.

www.roboned.nl

8 November 2012, Den Bosch (NL)
Bits&Chips 2012 Embedded Systems

Eleventh edition of the conference on embedded systems and software. Last November, the event celebrated its tenth anniversary with over 600 participants and some fifty high-tech companies and organisations presenting themselves at the conference venue.

www.embedded-systems.nl

28-29 November 2012, Veldhoven (NL)
Precision Fair 2012

Twelfth edition of the Benelux premier trade fair on precision engineering. Some 250 specialised companies and knowledge institutions will be exhibiting in a wide array of fields, including optics, photonics, calibration, linear technology, materials, measuring equipment, micro-assembly, micro-connection, motion control, surface treatment, packaging, piezo technology, precision tools, precision processing, sensor technology, software and vision systems. The Precision Fair is organised by Mikrocentrum, with the support of DSPE, NL Agency, the Dutch Precision Technology association, and Dutch HTS, the gateway to the Dutch High Tech Systems industry.

www.precisiebeurs.nl

5-6 December 2012, Teddington (UK)
Topical Meeting: Structured and Freeform Surfaces

This meeting of the euspen Special Interest Group Structured and Freeform Surfaces will focus on the technology, needs and design of engineered surfaces. This is the fourth in the series of topical meetings on the manufacturing and metrology issues that modern manufacturing industry faces.

www.euspen.eu

10-11 December 2012, Ede (NL)
Netherlands MicroNanoConference ’12

Conference on academic and industrial collaboration in research and application of microsystems and nanotechnology. The eighth edition of this conference is organised by NanoNext.NL and MinacNed. Previous editions enjoyed attendance levels of approximately 450 academics and industrialists, visiting both the exhibition and the conference.

www.micronanoconference.nl

26-27 February 2013, Veldhoven (NL)
RapidPro 2013

The annual event for the total additive manufacturing, rapid prototyping and rapid tooling chain.

www.rapidpro.nl

20-21 March 2013, UK
Lamdamap 2013

Event focused on laser metrology, machine tool, CMM and robotic performance.

www.lamdamap.com

Course	CPE points	Provider	Starting date (location, if not Eindhoven)
Basic			
Mechatronic System Design (parts 1 + 2)	10	HTI	1 October 2012 (part 1) 5 November 2012 (part 2)
Construction Principles	3	MC	30 October 2012 (Utrecht)
System Architecting	5	HTI	29 October 2012
Design Principles Basic	5	HTI	14 November 2012
Motion Control Tuning	6	HTI	20 November 2012
Deepening			
Metrology & Calibration of Mechatronic Systems	2	HTI	to be planned
Actuators for Mechatronic Systems	3	HTI	8 October 2012
Thermal Effects in Mechatronic Systems	2	HTI	to be planned
Summer school Optomechatronics	5	DSPE	to be planned
Dynamics & Modelling	3	HTI	3 December 2012
Specific			
Applied Optics	6.5 6.5	MC HTI	13 September 2012 30 October 2012
Machine Vision for Mechatronic Systems	2	HTI	27 September 2012
Electronics for Non-Electronic Engineers	10	HTI	8 January 2013
Modern Optics for Optical Designers	10	HTI	25 January 2013
Tribology	4	MC	30 October 2012 (Utrecht) 27 November 2012
Introduction in Ultra High & Ultra Clean Vacuum	4	HTI	29 October 2012
Experimental Techniques in Mechatronic Systems	3	HTI	9 April 2013
Design for Ultra High & Ultra Clean Vacuum	4	HTI	26 November 2012
Advanced Motion Control	5	HTI	8 October 2012

DSPE Certification Program

Precision engineers with a Bachelor's or Master's degree and with 2-10 years of work experience can earn certification points by following selected courses. Once participants have earned a total of 45 points (one point per course day) within a period of five years they will be certified. The CPE certificate (Certified Precision Engineer) is an industrial standard for professional recognition and acknowledgement of precision engineering-related knowledge and skills.
The certificate holder's details will be entered into the international Register of Certified Precision Engineers.

www.dsperegistration.nl/list-of-certified-courses

Course providers

- The High Tech Institute (HTI)
  www.hightechinstitute.nl
- Mikrocentrum (MC)
  www.mikrocentrum.nl
- Dutch Society for Precision Engineering (DSPE)
  www.dspe.nl

"One of the most interesting short courses"

The fifth edition of the Summer school Opto-mechatronics, organised by DSPE and The High Tech Institute, took place from 25 to 29 June 2012 at TNO's on the university campus in Eindhoven, the Netherlands. The fifteen participants came from various backgrounds (universities, research institutes, large companies and SMEs) and countries, including Saudi Arabia, Denmark and Germany. One of the participants, Farzad Foroughi Abari (Technical University of Denmark), wrote the following report.

"I was one of the participants in a truly attractive and challenging Summer school Opto-mechatronics. Having a background deeply rooted in applied signal processing, I have always had a deep interest in mechatronics where various engineering areas convene. Considering the course to be my first in mechatronics I was looking forward to it; and I was not disappointed. The event turned out to be one of the most interesting short courses I have taken. The curriculum was well-balanced and there was a diversity of professionals from different institutes invited to give lectures. Moreover, the lectures mainly revolved around a real-life example, i.e., the delay line designed for the European Southern Observatory's Very Large Telescope (VLT). In fact, the instructors walked us through the most important design steps as well as system management requirements. Thus, the course content was a unique mixture of practical issues, essential theoretical concepts, and hands-on experience.

So, what was the most interesting part of the summer school? Hard to answer when you like most parts. Yet, when I think and reflect back on it I find the summer school challenge and social event as the most appealing part. And believe me, it is not because I happened to be a member of the winning team! It was not a typical social event where you would eat and drink; in this one we had to compete, too! In a nutshell, it was a well-arranged social event where the participants were brought together in a loving and welcoming environment. Throughout that evening we socialised, had fun while we rivaled; the prize, a memorable trophy, is sitting on my table at the office.

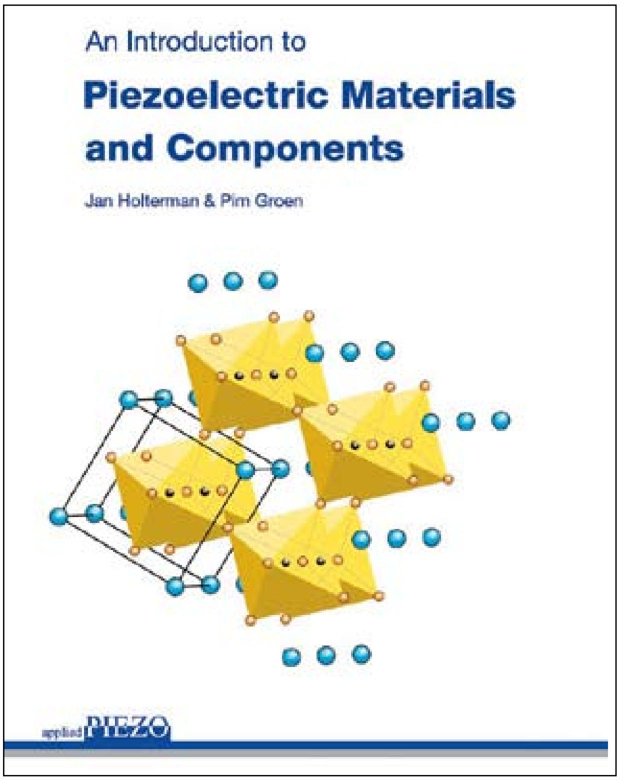
What's more, during the school I got to make new friends coming from a broad spectrum of professional backgrounds. Despite the course being a short one, the friendly environment bound the participants and lecturers together resulting in life-long acquaintance and friendship. At least, I know who to turn to next time I need to decide between a piezo actuator and a magnetic one."

The Summer school combined lectures and a challenging social event.

An Introduction to Piezoelectric Materials and Components

Piezoelectric materials are among the 'invisible' materials that are all around us. Consumer products, automotive electronics, medical technology and industrial systems are only a few of the areas where piezoelectric components are indispensable. Piezoelectric materials are used so widely because they can convert mechanical energy into electric energy and vice versa.

This summer, a new book was published on this subject: "An Introduction to Piezoelectric Materials and Components". This extensively illustrated book is indispensable for students and engineers looking for an introduction to the fascinating world of piezoelectric materials and components. It covers the basics of piezoelectricity, while also providing an overview of:
- piezoelectric applications;
- piezoelectric materials, with an emphasis on single crystals and ceramics;
- piezoelectric ceramic components and their manufacturing;
- general modelling tools to understand and describe the behaviour of piezoelectric materials and components.



Jan Holterman & Pim Groen, "An Introduction to Piezoelectric Materials and Components", hardcover, 98 full colour illustrations, 108 pages, ISBN 978-90-819361-0-1, € 58.50 (handling and shipping not included, special rate for students).

The book was published by the Dutch Applied Piezo Foundation, which aims to give the industry better access to piezo technology, as part of the dissemination activities of the SmartPie research programme (SMART systems based on integrated PIEzo).

A preview of the book and an order form can be found on the website of Applied Piezo.

www.applied-piezo.com
www.smartpie.nl

Metem and ECM Technologies join forces

Metem Corporation, a specialist in non-conventional machining for the gas turbine and aerospace industries, and ECM Technologies, a market leader in precision electrochemical machining (ECM), have announced a 50/50 partnership to recapitalise ECM Technologies. Based in Leeuwarden, the Netherlands, ECM Technologies harnesses a talented group of chemical, mechanical, and process engineering specialists to an ever-expanding database of proprietary scientific information to provide cutting-edge research, consultancy and training in the field of ECM solutions.

With headquarters in Parsippany, NJ, USA, and manufacturing facilities in North America and Europe, Metem offers advanced electrical discharge machining (EDM) and ECM and other technologies to machine complex cooling holes and patterns in the most advanced superalloys.

Precision electrochemical machining offers significant advantages over conventional machining for products with a complex 3D geometry in steel and superalloys. This unique machining process is also ideal for products where upper-layer deformations due to more conventional machining techniques are not acceptable.

www.metem.com
www.electrochemicalmachining.com

Sixtieth anniversary for GF AgieCharmilles' EDM technology

In 1969, GF AgieCharmilles revolutionised electric discharge machining (EDM) by introducing the world's first numerically controlled wire-cutting EDM machine (WEDM). According to a press release, the company's continual innovations demonstrate the vast potential of the EDM process first demonstrated 60 years ago. That tradition of innovation continues, with improvements in machine efficiency, ease of use and process chain integration on the horizon.

GF AgieCharmilles' approach to innovation and product development yields measurable performance improvements in die-sinking, wire-cutting, and drilling EDM. Over the past twelve years, GF AgieCharmilles' developments in the field of WEDM have reduced form tolerance by 50%, cut surface roughness by 66%, and decreased internal radii by 40%. With respect to die-sinking, the group has slashed the spark gap from 20 to 5 μm, decreased surface roughness by 75%, achieved a 75% reduction in internal radii, and virtually eliminated wear on copper and graphite electrodes. At the same time, GF AgieCharmilles' human machine interface has become more user-friendly, machine precision has improved, and generator efficiency has increased from 20% to 80%.

GF AgieCharmilles is celebrating EDM technology's sixtieth anniversary by launching special editions of its wire CUT machines: the CUT 200P and 300 (shown here).

Demcon headquarters move to Enschede

After years of steady growth, high-end technology supplier Demcon has outgrown its headquarters in Oldenzaal, the Netherlands. Therefore, in Q1 2013 it will move to the Business & Science Park in Enschede. The new location will give Demcon – which has secondary locations in Eindhoven and Amsterdam and currently employs 180 staff – the space to scale up its operations to 500 employees and 100 million euros in turnover by 2020.

Demcon, a University of Twente (UT) spin-off, started in 1993 as a mechatronic design agency. It soon outgrew its location on the UT campus, and, after a short stay in Enschede, it moved to nearby Hengelo. There, Demcon developed into an all-round business that not only offers design services, but prototyping and series production of high-tech systems and medical devices as well. In the summer of 2004, Demcon moved to Valkenaer, a multi-business building in Oldenzaal.

This location includes offices, as well as laboratories, production and clean assembly rooms, and a measurement room, and it is now being used to more than full capacity.

The new building in Enschede was constructed in the nineties by telecom giant Ericsson. Demcon will initially lease 6,500 m^2, 2,000 m^2 of which will be for production and prototyping activities. An additional 1,000 m^2 will be realised for cleanroom facilities.

www.demcon.nl

Australian Astronomical Observatory – starring innovative instruments

The Australian Astronomical Observatory (AAO) provides world-class optical and infrared observing facilities enabling Australian astronomers to engage in excellent science. The AAO is a world leader in astronomical research and in the development of innovative telescope instrumentation.

The AAO's astronomical instrumentation programme consists of two main components: the Instrumentation group, which designs and builds instruments for telescopes, and the Instrument Science group, which develops new technologies for such instruments.

Instrumentation

The AAO Instrumentation group has a widely experienced technical staff. Its technical strengths are in fibre feeds (including single fibres, fibre integral field units (IFUs), and image slicers), robotic fibre positioners (including pick and place, and autonomous systems), optical and infrared spectrographs (such as IRIS2, AAOmega and HERMES), and software (particularly for detector controllers and data reduction).

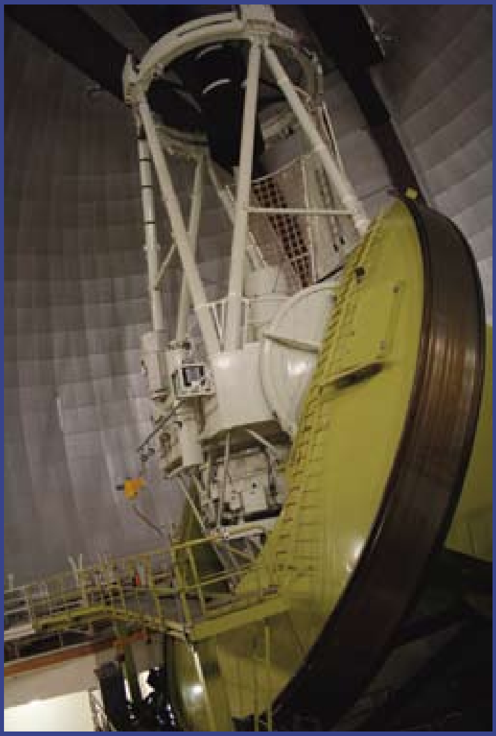
Instrument Science

The AAO's Instrument Science group is developing photonic technologies that look to the longer term future of astronomical instrumentation. These devices include fibre Bragg gratings for OH suppression filters, fibre hexabundles for efficient IFUs, photonic lanterns for fibre mode conversion, and solid-state photonic spectrographs, all of which have the potential to revolutionise the design, construction and capabilities of astronomical instrumentation on timescales that vary from tomorrow (e.g. OH suppression and hexabundles) to more than a decade (e.g. photonic spectrographs).

Powering telescopes

The instrumentation programme currently has a staff equivalent to 32 FTEs. For the past five years it has run on a total annual budget (including external revenue) typically in the range of 7 to 10 million Australian dollars. At this scale the AAO programme can simultaneously accommodate two major instrument projects (one in design, one under construction), or one major and two medium projects, along with up to five smaller projects and ongoing support of the telescopes and existing instruments.

This programme has been a key factor in the AAO's scientific success, producing innovative instruments that have powered the research programmes on the Australian telescopes, the AAT (3.9 metre Anglo-Australian Telescope) and UKST (1.2 metre UK Schmidt Telescope), and has provided access to other large telescopes such as the European VLT (Very Large Telescope) and the Japanese Subaru telescope in Hawaii. Instruments include, for AAT, the 2-DoF fibre positioner (to feed the light of individual stars into fibre-fed spectrographs, such as the AAOmega VPH grating spectrograph, and the soon to be delivered even larger, 4-channel HERMES spectrograph), and, for UKST, the 6-DoF fibre positioner (DoF = degrees of freedom).



The Anglo-Australian Telescope, powered by AAO's instruments.

Information

www.aao.gov.au

Première features 'Systems Thinking'

The first DSPE conference on precision mechatronics, an initiative of DSPE and Brainport Industries, will be held at the inspiring conference location of Willibrordhaeghe in Deurne, the Netherlands, on 4-5 September 2012.

The target group of the DSPE Conference includes technologists, designers and architects in precision mechatronics, who, through their respective organisations, are connected to DSPE, Brainport Industries, the mechatronics contact groups MCG and MSKE, or selected companies and research/educational institutes. In addition to paper and poster presentations and demos, the conference will provide the ideal setting for networking, technical discussion and sharing the enthusiasm of working in this challenging field. The theme this year is 'Systems Thinking'.

The following pages feature:
- the programme;
- the abstracts of the papers;
- the overview of the posters and demos.

Brainport Industries

DSPE

The DSPE Conference is organised by DSPE and Brainport Industries, the association of leading tier-one, tier-two and tier-three high-tech suppliers in the Eindhoven region.

Information

www.dspe-conference.nl
www.brainportindustries.com

The DSPE Conference will be held at the inspiring conference location of Willibrordhaeghe in Deurne.

Tuesday 4 September 2012

Opening session

Introduction
Harry Borggreve (ASML)

Systems thinking in advancing productivity of ultra precision machines
Paul Shore (Cranfield University)

Session 1 Precision Technology I

450 mm lithography challenges
Hans Vermeulen, R. van Lieshout, H. Butler, M. van de Wal, W. Aangenent, H. Heintze, R. Beerens, S. Donders (AMSL)

Design of a 2 DOF scan stage with nanometer accuracy in an electron microscope
Eelco van Hoeven, J. van Koppen, P. Kappelhof (Hittech Multin Netherlands)

Novel through-wall 450 mm vacuum compatible wafer stage
D. Laro (MI-Partners), E. Boots (Delft University of Technology), J. van Eijk (Delft University of Technology, MICE), L. Sanders (MI-Partners)

Session 2 Motion Control I

UHR-Stage Motion Control Tuning
Edwin Verschueren (FEI Electron Optics)

Motion Challenges in a Medical Environment
Eric Smeets (Philips Healthcare)

How to get 50% more speed out of an existing print platform
Sjirk Koekebakker (Océ Technologies, Eindhoven University of Technology), R. Blom, P. van den Bosch (Océ Technologies), B. Lemmen, O. Bosgra (Eindhoven University of Technology)

Session 3 System Engineering and Design I

Back end laser scribing and inkjet for thin film solar R2R production tool
Johan Bosman, H. Kooter (ECN Solliance, ECN Environment & Energy Engineering)

Atmospheric Spatial Atomic Layer Deposition in Roll-to-Roll Processes
Raymond Knaapen, P. Poodt, R. Olieslagers, A. Lankhorst, M. van den Boer, D. van den Berg, A. van Asten (TNO), F. Roozeboom (TNO, Eindhoven University of Technology)

Load Sensing and Condition Monitoring for a Subsea-multiphase pump
Philippus J. Feenstra, N.S.W. den Haak (SKF)

Wednesday 5 September 2012

Session 4 Business/System Architecture

Mechatronics as a money maker
Henk Tappel (Frencken Europe)

Extending Boundaries in System Thinking
David Rijlaarsdam, E. Hezemans (NTS Systems Development)

System Architecture in Medical Application for Pathology
Hans Kuppens (CCM)

Session 5 New Business

System and Business Architecture of Spatial ALD Equipment for Solar Cell Production from SoLayTec
Ad Vermeer (Adinsyde)

Design aspects of the TriNano ultra precision CMM
Ton Moers, E.J.C. Bos, M.C.J.M. van Riel (Xpress Precision Engineering)

Revolutionizing the PCB industry with an industrial inkjet printing soulution
Henk Jan Zwiers (MuTracx)

Session 6 Motion Control II

A practical comparison of feedforward control design techniques for high-precision motion systems
Dennis Bruijnen, N. van Dijk, J. Songtao (Philips Innovation Services)

NXP ITEC implements advanced control in high speed wire bonder
Thiemo van Engelen (NXP Semiconductors)

Data-based control design methods for lightweight high-precision motion systems
Rob Hoogendijk, R. van de Molengraft, M. Steinbuch (Eindhoven University of Technology)

Session 7 Precision Technology II

Angle Sensing Bearings for electric traction: Precision for induction motor commutation
Henk Mol (SKF Engineering and Research Centre)

FEM model based POD reduction to obtain optimal sensor locations for thermal-elastic error compensation
Jack van der Sanden, P. Philips (Philips Innovation Services)

Carbon-Nanotube-Based Constant Force Mechanisms
Nima Tolou, P.P. Pluimers (Delft University of Technology), B.D. Jensen, S. Magleby, L. Howell (Brigham Young University), J.L. Herder (Delft University of Technology)

Session 8 System Engineering and Design II

A closed-loop large range of motion positioning system in MEMS
Bram Krijnen, D.M. Brouwer (Demcon Advanced Mechatronics, University of Twente)

“Systems thinking” to meet contradicting system requirements
Gerrit van der Straaten (Settels Savenije van Amelsvoort)

Mechatronic Challenges in Extreme Ultra Violet Projection Optics
Rob de Jongh (ASML)

Both days

Poster sessions and demonstrations

SESSION 1 PRECISION TECHNOLOGY 1 – 1

450 mm lithography challenges

Hans Vermeulen, R. van Lieshout, H. Butler, M. van de Wal, W. Aangenent, H. Heintze, R. Beerens, S. Donders (AMSL)
www.asml.com

Main driver for semiconductor equipment manufacturers is to continuously enable cost reduction for IC fabrication (Moore's law). Although shrink is considered the most effective way to do so, e.g. through EUV lithography, the transition to 450 mm wafers has gained serious momentum over the last year to further improve cost per function. Currently, a turning point to 450 mm seemingly gets closer, since it is expected to become increasingly difficult to add fab capacity in line with the growth rate of electronics. Therefore, the semiconductor industry is planning for a transition to 450 mm high-volume manufacturing towards the second half of this decade.

Stretching current 300 mm stage technology towards a 450 mm system is doable to some extent. To meet increasing demands on on-product overlay and CD uniformity, however, for which the roadmap is considered to continue at an improvement rate of about 15% year-on-year [1], the application of new stage technologies is currently considered. By the application of advanced control via over-actuation and over-sensing, excitation of internal flexibilities can be avoided and deformations can better be observed, and so, control bandwidth potential can be decoupled from existing eigenfrequency limitations of more flexible stage mechanics.

In addition to new control strategies, high-efficient actuation systems, advanced measurement systems and cooling technologies are among the main mechatronic topics that are currently being investigated. This paper will elaborate on key technical challenges and advancements in these areas.

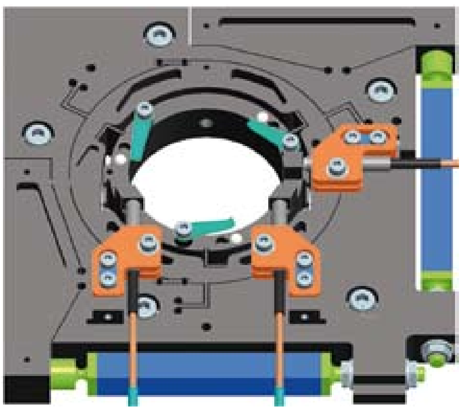
[1] International Roadmap for Semiconductor Industry: 2008 Update, www.itrs.net/Links/2008ITRS/Update/2008_Update.pdf.

SESSION 1 PRECISION TECHNOLOGY 1 – 2

Design of a 2 DOF scan stage with nanometer accuracy in an electron microscope

Eelco van Hoeven, J. van Koppen, P. Kappelhof (Hittech Multin Netherlands)
www.hittech.com

This papers presents design, realisation and test results of a two-stage, 2-degrees-of-freedom linear stage for use in a scanning electron microscope (SEM). The SECOM platform allows for the integration of a SEM with fluorescence microscopy, to obtain structural information and functional colour information in one run. As the optical axes of both microscopes are aligned, the overlay of the fluorescent and electron images becomes as easy as drag-and-drop.


The two-stage positioning system.

The scan stage inside the SECOM platform consists of two stages: a coarse one for large strokes to find the area of interest and a second stage for fast scanning. Together, the system delivers high performance giving a position accuracy of 1 nm, with a maximum stroke of 20 mm. This is all achievable with speeds up to 40 mm/s and accelerations up to 5 g. The mechanical design of the fine scan stage is a state-of-the-art high-stiffness and play-free flexure design.

The motion control is two-fold. A Learning Feed Forward Controller does most of the error correction. For robustness a PID-Feedback Controller can be added to correct for all the non-deterministic errors coming from the environment.

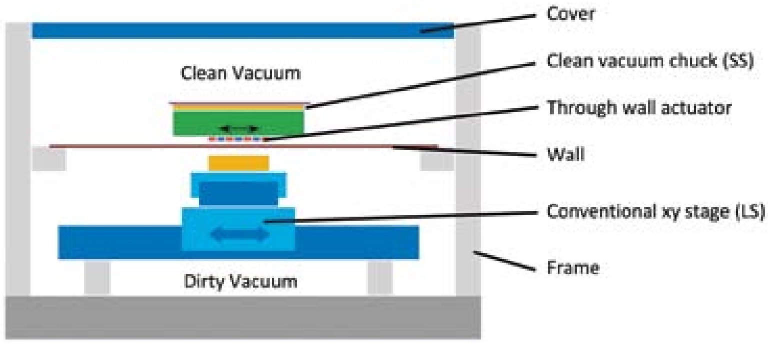
SESSION 1 PRECISION TECHNOLOGY I – 3

Novel through-wall 450 mm vacuum compatible wafer stage

D. Laro (MI-Partners), E. Boots (Delft University of Technology), J. van Eijk (Delft University of Technology, MICE), L. Sanders (MI-Partners)
www.mi-partners.nl, www.tudelft.nl, wwwmicebv.nl

High-precision machines require a high vacuum level. Contamination of this vacuum due to moving cables and bearings of the positioning stages within are an issue. An inverted planar motor solves this contamination issue but leads to a complex system due to position-dependent commutation and a large number of coils. An alternative stage design was developed at MI-Partners, which has a low degree of complexity and does not cause contamination of the vacuum.

In this concept a wall has been introduced, separating between two vacuum levels: clean/precision and dirty/non-precision. The design uses a Short Stroke-Long Stroke (SS-LS) stage configuration, with the SS stage exerting its actuation forces through the wall. The precision vacuum contains the SS chuck carrying a wafer for manufacturing or inspection. In the non-precision vacuum a conventional stacked LS xy stage is placed. The function of this xy stage is to enable a larger stroke for the short-stroke system. This paper describes the development of a demonstrator system for the concept, focusing on the actuator development.



Through-wall vacuum wafer stage design.

SESSION 2 MOTION CONTROL I – 1

UHR-Stage Motion Control Tuning

Edwin Verschueren (FEI Electron Optics)
www.fei.com

A Scanning Electron Microscope, because of its scanning principle, allows for bigger size and more flexibility of shape of the sample than a Transmission Electron Microscope. In 2003, the Ultra High Resolution (UHR) stage was introduced for better sample manipulation. Requirements for sample manipulation are for example a ±50 nm position accuracy to allow for navigation of features less then 200 nm in size. The biggest challenge was to find motor technology without any magnetic materials to avoid any influence on the position and shape of the beam.

One of the alternatives for a magnetic motor is an ultrasonic piezomotor. Major disadvantages are however the stick-slip behavior at low velocities and the non-linear relation between controller output and resulting velocity. To overcome these disadvantages, three techniques are applied in the field of motion control. The first technique is setpoint velocity depending proportional and integral gain. The second technique is the Clegg-integrator, which resets the integral part of the control loop to zero when the position error changes sign. This works well for moves in the order of micrometers, but fails for moves in the order of millimeters.

Therefore, the macro-micro move strategy is introduced. Goal of the first move is to reach the target within micrometer accuracy. Enhanced gains and integral reset are not applied, resulting in a less aggressive controller output and eventually less mechanical wear. The second move is aimed at ±50 nm settling accuracy. For this move enhanced gains and integral reset are applied.

The introduction of the three techniques results in a stage performance that allows for stage navigation in the order of tens of nanometers.

SESSION 2 MOTION CONTROL I – 2

Motion Challenges in a Medical Environment

Eric Smeets (Philips Healthcare)
www.healthcare.philips.com

In Image Guided Intervention Therapy (IGIT) X-ray equipment is used during treatment of a patient, often in the field of cardiology, neurology or oncology. In such a high-end X-ray system, machine functionality and image quality is of prime importance. Immediate secondary important aspects are safety (patient and personnel) and machine reliability. Medical equipment, by nature of its field of operation, is also bound by many regulations. And it must support new medical applications and equipment. Functional requirements are more or less the same all over the world (humans are much alike from a biological point of view), but the same X-ray equipment is used in a wide field of diagnostic and intervention procedures.

This paper is about the consequences this all has on the drive architecture of the high-end X-ray systems. The importance of their architecture is stressed and from the above considerations development characteristics of the X-ray machine and thus of the drive functions are formulated: open to new interfaces; insensitive to physical interfaces from third parties; flawless safety approach; evidence of correct operation; backwards compatible and upgradeable; modular approach for cost and option control.

Mechatronic system dynamics are likely to be simpler than often found in machinery business involving position servos. In the case of X-ray equipment in IGIT, the complexity houses in the extreme demands for versatility, reliability and safety and this needs to be translated into a machine (motion control) architecture. The X-ray IGIT equipment has a distributed drive system based on EtherCat, where other functional modules interface on the same network. This concept is reliable, safe, open, low-cost and (hopefully) future-proof.

SESSION 2 MOTION CONTROL I – 3

How to get 50% more speed out of an existing print platform

Sjirk Koekebakker (Océ Technologies, Eindhoven University of Technology),
R. Blom, P. van den Bosch (Océ Technologies), B. Lemmen,
O. Bosgra (Eindhoven University of Technology)
www.oce.com, www.tue.nl

The ColorWave 600 printer was the first wide-format inkjet colour printer of Océ with proprietary image devices. In this market productivity (number of prints per hour) is one of the most important requirements. Although pure print speed evaluated on the image device or the printheads simply involves multiplication of the number of nozzles, jet frequency and pixel drop size, integral system productivity is a more complex quantity.

The ColorWave is a wide-format inkjet printer

With roughly two measures it appeared possible to achieve a 50% larger integral productivity for D-size prints. Firstly, integral print speed could be increased by 20% through 50% faster motion of the carriage moving the printheads over the paper. To maintain performance under all required circumstances a learning feed forward was implemented. A new iterative learning control setting was developed which can deal with trial-to-trial system interaction.

An even more important step was decreasing the interpage time of the prints, by implementing a cut-while-print mode. Together with image processing means to maintain print quality, this formed the basic building stones of the new printer Colorwave 650.

SESSION 3 SYSTEM ENGINEERING AND DESIGN I – 1

Back end laser scribing and inkjet for thin film solar R2R production tool

Johan Bosman, H. Kooter (ECN Solliance, ECN Environment & Energy Engineering)
www.ecn.nl

The combination of back-end laser scribing and inkjet printing introduces a potentially cost-saving decoupling of (vacuum) deposition steps and interconnection steps in the production flow of (roll-to-roll) thin film PV solar cells. This break makes it possible to optimise the back-end series interconnection independent of the front-end coating and deposition processes. To facilitate this development and optimisation of depth-selective laser scribing with respect to the subsequent print processes, a generic laser platform has been built.

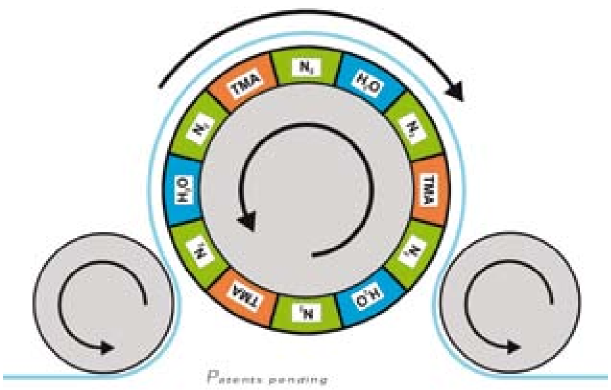
The platform enables the integrated use of multiple laser sources at three different wavelengths (1,030 nm, 515 nm and 343 nm) in combination with femtosecond and picosecond pulses. The use of inkjet printing for the conductive and isolating lines enables the integration of serialisation into one machine. This concept also opens the possibility to integrate the interconnection combined with inkjet finger printing into the module production (~ 250 MW production machines) The integrated laser platform is also a first step in ECN's development towards a complete integrated connection module production concept, enabling a 1 GigaWatt/year production tool.

SESSION 3 SYSTEM ENGINEERING AND DESIGN I – 2

Atmospheric Spatial Atomic Layer Deposition in Roll-to-Roll Processes

Raymond Knaapen, P. Poodt, R. Olieslagers, A. Lankhorst, M. van den Boer, D. van den Berg, A. van Asten (TNO), F. Roozeboom (TNO, Eindhoven University of Technology)
www.tno.nl, www.tue.nl

Amongst thin-film deposition techniques, Atomic Layer Deposition (ALD) has a number of unique properties like high conformality to substrate geometry, high layer quality and thickness control down to Å level. Deposition rate, however, is very low in conventional ALD reactors.
To achieve high throughput and to reduce costs, there have been recent developments regarding spatial ALD.



A new type of atmospheric, spatial ALD reactor for deposition on flexible substrates. Instead of a flat ALD injector head, a rotating drum is used to supply the precursor gases to slots at the peripheral surface of the drum, parallel to its rotation axis.

Whereas in conventional ALD precursors are dosed separated in time using a purge step, in spatial ALD precursors are dosed simultaneously and continuously at different physical locations. Without the need for a purging step, the process can be operated at much higher speeds, limited by layer deposition chemistry rather than pumping times. This has led to the development of high-throughput, industrial-scale ALD tools for surface passivation of crystalline silicon solar cells. And a new field of applications is flexible electronics, including system-in-foil, flexible displays, OLEDs and solar cells.

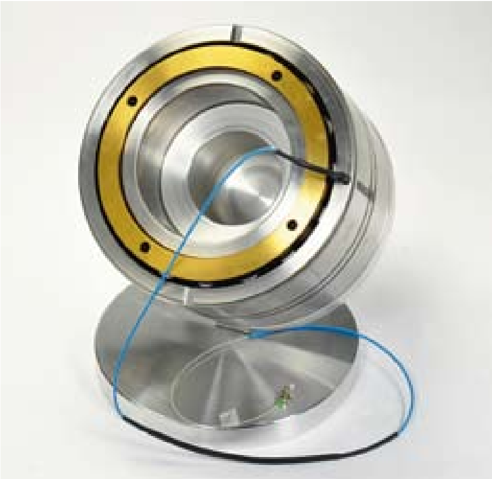
SESSION 3 SYSTEM ENGINEERING AND DESIGN I – 3

Load Sensing and Condition Monitoring for a Subsea-multiphase pump

Philippus J. Feenstra, N.S.W. den Haak (SKF)
www.skf.com

SKF has developed, in co-operation with Shell, Flowserve and SmartFibres, a condition monitoring and loadsensing technology for a next-generation subsea pump. This paper describes the experimental setup and results of the fiber-optic based condition monitoring system. The objective was to verify the feasibility of the system. To this end, bearing behaviour was recorded and processed to load, speed, bearing condition and other measures, and stored in a database.

The outcome of the study was successful and showed that the resulting load values correspond with simulated values, the main roller frequency was extracted and used to derive key parameters to ensure proper running of the bearing.



Sensorized bearing (on a pedestal), machined with two circumferential grooves and a hole for the cable ingress.

The condition monitoring software showed its sensitivity by detecting a minor defect of one of the rollers. At the end of the year 2012, the bearings will be disassembled, inspected and compared to the measured behaviour. The next phase in the development will address design-for-manufacturing and design-for-robustness of the system and further industrialisation and commercialisation.

SESSION 4 BUSINESS/SYSTEM ARCHITECTURE – I

Mechatronics as a money maker

Henk Tappel (Frencken Europe)
www.frencken.nl

It can easily be demonstrated that the Dutch economy depends more on the export of products than on the export of knowledge to fund its prosperity. High-tech mechatronics products can contribute to this export, if they can be produced competitively, at the right quality, lead times and costs.

This paper zooms in on the issues that the Dutch industry faces to continue its leading role as a high-tech products provider. Issues discussed include the battle for talent, the need to join forces, and the need to increase the sense of urgency to act, all seen through the eyes of one of the leading system suppliers in the Netherlands.

This all goes with a far-reaching cultural change within the supply chain. A transition takes place from a position in which the customer took all the business risk, to a position in which the suppliers have to take ownership, will run a business risk similar to the customer, and can no longer send an invoice for every hour spent. Customers will have to accept cost models that lead to a higher bill of materials cost, but lower cost of ownership.

SESSION 4 BUSINESS/SYSTEM ARCHITECTURE – 2

Extending Boundaries in System Thinking

David Rijlaarsdam, E. Hezemans (NTS Systems Development)
www.nts-group.nl

In engineering, system thinking traditionally relates to the process of considering the interaction between technical subsystems and components during the system's design phase. However, as any design process originates from a business case, it is strongly linked to the parameters that define this business case as well. This paper discusses the concept of extending the traditional system boundary to include not only the physical system, but also the business case to which the development process is inevitably connected.

When extending the system boundary to include the end-user's business case, the design process contains several types of additional requirements. Some of these relate to the utilisation phase of the product and are transferable to engineering specs and constraints, such as for example speed, accuracy, weight and price. However, other requirements such as those related to supplies and maintenance also relate to the utilisation phase of a product but are less straightforwardly translated to engineering specifications. Finally, requirements such as testability, accessibility and manufacturability can be translated to design specifications, but may be implicitly present in the end-user's business case. Moreover, numerous explicit and implicit requirements relate to a product's lifecycle, from time-to-markt to environmental issues to logistics, and these may be hard to translate into design specifications.

To conclude, the challenge of incorporating relevant aspects of the business case in the development lifecycle requires a novel mindset in system thinking. Extending the system boundary in 'engineering-based system thinking' to include the end-user's business case, provides a stepping stone towards an optimised development process, which allows to incorporate not only relevant engineering requirements but operational, environmental and economical requisites as well.

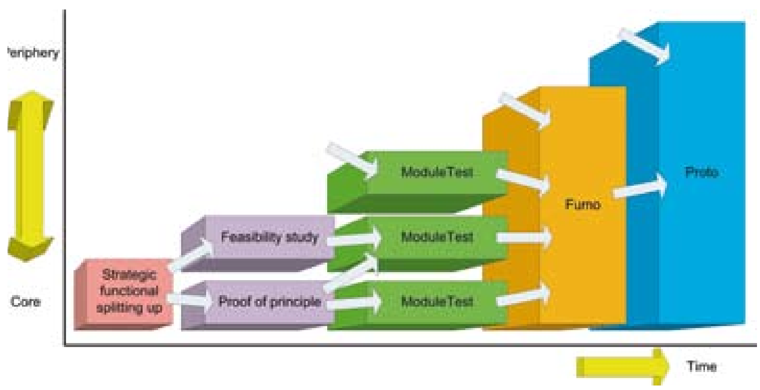
SESSION 4 BUSINESS/SYSTEM ARCHITECTURE – 3

System Architecture in Medical Application for Pathology

Hans Kuppens (CCM)
www.ccm.nl

With large and innovative companies in the lead, a coherent group of SMEs is working together on revolutionary and state-of-the-art technological solutions. Such as the UltraFast Scanner (UFS), a high-speed device for automated digitisation of slides containing pathological tissue. Philips is marketing and servicing this device, and owns the mission-critical knowledge, provided by Philips Research. Prodrive has developed and is supplying the electronics, while Frencken Mechatronics accounts for the production and qualification. CCM is responsible for system architecture and system integration, as well as the mechanic, mechatronic and software design.

One of the primary tasks of system architects is to adequately divide the project development activities into smaller workpackages, by decomposition and phasing, based on an initial strategic functional splitting up. With decomposition, the development is split up into more or less independent activities. But that is only part of the story. For challenging projects (such as the UFS), it is important to identify and mitigate all technical risks in an early stage, thereby giving other activities less priority. This is what is accomplished by phasing.



Phasing: high-risk and 'mission-critical' core technologies are addressed early in the project, low-risk and peripheral technologies are postponed to a later project phase.

SESSION 5 NEW BUSINESS – 1

System and Business Architecture of Spatial ALD Equipment for Solar Cell Production from SoLayTec

Ad Vermeer (Adinsyde)
www.adinsyde.nl

At TNO, record deposition rates for alumina (Al_2O_3) of up to 1 nm/s were reached using spatial Atomic Layer Deposition (ALD) while maintaining the typical assets regarding film quality as obtained by conventional, slow ALD. One interesting application enabled by this disruptive improvement is passivation of crystalline silicon solar cells. Applying a thin alumina layer is reported to increase solar cell efficiency and enables the use of thinner wafers, thus reducing the required amount of silicon, the main cost factor.

A new, independently operating OEM company, named SoLayTec, launched a Process Development Tool to enable customers to further develop the cell concepts and related production processes incorporating alumina. Based on the same concept, a High Volume Tool is now being developed, targeting throughput numbers of up to 3,600 wafers/hr. Both products use the same core process modules to assure a smooth transition from lab to fab.

SoLayTec products: Process Developement Tool (left) and High Volume Tool.

This paper will elaborate on the scope of system thinking, including organisational and business aspects on top of integral technical architecture.

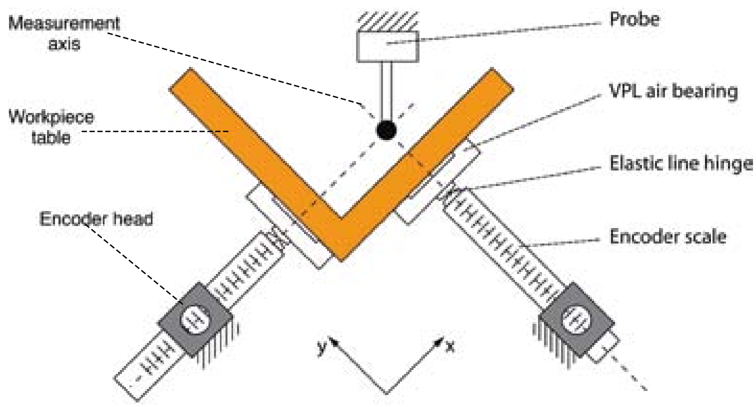
SESSION 5 NEW BUSINESS – 2

Design aspects of the TriNano ultra precision CMM

Ton Moers, E.J.C. Bos, M.C.J.M. van Riel (Xpress Precision Engineering)
www.xpresspe.com

A novel coordinate measuring machine (CMM) has been developed to provide a cost-effective solution for measuring micro components with a 3D uncertainty of 100 nm. The workpiece table in the TriNano CMM moves in three directions with respect to a stationary probe. This is achieved by means of three identical linear translation stages. The stages are positioned orthogonally and in parallel and support the workpiece table via vacuum preloaded (VPL) air bearings. This paper describes the design and part of the verification experiments concerning repeatability and surface scanning using a Gannen XP 3D probing system.

Two important aspects that determine the performance of this CMM are stability and the dynamic behaviour during scanning. After compensation for thermal expansion, single-point measurements show that the repeatability is within 28 nm during a 3 hours period. The difference between repeated scanning cycles at 1 mm/s is within a band of ± 20 nm.



Schematic 2D representation of the TriNano, after the workpiece table – starting from its neutral position – has made a translation in the y direction.

SESSION 5 NEW BUSINESS – 3

Revolutionizing the PCB industry with an industrial inkjet printing soulution

Henk Jan Zwiers (MuTracx)
www.mutracx.com

MuTracx is an Océ spin off founded in 2009 based on an application search by Océ at the Inkjet Application Centre on the High Tech Campus Eindhoven. Its focus is to revolutionise the production of printed circuit boards (PCBs) by producing the world's first industrialised PCB printer based on inkjet technology to replace conventional lithography.

MuTracx's launch product Lunaris addresses a $3 billion segment of the PCB market, i.e. inner layer manufacture. Lunaris's disruptive technology offers exceptionally high yield and productivity gains. Advantages over contemporary inner layer production include faster turnaround, lower integral running costs, less complexity, and guaranteed 100% yield.
Additionally, Lunaris will bring ecological benefits, reducing the impact on the environment by PCB manufacturers. Lunaris is an additive process and will only add non-toxic photoresist where needed.

The technology base of Lunaris is CrystalPoint Technology, Océ's proprietary printhead-toner combination. High productivity is achieved through a combination of an accurate printhead and accurate dot positioning on the media. From the start of the Lunaris project the target market with its specifics were taken into account in the product architecture. Key parameters were a seamless fit with the existing infrastructure of etch and strip lines, a fully automated flow panel handling, a clean machine and a very strict control of the bill of materials and running costs. This last point was achieved through a unique cooperation with industrialisation partners and primary design choices based on mechatronics and an in-process scanner.

Recently, the first beta placement was launched. In the future, the platform has the potential of higher throughput and finer imaging with smaller drop size heads.

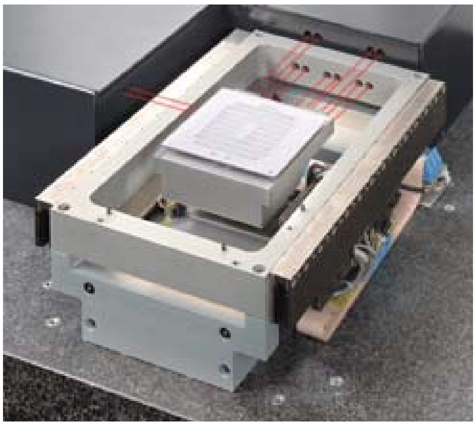
SESSION 6 MOTION CONTROL II – 1

A practical comparison of feedforward control design techniques for high-precision motion systems

Dennis Bruijnen, N. van Dijk, J. Songtao (Philips Innovation Services)
www.innovationservices.philips.com

High-precision motion systems are being pushed to the limit in terms of speed and accuracy. Although system designs are typically driven by stiffness, performance deteriorates due to the flexibilities present at relatively high frequencies. Philips Innovation Services investigates how to cope with such system limitations. One of the projects is the "Pieken in de Delta"-project called XTreme Motion.

In general, this project aims at improving next-generation lithography equipment for 450mm wafers. One of the topics focuses on development of advanced control strategies for positioning systems. In this paper, several feedforward (FF) control design techniques are compared in practice. The experimental setup under consideration is the N-Forcer, a 6-DoF magnetically levitated positioning system with one long stroke of approximately 0.1 m. The strokes in the remaining directions are 0.2 mm and 2 mrad. The position is measured using interferometry with a resolution of 0.6 nm.
It is concluded that so-called Beyond Rigid Body (BRB) FF is able to improve tracking performance by reducing excitation of system flexibilities.



N-Forcer setup.

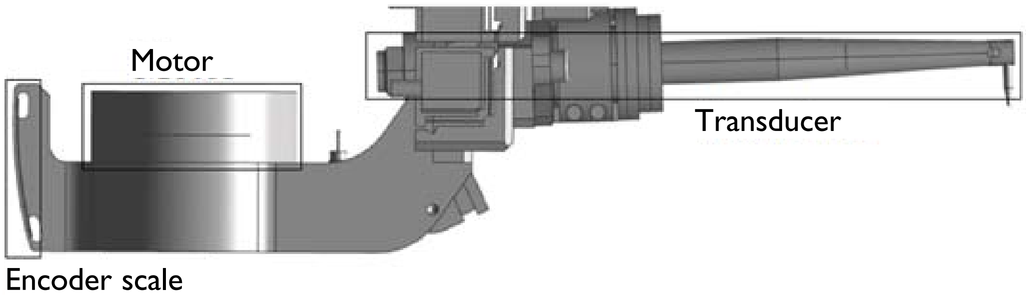
SESSION 6 MOTION CONTROL II – 2

NXP ITEC implements advanced control in high speed wire bonder

Thiemo van Engelen (NXP Semiconductors)
www.nxp.com

To be able to decrease the production cost of standard discrete products, ITEC, a department of NXP Semiconductors, had to develop a wire bonder that is 50% faster than its current generation wire bonder, without compromising product quality. The movements in wire bonding are performed using four servo axes, of which the Z axis is the most important one for the work presented in this paper; it moves up and down an ultrasonic transducer which carries the wire at its tip.

To meet the required cycle time of 100 ms, the acceleration of the Z axis had to be increased from 300 m/s² to 800 m/s². When using these accelerations without further changes, the velocity settling on the tip of the transducer will not be not good enough to produce within specification. To counter this, two improvements were made in the motion control software, namely optimal feedforward generation and trajectory filtering.



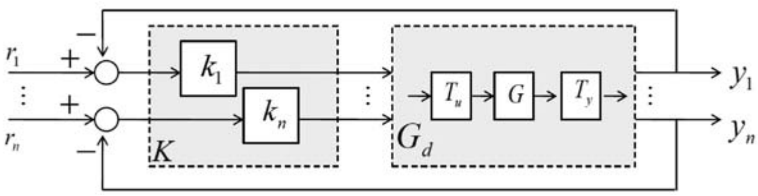
The Z axis mechanics, consisting of a voice coil motor and an encoder scale connected to a main support structure of aluminum. This structure is connected with hinges to an XY table. The support structure also contains a clamp bush that clamps the ultrasonic transducer that is made mainly of steel.

SESSION 6 MOTION CONTROL II – 3

Data-based control design methods for lightweight high-precision motion systems

Rob Hoogendijk, R. van de Molengraft, M. Steinbuch
(Eindhoven University of Technology)
www.tue.nl

The trend towards lightweight design of high-precision motion systems poses a challenge for the control design. Due to the reduced stiffness of these systems, low-frequency structural modes tend to decrease the performance. This calls for advanced control strategies. In control literature, many model-based approaches can be found, e.g. H-infinity control. These methods require an accurate model of the system, and are not very intuitive.



General negative feedback structure for MIMO system under decentralised control.

Research has been aimed at extending the currently used control design techniques, such that they can be applied to systems that have low-frequency structural modes. Topics include the design of decoupling matrices T_u and T_y that decouple the rigid-body degrees of freedom as well as the flexible modes to improve system performance. This is especially beneficial if the system has more actuators and sensors than rigid-body modes, which is sometimes referred to as over-actuation. Another research topic involves the computation of closed-loop poles of the system without a parametric model, using frequency response data. By visualising the closed-loop poles, the damping of the low-frequent structural modes can be predicted during the control design process.

Angle Sensing Bearings for electric traction: Precision for induction motor commutation

Henk Mol (SKF Engineering and Research Centre)
www.skf.com

Large induction motors are popular for traction purposes due to their low cost with respect to the power offered and a long trouble-free life. SKF offers traction motor bearings with electrical isolation avoiding spark damage, a flange to make mounting simple, and an integrated angle sensor to replace an externally mounted solution. Advantages of a sensorised traction motor bearing unit include a more compact total motor design, and a more robust sensor compared to the bolt-on solution.
In an induction motor control system one requires not only currents (and voltages) of the stator, but also the instantaneous rotor speed to meet the required torque and output speed. Speed measurement is done by asynchronous sensors that deliver a number of pulses per revolution. A quadrature (90 degrees shifted) signal pair allows both speed and direction measurement.
The sensor solution combined with bearings is based on magnetic principles. Magnetic sensors are in principle not sensitive to lubricants, and are very robust with respect to temperatures and mechanical tolerances. In case of large production volumes, the solution consists of a permanent magnetic ring that rotates, and Hall effect or magnetoresistive sensors that detect the resulting fields. The niche solution uses magnetic principles as well, but then exploits the variable-reluctance principle. Variable-reluctance angle sensors use steel rings or discs with cut or stamped patterns. The magnetic field sensors are biased by permanent magnets and the pattern in the rotating ferritic steel target modulates the bias field and thus reveals the angle information.

This paper discusses the case of a traction motor bearing unit that was modified into a prototype sensor bearing, for accurate measurement of the running speed of the AC induction motor.

SESSION 7 PRECISION TECHNOLOGY II – 2

FEM model based POD reduction to obtain optimal sensor locations for thermal-elastic error compensation

Jack van der Sanden, P. Philips (Philips Innovation Services)
www.innovationservices.philips.com

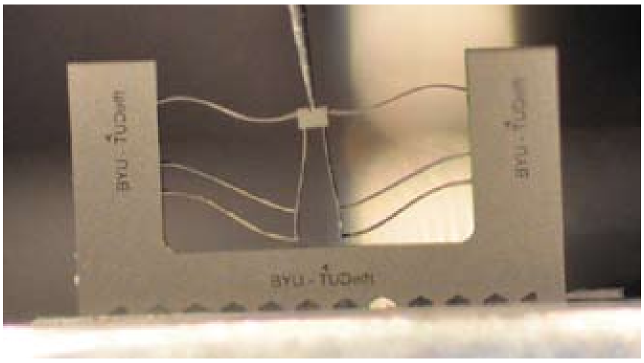
Thermal-elastic deformations are often the biggest contributors to position errors in precision machines. An approach to minimise position errors due to thermal-elastic deformations is the use of a thermal error compensation model. Basically, this is a matrix that predicts the relation between the temperature readings of a limited number of sensors on a structure and the position shift of the point(s) of interest.
Structural Modal model reduction shapes are commonly used in dynamic analysis, e.g. to make compact system models for analysis of position errors due to dynamic vibrations. The use of Modal, Arnoldi and POD (Proper Orthogonal Decomposition) reduction techniques for thermal analysis has been introduced to obtain thermal compensation models. Which technique to use depends on the available knowledge of the system.
In case only the thermal system properties (heat capacity and internal thermal conductivity) are known, one is limited to Modal reduction. In case the positions of heat loads are also known, Arnoldi reduction might be applied as well. If also the time dependencies of the heat load variations are known, POD reduction can be applied. The more system information is known, the bigger the chance a good reduced model can be obtained with a relative low number of temperature shapes/states. Therefore, if time-dependent information is available POD reduction seems to be the most appropriate reduction method.
A method is presented – and illustrated for the case of a precision stage – to apply POD reduction on a FEM model to obtain the most dominant temperature shapes for describing the thermal-elastic behaviour. The resulting temperature shapes have a high number of possible sensor locations to choose from. This requires an efficient method to find optimal sensor locations to observe the dominant temperature shapes.

SESSION 7 PRECISION TECHNOLOGY II – 3

Carbon-Nanotube-Based Constant Force Mechanisms

Nima Tolou, P.P. Pluimers (Delft University of Technology), B.D. Jensen, S. Magleby, L. Howell (Brigham Young University), J.L. Herder (Delft University of Technology)
www.tudelft.nl, www.byu.edu

Many devices benefit from microelectromechanical systems (MEMS). In particular, constant force compliant micromechanisms (CF-CMM) are needed for several applications such as in medical devices and electrical switches. However, constant force mechanisms have never been presented at the microscale. This paper presents the first carbon-nanotube-based microscale constant force compliant mechanism.



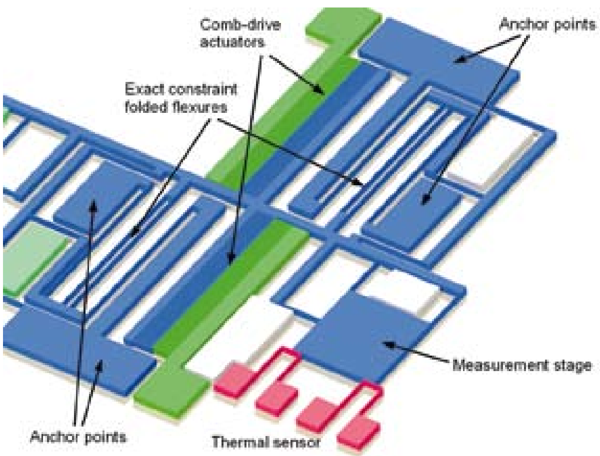
Close-up of a CF-CMM fabricated in the CNT-M process shows the deflection during measurement.

A bi-stable mechanism and a crab-leg suspension (i.e. linear stiffness spring) have been combined to create a constant force. The mechanism was fabricated out of a forest of carbon nanotubes (CNTs) in order to enhance the mechanical properties. The CNT-based CF-CMM showed a long constant force stroke (840 µm) with an error of less than 4%. Moreover, CNT-templated Microfabrication is suitable for fabrication of zero-stiffness structures (i.e. CF-CMMs) due to small hysteresis, high aspect ratio fabrication with small fabrication error for in-plane thicknesses and exceptionally large ratio of Young's modulus to the yield strength.

SESSION 8 SYSTEM ENGINEERING AND DESIGN II – I

A closed-loop large range of motion positioning system in MEMS

Bram Krijnen, D.M. Brouwer (Demcon Advanced Mechatronics, University of Twente)
www.demcon.nl, www.utwente.nl



An overview of the complete microsystem. The parts that are electrically insulated from each other are depicted in different colours.

In MEMS (microelectromechanical systems) thermal or electrostatic actuators in combination with flexure-based stages are able to reach sub-micrometer positioning accuracies. However, accurate positioning is limited by many factors, such as drift, external disturbances and load forces. Adding feedback control, and thus position sensing, can enhance the performance of MEMS positioning systems.

A closed-loop positioning system in MEMS with integrated sensor was designed, fabricated and tested. The flexure mechanism, electrostatic actuators and thermal position sensor have all been designed for integration in a fairly simple single-mask fabrication process. Control of the flexure-based MEMS stage is straightforward; the stage hardly suffers from friction, play and hysteresis. A PID controller with additional low-pass filter and feed-forward for stiffness compensation can position the MEMS stage with an accuracy of 80 nm; the integrated thermal position sensor is used for feedback control.

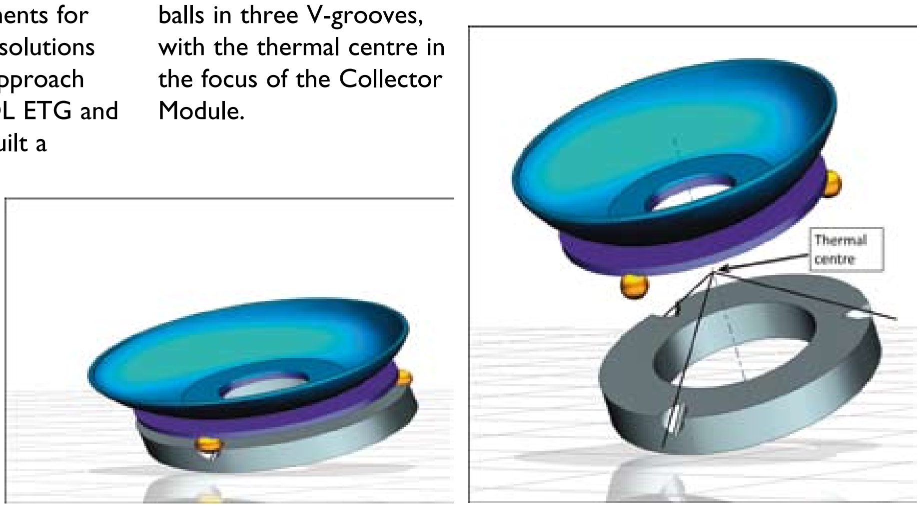
SESSION 8 SYSTEM ENGINEERING AND DESIGN II – 2

"Systems thinking" to meet contradicting system requirements

Gerrit van der Straaten (Settels Savenije van Amelsvoort)
www.sttls.nl

High accuracy, high thermal loads and a high-vacuum environment seem to be contradicting requirements for the design of a system. By separating functions, solutions were found to meet these requirements. This approach requires "systems thinking" on system level. VDL ETG and Settels Savenije van Amelsvoort designed and built a vacuum system ($D \times h$ = 1.5 m x 1 m) for a light source for EUV lithography, where mechanical tolerances are within 100 μm absolute and less than 10 μm on local level. With a vacuum frame that absorbs the heat load and creates a vacuum environment, and an accurate metrology frame to create accurate mechanical interfaces, all specifications were met.

Part of the tolerance stack of the system is the Collector Module interface. The Collector Module is mounted in the metrology frame. The requirements on absolute accuracy are high, but there also is a strict requirement on repeatability when replacing the component. A stiff kinematic mount was designed: three balls in three V-grooves, with the thermal centre in the focus of the Collector Module.



The kinematic mount with the thermal centre.

SESSION 8 SYSTEM ENGINEERING AND DESIGN II – 3

Mechatronic Challenges in Extreme Ultra Violet Projection Optics

Rob de Jongh (ASML)
www.asml.com

The purpose of an ASML lithography tool is to expose wafers with a light pattern defined by a mask, or reticle. To be able to do this, the system contains subsystems including: wafer stage(s), reticle stage, projection optics, reticle masking, illuminator, etc. Both reticle stage and wafer stage are, from a mechatronic point of view, important sub-modules. These modules combine high speed and acceleration with tight position accuracy specifications. Projection optics also have specific mechatronic challenges compared to stages: Multiple optical elements are controlled up to six degrees of freedom, with high accuracy, to meet the optical specifications of the ASML lithography tool.

The transition from deep ultraviolet (DUV, λ = 100 .. 300 nm) to extreme ultraviolet (EUV, $\lambda \approx$ 13,5 nm) is an enabler to reduce the critical dimension (the smallest feature size that can be exposed by the system) in a substantial way. This transition has significant impact on the projection optics design:

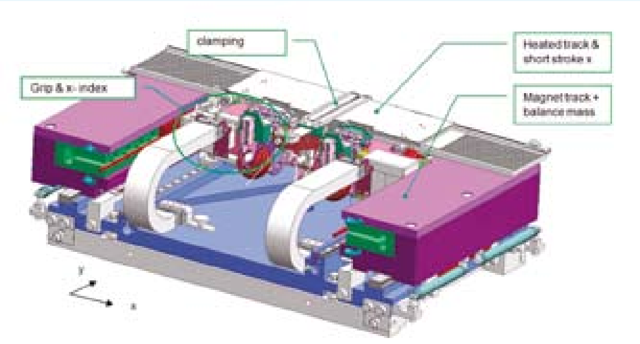
- EUV light is absorbed in air, so the system must be operated under high vacuum.
- EUV light is absorbed by glass; refractive optics must be replaced by reflective optics.
- EUV light will break carbohydrate into carbon hydrogen and oxygen; carbon limits the lifetime of mirrors.
- EUV mirrors are limited in the angle of incidence.

It will be shown that, compared to stage design, the controller design of projection optics is relatively easy. Challenging, however, are sensor requirements, actuator design, structural dynamics and the reduction of environmental vibrations.

Implementing a balance mass in the linear stage of a die-bonding machine for improvement of die-placement accuracy

Albert Verburg (NXP-ITEC, *www.nxp.com*)

The stage described here positions a carrier leadframe underneath a pick and place module. In order to reduce the reaction forces to the machine frame and reduce disturbance of the stage itself and other modules, a balance mass was introduced. Both the actuator and balance mass had to be split up in two, in order to actuate in the center of gravity of the stage. The resulting dual drive system is operated in MIMO-mode, controlling both position and rotation. The challenge was to realise many functions within a limited volume and mass budget.



Towards 3D cantilever sensitivity for AFM applications

Richard Koops, V. Fokkema (VSL, *www.vsl.nl*),
F. Bastiaansen, P. Brandhoff, H. Miro (Delft University of Technology, *www.tudelft.nl*)

The interaction mechanism in an atomic force microscope (AFM) typically results in unidirectional sensitivity, because the AFM only detects the deflection changes due to probe-sample interactions of the first bending mode of the cantilever. For high-end applications additional information on, e.g., side walls of nanostructures has become increasingly important, but this information is difficult to record using conventional cantilevers. This poster will present an approach towards 3D sensitivity for AFM based on simultaneous excitation and optical detection of multiple resonance modes of micro-engineered cantilevers.

Magnetic Bearings

Defeng Lang (SKF, *www.skf.com*)

No addititional information available at the time of publication.

A Load Carrying Stage with Low Stiffness in Six Degrees of Freedom

Gerard Dunning, N. Tolou, J.L. Herder (Delft University of Technology, *www.tudelft.nl*)

Based on an inventory of available architectures, a compliant structure is proposed in which all six degrees of freedom are statically balanced (i.e. near zero stiffness) while the device is subject to gravity. This will cancel out the stiffness due to the compliant design of the structure. A demonstrator was manufactured and finite element modelling was performed to evaluate the concept.

Near-Zero-Stiffness Linear Motion Stage with High Orthogonal and Out-of-plane Stiffness

Nima Tolou, P.P. Pluimers (Delft University of Technology, *www.tudelft.nl*), B.D. Jensen, S. Magleby, L. Howell (Brigham Young University, *www.byu.edu*), J.L. Herder (Delft University of Technology)

A major concern when fabricating precise linear motion stages is to ensure the high stiffnesses orthogonal and out-of-plane to the motion direction while having a near-zero-stiffness in the motion direction. A linear motion precision stage is proposed that essentially does not need any energy for any precise motion while having very high orthogonal and out-of-plane stiffnesses. This design potentially may change the design boundaries in precision engineering. Currently micro versions are being developed.

Passive seismic attenuation as applied in gravitional wave detection

Eric Hennes et al. (Nikhef, *www.nikhef.nl*)

If a gravitational wave passes the earth, it will deform space. To prove that those waves exist VIRGO has been built near Pisa. VIRGO is a detector using a Michelson interferometer to measure the length difference of its two arms. Each of these arms is 3 kilometers long. A passing gravitational wave makes one arm longer and the other shorter or vice versa. These length fluctuations are typically 10^{-18} meters, this is 10,000 times smaller than an atomic nuclear diameter. Seismic vibrations disturb the measurements of VIRGO. NIKHEF and partners developed a seismic attenuation system, which will be presented.

Multi-stage seismic attenuation system for the Advanced VIRGO gravitational wave detector

Eric Hennes et al. (Nikhef, *www.nikhef.nl*)

Advanced VIRGO will measure relative length differences in the range 10 Hz to 10 kHz down to $4 \cdot 10^{-24}$ at 200 Hz. An in-vacuum optical bench houses optics for alignment of the interferometer beams and the detection of the gravitational wave signal. The bench is seismically isolated horizontally by suspending it from two single wires in cascade. Three inverted pendulums isolate the top stage. Vertical seismic isolation is obtained from two geometric anti spring filters.

Horizontal seismic isolation with an inverted pendulum

Eric Hennes et al. (Nikhef, *www.nikhef.nl*)

The design of an inverted pendulum for horizontal seismic isolation will be presented.

Geometric Anti Spring (GAS) Filter used for vertical seismic isolation

Eric Hennes et al. (Nikhef, *www.nikhef.nl*)

Demonstration of a model system, with a large mass suspended from three blade springs. The blades are mounted on a filter plate, which is set into oscillation, mimicing seismic motion. By horizontal compression of the blades the stiffness strongly decreases, resulting in a lower resonance frequency and a much larger attenuation.

More-than-Moore: technical challenges and opportunities for the Dutch high-tech industry

Sander Gielen, C.M.B. van der Zon, C.A. Yuan (TNO, *www.tno.nl*)

Many of today's societal issues require multi-disciplinary solutions that in many cases are implemented in highly integrated, autonomous, networked and energy-neutral electronic devices, so-called More-than-Moore devices. The Netherlands can take the lead in resolving most of the technological challenges involved and can create many new products, processes, and equipment solutions for cost-effective More-than-Moore devices.

Role of System Architect underestimated in development projects

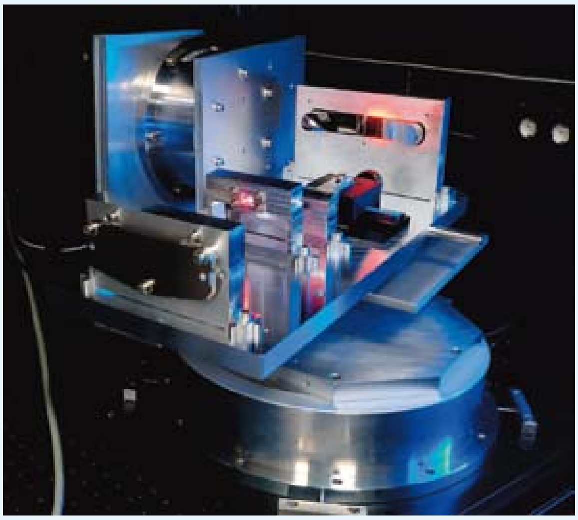
Max van den Berg (Festo, *www.festo.nl*)

When in product development a project leader is responsible for time, money and quality, this is a task that takes too much of one person. Using the skills of a system architect – well-known in the IT industry, not so familiar yet in the high-tech industry – for watching over the consistency of the design as a whole, may change things for the better. The role of the system architect is to balance technology, costs, competences, and time, but also politics within the organisation.

The TROPOMI telescope: design, fabrication and test of a freeform optical system

David Nijkerk, R. Henselmans, F. Draaisma, A. Hoogstrate, B. van Venrooy (TNO, *www.tno.nl*)

The TROPOspheric Monitoring Instrument (TROPOMI) is an advanced absorption spectrometer for Earth observation. This push-broom instrument combines a very large field of view of 2,600 km with a 7 km resolution and a spectral range encompassing UV, VIS, NIR and SWIR bands. A test setup for the freeform optical system was built and it demonstrated that the spotsize performance of the freeform telescope exceeds its conventional spherical predecessor used in the Ozone Monitoring Instrument (OMI) by an order of magnitude.



Carrierless substrate motion concept for spatial ALD reactor

Ad Vermeer, I. Kerp (SoLayTec, *www.solaytec.com*)

For spatial Atomic Layer Deposition (ALD) the carrierless substrate motion concept was applied in the core process module. Carrierless operation is preferred to reduce heat consumption and maximize reliability and uptime (no cleaning) at the lowest cost. This has led to the concept of a substrate floating between symmetrical surfaces on a gas bearing, also functioning as a gas separation for the precursor gases that cause contamination if they get mixed.

Secure tailgating in a tunnel

Jelmer Kamminga, N. de Vos (ASML, *www.asml.com*)

Imagine driving 80 km/h into a tunnel with two heavily suspended trucks only 0.5 mm apart and 4 mm clearance to the ceiling. This is in a nutshell the scaled situation during a chuck exchange in a known advanced lithographic apparatus. Multiple safety mechanisms may continuously run to guarantee the safety of the machine and the (exposed) wafers. This process may be summarised as Machine and Materials Damage Control (MMDC).

Future perspective of system dynamics in microchip manufacturing

Alexander Steenhoek (ASML, *www.asml.com*)

The roadmap for ever smaller feature sizes in chip technology drives production to tighter precision specifications. For the lithography technology used within ASML this introduces tighter specifications on the precision alignment. The contribution of dynamics to this alignment is important to meet the overlay and focus targets. It will be discussed how the lithography roadmap translates into new challenges and the desire for new solutions from the perspective of system dynamics.

System thinking in high-accuracy motion stages: Improving servo performance by over-actuation and over-sensing

Marc van de Wal, W. Aangenent, S. van der Meulen (ASML, *www.asml.com*), J. van Eijk (MICE, *www.micebv.nl*)

Increasing dimensions and/or reducing mass of substrate wafers, for example by the transition towards 450 mm wafers, will result in more flexible structures. To enable accurate servo control of such 'FlexStages', motion design of the Rigid Body (RB) modes must be combined with active vibration control of the Non-Rigid Body (NRB) modes.

High-Performance Motion Control of Lightweight Systems: Advanced Modeling, Multivariable Compensation

Robbert van Herpen, T. Oomen, M. Steinbuch, O. Bosgra, F. Boeren, J. van Wijk (Eindhoven University of Technology, *www.tue.nl*), M. van de Wal, W. Aangenent, S. van der Meulen (ASML, *www.asml.com*)

When large accelerations are applied to a lightweight motion system with flexible dynamical behaviour, the system will undergo intrinsically multivariable deformations, which are detrimental to high positioning accuracy. Therefore, multivariable compensation is crucial. Model-based control provides a systematic way to synthesise multivariable controllers. Results will be presented.

Does Generic Motion Control Exist? – A Roadmap for Industrial Motion Control in High Tech Applications

Wilco Pancras, B. Verhelst (Bosch Rexroth, *www.boschrexroth.nl*)

Architecture complexity increases with increasing demands on motion performance. The associated motion control challenge may be addressed by using distributed application software. Drivers for this development include increasing system complexity; the rise of modular and scalable systems; tighter coupling between axes, IO and vision. Enablers include increased processing power; multicore technology; availability of (RT)Oses. A solution for future motion control will be proposed.

Learning control systems for high performance printing

Joost Bolder (Eindhoven University of Technology, *www.tue.nl*)

In printing systems, the positioning accuracy of the medium with respect to the printheads directly impacts print quality. Most media have the tendency to deform during printing due to variations in temperature and moisture content. To compensate for these deformations, Iterative Learning Control (ILC) may be used. It is demonstrated that ILC improves the tracking accuracy of a motion system substantially.

Extend your PI, SI and EMC requirements to enable profound modular Mechatronic designs

Mart Coenen (EMCMCC, *www.emcmcc.nl*)

The required precision, speed, efficiency, stability, reliability and safety of mechatronics systems are co-determined by the reliability of all kinds of sensors with electronics, embedded controllers and PWM motion drives with increasing performance and bandwidth. When building modular mechatronic sub-systems together, next to inter-system compliance (CE-mark) also intra-system PI, SI and EMC have to be addressed to ensure reliable operation at the required performance level.

Design for Diagnostics – An Approach for Improving High Tech Systems Problem Solving

Evert van de Plassche (Greentech Engineering, *www.greentech-engineering.nl*)

High-tech systems tend to be state-of-the-art, but immature when they leave the factory. They frequently have teething problems and field updates. Traditional diagnostic methods do not fill the knowledge gap between experts (designers) and generalists (field service engineers). An approach is discussed for shortening the availability ramp-up by design for diagnostics, focusing on diagnostic strategies and the optimisation of feedback from the field.

Active Vibration Isolation Control Design: a Sliding Surface Approach

Chenyang Ding (NTS System Development, *www.nts-group.nl*)

High-performance active vibration isolation systems (AVIS) are crucial for many high-precision machines. An AVIS is used to minimise a payload *absolute* displacement under two categories of disturbance sources: base vibrations and directly acting disturbance forces. A sliding surface approach is proposed to make the control design easier and to push the closed-loop performance to system limit.

A predictive control strategy for productive printers

Ewout van der Laan (Océ Technologies, *www.oce.com*), Carmen Cocchior (Eindhoven University of Technology, *www.tue.nl*), Danny Driessen (Océ Technologies)

In industrial printers, productivity combined with sufficient print quality is often a key performance indicator. Performance, however, is influenced by many uncertainties. The challenge is to maintain maximum productivity, given the limitations of industrial embedded systems. Inherently, using robust feedback controllers comes at the cost of performance. An alternative is adaptive control, provided that the system behaves predictable, and that sufficiently accurate models and measurements are present.

Performance results of the LISA thermal vacuum chamber

Martin Lemmen, A. Verlaan, T. Duivenvoorde, H. Hogenhuis (TNO, *www.tno.nl*)

The LISA (Laser Interferometer Space Antenna) thermal vacuum chamber has to measure the coefficient of thermal expansion (*CTE*) of the LISA telescope assembly ($< 10^{-7}$ K^{-1}) with (sub)nanometer accuracy. It was designed for high optical stability measurements. Extremely low vibration levels and high temperature stability of a test subject and the environment (< 0.01 K) were achieved. Remote and accurate control of the facility proved possible, using a Eurotherm control system (T2550).

Micro Metal Direct Write – Robust Process Windows for Laser Induced Forward Transfer

Merijn Giesbers, G. Oosterhuis, A. Prenen, M. Hoppenbrouwers, S. van Melick, B. Huis in 't Veld (TNO, *www.tno.nl*)

Laser Induced Forward Transfer is a single-step, dry deposition process that shows great potential for direct writing of micrometer-scale metal structures. The influence of process parameters such as laser pulse length and wavelength, as well as donor layer thickness, has been studied experimentally and by modeling, to enable the production of robust, contamination-free deposits using thin-film copper as donor material. With these deposits a pattern of 8μm wide copper lines has been produced.

System level integrated modeling and testing of the Optical Tube Assemblies for the ESO VLT Four Laser Guide Star Facility

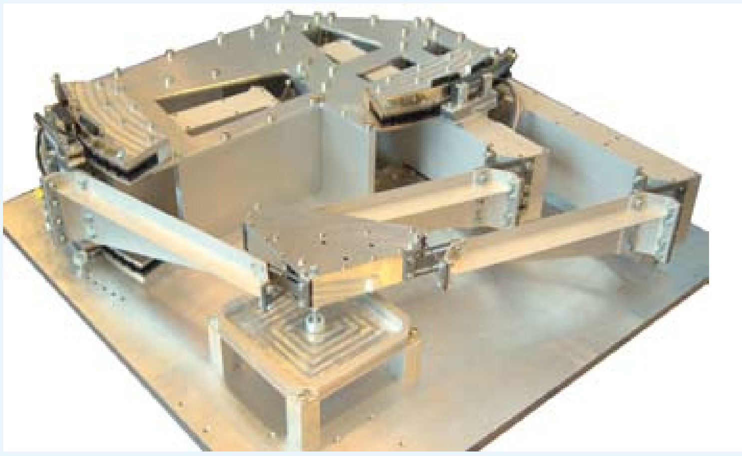
Rens Henselmans, M. Lemmen, D. Nijkerk, F. Kamphues (TNO, *www.tno.nl*)

TNO has developed the Optical Tube Asssemblies (OTAs), using an integrated system level modelling approach to predict the thermally induced defocus of the system, by combining optical, lumped-mass and FE analyses. Thermal tests have shown the good correlation between the model and the actual system. The OTAs meet their requirements, and four units have recently been delivered to the European Southern Observatory (ESO).

Flexure hinge with a high support stiffness in a large range of motion

Dannis Brouwer (University of Twente, *www.utwente.nl*; Demcon, *www.demcon.nl*), S.E. Boer, D.H. Wiersma, K.G.P. Folkersma (University of Twente), H. Jacobs (University of Twente, Demcon), R.G.K.M. Aarts, J.L. Herder (University of Twente)

Flexure-based mechanisms do not suffer from friction, stiction or backlash, and therefore they show a high level of determinacy. Several new flexure hinge designs will be presented, as well as a method for optimising the geometry of flexure hinges to maximise the support stiffness over a range of motion. The results will be demonstrated by a two-degree-of-freedom stage that combines a large range of motion with high eigenfrequency.



Force and stiffness calibration unit for scanning probe instruments

Hamed Sadeghian, P. Harmsma, T.C. van den Dool (TNO, *www.tno.nl*)

An accurate determination of the AFM (atomic force microscope) cantilever spring constant is the keystone to fulfil the needs of future high-resolution force spectroscopy. A recent development regarding a force and stiffness calibration unit for AFM applications will be presented. The unit consists of a micromechanical lever integrated with a nanophotonics ring resonator and accompanying micro-scale mechatronics, allowing for very low noise performance and a reasonably high sensitivity.

SOI based mechano-optical pressure sensor

Shahina Abdulla, P. Harmsma, R.A. Nieuwland, J. Pozo, M. Lemmen, H. Sadeghian, J.H. van den Berg, P. Bodis (TNO, *www.tno.nl*)

Silicon-On-Insulator (SOI) components characteristics include: mechanically robust; small size, low weight; ideal form factor for precise temperature control; CMOS compatible fabrication: low-cost, high volumes and quick time-to-market. An integrated photonic pressure sensor based on a folded micro ring resonator on a circular diaphragm was successfully designed, fabricated and characterised. It may be a potential candidate in a multi-parameter sensor network.

Metrology for ultra-precise form characterization of optical surfaces

Rob Bergmans, G. Kok, H. Nieuwenkamp (VSL, *www.vsl.nl*)

Measuring optical surfaces to an accuracy of less than 1 nm for flats and some tens of nm for aspheres and freeforms remains a challenge on an industrial level as of today. Therefore under the European Metrology Research Program a project has started to achieve fundamental improvements in measuring high-quality optical surfaces. The focus of VSL is on the improvement of single-point scanning techniques, both tactile and optically.

Opto-mechatronics imaging system with 3D stitching method for micron accurate in-situ industrial measurements

Milan Maksimovic, J.A. Kauffman, G.M. Beumer, R. Niemans, G. van den Eijkel, R. Evers (Focal Optical Systems & Machine Vision, *www.focal.nl*)

A mature machine vision technology was used, based on a depth-from-focus estimation algorithm for obtaining 3D measurements. Special emphasis on synchronisation between the imaging module and the scanning mechatronics in the z-range provided stable and accurate 3D imaging of objects with complex shapes. An advanced 3D matching algorithm was used to stitch depth measurements into a single image. Test results will be presented.

System architecture and design of the iFlex

Roelof Hoefs, R.A.J. van der Burg (Assembléon Netherlands, *www.assembleon.com*)

The past focus in the Pick and Place SMT machine industry on production quality (placement quality) and cost per placement/cost of operation does not suffice today. Flexibility in production equipment is required as well. Assembléon translated the flexibility requirement into a completely new machine concept, the iFlex. The presentation will focus on the system architecture and the development process.

Frequency Domain Based Performance Optimization of Nonlinear Systems

David Rijlaarsdam, P. Nuij (NTS Systems Development, *www.nts-group.nl*; Eindhoven University of Technology, *www.tue.nl*), M. Steinbuch (Eindhoven University of Technology)

The widespread acceptance and applicability of frequency domain techniques for linear and time-invariant systems has been an impetus for the extension of these methodologies towards nonlinear systems. However, this is generally not straightforward. A novel frequency domain based approach for detection, quantification and optimal compensation of performance-degrading nonlinear effects will be presented.

Mikroniek guide

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Schaeffler Nederland B.V.
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W www.tno.nl

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W www.engenia.nl

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Postbus 2
3700 AA Zeist
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