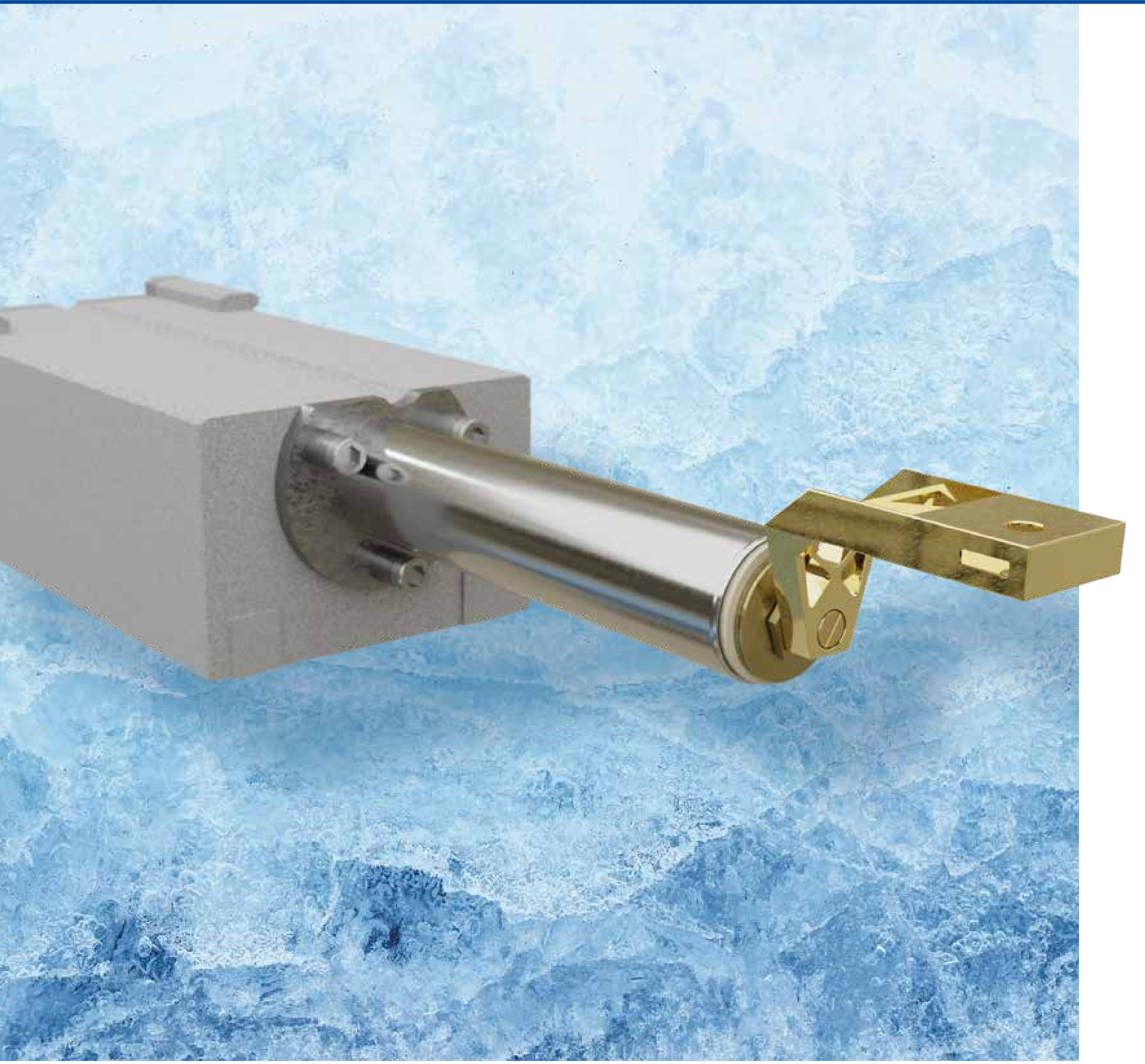
DSPE MIKRONIEK

2022 (VOL. 62) ISSUE 3

PROFESSIONAL JOURNAL ON PRECISION ENGINEERING



- THEME: COOLING & CRYOGENICS
- ZERO-VIBRATION COLD TIP FOR CRYOGENIC ELECTRON MICROSCOPY
- IN-LINE INTERFEROMETRY FOR PRECISION IN ROLL-TO-ROLL PRODUCTION
- WIM VAN DER HOEK'S DESIGN PRINCIPLE OF ENERGY MANAGEMENT

MIKRONIEK IS A PUBLICATION OF THE DUTCH SOCIETY FOR PRECISION ENGINEERING – WWW.DSPE.NL

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.

DSPE
YOUR PRECISION PORTAL

Publisher
DSPE
Julie van Stiphout
High Tech Campus 1, 5656 AE Eindhoven
PO Box 80036, 5600 JW Eindhoven
info@dspe.nl, www.dspe.nl

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

Advertising canvasser
Gerrit Kulsdom, Sales & Services
+31 (0)229 – 211 211, gerrit@salesandservices.nl

Design and realisation
Drukkerij Snep, Eindhoven
+31 (0)40 – 251 99 29, info@snep.nl

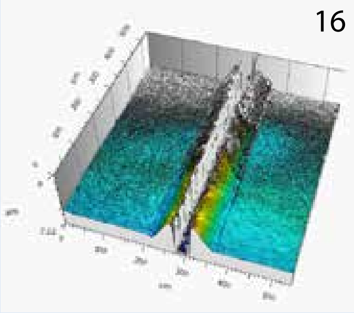
Subscription
Mikroniek is for DSPE members only.
DSPE membership is open to institutes, companies, self-employed professionals and private persons, and starts at € 80.00 (excl. VAT) per year.

Mikroniek appears six times a year.

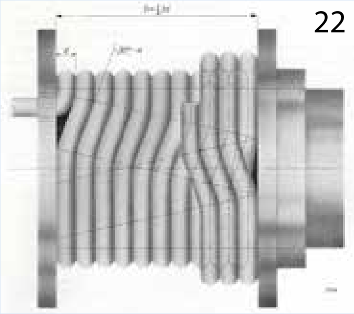
ISSN 0026-3699

The cover image (featuring a cryogenic micro-cooler) is courtesy of Demcon kryoz. Read the article on page 10 ff.

IN THIS ISSUE



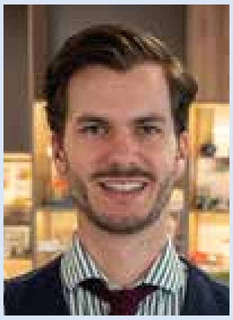
16



22

FEATURES

THE VALUE OF MEETING, COLLABORATING AND SHARING KNOWLEDGE IN FACING CURRENT CHALLENGES IN TECHNOLOGY



With common roots that go back more than 50 years, Mikrocentrum and DSPE recently intensified their collaboration. While collaborating many times over the years, for example on the yearly Precision Fair which is organised by Mikrocentrum, we both realised there are more common grounds. With both having a strong focus on knowledge sharing and networking, we decided to boost our collaboration by co-organising events. One of these new events is the Techcafé.

A Techcafé was born

As of January 2022, I am the new Mikrocentrum High Tech Platform manager. When starting this position, I soon got the opportunity to collaborate with DSPE and together we created the Techcafé. The concept is simple: it's an accessible event where you go for content, new contacts and inspiration. It's the place to discuss tech challenges and exchange best practices. All this is presented in a talk show setting with experts from science and industry. And afterwards we enjoy drinks and bites. The first edition of the Techcafé, on 28 April at our premises in Veldhoven (NL), focused on robotisation, and immediately whetted everyone's appetite for more.

Calling on SMEs

The room was packed and a vibrant discussion by Heico Sandee (founder of Smart Robotics), Mark Stappers (lecturer at Fontys University of Applied Science), Wouter Kuijpers (program officer at Eindhoven University of Technology) and Martin van der Have (sales & marketing manager at ABB) filled up the room. Their message was twofold: on the one hand, they noted that the introduction of industrial robots is still lagging behind considerably and that there are just as many obstacles surrounding this. Yet, at the same time they called on the SMEs present to make a start anyhow. The discussion didn't stay between these four experts, the crowd was also invited to participate and ask questions.

Next up: systems engineering

The enthusiasm for the first edition was so great that the second edition has already been scheduled. 7 July will be all about systems engineering, another typical high-tech theme. We will discuss design issues and their increasing complexity within the high-tech and manufacturing industry. This year, there's also an edition planned on 22 September and there's even a special edition on 16 November during the Precision Fair.

Ecosystem collaboration

The value of facing challenges as an ecosystem instead of one company on its own will become more and more important in the near future. Products are becoming more complex, have to operate faster, require more functions and have to become more and more sustainable and must have a lower carbon footprint. The same applies to the machines that have to make these products, which are also becoming more complex, larger and more critical. In addition, these machines must be delivered faster at a time when the global market is still upside down.

To face these challenges, collaboration is the way forward. This necessity is becoming increasingly clear to me and I'm proud that as the Mikrocentrum High Tech Platform manager, I have the opportunity to facilitate these collaborations and to connect people with each other, together with partners such as DSPE. Ultimately, working together is a lot easier if you already know each other or when you know where to find people who can help.

Maarten Roos
Manager Mikrocentrum High Tech Platform
m.roos@mikrocentrum.nl, www.mikrocentrum.nl

FROM BATHTUB TO REFRIGERATOR

The use of superconducting magnets for high-field magnetic resonance imaging poses a big cooling challenge. Classic magnet cooling technology comes with operational and environmental issues, related to the venting and refilling of large quantities of helium. These issues are overcome by the Philips BlueSeal micro-cooling technology, which uses only seven litres of helium in a fully sealed system. This is just one step on the technology roadmap towards more patient- and environment-friendly MRI systems.

SHUBHARTHI SENGUPTA, MICHEL HAGENAAR AND MAARTEN DEKKER

MRI for hospitals

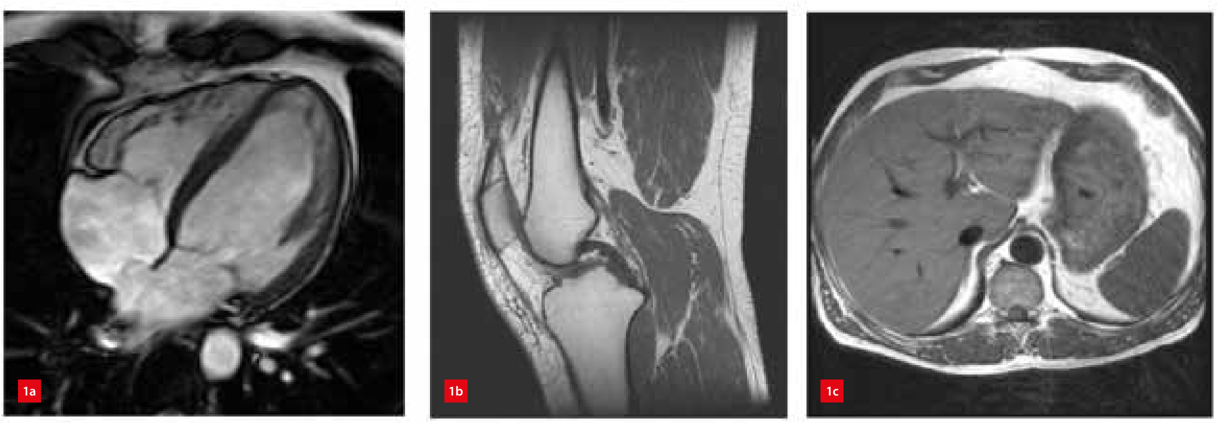
MRI, or magnetic resonance imaging, is the preferred imaging modality when it comes to imaging soft tissues – such as the brain, liver, heart, among others – but also for imaging joints and blood vessels; see Figure 1 for a few examples. In contrast, CT, or computed tomography, scans are used for imaging fractures, tumours and cancer screening. In some cases, a patient may have a CT scan, followed by an MRI – with the images overlaid to determine abnormalities in pathologies.

Classic MRI technology

MRI is an imaging method based on the sensitivity to the presence and properties of water, which – incidentally – makes up between 70% and 90% of most tissues. The amount of water (or to be precise, mobile hydrogen atoms), and thereby its properties, can vary substantially with disease or injury, making MRI a sensitive and useful tool for patient diagnosis. MRI is able to detect the tiny perturbations in the magnetism of the nucleus – the entity at the centre of an atom.

Hydrogen happens to contain the simplest nucleus – a single, positively charged proton. Protons possess an inherent characteristic – spin. Atomic nuclei with an uneven number of protons will have a net spin, known as nuclear spin – as is the case with hydrogen ^{1}H, while nuclei with an even number of protons (and neutrons) do not have a net nuclear spin, like oxygen ^{16}O. This is in line with the Pauli exclusion principle – which posits that in an atomic nucleus, two identical particles cannot be in the same state [2,3].

In free space (without an external magnetic field), the spins are randomly oriented and their effects cancel each other. However, when these same spins are placed in an external magnetic field (such as that of an MR magnet), the spins align themselves parallel (spin up) or anti-parallel (spin down) to the magnetic field. The ratio of spin-up and spin-down states is not 1:1 – instead, there is a small number of excess spins (aligned parallel to the external magnetic field). These excess spins add up, resulting in a net magnetisation *M*. MR imaging exploits this net magnetisation *M* to generate images (Figure 2). Therefore, a well-designed

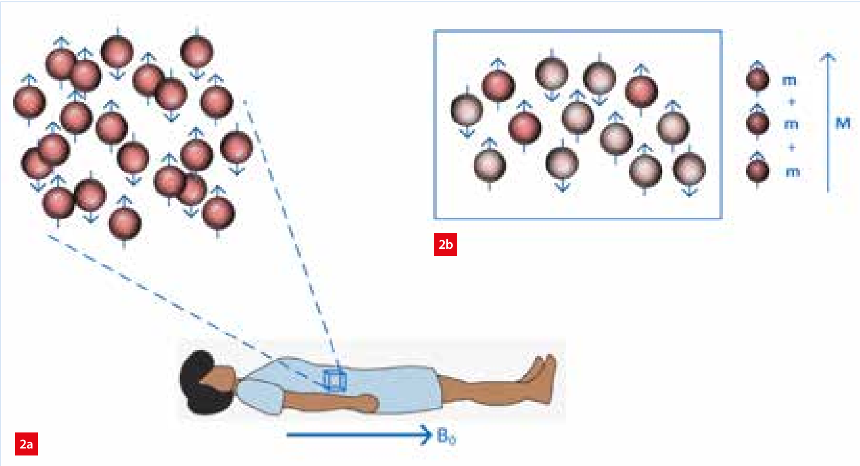


Magnetic resonance imaging applications [1].
(a) Cardiac imaging.
(b) Knee imaging.
(c) Liver imaging.

AUTHORS' NOTE

Shubharthi Sengupta (RF specialist and project leader), Michel Hagenaar (electronic hardware architect) and Maarten Dekker (group leader) all work in the Patient Centric Subsystems group at Philips MRI R&D in Best (NL).

maarten.dekker@philips.com
www.philips.com/mri



MRI's concept of net magnetisation.
(a) Alignment of spins in a small section of the body when subjected to an external magnetic field.
(b) The net vector sum of the spin-up and spin-down states results in a net magnetisation M.

The Philips MRI 5300 1.5T scanner.

magnet that is capable of producing a homogeneous B_0 field (or main magnetic field) is crucial for MRI.

But how do we go from spins to an MRI image? For this, see Figure 3. It requires the confluence of several different hardware and software solutions, working in perfect sync with each other. With the subject prepped for a scan, they are placed inside the bore such that the anatomy under investigation (brain, heart, knee, for example) is centred around the magnet isocentre (the area of the magnet with the most homogeneous B_0 field).

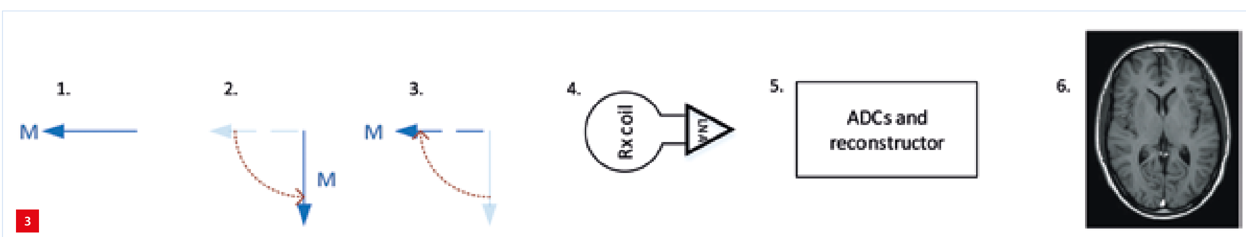
With the spins in the subject aligned along the main magnetic field, an instantaneous RF (radio-frequency) pulse (called a transmit pulse, or B_1 field) generated using a transmit coil is made incident on the subject, orthogonal to the B_0 field. This flips the net magnetisation away from the B_0 field and into the plane transverse to the main magnetic field. Spatial localisation of the MR signal requires the use of three orthogonal linear magnetic field gradients – and these are generated by gradient coils mounted on a cylindrical former just inside the bore of the magnet.

Once the RF excitation plays out, the nuclei start releasing the absorbed energy and slowly move back in alignment with the B_0 field. A receive (Rx) coil, placed in close proximity to the subject, picks up this energy and produces an electrical signal across its terminals. This electrical signal is then fed into a low-noise amplifier that further amplifies the signal, upon which the resulting signal is routed to a signal processor (containing analog-digital convertors and other processing hardware) that helps form the final image [7].

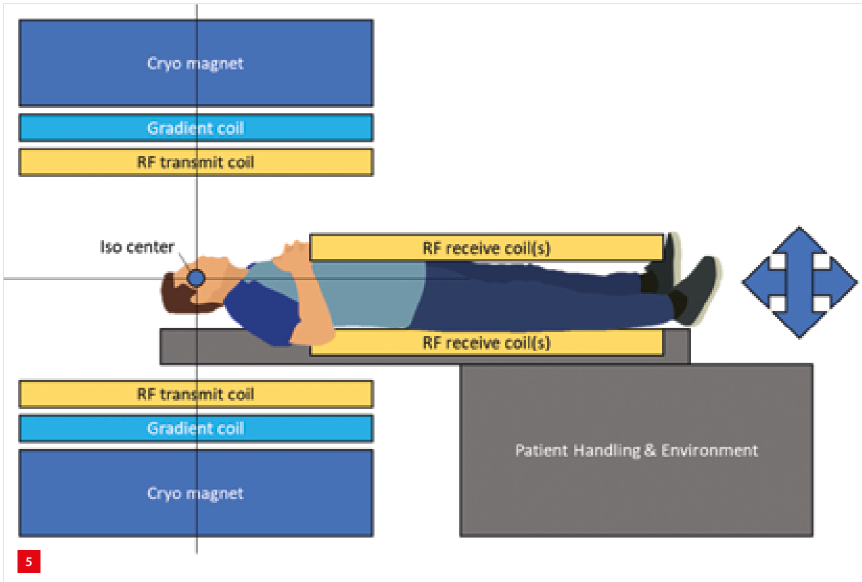
Figure 4 shows the Philips MRI 5300, a 1.5T scanner. A very basic hardware decomposition could be summarised as depicted in Figure 5.

MRI superconducting cryo magnet technology

While permanent and resistive magnets are capable of generating fields of up to 0.4 T, superconducting magnets are used for generating stable magnetic fields above 0.4 T [1]. Superconducting magnets use alloy wires (niobium-titanium, for example) cooled to ~4 K (–269 °C) using liquid helium, at which point they become superconducting. The conductor used in most clinical MRI scanners is



Going from spins to an MRI image.
(1) Net magnetisation M aligned with the main magnetic field.
(2) An orthogonal transmit pulse flips the magnetisation into the transverse plane.
(3) Excited spins now start moving back towards B_0 and release energy.
(4) The released energy is picked up by a local receive coil, thus generating the MR signal.
(5) The amplified signal is fed into a reconstructor.
(6) The final MR image is generated.

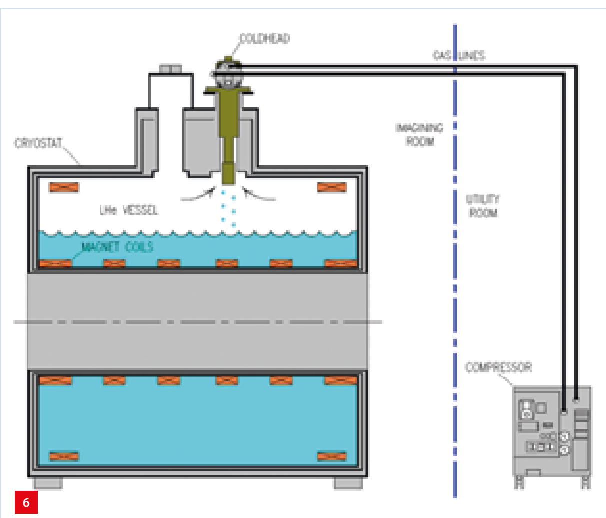


A very basic hardware system decomposition of an MRI machine.

niobium-titanium (NbTi), which becomes superconductive below 9.4 K.

The wires are composed of several microfilaments of NbTi embedded in a copper matrix – the copper not only provides support to the microfilaments, but also a low resistance path for large currents in the event of loss of superconductivity. Instead of a continuous winding, the coils are broken up into several windings, spaced apart, for increased B_0 field homogeneity [4]. The magnets also include additional shim coils (to increase B_0 field homogeneity) and active shielding coils, one at each end of the magnet (to minimise stray fields). The current direction in the active shielding coils is opposite to that in the main coils [5].

In order to enable the superconductivity in these coil windings, magnets employ a cryostat – a large chamber



Cut-out of a magnet showing the cryostat and superconductors.

filled with liquid helium (up to 1.500 ℓ, boiling point of 4.2 K) in which the magnet coils are immersed, surrounded by a further vacuum chamber (Figure 6). Early magnets added a further chamber of liquid nitrogen (at 77 K) to help reduce the continuous boil-off of the helium (due to external thermal energy entering the cryostat). Modern MRI magnets use cryogenic coolers to reduce or even eliminate helium boil-off, and thus do not require liquid nitrogen.

Compressed helium gas is circulated around a two-stage ‘cold head’ mounted on the magnet. Controlled gas expansion in this cold head is used to create very low temperatures at the two stages of the cold head. When the cooling cycle is completed, the helium gas is returned to a water-cooled compressor [1]. In older magnets, the two stages of the cold head were connected to two circumferential aluminium shields that intercept heat and thereby reduce the evaporation (boil-off) of the helium to a level of less than 50 mℓ/h. Later magnets have the first stage connected to a single shield, and the second stage connected to a recondensor so that helium reliquefies and cannot escape the magnet; see Figure 6. These latter magnets are referred to as ‘zero-boil-off’.

Superconducting magnets are a costly proposition, and the use of cryogenic helium in such vast quantities results in an added expense – not to mention the environmental impact. Nonetheless, helium-cooled superconducting magnets are still the best option when it comes to generating stable, high magnetic fields for MRI.

Cooling innovation

Based on a decade of innovation, Philips BlueSeal (Figure 7) is a fully sealed magnet designed to simplify MRI installation, reduce lengthy and costly disruptions in MR services, and help hospitals transition to sustainable, helium-free operations. This revolutionary magnet operates with only 7 ℓ of liquid helium and is fully sealed [6].

Here, fully sealed refers to the fact that the helium used to transfer the dissipated energy to the second stage of the cold head is completely enclosed, without loss of helium for the lifetime of the magnet (leakage nor vaporisation). The cooling system does not require to be vented or refilled, even in an emergency event, since it is designed for the apparent pressure at room temperature.

The superconducting magnet coils are situated in vacuum to provide thermal isolation from the surroundings, and cooling channels are thermally connected to the coils. At the highest point of the system, a cold head is installed to exchange the heat. A self-generated heat flow sustains itself since the specific weight of helium increases at lower

7a 7b

Innovation in magnet cooling.
(a) Classic magnet technology with ~1.500 ℓ of liquid helium.
(b) BlueSeal micro-cooling technology using only ~7 ℓ of liquid helium [6].

temperatures. The power capacity of the heat exchanger increases when the medium temperature increases, ensuring a self-regulating and intrinsically reliable system. With the use of a redundant compressor and an uninterruptible power supply, the system can keep its magnetic field even during loss of electricity or water.

With the BlueSeal magnet, Philips aims to help MRI facilities overcome potential helium-related issues related to the classic magnet design, and eliminate dependency on scarce helium supply, which is now more expensive than ever before. The concept of sealed magnet technology also offers a variety of benefits to both the site architect as well as the MR system designer. Since the procedures for ramping the main magnetic fields up and down are simplified (venting and refilling the coolant medium is not required anymore), these can even be executed without the need for specially trained service personnel. With the introduction of additional sensors and digital controllers, this gets further simplified to a single click of a button, whilst increasing the reliability of the process through continuous monitoring.

One can draw an analogy here: it is a bit like moving on from using a bathtub's worth of cryogenic fluid to using a refrigerator's worth. The traditional safety measures that MRI facilities would otherwise have to adhere to (concerning infrastructure related to conventional MR systems cryogenics), do not apply anymore, since the helium will remain within the system even during emergency situations [6].

MRI future in patient handling & environment

MRI scans are being made every day in almost every corner of the world. Therefore, one can say that MRI is a common imaging modality. When compared to the car industry, one could observe similar trends in what customers want from their machine.

At the start of MRI in the early 1980s, customers were happy if the technology worked. Much like cars should get one from point A to point B, MRI scanners should create MR images. Later, when this was achieved, power became the selling point: customers demanded cars with larger engine displacements and substantial horsepower. For MRI, this meant higher magnetic fields, and with that came sharper, clearer pictures.

Then, accuracy became the next big thing: optimising the motor meant that a new 1.6ℓ engine was able to provide the power that an older 2.0ℓ engine would make; so, the car got more efficient. Again, same for the MRI machine: improved hardware, coupled with innovative software advancements made for improved image quality on a 1.5T system, parallelling that on earlier 3T systems. The cost reduction generated through this increased efficiency was a big selling point. This competition on accuracy and cost-down started in the early 2000s, and we are now at the verge of a new era: value up.

This trend has been observed in the car industry for some time now: prices go up, but the value – and the outcome – goes up as well. Nowadays, one would not necessarily have a look under the hood when buying a car, but would rather check how easily their phones connect to the car, and whether all the apps work. This is exemplary of the marketing shift for MRI systems as well. The customer's ease of use, patient safety and comfort, along with the diagnostic support that the system provides to the technologist and radiologist, are the current selling points.

8

The Philips VitalEye comprises a camera that uses vision software to observe the respiratory behaviour of a patient. Easy hardware? No, this should work in extreme environments, where large magnetic and RF fields could harm the hardware, while the hardware could disturb the quality of the picture or, when coming loose, even harm the patient. Hence, perfect performance on all competencies is needed in development.

These selling points require a lot of new functionalities and technologies to assist patients and staff. Engineers can now focus on exciting and emerging technologies to integrate into the MRI system (which is just plain fun for mechatronic engineers); harnessing optical fibre technologies for enabling patient and machine diagnostics; time-of-flight camera and vision technologies for sensing (see the example of the Philips VitalEye in Figure 8) and communicating; self-driving systems, biometric sensing technologies, integrating virtual and augmented reality for patient comfort (and early system validation in the development phase), novel electronics, piezo technology, and much more. All in all, a fine playground for mechatronic (system) engineers,

Besides, there is an increasing demand for new fundamental technologies in the MRI domain, just like cars are advancing into new technological domains through autonomous electric vehicles. Similarly, architects are looking into developing ultra-wide-bore MRI systems with a view on eliminating patient anxiety; building digital twins, combined with SysML and field data, to help refine simulations to predict and eliminate the dreadful sounds that MRI systems generate; achieving superior image quality with lower field strength systems (< 1 T), and of course, how to eliminate the radio-frequency coils that enclose the patient during scanning.

In the future, MRI systems will become more autonomous, faster and less intimidating – maybe even comfortable. Philips has already made a big step by eliminating the big helium systems.

REFERENCES

[1] McRobbie, D., Moore, E., Graves, M., and Prince, M., *MRI from Picture to Proton*, 2nd ed., Cambridge University Press, Cambridge, UK, 2006, *doi:10.1017/CBO9780511545405*
[2] Koninklijke Philips Electronics, "Basic principles of MR Imaging", 2010.
[3] Wolfgang Pauli – Nobel Lecture, Nobel Prize Outreach AB 2022, *www.nobelprize.org/prizes/physics/1945/pauli/lecture*
[4] Questions and Answers in MRI – Superconductive magnet design, *www.mriquestions.com/superconductive-design.html*
[5] Parizh, M., Lvovsky, Y., and Sumption, M., "Conductors for commercial MRI magnets beyond NbTi: requirements and challenges", *Supercond. Sci. Technol.* 30 (1): 014007, 2017, *doi:10.1088/0953-2048/30/1/014007*
[6] Philips BlueSeal Magnet, *www.philips.com*
[7] Sengupta, S., "RF coils for high resolution imaging of the human visual cortex at ultra-high fields", Ph.D. thesis, Maastricht University, 2018, *doi.org/10.26481/dis.20181128ss*

LOW FORM FACTOR, HIGH STABILITY

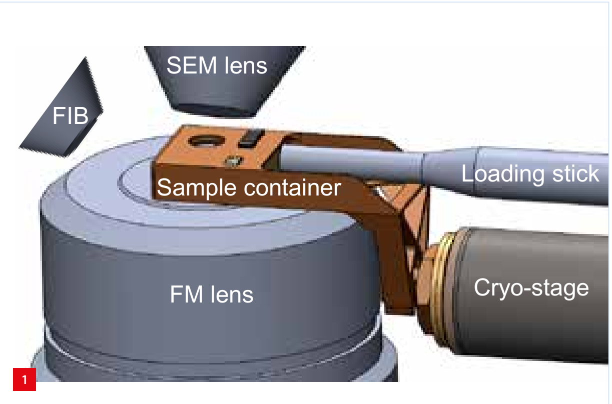
In life-sciences research, cooling biological samples of, for example, proteins, viruses and bacteria to extremely low temperatures facilitates new forms of microscopy. This requires the integration of a sample holder provided with a cold stage into the workflow of preparing and analysing samples. Demcon kryoz designed an efficient cryogenic micro-cooler that has a low form factor and demonstrated its high mechanical and thermal stability.

PIETER LEROU

One of the upcoming techniques in life-sciences research is CLEM (correlative light and electron microscopy), which combines light microscopy and electron microscopy. The two modalities are complementary to one another due to their different length scales: nanoscale electron microscopy provides high-resolution images of a sample while microscale light microscopy can be used for identifying regions of interest in the sample.

In a CLEM system, the sample is imaged using an electron beam and an optical light path simultaneously. This ensures that no changes have occurred in the sample during the analysis, as could be the case when the two microscopy modalities are used consecutively. Overlay of the two images is thus achieved automatically. Cooling to cryogenic temperatures is often used to fix (vitrify) the sample in order to obtain the highest resolution in imaging.

Delmic, located in Delft (NL), developed a fluorescence microscope (FM) that can be integrated with a scanning electron microscope (SEM). If the SEM is additionally provided with a focused ion beam (FIB) for preparing samples before imaging, the resulting system comprises three 'lenses' centred around the sample (Figure 1). This restricts the available space for a sample holder fitted with cooling infrastructure. Nevertheless, it has to have high mechanical and thermal stability to achieve high-resolution imaging. As part of a joint development project, Demcon kryoz and Delmic collaborated to design and realise a cryo-FM/FIB/SEM using Demcon kryoz' novel cryogenic micro-cooler technology.



Schematic of a cryogenic sample holder for a microscopy system integrating three modalities: scanning electron microscopy (SEM), fluorescence microscopy (FM) and focused ion beam (FIB).

Design

Challenging requirements were defined for the cryogenic micro-cooler; see Table 1. Given the limited form factor and the long standing time, an efficient cooling solution was needed. For this, the Hampson-Linde cycle was selected, which is commonly used for the liquefaction of gases, in a regenerative cooling process that relies on the Joule-Thomson effect. Upon free expansion of a gas through a flow restriction, the gas cools and its temperature decreases. The advantage of this solution is that no compressor is required in the cooling device, i.e. there are no moving parts that can induce vibrations.

The actual implementation consists of a cooler chip that is made using lithographic techniques (Figure 2). Nitrogen gas is expanded from 95 to 1 bar, yielding a net cooling power of 200 mW at 80 K. No boiling liquid nitrogen is present in

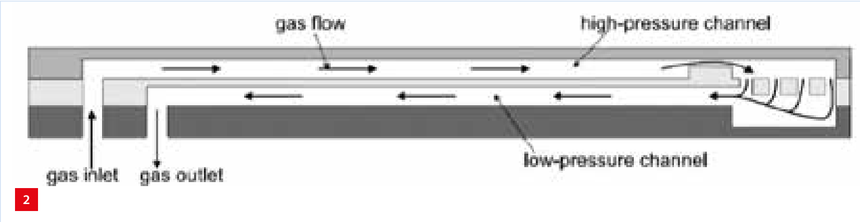
Table 1
Main requirements for the cryogenic micro-cooler.

Sample temperature	≤ 108 K
Thermal stability	±20 mK (stationary)
Mechanical drift	≤ 4 nm/min
Vibration level (peak-to-peak)	≤ 1 nm @ 200 Hz
Degrees of freedom (DoFs)	5
Cool-down time	≤ 2 h
Standing time	> 6 h

AUTHOR'S NOTE

Pieter Lerou is CTO of Demcon kryoz, a full-service design house specialised in thermal systems engineering and located in Enschede (NL).

pieter.lerou@demcon.com
www.demcon.com/kryoz



The cold stage with the flow restriction on the right.

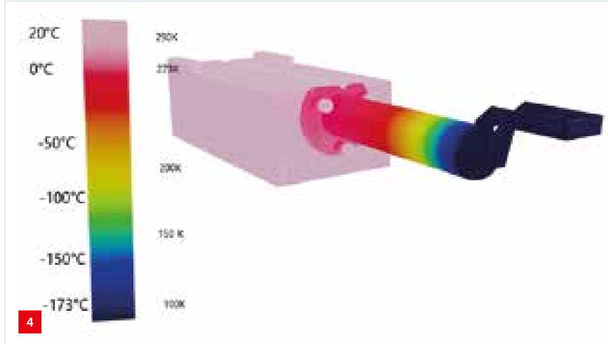
the system during operation, which keeps vibrations low. A sample holder is mounted on the cold stage, which in turn is integrated with cooling infrastructure (nitrogen high-pressure gas supply) into a complete micro-cooler. For manipulation of the sample, i.e. to position it with respect to either of the three 'lenses', the micro-cooler is mounted on a 5-DoF motion stage. Figure 3 shows the design of the micro-cooler and its mounting on an example stage.

Thermal analysis of the complete system was performed using lumped-element modelling (LEM). Demcon kryoz has developed a dedicated LEM toolbox for use in the popular simulation environment Simulink, for modelling thermal, fluidic and vacuum systems to predict their (real-time) dynamic behaviour. It comes with a LEM library containing a large number of predefined modelling blocks that combine physical models with actual (off-the-shelf) part performance data, making detailed dynamic modelling of complex systems possible.

A schematic result of the LEM analysis is shown in Figure 5. It confirms that only the sample holder itself is cooled down to, for example, 100 K, while the cooler's base remains at room temperature. The large temperature gradient extends over a small distance (about 50 mm), which makes it possible to provide all mechanical interfaces to the cooler at room temperature, while the cryogenic temperature is only produced at the location where it is relevant, i.e. on the sample.

Verification

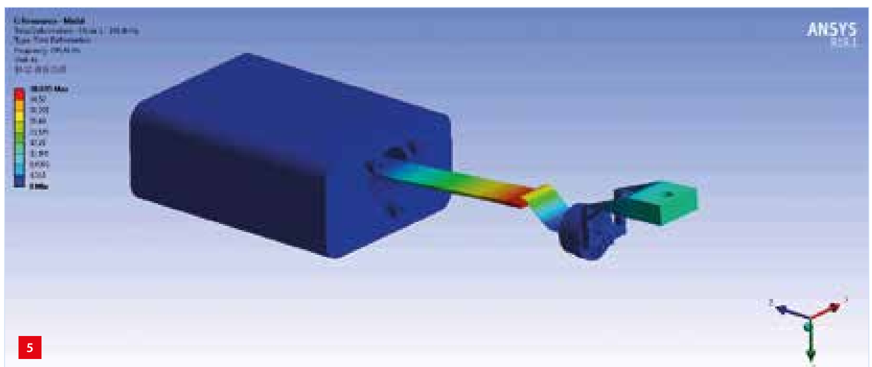
Testing of the mechanical and thermal performance was conducted at the Max Planck Institute of Molecular



Result of thermal LEM analysis of the cryogenic micro-cooler design.

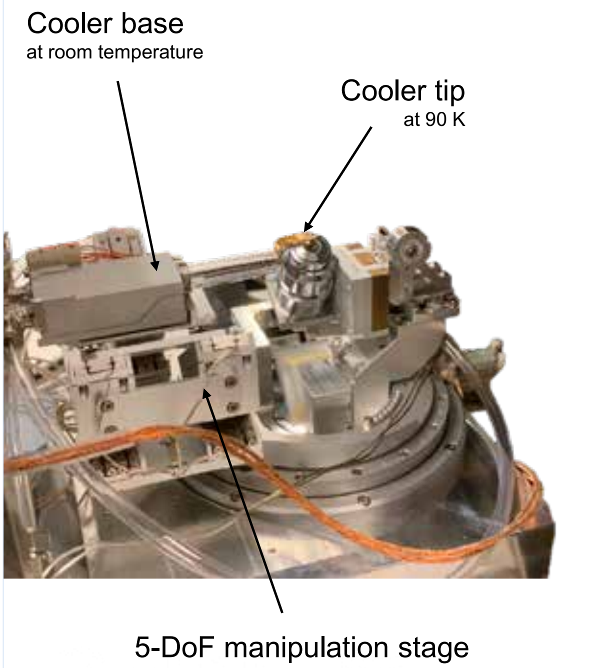
Physiology in Dortmund, Germany (Figure 6). The cryogenic micro-cooler was integrated in a dual-beam system, comprising a FIB for sample preparation and a SEM for analysis, while retro-fitted with an FM.

Peak-to-peak vibration levels for the cold tip (Figure 7) were found to be well below 1 nm over a wide frequency range up to 2 kHz, except for a peak at 50 Hz (probably a mains-related artefact). Hence, the requirement of ≤ 1 nm @ 200 Hz is amply met. Mechanical drift of the cold tip was measured to be below 3 nm/min, which satisfies the requirement of ≤ 4 nm/min. A duration test was performed to test the thermal stability (Figure 8), demonstrating the required ±20 mK, and the standing-time, for which 6 h was specified.



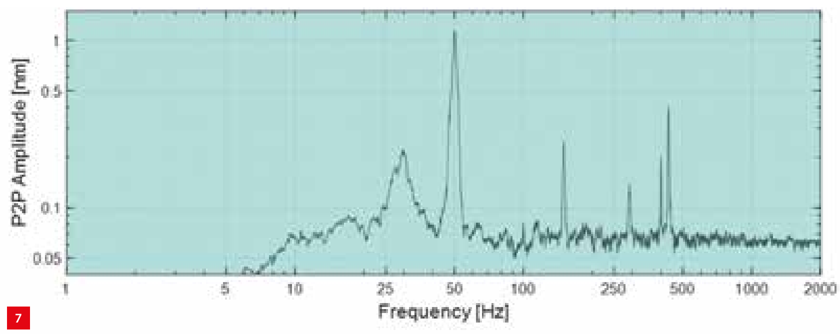
Modal analysis of the micro-cooler, showing the first mode and demonstrating the stability of the cold tip, of which the amplitude remains below 1 nm.

Design of the cryogenic micro-cooler. On the right, a still from an animation of the cooler mounted on a moving 5-DoF manipulation stage.



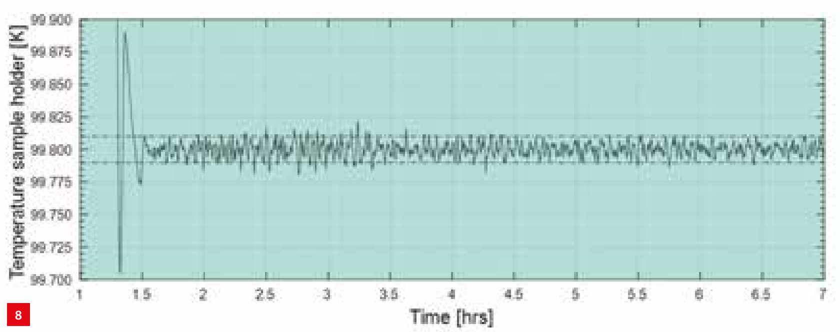
6

Set-up for verification testing of the cryogenic micro-cooler.



7

Mechanical performance of the cryogenic micro-cooler cold tip: peak-to-peak vibration amplitude as a function of frequency.



8

Thermal performance of the cryogenic micro-cooler cold tip: sample holder temperature over time. The dashed horizontal lines indicate a ±20 mK range.

Conclusion

A cryogenic micro cold stage has been designed that satisfies strict requirements concerning mechanical and thermal stability. It is a first milestone on the CryoEM roadmap being pursued by Demcon kryoz. New challenges include expanding the standing time to several working days and shifting the cooling regime down to 40 K and below. In addition, the micro-cooler has to be made suitable for transmission electron microscopy, next to SEM. This means that vibration reduction has to move from the nanometer down to the picometer level. And finally, applications for different types of microscopes each require their own form factor for the micro-cooler and its integration with different types of sample holders.

DECREASING STIFFNESS AT THE COST OF EMERGING HYSTERESIS

Minimising power dissipation is critical for applications in cryogenic environments. Experimental results show that the guiding stiffness, and with that the associated motor-current-induced dissipation, of a voice-coil-actuated positioning stage can be significantly decreased using a stiffness-compensation mechanism, as demonstrated by JPE. However, as expected, the contribution of hysteresis from the compensation mechanism becomes noticeable in the force-displacement graph.

DENNIS STRUVER

Dissipation under cryogenic conditions

Cryogenic environments are becoming more relevant for high-tech applications and state-of-the-art scientific research. At cryogenic temperatures, generally below 120 K, the motion of particles is inhibited and 'permanent' gases begin to liquify. Additionally, various material properties change substantially under cryogenic temperatures.

Since a cryogenic environment is typically achieved in a vacuum (or even an ultra-high vacuum, UHV), cooling is performed by conductive heat transfer. For most materials, thermal conductivity decreases with decreasing temperature, which makes it more difficult to continue cooling the materials further down. Therefore, achieving a cryogenic environment is a slow process, which is highly sensitive to power dissipation as well. Hence, it is important to consider the thermal behaviour of the system and minimise dissipation for temperature stability during the experiment.

A more beneficial change in material properties is the decrease of electrical resistivity, which is quite significant for some materials, such as copper. This change results in an increased efficiency of Lorentz-force-based actuators. JPE has developed a UHV- and cryo-compatible voice-coil actuator (Figure 1) that is optimised for efficiency while minimising dissipation. The actuator constant, which is given as the generated force per unit of dissipation, is increased from 2.07 $NW^{-1/2}$ in ambient to 58.2 $NW^{-1/2}$ at 10 K, which is an improvement of almost a factor 30. Although these actuator properties seem very beneficial for cryogenic temperatures, the eventual application must be considered carefully.

In positioning applications, it is important to consider the load that the actuator must carry. For example, a vertical positioning application would require the actuator to carry the weight in full, and thus a continuous power dissipation is required to maintain the neutral position. Therefore,

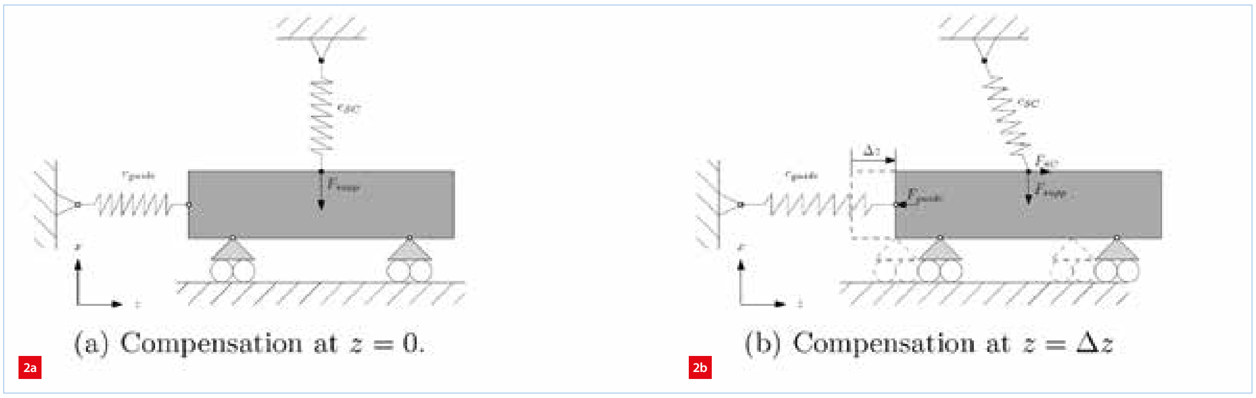

1

The CVCA, a UHV- and cryo-compatible voice-coil actuator developed by JPE.

AUTHOR'S NOTE

Dennis Struver is a mechanical engineer at JPE, located in Maastricht-Airport (NL). This article is in part based on the internship work of Tom Berkers, "Voice coil actuated stage for cryogenic environments", conducted for his M.Sc. thesis in mechanical engineering at Eindhoven University of Technology.

dennis.struver@jpe.nl
www.jpe-innovations.com



Schematic representation of the stiffness-compensation principle.
(a) At z = 0, only a parasitic force F_{supp} is generated.
(b) Under displacement of the moving body, a compensation force F_{SC} is generated in the guiding direction.

a weight-compensation mechanism may be crucial to prevent unacceptable power dissipation and maintain the desired cryogenic conditions.

Furthermore, demanding positioning applications typically integrate a flexure-based guidance mechanism, which introduces a significant guiding stiffness. Therefore, the actuator has to continuously deliver a force proportional to the guiding stiffness in order to maintain its position, other than the neutral position. The larger the stroke of the mechanism, the higher these forces become, which possibly need to be maintained for relatively long durations. A stiffness-compensation (SC) mechanism is able to improve the performance of such a positioning system and minimise the power dissipation.

To summarise, although the efficiency of a voice-coil actuator increases substantially under decreasing temperatures, it is important to minimise power dissipation of an accurate positioning system in order to reach and maintain cryogenic temperatures. This article elaborates upon a stiffness-compensation mechanism that is incorporated in a 1-DoF (degree-of-freedom) voice-coil-actuated positioning stage designed for cryogenic conditions. The stage contains a linear guidance mechanism based on two parallel leaf-springs and is mainly flexure-based. Additionally, a cryo-compatible resistive linear sensor developed by JPE is integrated in the system for closed-loop positioning.

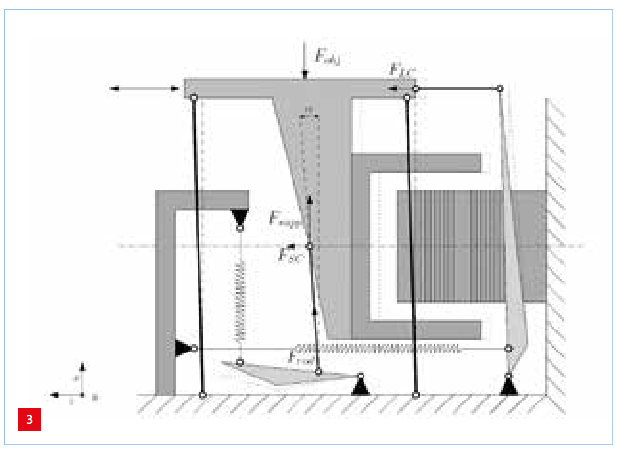
Stiffness compensation

The stiffness-compensation principle used in the positioning stage is schematically depicted in Figure 2. The addition of a compressed spring mounted on the moving body basically introduces a negative stiffness, which results in a lowered effective guiding stiffness. The stiffness-compensation force F_{SC} in the $z = 0$ position is zero, since the stiffness-compensation spring is perpendicular to the guiding direction. However, when the moving body is displaced, the added spring will generate a force F_{SC} in the guiding direction, depending on the rotation of the spring α with respect to the vertical axis and its preload force F_{rod}, following $F_{SC} = \sin(\alpha) \cdot F_{rod}$.

This stiffness-compensation principle has been integrated in the positioning stage by means of a knife-edge bearing and a lever connected to an adjustable spring, which can be used to adjust the preload force F_{rod} and therewith the amount of negative stiffness. To prevent instability, the effective stiffness must be greater than zero, which is the limiting factor for the adjustment. Figure 3 shows a schematic representation of the positioning stage with the parallel leafspring guidance, voice-coil actuator and stiffness-compensation mechanism.

Efficiency improvement and hysteresis

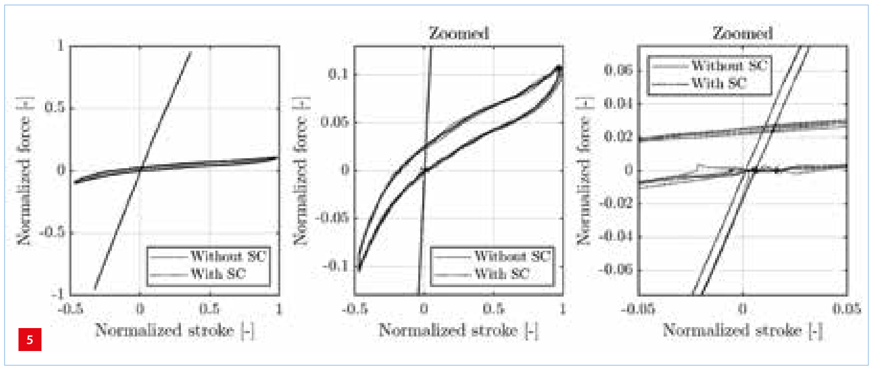
Experiments conducted on the realised positioning stage prove its functionality and show that the stiffness due to the compensation has become approximately a factor 16 smaller. Thus, the force necessary to achieve the full stroke



Schematic representation of the positioning stage under displacement, showing the (vertical) parallel leafsprings, voice-coil actuator (on the right) and stiffness-compensation mechanism. The force F_{rod} is introduced via a (vertical) pressure bar (rod) connected to a knife-edge bearing (bottom centre). F_{LC} can compensate constant loads, for example a mass in vertical motion (in the case that this stage has been rotated over 90°), and is not further discussed here.

4

Positioning stage as realised by JPE, in agreement with the schematic of Figure 3.



5

The normalised force-displacement curve of the positioning stage without and with stiffness compensation (SC), showing a significant decrease in effective stiffness due to the stiffness compensation. Zoomed windows are shown in the middle and on the right.

(which here amounts to 5 mm) is only 1/16th, or 6%, of that in a system without stiffness compensation, and the power dissipation of the system is reduced by 16^2, to only 0.4% of the non-compensated situation.

Of course, due to the low drive force, hysteresis plays, relatively speaking, a more significant role in the system. The frictional components in the positioning system, in this case the resistive position sensor and the knife-edge bearing, cause hysteresis in the system, which can distinctly be observed in the force-displacement curve shown in Figure 5.

The force-displacement relation is therefore also depending on the previous stage position and its direction of motion. It is observed that for the uncompensated case, without the knife-edge bearing, the amount of hysteresis is not that much different from the compensated case. However, in the compensated case the relative contribution of the static friction is substantially increased. The positioning system follows almost the textbook hysteresis curve in clockwise direction, showing the practical consequences of the phenomenon.

Conclusion

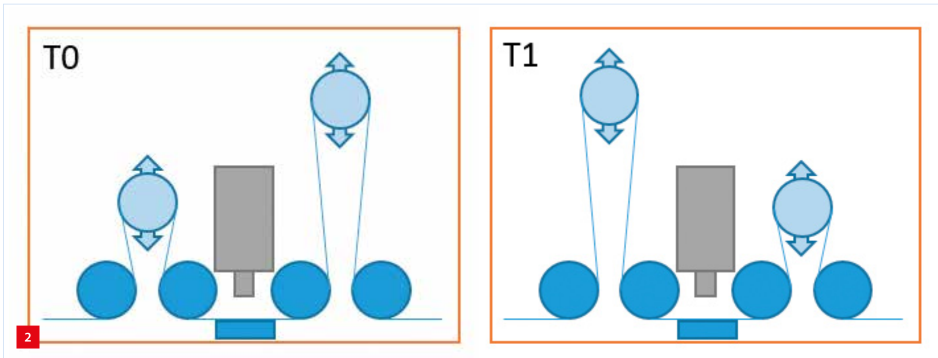
It is important to minimise power dissipation for applications under cryogenic conditions in order to maintain stable and low temperatures. Although the efficiency of a voice-coil actuator significantly increases for decreasing temperatures, the relevance of guiding stiffness has been addressed for positioning applications. A stiffness-compensation mechanism that is integrated in a voice-coil-actuated positioning stage designed for cryogenic conditions has been elaborated and experimental results show the achievable improvement. However, these results also expose the increased relevance of hysteresis.

DANCES WITH FOILS

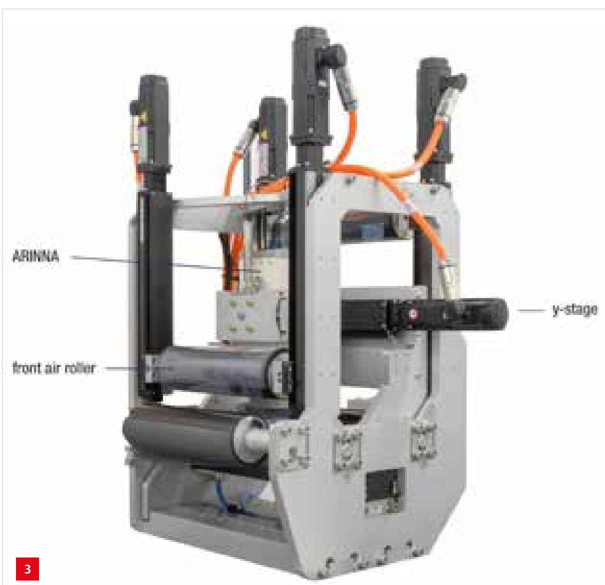
In-line interferometry of nanometer-scale profiles in flexible electronics has been developed for application on a moving flexible foil. The solution developed by IBS Precision Engineering includes control techniques for tracking in both the travel and the orthogonal direction, and stabilisation techniques for the vertical direction. Foil handling has been optimised to reduce damage to sensitive foils. The interferometric system has been demonstrated on a pilot line, handling photovoltaic foils with ultra-low reflectivity, measuring nanometer features – this is a world first.

THERESA SPAAN-BURKE

The ARINNA interferometer located above a moving foil.



Schematic of the dancer. Dark blue: standard rollers. Light blue: cylindrical porous media air bearings (airturns).



Dancer as built.

In the production of flexible electronics, such as organic LEDs or photovoltaic foils, often nanometer-scale features critical to the device performance are implemented. In-line 3D metrology of such profiles promises to revolutionise the production process by avoiding time-consuming off-line measurements for process control. Achieving such measurements in a roll-to-roll environment is a precision challenge.

Wavelength-scanning interferometry

An areal interferometer, named ARINNA, has been developed for quality control of surface features at the nano- and microscale in production. The measurement technique employed by ARINNA (Figure 1) is based on the principle of wavelength-scanning interferometry (WSI). The technique involves the capture of a set of interferograms across a range of wavelengths incident on the sample or product.

The interferometer is able to measure discrete step heights and surface quality with a vertical resolution < 2 nm, as verified by earlier experiments [1]. In-line measurement of printed electronic foils requires the ability to measure low-reflective samples, 'capture' of the moving foil, stabilisation techniques and methodologies to overcome residual surface vibrations. Measurements can be taken across the full width of the web using y-motion control and autofocus functionality in the z-direction. Feedback from the

AUTHOR'S NOTE

Theresa Spaan-Burke is innovation director at IBS Precision Engineering, located in Eindhoven (NL).

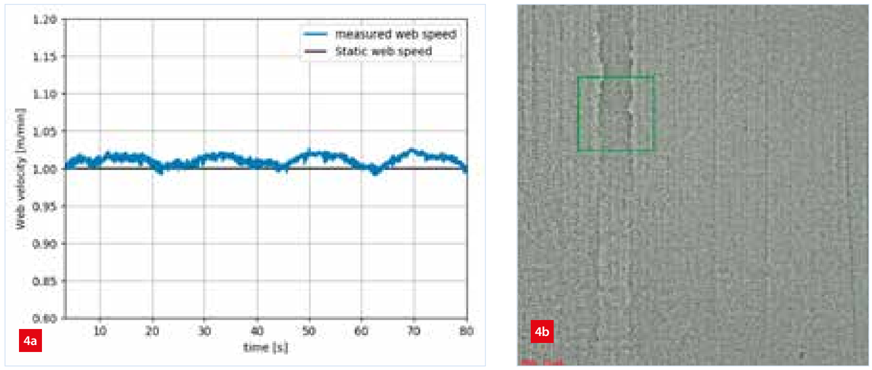
burke@ibspe.com
www.ibspe.com

ARINNA head is used to identify the optimum *z*-position for measurement. This allows for minor tilts in the foil along the *y*-direction.

An in-line system was developed to measure laser scribes in organic printed voltaics (OPVs), as elaborated below. Scribe depths and widths were of the order of 100 nm and tens of microns, respectively.

Dancer development

Nanometer features on foils moving at 1-5 m/min were targeted. Several potential strategies for capturing images from a moving web were explored, including mechanical (chasing the foil) or electronic (tracking in the camera). Given limited integration space in the final manufacturing line a so-called dancer solution was chosen; here, dancing refers to two airturns moving up and down in (anti-)sync, to keep the foil at a stable position under the interferometer. A schematic is shown in Figure 2.



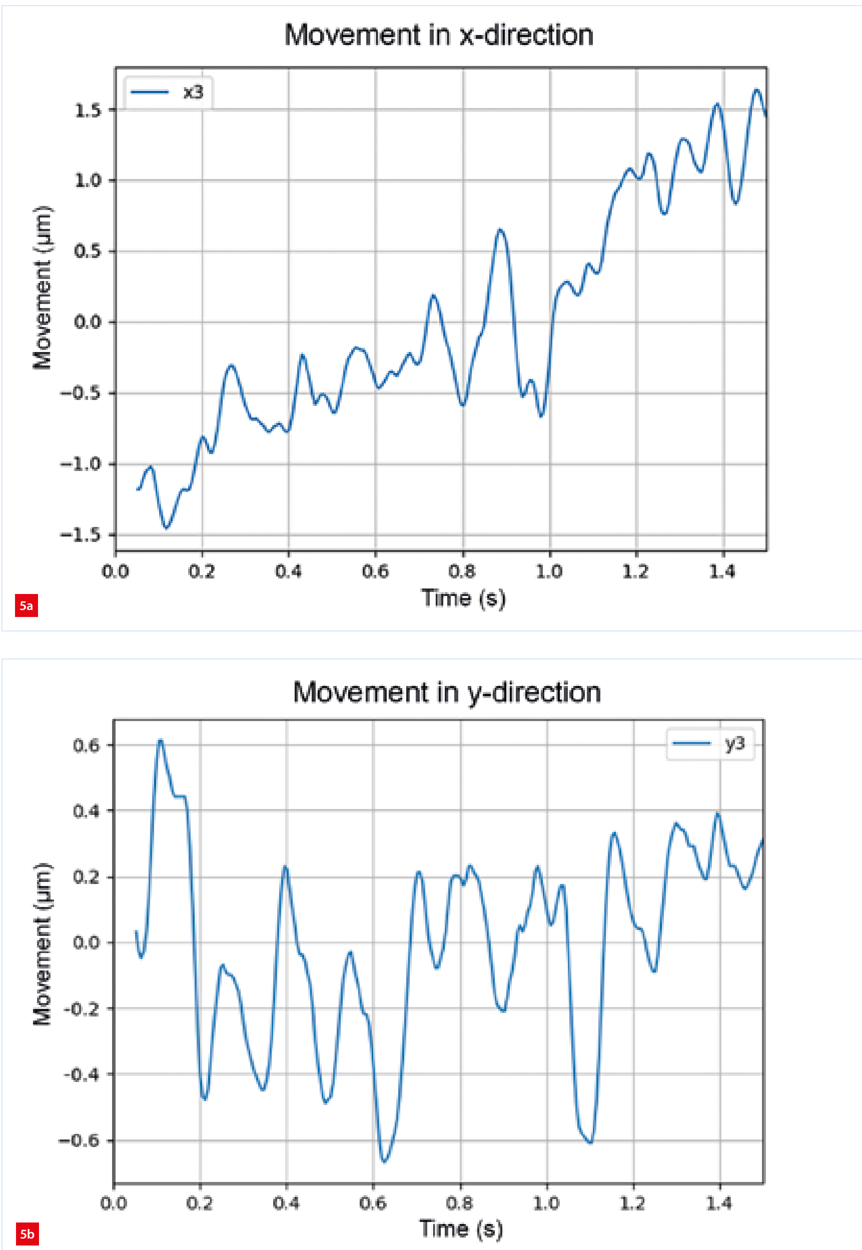
(a) Encoder-measured web speed.
(b) Marker detection (green square); its position is used to verify dancer speed accuracy.

At T0, the left airturn (cylindrical porous media air bearing) starts in the lower position while the right airturn starts in the higher position. A buffer action is started to enable the remainder of the roll-to-roll line to continue production uninterrupted while the measurement occurs. Then, the left airturn moves with half the speed of the web in the vertical direction towards position two. The right airturn follows the left airturn with the same speed in the opposite direction.

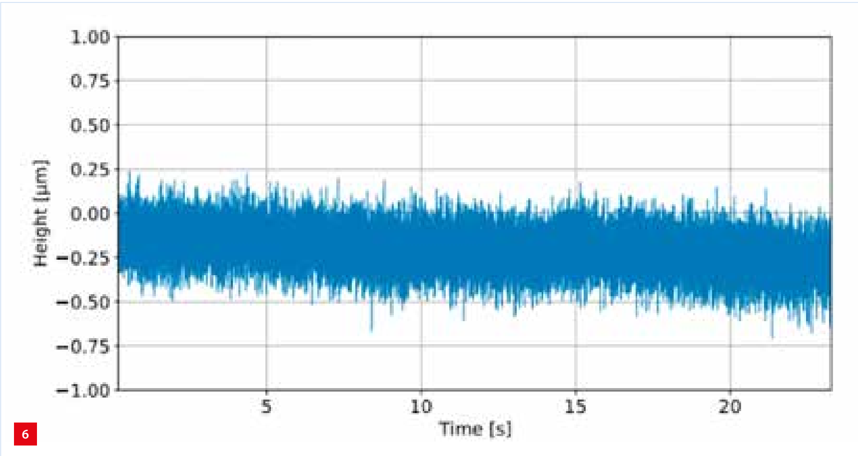
At T1, the right airturn lies in the lowest position and the reverse process begins. Four contact rollers and two airturns are used so that front contact is not made with the sensitive web. Buffering is triggered by a marker on the foil or, alternatively, can be controlled by a set of user-chosen intervals. Figure 3 shows the dancer as built.

During laser-scribe measurements, the web under the measurement system should be stationary in *x*, *y* and *z*, while the rest of the line continues at a typical speed between 1 and 5 m/min. Most critical is the movement perpendicular to the travel direction, which should be smaller than the width of the laser scribe, hence of the order of microns.

To evaluate the dancer performance, new object tracking software was implemented. This software can track an arbitrary object for the duration of the interferometer image capture, by analysing the movement of the object during the wavelength sweep used to measure the surface. So, not only the marker on the edge of the web can be analysed but any position on the web. This software is used to detect the *x*/*y*-accuracy the dancer achieves.



Measured web displacement with the improved speed monitoring.
(a) *x*-Position of a laser scribe on the web during dancing (0.8 μm standard deviation).
(b) *y*-Position (0.3 μm standard deviation).

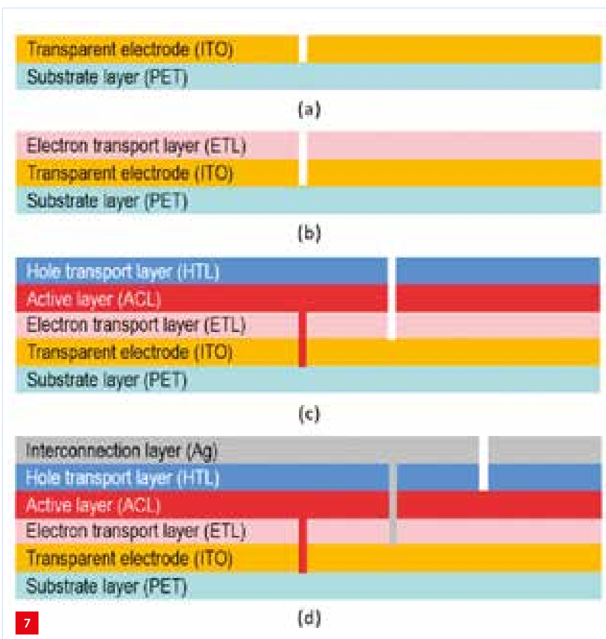


z-Stability of the web during dancing and stabilisation with air table.

Figure 4a shows the encoder-measured web speed at the entrance to the dancer in the IBS line, whereas Figure 4b shows object detection on a laser scribe. The marker is used to measure the movement in x and y during dancing – the target is zero motion in x and y. Figure 5 presents the measured displacement of the web with the improved speed monitoring. The data of Figure 5a shows the x-direction performance that was measured as stationary, with an 0.8 µm standard deviation. From the data in Figure 5b, a standard deviation of 0.3 µm has been obtained in the y-direction.

Web stabilisation

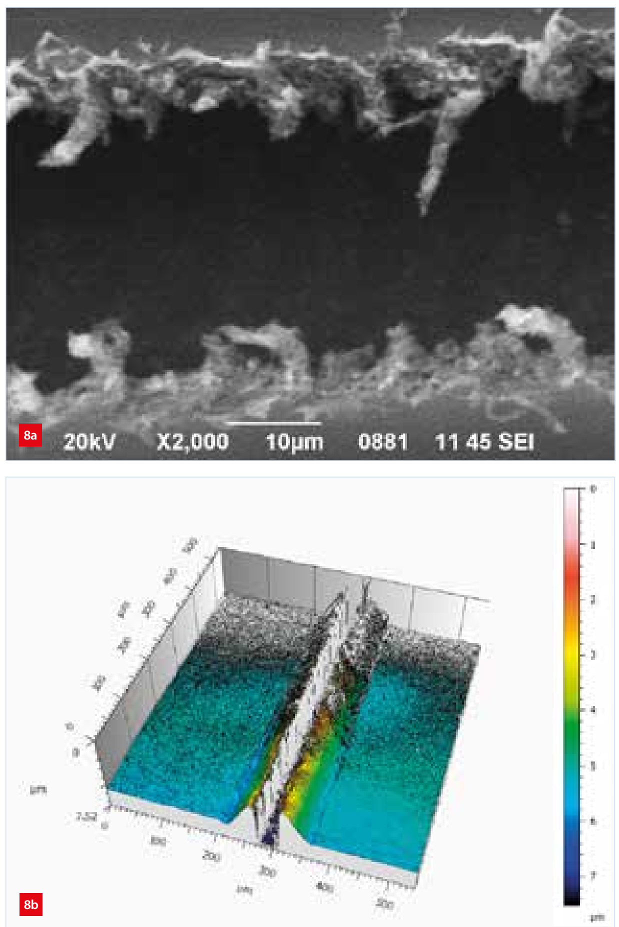
Laser-scribe depths can be measured by the interferometer to an accuracy of nanometers. It is critical that the web is stable in the vertical z-direction during measurement to achieve these accuracies. Typical motion of webs in the z-direction during production is of the order of more than 300 µm (as previously measured by IBS). To stabilise the web below the ARINNA in the vertical direction, an air table has been placed under the web. The air table utilises both vacuum and air pressure to set pretension on the web and cancel any vibrations from the roll-to-roll line. To cancel any vibration induced by the dancer motors, the metrology frame has been decoupled from the dancer frame. Figure 6 shows the z-stability during dancing to be of the order of +/– 0.25 µm.



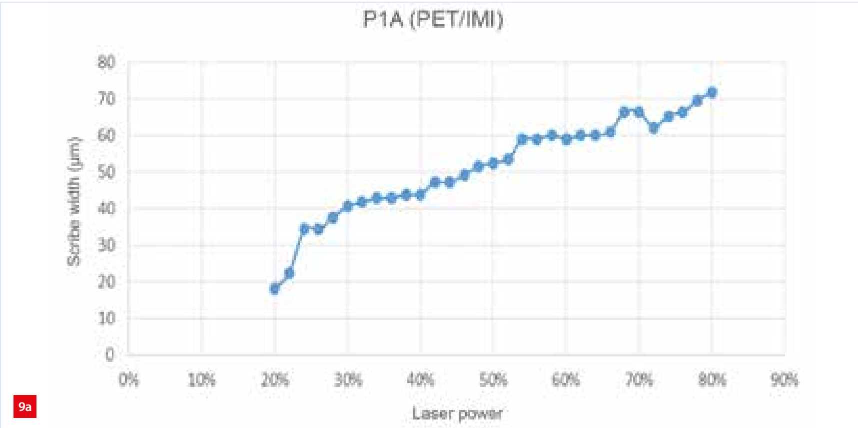
Schematic representation of the organic electronics stack that was investigated, with the various types of laser scribes.
(a) P1A.
(b) P1B.
(c) P2.
(d) P3.

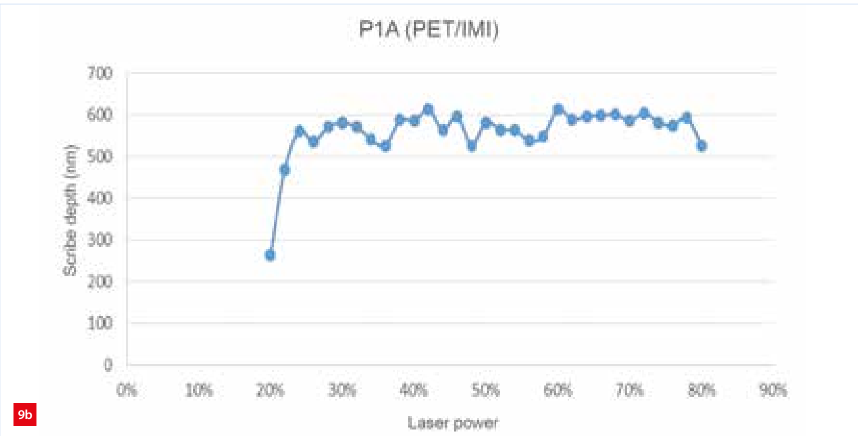
Vibration compensation

With the foil stabilised in x, y and z, the surface topology can be measured. Within the interferometer, compensation is applied for residual vertical motion of the foil during data capture. Advanced modelling identified a number of improvement opportunities, including enhanced hardware filtering and optimised microprocessor speeds, to increase the bandwidth of this vibration compensation. Applying these improvements enhanced the bandwidth of the vibration compensation from 280 Hz to 650 Hz. This in turn has enabled stable measurement of webs floating on the air table.



Comparison between SEM image (top) and ARINNA interferometer measurement (bottom) for the P3 scribe; all units µm.





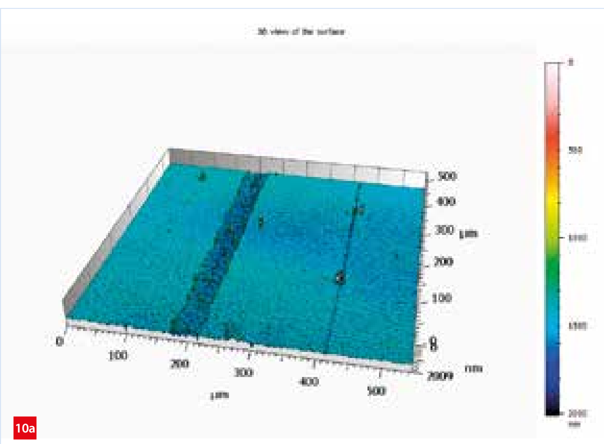
P1A scribe measurements as a function of laser power.
(a) Width.
(b) Depth.

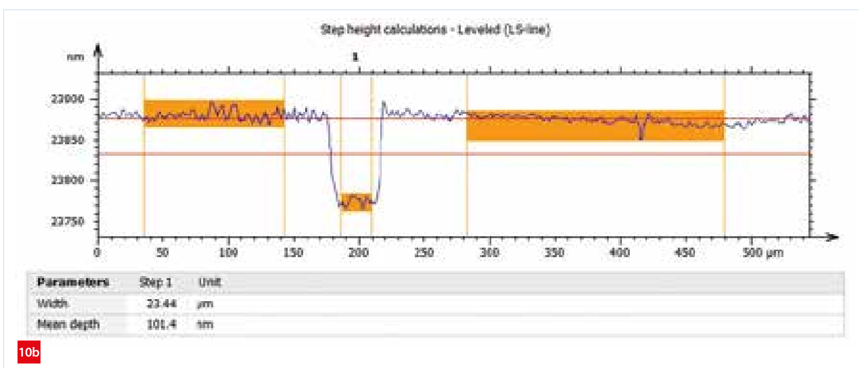
In-line measurement

The OPV samples that were measured are shown in Figure 7. Laser scribes are made at four stages in the processing of these devices. Scribe depths vary from 100 nm for the P1A type to 1.5 µm for P3. Scribe widths are of the order of tens of microns. OPV samples have by definition low reflectivity. Thus, ARINNA was optimised to enable measurement at low return-light levels. This included both hardware updates to increase the incident light and software updates to accommodate potentially higher noise levels. To our knowledge the measurements presented here are the first-ever topological surface measurements for such materials. When manufacturing such devices, SEM (scanning electron microscopy) measurements have typically been used to assess laser scribes. A small piece of the print run is removed and sent for analysis, which typically takes more than a week. Measurements provide 2D data only, indicating a scribe width. Quantitative interpretation of the images by a person is used to confirm the form of the scribe (wall edges, debris, etc.)

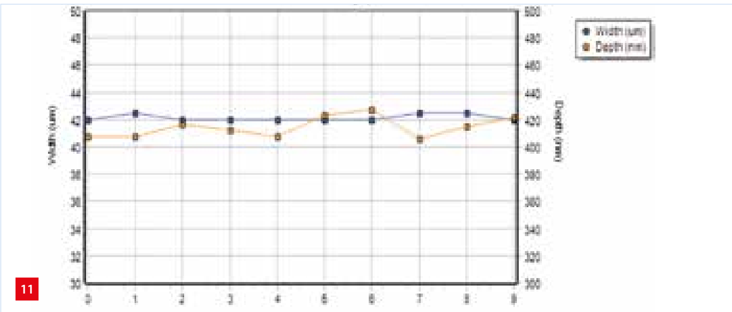
First measurements from the interferometer were compared to SEM images. An example is shown in Figure 8, where features apparent at the base of the scribe are also present in the surface topology measurement by the interferometer. Figure 9 shows measurements for P1A scribes in PET/IMI (PET is a standard plastic substrate used in printed electronics; IMI stands for insulator/metal/insulator). Here, the laser power has been varied from 20% to 80% of maximum power. The scribe width is seen to increase continuously from 20 µm to 70 µm. At the same time, the scribe depth is seen to increase between laser power levels of 20% to 24% and thereafter plateau at the nominal depth of 100 nm, as the scribe has cut through to the PET. In-line measurements of a P1A scribe in PET/ITO (indium tin oxide, one of the most widely used transparent conducting oxides) are shown in Figure 10, on foil moving at 1 m/min. The cross-section shows a scribe depth of 100 nm, in line with the expected ITO layer thickness.

The system has been developed to provide automated measurement at a predefined time interval. Automatic feature extraction is performed for surface features, in this instance the scribe width and depth. A validity check is made against pre-set tolerance values. TCP/IP communication is used to send the depth and width values to a client to allow for laser power adjustment. A typical trend graph is shown in Figure 11.

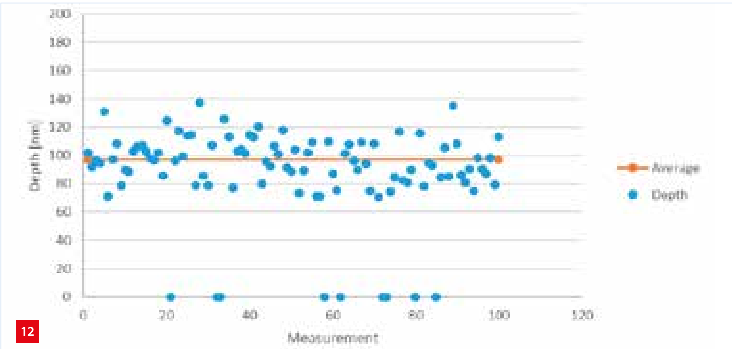




P1A scribe measurements in PET/ITO on foil moving at 1 m/min, showing the depth profile.
(a) Bird's eye view.
(b) Cross-section.



11 Trend graph of laser scribe depth and width measurements taken in-line at 20-s intervals.



12 100 Scribe measurements measured in-line at 1 m/min.

Statistical analysis of 100s of data measurements in a fully stationary setting (the foil not moving) was used to identify the impact of factors including light intensity, exposure time and interferometer optical settings. From these, optimum conditions were identified. A dataset with the preferred settings comprised 367 measurements. The mean depth obtained from this set for a laser scribe of nominal depth 100 nm was 104.7 ± 1.0 nm. The standard deviation of the measurements was 9.5 nm, the standard error of the mean was 0.497 nm. A further 100 measurements were taken of the same foil moving at 1 m/min, as shown in Figure 12. The tolerance range was set between 50 and 150 nm. Nine out of the 100 measurements were seen to fall out of the tolerance range. The mean depth obtained from the remaining data set was 96.96 nm. The standard deviation of the measurements was 15.3 nm, the standard error of the mean was 1.92 nm.

Conclusion

For the first time, laser scribes have been measured interferometrically for OPV samples. Measurements have been successfully made in-line across the full web width using a dancer combined with autofocus capability and feature extraction.

REFERENCE

[1] IBS, "Robuste Oberflächenmessung mit Interferometrie", *Mikroproduktion*, 04/15, pp. 64-68, 2015.

7 July 2022, Veldhoven (NL)
Techcafé
Second edition of this DSPE-Mikrocentrum collaboration, this time dedicated to systems engineering. For more information, read the Editorial on page 4.

WWW.DSPE.NL/EVENTS

11-14 July 2022, Knoxville, TN (USA)
ASPE Summer Topical Meeting
Event of the American Society for Precision Engineering (ASPE), in collaboration with its European counterpart euspen, devoted to advancing precision in additive manufacturing

WWW.ASPE.NET

30 August - 2 September 2022, Utrecht (NL)
ESEF 2022
The premier industrial exhibition in the Benelux area in the field of supply, subcontracting, product development and engineering, showcasing the latest innovations.

WWW.MAAKINDUSTRIE.NL/ESEF

12-16 September 2022, Porto (PT)
European Optical Society Annual Meeting 2022
This event provides a platform for experts in the field of optics and photonics, bridging the gap between research, education and industry.

EOSAM 12-16 September 2022 Porto, Portugal

WWW.MYEOS.ORG/EVENTS/EOS/EOSAM2022.HTML

22 September 2022, Veldhoven (NL)
Techcafé
Third edition of this DSPE-Mikrocentrum collaboration; theme to be announced. For more information, read the Editorial on page 4.

WWW.DSPE.NL/EVENTS

27-30 september 2022, Utrecht (NL)
World Of Technology & Science 2022
Four 'worlds' (Automation, Laboratory, Motion & Drives, and Electronics) and Industrial Processing will be exhibiting in the Jaarbeurs Utrecht.

WWW.WOTS.NL

28-30 September 2022, Huddersfield (UK)
SIG Meeting Structured & Freeform Surfaces
Special Interest Group Meeting, hosted by euspen and dedicated to replication techniques, structured surfaces to affect function, precision freeform surfaces, large-scale surface structuring, surfaces for nanomanufacturing, and metrology.

WWW.EUSPEN.EU

10-14 October 2022, Bellevue, WA (USA)
ASPE Annual Meeting
The 37th Annual Meeting of the American Society for Precision Engineering (ASPE) will have special focus areas in precision engineering for virtual and augmented reality, aerospace engineering and large-scale metrology.

American Society for Precision Engineering

WWW.ASPE.NET

12-14 October 2022, Eindhoven (NL)
Optomechanical System Design course
The course focuses on the mechanical and mechatronic design of optical systems, and is intended for mechanical, mechatronic and optical engineers involved in optomechanical system design. It will also be a very valuable course for any engineer interested in opto-mechanical design approaches and solutions. See the course description on page 25.

WWW.DSPE.NL/EDUCATION

15-16 November 2022, Den Bosch (NL)
Special Interest Group Meeting: Precision Motion Systems & Control
The second edition of this SIG Meeting is organised prior to and partly in parallel with the Precision Fair 2022 (see below). Deadline for abstract submission is 19 August 2022.

WWW.EUSPEN.EU

16-17 November 2022, Den Bosch (NL)
Precision Fair 2022
The 21th edition of the Benelux premier trade fair and conference on precision engineering, organised by Mikrocentrum.

Precision Fair

WWW.PRECISIEBEURS.NL

22 November 2022, Veldhoven (NL)
Health Tech Event
This new conference is organised by Brainport TechLaw, Jakajima and Mikrocentrum. It covers the interaction between innovation and regulation in the areas of medical devices, instrumentation, consumables, software, data-driven healthcare and healthcare platforms.

WWW.HEALTHTECHEVENT.EU

24 November 2022, Utrecht (NL)
Dutch Industrial Suppliers & Customer Awards 2022
Event organised by Link Magazine, with awards for best knowledge supplier and best parts & process supplier, and the Best Customer Award.

WWW.LINKMAGAZINE.NL

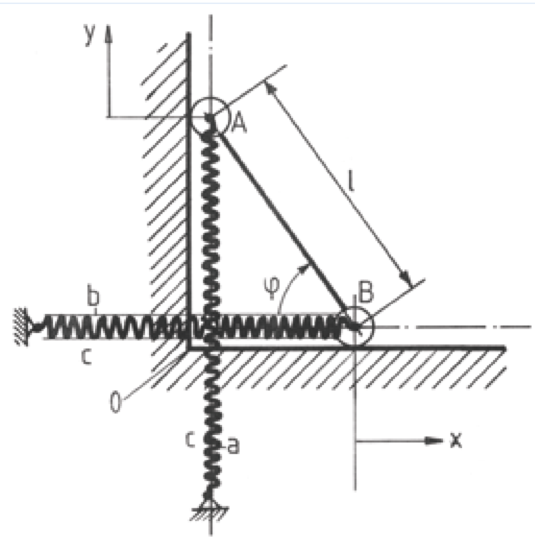
ENERGY MANAGEMENT

Wim van der Hoek had little to do with low temperatures and cooling in his career, but thermal issues such as temperature differences and heat loads did play an important role in his work. Examples of these range from the well-known thermal centre in a temperature-sensitive design to the impact of temperature changes on the tuning of a piano. This third in a series of articles covers energy management as one of his leading design principles, as described in DSPE's Dutch-language book "Wim van der Hoek (1924-2019) – A constructive life".

A thermal centre is a point in a construction, for example of a precision instrument, that remains stable during expansions and contractions due to temperature changes. Such a formal definition is important, but Van der Hoek liked to make such concepts 'tangible', for example in the famous Monday afternoon sessions for his Designs and Mechanisms elective course. "A completely different format than we were used to", as one of his students at the time recalls. "Not a lecture in the traditional sense, but an intensive consultation with a small group of students in his office. We sat together for two hours around an A0 drawing. 'Imagine', Wim asked, 'this machine has its back in the sun; what happens due to the temperature change? What does the steel feel, how will it react?' In this way, concepts such as thermal centre, temperature gradients and position stability gradually became clear."

Elastic hinges

A VanderHoekean example of clever energy management is concerned with the deformation of elastic hinges. The energy required can be compensated for by supplying the energy from elsewhere in a construction (Figure 1). Moving the body AB, along the perpendicular, straight-guided points A and B, where a and b represent linear elastic elements, does not have to require net energy. The condition is that a, respectively b, is unstressed if A, respectively B, is located in O. The body then has no preferred position. Its natural frequency is zero. This design principle forms, for example, the basis for the superb low-frequency suspension of the mirrors for Virgo, the European instrument for gravitational-wave detection.



1

Energy management in a construction with elastic elements.

Orthocyclic winding

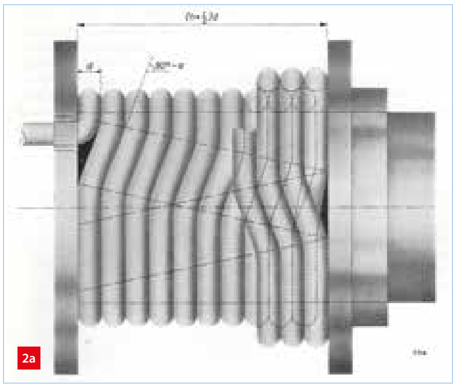
More than sixty years ago, energy considerations played a role in the development of orthocyclic winding technology. That was an invention of Wil Lenders, a colleague of Van der Hoek in the production mechanisation department within Philips's main industrial group RGT (Radio, Gramophone and Television). "Wil and I have fully understood it step by step and Wil has fully realised it." It involved winding in such a way that a regular pattern of windings was created with the highest possible density of stacking (Figure 2).

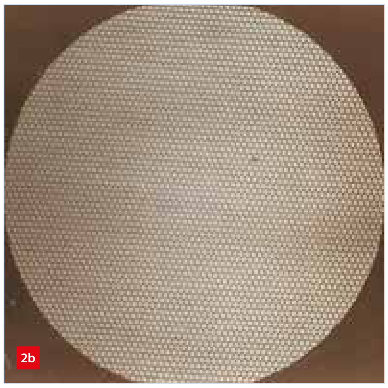
Due to the windings' regular build-up, they could not 'collapse' to deeper layers, which prevented stress concentrations. As a result, compared to 'wildly wound' coils, the breakdown voltage was high and the inherent capacitance small. Also, the heat conduction in an orthocyclic coil was particularly high due to the good connection between the layers, so that no large (undesirable) temperature differences could occur within a coil. All this resulted in a smaller outer diameter, a lower weight, a more concentrated field, a lower resistance, a more constant temperature distribution, a higher allowable temperature, and more precise tolerances than with non-orthocyclic coils.

Within Philips, orthocyclic winding applications were included in microphone, choke and deflection coils, relay coils for telephone diallers (figure 3) and special products such as 'lenses' for electron microscopes.

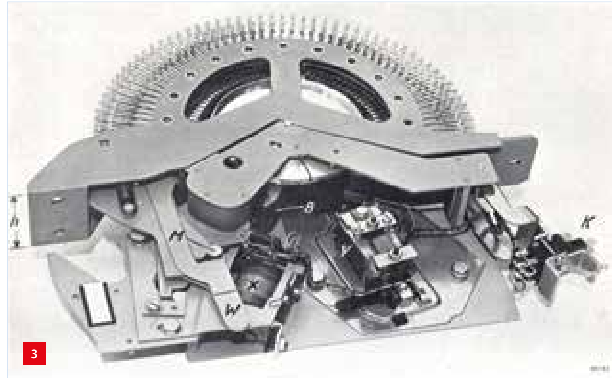
Staying in tune

As a retiree, Van der Hoek continued to delve into technical subjects as a mechanical designer: serious subjects, such as an alternative storm surge barrier or a patient-friendly hypodermic needle, and more light-hearted subjects, such as the tuning of a piano. The latter was triggered by a visit in 1999 with a group of Philips pensioners to the factory


2a


2b

The first layer and some windings of the second layer of a circular orthocyclic coil. Each winding crosses the centreline of the coil orthogonally over approximately 90% of its length. The remaining, skewed, part is the so-called transfer; the transfers of one layer together form a (slanting) transfer line. The windings of the second layer (with the exception of the transfers) lie neatly in the 'groove' formed by the windings of the first layer. On the right, the cross-section of an orthocyclically wound coil shows the high fill factor.


3

A fast rotary selector for telephony from Philips Telecommunications Industry. The coils for the coupling magnet X (which couples the axis of the contact brushes to a permanently rotating shaft) and the stop magnet Y (which stops the brushes at the desired location) are wound orthocyclically. This application reduced the required electrical power and heat generation in telephone exchanges.

of the famous piano manufacturer Bösendorfer in Vienna. A week later, Van der Hoek sent a 22-page letter to the management. He had been studying the piano's design for months. "In the days following the visit, I've thought a lot about it and there are some areas where I see room for improvement, especially with regard to the stability of the tuning, i.e. slowing down its going out of tune." This was under the influence of, among other things, temperature and humidity. So, he started calculating and measuring at home. If a string in an infinitely stiff frame underwent a temperature change of 10 °C, a tone of 440 Hz would change 5.5 Hz: "a massive detuning!" Van der Hoek came up with constructive improvements and presented them to Bösendorfer in his letter. However, he received no response from Vienna. He had put a lot of time and energy into it and all it had brought him was fun.

"Wim van der Hoek (1924-2019) – A constructive life"

After Wim van der Hoek passed away in early 2019, DSPE took the initiative to publish a book (in Dutch) about the Dutch doyen of design principles (Figure 4). It covers his formative years, including his World War II 'adventures', his career at Philips and Eindhoven University of Technology, his breakthrough ideas on achieving positioning accuracy and control of dynamic behaviour in mechanisms and machines, and their reception and diffusion. It concludes with his busy retirement years in which he continued to tackle design challenges, technical as well as social, believing that technology should support people.

His specialism, dynamic behaviour and positioning accuracy, was the main subject of his part-time professorship at Eindhoven University of Technology, from 1961 to 1984. There, he endeavoured to enthuse first-years in the mechanical engineering profession and to teach fourth-year students (some 600, over the years) mechanical design. In his lecture notes, he built on his research at Philips. He collected examples of designs that were lightweight, sufficiently stiff and play-free with regard to dynamics in his famous "The Devil's Picture Book" (*Des Duivels Prentenboek*, DDP), which he presented as a source of inspiration for upcoming and experienced designers. Now, this book about Wim van der Hoek conveys the same enthusiasm.

4

Lambert van Beukering & Hans van Eerden (eds.), "Wim van der Hoek (1924-2019), Een constructief leven – Ontwerpprincipes en praktijklessen tussen critiek en creatie", ISBN 978-90-829-6583-4, 272 pages, €49.50 (€39.50 for DSPE members) plus €6.50 postage, published by DSPE in 2020.

INFO@DSPE.NL
WWW.DSPE.NL

ECP2 COURSES OFFER BENEFITS TO MECHATRONIC PROJECTS

Gert van Ooik, principal system designer mechatronics at Sioux Technologies in Eindhoven (NL), has been awarded the Bronze certificate from the ECP2 programme. ECP2 is a European certified precision engineering course programme, a collaboration between euspen and DSPE. He is the ninth person to receive this certificate since the first one was presented in 2015.

Euspen's ECP2 programme grew out of DSPE's Certified Precision Engineer programme, which was developed in the Netherlands in 2008 as a commercially available series of training courses. In 2015, euspen, DSPE's European counterpart, decided to take certification to a European level. The resulting ECP2 programme reflects industry demand for multidisciplinary system thinking and in-depth knowledge of the relevant disciplines. To promote participation, a certificate scheme was instigated. The Bronze certificate requires 25 points (one point equals roughly one course day), Silver requires 35 points and Gold 45 points, which qualifies a participant for the title 'Certified Precision Engineer'.

Gert van Ooik (right) receiving flowers and the ECP2 Bronze certificate from the hands of Jan Willem Martens, founding father of the precursor DSPE certification programme.

High-tech

Gert van Ooik studied Electrical Engineering at Eindhoven University of Technology and worked subsequently at various high-tech companies in the Brainport Eindhoven region. At ODME, a manufacturer of CD mastering and production machines, he was responsible for the development of testing equipment for masters and CD quality. "I worked on the electronics, the software and the test principle. It was very broad in terms of disciplines and that is still characteristic of my interests." Next, he worked at IAI in Veldhoven (NL) on laser applications for, among other things, document security solutions. "I was involved in system design and developed embedded software and electronics. At a certain point, the machines concerned became a product and it was from then on a matter of fine-tuning that product. My interest faded."

CCM/Sioux

Hence, Van Ooik applied for a job at CCM (a mechatronics company that merged into Sioux Technologies in 2014, ed.). "I was attracted by the large pool of disciplines they worked with, from physics and optics to software and control engineering. I really got to learn mechatronics there." CCM/Sioux is where Van Ooik collected his ECP2 points. "I started with courses that are part of the foundation of mechatronics and were in line with my daily practice: Advanced Motion Control and Motion Control Tuning. If mechatronics is easy, it won't come to us. When it involves extremely high speed or accuracy, or extreme thermal conditions, it will. For example, the Advanced Motion Control course fitted in perfectly with the design that I was working on at the time, a master-slave long-stroke linear stage with a short-stroke six-axis stage that compensated the guiding errors. If you take your courses at the right time, you can benefit a lot from them."

Learning control

"Nowadays, we often have projects for cost-effective mass products, for which we have to use low-grade sensors and actuators while still achieving high accuracy in a smart way. Here, learning techniques can help. That's why I have also taken the Advanced Feedforward & Learning Control course, which I was able to apply, for example, in a project for an extremely accurate mastering machine for both DVDs and Blu-ray discs. I developed a learning technique to deal with repetitive errors, such as unevenness in the rotating master disc, because the required performance of nanometer accuracy at 4 kHz bandwidth could not be achieved with solely feedback-based control."

Optics

A common thread in many of Van Ooik's projects is optics; his interest dates back to his youth, when he was a member of *De Jonge Onderzoekers* (The Young Investigators) and built his own telescope (and computer). He therefore also attended the ECP2-certified Summer school Opto-Mechatronics. "That was a nice, broad course, in which the basic rules for optics were revived, precision engineering aspects were discussed and thermal problems were presented, and you were challenged to devise an appropriate control strategy for an optical delay line in a large telescope. Typically, a task for which you really have to come up with an outside-the-box solution."

Experiment and calibration

The Experimental Techniques in Mechatronics course is more recent. "At Sioux I am responsible for the investments in equipment for modal analysis. This is becoming increasingly important due to the ever-increasing demands on dynamic behaviour. It gives you more confidence if you can validate your designs not only with FEM simulations but also experimentally." This year, Van Ooik took the Metrology and Calibration of Mechatronic Systems course. "If you have to achieve high accuracy, you will only succeed if you take the required calibrations into account in the system design."

Fun

And Van Ooik hasn't finished learning yet. "My position at Sioux touches on system architecture; I have to understand all disciplines." So, he also took courses on soft skills and system architecture and is considering the topic of actuators. "Taking a course is also always good for expanding your network and gaining new inspiration from your teachers and fellow students. It's just fun."

WWW.ECP2.EU
WWW.SIOUX.EU

WIM VAN DER HOEK AWARD 2022: CALL FOR RECOMMENDATIONS

The Wim van der Hoek Award is an annual prize awarded to the student with the best graduation project in the field of mechanical engineering at a university of technology or a university of applied sciences in the Netherlands or Belgium. In 2022 the prize will be awarded for the seventeenth time. Award candidates can be recommended by their graduation supervisor, graduation teacher or lecturer/professor. The submission deadline for recommendations is 9 September 2022.

Every year, the second day of the Precision Fair features the presentation of the Wim van der Hoek Award under the auspices of DSPE. This award (also known as the Constructors Award) was introduced in 2006 to mark the 80th birthday of the Dutch doyen of design engineering principles, Wim van der Hoek (1924-2019). It includes a certificate, a trophy made by the Leidse instrumentmakers School and a sum of money, sponsored by TU/e institute EIASI.

The graduation theses of the candidates that have been recommended will be assessed by the jury. The criteria are design quality, substantiation and innovativeness of the chosen solutions, as well as the possibility to serve as an example in design principles education. The jury will subsequently decide on the nominations and invite the nominees to give an online presentation, after which the jury will designate the winner. All nominees will be invited to attend the award ceremony on Thursday 17 November at the Precision Fair in Den Bosch (NL), where the winner will be announced.

The jury of the Wim van der Hoek Award in the Wim van der Hoek conference room of JPE, located at Maastricht-Airport (NL). From left to right: chairman Jos Gunsing (MaromeTech), Johan Vervoort (Vervos), Marc Vermeulen (ASML), Maurice Teuwen (JPE), Hans Steijaert (Vanderlande) and Wouter Vogelesang (VH Consult).

The nominees will be given the opportunity to submit an abstract for an oral or poster presentation or demonstration at the forthcoming DSPE Conference on Precision Mechatronics, in September 2023. When their abstract has been accepted, they can participate in the conference free of charge.

INFO@DSPE.NL
WWW.DSPE.NL/AWARDS

NEW EDITION OF OPTOMECHANICAL SYSTEM DESIGN COURSE

Mid-October, a new real-life edition of the Optomechanical System Design course wil be held in Eindhoven (NL). The DSPE initiative targets mechanical, mechatronic and optical engineers, offering a broad overview of this omnipresent multidiscipline. It contains numerous design examples that illustrate the tricks of the trade in optomechanical system design, which increasingly impacts the overall performance of high-tech systems. One of the objectives of the course is to help engineers from the various disciplines develop a common optomechanical language.
The feedback from previous editions has been generally very positive. Participants appreciate the overview of the field, the in-depth treatment of various topics, the teacher-class interaction and the exercises. The teachers are experienced engineers, who know the tricks of the trade in optomechatronics, system architecture, system design and engineering, and optomechanical engineering. Together they draw upon more than 100 years of experience in this field at Dutch universities and research institutes, and in the high-tech industry.

WWW.DSPE.NL/EDUCATION

YPN VISIT TO PRODRIVE TECHNOLOGIES

This spring, DSPE's Young Precision Network (YPN) paid a visit to Prodrive Technologies in Son (NL). After a warm welcome with drinks, HR manager Ruud de Vries gave a presentation about the company Prodrive. He presented the various technology programmes and the products typically developed in these programmes. It was interesting to see that Prodrive started as a primarily electronics-based company and that it is currently more and more into developing and manufacturing entire systems including software and mechanics.

After this general introduction to Prodrive, mechanical engineer Moos Senden continued with a technical presentation about a newly developed high-precision motion stage: the Proton Motion Stage. He had started the design for this stage during his graduation project at Prodrive and the Constructions and Mechanisms group of Eindhoven University of Technology. Following his graduation, he started working at Prodrive and continued with the development of this stage.

The Proton Motion Stage.

Sub-micron-accurate stage

The Proton Motion Stage is a sub-micron-accurate gantry stage that was developed with the well-known design principles in mind. It has a statically determined preload mechanism to ensure highly smooth motion and robustness for temperature variations and other disturbances. It was interesting to see that the stage was developed with mainly off-the-shelf Prodrive products as building blocks, such as actuators, vibration isolation, servo drives, motion controller and interferometer system.

Thermal behaviour

After this talk, mechanical engineer Simon Kregting continued with a presentation entitled "Thermally stable design of a camera system". His talk was about the design of an actuator unit for placing an image sensor in or out of a beamline of an optical imaging system. Since the image sensor itself was placed in a vacuum environment, especially the thermal behaviour was critical in this application. Simon showed the different measures he took to provide sufficient cooling within a small design volume.

Factory tour

After this second technical presentation, the visit continued with a factory tour. During the tour, the impressive production capabilities of Prodrive were shown, including actuator coil winding, injection moulding and additive manufacturing. Highlights were the automated production lines for automotive products and the large EMC test chambers. In addition, a demonstration was given with the Proton Motion Stage as discussed previously.

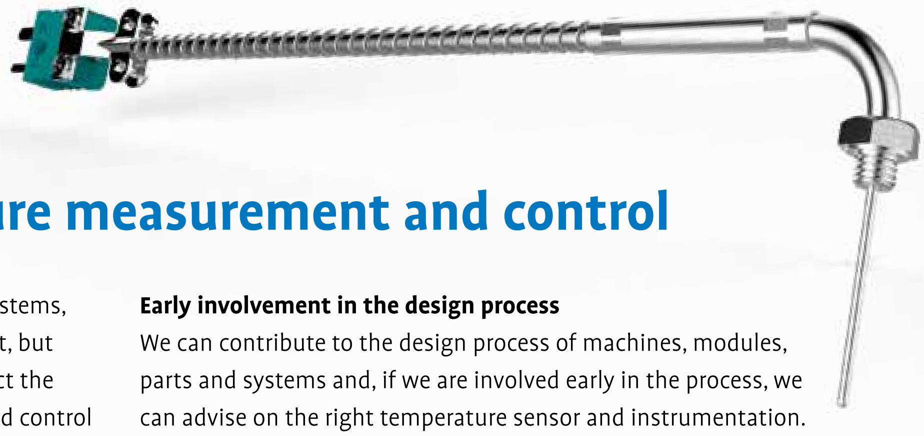
This interesting afternoon ended with drinks, snacks and time for networking. YPN would like to thank Prodrive Technologies, and in particular mechanical design engineer Pim Duijsens, as host of the day, for the hospitality and the inspiring visit.

(report by Matthijs van Gastel)

HR manager Ruud de Vries presenting to the YPN party.

Tempcontrol
Industrial Electronic Products

Tel: 015 - 251 18 31 | info@tempcontrol.nl | tempcontrol.nl



The specialist in temperature measurement and control

Temperature is an important parameter in many processes, systems, machines or parts of machines. Temperature variations or drift, but also unwanted temperature differences, can considerably affect the performance of a machine or system. Proper measurement and control of temperature in a process have a positive effect on the lifespan of machines, ensure fewer downtime and improve performance.

Customized temperature sensors
Tempcontrol develops and manufacturs customized and standard temperature sensors, specializing in tailor made solutions. With over 40 years of experience, we are always able to find the right solution for each specific application. A quick response time, high accuracy, long-term stability, resistance to high or low temperatures, nearly anything is possible.

Early involvement in the design process
We can contribute to the design process of machines, modules, parts and systems and, if we are involved early in the process, we can advise on the right temperature sensor and instrumentation.

At our location we have a production department, a warehouse, a cleanroom and a calibration and research lab. Here we develop, produce, measure, optimize, calibrate and stabilize temperature sensors and instrumentation. Testing (long-term) and investigation of temperature sensors is also possible.

In addition, we can provide high-quality instrumentation and precision measuring equipment from quality brands such as AsconTecnologic, ASL/Wika, Dostmann, Inor, MBW, Giussani, Kambic and Weidmann.

Temperature sensors in many designs

Controllers

High quality measuring equipment

Transmitters, isolators

Tempcontrol supplies to almost all industries where temperature is a critical factor: medical and food industry, aviation and shipping, semiconductor and plastics industry, defence industry, pharma and petrochemicals, machine and equipment construction, installation companies and laboratories etc. Visit **www.tempcontrol.nl/solutions** for our full product portfolio.

ECP² COURSE CALENDAR

COURSE (content partner)	ECP² points	Provider	Starting date
FOUNDATION			
Mechatronics System Design - part 1 (MA)	5	HTI	3 October 2022
Mechatronics System Design - part 2 (MA)	5	HTI	10 October 2022
Fundamentals of Metrology	4	NPL	to be planned
Design Principles	3	MC	28 September 2022
System Architecting (S&SA)	5	HTI	7 November 2022
Design Principles for Precision Engineering (MA)	5	HTI	7 November 2022
Motion Control Tuning (MA)	5	HTI	21 November 2022
ADVANCED			
Metrology and Calibration of Mechatronic Systems (MA)	3	HTI	21 March 2023
Surface Metrology; Instrumentation and Characterisation	3	HUD	to be planned
Actuation and Power Electronics (MA)	3	HTI	1 November 2022
Thermal Effects in Mechatronic Systems (MA)	3	HTI	13 December 2022
Dynamics and Modelling (MA)	3	HTI	22 November 2022
Manufacturability	5	LiS	26 September 2022
Green Belt Design for Six Sigma	4	HI	26 September 2022
RF1 Life Data Analysis and Reliability Testing	3	HI	12 September 2022
Ultra-Precision Manufacturing and Metrology	5	CRANF	to be planned
SPECIFIC			
Applied Optics (T2Prof)	6.5	HTI	31 October 2022
Advanced Optics	6.5	MC	23 February 2023
Machine Vision for Mechatronic Systems (MA)	2	HTI	upon request
Electronics for Non-Electronic Engineers – Analog (T2Prof)	6	HTI	to be planned
Electronics for Non-Electronic Engineers – Digital (T2Prof)	4	HTI	to be planned
Modern Optics for Optical Designers (T2Prof) - part 1	7.5	HTI	23 September 2022
Modern Optics for Optical Designers (T2Prof) - part 2	7.5	HTI	to be planned (Q1 2023)
Tribology	4	MC	18 October 2022
Basics & Design Principles for Ultra-Clean Vacuum (MA)	4	HTI	31 October 2022
Experimental Techniques in Mechatronics (MA)	3	HTI	to be planned (Q2 2023)
Advanced Motion Control (MA)	5	HTI	17 October 2022
Advanced Feedforward & Learning Control (MA)	3	HTI	to be planned (Q2 2023)
Advanced Mechatronic System Design (MA)	6	HTI	to be planned (2023)
Passive Damping for High Tech Systems (MA)	3	HTI	29 November 2022
Finite Element Method	2	MC	3 November 2022
Design for Manufacturing (Schout DfM)	3	HTI	4 October 2022

ECP² program powered by euspen

The European Certified Precision Engineering Course Program (ECP²) has been developed to meet the demands in the market for continuous professional development and training of post-academic engineers (B.Sc. or M.Sc. with 2-10 years of work experience) within the fields of precision engineering and nanotechnology. They can earn certification points by following selected courses. Once participants have earned a total of 45 points, they will be certified. The ECP² certificate is an industrial standard for professional recognition and acknowledgement of precision engineering-related knowledge and skills, and allows the use of the ECP² title.

WWW.ECP2.EU

Course providers

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

Content partners

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

NXTGEN HIGHTECH receives M€ 450 from Dutch National Growth Fund

Dutch companies produce high-tech equipment for the semiconductor, medical technology, data communication, and other markets. As a crucial pillar of the Dutch economy, high-tech equipment makes up a large share of the Dutch export total. High-tech equipment also offers solutions for the biggest challenges our society is facing, from the energy and climate transition, optimal health care, and safe communication to the sustainability of our food chain. Moreover, it is at the core of (European) production and technology sovereignty, which has proved to be crucial during the Covid-19 pandemic.

However, to strengthen future earning capacity, the Dutch high-tech equipment ecosystem needs to take a leap forward. The investment programme NXTGEN HIGHTECH initiates this leap with the objective of making the Dutch high-tech equipment ecosystem one of Europe's leading high-tech clusters by 2030. The programme aims to develop a new generation of high-tech equipment focusing on sustainability, digitalisation, health and technology sovereignty. This ambition has been recognised by the Dutch National Growth Fund, which recently awarded M€ 450.

NXTGEN HIGHTECH will use this funding to develop new equipment in six areas of application with a shared basis in key technologies, for example:

- Clean energy: clean hydrogen by manufacturing efficient electrolysers using thin-film technology.
- Data communication: transferring from radio to light. Communication through laser beams is safer and has a much higher capacity.
- Health equipment: production technology for new chips used to simulate organs and accelerate the search for new drugs without the need for animal testing.
- Stacked microchips: a step towards even faster and more efficient chips that partly switch using light as well.
- Compact, flexible and robotised production lines for lightweight composite structures.
- The food chain: introducing faster and more precise robots in agriculture and horticulture.

The NXTGEN HIGHTECH programme facilitates joint ventures by companies and knowledge institutions focused on the development of new value chains, new activities and international positions. The programme is built on three coordinated pillars: application programmes, technological and scientific advancements, and ecosystem development.

WWW.NXTGENHIGHTECH.NL

Design for Antarctica

To fight climate change, we have to understand it. However, understanding it means obtaining information in places where nature is pristine, as well as places where the consequences of global warming can be observed first-hand. These places are found in extremely cold, harsh environments like the North Pole, Antarctica, and the oldest glaciers. At the moment, research is often inefficient, very expensive and unsustainable, mainly due to the human involvement with data acquisition and the research infrastructure being powered by fossil fuels.
It is the ambition of Team Polar to make research equipment sustainable, autonomous, and affordable, in that order. Practically, the student team of Eindhoven University of Technology aims to venture into the unexplored territories of Antarctica with an autonomous and sustainable vehicle; enabling global accessibility of Antarctic research via a modular research platform, detecting new routes, and doing this all in an economical, safe and environmentally friendly way.

Design of an Antarctic rover by Team Polar.

Last winter (i.e. Antarctic summer), two team members visited the continent to take some measurements using a test set-up made up of a spectrometer and two pyranometers. They collected data that will help the team to build their 'Antarctica rover', a self-designed solar mobile that will make unmanned climate research at the South Pole possible. Their findings were positive: "Driving a solar car at the South Pole is certainly possible, but it is not an easy task." The polar rover is comparable to Martian rovers that collect data in a similar way on the red planet.

Engineering focuses on the electrical, mechanical and computational domain. The biggest electrical challenges are the low temperatures and the limited amount of energy that the low-hanging sun provides on the Antarctic continent. The main mechanical issue is the limited amount of knowledge about vehicle behaviour under the harsh conditions. In the computational domain, satellite connectivity is limited and the detection of crevasses in the ice using a ground-penetrating radar poses a high burden on processor capacity. The first prototype is scheduled for the end of the summer.

WWW.TEAMPOLAR.ORG

"Unmanned robots as humans"

Mid-June, during the TValley Tech Conference, Abeje Mersha delivered his inaugural lecture as professor of Unmanned Robotic Systems at Saxion University of Applied Sciences in Enschede (NL). Mersha is affiliated with Saxion's School of Life Science, Engineering & Design. With his team of the Mechatronics research group, he contributes to applied research in advanced robotic systems and artificial intelligence for a wide range of application domains, including safety & security, smart industry, agriculture, sustainable energy and healthcare.

In his inaugural lecture, entitled "Unmanned Robots as Humans: A Mission-drive Approach", Mersha presented exemplary and innovative joint initiatives of his group and public & private partners. He addressed the unlimited and unparallelled opportunities these robots offer in solving urgent societal challenges, ranging from safety and climate change to food security. He touched upon the multidimensional roadblocks we are facing in fully utilising the potentials of these robots, and why treating them as humans with specific missions is crucial to guiding the technological development and their acceptance in our society. He concluded his lecture with an outlook on the field of unmanned robotics and the 2030 ambition of his applied research group.

Abeje Mersha, professor of Unmanned Robotic Systems at Saxion University of Applied Sciences.

TValley is a network cluster that provides a platform for engineers who work on challenging and innovative projects in the field of robotics, mechatronics and artificial intelligence.

WWW.SAXION.NL
WWW.TVALLEY.NL

Multiple e-beam wafer inspection

ASML has announced the first customer installation of its HMI eScan 1100, the first multiple e-beam (multibeam) wafer inspection system for in-line yield enhancement applications, including voltage contrast defect inspection and physical defect inspection. With 25 beams (5x5), the eScan 1100 is able to increase throughput by up to 15 times compared to single e-beam inspection systems that are currently used. It delivers the sensitivity and speed to cover a wide range of defect types in R&D for process development, and in high-volume manufacturing for excursion monitoring.

According to HMI, an ASML company since 2016, there is a need for more accurate defect inspection to capture small defects down to below 10 nm in size with high throughput for sufficient wafer area coverage. The eScan 1100 multibeam system was designed to fill that gap. Its proprietary die-to-database defect inspection capability enables further enhancements in sensitivity and throughput for the most demanding applications such as EUV mask defect monitoring by using wafer print check. HMI claims the eScan 1100 can detect defects currently overlooked by optical inspection systems in a fraction of the time that it takes single e-beam solutions.

WWW.ASML.COM

New maxon products

In maxon's 2022/2023 catalogue, various new products are presented. One example is the radiation-resistant ENX GAMA encoder, a magnetic 2-channel encoder that is available in 10 mm and 13 mm sizes. It replaces the existing MEnc encoders and has been developed for radiation-affected environments. It is resistant to ionising radiation and can withstand a dose of up to 500 krad (SIO 2). This means that the GAMA encoders can be used in applications such as radiotherapy devices (multileaf collimators). The axially arranged connecting cable is designed as a single-cable system and simultaneously integrates the motor cables of the installed DC motor. This single-cable solution permits compact and space-saving installation.

There also is a new addition to the EC frameless DT series; brushless motors with a frameless design that can be integrated into a wide range of applications easily. The new EC frameless DT50S motor, a shortened version of the DT50M, has been optimised to have even higher power density, providing first-class heat dissipation, and including integrated temperature sensors that enable high-precision temperature monitoring. The motor is provided with a TSX-MAG encoder; a through-shaft encoder that is not installed directly on the motor axis (off-axis installation). The encoder generates both Hall and incremental signals, which makes it an optimal signal transmitter for precision positioning tasks.

The 2022/2023 catalogue is fresh off the printing press and provides a complete overview of the maxon product portfolio – also available online.

EPAPER.MAXONGROUP.COM
WWW.MAXONGROUP.COM

Precise mirror positioning in space

Piezosystem jena, a leader in piezo-technology research, design and manufacturing, has announced a new product solution aimed largely at the aerospace industry. Adding to the existing product line of tip-tilt systems, the new PSH 40 is the newest iteration of solutions for satellites and other space vehicles.

Many aerospace applications still rely upon radio-frequency communications. Newer laser communications technology is becoming widely implemented and offers significantly more speed, higher bandwidth and more secure communications. One of the crucial components that makes this communication possible is the fast-steering mirror that directs laser beams for intersatellite communication. Several years ago, piezosystem jena worked with MIT (Cambridge, Massachusetts), which in collaboration with NASA used its piezo technology to align a laser with a satellite orbiting the moon. Since that time, piezosystem jena has continued working in defence and aerospace applications.

The piezo mirror-tilting platform PSH 40 has an 18 mm x 4 mm mirror with a tilt range of +/– 15 mrad, a closed-loop resolution below 2 microrad, and a resonance frequency of 500 Hz. The design features a three-axis system, active control of z-position and pivot point, and a high displacement at low system height. Dimensions are 62 mm x 62 mm x 30 mm.

WWW.PIEZOSYSTEM.COM

New replication technology for micro-ceramic components

Conventional PDMS (polydimethylsiloxane) replication is based on using master moulds made by lithography. Through litho, it is possible to make small microstructures that can be replicated by PDMS moulding. This is always a two-step PDMS replication process because of the fact that the wafer and structures of the master mould are relatively fragile and are damaged easily. Furthermore, the litho process is limited by design, because the design needs to be built by resist layers, exposures, and bake cycles.

Besides the wafer being quite fragile also, the structures are not as though as a glass structure would be. After applying PDMS on the master mould wafer, the peeling off of the PDMS can create forces on the wafer that will break it or damage the structures. For this reason, the litho master mould is replicated twice so that the first replicate can be used as a master mould to create multiple replicates.

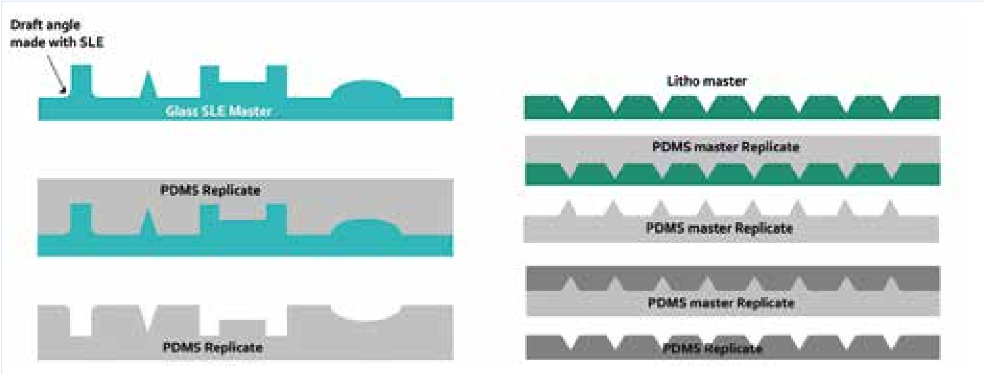
As an alternative to the two-step replicate process, which uses a litho master, a one-step replicate process, using a glass master mould, can be run. The litho master is a positive replicate of the final PDMS replicate and a glass master is a negative form of the final PDMS replicate. To make stronger master moulds, selective laser-induced etching (SLE) can be used to create microstructures in glass and eliminate the limitations in design as well as the need for a two-step process. Thanks to the proven durability of the glass material, it can be used many times, making the need for a double replication step unnecessary. These SLE master moulds can hold 3D structures that are built using step sizes ten times smaller in size than used for 3D-printed structures. This way, it is possible to create very sharp microstructures and even nicely rounded structures, or a combination of these.

Creating small structures with high aspect ratios and a rounded design towards the bottom makes it possible to create draft angles in replicated PDMS moulds. Thus, the SLE master has proven its use for the production of PDMS working moulds for casting, releasing, and sintering ceramic microstructures down to 200 µm in width, with sharp edges down to 1 µm.

Because of the possibility to add draft angles in the design, the casted ceramic microstructures are much more ridged, preventing easy breakage.

LouwersHanique, manufacturer of critical glass and ceramic components, located in Hapert (NL), has proven that the glass master mould can be replicated very precisely in PDMS, and that it is then possible to use the PDMS as a mould for casting ceramic microproducts. Besides producing the glass master mould, also a process has been set up to produce exact PDMS replicates. PDMS replicates can be used as microfluidic devices and for creating microprecision ceramic components such as MEMS, medical implants, or electronics.

WWW.LOUWERSHANIQUE.COM



Schematic of PDMS replication by using either an SLE master (left) or a litho master (right).

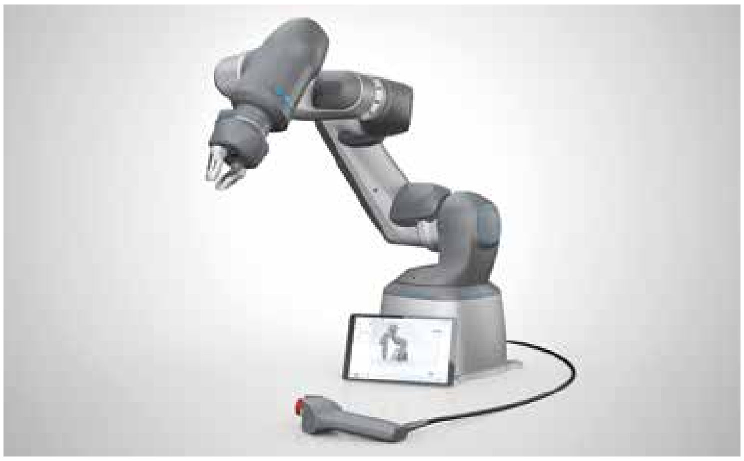
UT's cryogenic cooling contribution to ET

Gravitational waves originating from events in the universe such as the merging of black holes were for the first time detected in 2015 by the LIGO observatories in the USA. These waves were already predicted by Albert Einstein more than hundred years ago on the basis of his general theory of relativity.

In Europe a project has been started a decade ago to realise an observatory, the Einstein Telescope (ET), which is orders of magnitude more sensitive than LIGO or the European Virgo facility. Detection is based on laser interferometry as in LIGO and Virgo, but the sensitivity is greatly improved by increasing the size of the interferometer arms (from 3 to 10 km), by using a triangular arrangement forming three interferometers, by realising the set-up underground at a depth of 200 to 300 m, and by cooling the mirrors to a very low (cryogenic) temperature to reduce thermal noise (around 10 K).

The border region of the Netherlands, Belgium and Germany is a potential ET location. In order to develop technologies required for ET, scientists and companies from these three countries are setting up a joint R&D facility: ETpathfinder (ETPF). It is a scaled-down version of ET with arms of 20 m rather than 10 km, not aiming to detect gravitational waves but intended to develop the precision technology, coatings and optics as well as special measurement and control technology, seismic isolation, required for ET and to test these in an ET-like environment.
The ETPF laboratory is currently being established at the University of Maastricht (NL).

The first pneumatic cobot



Industrial automation supplier Festo has introduced the world's first pneumatic robot. "What if there was a robot that was easy to operate, did not require a safety fence and was also attractively priced? That would introduce a whole new era in human-robot collaboration. This new era is now dawning", a press release states. "Hardly any industrial market segment will grow as rapidly over the next few years as human-robot collaboration. Cobots relieve employees of particularly strenuous or monotonous tasks, thus giving them new levels of freedom and making their work easier and healthier. And no other technology has such a sensitive and flexible approach to human-robot collaboration as pneumatics."

The new cobot owes many of its advantages, such as its sensitivity, weight and value for money, to the benefits of pneumatics, so Festo claims. The direct drives in the articulated joints are very cost-effective and particularly lightweight because, unlike electric solutions, no heavy gear units or expensive force-torque sensors are required. In its main application area of small parts handling with payloads of up to 3 kg, the Festo Cobot makes using cobots even cost-effective for SMEs, as they often rely on manual work processes. This is achieved because of the flexible application options so that small batch sizes or work steps can also now be processed automatically.

The Festo Cobot consists of the hardware itself, a handheld module and the Robotic Suite – software for intuitive commissioning and programming. This package makes it possible to commission and program the cobot in less than an hour. Prior knowledge of robotics is not required either because the self-explanatory software contains clearly visualised and standardised function blocks. Pneumatic drives enable the robot arm to be easily guided by hand and without any resistance so that waypoints or paths can be taught quickly and precisely. The compact controller that is integrated in its own base makes it particularly flexible.

Thanks to state-of-the-art, lightweight construction methods, the weight has been reduced to well under 20 kg. With a length of 670 mm, the Festo Cobot is just like a human arm and has the right reach for it to be perceived as a helping third hand when working with a member of staff. Thanks to the flexibility of the pneumatic drives, the cobot acts sensitively – at a speed appropriate to the situation and with fluid, harmonious movements. It is as soft to the touch as human contact. The cobot's pneumatic direct drives and its light weight reduce its contact energy. Thanks to precise pressure regulators in the articulated joints, the robot recognises when it is being touched and responds with appropriate safety functions.

WWW.FESTO.COM

The Dutch University of Twente (UT) is one of the founding partners of ETPF. Based on its cryogenic expertise, UT will have an important role in he development of ET. Vibration-free cooling technology that has been developed in the UT research group Energy, Materials and Systems in earlier projects for the European Space Agency will be applied and tailored to the needs of ET.

Furthermore, a dedicated cryogenic test facility will be realised at UT for developing, testing and validating cryogenic technologies for ET. For this purpose, an extra copy of the vacuum towers designed for ETPF has been built by the Italian company ALCA Technology and was shipped to UT. It measures around 3 m at maximum in diameter and about 2 m inside height. All cryogenic technologies to be used in ETPF will be tested and validated in this tower applying the same cryogenic infrastructure as will be used in ETPF.

WWW.ET-GW.EU
WWW.EINSTEINTELESCOPE.NL
WWW.ETPATHFINDER.EU
WWW.UTWENTE.NL

The vacuum tower at UT for testing ETPF cryogenic infrastructure.

Automation Technology

FESTO

Festo BV
Schieweg 62
2627 AN DELFT
The Netherlands
T +31 (0)15-2518890
E sales@festo.nl
W www.festo.nl
Contact person:
Mr. Michiel Deen

Festo is a leading world-wide supplier of automation technology and the performance leader in industrial training and education programs.

member DSPE

Cleanrooms

BRECON GROUP

Brecon Group
Droogdokkeneiland 7
5026 SP Tilburg
T +31 (0)76 504 70 80
E brecon@brecon.nl
W www.brecon.nl

Brecon Group can attribute a large proportion of its fame as an international cleanroom builder to continuity in the delivery of quality products within the semiconductor industry, with ASML as the most important associate in the past decades.

Brecon is active with cleanrooms in a high number of sectors on:
* Industrial and pharmaceutical
* Healthcare and medical devices

member DSPE

Cleanrooms

Connect 2 Cleanrooms BV
Poppenbouwing 26 C
4191 NZ Geldermalsen
Nederland
T +31 (0)85-130 16 66
E info@connect2cleanrooms.com
W www.connect2cleanrooms.nl

Developing the most appropriate cleanroom to transform your production is our passion. Our scalable and connected cleanrooms have been delivering regulatory compliance to our clients since 2002. We innovate to overcome your contamination control challenges – resulting in a new generation of scalable cleanrooms that set an unprecedented benchmark in the industry.

member DSPE

PROCLEANROOM
BUILD YOUR EXPERTISE

ProCleanroom
Dragonder 13c
5554 GM Valkenswaard
The Netherlands
T +31 (0)40 4002874
E niels.ferguson@procleanroom.com
I www.procleanroom.com

ProCleanroom enables industrial, high-tech and medical companies as well as research institutions to accelerate breakthrough technology by providing professional, fit-for-purpose cleanroom and flow unit solutions for critical environments.
As full service provider we offer cleanroom and flow unit design & manufacturing, installation and ISO validation services as well as a full program of cleanroom accessories & consumables accessible through our leading webshop.

Development

TNO innovation for life

TNO
T + 31 (0)88-866 50 00
W www.tno.nl

TNO is an independent innovation organisation that connects people and knowledge in order to create the innovations that sustainably boosts the competitiveness of industry and wellbeing of society.

member DSPE

Education

LiS Leidse instrumentmakers School

Leiden school for Instrumentmakers (LiS)
Einsteinweg 61
2333 CC Leiden
The Netherlands
T +31 (0)71-5681168
E info@lis.nl
W www.lis.nl

The LiS is a modern level 4 MBO school with a long history of training Research instrumentmakers. The school establishes projects in cooperation with industry and scientific institutes thus allowing for professional work experience for our students. LiS TOP accepts contract work and organizes courses and summer school programs for those interested in precision engineering.

member DSPE

Electrical Discharge Machining (EDM)

CVT BV
Heiberg 29C
5504 PA Veldhoven
The Netherlands
T +31 (0)497 54 10 40
E info@cvtbv.nl
W www.cvtbv.nl

Partner high tech industry for wire EDM precision parts. Flexible during day shifts for prototyping. Outside office hours low cost unmanned machining. Call and enjoy our expertise!

member DSPE

Ter Hoek Vonkerosie
Propaanstraat 1
7463 PN Rijssen
T +31 (0)548 540807
E info@terhoek.com
W www.terhoek.com

INNOVATION OF TOMORROW, INSPIRATION FOR TODAY
Staying ahead by always going the extra mile. Based on that philosophy, Ter Hoek produces precision components for the high-tech manufacturing industry.

We support customers in developing high-quality, custom solutions that can then be series-produced with unparalleled accuracy. That is what makes us one of a kind.
It is in that combination of innovative customization and repeated precision that we find our passion. Inspired by tomorrow's innovation, each and every day.

member DSPE

Lasers, Light and Nanomotion

Laser 2000 Benelux C.V.
Voorbancken 13a
3645 GV Vinkeveen
Postbus 20, 3645 ZJ Vinkeveen
T +31(0)297 266 191
F +31(0)297 266 134
E info@laser2000.nl
W www.laser2000.nl

Laser 2000 Benelux considers it her mission to offer customers the latest photonics technologies available.
Our areas of expertise are:

- Piezo- and stepper motion products for nano- and micro positioning
- Lasers, scanners and laser machines for industry and research
- Light metrology instruments for LED and luminaire industries
- Light sources for scientific applications
- Laser safety certified products

te lintelo systems bv
photonics. our passion!
35 YEARS

Te Lintelo Systems B.V.
Mercurion 28A
6903 PZ Zevenaar
T +31 (0)316 340804
E contact@tlsbv.nl
W www.tlsbv.nl

Photonics is our passion!
Our experienced team is fully equipped to assist you with finding your best optical business solution.
For over 35 years TLS represent prominent suppliers in the photonics industry with well-educated engineers, experience and knowledge.
Over the years we became the specialist in the field of:

- Lasers
- Light metrology,
- Opto-electronic equipment,
- Positioning equipment
- Laser beam characterization and positioning,
- Interferometry,
- (Special) Optical components,
- Fiber optics,
- Laser safety

Together with our high end suppliers we have the answer for you!

member DSPE

Mechatronics Development

creating mechatronics

MTA B.V.
Maisdijk 12
5704 RM Helmond
T +31 (0)492 474992
E info@mtagroup.nl
W www.mtagroup.nl

CHANGING THE GAME OF MECHATRONICS.
We develop mechatronic products in such a way that they can be produced in series, at a pre-defined price point, at a pre-defined quality level and with the shortest time-to market.
Our unique "V²-way of working" enables viable business cases.
Product and production design run concurrently and are continuously coordinated and synchronized during the development process.
This is how we make a difference in the world of mechatronics.

member DSPE

Mechatronics Development

MI Partners
PARTNERS IN MECHATRONIC INNOVATION

MI-Partners
Habraken 1199
5507 TB Veldhoven
The Netherlands
T +31 (0)40 291 49 20
F +31 (0)40 291 49 21
E info@mi-partners.nl
W www.mi-partners.nl

MI-Partners is active in R&D of high-end mechatronic products and systems. We are specialised in concept generation and validation for ultra-fast (>10g), extremely accurate (sub-nanometers) or complex positioning systems and breakthrough production equipment.

member DSPE

Metal Precision Parts

etchform
Wickeder Group

Etchform BV
Arendstraat 51
1223 RE Hilversum
T +31 (0)35 685 51 94
F info@etchform.com
W www.etchform.com

Etchform is a production and service company for etched and electroformed metal precision parts.

member DSPE

Micro Drive Systems

maxon

maxon benelux
Josink Kolkweg 38
7545 PR Enschede
The Netherlands
T +31 (0)53 744 0 744
E info@maxongroup.nl
W www.maxongroup.nl

maxon is a developer and manufacturer of brushed and brushless DC motors, as well as gearheads, encoders, controllers, and entire mechatronic systems. maxon drives are used wherever the requirements are particularly high: in NASA's Mars rovers, in surgical power tools, in humanoid robots, and in precision industrial applications, for example. To maintain its leadership in this demanding market, the company invests a considerable share of its annual revenue in research and development. Worldwide, maxon has more than 3.050 employees at nine production sites and is represented by sales companies in more than 30 countries.

member DSPE

Micro Drive Systems

FAULHABER

FAULHABER Benelux B.V.
Drive Systems
High Tech Campus 9
5656 AE Eindhoven
The Netherlands
T +31 (0)40 85155-40
E info@faulhaber.be
E info@faulhaber.nl
W www.faulhaber.com

FAULHABER specializes in the development, production and deployment of high-precision small and miniaturized drive systems, servo components and drive electronics with output power of up to 200 watts. The product range includes brushless motors, DC micromotors, encoders and motion controllers. FAULHABER also provides customer-specific complete solutions for medical technology, automatic placement machines, precision optics, telecommunications, aerospace and robotics, among other things.

PI

Physik Instrumente (PI)
Benelux BV
Hertog Hendrikstraat 7a
5492 BA Sint-Oedenrode
The Netherlands
T +31 (0)499-375375
F +31 (0)499 375373
E benelux@pi.ws
W www.pi.ws

Stay ahead with drive components, positioners and systems by PI. In-depth knowledge, extensive experience and the broadest and deepest portfolio in high-end nanopositioning components and systems provide leading companies with infinite possibilities in motion control.

member DSPE

Motion Control Systems

AEROTECH

Aerotech Ltd
The Old Brick Kiln
Ramsdell, Tadley
Hampshire RG26 5PR
UK
T +44 (0)1256 855055
E sales@aerotech.co.uk
W uk.aerotech.com

Aerotech's motion control solutions cater a wide range of applications, including medical technology and life science applications, semiconductor and flat panel display production, photonics, automotive, data storage, laser processing, electronics manufacturing and testing.

Motion Control Systems

Newport Spectra-Physics B.V.
Vechtensteinlaan 12 - 16
3555 XS Utrecht
T +31 (0)30 6592111
E netherlands@newport.com
W www.newport.com

Newport Spectra-Physics B.V. is a subsidiary of Newport, a leader in nano and micro positioning technologies with an extensive catalog of positioning and motion control products. Newport is part of MKS Instruments Inc., a global provider of instruments, subsystems and process control solutions that measure, control, power, monitor, and analyze critical parameters of advanced processes in manufacturing and research applications.

member DSPE

Physik Instrumente (PI)
Benelux BV
Hertog Hendrikstraat 7a
5492 BA Sint-Oedenrode
The Netherlands
T +31 (0)499-375375
F +31 (0)499 375373
E benelux@pi.ws
W www.pi.ws

Opt for state-of-the-art motion control systems from the world's leading provider PI. Developed, manufactured and qualified in-house by a dedicated and experienced team. Our portfolio includes a wide and deep range of components, drives, actuators and systems and offers infinite possibilities in motion control on a sub-micron and nanometer scale.

member DSPE

Optical Components

Molenaar Optics
Gerolaan 63A
3707 SH Zeist
T +31 (0)30 6951038
E info@molenaar-optics.nl
W www.molenaar-optics.eu

Molenaar Optics is offering optical engineering solutions and advanced products from world leading companies OptoSigma, Sill Optics and Graticules Optics.

member DSPE

Piezo Systems

HEINMADE BV
Heiberg 29C
NL - 5504 PA Veldhoven
T +31 (0)40 851 2180
E info@heinmade.com
W www.heinmade.com

As partner for piezo system solutions, HEINMADE serves market leaders in the high tech industry. Modules and systems are developed, produced and qualified in-house.

member DSPE

Piezo Systems

Physik Instrumente (PI)
Benelux BV
Hertog Hendrikstraat 7a
5492 BA Sint-Oedenrode
The Netherlands
T +31 (0)499-375375
F +31 (0)499 375373
E benelux@pi.ws
W www.pi.ws

High-precision piezo systems and applications that perform on a sub-micron and nanometer scale: world leader PI develops, manufactures and qualifies these in-house. With a broad and deep portfolio with infinite possibilities in components, drives, actuators and systems at hand, our experienced team is dedicated to find the best solution for any motion control challenge.

member DSPE

Precision Electro Chemical Machining

Ter Hoek Vonkerosie
Propaanstraat 1
7463 PN Rijssen
T +31 (0)548 540807
F +31 (0)548 540939
E info@terhoek.com
W www.terhoek.com

As Application Centre we possess the required knowledge to support our clients in every phase of development and process selection.
With our own PEM800 machine we can also use PECM in-house for the benefit of our clients.

member DSPE

Temperature Sensors

Tempcontrol B.V.
Ambachtshof 54
2632 BB Nootdorp
T +31 (0) 15 251 18 31
E info@tempcontrol.nl
W www.tempcontrol.nl

Tempcontrol is thé specialist for temperature measurement and temperature control. We produce customer specific temperature sensors, such as thermocouples and resistance thermometers for immersion, surface and air temperature measurement, and we supply a large diversity of quality instruments for measuring and controlling temperature.

Ultra-Precision Metrology & Engineering

IBS Precision Engineering
Esp 201
5633 AD Eindhoven
T +31 (0)40 2901270
F +31 (0)40 2901279
E info@ibspe.com
W www.ibspe.com

IBS Precision Engineering delivers world class measurement, positioning and motion systems where ultra-high precision is required. As a strategic engineering partner to the world's best manufacturing equipment and scientific instrument suppliers, IBS has a distinguished track record of proven and robust precision solutions. Leading edge metrology is at the core of all that IBS does. From complex carbon-fibre jet engine components to semiconductor chips accurate to tens of atoms; IBS has provided and engineered key enabling technologies.

member DSPE

ADVERTISERS INDEX