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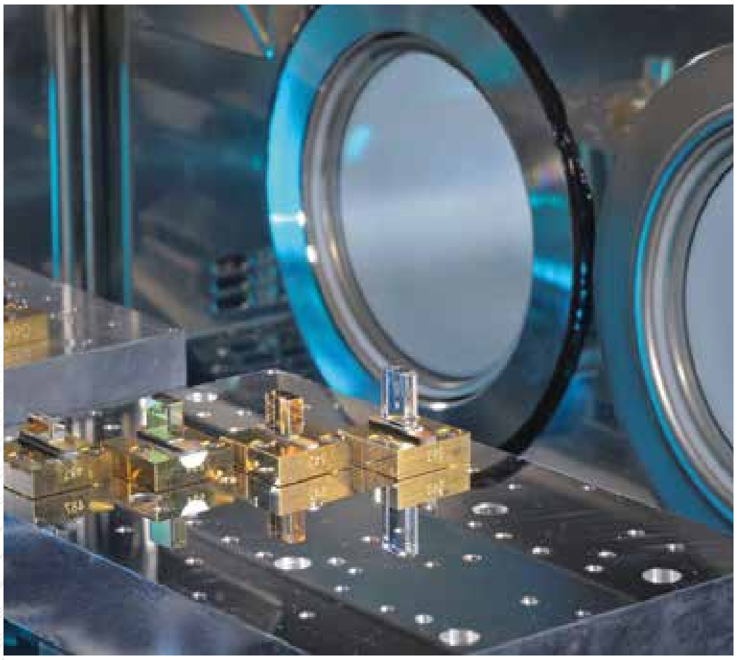
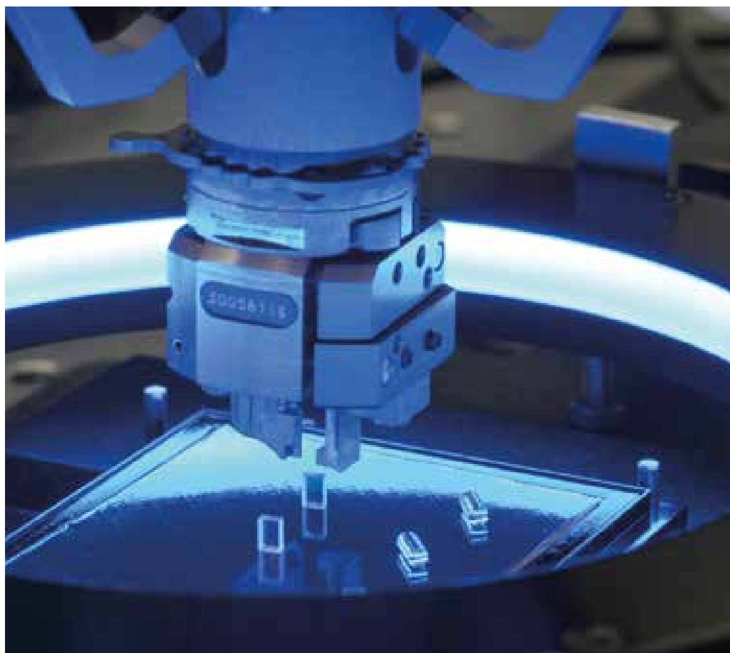
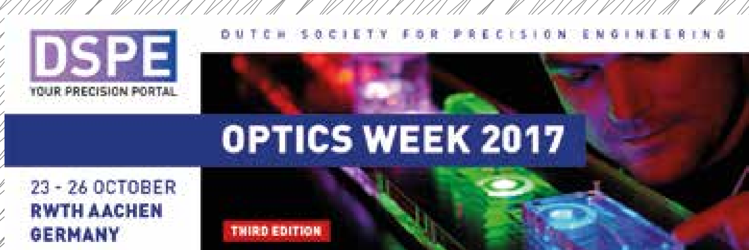
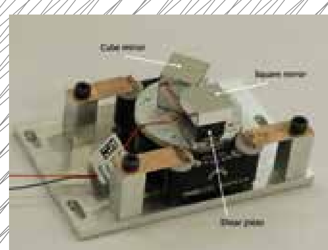




- THEME: **OPTOMECHATRONICS**
- **OPTICS WEEK 2017** PREVIEW
- **MECHATRONICS** FORUM REPORT
- **VIRTUAL** AFM CALIBRATION **STANDARDS**





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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

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The main cover photos (representing projects featured at the Demonstration Day of the DSPE Optics Week 2017) are courtesy of Fraunhofer ILT and IPT.

Read the preview on page 5 ff.

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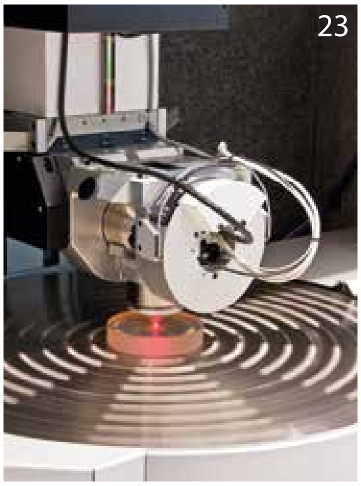
Theme: Optomechatronics



FEATURES

NEW DEVELOPMENTS IN OPTICS AND OPTOMECHATRONICS

Optomechatronics, the fusion of optics with mechanics, electronics and software, is essential for high-tech optical instruments. High-speed scanning of focused spots, adaptive optics with deformable mirrors and atomic force microscopy are only a few examples out of many.

Since there are very few educational programmes in optomechatronics, engineers working in the field typically have either a master in optics or in mechanics, and then have to acquire their knowledge of the other discipline on the job. But this situation will soon improve. The Faculty of Mechanical, Maritime and Materials Engineering (3mE) of Delft University of Technology (TU Delft) will start a Master track in optomechatronics with the aim to educate a new generation of multidisciplinary engineers.

And there are more new developments related to optics and optomechatronics. Recently, the Dutch Optics Centre (DOC) has been installed by TU Delft and TNO. The aims of DOC are:

1 to increase the industrial impact of research and development in the fields of optical imaging, metrology and spectroscopy, by involving industrial partners in research projects at an early stage and by carrying out high-TRL (technology readiness level) projects together with industry;
2. to foster and stimulate education and training in optics and optomechanics of students and of people in industry;
3. to share facilities.

DOC builds on a long tradition in optics and optomechatronics of TU Delft and TNO.
The Van Leeuwenhoek Laboratory, which they founded, contains advanced equipment for nanofabrication. Furthermore, TNO houses a high-quality manufacturing facility for freeform optics.

Although started by TU Delft and TNO, DOC is not restricted to Delft research groups. Projects with partners from other universities in the Netherlands will be started. Companies can participate for free in DOC by using the contact button on www.doc.com. They will then receive invitations for DOC meetings, brainstorm sessions and network events.

To efficiently represent the interests of the Dutch optical community and to speak with one voice in contacts with governmental and funding agencies, DOC will collaborate with PhotonicsNL, DSPE, and PhotonDelta, the ecosystem initiated by Eindhoven University of Technology that specialises in integrated photonics, i.e., in optics on a chip.

The upcoming Optics Week, organised by DSPE, has become the major biennial event for optomechatronics in the Netherlands, and beyond. This year it is held from 23 to 26 October in Aachen, Germany. Apart from a symposium and a fair, a visit to the Fraunhofer Institute in Aachen is scheduled and courses in optomechanics and optical design will be given. More detailed information about this eventful week can be found in this issue of Mikroniek.

I hope to see you in Aachen!

Paul Urbach
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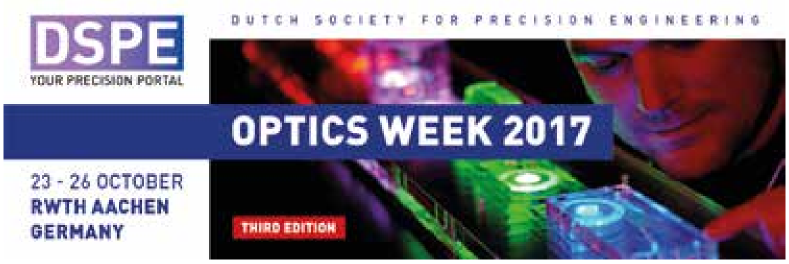
CROSSING DISCIPLINARY AND GEOGRAPHICAL BORDERS

The third ever DSPE Optics Week will be held in the German city of Aachen on 23-26 October 2017. The 4-day event will include a symposium and fair, a demonstration day and two high-level optics courses. This year will be the first time the multidisciplinary event that combines optics and mechatronics also crosses geographical borders.



The DSPE Optics Week 2017 is a unique collaboration by Dutch, German and international organisations. The third edition of the biennial event will be held on 23-26 October at the RWTH Aachen University, Germany (Figure 1). The 4-day event will bring together outstanding international speakers and lecturers from a variety of backgrounds, ranging from semiconductors and the medical profession to other industries and academia.

DSPE initiative

The event debuted in 2013, with the one-day DSPE Optics and Optomechatronics Symposium in Eindhoven, the Netherlands. The second edition in 2015 in Delft, the Netherlands included two courses on optics as well as the symposium. Both events attracted more than 250 precision engineers. "To extend our scope abroad, we decided to organise the DSPE Optics Week 2017 in the German city of Aachen and to involve representatives from renowned German companies and institutes", says DSPE president Hans Krikhaar. "Home to the Fraunhofer Institutes IPT (production technology) and ILT (laser technology), as well as the RWTH research university, Aachen is a hotspot for every facet of the optics industry and ideally located close to the Dutch border. We want to strengthen the relationship between the Dutch and German precision engineering and optics communities

Symposium & Fair

The 4-day event kicks off on Monday, 23 October with the DSPE Optics and Optomechanics Symposium & Fair. As chairman for the day, Jos Benschop, Senior Vice President Technology at ASML (Figure 2), will preside over the presentation of a range of topics, including the 3D printing of optical components, as well as adaptive optics, thermal effects in optical systems, and complex optical coatings. Speakers will be from various companies, including Demcon Focal, Fraunhofer, PTB, Qioptiq, TNO and Zeiss SMT.

1 *The conference will be held in the Super C Building of RWTH Aachen University.*

2 *Jos Benschop, Senior Vice President Technology at ASML and Professor of Industrial Physics at University of Twente, will be chairman for the DSPE Optics and Optomechanics Symposium. (Photo: University of Twente)*

3 *Daniel Vukobratovich delivering his Optomechanics course during the DSPE Optics Week 2015. (Photo: Sjoerd van Luijn)*

Demonstration Day

Tuesday, 24 October will mark the debut of the Demonstration Day. This event will give event delegates the opportunity to visit the Fraunhofer IPT and ILT institutes and the Digital Photonic Production research campus, which was set up in Aachen two years ago. Topics will range from the digitalisation of precision blank moulding processes and the non-isothermal glass moulding of optical components to EUV metrology/lithography and the self-optimising assembly of optical systems. Places are limited to 50, so early registration is advised.

Optomechanics course

The two-day course on optomechanics will be delivered on 24-25 October by Daniel Vukobratovich, Senior Scientist at Raytheon, as well as Adjunct Professor in the College of Optical Sciences, University of Arizona, USA (Figure 3) – also read his contribution on page 16 ff in this issue. The course is aimed at (systems) engineers, Ph.D. students and technicians, and will cover optics and optics mounting alignment, dynamics, and thermal as well as material stability.

Participants will learn how to:

- select materials for use in optomechanical systems;
- determine the effects of temperature changes, and develop design solutions for those effects;
- solve vibration problems;
- design effective adjustment mechanisms;
- design high-performance optical windows;
- design low-stress mounts for lenses;
- select appropriate mounting techniques for mirrors and prisms;
- understand different approaches to lightweight mirror design.

Optical design course

A 3-day course entitled 'Optical Design for Imaging Systems', coordinated by Prof. Paul Urbach from Delft University of Technology, the Netherlands, will be held on 24-26 October. This course is a continuation of the European project SMETHODS (SMEs Training and Hands-on practice in Optical Design and Simulation) and will provide hands-on training in the design and optimisation of optical imaging systems supported by a theoretical introduction.

At the end of the course, participants will be able to specify an optical imaging system, propose the general layout, and understand the methods used to characterise its performance. In terms of simple systems, they will be able to select a starting point, run the optimisation and estimate tolerances. In the case of more complex cases, including for their own needs, participants will have the opportunity to meet with highly skilled experts.

Information & registration

The Optics Week 2017 is being organised by DSPE in collaboration with Fraunhofer IPT and ILT, and RWTH. Other partners are Brainport Industries, Holland Instrumentation, Optence, PhotonicsNL, Spectaris and Cluster NanoMikroWerkstoffePhotonik.NRW.

WWW.OPTICSWEEK.NL

HARNESSING THE NEXT GENERATION OF EXTREMELY LARGE TELESCOPES

Tomorrow's extremely large optical-infrared telescopes, TMT and ELT, are enabled by segmented, primary mirrors and advanced multi-conjugate adaptive optics systems. Each primary, active mirror is supported by a warping harness for periodic low-order optical corrections. The warping harness is essential for achieving the optical surface accuracy and requires accurate verification at subsystem and component level. S[&]T contributed to both telescope programmes with versatile test control systems, used to prove that the warping harness designed for each telescope meets the requirement specifications.

LUDO VISSER, LAURA TEN BLOEMENDAL, FRED KAMPHUES, JAN NIJENHUIS, REMCO DEN BREEJE AND GERT WITVOET

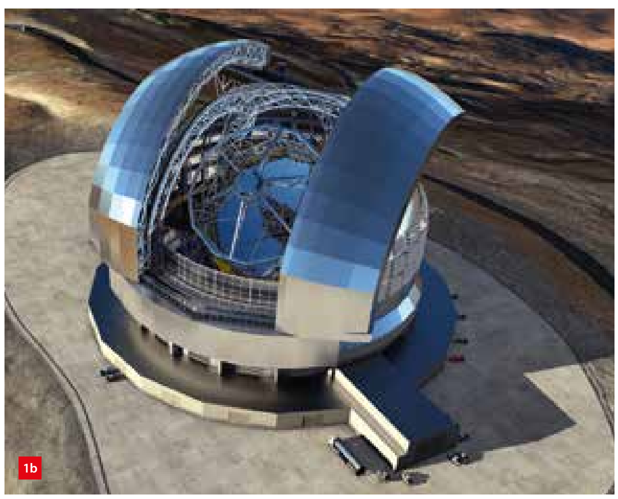
Introduction

Scientists and engineers are constantly pushing the technological boundaries of ground-based optical telescopes. In principle, larger mirrors yield better telescopes, but at some point these monolithic mirrors became impractical (because of cost, weight and optical performance). In 1977, astronomer Jerry Nelson proposed a design for a segmented primary mirror, which became the basis for the twin W.M. Keck Observatory telescopes.

The advantage of segmented mirrors is that each segment can be small, eliminating problems astronomers were facing with large monolithic mirrors, such as inaccurate polishing and optical aberrations caused by their massive weight. The Keck telescopes, each 10 m across with 36 hexagonal segments, use 160 sensors and 108 position actuators to position all of the segments accurately.

In principle, the segmented approach allows arbitrarily large mirrors. The Thirty Meter Telescope (TMT, Figure 1a) [1] with 492 segments and the European Southern Observatory's (ESO's) 39m Extremely Large Telescope (ELT, or E-ELT for European ELT, Figure 1b) [2] with 798 segments are realising a new class of extremely large telescopes; feasible only via the segmented approach. While conceptually easy to envisage, there are technical challenges in achieving a single continuous reflective surface from many segments.

In both the TMT and the ELT designs, the segments that form the primary mirror are interchangeable units that have individual positioning actuators. All segment units together are supported by a structure that moves the mirror as a whole along azimuth and elevation angles (Figure 2). The



1 *Artist impressions of next-generation telescopes.*
(a) Thirty Meter Telescope observatory. (Courtesy: TMT International Observatory)
(b) Extremely Large Telescope observatory. (Courtesy: ESO/L. Calçada/ ACe Consortium)

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2 *The inner structure of the ELT, showing the segmented primary mirror. (Courtesy: ESO/ Dorling Kindersley)*

3 *Each ELT mirror segment is supported via struts by the whiffletree support structure (green); large actuators (blue) are used to control tip-tilt and piston motion of the mirror. (Courtesy: TNO)*
(a) Design.
(b) Realisation.

position actuators control the piston and the tip-tilt motion of a segment assembly with respect to this structure.

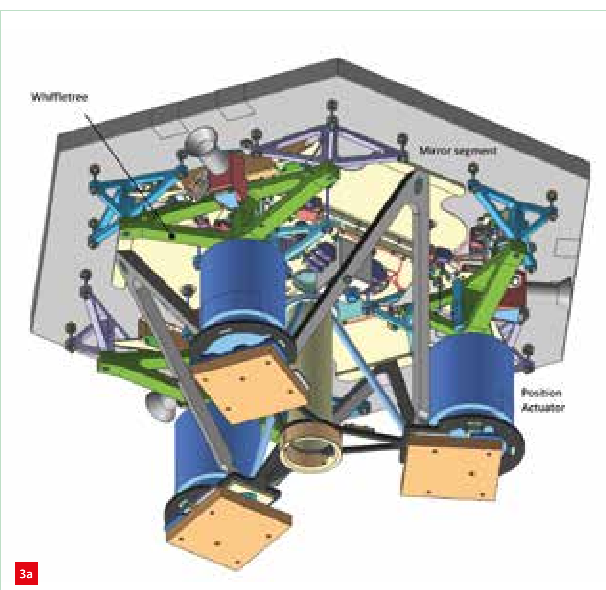
Furthermore, each mirror segment is supported by a warping harness that can deform the mirror segment to correct for small errors (with nanometer accuracy) in the overall mirror surface (Figure 3). The corrective deformation is done by small actuators applying a moment to the whiffletree support structure. The control system for the warping harness is used to compensate for changing factors in deformation, and is therefore essential to overall telescope performance, and must be exhaustively tested and validated.

Both the TMT and ESO ELT programmes have a separate S[&]T control system to support the validation testing of each warping harness. The control systems were built to allow engineers to measure the applied moments of the warping harness actuators in real time during tests. The control systems are used throughout the entire design and development cycle, from component-level testing to subsystem-level testing.

The warping harnesses

The warping harness is an important part in the telescope's design, as it allows active correction of small wavefront errors. It is an integral part of the mirror support structure and is designed for high accuracy and reliability with a design lifetime requirement of 30 years for ELT and 50 years for TMT. The design needs to be vacuum-compatible to allow periodic re-coating of the mirror, after removing the segment from the support structure. Finally, because of the high number of segments in the telescope, the warping harness needs to be cost-effective.

Although the designs of the mirror segment support for TMT and ELT are different, they are based on the same principle [3]. The design for ESO's ELT, developed by TNO, has been extensively described in a previous article [4]. Each segment support has a whiffletree structure, which supports the mirror via thin struts and a central membrane attached to the back of the mirror. The struts support the mirror radially (i.e., in the direction perpendicular to the mirror surface), while the membrane supports the mirror laterally. The passive support of the whiffletree and the membrane minimises mirror segment deformation or displacement during operation, e.g., as a function of the telescope elevation angle and ambient temperature variations.



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3b