MEASURING BY LIGHT

28-30 MARCH

2023

"CONNECTING INDUSTRY AND ACADEMICS"

BOOK OF ABSTRACTS

CONFERENCE ON OPTICAL MEASUREMENT TECHNIQUES AND INDUSTRIAL APPLICATIONS

Konnexxions TU Delft MMATIDIA A NEW LOOK AT LIDAR Polytec

MEASURING BY LIGHT

28-30 MARCH

2023

"CONNECTING INDUSTRY AND ACADEMICS"

PROGRAMME

CONFERENCE ON OPTICAL MEASUREMENT TECHNIQUES AND INDUSTRIAL APPLICATIONS

Konnexxions TU Delft MMATIDIA A NEW LOOK AT LIDAR Polytec

KEYNOTE LECTURE I

XAVIER ROTTENBERG

IMEC

28 MARCH 2023

AUDITORIUM - 10:50 - 11:30

MEASURING BY LIGHT

PHOXONIC MICROSYSTEMS – WAVE-BASED SENSORS AND ACTUATORS

abstract

KEYNOTE LECTURE 2

ANDREA FIORE

EINDHOVEN UNIVERSITY OF TECHNOLOGY

28 MARCH 2023

AUDITORIUM - 10:30 - 12:10

MEASURING BY LIGHT

SPECTRAL SENSING AT YOUR FINGERTIPS

The optical spectrum carries information on the chemical composition of the object by which light is transmitted or reflected. Also, many other physical, chemical and biological signals can be effectively transduced into a spectral change and measured from the reflection spectrum of a sensor. However, until recently, complex lab instruments, spectrometers, were needed to capture this spectral information. In this talk I will describe the integrated spectral sensing technology recently developed in our group, based on small arrays of resonant-cavity detectors. I will also show how it can be used to measure chemical properties of materials, and to read out picometer-level spectral shifts from fiber sensors and biosensors. Due to their small size, simplicity and scalability, these chips open the way to compact and low-cost optical sensor systems for a variety of application fields, from industrial process monitoring to agrofood and medical technology.

PS I - MATERIALS & COMPOSITES

MATHIAS KERSEMANS

GHENT UNIVERSITY

28 MARCH 2023

AUDITORIUM - 13:10 - 13:30

MEASURING BY LIGHT

INSPECTING STIFFENED CFRP AEROSPACE PANELS BY SCANNING LASER DOPPLER VIBROMETRY

In this contribution, scanning laser Doppler vibrometry is employed for non-destructive damage detection in industrial composite components. Broadband elastic waves are excited by either a piezo-electric actuator or a pulsed laser, and the full-field vibrational response is monitored by a 3D infrared scanning laser Doppler vibrometer of Polytec. An automated time-wavenumber-frequency filtering method has been implemented in view of decomposing the acquired vibrational data, identifying damage features and constructing a high-quality damage map. To improve the sensitivity of the method to incipient and small damage, the analysis is performed in both the linear and nonlinear wave regime.

The high performance of the proposed damage imaging method is demonstrated on a variety of industrial composite parts from Airbus, Honda and Ridley.

PS I - MATERIALS & COMPOSITES

ADIL HAN ORTA

GHENT UNIVERSITY

28 MARCH 2023

AUDITORIUM - 13:30 - 13:50

MEASURING BY LIGHT

IDENTIFICATION OF THE ORTHOTROPIC VISCOELASTIC TENSOR OF COMPOSITES USING 3D INFRARED SCANNING LASER DOPPLER VIBROMETRY

In the present study, a two-stage inversion scheme is proposed to determine the full set of 18 viscoelastic stiffness parameters of composite plates using 3D infrared scanning laser Doppler vibrometry. A 2D Fast Fourier Transform is used to convert the recorded surface velocity response into a frequency-wavenumber domain, and a hybrid wave decomposition and correlation method are employed to extract complex-valued wavenumber-frequency pairs that correspond to Lamb waves and shear horizontal plate waves. In view of inversely estimating the orthotropic viscoelastic properties from the measurement data, the semi-analytical finite element method is used as a forward model to compute wavenumbers and is coupled to particle swarm optimization. The accuracy of the proposed method is validated on a series of numerically generated 3D wavefield data, as well as on broadband experimental vibrometry measurements on composite plates. The optimization process for each numerical or experimental case study is repeated 20 times to obtain statistics, and the median and median absolute deviation values are reported. It is shown that the inverted orthotropic viscoelastic properties for the numerical case studies are in close agreement with the target values, showing a mean relative error of less than 2% and 5% on the elastic and viscous properties, respectively. Additionally, the median absolute deviations are negligible showing the robust convergence of the inversion procedure to a global minimum, even when noise is present. The proposed characterization method can be used for various orthotropic viscoelastic materials, including metal sheets, fiber-reinforced polymers laminates, and wooden plates.

PS I - MATERIALS & COMPOSITES

ANDREI ANISIMOV

TECHNICAL UNIVERSITY OF DELFT

28 MARCH 2023

AUDITORIUM - 13:50 - 14:10

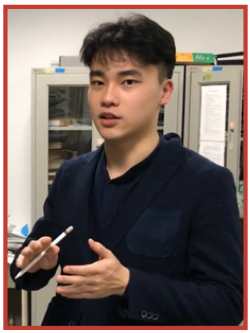
MEASURING BY LIGHT

OPTICAL INSTRUMENTATION FOR HIGH STRAIN RATE TESTING OF COMPOSITE MATERIALS: MAXIMISING THE VALUE OF MEASUREMENTS

Composite materials are vulnerable to extreme dynamic loadings such as impact, blast, and crash where there is limited knowledge of material behaviour at very high strain rates. The development of new instruments to reconstruct extreme dynamic events will provide key insight into the understanding of the behaviour of composites. These challenges are addressed in a recently established COST Action CA21155, Advanced Composites under HIgh STRAin raTEs loading: a route to certification-by-analysis (HISTRATE, 2022-2026). In this presentation, we will give an overview of the state-of-the-art optical instrumentation for the high strain rate testing, including characterisation of wave propagation and shock loading, assessment of damage initiation, evolution and failure under multi-axial and high-speed loading. Specific examples include recent developments in new specimen geometries for split Hopkinson bar assisted with high-speed digital image correlation, and EXTREME high-speed shearography for full-field wave characterisation during an impact event. A special focus is made on what actually needs to be measured and how during high strain rate testing to result in valuable information for the material science, numerical modelling and design points of view rather than isolated advancing optical techniques.

This overview of the recent developments and challenges also describe how the HISTRATE COST Action will steer the research and development of new optical instrumentation for high-strain rate testing and involve new academic and industrial partners. This Action will be one of the steps towards the application of certification by analysis of high strain rate loaded composite structures.

PS I - FUNDAMENTALS



MEASURING BY LIGHT

RAPHAEL ZHIZHI YANG

GHENT UNIVERSITY

28 MARCH 2023

FRANS VAN HASSELTZAAL - 13:10 - 13:30

THEORETICAL COMPARISON OF THE SIGNAL-TO-NOISE RATIOS OF TWO TYPES OF VIBROMETERS: MACH-ZEHNDER AND SAGNAC INTERFEROMETERS

As well-recognized analytic techniques, non-destructive testing methods, including contact and non-contact, are widely used in evaluating and characterizing the properties of composite materials or other structures. The limitation of mobility of current implementations of contact methods narrows down the applications for flexible sensing from a distance. Meanwhile, non-contact testing methods can provide more flexibility than contact methods by measuring from a distance using coherent or incoherent light. Laser Doppler vibrometry (LDV) and Sagnac-based vibrometry are two competent interferometer-based non-contact testing methods. Here, we analyze and compare LDV and the Sagnac-based vibrometry from the perspective of their signal-to-noise ratio (SNR), considering the shot noise limitation. Then, we discuss possible approaches to reduce the overall noise level. We also discuss the possibility of minimizing a Sagac-based non-destructive testing system on a photonic integrated chip since current fiber-based or free-space implementations are too bulky and expensive.

PS I - FUNDAMENTALS

MEASURING BY LIGHT

VICTOR DOLORES CALZADILLA

EINDHOVEN UNIVERSITY OF TECHNOLOGY

28 MARCH 2023

FRANS VAN HASSELTZAAL - 13:30 - 13:50

INP INTEGRATED PHOTONICS FOR ENABLING FMCW LIDAR

Recent progress on InP photonic integrated circuits (PICs) relevant for solid-state light detection and ranging (LiDAR) will be presented, including integrated lasers with frequency-modulated continuous wave (FMCW) operation and optical phased arrays with amplification. The relevance and opportunities of these components to enable on-chip LiDAR sensing with customized performance (optical power, field of view, angular resolution) will be highlighted, as well as the challenges to scale the PIC concepts for applications requiring a demanding performance.

PS I - FUNDAMENTALS

ROEL BURGWAL

AMOLF

28 MARCH 2023

FRANS VAN HASSELTZAAL - 13:50 - 14:10

MEASURING BY LIGHT

STRONG LINEAR AND NONLINEAR DISPLACEMENT MEASUREMENTS IN NANOPHOTONIC OPTOMECHANICAL RESONATORS

Nano- and micromechanical oscillators serve as great sensors of a wide variety of signals impacting the oscillators through force, mass, or acceleration. The advances of cavity optomechanics have enabled extremely sensitive readout of mechanical motion in recent years. Sensitivity and bandwidth are however fundamentally constrained through measurement backaction, giving rise to the standard quantum limit. Evading measurement backaction, and exploiting squeezed and entangled mechanical quantum states with reduced fluctuations in specific degrees of freedom may boost the performance of several sensing applications, including broadband mechanical force sensors. Moreover, whereas mechanical displacement is normally transduced linearly to an optical signal, nonlinear measurements of sufficient strength could be a powerful resource for the control of mechanical oscillators down to the quantum level. We explore the possibility to perform strong linear and nonlinear optical measurements using on-chip nanophotonic systems that confine light and motion to subwavelength scales. On the one hand, we experimentally demonstrate optomechanical measurements that exploit short light pulses, which can evade measurement backaction, detecting displacement with sub-quantum-limit resolution for sufficient strength. Using these, we develop a new protocol to deterministically produce squeezed states of the mechanical oscillator, with reduced uncertainty in one of its motional quadratures. On the other hand, we demonstrate how multimode nano-optomechanical systems can be engineered such that nonlinear displacement measurement is strongly enhanced. We quantify the optimal nonlinear sensing enhancement that can be reached, and discuss the applications and limits of these principles towards the generation of nonclassical states of macroscopic mechanical systems.

PS I - MEDICAL & BIO I

IREK ROSLON

SOUNDCELL

28 MARCH 2023

SENAATZAAL- 13:10 - 13:30

MEASURING BY LIGHT

GRAPHENE DRUMS TO HEAR THE BEAT OF BACTERIA

Antimicrobial resistance is a global health problem, endangering millions of lives. Rapid Antimicrobial Susceptibility Testing (AST) plays a crucial role in determining the right concentration of antibiotics required to inhibit the growth of a pathogen. With SoundCell and the TU Delft, we developed a breakthrough technique that shrinks the AST time from few days to less than 1 hour. We use a laser interferometric system in combination with graphene-based biosensor technology that uses nanomechanical vibrations of ultrathin micron-sized graphene drums to detect the motion of a single bacterium. Our device measures nanoscale motion from living cells with graphene membranes. We demonstrated that motion of alive and dead bacteria are different when adhered to the graphene sensors and we can correlate such changes to antibiotic susceptibility. Our platform is not limited by the growth rate and expands on the available tools for AST, and sets a new benchmark for sensitivity with respect to the available methods. With the significant reduction in size and increase in sensitivity, nanomotion detection potentially can evolve into an important non-invasive monitoring tool in cell biology and provide new routes for rapid screening tests in personalized medicine and drug development.

PS I - MEDICAL & BIO I

MEASURING BY LIGHT

IRINA WILS

KU LEUVEN

28 MARCH 2023

SENAATZAAL- 13:30 - 13:50

READING SOUND PRESSURE WAVES IN THE HEARING ORGAN WITH FIBER-OPTIC SENSING

The cochlea, the hearing organ, is filled with perilymph, a fluid that transfers pressure waves arising from audio signals. For preclinical testing of next-generation hearing implants, it is essential to have an objective measure of the mechanical stimulation of the auditory hair cells. The pressure in the cochlear fluid is a good indicator of this. However, the fluid-filled canals inside the cochlea are only 1 mm in diameter or smaller and can only be accessed by drilling through a layer of bone. This limitation makes it necessary to use optical fibers to record the pressure.
The fibers are capped with a reflective, flexible membrane that forms one of the mirrors of a Fabry-Perot interferometer. Changes in fluid pressure deform the reflective membrane inwards or outwards, which changes the optical path length. A photodiode monitors the light intensity, and the electrical output is locked-in to the sound stimulus for noise filtering. This allows us to measure the pressure in the cochlear fluid and thus reliably test the performance of the next generation of hearing implants.

PS I - MEDICAL & BIO I

PIETER LIVENS

UNIVERSITY OF ANTWERP

28 MARCH 2023

SENAATZAAL - 13:50 - 14:10

MEASURING BY LIGHT

DIGITAL IMAGE CORRELATION (DIC) APPLIED TO THE HUMAN EARDRUM: CHALLENGES, STRENGTHS, AND INSIGHTS IN THE MECHANICS OF HEARING

The human middle ear (ME) contains the eardrum and three hearing bones called ossicles. The ME allows us to detect sounds ranging from faint whispers to loud explosions across a fairly broad range of frequencies. To date, studying such a complicated biomechanical system remains challenging.
Digital image correlation (DIC) is a versatile technique which allows for measuring both static and dynamic properties of the eardrum. Yet, some challenges need to be overcome to allow high quality DIC measurements. For example, the eardrum is moist, and images will often contain specular reflections. The curved shape of the eardrum also poses a problem, since the depth of field needs to be large enough to allow the entire TM to stay in focus during the measurements. Moreover, DIC requires a stochastic pattern to be applied, but the choice of paint and corresponding illumination influence the accuracy of the results.

Despite these challenges, DIC is well suited to measure the eardrum in a variety of conditions. We will present our current setup and methods to achieve the best possible DIC measurements. We will highlight the strengths and weaknesses of DIC for our use case, and aim to achieve a fruitful discussion with other DIC users during and after the presentation.

PS I - OPTICAL FIBER SENSING

CHRISTOPHE CAUCHETEUR

UNIVERSITY OF MONS

28 MARCH 2023

COMMISIEKAMER 3 - 13:10 - 13:30

MEASURING BY LIGHT

SMART RAILWAY TRAFFIC MONITORING USING FBG SENSORS

There is today ample evidence that fiber Bragg gratings (FBGs) distributed along a railway track can provide robust axle counting and bring numerous assets compared to competing technologies in this practical environment. We are active in field since 2014. Our work bring relevant originalities with respect to the state-of-the-art solutions. First, a study of the strain distribution in the rail cross-section has been performed to determine the sensitivity according to the charge and the position on the rail. Secondly, the technology was deployed along the rail track as a smart object where the sensor head is composed of four FBG wavelength-division-multiplexed in a single telecommunication-grade optical fiber and interrogated by a miniaturized read-out device. Two FBGs ensured the detection of the train direction and another two bring the required redundancy to reach a safety integrity level (SIL) 4. The read-out unit has been specifically developed for the application and contains a vertical-cavity surface-emitting laser (VCSEL) and a photodiode driven by a high-speed microprocessor unit that processes the data and communicates the useful information, i.e., the number of axles. Numerous on-field tests accumulated over different months and seasons have confirmed that the proposed approach makes the installation process easier while it democratizes the technology. All these achievements will be presented at the conference.

PS I - OPTICAL FIBER SENSING

XIANG WANG

TECHNICAL UNIVERSITY OF DELFT

28 MARCH 2023

COMMISIEKAMER 3 - 13:30 - 13:50

MEASURING BY LIGHT

SIMULATIONS FOR NANOPARTICLE-DOPED OPTICAL FIBRE USED FOR SMALL STRAIN MONITORING UNDER DIFFERENT SIGNAL TO NOISE RATIOS

Monitoring strain of the aerospace structures, for example the fuselage, can be used to evaluate the structure's health. When there are cracks in the structures, the local stress causes local strain changes which can be used to distinguish a damaged structure from an undamaged structure based on strain information. Fibre optic sensors are competitive technology for strain monitoring, for example distributed fibre optic sensors based on Rayleigh backscattering. However, when the crack is not at the position of the optical fibres or the crack is not close to the optical fibre sensor, the strain values will not show high difference. In this case, developing high sensitivity optical fibre strain sensors could be beneficial for noise sensitive strain monitoring. Nanoparticle-doped optical fibres have attracted interest in recent years. By increasing the backscattered light using nanoparticles in the core of the optical fibres, the signal to noise ratio may increase and then the strain sensitivity may be improved. In this work, simulations of gold nanoparticle-doped backscattered light enhanced distributed fibre optic sensors based on Rayleigh backscattering are investigated under different signal to noise ratios at a strain value at zero. By simulation, the cases of the fluctuation of the obtained strain values show that it would be an advantage of small strain monitoring for structural health monitoring when the signal to noise ratio increases caused by nanoparticle doping. Therefore, nanoparticle doped optical fibre shows the potential to be a novel sensor used for aerospace structural health monitoring in the future.

PS I - OPTICAL FIBER SENSING

BRAM VAN HOE

FBGS

28 MARCH 2023

COMMISIEKAMER 3 - 13:50 - 14:10

MEASURING BY LIGHT

DYNAMIC SENSING OF LARGE ARRAYS OF DRAW TOWER GRATINGS USING CODE DIVISION MULTIPLEXING

In this contribution, the method of Code Division Multiplexing (CDM) is being investigated for its dynamic measurement capabilities. In earlier publications, this technique has already been shown to be capable to measure thousands of Draw Tower Grating® (DTGs®) on a single fiber, where many FBG's with identical wavelengths are being used. This readout can be obtained by modulating the outgoing and incoming light from the optical source and spectrometer with a binary code that is auto-correlated.

However, since CDM relies on two sequential measurement steps, dynamic measurements are more challenging because it is assumed that no changes on the sensors take place in between 2 consecutive measurements. Therefore, it is important to understand how dynamic changes affect the CDM measurement and what the limitations are. This was studied both theoretically and experimentally and the results will be presented. For the experimental study, a section in a sensor network with 160 serial DTGs® is harmonically strained with frequencies of 0.5Hz and 40Hz. The strained DTGs are measured and the data is compared to the expected responses in order to quantify the error that originates from dynamical effects. Possible system improvements are proposed to find a suitable compromise between detection accuracy and system speed for large optical sensor networks.

PS 2 - MATERIALS & DEGRADATION

SAEID HEDAYATRASA

GHENT UNIVERSITY

28 MARCH 2023

AUDITORIUM - 14:40 - 15:00

MEASURING BY LIGHT

3D INFRARED SCANNING LASER DOPPLER VIBROMETRY FOR MEASURING WAVE DYNAMICS IN ACOUSTIC METAMATERIALS

Phononic crystals are acoustic metamaterial lattices which manipulate elastic wave propagation in an extraordinary way. A prominent characteristic of phononic crystals is suppression of wave propagation over particular frequency ranges, so called phononic bandgaps.

In this study, a phononic crystal plate is manufactured by water jetting an aluminum plate and its inter- and intra-cellular wave dynamics are analyzed by 3D scanning laser Doppler vibrometry. The optimized cellular design of the phononic plate includes a wide complete bandgap of both symmetric and antisymmetric guided wave modes with dominant in-plane and out-of-plane particle displacement, respectively. Broadband sine sweep excitation is applied by a piezoelectric transducer, and transmission characteristics of guided waves throughout the plate is studied.

The operational deflection shapes of the plate are measured and compared with the mode shapes calculated by finite element simulation. The results confirm the strong attenuation of both symmetric and antisymmetric guided wave modes inside the phononic bandgap, as well as the resonation of modes in the vicinity of the bandgap edges. Furthermore, the measurements reveal that despite the absence of in-plane wave energy in the excitation area, the symmetric wave modes are effectively excited. This observation is explained by asymmetry of the water jetted cutting edges which lead to the coupling of symmetric modes with co-existing antisymmetric modes.

The results demonstrate the performance of 3D scanning laser Doppler vibrometry for inspection of acoustic metamaterials with complex cellular design in gaining full insight about their wave dynamics, and in revealing any deviations induced by manufacturing imperfections.

PS 2 - MATERIALS & DEGRADATION

BART VAN DAMME

EMPA

28 MARCH 2023

AUDITORIUM - 15:00 - 15:20

MEASURING BY LIGHT

ASSESSING THE DYNAMICS OF QUASIPERIODIC BEAMS AND PLATES USING SCANNING LASER VIBROMETRY

Metamaterials are a class of structures in which a certain physical property is defined by a well-engineered combination of its design and material properties. They can give rise to optical, acoustical and mechanical properties that are outside the possibilities of homogeneous materials. Vibro-acoustic metamaterials typically aim to reduce vibration levels or acoustic radiation by inhibiting wave propagation in certain frequency bands, so-called band gaps. Using such optimized structures, unseen combinations of low weight, high stiffness and vibration reduction can be achieved.

Most metamaterials have a periodic structure, since they allow fast calculation of the desired properties. However, just like in nature, structures with an aperiodic or quasiperiodic design can have particular properties of interest. We show two examples of scanning laser vibrometry measurements in the assessment of bending waves in quasiperiodic beams and plates. The first example shows that beams without repeating stiffness patterns can exhibit low-frequency band gaps for flexural motion. The second example of bending waves in a plate adorned with scatterers placed according to a Penrose pattern yields efficient band gaps in the bulk of the plate, and areas with localized vibration modes. They can be used to diverge vibrational energy from critical structural points to locations where the energy can be efficiently damped.

PS 2 - MATERIALS & DEGRADATION

MEASURING BY LIGHT

JOERG SAUER

POLYTEC

28 MARCH 2023

AUDITORIUM - 15:20 - 15:40

OPTICAL STRAIN MEASUREMENT TECHNIQUES FOR VERY HIGH CYCLE FATIGUE (VHCF) TESTING

High-cycle fatigue (HCF) and very high cycle fatigue (VHCF) testing is an appropriate mean to evaluate new engineered materials regarding their durability properties in an economic way. Testing at higher frequencies brings down testing time at high number of cycles. Monitoring the strain values at the specimen is a prerequisite for a proper test result. Conventional sensors have a limitation in terms of highest frequency and maximum temperature of operation which are addressed with the proposed method. In this research, a detailed account of the motivation and the procedure to go from vibrational velocity to dynamic strain using laser doppler Vibrometry (LDV) is provided. Specifically, the potential of multi-path interferometers featuring diversity combining (QTec) is exploited. Comparison is shown between strain measured with LDV featuring QTec, 3-dimensional scanning LDV and a strain gage. Results show a good agreement between these techniques.

PS 2 - MATERIALS & DEGRADATION

ŁUKASZ PIECZONKA

AGH UNIVERSITY OF SCIENCE & TECHNOLOGY

28 MARCH 2023

AUDITORIUM - 15:40 - 16:00

MEASURING BY LIGHT

MULTI-RESOLUTION LASER-BASED DAMAGE DETECTION IN THIN-WALLED STRUCTURES USING ULTRASOUND

We discuss a two-step damage evaluation framework based on laser ultrasonic techniques. In the first step, a global full-field screening with the use of guided ultrasonic waves is performed to determine the possible damage locations. In the second step, the identified hot spots are further evaluated with a high-frequency ultrasonic bulk wave system. Both testing modalities are implemented using non-contact laser vibration sensors. A piezoceramic exciter is used for the guided wave setup, while a pulsed laser excitation source is used in the bulk wave setup. The proposed approach minimizes sample preparation time and is completely non-intrusive. The feasibility of the proposed framework is demonstrated in thin-walled composite samples with localized defects.

PS 2 - MICROSCOPY

MEASURING BY LIGHT

SJOERD STALLINGA

TECHNICAL UNIVERSITY OF DELFT

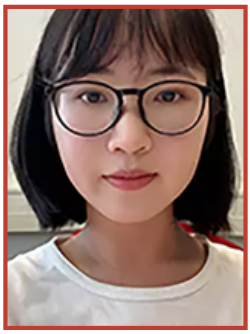
28 MARCH 2023

FRANS VAN HASSELTZAAL - 14:40 - 15:00

COMPUTATIONAL MICROSCOPY FOR BREAKING FUNDAMENTAL IMAGING BARRIERS

In my presentation I will highlight recent developments by our group in super-resolution microscopy. The use of patterned illumination can improve the single molecule localization precision, I will explain these principles and explore possible consequences of iterative localization schemes. Next, I will show results on fast particle fusion of nuclear pore complex single molecule data, wherein multiple imperfectly labelled and imaged nano-structures are registered and averaged to boost signal-to-noise ratio. Finally, I will talk about novel ways to extract signal and noise information from a single image, and how that can be used for camera calibration, image resolution measurement, and deconvolution.

PS 2 - MICROSCOPY



QINGRU LI

TECHNICAL UNIVERSITY OF DELFT

28 MARCH 2023

FRANS VAN HASSELTZAAL - 15:00 - 15:20

MEASURING BY LIGHT

CRYO-4PI SINGLE MOLECULE LOCALIZATION MICROSCOPY: A 3D SUB-NM IMAGING TECHNIQUE

4Pi microscopy can deliver three-dimensional isotropic sub-10 nm resolution images via a sharpened axial point spread function (PSF) [1]. Imaging at cryogenic temperatures not only enables observing structures in a near-native and fixed state but also suppresses irreversible photo-bleaching rates, resulting in increased photo-stability of fluorophores [2]. According to previous investigations, an increase of one to two orders of magnitude in the number of detected photons can be achieved at cryogenic temperatures [3-5]. Sub-nm imaging resolution has been achieved by cryogenic optical localization microscopy of proteins by using stochastic blinking dyes [6] and a polarization encoding method [7], although blinking behavior of dyes at cryogenic temperatures limits the application to a sparsely labeled structure. Theoretically, sub-nm imaging resolution is achievable by 4Pi single molecule localization microscopy at cryogenic temperatures (Cryo-4Pi SMLM) as well. In practice, however, the resolution is limited due to suboptimal analysis methods and aberrations introduced by optical components. In the presentation, we will show the mechanism for achieving isotropic high localization precision with Cryo-4Pi SMLM, the construction of the complex interferometric 4Pi detection, and the effect of specific aberrations on localization precision.

PS 2 - MICROSCOPY

MEASURING BY LIGHT

CARLAS SMITH

TECHNICAL UNIVERSITY OF DELFT

28 MARCH 2023

FRANS VAN HASSELTZAAL - 15:20 - 15:40

ADAPTIVE OPTICS IN SINGLE OBJECTIVE INCLINED LIGHT SHEET MICROSCOPY ENABLES THREE-DIMENSIONAL LOCALIZATION MICROSCOPY IN ADULT DROSOPHILA BRAINS

Single-molecule localization microscopy (SMLM) enables the high-resolution visualization of organelle structures and the precise localization of individual proteins. However, the expected resolution is not achieved in tissue as the imaging conditions deteriorate. Sample-induced aberrations distort the point spread function (PSF), and high background fluorescence decreases the localization precision. We have synergistically combined sensorless adaptive optics (AO), in-situ 3D-PSF calibration, and a single-objective lens inclined light sheet microscope (SOLEIL), termed (AO-SOLEIL), to mitigate deep tissue-induced deteriorations. We apply AO-SOLEIL on several dSTORM samples including brains of adult Drosophila. We observed a 2x improvement in the estimated axial localization precision with respect to widefield without aberration correction while we used synergistic solution. AO-SOLEIL enhances the overall imaging resolution and further facilitates the visualization of sub-cellular structures in tissue.

PS 2 - MICROSCOPY

PAUL PLANKEN

ARCNL

28 MARCH 2023

FRANS VAN HASSELTZAAL - 15:40 - 16:00

MEASURING BY LIGHT

PHOTOACOUSTIC DETECTION OF BURIED GRATINGS

In semiconductor device manufacturing, techniques to detect alignment gratings buried below the surface of deposited layers are extremely important. Alignment gratings are gratings etched into Si wafers that are used to position wafers with subnanometer accuracy. This is done by illuminating the grating with a light source and by measuring (phase) changes in diffracted orders emerging from the grating when the grating is translated. This technique becomes challenging when layers of (partially) optically opaque materials are deposited on these gratings during the fabrication of devices.

Fortunately, layers that are opaque to light are often transparent to sound. In this presentation I will show how laser-induced extremely-high frequency sound waves can be used to detect alignment gratings buried underneath opaque layers. We use a femtosecond light pulse to generate a propagating strain wave at an interface (see Fig. below) which reflects off the buried grating. The resulting strain-wave copy of the grating can diffract light when it reaches the surface and becomes accessible to light. This grating can be a grating in the optical constants of the material or a spatially periodic vertical displacement of the interface with amplitudes in the (sub-)picometer domain.

The technique is capable of observing buried gratings through many layers, but with a fairly low signal strength. In the remainder of the presentation I will therefore describe ongoing work to use optical resonances to significantly enhance strain-wave induced changes in optical signals in these types of measurements. Examples are the use of surface plasmon-polariton resonances at metallic surfaces, and optical etalon resonances in extremely thin (~10 nm) absorbing layers.

PS 2 - MEDICAL & BIO 2

MEASURING BY LIGHT

YANLU LI

GHENT UNIVERSITY

28 MARCH 2023

SENAATZAAL - 14:40 - 15:00

DEVELOPMENT OF MULTI-BEAM LASER DOPPLER VIBROMETER FOR CARDIOVASCULAR DISEASE MONITORING AND DIAGNOSIS

We report the development of a hand-held multi-beam laser Doppler vibrometer (LDV) for the measurement of skin movement originating from cardiovascular actions. The measured data can be used to monitor and diagnose cardiovascular conditions, such as arterial stiffness, stenosis, and heart failure. The multi-beam LDV is realized on a silicon-based photonic integrated circuit (PIC) to ensure a compact and low-cost sensor device. The main challenge of this project is to enable the vibration measurement on bare skin as the reflection is highly diffuse and leads to a very weak signal coupled back to the on-chip interferometer. We will discuss how we design the PIC, the optical system, and the electronic system to ensure the measurement can be realized on bare skin.

PS 2 - MEDICAL & BIO 2

MEASURING BY LIGHT

TRISTAN PUTZEYS

KU LEUVEN

28 MARCH 2023

SENAATZAAL - 15:00 - 15:20

NON-DESTRUCTIVE INTRACOCHLEAR VIBROMETRY VIA OPTICAL COHERENCE TOMOGRAPHY

The cochlea is the hearing organ containing micro-meter sized structures that vibrate when we listen to sound. For research and future diagnostics, it is vital that the acousto-mechanical relationship can be monitored and understood without opening or altering the hearing organ.

With Optical Coherence Tomography (OCT) it is possible to obtain a 3D image of anatomical structures, imaging through membranes and thin sections of bone. OCT uses low-coherence, broad bandwidth infrared light in a Michelson-like interferometer. The Fourier transform of the interference spectrum yields a depth profile (a-scan), that can be extended to a 2D (b-scan) or 3D (c-scan) image by scanning the light beam across a surface with the aid of galvanometer mirrors.

While the amplitude of the Fourier transform yields the morphology of the anatomy, the phase can be used to observe submicrometer displacements during mechanical stimulation. By synchronizing the image acquisition with an external (audio) stimulation source, the acousto-mechanical response of the cochlear micro-anatomy can be observed and analyzed.

PS 2 - MEDICAL & BIO 2

DAAN BRINKS

TECHNICAL UNIVERSITY OF DELFT

28 MARCH 2023

SENAATZAAL - 15:20 - 15:40

MEASURING BY LIGHT

VOLTAGE IMAGING WITH GENETICALLY ENCODED VOLTAGE INDICATORS: DEVELOPMENT AND APPLICATIONS

Technologies that allow high-speed imaging of cellular dynamics are central to our ability to ask and answer new questions in cell biology and neuroscience. Here, I will focus on voltage imaging: the optical recording of membrane potentials and their fast dynamics in excitable cells. I will discuss recent developments in our lab expanding the palette of available tools and applications for voltage imaging in vitro and in vivo. I will touch upon the synergistic development of hardware, screens, targeted gene expression schemes, functionalization strategies and improved near-infrared voltage indicators and recent functional transcriptomics work that enhances the potential of voltage imaging as a diagnostic tool.

PS 2 - MEDICAL & BIO 2

MEASURING BY LIGHT

SABINA CANEVA

TECHNICAL UNIVERSITY OF DELFT

28 MARCH 2023

SENAATZAAL - 15:40 - 16:00

2D MATERIAL PHOTONIC NANOSTRUCTURES FOR SINGLE-MOLECULE FINGERPRINTING

Reading biomolecular signatures and understanding their role in health and disease is one of the greatest scientific challenges in genome and proteome biology. While we have the technology to sequence an entire human genome, full cellular protein identification and characterization remains out of reach.

We are developing an optofluidic platform based on photonic 2D material nanopores and nanochannels to enable fingerprinting of single proteins. The 2D material nanostructures are generated by focused ion beam milling and femtosecond laser irradiation and host quantum emitters that are optically-active in the visible range at room temperature and in liquid. By performing optical nanoscopy measurements with labelled DNA samples, we characterize the photophysical interaction and conformational changes of the biomolecules on the crystal surfaces.

Photonic 2D material nanostructures are thus highly promising for single-molecule proteomics because they can be massively parallelized and imaged with wide-field microscopy, enabling high-resolution and high throughput optical screening of single proteins.

PS 2 - WAVES & FLOW

NATALIA RIBEIRO MARINHO

UNIVERSITY OF TWENTE

28 MARCH 2023

SENAATZAAL - 14:40 - 15:00

MEASURING BY LIGHT

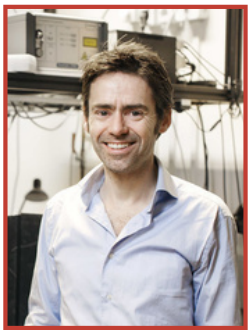
EXPLOITING HIGH FREQUENCY WAVES FOR SHM USING 3D SLDV SYSTEM: WHAT CAN WE LEARN MORE?

This research work will present a study on the use of a 3D Scanning Laser Doppler Vibrometer (3D-SLDV) to visualise the wave field in three-dimensional composite structures. Knowledge of the wave field in structures, induced either actively by for example piezo-electric transducers or by an impact, supports the design of integrated Structural Health Monitoring (SHM) sensor systems on aerospace components to detect damage precursors.

Reconstruction of an impact location and the possibly associated damage, may be relatively straightforward in simple geometries of homogeneous materials, whereby sensor and signal analysis are not biased by any geometrical feature other than the location of the impact and damage in the structure. The more complex the geometry, the more complex the wave field. Any additional feature to a simple geometry can bias the measurement interpretation. Understanding of the wave field is often supported by numerical models, which are also limited by these geometrical complexities. Experimental validation of the calculated wave fields is therefore of great importance. One of the goals of this research is to exploit the 3D-SLDV to overcome the identified challenges.

It is believed that better measurement strategies for SHM can be achieved by investigating how vibrations and acoustic waves generate and manifest in complex geometrical structures. SLDV based experimental validation is an important tool assisting the development of SHM systems in aerospace applications.

PS 2 - WAVES & FLOW



MEASURING BY LIGHT

JEROEN KALKMAN

TECHNICAL UNIVERSITY OF DELFT

28 MARCH 2023

SENAATZAAL - 15:00 - 15:20

HIGH DYNAMIC RANGE FLOW SPEED IMAGING WITH OPTICAL COHERENCE TOMOGRAPHY

Optical coherence tomography (OCT) can image both sample structure and flow. Flow measurements can be performed through phase resolved Doppler OCT or dynamic light scattering OCT (DLS-OCT). However, both have the drawback that the maximum flow speed is limited by the acquisition rate and that the minimum speed is limited by Brownian particle motion.
Here we present two DLS-OCT measurement strategies to measure either very low or very high flow speeds.
We show that the maximum sampling limited flow that can be measured with Doppler OCT and DLS-OCT can be significantly enhanced through B-scan DLS-OCT. In this technique we scan the optical beam along the flow direction to reduce the flow decorrelation. Using the known scan speed and numerical depth re-alignment of the sample along the scan we demonstrate a more than two time higher flow measurement range compared to non-scanning DLS-OCT and Doppler OCT. We demonstrate the general applicability of our technique to omnidirectional flow measurement using multiple B-scans at different scan speeds and solving the associated set of equations.
We show that the minimum diffusion limited flow that can be measured with Doppler OCT and DLS-OCT can be significantly lowered through the use of number fluctuation DLS-OCT. For dilute suspensions the number fluctuation flow is uncoupled from the diffusion decorrelation. By fitting the number fluctuation part of the autocovariance function, we enable sub-diffusion flow measurement that outperforms Doppler OCT. In addition, we show B-scan number-fluctuation flow imaging in the same time frame by sub-sampling of the correlation function.

PS 2 - WAVES & FLOW

DIANA VAN DER VEN

UNIVERSITY OF TWENTE

28 MARCH 2023

SENAATZAAL - 15:20 - 15:40

MEASURING BY LIGHT

NOVEL HIGH-BANDWIDTH LASER-DOPPLER VIBROMETRY-BASED SETUP WITH MICROFABRICATED CANTILEVERS TO MEASURE THE IMPACT FORCE OF MICROFLUIDIC-JETS.

Controlled microfluidic jet injections could enhance the pharmacokinetics of various therapeutics while simultaneously reducing the environmental burden of solid needle injections. However, control over injection depth requires knowledge on how jet-impact determines injection outcome. Currently, microjet-impact (0.5-5 mN, 100-400 µs) cannot be measured as it falls either below sensitivity or temporal resolution of commercial systems. To bridge this gap, a setup was designed consisting of microfabricated cantilevers, impacted by microfluidic-jets while monitoring cantilever velocity using laser-Doppler vibrometery.

Cantilevers (500×500×25 µm, l×b×t) were fabricated in a SOI wafer using two photomasks. The first two eigenfrequencies were determined (74 KHz and 240 KHz) using a Polytec MSA600 vibrometer. Cantilever tips were pressed down using known force while displacement was measured using white-light interferometry to determine the relation between static force and cantilever deflection ($y = (1.5995 \times Fjet) + 0.1569$, $R^2 = 0.9997$) and the Youngs' modulus (38.8 GPa). Cantilevers were aligned with the microfluidic-chip and vibrometer, jet-impact occurred at the frontside while the vibrometer measured the cantilever velocity from the backside. Using two high-speed camera's jet characteristics were captured and impact position on the cantilever tip was verified, while the vibrometer measured the cantilever displacement velocity during impact.

Beam deflections were measured with maximum velocities of 3 m/s and a bandwidth of 1.5 MHz. However, jet-impact triggered non-linear resonance behavior in the cantilevers, complicating data analysis. Therefore, improved cantilevers were designed, fabricated and calibrated, to prevent or dampen resonance in future studies, and will be tested shortly.

.

PS 2 - WAVES & FLOW

PAWEL KUDELA

INSTITUTE OF FLOW MACHINERY

28 MARCH 2023

SENAATZAAL - 15:40 - 16:00

MEASURING BY LIGHT

DEEP LEARNING AIDED LASER DOPPLER VIBROMETRY FOR DELAMINATION IDENTIFICATION IN COMPOSITE LAMINATES

A scanning laser Doppler vibrometer is an excellent tool for conducting full wavefield measurements of propagating guided waves. Wavefield anomalies carry rich information about the presence of hidden defects in the structural materials such as delaminations. However, the long acquisition time and complexity of the guided wave propagation phenomenon hinder the practical application. We propose to use deep learning super-resolution which can upscale very low-resolution wavefield acquired below the Nyquist rate to high-resolution so that the scanning time can be significantly reduced. Moreover, we propose the convolutional long short-term type of deep neural networks for delamination identification which surpasses the conventional signal processing techniques such as adaptive wavenumber filtering.

KEYNOTE LECTURE 3

ROGER M. GROVES

TECHNICAL UNIVERSITY OF DELFT

29 MARCH 2023

AUDITORIUM - 09:50 - 10:30

MEASURING BY LIGHT

OPTICAL TOOLS FOR ASSESSING THE STRUCTURAL INTEGRITY OF AEROSPACE STRUCTURES

Aerospace components and structures are subjected to rigorous quality inspection and monitoring processes during manufacturing and in-service to ensure the structural integrity of the aerospace vehicle and its safe operation. Optical tools are used extensively to support these quality inspections and monitoring processes and this presentation will give an overview of the state of the art of these optical tools and how they can contribute to safe operation of the aerospace vehicle. At the design phase of the aircraft/spacecraft, research is performed into the materials development, the mechanical performance of the materials and is concluded by full-scale testing. Optical technology plays a role in this design phase in the microscopy and spectroscopy tools used to assess materials and the imaging, optical metrology and fibre optic sensing technology used in the testing phases. During manufacturing optical tools are used to ensure the manufacturing quality. Laser line scan sensors (LLSS) and imaging systems are used for inspection and increasingly light projection systems are used to guide manufacturing staff in assembly processes. In service there is competition between optical and ultrasonics technology for inspection and monitoring. For inspection, thermography, shearography and x-ray imaging are used, while fibre optic sensing is used for monitoring structures. At end of life, laser spectroscopy techniques are used to separate plastics. Looking towards the future there is increasing use of spectral imaging techniques for inspection, as well as terahertz imaging for non-conducting materials and also optical coherence tomography (OCT) for high resolution sub-surface inspection.

PS 3 - AUTOMOTIVE, MOB. & ROB.

MICHAËL WIERTLEWSKI

TECHNICAL UNIVERSITY OF DELFT

29 MARCH 2023

AUDITORIUM - 11:00 - 11:20

MEASURING BY LIGHT

TACTILE SENSING VIA COLOR MIXING FOR ROBOTIC GRASP

The successful grasp of an object has everything to do with applying the proper squeezing force: with forces too small the object slips and excessive forces can induce damage. To find the optimal force, the coefficient of friction needs to be known otherwise, the controller has to make assumptions that can lead to dramatic failure of the grasp.

Here, we demonstrate a new tactile sensor and data-driven processing pipeline that can detect the distribution of frictional strength over complex shapes during the first instant of contact. Our camera-based tactile sensor is able to track the three-dimensional displacement of 441 points of measurement. Each measurement point is a color-changing marker placed where its shape and color correlate to the three-dimensional deformation of the membrane. We calibrated the tactile sensor using a convolutional neural network. The network inputs snippets of the membrane image and outputs the local normal and shear deformation of the selected region and the local friction. To learn the proper transformation, we trained the network on a ground truth composed of examples of spherical contacts simulated by finite-element methods with high or low friction.

After training, the network generalizes to unknown shapes. More importantly, it can map the distribution of friction when presented with an object that has one part covered with lubricant.

We demonstrate the effectiveness by mapping the friction of a wide range of objects, and show how this approach can prevent slippage when used for grasping.

PS 3 - AUTOMOTIVE, MOB. & ROB.

ANDRÉ TAVARES

SIEMENS INDUSTRY SOFTWARE NV

29 MARCH 2023

AUDITORIUM - 11:20 - 11:40

MEASURING BY LIGHT

EXPERIMENTAL MODAL ANALYSIS OF A COMPOSITE B-PILLAR CAR COMPONENT MEASURED WITH OPTICAL TECHNIQUES

Composite materials have excellent mechanical properties with respect to their overall weight, such as high strength to weight ratio, high fatigue resistance, among others. Their application in the automotive industry benefits the design of vehicles in a way to reduce their mass while maintaining their structural integrity, which consequently improves their performance and reduces fuel consumption. The complexity of composites as materials generates increased difficulty in the development of simulation models for composite structures. However, it is ever more important to leverage accurate simulation models in the development and life of complex structures, in accordance with the digital twin concept. Better correlation of simulation models can be achieved through updating these with respect to coherent experimentally measured data for multiple points on a structure. In this way, optical measurement techniques can be used to make highly accurate measurements with dense grids of points, while avoiding to mass load the measured structure with conventional sensors. Therefore, in this work, Laser Doppler Vibrometry (LDV) and Digital Image Correlation (DIC) are used to perform measurements on a woven reinforced composite B-Pillar component of a car. Experimental modal analysis (EMA) is then performed to calculate the modal parameters (i.e., natural frequencies, damping ratios, and mode shapes). A comparison of the results obtained for both measurement techniques is described in this work.

PS 3 - AUTOMOTIVE, MOB. & ROB.

MEASURING BY LIGHT

ANDREW DRESSEL

TECHNICAL UNIVERSITY OF DELFT

29 MARCH 2023

AUDITORIUM - 11:40 - 12:00

USE OF A SCANNING LASER DOPPLER VIBROMETER TO INVESTIGATE CAUSES AND POSSIBLE MITIGATIONS OF BICYCLE DISC BRAKE NOISE

We used a Polytec PSV-400 scanning laser Doppler vibrometer to measure vibration velocities, magnitudes, frequencies, and mode shapes of a bicycle calliper, rotor, and the front fork during braking. We detected three frequency peaks, at about 600, 1200, and 1800 Hz, and also confirmed these frequencies in plots of amplitude verses frequency of the recorded sound.
We then modelled the rotor and pads, separately and together, with finite elements to calculate theoretical frequencies and mode shapes. The calculated values closely approximate the measured values, which confirmed the fidelity of the numerical model, and this numerical analysis also revealed the presence of doublet modes.

Altogether, these steps confirmed the occurrence of mode lock-in, the likelihood of doublet merging, and suggested that merely breaking the symmetry of the rotor mass distribution, thereby altering its natural frequencies, could limit sound generation.

Finally, to confirm its effectiveness, we tested this hypothesis physically by simply adding small masses to the arms on only one side of the rotor spider and measured reductions in sound magnitude of 70-100%, depending on the frequency, with the highest frequency, 1800 Hz, being effectively silenced.

PS 3 - AUTOMOTIVE, MOB. & ROB.

MEASURING BY LIGHT

GRÉGORY PANDRAUD

OMMATIDIA LIDAR

29 MARCH 2023

AUDITORIUM - 12:00 - 12:20

FLASH FMCW LIDAR FROM VIBROMETRY TO AUTOMOTIVE

Accurate three-dimensional (3D) imaging is essential for machines and vehicles to map and interact with the physical world. Although numerous 3D imaging technologies exist, each addressing niche applications with varying degrees of success, none has achieved the breadth of applicability and impact that digital image sensors have in the two-dimensional imaging world.

FMCW based LiDAR sensors allow to go beyond the limitations of actual LiDAR systems such as limited depth accuracy and immunity to interference from sunlight, as well as limited ability to measure the velocity of moving objects directly. Ommatidia s LiDAR FMCW based solution offers a unique product that finds applications in a number of fields ranging from vibrometry to industrial metrology. Beyond being scalable the solution offers the possibility to match the pricing request (while keeping the performance) of markets such as automotive.

PS 3 - NANO PARTICLES

MEASURING BY LIGHT

PETER SPEETS

TECHNICAL UNIVERSITY OF DELFT

29 MARCH 2023

FRANS VAN HASSELTZAAL - 11:00 - 11:20

MEASUREMENT OF THE REFRACTIVE INDEX OF PARTICLE SUSPENSIONS USING SPECTRAL INTERFEROMETRY

Dependent scattering is a well-known effect in the scattering attenuation of turbid media. Less well-known is the effect of dependent scattering on the effective refractive index of a suspension. There are various theoretical scatting models that predict an explicit dependence of the effective refractive index on the radial correlation function. However, measuring this is very challenging. This work shows that by measuring both group index and the group velocity dispersion (GVD) for a broad wavelength range this effect can be measured accurately.

The group refractive index and GVD of a suspension of 100 nm silica particles is measured with a Mach-Zehnder interferometer. The part of the spectrum between 420 nm and 920 nm of a supercontinuum laser is guided into the two arms of the interferometer. The concentration and wavelength dependence of the group refractive index and the GVD were obtained from the phase of the interference spectrum. The higher sensitivity of the GVD to local structure of the suspended particles allows us to test the particle concentration dependence of the real part of the refractive index. The nonlinear dependence of the GVD on the volume fraction of particles matches the theoretical model predicted in literature. This opens the possibility to measure particle size distribution both from the scattering attenuation as well as from the refractive index.

PS 3 - NANO PARTICLES

WALTER KNULST

VSL NATIONAL METROLOGY INSTITUTE

29 MARCH 2023

FRANS VAN HASSELTZAAL - 11:20 - 11:40

MEASURING BY LIGHT

REFRACTIVE INDEX DETERMINATION OF LIQUIDS WITH THE LOWEST UNCERTAINTY TO IMPROVE STANDARDIZATION OF FLOW CYTOMETRY FOR (BIO)NANOPARTICLES

Introduction. The concentration of extracellular vesicles (EVs) in body fluids has excellent potential to become a biomarker and can be measured by flow cytometry. Flow cytometers are calibrated using Mie theory to relate light scattering signals in arbitrary units to the diameter of these bionanoparticles. A required input variable of Mie theory is the refractive index (RI) of the liquid surrounding the EVs. To accurately and traceably determine the RI of liquids, we developed a metrological goniometer.

Methods. We have developed a new automated set-up and procedure, based on measuring the angle of minimum deviation, to determine traceable RIs for prismatic shapes under controlled environmental conditions between 405 nm and 633 nm. The set-up can be used for both measurements of solids and liquids. The procedure simultaneously measures the RI and the prism angles, and thus does not require independent prism angle measurements or multiple rotary tables. As a result, our set-up is more cost-effective than conventional refractometers, since existing methods with similar measurement uncertainty require at least two measurements per prism angle as well as two measurements per deviation angle. Another advantage of the reported method is that correlations in the uncertainty propagation reduce the sensitivity coefficients greatly.

Results. We have measured the absolute RI of fused silica and a few fluids for that used in flow cytometers. The expanded uncertainty (k=2) of the measurements is 1.4e-6, with the main factors affecting the expanded uncertainty being (I) the calibration uncertainty of the rotary stage and (II) the measurement repeatability.

PS 3 - NANO PARTICLES

MEASURING BY LIGHT

LAURENT FRANCIS

UNIVERSITÉ CATHOLIQUE DE LOUVAIN

29 MARCH 2023

FRANS VAN HASSELTZAAL - 11:40 - 12:00

IMPROVING THE DETERMINATION OF STRAIN IN THE DEFORMED SILICON MEASURED BY RAMAN SPECTROSCOPY

The local determination of mechanical strains in semiconductors is of interest for a range of applications, such as strain engineering in 2D materials and piezoresistive and piezoelectric sensing. It also confirms or assists the understanding of mechanical failures in related microstructures such as beams, cantilevers, or membranes. The strain is shifting the Raman scattering of a monochromatic light due to the interactions between the electromagnetic field and the crystal lattice vibrations. In this work, we report an improved determination of the strain in Silicon along the [110] direction using a combination of first-principles simulations with the Density Functional Perturbation Theory (DFPT) and experimental backscattering Raman measurements on highly-strained Silicon microbeams. DFPT is a highly accurate and computationally efficient method for simulating the response of materials to external perturbations, such as mechanical strains. The beams are fabricated using a top-down microfabrication approach and include an in-situ silicon nitride actuator. Compared to the classically used phonon deformation potentials (PDP) theory, our approach improves the confidence between the Raman shifts and the actual strains.

PS 3 - NANO PARTICLES

JACOB HOOGENBOOM

TECHNICAL UNIVERSITY OF DELFT

29 MARCH 2023

FRANS VAN HASSELTZAAL - 12:00 - 12:20

MEASURING BY LIGHT

INTEGRATED, COINCIDENT LIGHT, ELECTRON, AND ION BEAM MICROSCOPY FOR HIGH-RESOLUTION STRUCTURAL IMAGING

Electron microscopy (EM) is a key technology to image materials, tissues, particles, and proteins at nanometer or even atomic scale resolution. A prerequisite for highest-resolution EM is a sample thickness of ~100 nm, which often needs thinning the sample, e.g., using focused ion beam (FIB) milling. Milling a 100nm section out of a macroscopic sample, e.g., a ~10.000µm3 cell, such that it contains precisely the molecules of interest is highly challenging as standard FIB milling is blind to material composition or locations of specific (bio-)molecules. I will present a novel integrated microscope in which photon, electron, and ion beams coincide to allow fluorescence guided electron microscopy or ion beam milling. Moreover, we incorporated a microcooler to allow investigation of frozen hydrated cells at ~100K. With this microscope, in-situ fluorescence microscopy (FM) can be used to guide the FIB milling to a target protein or labelled biological structure. We show fluorescence controlled targeting at every milling step in the fabrication process, validated with high-resolution EM reconstructions of the target regions. The ability to check the sample with FM during and after the milling process results in a higher success rate in the fabrication process and will increase the throughput of fabrication for samples for highest-resolution microscopy.

PS 3 - MICROSYSTEMS

MARKUS HEILIG

POLYTEC

29 MARCH 2023

SENAATZAAL - 11:00 - 11:20

MEASURING BY LIGHT

GHZ MEMS TESTING: CHALLENGES AND TECHNIQUES FOR EVALUATING HIGH-FREQUENCY PERFORMANCE

GHz MEMS (micro-electromechanical systems) testing is an essential process for ensuring the reliability and performance of MEMS devices that operate at high frequencies. As the demand for faster and more efficient electronic devices increases, GHz MEMS testing has become more critical in evaluating the performance of these devices under extreme conditions. This testing involves measuring the resonance frequency, quality factor, and wave propagation on MEMS devices, which are crucial for designing and optimizing their performance. Several techniques, such as laser Doppler vibrometry, electrical excitation, and optical interferometry, are used for GHz MEMS testing. In this talk, we provide an overview of the challenges and techniques associated with GHz MEMS testing and highlight the importance of this process in ensuring the quality and reliability of high-frequency MEMS devices.

PS 3 - MICROSYSTEMS

MEASURING BY LIGHT

RICHARD NORTE

TECHNICAL UNIVERSITY OF DELFT

29 MARCH 2023

SENAATZAAL - 11:20 - 11:40

MECHANICAL FREQUENCY COMBS VIA OPTICAL TRAPPING

Mechanical frequency combs are poised to bring the applications and utility of optical frequency combs into the mechanical domain. Their main challenge has been strict requirements on drive frequencies and power, which complicate operation. We demonstrate a straightforward mechanism to create a frequency comb consisting of mechanical overtones (integer multiples) of a single eigenfrequency, by monolithically integrating a suspended dielectric membrane with a counter-propagating optical trap. The periodic optical field modulates the dielectrophoretic force on the membrane at the overtones of a membrane's motion. These overtones share a fixed frequency and phase relation, and constitute a mechanical frequency comb. The periodic optical field also creates an optothermal parametric drive that requires no additional power or external frequency reference. This combination of effects results in an easy-to-use mechanical frequency comb platform that requires no precise alignment, no additional feedback or control electronics, and only uses a single, mW continuous wave laser beam. This highlights the overtone frequency comb as the straightforward future for applications in sensing, metrology and quantum acoustics.

PS 3 - MICROSYSTEMS

PIETER GIJSENBERGH

IMEC

29 MARCH 2023

SENAATZAAL - 11:40 - 12:00

MEASURING BY LIGHT

LASER DOPPLER VIBROMETRY AS A VERSATILE TOOL FOR PIEZOELECTRIC MICROMACHINED ULTRASOUND TRANSDUCER CHARACTERIZATION AND DEVELOPMENT

Imec's combined experience on displays and sensors/actuators enables a unique synergy between designing and fabricating piezoelectric micromachined ultrasound transducers (PMUT) targeting commercial large-area applications such as near-future flat-panel displays with haptic feedback, flexible high-frequency biomedical imaging, and acoustic power transfer. However, such multiphysics ventures are grounded in a firm, fundamental understanding of the underlying principles. Laser Doppler vibrometry (LDV) is a crucial tool in this endeavour.

From basic building blocks to prototype demonstrators, we use LDV to characterize resonance frequencies, vibrational amplitudes, and uniformity of single transducers, large PMUT arrays, and even full substrates. These characteristics are necessary to improve the latest generation of imec's glass-based polymer PMUT technology, which relies on scandium-doped aluminium nitride (ScAlN). This material outperforms PVDF, however, depends greatly on its scandium concentration and deposition method. We use LDV to analyse the displacement behaviour of multilayer structures to extract material and electromechanical properties from finite element models (FEM) for the finetuning of PMUT models in the future ultrasound roadmap.

PMUT and CMUT development is just one part of our MEMS characterization portfolio. LDV has also proven a valuable (complementary) tool for studying large amplitude dynamics of ferroelectric cantilevers, mechanical creep analysis, or general material property determination.

PS 3 - MICROSYSTEMS

DAVID DE VOCHT

EINDHOVEN UNIVERSITY OF TECHNOLOGY

29 MARCH 2023

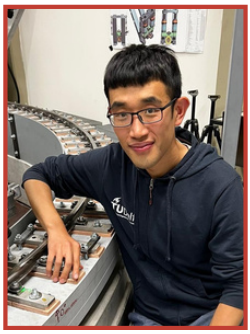
SENAATZAAL - 12:00 - 12:20

MEASURING BY LIGHT

DESIGN OF MULTIWAVELENGTH WAVEGUIDE HOLOGRAM COUPLER FOR FREE-SPACE BEAM PROJECTION FROM SIN PHOTONIC INTEGRATED CIRCUITS

Photonic integrated optical sensors are smaller, enable advanced functionalities and can be mass-produced. However, no monolithically integrated building block exists to focus a beam of light at multiple widely separated wavelengths to the same target spot several millimetres from the chip surface. Therefore, we designed a coupler based on waveguide holograms to couple light from single-mode waveguides in the integrated circuit to free space optical beams with a near Gaussian intensity profile. It can operate in the visible regime at the wavelengths of 635 nm, 780 nm and 850 nm and focus the light to a spot with a diameter of 27.6, 30.0 and 32.4 µm, respectively, at a distance of 5 millimetres above the chip's surface. We calculate the efficiency to be 9.9, 11.4 and 10.3 % respectively. These couplers can enable the miniaturization of various optical sensors, e.g. in gas sensing or metrology.

PS 3 - HIGH PERF. SENSORS I



YUANCHEN ZENG

TECHNICAL UNIVERSITY OF DELFT

29 MARCH 2023

COMMISSIEKAMER 3 - 11:00 - 11:20

MEASURING BY LIGHT

A POST-PROCESSING METHODOLOGY FOR REDUCING SPECKLE NOISE IN LASER DOPPLER VIBROMETER MEASUREMENTS

Laser speckle is a major source of noise for structural vibration measurements using a laser Doppler vibrometer (LDV), especially when the in-plane motion occurs between the laser spot and the target. In addition to the proper selection and setup of an LDV, post-processing is needed to reduce speckle noise, especially when the in-plane motion speed is high and repeated measurement is not possible. However, due to the highly random and broadband nature of speckle noise, conventional filtering methods may provide unsatisfactory performance. To handle this problem, we develop a new post-processing methodology based on a case study of LDV measurements on a novel vehicle-track test rig at TU Delft. The methodology consists of three steps: spike detection, imputation, and smoothing. We showcase this methodology by using a wavelet-based method, an autoregressive integrated moving average (ARIMA)-based method, and a Butterworth filter for the three steps, respectively. We demonstrate that the proposed methods effectively reduce the speckle noise at in-plane motion speeds of at least 20 km/h.

PS 3 - HIGH PERF. SENSORS I

ALEXANDRE RICARDO MAURICIO

KU LEUVEN

29 MARCH 2023

COMMISSIEKAMER 3 - 11:20 - 11:40

MEASURING BY LIGHT

STRAIN-BASED BEARING DIAGNOSTICS VIA FIBER BRAGG GRATING (FBG) SENSORS

Rolling element bearings are important components of machinery, being the interface between stationary and rotational components. They are prone to fatigue, causing damage and spall propagation, leading ultimately to sudden breakdowns. Thus bearings of critical machinery are monitored in order to detect and diagnose as early as possible faults, avoiding accidents and unexpected downtimes. Accelerometer signals are commonly used in bearing diagnostics as they are sensitive and carry early information of bearing localized damages. However, the vibration signals from electrical accelerometers are also sensitive to electro-magnetic interference (EMI) noise, which may influence the effectiveness of diagnostics. Fiber Bragg Grating (FBG) sensors provide strain measurements that are not influenced by EMI noise and can provide an interesting solution for bearing diagnostics under such noise conditions. On top of the small diameter of the fibers, several sensors can be multiplexed in a single fiber, which makes these sensors suited candidates for integration on the components close to the damage, extending any possible bearing damage detection to bearing damage location. The goal of this work is the exploitation of FBG sensors for bearing diagnostics. A methodology is proposed and an experimental setup with several bearing damage sizes is used to validate its performance.

PS 3 - HIGH PERF. SENSORS I

ISABEL DROSTE

TECHNICAL UNIVERSITY OF DELFT

29 MARCH 2023

COMMISSIEKAMER 3 - 11:40 - 12:00

MEASURING BY LIGHT

FITTING FIELD-DEPENDENT ABERRATIONS WITH A VECTORIAL PSF MODEL USING NODAL ABERRATION THEORY

Single Molecule Localization Microscopy (SMLM) overcomes the diffraction limit by separating fluorescent emitters in time, leading to nanoscale resolution images. In SMLM, the location of a fluorescent emitter is determined by fitting a PSF model to the measured data of a single emitter. A vectorial PSF model that takes into account optical aberrations and emitter dipole orientation can lead to a higher localization accuracy and precision [1,2]. Potentially present aberrations are dependent on the field-of-view (FOV), but often taken constant or neglected all together.

We are developing a computational method that fits field-dependent aberrations directly from single molecule data. The phase aberration function can be described by a linear combination of Zernike polynomials where the coefficients vary over the FOV. According to Nodal Aberration Theory (NAT), the variation of the Zernike coefficients over the FOV is described by low order polynomials [3]. The 2D image of a single emitter does not contain enough information to determine aberrations. We try to overcome this by combining the data of many emitters and using the constraints imposed by NAT to fit the low order polynomials that describe the aberrations. In this way, both the locations and aberrations will be fitted without the need of a calibration procedure using z-stacks of beads, making localization using a vectorial PSF that includes aberrations more attractive for practical use.

PS 3 - HIGH PERF. SENSORS I

NANDINI BATTACHARYA

TECHNICAL UNIVERSITY OF DELFT

29 MARCH 2023

COMMISSIEKAMER 3 - 12:00 - 12:20

MEASURING BY LIGHT

DISTANCE METROLOGY WITH PULSED LASERS

Distance measurement is extremely relevant in most industries as a metrology step for quality control. We have explored many techniques for pulsed laser based distance measurements ranging from detecting time correlation to spectrally resolved measurements. In recent years we have extended our work to investigating more compact pulsed laser sources for distance metrology. In this talk I will report the work done in Delft on distance measurement using pulsed lasers.

KEYNOTE LECTURE 4

CHRISTIAN REMBE

CLAUSTHAL UNIVERSITY OF TECHNOLOGY

29 MARCH 2023

AUDITORIUM - 13:30 - 14:10

MEASURING BY LIGHT

REACHING AND EXCEEDING THE SHOT NOISE LIMIT WITH LASER DOPPLER VIBROMETERS

A laser Doppler vibrometer (LDV) is an amazing measurement instrument that can measure under various environmental conditions on all types of surfaces, over a frequency range from µHz to several GHz, and over a velocity range from standstill to over several 10 m/s. However, the most fascinating aspect is the resolution of the vibration amplitude in the picometer range and below. The resolution depends on two factors: the noise level and the sensitivity. In a two-beam interferometer, the sensitivity is well-defined for a given wavelength and can only be improved by a shorter wavelength or by introducing multibeam interference.

Another approach to achieve higher resolution is to reduce the noise level. The treatment of the main noise sources such as laser speckle noise, proper motions of the LDV or optical turbulence in the optical path length will be discussed. However, even after eliminating all environmental influences, a modern LDV does not reach the physical limit given by photon shot noise. Photodetector saturation, digitization noise, and jitter between different clocks define a noise level that is still above the physical shot noise limit for an eye-safe laser Doppler vibrometer for measurements on a mirror. The presentation will highlight the state of the art and discusses technical ways to overcome the current technical limitations. The shot-noise limit is defined for coherent states of light. Squeezed states of light can provide resolutions below the shot noise. Finally, the potential of squeezed light for resolutions below shot noise is discussed.

PS 4 - MODEL & ANALYSIS

MICHAL KOZUPA

HITACHI ENERGY

29 MARCH 2023

AUDITORIUM - 14:10 - 14:30

MEASURING BY LIGHT

HYBRID MODELING BY USING LASER VIBRATION MEASUREMENT RESULTS IMPLEMENTED IN FEM

When measuring vibrations using scanning laser vibrometer one can apply measurement grid and number of points that is representative to the FEM modeling. The results of such measurement can be already applied to the numerical model as real object deflections or excitations. In this paper we want to show how two areas, measurement results and numerical modeling can interpenetrate creating a new value. The simulation model combines measurement results from real vibrating structure and results from numerical modification of some specific part crating hybrid modeling. This hybrid modeling allows to quickly prototype changes to the design while at the same time keeping the real vibration deflections of the structure.

PS 4 - MODEL & ANALYSIS

YONGGANG WANG

KU LEUVEN

29 MARCH 2023

AUDITORIUM - 14:30 - 14:50

MEASURING BY LIGHT

COMPARISON OF PSEUDO-RANDOM EXCITATION AND IMPULSE EXCITATION IN MODAL ANALYSIS USING RANDOMLY TRIGGERED CAMERAS

Camera-based Experimental Modal Analysis (EMA) benefits from full-field contactless vibration data to obtain eigenfrequencies and easy-to-interpret mode shapes. However, it has a lower sampling frequency in comparison with accelerometer based EMA. Since regular sampling is confined to the Nyquist frequency (i.e., half the frame rate), in this paper we use a recently proposed approach that exploits random pulses to trigger the camera thus allowing to go beyond the Nyquist frequency. Within this approach, in this paper we present the results of employing two types of excitation commonly used in EMA, namely the impulse excitation via a hammer and the pseudo-random excitation via a shaker. The frequency spectrum of the pseudo-random excitation is also artificially modified to amplify the high-frequency response. Through numerical simulations we compute and discuss the accuracy of the approach in the case of both excitation types. Finally, the two excitation types are employed experimentally on a curved panel. In both cases, modes at 83 Hz and 105 Hz are obtained from a sequence of irregularly sampled images equivalent to a framerate lower than 50 fps (such that the Nyquist frequency would be below 25 Hz). The modified pseudo-random excitation allows to additionally measure a mode at 238 Hz.

Acknowledgments: This research was partially supported by Flanders Make, the strategic research centre for the manufacturing industry. The Research Foundation – Flanders (FWO) is gratefully acknowledged for its support through research grant no. G095120N. Furthermore, Internal Funds KU Leuven are gratefully acknowledged for their support.

PS 4 - MODEL & ANALYSIS

DAVIDE MASTRODICASA

SIEMENS INDUSTRY SOFTWARE

29 MARCH 2023

AUDITORIUM - 14:50 - 15:10

MEASURING BY LIGHT

OPERATIONAL DEFLECTION SHAPE EXTRACTION ON A SIMPLE CANTILEVER BEAM BY USING 3D-DIC AND VIDEO MOTION MAGNIFICATION

Many recent studies have demonstrated the ability of optical techniques such as digital image correlation (DIC) and video motion magnification (VMM) to characterize structures' modal behavior. These approaches provide a global understanding of the structure or component behavior, implying vast spatial information that typical pointwise sensors cannot supply. Digital image correlation is a valuable tool in vibration analysis because it can provide quantitative full-field data on the response of a structure subjected to excitation. Video motion magnification has been proposed as an effective methodology to visualize operational deflection shapes (ODSs) using a single camera. In recent work, magnification allowed the observation of these ODSs in a powerful and unique way representing a great tool for interpreting deformations. However, because just one camera is used, the interpretation is essentially qualitative and should be avoided if out-of-plane motion is captured.
To overcome this issue, the combination of stereo DIC and VMM shows high potential in providing full-field maps to magnified images.
In this work, a simple aluminum cantilever beam has been used as a test bed structure to validate the approach. Firstly, a qualitative comparison between the obtained results using DIC and VMM has been carried out. Secondly, VMM has been used as a pre-processing step to magnify images for the extraction of full-field ODSs by using DIC.

PS 4 - MODEL & ANALYSIS

NAVID HASHEMINEJAD

UNIVERSITY OF ANTWERP

29 MARCH 2023

AUDITORIUM - 15:10 - 15:30

MEASURING BY LIGHT

A NOVEL TECHNIQUE TO CHARACTERIZE THE VISCOELASTIC PROPERTIES OF BITUMINOUS MORTAR USING A SCANNING LASER DOPPLER VIBROMETER

Asphalt mixtures are the most common types of pavement material used in the world. Bituminous mortar (mixture of bitumen, filler, and fine aggregates up to 0.5 mm) is part of the asphalt mixture that serves as the medium that envelops and bonds the mineral skeleton. Recent studies have shown that the mechanical testing of bituminous mortar is an efficient and repeatable approach to predicting the performance of asphalt mixtures. However, there are still no effective lab tests to investigate the mechanical properties of bituminous mortar. The state-of-the-art mechanical testing methods use traditional low-frequency (between 0.1 and 30 Hz) cyclic-loading approaches that are quite time-consuming (about 10 hours to condition the samples at five different temperatures and several minutes to run the tests at each temperature).

In this research, we aim to develop an advanced experimental setup using a high-power ultrasound transducer to excite mortar samples and a Scanning Laser Doppler Vibrometer (SLDV) to conduct vibration measurements on the surface of the specimens. The ultrasound transducer is used to apply a harmonic load at the longitudinal resonance frequency of a beam-shaped specimen. Then a procedure is developed to calculate the stress, strain and strain rate from the SLDV measurements along the beam. Since the specimen vibrates at its first natural frequency, the temperature, strain, strain rate, and stress vary along the beam. This information is then used to calculate the complex modulus of mortar samples at various temperatures and strain rates in a few minutes.

PS 4 - ENERGY & EARTH SCIENCE

JASPER SMITS

UNIVERSITY OF UTRECHT

29 MARCH 2023

FRANS VAN HASSELTZAAL - 14:10 - 14:30

MEASURING BY LIGHT

ULTRASONIC IMAGING OF GEOLOGICAL ANALOGUE SCALE MODELS

Physical analogue modelling has proven itself as a valuable method for the study of geological phenomena and has significantly contributed to understanding fundamental mechanisms of deformation of the Earth crust and lithosphere. Traditionally, in such analogue scale models, structural deformation is monitored and quantified using top-view images or cross-sections, where the latter allow for portraying the final state of internal deformation of the model in great detail. Monitoring the evolution of internal deformation while the experiment is running is however a major challenge, and currently is possible only with X-ray scanning using medical-type CT scanners.

We are developing a novel method to image the evolving interior of analogue scale models using ultrasonic techniques. Similar to reflection seismology used in field studies, the internal structure of the analogue model can be imaged using sound waves. We employ a completely non-contact and non-invasive method, utilizing a laser Doppler vibrometer to detect the arrivals of seismic body waves at the model surface. A laser pulse acts as a point source and is used to introduce acoustic waves in the model. By moving the detector and source, acoustic data is recorded for a series of source-recorder combinations, allowing the reconstruction of the internal layering and structure along cross sections. By developing this technique, we aim to provide novel tools to characterize the acoustic behaviour of subsurface structures under well-controlled laboratory conditions with the aim of improving our understanding of waveforms and wave propagation in analogue models and earth materials in general.

PS 4 - ENERGY & EARTH SCIENCE

MEÜS VAN DER POEL

OPTICS II

29 MARCH 2023

FRANS VAN HASSELTZAAL - 14:30 - 14:50

MEASURING BY LIGHT

HIGH SENSITIVITY PARTIAL DISCHARGE MONITORING USING FIBER OPTIC SENSING: EXPERIENCE AND EXAMPLES

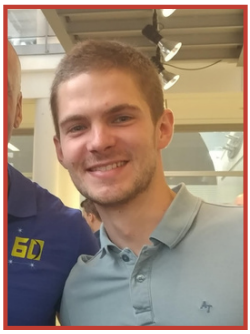
Partial discharges (PDs) are electrical pulses that happen within the insulation of medium and high voltage equipment, such as cable accessories, transformers, and switchgears. This can be due to aging or damage, or other external factors. Currently, PD is considered the main factor in the early deterioration of electrical equipment and is responsible for most failures in substations.

OptiFender is a fiber optic-based acoustic PD sensing solution, developed by Optics11 B.V. It has a similar sensitivity to the state-of-the-art electrical acoustic PD sensors, with all the added benefits of fiber optic sensing. The OptiFender sensors are immune to electromagnetic interference, are fully passive, non-metallic, and galvanically isolated, and can detect PD from distances of more than 40 km. One readout unit can currently measure 32 sensors at the same time, with sensors that are resonant in the range of 20 kHz up to 150 kHz, perfectly matching the frequency content of acoustic PD events.

The system has already been implemented in several proof-of-concept tests and has been successful in detecting PD. Some examples include:

- Successfully embedding 3 sensors in compound casted HV joints, and measuring PD levels of down to 10 pC at 180 kV voltages.
- Retrofitting sensors on a 72 kV HV joint and detecting internal PD levels of down to 2 pC at 50 kV.
- Retrofitting sensors on HV and MV terminations and detecting PD down to a few pC.
- Retrofitting sensors on HV transformers, detecting internal PDs, and localizing them using multiple sensors.

PS 4 - ENERGY & EARTH SCIENCE



CHARLES SNYERS

VRIJE UNIVERSITEIT BRUSSEL

29 MARCH 2023

FRANS VAN HASSELTZAAL - 14:50 - 15:10

MEASURING BY LIGHT

TOWARDS CLASSIFICATION OF THE NEAR INFRARED MELT POOL SIGNATURE IN DIRECTED ENERGY DEPOSITION

Directed Energy Deposition is a metal additive manufacturing process with applications in demanding industries with stringent requirements. Quality assurance is critical to make Directed Energy Deposition reliable and repeatable. In this work, a set-up to collect real-time coaxial NIR infrared images of the melt pool is presented and an experimental plan is conducted. The collected NIR data is used in conjunction with expert knowledge of the process to build a data-driven model that flags irregular melt pools that could lead to defects.

The MiCLAD machine, designed at VUB (Belgium), is equipped with an in-situ hyperspectral NIR camera that is monitoring the melt pool during the building process. This camera captures the emitted light from the hot melt pool at 25 different wavelengths.
This high-dimensional data is used as training data for a Convolutional Neural Network.

A study is conducted to compare the efficiency of the model depending on the wavelength(s) that are considered in the training dataset. The correlation performance is be assessed by applying the model on a test set partitioned from the original dataset. This virtual sensing approach is a stepping stone for future condition monitoring of the Directed Energy Deposition process.

PS 4 - ENERGY & EARTH SCIENCE

JASPER RYVERS

GHENT UNIVERSITY

29 MARCH 2023

FRANS VAN HASSELTZAAL - 15:10 - 15:30

MEASURING BY LIGHT

DISTRIBUTED FIBER OPTIC STRAIN SENSING OF SUBMARINE POWER CABLE BENDING: THE INFLUENCE OF TEMPERATURE

Submarine power cables are a key vulnerability of offshore energy production facilities. Damages to offshore power cables make up almost 85% of total project insurance costs. Optical fibers are an integral part of a submarine power cable. They are bundled inside a fiber optic cable that is helically coiled within the power cable. The optical fibers are of the loose tube type: they are surrounded by a gel compound with a temperature dependent viscosity. The loose tube fibers can be interrogated using distributed strain sensing. In practice, the internal temperature of the power cable changes. This complicates the strain analysis. In this paper, the influence of different power cable temperatures on bending strain readings is studied. A 3-point bending setup is built for a 25 m submarine power cable segment. Different alternating currents are injected into two of three power cores, which results in different steady state internal temperatures. The loose tube optical fibers are interrogated using two distributed sensing techniques: Distributed Acoustic Sensing (DAS) and Optical Frequency-Domain Reflectometry (OFDR). Though the OFDR measurements show robustness against temperature changes, our results indicate that temperature does affect the DAS strain readings.

PS 4 - AEROSPACE & LEVITATION

HENK VAN WEERS

SRON

29 MARCH 2023

SENAATZAAL - 14:10 - 14:30

MEASURING BY LIGHT

MECHANICAL PIXEL RESONANCES ON AN X-RAY TES DETECTOR DEVELOPED FOR SPACE INSTRUMENTATION

In this talk pixel resonance measurements performed on sample detectors for the X-ray Integral Field Unit Focal Plane Assembly (X-IFU FPA) on the Athena observatory will be described. The X-IFU instrument will provide spatially resolved X-ray spectroscopy, with a spectral resolution of 2.5 eV up to 7 keV using a Transition Edge Sensor (TES) detector array. To meet these breakthrough capabilities the detector thermal stability needs to be within 0.8 μK rms (bandwidth 0.125 mHz to 1 Hz). From previous cryogenic space instruments it is known that micro-vibration induced heating can cause thermal fluctuations and impact instrument performance. To increase our knowledge and understanding of the X-IFU FPA design including the detector itself an attempt has been done to measure the detector pixel mechanical resonances. Digital Holographic Microscopy (DHM) stroboscopic mode test-results are presented and compared to FEM model predictions. The talk concludes with the potential of using DHM during TES detector fabrication as a non-destructive inspection method prior to cryogenic testing.

PS 4 - AEROSPACE & LEVITATION

MEASURING BY LIGHT

IZHAK BUCHER

TECHNION

29 MARCH 2023

SENAATZAAL- 14:30 - 14:50

LASER VIBROMETER BASED RECONSTRUCTION OF NONLINEAR ACOUSTIC FIELDS IN CONTACTLESS LEVITATION

Powerful acoustic fields with standing waves portions can hold small particles in the air and move them in a controlled manner. The actual 3-dimensional acoustic field can be reconstructed using laser vibrometer based tomography without disrupting the field. The presented approach is advantageous to microphone-based measurements in terms of resolution, frequency range and since it does not affect the field opposed to microphones. The latter will be discussed and highlight during the presentation. The presented Lased-based approach is currently the only method capable of measuring the nonlinear harmonics and the power flow patterns, thus aiding in fine-tuning the exciting ultrasonic transducers until stable acoustic potential-wells are formed. A potential use of the high-intensity field is demonstrated by modulating the boundary excitation in order to create a mutual resonance and parametric resonance of the particle and the standing waves, thus controlling to motion of the levitated particles.

PS 4 - AEROSPACE & LEVITATION

SIMONE GALLAS

KU LEUVEN

29 MARCH 2023

SENAATZAAL - 14:50 - 15:10

MEASURING BY LIGHT

LASER DOPPLER VIBROMETRY FOR ADVANCED DYNAMICS CHARACTERIZATION OF LIGHTWEIGHT ASSEMBLED STRUCTURES

Increasingly stringent economic and ecological requirements have pushed the use of lightweight design. Lighter and multi-material assemblies are emerging, in combination with novel fastening strategies. Also novel lightweight material concepts such as vibro-acoustic metamaterials are coming to the fore to improve the noise and vibration performance by tailoring structural wave propagation. Lightweight assembled structures, however, often come with deteriorated noise and vibration performance as the stiffness to mass ratio has increased. In order to be able to characterize and understand the dynamic performance of these novel lightweight assembled structures, accurate and reliable structural dynamic measurements are of utmost importance. In this context, the use of Laser Doppler Vibrometry for accurate and full-field vibration measurements has recently proven very beneficial.

While conventional measurement strategies relying on accelerometers might introduce too high relative mass loading and/or damping, contactless Laser Doppler Vibrometry based measurements can provide a more accurate characterization. Moreover, using Scanning Laser Doppler Vibrometry, otherwise very time-consuming full-field vibration measurements can readily be performed to identify material properties and characterize wave propagation behaviour of such novel lightweight materials. In this presentation, the added value of using Laser Doppler Vibrometry in structural dynamic characterization of novel lightweight system assemblies will be shown through a variety of application cases, including bonded assemblies, flow induced vibrations, rotating assemblies and structural wavefield measurements.

PS 4 - AEROSPACE & LEVITATION

THIBAULT BOULANGER

OPTRION

29 MARCH 2023

SENAATZAAL - 15:10 - 15:30

MEASURING BY LIGHT

SHEAROGRAPHY – A CONTACTLESS, FULL FIELD AND HIGH THROUGHPUT METHOD FOR THE INSPECTION OF AEROSPACE COMPOSITE PARTS : IMPROVEMENTS AND ROBOTIZATION

The Non-Destructive Inspection (NDI) of composite parts is a key element in the value chain guaranteeing its integration in aerospace applications. Inspection methods based on the use of ultrasonic (US) systems have been the reference for many years and remain the most common solution deployed in the industry. Furthermore, these methods are recognised by the largest manufacturers as the only ones capable of efficiently detecting 6mm flaws with the required probability of detection.

Nevertheless, US based methods present weaknesses such as requiring direct contact between the part and the probe, the necessary use of a coupling agent such as water which presents difficulties for the industrial application .

Alternatively, new inspection methods have been developed in the past years which offer new perspectives to the NDI market either with similar detection capabilities or even higher in specific applications, or with reduced costs thanks to higher inspection throughput or lower investment and operating costs.

Among these methods, one can find shearography (ST) which is a little known and often underestimated contactless, high resolution full frame NDI solution.

The basics of the technology, the improvements gained in the past few years thanks to the reduction in size of laser sources, the computational power and the use of post-processing algorithms will be described.

Finally the specificities and gains related to the robotisation of the ST method for the inspection of large and complex aero composite parts will be evaluated.

PS 4 - HIGH PERF. SENSORS 2

OLIVIER FONTAINE

LAMBDA-X

29 MARCH 2023

COMMISSIEKAMER 3- 14:10 - 14:30

MEASURING BY LIGHT

BIOIMAGING - USE CASES FROM CUSTOM MICROSCOPY AND SPECTROMETRY SYSTEMS

Lambda-X is an OEM service company specializing in innovative optical systems. We create and manufacture optical systems for metrology and imaging applications. In this presentation we introduce some industrial cases and show how we develop innovative instruments in partnership with our customers. We present several applications, from the medical, industrial and space sectors, which are lambda-x's historical and priority markets: • A custom microscope for the analysis of enzymatic activity by interferometric imaging • A custom light source for a MID-IR spectroscopy & imaging platform on biopsies • A commercial microscope for cell expansion monitoring by 3D imaging • An industrial sensor for fluid composition monitoring by Mid-IR spectroscopy • A dynamic light scattering instrument for the measurement of colloidal materials Lambda-X has contributed to these applications by providing end to end engineering services, from the conceptual stage to the industrialization of the product until recurrent production. The presentation will highlight the challenges we face and the methodologies we use to derisk the product development.

PS 4 - HIGH PERF. SENSORS 2

ANTHONY AMOROSI

UNIVERSITY OF LIÈGE

29 MARCH 2023

COMMISSIEKAMER 3- 14:30 - 14:50

MEASURING BY LIGHT

COMPACT OPTICAL ACCELEROMETER FOR LOW-FREQUENCY VIBRATION SENSING

We present the design and experimental validation of a monoaxial vertical accelerometer for low-frequency sensing. The sensor design is a leaf-spring-supported pendulum guided by a four-bar mechanism. The mechanics features fused-silica joints produce via laser-assisted etching. It is characterized by a 2.8 Hz natural frequency and the fused-silica flexures allow a mQ-product of 1120 kg in open air. The accelerometer proof-mass motion is read out using a quadrature homodyne Michelson interferometer with a sub-picometer resolution. The accelerometer is a force-feedback sensor where a custom quadrature magnet is used as a force actuator. This allows the sensor response to cover a broadband frequency bandwidth spanning from 10 s to 100 Hz, with a reading resolution of 2e-13 m/Hz^(-1/2) above 1 Hz. The sensor design is compact, 10 x 10 x 10 cm, and is compatible with an ultra-high vacuum environment down to 1e-5 mbar. We present the sensor design and experimental performance curves.

PS 4 - HIGH PERF. SENSORS 2

RUBEN GUIS

TECHNICAL UNIVERSITY OF DELFT

29 MARCH 2023

COMMISSIEKAMER 3 - 14:50 - 15:10

MEASURING BY LIGHT

CONOSCOPIC INTERFEROMETRY FOR OPTIMAL ACOUSTIC PULSE DETECTION IN ULTRAFAST ACOUSTICS

In picosecond ultrasonics, usually, the acoustic wave arriving at the surface is measured via a change in refractive index (reflectometry). However, reflectometry requires a strong photoelastic coefficient, therefore limiting the materials that can be used.

In 2006, Chigarev et al. proposed beam distortion detection (BDD).

In BDD, the Gaussian surface displacement due to the acoustic wave will change the divergence angle. By cutting the spot with a diaphragm, the power after the diaphragm aperture will scale with the acoustic amplitude. This detection technique could work with more materials since it is purely geometrical.

In 2018, Liu et al. found that placing a sapphire plate in the objective focus creates conoscopic interference patterns that enhance the sensitivity of BDD. However, the physical origin remains unknown.

We present a model that unifies BDD with conoscopic interferometry. We experimentally validate the model on a 2.4um thick silicon plate coated with 30nm aluminium. Using the model, we optimize the detection sensitivity of conoscopic interferometry by varying the diaphragm aperture and quarter wave plate orientation. We obtain a maximal sensitivity for acoustic wave detection when placing the diaphragm edge on the dark fringes of the conoscopic interference patterns. In the configurations studied in this work, we find that conoscopic interferometry can be 8 times more sensitive to acoustic waves than BDD. Our results can push the sensitivity of acoustic wave detection and thereby enable the measurement of weak acoustic signals from thick structures, interfaces with low acoustic impedance mismatch, or materials with high acoustic damping.

PS 4 - HIGH PERF. SENSORS 2

AXEL SCHÖNBECK

UNIVERSITÄT HAMBURG, INSTITUT FÜR LASERPHYSIK

29 MARCH 2023

COMMISSIEKAMER 3 - 15:10 - 15:30

MEASURING BY LIGHT

ENHANCING THE MEASUREMENT PRECISION OF LASER-BASED LOW-LOSS MEASUREMENTS WITH QUANTUM SQUEEZE LASERS

Photon shot noise imposes limits on high-precision laser-based measurements, which is often the case today across all possible power levels. Quantum squeezing is a technology that can circumvent the need for even higher powers and the associated side effects.

Conventionally, the signal-to-noise ratio of photon shot noise limited high-precision measurements is further increased by increasing the optical power. This approach is associated with side effects. Biological samples cannot handle high powers and are destroyed or suffer from photo-bleaching. Delicate mechanical devices suffer from heating. Leaving the regime of eye-safe laser powers enforces laser-safety measures on the applicant of the measurement device. These are connected with additional costs and efforts. Even at very high laser power levels, the issue persists. Increasing the laser power further can induce thermal effects like thermal lensing and result in a misalignment of the measurement device or might not be economic due to the high development and energy costs associated with high power systems.

Squeeze lasers do not increase the signal power but reduce the photon shot noise – with almost zero additional optical power. After several decades of research, a noise reduction by a factor of more than 10 [Phys. Rev. Lett. 117, 110801 (2016)] [Opt. Lett. 43, 110-113 (2018)] is feasible if most of the light is detected. Use-cases have been identified [Nature Photon. 7, 229-233 (2013)] [arXiv:2209.05858] and squeeze lasers have proven their reliability and applicability in gravitational-wave detection [Nature Physics 7, 962-965 (2011)]. Compact, portable and user-friendly systems are now available.

INDUSTRIAL SESSIONS - PART I

JOCHEN SCHELL

POLYTEC GMBH

30 MARCH 2023

SENAATSZAAL - 09:40 - 10:05

BASIC PRINCIPLES AND APPLICATION EXAMPLES OF LASER DOPPLER VIBROMETERS

GRÉGORY PANDRAUD

OMMATIDIA LIDAR

30 MARCH 2023

SENAATSZAAL - 10:05 - 10:30

BASIC PRINCIPLES AND APPLICATIONS OF PARALLEL LASER RADAR TO VIBROMETRY

INDUSTRIAL SESSIONS - PART 2

MEASURING BY LIGHT

ALEX NILA

LAVISION

30 MARCH 2023

SENAATSZAAL - 11:00 - 10:20

LAVISION IMAGING-BASED OPTICAL METROLOGY FOR FLUID-STRUCTURE INTERACTION APPLICATIONS

THIBAULT BOULANGER

OPTRION

30 MARCH 2023

SENAATSZAAL - 11:20 - 11:40

NON-DESTRUCTIVE TESTING WITH SHEAROGRAPHY: PRINCIPLES AND CASE STUDIES

GERALD WERNER

FIBOTEC

30 MARCH 2023

SENAATSZAAL - 11:40 - 12:00

SPECTRALLY BROADBAND LIGHT SOURCES - CASE STUDIES