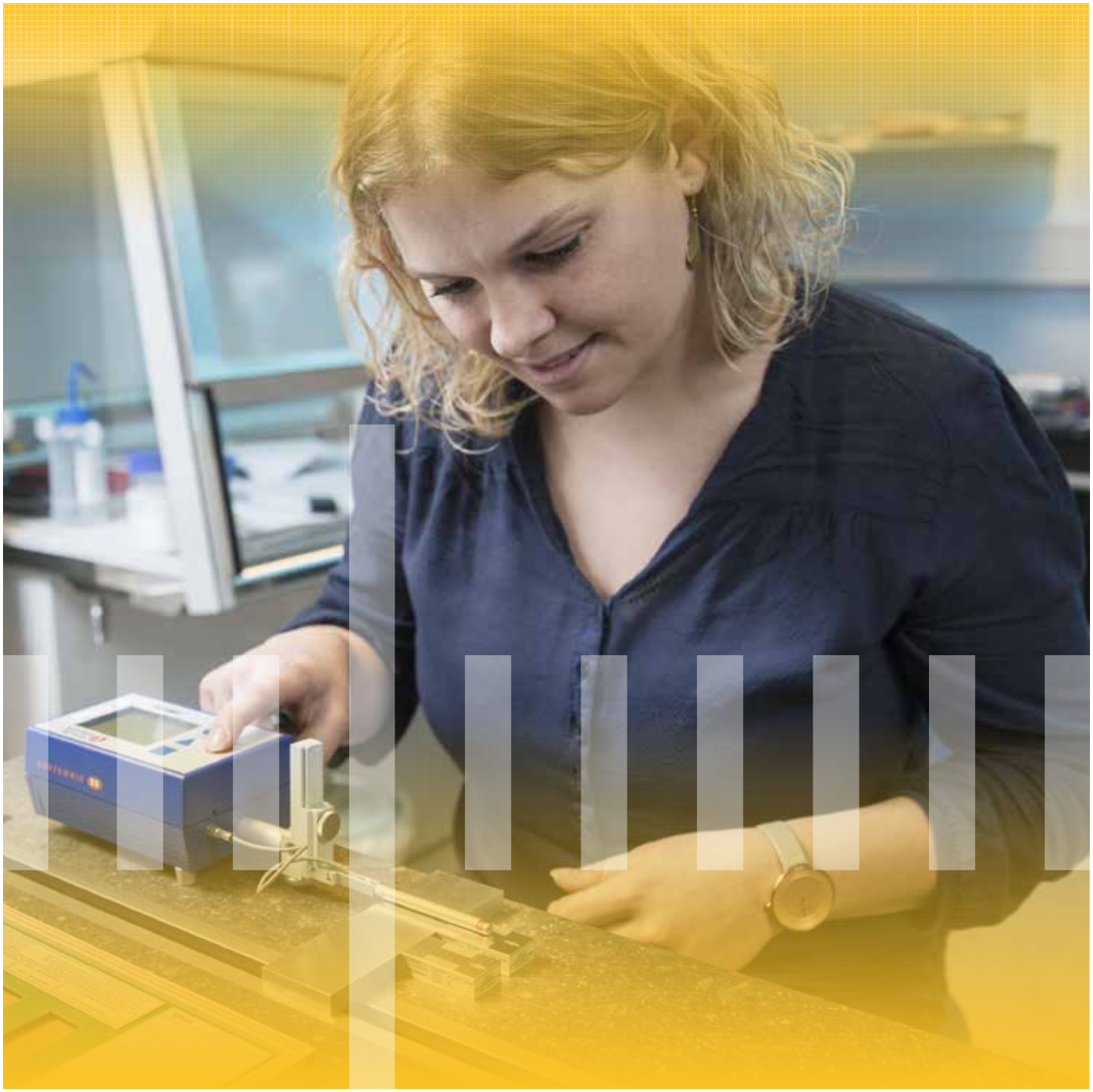
DFM
Danish National Metrology Institute

ANNUAL REPORT
2015



METROLOGY: THE SCIENCE OF MEASUREMENT

Metrology is the science of measurements and is the backbone of our high-tech society. Most aspects of daily life are influenced by metrology, and increasingly accurate and reliable measurements are essential to drive innovation and economic growth.

DFM PROFILE

DFM is appointed as the Danish National Metrology Institute and contributes to the integrity, efficiency and impartiality of the world metrology system. DFM is also responsible for coordinating the Danish metrology infrastructure. DFM is a fully owned subsidiary of DTU, the Technical University of Denmark.

DFM ACTIVITIES

DFM's scientific research results in new knowledge, measurement techniques and standards, which support the needs of Danish industry and authorities for accurate measurements.

The services offered are high-level calibrations and reference materials traceable to national primary or reference standards, training courses related to metrology and consultancy services.

DFM has a special role in developing measurement capabilities needed by small and medium sized high-tech companies in order for them to evolve and prosper.

DFM works to ensure global confidence in Danish metrological services, which are critical for competing in the global market place.

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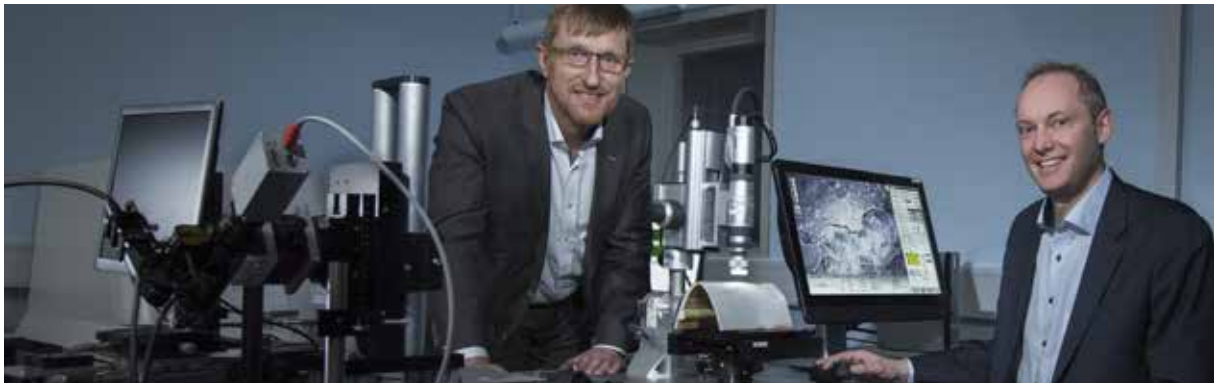


Bjarne Fjeldsted, Chairman of the Board, and Michael Kjær, CEO

DFM experienced strong growth in commercial sales in 2015, both in calibration services and in contract research for Danish industry. The growth was driven by the introduction of new metrology services and development of new competences, primarily supporting Danish advanced technology companies. Commercial sales grew 46 %. Total revenue reached 27.2 million DKK while profit was 0.4 million DKK. The management considers both revenue and profit for the year as satisfactory.

In March, 2015, Mr. Bjarne Fjeldsted became the new chairman of the board of DFM when the previous chairman, Mr. Steen Konradsen, retired from the Board after 18 years of service. Mr. Fjeldsted is director at Grundfos Holding A/S and has significant experience in strategy development and deployment, organizational development and quality management of accredited calibration laboratories. Mr. Fjeldsted has been a member of the Board of DFM since 2014. In addition to Mr. Konradsen, Mr. Søren Stjernqvist also retired from the Board in 2015. DFM is deeply grateful to both of them for the many years of service they provided and their significant contributions to the development of DFM.

A new strategy for the period 2016 - 2018 was developed by DFM in close collaboration with the board and later approved by the Ministry of Higher Education and Science. Basic funding for DFM was increased 21 % for the period 2016 - 2018 compared to the period 2013 - 2015. DFM is pleased with this increase, which ensures that development of new metrology services for Danish industry can be accelerated.

The number of peer reviewed publications increased to twenty three – the highest in DFM's history, showing DFM's continued ability to deliver high quality science in close collaboration with universities, industry and other national metrology institutes.

One of the DFM's key activities as the National Metrology Institute is to coordinate the overall Danish metrology structure. Administration of Danish EMPIR co-funding was transferred from the Ministry of Higher Education and Science to DFM, and responsibilities for all new Danish CMC entries was transferred from the Ministry of Business and Growth to DFM. DFM is pleased to accept the new responsibilities supporting the Danish metrology infrastructure.

As a result of the increased funding from 2016, DFM will significantly increase research activities in emerging scientific areas such as biotechnology and nanotechnology in order to address the growing demand for metrology services.

DFM will also begin activities that address the development of metrology skills of the future workforce. DFM will partner with a number of Danish University Colleges and Academies of professional higher education, developing curricula and educating teachers within metrology.

Bjarne Fjeldsted
Chairman of the Board

Michael Kjær
CEO

DIMENSIONAL METROLOGY SERVICES TRANSFERRED FROM DTU TO DFM

Positioning of the stylus onto a roughness standard.

Calibration of a hand held roughness tester against roughness standards of different roughness levels.

On the 30th of November 2015, DFM and DTU Mechanical Engineering signed an agreement transferring accredited services within dimensional metrology from DTU to DFM.

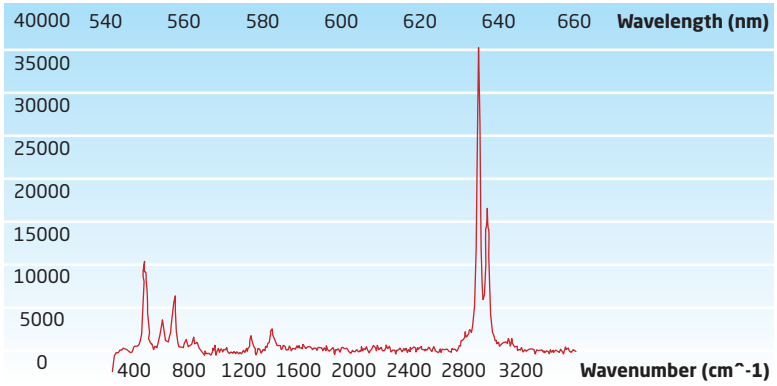
Since 1992, Centre for Geometrical Metrology (CGM) at DTU Mechanical Engineering has offered accredited calibration of roughness standards, tactile roughness measurement instruments and hole plates. Roughness measurement instruments are used in industry to quantify surface properties of products, and calibrated hole plates are used to ensure traceability of coordinate measurement machines. These accredited services were transferred to DFM from 1st of January 2016.

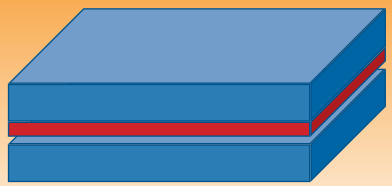
The transfer will add new competences in dimensional metrology at DFM. The new services expand DFM's capabilities in surface characterisation by complementing existing activities in nanometer-scale surface characterisation using atomic force microscopy, optical microscopy and scatterometry. The consolidation will enhance synergies in research ensuring development of more services for Danish industry and will contribute to a strengthened metrological infrastructure in Denmark.

DFM and DTU are working closely together to implement the new capabilities at DFM, and DFM will for a period use DTU's facilities and resources to ensure continuity. Some of DTU's equipment for roughness measurements is too fragile to be moved to DFM and needs replacement. The Swiss National Metrology Institute, METAS, has provided invaluable assistance to DFM by training staff and providing equipment, which greatly facilitated the transfer. The equipment provided by METAS was used when piloting a EURAMET Key Comparison on roughness standards in 2013-2014, ensuring a proven track record.

Both the transfer of services as well as obtaining accreditation was achieved in a very short time ensuring that customers did not experience a gap in the availability of services. The Danish Safety Technology Authority has since then expanded the designation of DFM as National Metrology Institute to include the subfield Dimensional Metrology based on the new activities. The Calibration and Measurement Capabilities (CMCs) in the BIPM Key Comparison Database (KCDB) cannot simply be transferred to a new legal entity, and DFM has therefore submitted new CMCs for approval.

PROVIDING NEW SOLUTIONS TO DANISH INDUSTRY





Reference material developed by DFM to provide stable, robust optical signals to improve product testing. The left figure shows the Raman spectrum of the sample on the right side.

DFM is committed to support Danish industry and institutions in performing challenging measurements. The following examples illustrate recent contributions to everyday challenges of Danish industry.

New reference material for improved product testing

DFM is developing a reference material in collaboration with RSP Systems A/S (based in Odense) that will provide repeatable and reliable testing of Raman spectroscopy instruments used for point-of-care glucose measurements. The new reference material will fulfil an important need in industry to provide accurate performance information. The developed reference material consist of a number of robust and stable polymer layers, with structure dimensions validated at DFM using advanced microscopy techniques. This project was funded by Innovation Fund Denmark for a 12 month period. The first prototype is available and DFM anticipates further development, both with Danish partners and as part of international efforts to standardise Raman spectroscopy measurements.

DFM assists Capres A/S in developing methodology to validate its products

Capres A/S produces advanced systems for electrical characterization of silicon wafers. DFM has assisted Capres in developing traceability and calibration methodology to validate and specify their characterization systems. The systems utilize unique four-terminal probes to measure material parameters. In an effort to further qualify their measurement systems, DFM has assisted in developing specialized hardware, software and data analysis routines to enable built-in calibration of the core measurement system in their products. This has enabled Capres A/S to ensure long term accuracy and traceability of their systems.

New imaging solution for Radiometer Medical ApS

DFM provides imaging solutions for customers who need to examine challenging surfaces by using a combined interference and confocal optical microscope. For example, Radiometer Medical ApS, a leading provider of automatic acute care solutions, had a need to examine a tilted surface covered with carbon black. Carbon black is ideal for fabrication of non-reflecting surfaces, but this same property makes it very difficult to measure using microscopy. By applying DFM's very sensitive, advanced confocal microscopy system, detailed 3D images of the surface were obtained. DFM can provide traceable and accredited calibrations with the optical microscope on a range of transfer standards. Together with DFM's state-of-the-art atomic force microscope, the range for accredited calibrations covers distances from a few nanometers to hundreds of microns. This enables DFM to choose the most optimal instrument for imaging tasks and serve a broad range of customers.

METROLOGY AND STANDARDISATION

Metrology is the fabric of international standards, of essence to the deployment of technology and for market success.

Metrology and standardisation both contribute to consistent and reproducible measurement procedures, paving the way to a global acceptance of measurements and eventually facilitating trade. Many researchers are involved in both metrology and standardisation, thus providing the necessary know-how for the quality of international standards.

In the field of acoustics, for instance, DFM is active in standardisation work. DFM participates in the Danish standardisation committees and in the International Committees, particularly in working groups set up by Technical Committee 29 of the International Electrotechnical Commission (IEC) in the field of electroacoustics. DFM is leading the process of writing new basic standards, as well as producing revisions of existing international standards and technical specifications in order to keep them updated. An example of the latter is the revision of the standard IEC 61094-3, which describes primary calibration of microphones under free-field conditions. The work has resulted in a document, which will be circulated for voting among the members of IEC TC29. If approved, it will be published as the most recent version of the international standard.

In order to reach the consensus required for standards which are both metrologically sound and useful, many stakeholders must be present to defend their interests. The combination of metrologists and researchers provides a common ground on which to build solid standards. This cooperation occurs at many levels, e.g. for standards dealing with instrumentation specifications and the establishment of measurement references, as well as standards dealing with measurement procedures to determine the properties of devices, materials, etc.

Traditionally, Denmark has been very active in standardisation work with participation of both researchers and industrial developers. Several of the most influential Danish acoustic companies have their seat in the standardisation committees. Some are concerned with measurement instrumentation, others with hearing aids and audiological instrumentation and there is a large sector covering audio applications. Additionally, the Danish acoustic research environment is highly recognised internationally, and DFM is proud to be a part of this.

DFM – A WORLD-LEADER IN METROLOGY FOR ELECTROLYTIC CONDUCTIVITY

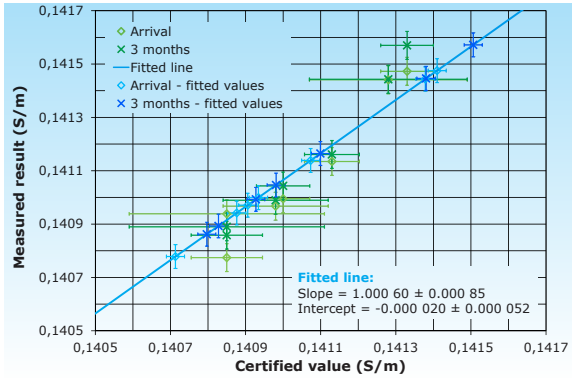


Figure 1. The error bars on this figure show the standard uncertainties.

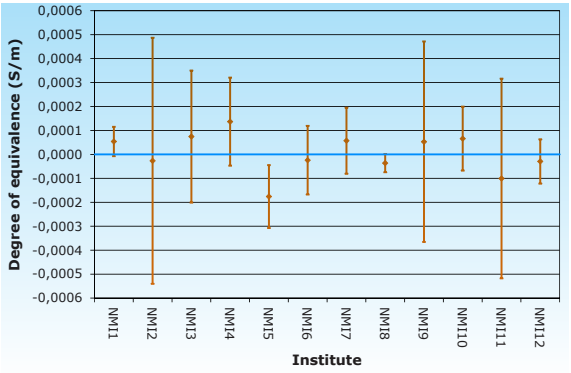


Figure 2. Final degrees of equivalence with expanded uncertainties. The participants are anonymous, as the comparison report is not yet finalised.

DFM's capabilities in electrolytic conductivity (EC) ranges from ultrapure water to high values of EC. The first comparison of certified reference materials (CRMs) for EC was coordinated by DFM.

DFM has had activities in EC since 1996 as a consequence of a demand in the 1993 US pharmacopeia to assess water purity via EC, which is a non-specific measure of the ionic content in a liquid. EC, however, is an important control parameter in many industries. Today, DFM is one of two institutes in the world with a capability listed in the CIPM MRA[1] database for primary measurement of ultrapure water conductivity as well as capabilities for conductivity measurements and CRMs at at higher conductivities. DFM's expertise in the field of EC has been much asked for by institutes that has started activities in EC over the past decade.

Different studies done in the past five years have shown challenges in evaluating results at extreme conductivities and in evaluating conductance ratios. They are important for assessing (amongst other) the salinity of seawater, which is a crucial parameter for assessing the effects of global climate change. To overcome these challenges the EAWG of CCQM[2] in 2014 formed an expert group on EC to be in charge of improving the understanding of metrological measurements of EC including data evaluation. It was considered obvious that DFM had to be a member of this group.

Dissemination of traceability in the field of chemistry is often done via CRMs; 51% of all capabilities in the CIPM MRA database in the field of chemistry are for CRMs. Comparisons assessing the capability of the metrology institutes to assign a value to a CRM are therefore needed to underpin this type of capability.

Since 2001 DFM has coordinated several pilot studies and key comparisons under CCQM including, in 2015, the very first pilot study on CRMs done in the EAWG. This study, called CCQM-P143, concerned CRMs for EC in the range from 50 mS/m to 500 mS/m.

Values of the participating CRMs as certified and as measured by DFM (at two different times for stability checking) were compared via a linear reference function (RF). The slope and intercept of the RF are found by least squares minimisation taking into account the uncertainties of the certified values and the uncertainties and correlations between the measured values. The DFM-LSQ Analyzer© was a strong tool in the analysis.

Figure 1 shows a part of the RF with both the certified/measured and the fitted values. The numerically largest distance from certified/measured values to the fitted values is a consistency measure called the degree of equivalence and plotted in figure 2. The two figures show that the results underpin comparability of EC CRMs.

1) http://www.bipm.org/en/cipm-mra/

2) http://www.bipm.org/en/committees/cc/ccqm/

PREPARING A NEW DEFINITION OF THE KILOGRAM



The unit of mass will be redefined in terms of the value of a fundamental constant. Although the prototype kilogram will loose its current status, traditional weights kept in air will still be needed.

A new definition of the kilogram based on a fixed value of a fundamental physical constant is expected to be approved at the General Conference on Weights and Measures in 2018. A number of projects supported by the European Metrology Research Programme (EMRP) aim at preparing the road to this new definition. DFM participated in one of these projects, NewKILO, which was concluded in 2015 with a number of interesting results.

When the new definition of the kilogram has been adopted, the unit of mass will be realised in vacuum (e.g. by a Watt balance experiment or a silicon crystal density experiment), but it will still be disseminated by weights stored in ambient air. In the project NewKILO, DFM has focused on developing models for describing 1) the transfer of the mass unit between vacuum and air, 2) the change in mass over time for weights kept in air, and 3) the maintenance of the mass unit using a pool of weights traceable to several realisations of the kilogram performed at different places and at different times.

The transfer of mass between vacuum and air is performed using a set of so-called sorption standards, which are basically at set of weights of same volume, nominal mass and surface finish, but with different surface areas. DFM has modelled the use of such standards, and from simulations of the mass transfer, recommendations for the choice and use of sorption have been given. DFM has shown that a standard uncertainty contribution of 0.006 mg from the mass transfer can be achieved.

The drift of 17 BIPM platinum-iridium working standards relative to the international kilogram prototype was analysed by DFM from historical comparison data performed by the BIPM in the period 1885-2009. This lead to the discovery of an unexpected large drift in two working standards used to calibrate the national copies of the kilogram prototype, but more important DFM has demonstrated how comparisons within a pool of weights can be used to monitor the drift of each weight even if a reference standard is included only occasionally. This is important since the time span between future realisations of the kilogram might be several years.

Finally, DFM has shown that if a pool of weights is regularly calibrated against at least two independent realisations of the kilogram, the unit of mass can be disseminated to the users with a standard uncertainty of 0.025 mg or less, which is comparable to the standard uncertainty provided by DFM today.

EAR SIMULATOR AND HUMAN PERCEPTION OF NON-AUDIBLE SOUND

This second prototype of an ear simulator for newborn children was manufactured according to the specifications developed under the EARS project. Besides, it incorporates many recommendations gathered during the testing of the first prototype for easier calibration, and the possibility of using different adapters for audiometric instrumentation.

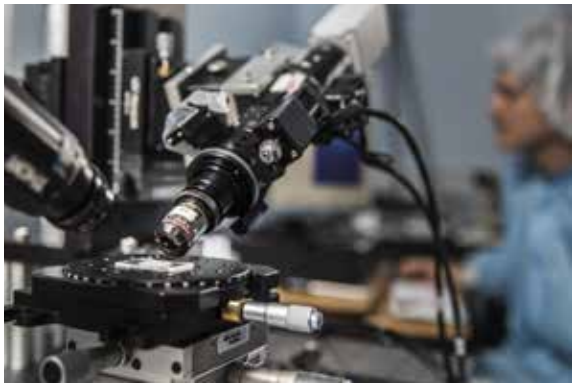
DFM was partner in the EMRP EARS project "Metrology for a universal ear simulator and the perception of non-audible sound", 2012 to 2015. The aim of the project was to support preventive strategies for hearing conservation through two major interdisciplinary research and development activities.

The first research and development activity of the EARS project was to establish a new understanding of human perception of non-audible sound based on novel neural imaging assessment of perception thresholds, and to provide the metrology infrastructure necessary to put in place effective safety criteria.

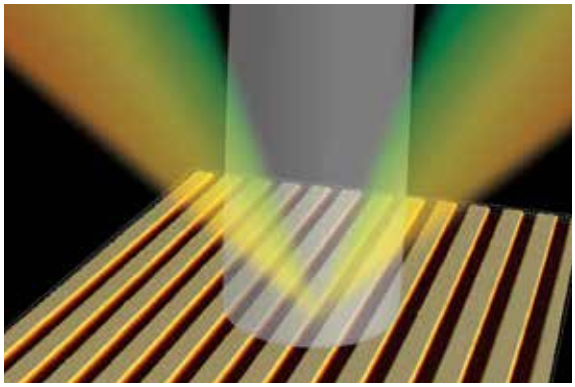
The second was to develop concepts for a new methodology in specifying, design and characterisation of a universal ear simulator; a device intended to be more appropriate for modern audiological practices, and thereby bring about improved quality and reliability of results. DFM was an active participant in these two lines of research: DFM developed a primary calibration system able to calibrate microphones at high frequencies (up to 150 kHz) in a free field, providing sound metrological references for the sound sources used in the perception assessment and for the characterisation of the performance of the ear simulators designed during the project.

While the outcome of the EARS project was very satisfactory, it was also clear that the answers to the main questions posed by the project led to further questions requiring additional research. DFM enthusiastically proposed and supported the application for a new project now under EURAMET's EMPIR program. The proposal entitled "Metrology for modern hearing assessment and protecting public health from emerging noise sources", EARS II, was supported by several NMIs, universities and industrial companies. As did its predecessor, EARS II scored highly in the evaluations, and was approved for funding with an expected start by mid 2016. The goals of EARS II are to further develop the universal ear simulator concept and novel calibration techniques to fulfil audiological requirements related to otoacoustic emission, tympanometry, audiometry, and instrumentation. In cooperation with stakeholders and collaborators, it is aimed to establish clinical protocols and international standards for the use of the universal ear simulators. On the perception side, it will help to create the knowledge for future guidelines and policy framework to enhance the wellbeing of European citizens and protect them from health hazards associated with infrasound and ultrasound.

MEASURING NANOSTRUCTURES WITH VISIBLE LIGHT



Imaging scatterometer in the split configuration. Images are acquired individually for multiple wavelengths to form a multi-spectral image. Scatterometry analysis is performed afterwards on a single pixel of the image.



White light diffracted off a periodic grating structure. The light is split up similar to a rainbow. In scatterometry the intensities of the diffracted light are used for reconstruction of the surface topography with nm accuracy.

A new method gives robust and fast measurements of nano-textured surfaces and can be implemented directly on a production line. Scientists at DFM have developed Imaging Scatterometry as a technique for characterization of nanostructured surfaces with visible light.

The new method enables local characterization of areas of several cm^2 with an accuracy of a few nanometers. Without compromising accuracy and user-friendliness, *Imaging Scatterometry* is up to 100 times faster than conventional characterization techniques (such as Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM)). For the user, *Imaging Scatterometry* offers easy localization of the areas of interest on a microscope image (typically 1 cm × 1 cm), where areas down to 3 µm × 3 µm can be selected and analyzed AFTER the image acquisition.

Several Danish and European research labs and small and large companies have already shown interest in the new technique because of the fast and robust measurements compared to traditional scatterometry, which is currently being used at large semi-conductor facilities. The Danish company NIL Technology ApS and DFM have recently demonstrated that *Imaging Scatterometry* can also be used on injection molded parts with micro/nano-textured surfaces. Applications of scatterometry in other industrial sectors, such as the roll-2-roll industry, are investigated further in the EMPIR project MetHPM.

Imaging Scatterometry is based on comparing measurements of diffracted light intensity from a grating and computer simulated diffraction intensities. Despite usage of an inverse modelling technique, the comparison only takes a few milliseconds on a desktop computer, and the technique is therefore attractive for large scale production of parts with nano-textured surfaces. Similar to quality control in the printing industry, dedicated test patterns of nanostructures can be implemented in the production and used for quality control with *Imaging Scatterometry.*

As a part of the FP7 project NEMI, DFM has filed a patent application for the *Imaging Scatterometry* technique and is now working on improvements and industrial field cases. The results have been published in the scientific journal Optics Express (doi: 10.1364/OE.24.001109).

METROLOGY AND THE ENVIRONMENT

Under the microscope is a piece of a wind turbine blade approx. 5 cm x 1 cm. The external white coating is on top of a composite material. The microscope can measure 3-dimensional structures by combining multiple images taken at different focus distances ('focusstacking') or by combining images from different angles ('stereographic imaging').

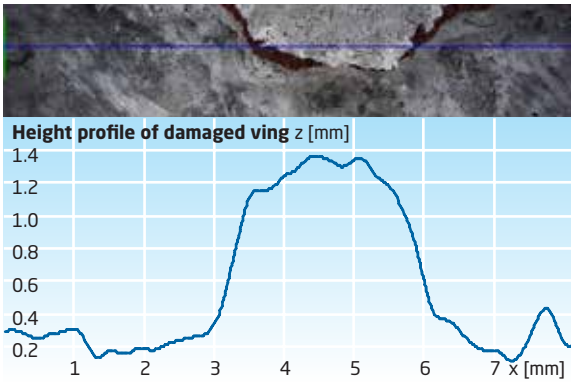


Image of an eroded wind turbine blade. In this example, a profile is made along the blue line. The profile shows that the depth of the erosion is approximately 1.1 mm.

New stable and reproducible measurement standards traceable to the SI are needed for reliable measurements of environmental changes.

DFM has metrology activities related to measurement of greenhouse gases, nano particles and surface characterization of wind turbine blades. These activities support the Danish aim of independency of fossil fuels by 2050 and with renewable energy as a major source of energy.

"Leading Edge Roughness on wind turbine blades" is an energy technological development and demonstration project supported by the Danish Energy Agency.

Although wind energy plays a major role in Denmark there are still challenges. Wind turbine blade surfaces degrade over time resulting in reduced efficiency and increased costs. In a project headed by Power Curve, the goal is to develop techniques for performing in-situ, quantitative measurements of the surface roughness on the edge of wind turbine blades. Based on images of the surfaces DFM will contribute to the development of a quantitative description of this erosion. The goal is an on-site imaging of the blades to provide guidance on repair or maintenance.

"Requirements to Measurements of Nanomaterials and Nanoproducts" is a project lead by DFM and supported by the The Danish Environmental Protection Agency.

The possible impact of nanoparticles on human health and the environment receives increased attention and the first regulatory decisions have been made in Denmark. Danish companies producing or importing consumer products containing nanomaterials have to report the products to a national register. However, so far, the performance of the analytical nanometer scale measurement to support the regulatory work was not sufficiently documented. DFM has prepared a report for the Danish Environmental Protection Agency that provides a better documentation for these nano measurements in terms of validation of parameters. The parameters were optimized to document the nano particle concentration in consumer products and to deal with agglomeration and coated nano particles.

"Metrology for high-impact greenhouse gases" is European metrology research project with the participations of 10 national metrology institutes.

The amount of greenhouse gases, carbon dioxide, methane and nitrous oxide is increasing in the atmosphere and is believed to contribute to the increase in the average surface temperature on Earth. Improved tracking of the amount of substance and the dynamics of these greenhouse gases is required to better understand and model climate changes. DFM is partner in the EMRP project HIGHGAS and contributes by developing optical methods for use in multi-component transfer standards. The aim is to provide experimental evidence and guidance on spectroscopic methods for high accuracy measurements of atmospheric concentrations of key greenhouse gases, and to address aspects of field measurements with particular focus on carbon dioxide and methane.

OPTOFLUIDIC SYSTEMS FOR LIQUID SENSING

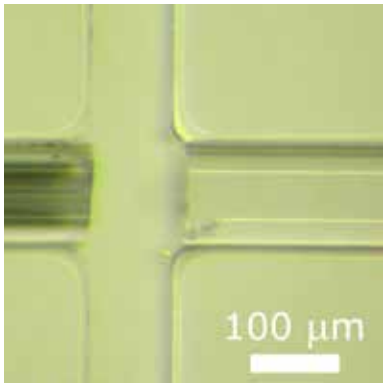


Figure 1: Image of two optical fibres lying horizontally across a vertical microfluidic channel in an assembled optofluidic system.

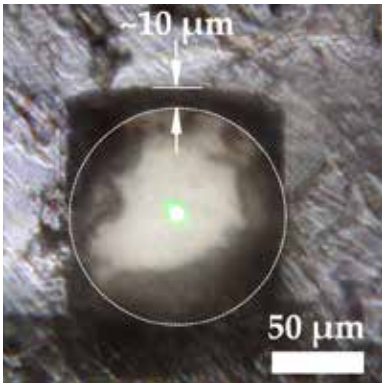


Figure 2: The end of an optical fibre (shown transmitting green laser light) embedded in a polymer optofluidic chip, with an unwanted gap identified by DFM.

Optofluidics is a term describing miniaturised sensors that combine optical measurements and microfluidic technologies.

Optofluidic systems have potential applications where regular measurements of liquids and solutions are needed (e.g. quality assurance in drink production, monitoring of fluids in healthcare), as they are smaller and cheaper than conventional, lab-based techniques and are suitable for on-line, automatic testing and quality assurance. However, these systems still require improved performance with respect to repeatability and reliability. DFM and partners from DTU Nanotech and DTU Physics are addressing this issue and have developed a new type of optofluidic system.

The system consists of a microfluidic polymer chip with embedded optical fibres. It is designed for measuring the concentration of chemicals in liquid samples (for example, ingredients in alcoholic beverages) at a location where the optical fibres meet the microfluidic channel (Figure 1). The system is made from a polymer material with excellent thermal and chemical resistance and minimal surface interaction with bio-molecules. In order to facilitate mass production of the system, it was assembled from four components (the polymer chip, two optical fibres and a lid).

The optofluidic system was validated using optical microscopy to measure the positioning of the optical fibres relative to the microfluidic channel. For a well-functioning system, it is important to ensure repeatability in fibre positioning. It was observed that there was a 5 % variation in spacing between the optical fibres in a set of ten assembled systems, but also that this had no influence on the measurement data from the nominal 100 µm wide channel. However, a small gap between the optical fibre and the surrounding polymer caused unwanted fibre movement during bonding of the lid (see Figure 2) reduced the sensing performance of the system.

In order to increase the sensitivity and measurement volume, a new version of the optofluidic sensor was created. A piece of hollow core optical fibre was used, where the ends of the fibre were embedded in two separate polymer chips and the core of the fibre was filled with the sample under investigation. We tested the sensor by filling it with water and ethanol solutions and monitoring the process using an optical technique called Raman spectroscopy. This resulted in a considerably enhanced signal and it provides the basis for the development of a compact and portable liquid sensing system through combination with fibre-coupled laser sources and spectrometers.

ACCOUNTS OF PARTICULAR ACTIVITIES

Participation in committees and working groups under the Metre Convention and EURAMET

- EMPIR Committee
- Consultative Committee for Amount of Substance (CCQM)
- Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV)
- EURAMET General Assembly
- EURAMET Board of Directors
- EURAMET Technical Committee for Mass (TC-M)
- EURAMET Technical Committee for Electricity and Magnetism (TC-EM)
- EURAMET Technical Committee for Length (TC-L)
- EURAMET Technical Committee for Photometry and Radiometry (TC-PR)
- EURAMET Technical Committee for Acoustics, Ultrasound and Vibration (TC-AUV)
- EURAMET Technical Committee for Time and Frequency (TC-TF)
- EURAMET Technical Committee for Interdisciplinary Metrology (TC-IM)
- EURAMET Technical Committee for Quality (TC-Q)
- EURAMET Technical Committee for Metrology in Chemistry (TC-MC)
- EURAMET TC-MC Sub Committee for Electrochemistry
- EURAMET TC-EM Sub Committee DC and Quantum Metrology
- BIPM Director's ad hoc Advisory Group on Uncertainty
- Joint Committee for Guides in Metrology – Working Group 1, Guide to the Expression of Uncertainty in Measurement (JCGM-WG1)
- Consultative Committee for Length – Working Group on Dimensional Nanometrology (CCL-WG-N)
- Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology – Working Group on Electrochemical Analysis (CCQM-EAWG)
- Consultative Committee for Mass and Related Quantities –Working Group on the Realization of the kilogram (CCM-WGR-kg)
- Consultative Committee for Mass and Related Quantities –Working Group on the Dissemination of the kilogram (CCM-WGD-kg)
- Consultative Committee for Acoustics, Ultrasound and Vibration – Working Group for Key Comparisons (CCAUV-KCWG)
- Consultative Committee for Ultrasound and Vibration – Working Group for RMO Coordination (CCAUV-RMO)
- Consultative Committee for Ultrasound and Vibration – Working Group on Strategic Planning (CCAUV-SPWG)

Participation in national and international projects

- Strategic Research Center in Precision and Nano-scale Polymer Mass Replication of Biochips (PolyNano), DSF
- Metrology for a universal ear simulator and the perception of non-audible sound (Ears), EMRP/FI
- Developing a practical means of disseminating the new kilogram (NewKilo), EMRP/FI
- Quantum sensor technologies and applications (QTEA), EU FP7/ITN
- Scanning neutral Helium microscopy (NEMI), EU FP7
- Crystalline surfaces, self-assembled structures, and nano-origami as length standards in (nano)metrology (Crystal), EMRP/FI
- Shape-engineered TiO2 nanoparticles for metrology of functional properties (SETNanoMetro), EU FP7
- 2D Kalibrering, IF
- Center for LED Metrologi (LEDMET), IF
- Advanced laser-based heat sensor for fire detection (FireDetect), IF/EU H2020
- A novel non-invasive trace gas analyser platform tageting breath analyses (NxPAS), IF/EU H2020
- Industrial Fourier Scatterometer (InFoScat), IF/EU H2020
- Metrology for high-impact greenhouse gases (HIGHGAS), EMRP/FI
- Metrology for ammonia in ambient air (MetNH3), EMRP/FI
- Traceable characterisation of thin-film materials for energy applications (ThinErgy), EMRP/FI
- UV-induceret biofilmforebyggelse (BIOFORS), IF
- Metrology for innovative nanoparticles (Innanopart), EMPIR/FI
- Metrology for highly-parallel manufacturing (MetHPM), EMPIR/FI
- Metrology for length-scale engineering of materials (Strength-ABLE), EMPIR/FI
- Leading Edge Roughness wind turbine blades (LER), EUDP
- Optical plastic lenses with super-hydrophobic surface properties (SuperLens), IF/EU H2020
- Advanced surface characterization of nanostructures on curved polymer surfaces, FI

DFM Reports

- **M. Kjær.** *Faglig rapportering til Forsknings- og Innovationsstyrelsen for 2014.* DFM-2015-R01
- **J. C. Petersen.** *DFM Årsrapport 2014.* DFM-2015-R02
- **L. Nielsen.** *Transferring the unit of mass between weights kept in air and in vacuum.* DFM-2015-R03
- **S. R. Johannsen.** *Analysis of TiO2 heat series from TI by KPFM.* DFM-2015-R04
- **P. T. Jakobsen.** *Preliminary procedure for handling of Hamilton single pore glass electrodes for secondary pH measurements.* DFM-2015-R05
- **M. H. Madsen, S. R. Johannsen.** *Optical characterization of steel surfaces.* DFM-2015-R06
- **S. R. Johannsen, M. H. Madsen.** *AFM investigation of membranes.* DFM-2015-R07
- **A. Snedden, C. Thirstrup.** *Comparison: open-cell and closed-loop measurements systems.* DFM-2015-R08
- **J. C. Petersen.** *Kvantitativ identifikation af kemiske stoffer: Status.* DFM-2015-R09

Calibration certificates and measurement reports

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Electrochemistry	283
Mass	15
Length	12
Optical Radiometry	61
Nano Structures	6
Acoustics	21
Particle Metrology	118
Total	521

Publications in refereed journals

- **M. H. Madsen, P. E. Hansen, B. Bilenberg, M. Karameh-medović.** *Characterixation of nano-textured samples in a production environment.* euspen conference proceedings, 149-150. DFM-2015-P01
- **P. J. Brewer, D. Panagoulia, R. J. C. Brown, A Tromans, A. Reyes, M. Arce, A. Vospelova, M. Roziková, K. W. Pratt, T. Asakai, P. T. Jakobsen, M. F. Camões, C. S. Oliveira, I. Godinho, P. Spitzer, B. Sander, M. Máriássy, L. Vyskoćil, P. Fisicaro, D. Stoica, E. Uysal.** *International comparison on Ag\|AgCl electrodes for pH measurement.* Measurement **66**, 131-138, 2015. DFM-2015-P02
- **M. H. Madsen, K. Dirscherl, N. A. Feidenhans'l, P. E. Hansen, J. Garnæs.** *Temperature dependent polymer shrinkage when replicating nanostructures.* euspen conference proceedings, 47-48, 2015. DFM-2015-P03
- **S. Davíðsdóttir, J. P. Petit, M. Mermoux, R. Shabadi, S. Canulescu, K. P. Almtoft, K. Dirscherl, R. Ambat.** *Interfacial structure and photocatalytic activity of magnetron sputtered TiO2 on conducting metal substrates.* ACS Applied Materials & Interfaces **6**, 22224-22234, 2014. DFM-2015-P04
- **M. H. Madsen, P. E. Hansen, J. Garnæs, M. Zalkovskij, M. Karamehmedović.** *Fast characterization of moving samples with nano-textured surfaces.* Optica **2**, 301-306, 2015. DFM-2015-P05
- **P. G. Westergaard, B. T. R. Christensen, D. Tieri, R. Matin, J. Cooper, M. Holland, J. Ye, J. W. Thomsen.** *Observation of motion-dependent nonlinear dispersion with narrow-linewidth atoms in an optical cavity.* Phys. Rev. Lett. **114**, 093002, 2015. DFM-2015-P06
- **M. Lassen, A. Brusch, D. Balslev-Harder, J. C. Petersen.** *Phase-sensitive noise suppression in a photoacoustic sensor based on acoustic circular membrane modes.* Applied Optics **54,** D38-D42, 2015. DFM-2015-P07
- **L. Nielsen, R. Davis, P. Barat.** *Improving traceability to the international prototype of the kilogram.* Metrologia **52,** 538-551, 2015. DFM-2015-P08
- **N. K. Kjøller, S. G. Porsev, P. G. Westergaard, N. Andersen, J. W. Thomsen.** *Hyperfine structure of the (3s3d) 3Dj manifold of Mg25 I.* Phys. Rev. A **91,** 032515, 2015. DFM-2015-P09
- **M. Triches, M. Michieletto, J. Hald, J. K. Lyngsø, J. Lægsgaard, O. Bang.** *Optical frequency standard using acetylene-filled hollow-core photonic crystal fibers.* Opt. Express **23,** 11227-11241, 2015. DFM-2015-P10
- **F. Stöhr, J. Michael-Lindhard, H. Simons, H. F. Poulsen, J. Hübner, O. Hansen, J. Garnaes, F. Jensen.** *Three-dimensional nanometrology of microstructures by replica molding and large-range atomic force microscopy.* Microelectronic Engineering **141,** 6-11, 2015. DFM-2015-P11

- **S. Davíðsdóttir, J. P. Petit, R. Shabadi, S. Canulescu, K. P. Almtoft, K. Dirscherl, I. H. Andersen, R. Ambat.** *Effect of the interfacial oxide thickness on the photocatalytic activity of magnetron sputtered TiO2 coatings on aluminum substrate.* Phys. Status Solidi A **212**, 2805-2815, 2015. DFM-2015-P12
- **J. Seppa, M. Merimaa, A. Manninen, M. Triches, J. Hald, A. Lassila.** *Interference cancellation for hollow-core fiber reference cells.* IEEE Trans. Instrum. Meas. **64**, 1595-1599, 2015. DFM-2015-P13
- **N. A. Feidenhans'l, P. E. Hansen, L. Pilný, M. H. Madsen, G. Bissacco, J. C. Petersen, R. Taboryski.** *Comparison of optical methods for surface roughness characterization.* Measurement Science and Technology **26**, 085208, 2015. DFM-2015-P14
- **M.R. Sonne, K. Smistrup, M. Hannibal, J. Thorborg, J. Nørregaard, J.H. Hattela.** *Modeling and simulation of the deformation process of PTFE flexiblestamps for nanoimprint lithography on curved surfaces.* Journal of Materials Processing Technology **216**, 418-429, 2015. DFM-2015-P15
- **M. Calaon, M. H. Madsen, J. Weirich, H. N. Hansen, G. Tosello, P. E. Hansen, J. Garnaes, P. T. Tang.** *Replication fidelity assessment of large area sub-µm structured polymer surfaces using scatterometry.* Surf. Topogr.: Metrol. Prop. **3**, 045005, 2015. DFM-2015-P16
- **M. Zalkovskij, L. H. Thamdrup, K. Smistrup, T. Andén, A. C. Johansson, N. J. Mikkelsen, M. H. Madsen, J. Garnæs, T. T. Kristiansen, M. Diemer, M. Døssing, D. Minzari, P. T. Tang, A. Kristensen, R. Taboryski, S. Essendrop, T. Nielsen, B. Bilenberg.** *Smart plastic functionalization by nanoimprint and injection molding.* Proc. of SPIE **9423**, 94230T, 2015. DFM-2015-P17
- **M. Triches, A. Brusch, J. Hald.** *Portable optical frequency standard based on sealed gas-filled hollow-core fiber using a novel encapsulation technique.* Appl. Phys. B **121**, 251-258, 2015. DFM-2015-P18
- **N. A. Feidenhans'l, P. E. Hansen, L. Pilný, M. H. Madsen, G. Bissacco, J. C. Petersen, R. Taboryski.** *Industrial characterization of nano-scale roughness on polished Surfaces.* Proc. SPIE **9633**, 96330B, 2015. DFM-2015-P19
- **M. Matteucci, M. Triches, G. Nava, A. Kristensen, M. R. Pollard, K. Berg-Sørensen, R. J. Taboryski.** *Fiber-Based, Injection-Molded Optofluidic Systems: Improvements in Assembly and Applications.* Micromachines **6**, 1971-1983, 2015. DFM-2015-P20
- **R. Tanta, M. H. Madsen, Z. Liao, P. Krogstrup, T. Vosch, J. Nygård, T. S. Jespersen.** *Raman spectroscopy and electrical properties of InAs nanowires with local oxidation enabled by substrate micro-trenches and laser irradiation.* Appl. Phys. Lett. **107**, 243101, 2015. DFM-2015-P21
- **P. G. Westergaard, M. Lassen, J. C. Petersen.** *Differential high-resolution stimulated CW Raman spectroscopy of hydrogen in a hollow-core fiber.* Opt. Express **23**, 16320-16328, 2015. DFM-2015-P22
- **L.C. Oliveira, A.M.N. Lima, C. Thirstrup, H.F. Neff.** *Surface plasmon resonance sensors - A materials guide to design and optimization.* Springer Briefs In Physics, Springer International Publishing, 2015. DFM-2015-P23

Confidential Reports

- **M. Kjær**. *DFM's strategi for perioden 2016 - 2018.* DFM-2015-F01
- **P. G. Westergaard, J. Hald.** *Test laser (WP-1b).* DFM-2015-F02
- **P. G. Westergaard, J. Hald.** *Random noise wavelength measurement (WP-2).* DFM-2015-F03
- **P. G. Westergaard, J. Hald.** *Optical Feedback Sensitivity (WP-3).* DFM-2015-F04
- **J. Hald, P. G. Westergaard.** *Polarization stability for AVIM connectors (WP-6).* DFM-2015-F05
- **M. H. Madsen, A. Brusch, P.-E. Hansen.** *Comparing UV transmission of caps for devices.* DFM-2015-F06
- **J. Hald.** *Karakterisering af O2DS Z scanner.* DFM-2015-F07
- **J. Garnæs.** *Three-dimensional nanometrology of microstructures by replica molding and large-range atomic force microscopy.* DFM-2015-F08
- **C. Thirstrup, M. H. Madsen, P.-E. Hansen.** *UV and VIS transmission of caps for devices.* DFM-2015-F09
- **P. G. Westergaard, J. Hald**. *Theoretical model (WP-4).* DFM-2015-F10
- **P. G. Westergaard, J. Hald.** *FRLS EBB for CO2 at 2.05 µm: characterisation results.* DFM-2015-F11
- **P. G. Westergaard, J. Hald.** *Gas cell pressure (WP-5).* DFM-2015-F12
- **K. Dirscherl.** *Observations when disassembling faulty particle counters.* DFM-2015-F13
- **M. H. Madsen, J. Garnæs.** *Overfladekarakterisering af plast-emner.* DFM-2015-F14
- **M. H. Madsen.** *Optimering af DE måleopstilling.* DFM-2015-F15
- **P. T. Jakobsen.** *DFM Measurement report for measurements on solutions. 2015.* DFM-2015-F16
- **P. G. Westergaard, J. Hald.** *Final Conclusions & Recommendations - Technical Note 7.* DFM-2015-F17

Contribution at conferences

- **J. Hald, P. G. Westergaard, M. Triches, M. Michieletto, J. K. Lyngsø, J. E. Pedernsen, J. W. Thomsen.** *Gas-Filled Hollow-Core Fibres and Bulk Gas Cells as Optical Frequency References.* World of Photonics Congress, Application panel on Optical Metrology and Imaging, Munich, Germany, June 2015. DFM-2015-K01
- **M. Triches, A. Brusch, J. Hald.** *Fibre-based portable optical frequency standard for telecommunication.* Quantum Technology, sensors and applications Postgraduate Symposium, Hamburg, Germany, September 2015. DFM-2015-K02
- **M. Lassen, J. C. Petersen.** *Phase-Sensitive noise Suppression in a Photoacoustic Sensor.* 18th International Conference on Photoacoustic and Photothermal Phenomena (ICPPP18), Novi Sad, Serbia, September 2015. DFM-2015-K03
- **A. Torras-Rosell, S. Barrera-Figueroa.** *An acousto-optic method for free-field microphone calibration.* ICSV22, Firenze, Italy, July 2015. DFM-2015-K04
- **A. Torras-Rosell, K. Dirscherl, S. Davíðsdóttir.** *Establishing traceability in Kelvin probe measurements for photocatalytic surfaces.* International summer workshop NANOSCIENCE meets METROLOGY, Sicily, Italy, July 2015. DFM-2015-K05
- **A. Torras-Rosell, S. Barrera-Figueroa.** *A new method to characterize impulsive sources using acousto-optic interaction.* InterNoise 2015, San Francisco, USA, August 2015. DFM-2015-K06
- **M. Pollard, M. Triches, P. Westergaard, M. Lassen, J. Petersen, M. Matteucci.** *Applying photonic crystal fibers to improve sensitivity in Raman spectroscopy.* DOPS Årsmøde 2015, Odense, Denmark, November 2015. DFM-2015-K07
- **P. E. Hansen, L. Nielsen, M. H. Madsen, B. Bodermann, B. Loechel, F. Scholze, J. Endres, M. Wurm, V. Soltwisch.** *Performing traceable scatterometry and ellipsometry measurements.* E-MRS 2015 Spring Meeting, Lille, France, May 2015. DFM-2015-K08
- **M. H. Madsen, P. E. Hansen, P. Boher, M. Zalkovskij, J. F. Jørgensen, D. Dwarakanath.** *Scatterometry of nano-textured polymer samples.* Polymer Replication on Nanoscale (PRN), Lyngby, Denmark, May 2015. DFM-2015-K09
- **M. H. Madsen, P. E. Hansen, B. Bilenberg, M. Karamehmedović.** *Characterization of nano-textured samples in a production environment.* euspen's 15th International Conference & Exhibition, Leuven, Belgium, June 2015. DFM-2015-K10
- **M. H. Madsen, K. Dirscherl, N. A. Feidenhans'l, P. E. Hansen, J. Garnæs.** *Temperature dependent polymer shrinkage when replicating nanostructures.* euspen's 15th International Conference & Exhibition, Leuven, Belgium, June 2015. DFM-2015-K11
- **M. H. Madsen, P. E. Hansen, M. Zalkovskij and B. Bilenberg.** *Scatterometry for in-line characterization of micro/nano-textured surfaces.* Micro/Nano workshop, United Kingdom, November 2015. DFM-2015-K12
- **M. Triches, A. Brusch, J. Hald, J. Lægsgaard, O. Bang.** *Fiber-based portable optical frequency standard for telecommunication.* CLEO: Science and Innovations 2015, San José, California, May 2015. DFM-2015-K13
- **M. Triches, J. Hald, M. Michieletto, J. K. Lyngsø, J. Lægsgaard, O. Bang.** *High order modes influence in laser frequency stabilization using gas-filled hollow-core fibers.* The European Conference on Lasers and Electro-Optics 2015, Munich, Germany, June 2015. DFM-2015-K14
- **N. A. Feidenhans'l, P.-E. Hansen, L. Pilný, M. H. Madsen, G. Bissacco, J. C. Petersen, R. J. Taboryski.** *Industrial characterization of nano-scale roughness on polished surfaces.* SPIE Optifab, Rochester, New York, October 2015. DFM-2015-K15

Other Talks

- **J. Garnæs.** *Metrologiens historie.* Lecture for visitors from Munkensdam Gymnasium, DFM, 20 January 2015.
- **J. Garnæs.** *Investigation on surface analysis and functionality with AFM.* DTU course 42215, Lyngby, 8 April 2015.
- **J. Garnæs.** *Gauge block calibration - Demonstration on primary optical techniques.* DTU course 42215, Lyngby, 15 April 2015.
- **J. Garnæs.** *Ruhed - afgørende for overfladers funktion.* Go-home meeting, DFM, 15 April 2015.
- **H. D. Jensen.** *Introduction to the film '1001 gram'.* CPH-PIX, Dagmar Bio, København, 16 April 2015.
- **J. Hald.** *Ved du hvor lang en meter er?* Folkemødet, Bornholm, 12 June 2015.
- **J. Hald.** *Lasers applied for time- and length standards.* Applied laser physics course at Dept. of Physics and astronomy, University of Aarhus, Aarhus, 2 September 2015.
- **C. Thirstrup.** *Surface plasmon resonance sensors.* DTU course, Lyngby, 28 October 2015.
- **M. H. Madsen.** *Farvemålinger,* Go-home meeting, 11 November 2015
- **D. Baslev-Clausen.** *Gasanalyser vha. optisk spektroskopi,* Go-home meeting, 24 November 2015
- **H. D. Jensen.** *Ledningsevne - Er vandet i din produktion rent?,* Go-home meeting, 25 November 2015
- **K. Dirscherl.** *Luftbårne nanopartikler - En udfordring,* Go-home meeting, 2 December 2015
- **M. Pollard.** *Investigating chemicals with Raman Spectroscopy,* Go-home meeting, 3 December 2015
- **A. T. Rosell.** *Acousto-optic technology,* Go-home meeting, 9 December 2015

INCOME STATEMENT AND BALANCE SHEET

INCOME STATEMENT (1000 DKK)	2015	2014
Commercial revenue	5 335	3 647
Project revenue	6 927	8 703
Government funding	14 974	14 993
Total revenue	**27 236**	**27 343**
Travel expenses	418	432
Other out-of-pocket expenses	3 052	3 013
Total out-of-pocket expenses	**3 470**	**3 443**
Gross profit	**23 766**	**23 900**
Staff costs	17 061	16 757
Other external expenses	4 042	3 844
Total costs	**21 103**	**20 601**
Operating profit before depreciation and impairment losses	**2 663**	**3 299**
Depreciation and impairment losses on property, plant and equipment	2 263	2 652
Operating profit before financial income and expenses	**400**	**647**
Financial income	19	58
Financial expenses	13	6
Profit before tax	**406**	**699**
Tax on profit for the year	0	0
Profit for the year	**406**	**699**

Profit for the year to be carried forward.

BALANCE SHEET AT 31 DECEMBER (1000 DKK)

ASSETS	2015	2014
Deposits	657	657
Total investments	**657**	**657**
Equipment	9 293	8 462
Leasehold improvements	1 002	1 327
Total property, plant and equipment	**10 295**	**9 789**
Total non-current assets	**10 952**	**10 446**
Contract work in progress	**3 603**	**2 333**
Trade receivables	949	542
Prepayments	241	16
Other receivables	299	236
Total receivables	**1 489**	**794**
Cash at bank and in hand	**8 510**	**11 454**
Total current assets	**13 602**	**14 581**
Total assets	**24 554**	**25 027**

EQUITY AND LIABILITIES	2015	2014
Share capital	1 000	1 000
Retained earnings	15 906	15 500
Total equity	**16 906**	**16 500**
Prepayments from customers and of funding	4 417	5 261
Trade payables	542	584
Other payables	2 689	2 682
Total current liabilities	**7 648**	**8 527**
Total equity and liabilities	**24 554**	**25 027**

KEY FIGURES

KEY FIGURES IN MILLION DKK	2011	2012	2013	2014	2015
Net sales	20.1	21.6	25.4	27.3	27.2
Gross balance	17.9	19.2	21.6	23.9	23.7
Profit or loss for the financial year [1])	1.0	0.9	0.5	0.7	0.4
Net capital	14.4	15.3	15.8	16.5	16.9
Commercial sales	2.7	2.8	3.0	3.6	5.3
- to small enterprises (less than 50 employees)	0.6	0.5	0.4	0.6	0.4
- to medium size enterprises (50-250 employees)	0.5	0.7	0.7	0.7	0.8
- to large enterprises (more than 250 employees)	0.5	0.5	0.8	0.8	1.3
- to Danish public institutions	0.6	0.6	0.0	0.1	0.4
- to foreign enterprises and institutions	0.5	0.5	1.1	1.4	2.4
Foreign net sales	0.9	2.2	6.5	5.9	7.1
RESEARCH AND DEVELOPMENT					
Number of collaborative projects	18	18	21	23	23
- thereof innovation consortia	1	1	0	2	2
- thereof international projects	7	9	12	16	17
R&D activities (million DKK)	18.5	21.2	25.4	26.2	23.2
- thereof self-funded	1.2	2.4	3.1	1.8	2.1
R&D work (man-year)	12.3	13.9	16.2	19.0	17.5
NUMBER OF CUSTOMERS					
Danish private enterprises	27	32	31	33	25
- thereof small enterprises (less than 50 employees)	10	14	14	15	11
- thereof medium size enterprises (50-250 employees)	6	8	6	9	6
- thereof large enterprises (more than 250 employees)	11	10	11	9	8
Danish public institutions	5	11	5	3	5
Foreign enterprises and institutions	18	24	18	17	19
Total customer base	50	67	62	53	49
NUMBER OF STAFF CATEGORIZED BY EDUCATION (MAN-YEAR)					
Dr & PhD	11	13	17	18	18
MSc	4	3	3	4	4
Other technical staff	3	3	3	3	2
Administrative staff	2	2	2	2	3
Average number of staff	20	21	25	27	27
NUMBER OF PUBLICATIONS					
Refereed publications	9	7	12	14	23
PhD - og Master theses	0	0	1	0	0
Other reports	23	24	15	14	14
Conference papers	14	22	18	22	15
Calibration certificates and measurement reports	442	442	417	495	521
Press cuttings	4	9	9	27	28
EDUCATION					
DFM courses (number of days)	5	2	2	2	2
DFM courses (number of participants)	39	21	4	25	22
Supervision/teaching at universities (courses)	3	9	0	6	3
Co-supervision of master thesis and PhD students (number of students)	5	3	4	5	5
Contribution to teaching at universities (number of days)	8	5	5	6	4
Committee work (number of committees)	26	25	24	32	29
- thereof international committee work	22	22	21	27	23
EFFICIENCY					
Turnover per employee (1000 DKK)	999	1031	1011	1004	994
Profit per employee (1000 DKK)	49	43	20	26	15
Commercial turnover per DKK of governmental funding	0.2	0.2	0.2	0.3	0.4
R&D turnover per DKK of governmental funding	1.3	1.5	1.7	1.8	2.1

1) Excluding extraordinary items

DANISH METROLOGY INSTITUTES

According to the CIPM Mutual Recognition Arrangement, a country can have one national metrology institute (NMI) and a number of designated institutes (DI). In Denmark, these metrology institutes are appointed by the Danish Safety Technology Authority (www.sik.dk). In the list below, each appointed metrology institute is identified by the acronym used in the BIPM database for Calibration and Measurement Capabilities. The fields covered by the appointments are indicated in the table on the next page.

BKSV-DPLA
Brüel & Kjær Sound & Vibration
Measurement A/S
Skodsborgvej 307, DK-2850 Nærum
Contact: Erling Sandermann Olsen
Phone: +45 7741 2000
ErlingSandermann.Olsen@bksv.com

DELTA
Delta Danish Electronics, Lights & Acoustics
Venlighedsvej 4, DK-2970 Hørsholm
Contact: Anders Bonde Kentved
Phone: +45 7219 4275
abk@delta.dk

DFM
DFM A/S, Danish National Metrology Institute
Matematiktorvet 307, DK-2800 Kgs. Lyngby
Contact: Jan Hald
Phone: +45 4525 5876
jha@dfm.dk

DTI
Danish Technological Institute
Kongsvang Allé 29, DK-8000 Århus C
Contact: Jan Nielsen
Phone: +45 7220 1236
Jnn@teknologisk.dk

DTU
Technical University of Denmark
Anker Engelundsvej 1, Building 101A
DK-2800 Kgs. Lyngby
Contact: Niels Axel Nielsen
Phone: +45 4225 7120
nan@adm.dtu.dk

FORCE
FORCE Technology
Navervej 1, DK-6600 Vejen
Contact: Mogens Simonsen
Phone: +45 7696 1630
mss@force.dk

Trescal
Trescal A/S
Mads Clausensvej 12, DK-8600 Silkeborg
Contact: Torsten Lippert
Phone: +45 8720 6969
Torsten.Lippert@trescal.com

THE 12 SUBJECT FIELDS OF METROLOGY

Fundamental metrology in Denmark follows the EURAMET division into 12 subject fields, while the subfields reflect a Danish subdivision of metrological activities. Plans of action drawn up for each subject field serve as guidelines for the appointment of metrology institutes and give suggestions for other initiatives. The years in which plans of action have been published are shown in parenthesis.

SUBJECT FIELD	CONTACT PERSON	SUBFIELDS	METROLOGY INSTITUTE
MASS AND RELATED QUANTITIES	Lars Nielsen, DFM	Mass measurement	DFM
(1989, 1997, 2008)	ln@dfm.dk	Force and Pressure	FORCE
		Volume and Density	FORCE
ELECTRICITY AND MAGNETISM	Hans Dalsgaard Jensen, DFM	DC electricity	DFM
(1989, 1994, 2002, 2011)	hdj@dfm.dk	AC electricity	TRESCAL
		HF electricity	TRESCAL
LENGTH	Jan Hald, DFM	Basic length measurements	DFM
(1989, 1998, 2007)	jha@dfm.dk	Dimensional metrology	DFM & DTI
		Micro/Nano	DFM
TIME AND FREQUENCY	Jan Hald, DFM	Time measurement	
(1992, 2000)	jha@dfm.dk	Frequency	
THERMOMETRY	Jan Nielsen, DTI	Temperature measurement by contact	DTI
(1992, 1999, 2007)	jnn@teknologisk.dk	Non-contact temperature measurement	DTU
		Humidity	DELTA
IONISING RADIATION	Arne Miller, DTU	Absorbed radiation dose - Industrial products	DTU
(1992, 2000)	armi@dtu.dk	Absorbed radiation dose - Medical products	
		Radiation protection	
		Radioactivity	
PHOTOMETRY AND RADIOMETRY	Anders Brusch, DFM	Optical radiometry	DFM
(1990, 1996, 2004, 2014)	ab@dfm.dk	Photometry	
		Colorimetry	
		Optical fibres	
FLOW	Jesper Busk, FORCE	Gaseous flow (volume)	FORCE
(1990, 1999, 2007)	jrb@force.dk	Water flow (volume, mass and energy)	DTI
		Flow of liquids other than water	FORCE
		Anemometry	DTI
ACOUSTICS, ULTRASOUND AND VIBRATION	Salvador Barrera-Figueroa, DFM	Acoustical measurements in gases	DFM & BKSV-DPLA
(1992, 2000, 2009)	sbf@dfm.dk	Acoustical measurements in solids	BKSV-DPLA
		Acoustical measurements in liquids	
METROLOGY IN CHEMISTRY	Pia Tønnes Jakobsen, DFM	Electrochemistry	DFM
(1992, 1995, 2004)	ptj@dfm.dk	Laboratory medicine	
		Products and materials	
		Food chemistry	
		Pharmaceutical chemistry	
		Microbiology	
		Environmental chemistry	
INTERDISCIPLINARY METROLOGY	Hans Dalsgaard Jensen, DFM	No subdivisions	
	hdj@dfm.dk		
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Managing Director, Bavnehøj Invest ApS

Niels Axel Nielsen (Vice Chairman)
Senior Vice President,
Technical University of Denmark

Søren Stjernqvist (until March 17th 2015)
President, Danish Technological Institute

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CEO, Lithium Balance A/S

Marlene Haugaard
Director, NCC Building, Engineering

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Kai Dirscherl
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Thao Phuong Tran, Trainee
Daniel-Florin Stefan, Trainee
Søren Vinter Søgård, PhD student,
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