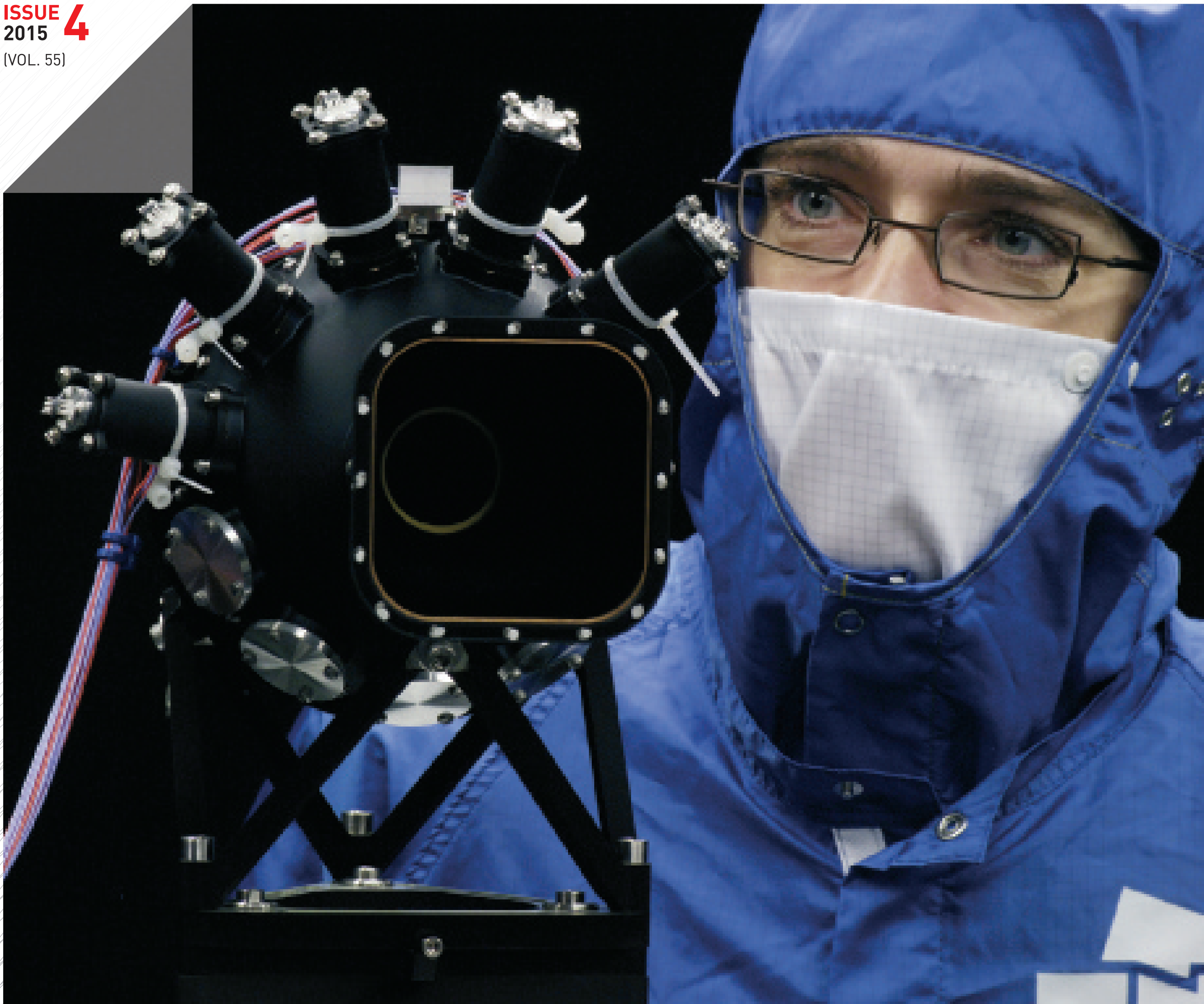
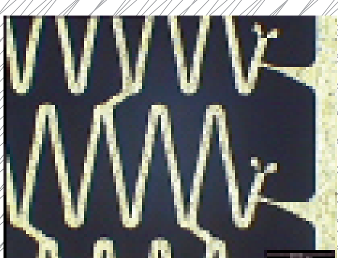
PROFESSIONAL JOURNAL ON PRECISION ENGINEERING

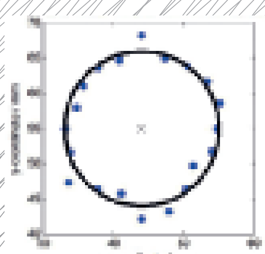
μ MIKRONIEK

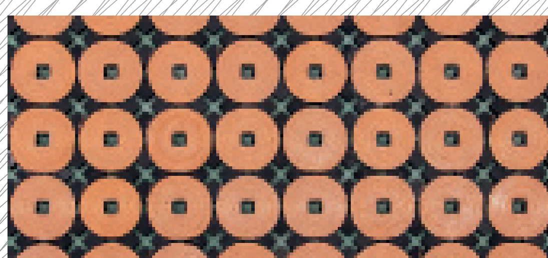
ISSUE 4
2015
(VOL. 55)

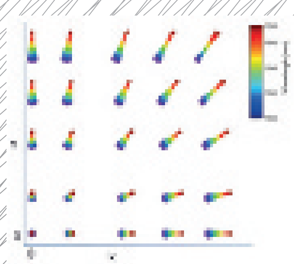


- OPTICS AND OPTOMECHATRONICS WEEK
- LOW-COST **SMART** SENSORS
- **ADAPTIVE** MICROMACHINING
- **CEILING** ROBOT
- LASER **MICROJET**









Mikroniek is a publication of the DUTCH SOCIETY FOR PRECISION ENGINEERING www.dspe.nl

DSPE

PUBLICATIONINFORMATION

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.

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

Editorial board
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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
Twin Media, Culemborg
+31 (0)345 – 470 500, info@twinmediabv.nl

Subscription costs

The Netherlands	€ 70.00 (excl. VAT) per year
Europe	€ 80.00 (excl. VAT) per year
Outside Europe	€ 70.00 + postage (excl. VAT) per year

Mikroniek appears six times a year.
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ISSN 0026-3699

The main cover photo (featuring the DSPE Optics and Optomechatronics Week 2015) is courtesy of TNO/Fred Kamphues. Read the preview on page 12 ff.

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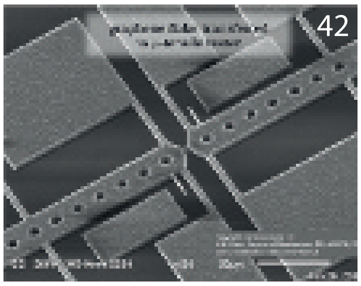


FEATURES

A WEEK FULL OF **OPTICS AND OPTOMECHATRONICS**

In everyday life, we use lots of devices that employ optics and optomechatronics, such as a camera, binoculars, a beamer, but also the glasses on your nose. If we look at professional applications, we see plenty of optics and optomechatronics in the measurement industry, such as microscopes and interferometers, but also in space travel and astronomy. There are satellites with high-resolution cameras, stargazers such as the Hubble Telescope and the Very Large Telescope in Chile, which consists of adjustable mirrors that together form one huge mirror. Closer to home, there are the wafer scanners from ASML with optical and optomechatronical systems with nanometer precision and stability.

The system notion is important in all these developments. The disciplines of optics, mechanics and mechatronics have to work closely together to arrive at an optimally functioning system. We only achieve an optimum result if we get the utmost out of the optics as well as the mechanics and mechatronics. It must be possible to translate the perfect optical design into mechanics, and actuation must be possible via the mechatronics, but the perfect mechanical or mechatronic design must also fit the optical design.

A function is created if the parts of the design connect optimally with one another. That happens automatically if the various disciplines get in depth into each other's discipline. You then create transition zones in which you can jointly arrive at the best solution.

DSPE helps people gain in-depth knowledge of each other's discipline by bringing experts together. To do that, we have special interest groups, for example. These groups organise networking and training activities for specific disciplines. Two years ago, the special interest group of Optics and Optomechatronics started organising an Optics and Optomechatronics Symposium in Eindhoven. As follow-up to that successful event, we are now organising the DSPE Optics and Optomechatronics Week to be held at the Delft University of Technology. This will again be an excellent opportunity to meet each other.

We start the week with a symposium with lectures and a trade fair about optics, optomechanics and optomechatronics with speakers from the Netherlands and abroad chaired by Jos Benschop, VP of technology at ASML, followed by two courses in the field of optics and optomechanics. The two-day optomechanics course given by Daniel Vukobratovich is a unique opportunity to follow this intensive and practical training for optomechanical designers. The SMETHODS+ Course on Optical Design is four days of hands-on training in the design of optical imaging systems in combination with a theoretical introduction.

We work together with several organisations, such as Holland Instrumentation, the high-tech network in the Dutch province of Zuid-Holland, and our German counterparts united in SPECTARIS, the industry association for optomechatronics in Germany.

You are cordially invited to join us in the week from 28 September to 2 October.

Cor Ottens
Chairman, DSPE Special Interest Group Optics and Optomechatronics
cor.ottens@dspe.nl

WORK IN PROGRESS: SMART MICROMACHINING

The European ADALAM project aims to develop a sensor-based adaptive micromachining system for zero-failure manufacturing, based on ultrashort-pulse laser ablation and a novel depth measurement sensor, together with advanced data analysis software and automated system calibration routines. The technology developed will generate new solutions for manufacturing of high-quality and innovative products, such as adaptive micromilling of 2.5D structures, defect detection and removal, and texturing of complex tool features.

GUILHERME MALLMANN, KEVIN VOSS, STEFFEN RESINK AND ALBERT BORREMAN

Miniaturisation, advanced high-performance materials and functional surface structures are all drivers behind key enabling technologies in high-end production. Ultrashort-pulse lasers have enabled new machining concepts, where the big advantages of laser machining are combined with a quasi-non-thermal and hence mild process, which can be used to machine any material with high precision.

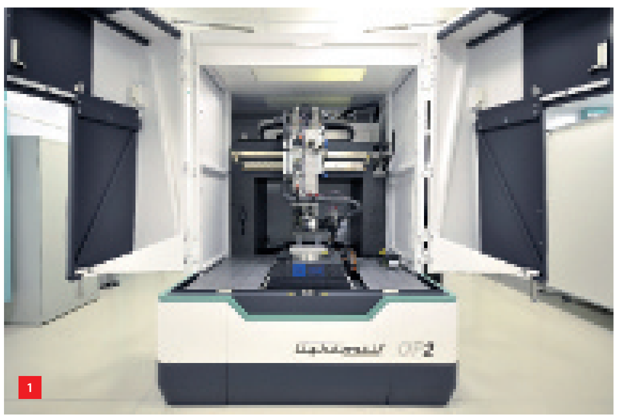
Current laser-based machine systems for microprocessing are built on a precision motion axis combined with a scanner using galvanometric moving mirrors. An innovative machine concept is presented by the company Lightmotif (Figure 1). This system enables high-precision micromachining of different structures over workpieces from small to large sizes (Figure 2).

However, there is a significant barrier for the full exploitation of the potential process characteristics, namely the lack of a smart/adaptive machining technology. The laser process in principle is very accurate, but small

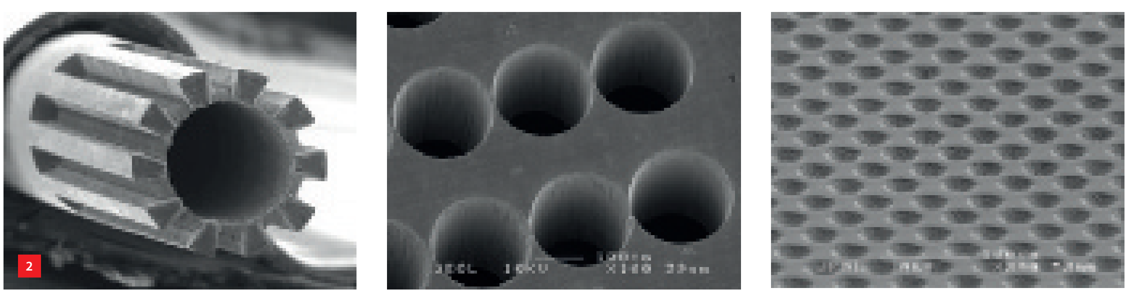
AUTHORS' NOTE

Guilherme Mallmann is group leader at the Fraunhofer Institute for Production Technology IPT in Aachen, Germany. Kevin Voss is mechatronic systems engineer at Demcon, a high-end technology supplier. Steffen Resink is optical engineer at Focal, an integration and development partner in the field of industrial precision inspection and optical systems. Albert Borreman is senior project manager at Focal. Both Demcon and Focal are based in Enschede, the Netherlands.

guilherme.mallmann@ipt.fraunhofer.de
www.ipt.fraunhofer.de
kevin.voss@demcon.nl
www.demcon.nl
albert.borreman@focal.nl
www.focal.nl



1 *Enschede-based Lightmotif, a Dutch spin-off from the University of Twente and the M2i institute, recently introduced a 5-axis laser micromachining system. The system features a picosecond laser, a 5-axis motion platform and a galvo scanner, enabling step-and-scan micromachining.*



2 *Examples, from left to right, of micromilling, -drilling and -texturing. (Source: Lightmotif)*

deviations, e.g. in the materials to be processed, can compromise the process results and the product functionalities to a very large extent. Therefore, feedback systems are needed to keep the process stable and constant, warranting an accurate result.

Objectives

In the context presented above, the ADALAM project was set up to develop an adaptive laser micromachining system using innovative feedback control. It should enable a reliable acquisition of real process information and its feedback to the machine system. Consequently, the hitherto limited machining application can be extended, being so able to adapt to variations caused for example by differences in material properties and fluctuations in the workpiece shape or laser output power.

Furthermore, it allows an accurate workpiece calibration in terms of its machine position and real shape. Because off-line measurements are time-consuming and compromise accuracy due to reclamping, the solution should be an inline measurement system that enables truly adaptive machining and does not hinder accessibility of the working area.

The complete ADALAM system will be based on ultrashort-pulse laser ablation and a novel depth measurement sensor associated with advanced data analysis software and automated system calibration routines. The sensor can be used inline with the laser ablation process, enabling adaptive processes by fast and accurate 3D surface measurements.

The first specific objective is to design and implement a complete solution for an inline topography measurement, based on low-coherence interferometry, and analysis for monitoring before, during and after the laser micromachining. Automatic point cloud analysis for smart feature detection and characterisation will produce qualified feedback to the micromanufacturing system.

Additionally, an adaptive process as well as the machine architecture and an adaptive control based on the inline measurement system will be designed. The synchronisation with the inline measuring system and data analysis software will enable processes to reach zero-failure manufacturing goals. Furthermore, the calibration of the measurement system, as well as of the complete solution (machine architecture + inline measurement system), regarding aspects such as traceability and certification will be addressed.

Applications

The adaptive laser micromachining system will be usable for a large variety of applications, each requiring a special adaptation of the control software. The system will therefore be developed in a modular approach, enabling a straightforward development of future new applications. Within the ADALAM project, three industrial end-user applications will be addressed.

In this article, the focus is on adaptive micromilling with an ultrashort-pulse laser for machining precise 3D structures into any material. It may be exploited for the production of micro-moulds, precision stamps and other tooling applications. The other two applications are defect detection and removal on workpieces, and shape recognition and texturing of complex tool features.

The sensor concept

The inline topography measurement concept (Figure 3) integrates a frequency domain low-coherent interferometer (FD-LCI) set-up in the beam path of the laser micro-machining system. The integrated sensor can be used to:

- measure the surface topography while machining a part, in order to adapt the micromachining process, leading to much higher machining accuracies and no defects;
- measure the surface topography before machining, to scan for existing surface defects that can be removed in an automatically generated machining process;

ADALAM

The European ADALAM project was set-up to deliver convincing evidence to SMEs of the benefits of the use of adaptive ultrashort-pulse laser based manufacturing systems and the monitoring and control with inline dimensional metrology as well as final quality assurance. All these goals lead to a considerable enhancement of the exploitation and usage of material and resources and the consequent generation of high-quality final products.

This Horizon 2020 project runs from 2015 to 2017 and is being coordinated by Unimetrik, a Spanish metrologic service company and calibration laboratory. Within the project one working group concentrates on the development of the inline high-precision measurement system under the coordination of the Fraunhofer Institute for Production Technology IPT in Aachen, Germany. Contributors include the Spanish companies Unimetrik and Datapixel, the German company Sill Optics, as well as the Dutch companies Demcon, Focal and Lightmotif.

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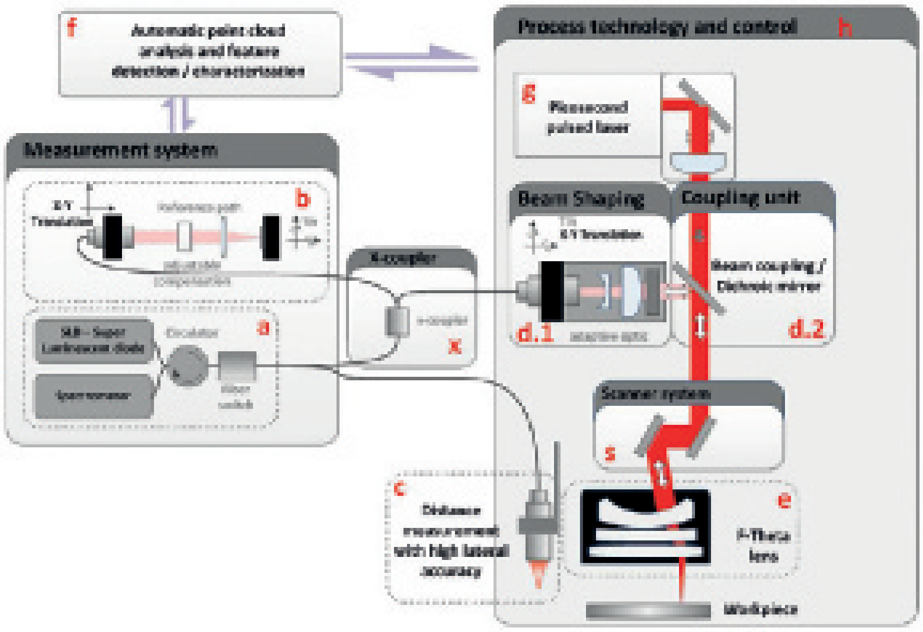

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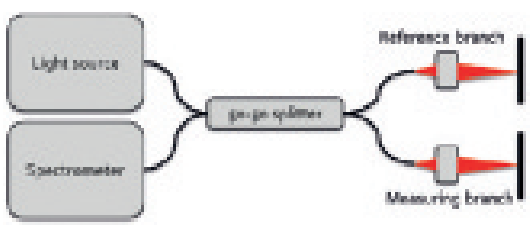
a. Spectral domain low-coherence interferometer
b. Automatically adjustable reference path system
c. External distance measurement sensing head with high lateral accuracy
d.1 Beam shaping unit for adjusting the measurement beam
d.2 Coupling unit for coupling the measurement beam into the laser beam
e. F-theta lens
f. Software for an automatic point cloud analysis and feature detection/ characterisation
g. High-power picosecond-laser source – switchable pulse length/synchronisation
h. Integrated adaptive laser micro-machining system
s. Optimised scanning objective with enhanced numerical aperture and lateral accuracy
x. Fibre-optic splitter



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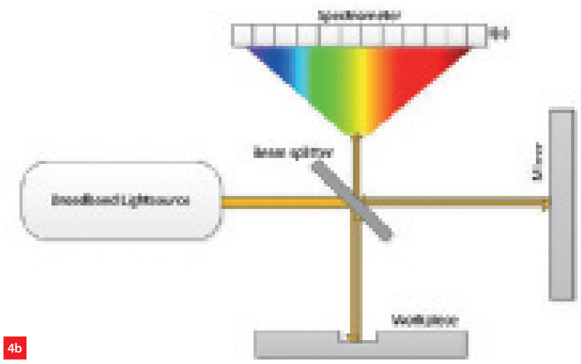


4b

- measure complex shaped objects prior to machining, to precisely align the machining pattern to the workpiece;
- quickly validate results after machining.

Interferometry principle

The low-coherence interferometry (LCI) solution is based on a Michelson interferometer set-up (Figure 4) [1]. The difference with normal low-coherence interferometers, which use a piezo element to find the maximum inter-ference point, is that the depth/height information is gained by analysing the spectrum of the acquired interferogram.

The calculation of the Fourier transformation of the acquired spectrum provides a back reflection profile as a function of the height. (In the time domain, time of flight corresponds to distance covered, i.e. the measured height.) For the generation of the interference pattern a measurement and a reference path are used, where the optical path difference between these arms is detected.

3 Conceptual design of inline topography sensor in a laser micro-machining system.

4 Michelson interferometer set-up.
(a) Schematic.
(b) Principle, showing the light paths, with the reference arm on the right (beam splitter to mirror) and the measuring arm below (beam splitter to workpiece).

Increasing the optical path length difference will result in more spectral modulation.
Figure 5 shows the signal processing for translating the measured spectrum into a distance measure. From the measured signal the unmodulated 'background' spectrum is subtracted. A Fourier transform of this shows two peaks, one being the mirrored version of the other. The next step is performing a Gaussian fit on one the peaks in the Fourier transform to obtain subpixel accuracy. The position of the fitted peak is a simple linear function based on the centre wavelength used and the path length difference.

The axial resolution for tomographic measurements and the FD-LCI measurement range when using a Gaussian-shaped light spectrum are given by [1]:

$$z_{\text{resolution}} = 0.44 \cdot \lambda_0^{\,2} / \Delta\lambda$$

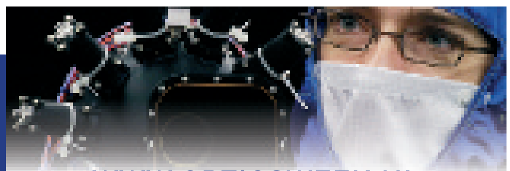
$$z_{\text{range}} = N/(4n) \cdot \lambda_0^{\,2} / \Delta\lambda$$

UNIQUE OFFER WITH A **SYMPOSIUM** AND TWO **COURSES**

The first Optics and Optomechatronics Week will be organised from 28 September to 2 October 2015, opening with a symposium at Delft University of Technology, the Netherlands. The event, which features a unique collaboration between Dutch and international organisations, comprises a symposium and two courses. The week brings outstanding speakers and lecturers from semicon to medical, from industry to academia, from Europe and abroad, presenting the latest trends and high-tech details.

DUTCH SOCIETY FOR PRECISION ENGINEERING

DSPE Optics and Optomechatronics Week 2015
28 September - 2 October 2015
Delft University of Technology



WWW.OPTICSWEEK.NL

The programme of the first Optics and Optomechatronics Week features three events:

- *28 September*
  DSPE Optics and Optomechatronics Symposium + Fair
- *29-30 September*
  Optomechanics course
- *29-30 September, 1-2 October*
  SMETHODS+ course on optical design

Symposium

The DSPE Optics and Optomechatronics Symposium is the second edition of the bi-annual event, which kicked off successfully two years ago in Eindhoven, attracting over 150 engineers. The target group includes engineers who can learn about the latest developments, managers who can get a quick overview of trends, and sales managers looking for new opportunities. Chairman of the day will be Prof. Jos Benschop, Senior Vice President Technology, ASML. The venue is the Aula Conference Centre in Delft.

Programme

Prof. Ralf Bergmann
Managing Director, BIAS (Bremer Institut für angewandte Strahltechnik), www.bias.de
Optical metrology for micro-parts

Optical metrology is a key technique when it comes to precise and fast measurement with a resolution down to the micrometer or even nanometer regime. Following an overview of optical metrology techniques, the rapidly emerging field of Computational Shear Interferometry

INFORMATION AND REGISTRATION

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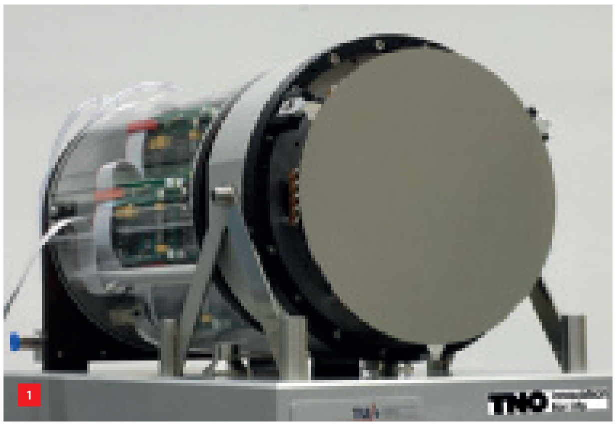

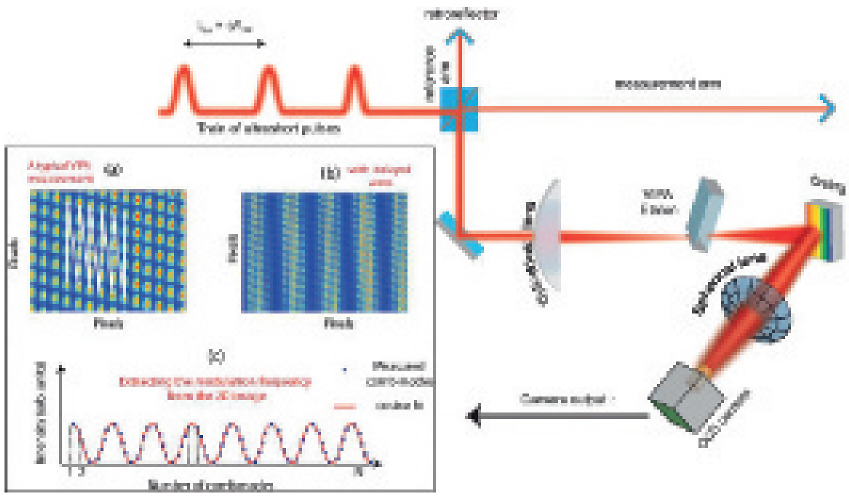

(CoSI) will be discussed. CoSI allows for determining arbitrary wave fields from a set of shear interferograms. It combines standard microscopic imaging with an axial resolution of a few nanometers and the possibility to use cheap and eye-safe low-brilliant light sources. Additionally, the technique allows for refocusing recorded images numerically, after the measurement.

The role of coherence of the underlying wave field and the reconstruction of the information derived from the object's sheared representations will be discussed. Experimental results of Digital Holography and quantitative phase-contrast imaging as well as Differential Interference Contrast (DIC) microscopy suitable for micro-objects will also be shown. Quantitative DIC microscopy is a versatile tool for the investigation of reflective and transparent specimens.

Ir. Ruud Beerens
Senior Architect Opto-Mechanics, ASML, www.asml.com
Design guidelines for stable opto-mechanics

Optimising the time-to-market is of great importance for the high-end products of ASML, as it enables increased revenues for its customers. Concurrent engineering is a means to reduce time-to-market. Quality, on the other hand, is maintained by having multi-directional information lines between the parallel operating planning paths running over multiple types of interfaces; e.g. system-to-system, system-to-module, discipline-to-discipline and concept-to-design. Risk mitigation is key throughout the entire process; hence architects and engineers are equipped with design guidelines. A clear example covering multiple interface types is that between optical functionality and stable hardware, i.e. stable opto-mechanics.

1 *Deformable mirror realised by Eindhoven University of Technology and TNO (not yet for high optical power).*
2 *Schematic set-up for spectrally resolved frequency-comb interferometry.*

Drs. Teun van den Dool
Senior System Engineer, TNO, www.tno.nl
Adaptive optics for high optical power

Optics systems have evolved from using spherical elements only, through non-spherical components, free-form, and more recently active and adaptive optics. This evolution often enables implementation of optical systems with improved performance using fewer components in a smaller volume. With the development of adaptive optics, mechatronics has explicitly entered the optical design domain. Not only in the sense that actuators (deformable mirrors), (wavefront) sensors, and controllers are needed, but the development of a deformable mirror (Figure 1) in itself also involves many disciplines like optical, mechanical, thermal, and electronics design. This presentation will show how all these disciplines have to interact, weigh interests and compromise to arrive at a well-balanced solution, especially in the case that the deformable mirror has to cope with a high optical heat load.

Dr Nandini Bhattacharya
Assistant Professor Optics Group, TU Delft, www.tudelft.nl
Speckle dynamics to monitor pulsatile flow

Portable devices for monitoring of cardiovascular parameters are becoming imperative nowadays. This leads to a significant interest to create low-cost reliable devices. In this regard optical methods have been most promising and a lot of applications have come up for diagnostics and monitoring. Their main advantage is that they can be non-invasive and low-cost. Many optical portable devices are susceptible to motion-induced artifacts. Results will be presented of an experimental study of detection of fluid pulsation based on multi-exposure speckle images to detect