DIFFER

Annual Report 2013

Dutch Institute for Fundamental Energy Research

Colophon

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Annual report and online appendix

This report presents DIFFER's scientific and technical highlights of 2013. Various images in this report link to online movies or animations via QR-code and web address. The full list of the institute's output and an overview of the DIFFER staff is given in the online appendix, http://www.differ.nl/en/annual_reports.

DIFFER's management team, from left to right:
Tony Donné, Wim Koppers and Richard van de Sanden

Preface
Building activities

It is my pleasure to present you the annual report of the Dutch Institute for Fundamental Energy Research DIFFER. In it, we highlight exciting results achieved in our mission to perform and support science for future energy.

On many different levels, the past year at DIFFER has been a year of building and growth. For one, our flagship experiment Magnum-PSI came into its own as a world-class facility, able to attract international top level visiting scientists and research contracts, amongst others from ITER. This world leading position was recognised with the granting of an FOM strategic program, bringing DIFFER in an excellent position to attract funding from the EUROfusion consortium.

Building takes a different meaning in the young solar fuels theme, where we are initiating new research projects as part of the recently granted NWO program on CO_2 neutral fuels, and as part of the Dutch Topsector Energy. To further grow and diversify the solar fuels theme, we are actively recruiting top talent via a tenure track scheme. Our first tenure track candidate will shape the collaboration on functional foils for sustainable energy applications together with Fujifilm, and we opened two more positions on photoelectrochemical approaches to solar fuels. The tenure track system fits into a new organizational structure, which gives our scientific staff increased freedom and responsibility to drive their research groups to a leading position in their fields.

Ahead of DIFFER's own move to Eindhoven, our nanolayer surfaces and interfaces division is undertaking its own relocation to become part of the MESA+ institute at Twente University. There, they face a bright future as the heart of the new public-private Industrial Focus Group on XUV Optics.
Through all these activities and more, we help bring together a multidisciplinary public-private network focused on creating tomorrow's sustainable energy infrastructure. By providing new opportunities for collaboration, such a network both strengthens and extends each partners' own research, and inspires innovative breakthroughs on the interfaces of disciplines in the network.

Last but not least, actual construction of our highly sustainable building is progressing rapidly on the campus of Eindhoven University of Technology. I am proud to see our staff taking up the challenge to organise the move of all our facilities while at the same time keeping up their high productivity - and spirits.

Richard van de Sanden,
Director

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About DIFFER

DIFFER is the Dutch Institute for Fundamental Energy Research, and is part of the Foundation for Fundamental Research on Matter (FOM) and the Netherlands Organisation for Scientific Research (NWO). The mission of DIFFER is to conduct leading fundamental research in the fields of fusion and solar fuels, in close partnership with academia and industry. To successfully transfer fundamental insights to society at large, DIFFER is actively building an energy science society through the formation of multidisciplinary networks.

Science for Future Energy

The issues of energy and climate change require us to develop sustainable energy on a global scale. This transition is one of mankind's biggest challenges in this century and its success depends on our solving a wealth of scientific questions. As national institute for fundamental energy research, DIFFER focuses its research efforts on two themes: solar fuels and fusion.

Fusion has the potential to provide concentrated, safe and clean energy from the process powering the sun and stars. DIFFER's two fusion research programmes both address high priority topics in the European Fusion Roadmap. With its unique high-flux plasma generators Magnum-PSI and Pilot-PSI, DIFFER explores plasma surface interactions under future fusion reactor conditions. In the program on control of burning plasma, DIFFER develops the understanding and tools to control magnetohydrodynamic instabilities in ITER, and tests these on intermediate sized tokamaks such as ASDEX Upgrade.

Solar fuels address the global challenge of energy storage and transport by converting intermittent sustainable energy into fuels. DIFFER is investigating the splitting of water into hydrogen or the activation of carbon dioxide into carbon monoxide, and the processing of these products into a hydrocarbon fuel. The research involves the synthesis and design of novel materials and processes to obtain scaleable, efficient and cost-effective systems.

In 2013, DIFFER's division nanolayer Surface and Interface Physics started its relocation to the University of Twente, notably the MESA+ Institute for Nanotechnology. The group will continue its pioneering work on multilayer mirrors for Extreme Ultraviolet wavelength photolithography and other applications in an upgraded setting in answer to the Dutch Topsectoren policy. This Industrial Focus Group XUV Optics includes industrial partners ASML Carl Zeiss., PANalytical, DEMCON, SolMateS, and TNO.

Plasma pulses test ITER wall material

The tungsten at the exhaust of the future fusion reactor ITER will face harsh plasma conditions, with trains of energy bursts (ELMs or Edge Localised Modes) on top of an already high continuous temperature and density plasma. DIFFER's plasma experiment Magnum-PSI can recreate these conditions via its unique pulsed plasma system. In 2013, ITER contracted DIFFER to expose a set of tungsten blocks to a pulse train of 17.600 ELMs on top of the continuous plasma load in Magnum-PSI.

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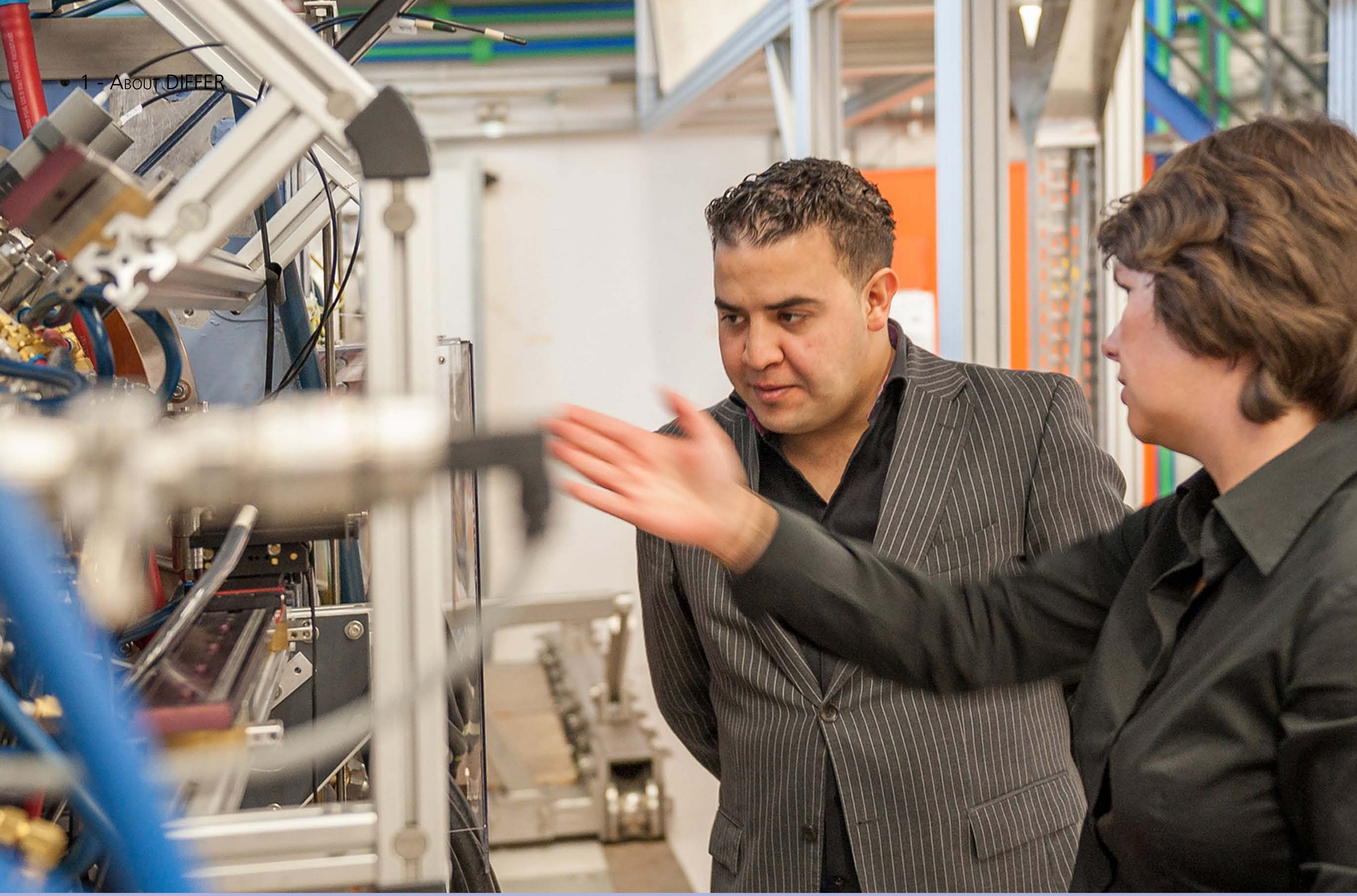
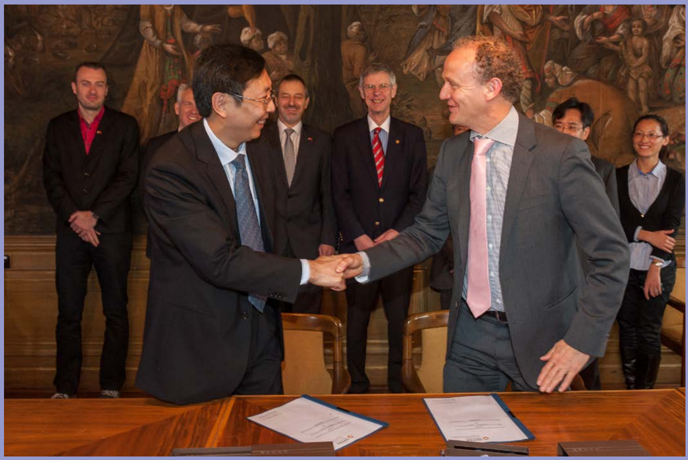


MP visit on energy research and topsector policy

On April 8th 2013, Member of Parliament Mohammed Mohandis for the PvdA labour party visited DIFFER together with a delegation from NWO and FOM. The programme included a discussion on the organisation of fundamental research in the Netherlands, on the cooperation between the research and industry, and on sustainable energy in general. During a lab tour, young researchers presented their work on solar fuels and on advanced materials for future fusion reactors.

Framework for collaboration with Chengdu University

On November 11th 2013, a delegation of four researchers from the Chinese Chengdu University visited DIFFER to sign a framework collaboration agreement. The university's Chengdu Development Center of Science and Technology CDCST has embarked on a mission for fundamental energy research in 2010 and is looking to form strategic partnerships. DIFFER's former director Aart Kleijn will advise CDCST on setting up research and the technical infrastructure in Chengdu.



DIFFER employees at the construction site on the campus of TU/e

Wim van Saarloos (Director FOM) and Hans van Duijn (Rector Magnificus TU/e) gave the official starting signal by drilling in one of DIFFER's foundation piles

A new building

Construction started in Eindhoven

To expand our research facilities, DIFFER will move to a new building on the campus of Eindhoven University of Technology (TU/e) starting 2015. Currently, the institute is still located at the Rijnhuizen estate in Nieuwegein.

On September 16th 2013, DIFFER celebrated the construction start of its new laboratory building in Eindhoven. The new DIFFER building will be located on the interface between the campus areas for research, education and industry. Joining DIFFER's staff in the 'first foundation pile' event were representatives from the university, provincial government and the research agencies FOM and NWO.

http://goo.gl/Az90Wy

Artist impression of the new building, a design by Ector Hoogstad Architects. The construction is realised by Dura Vermeer Group

BREAAM certificate 'excellent'

With the institute's new home, DIFFER's parent organisation FOM is aiming for a sustainable building. The design is based on the high standards of the sustainable construction rating 'BREEAM excellent'. On September 12th 2013, our new building was already awarded this certificate for its design phase.

Throughout the construction process, DIFFER is taking steps to ensure that our new building will be the first in the Netherlands to meet the 'excellent' standard for the materials and processes in both office and laboratory areas. As part of the sustainable building process, DIFFER's new building will feature a facade with a sawtooth profile that allows minimal use of active sunscreens while still allowing ambient light to enter. Large jetties on the south side block direct sunlight to prevent unwanted heating of the building, while triple glazing ensures that heat loss is minimized. DIFFER generates electricity via 1500 m^2 of photovoltaic panels on the top roof, and is connected to the campus' heat and cold storage.

breeam nl

Training ground for top position

In 2013, fusion researcher *Peter de Vries* accepted a position as scientific coordinator for plasma operations and control at the international fusion project ITER. De Vries headed DIFFER's Plasma diagnostics group and supervised the operation of the Plasma Surface Interactions facility, and was stationed in Culham (UK) where he was task force and session leader at the Joint European Torus fusion experiment.

Fellowships

Jonathan Citrin received the fifth and last of the prestigious Young Energy Scientists Fellowship (YES) from the Dutch physics funding agency FOM. Citrin performed his PhD research in DIFFER's computational plasma physics group. He will use the four year grant to investigate the effect of tungsten on fusion reactor plasma performance at the French CEA Research Institute on Magnetic Fusion (IRFM), located in Cadarache near the international fusion project ITER.

Fusion researchers Thomas Morgan and Dmitry Moseev were each awarded one of the prestigious European Fusion Researcher Fellowships by the European Fusion Development Agreement EFDA. The Fellowships fund two year post-doc positions on innovative techniques for fusion reactors. Thomas Morgan will work on a liquid wall concept to counter erosion, to be tested in DIFFER's plasma experiment Magnum-PSI. Dmitry Moseev will test methods to study the interaction between fast ions and instabilities in the plasma of the ASDEX Upgrade tokamak. Furthermore, PhD student Matthijs van Berkel received a Fellowship from the Japan Society for the Promotion of Science, which consists of a 1 year secondment at the National Institute for Fusion Science (NIFS).

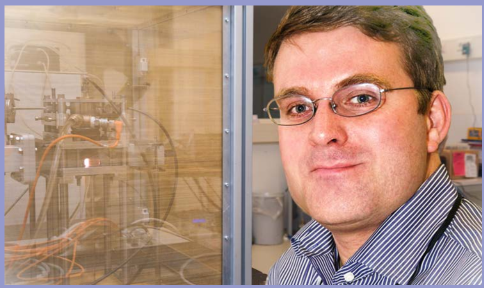
Prizes

At the annual Student Research Conference of the Dutch Universities' Association VSNU, physics student Christine Verbeke won the Dutch best bachelor research prize. As the first student in the solar fuels theme, Verbeke performed a theoretical analysis of plasma dissociation of CO_2 with a view to producing the building blocks for artificial fuels (see page 26).

Appointments

The Royal Netherlands Academy of Arts and Sciences (KNAW) has appointed fifteen new members, among which DIFFER's director Richard van de Sanden. The approximately 500 members of the KNAW come from all academic disciplines and are appointed on the basis of scientific and scholarly achievement.

Tony Donné, who heads DIFFER's fusion theme, has been appointed to Euratom's Scientific and Technical Committee (STC). The STC has a very broad strategic advisory mandate and covers the whole range of nuclear topics.



Peter de Vries

Thomas Morgan

Dmitry Moseev

Richard van de Sanden

Tony Donné

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2.1 Fusion

Plasma surface interactions

The plasma surface interactions theme explores the behavior of materials in a regime of extreme heat and particle flux conditions never seen before. Understanding and control of plasma-surface interaction effects is for example crucially needed to design materials able to withstand the harsh conditions expected in a fusion reactor. However, the non-equilibrium conditions induced by the bombardment by extreme fluxes of low-energy particles also open a novel route for the synthesis of advanced nanostructured materials.

The plasma surface interactions program actively studies:

- Surface evolution under extremely high ion fluxes;
- Diffusion/retention of hydrogen species under non-equilibrium irradiation conditions;
- Interplay between stationary and transient effects on metal surface damage;
- Power exhaust of liquid metals and prospects for future reactors;
- Exploration of novel plasma processing techniques.

The powerful in-house linear plasma generators Magnum-PSI and its predecessor Pilot-PSI, provide a cost-effective approach to the fundamental understanding of plasma-surface interactions, with a good access to the plasma-material interaction zone for diagnostics and sample manipulation. Those devices are worldwide unique in their abilities to reproduce and even exceed the heat (>30MWm^{-2}) and particle fluxes (up to $10^{25}m^{-2}s^{-1}$) expected in the divertor of a fusion reactor. In addition, combined steady-state/pulsed operations are possible to study the effects of transient heat loads on a plasma-facing surface, similar to those expected during so called Edge-Localized Modes (ELMs).

This unique system was designed and built in-house (see p9) and can generate 1ms plasma pulses in excess of 1GWm^{-2} with a repetition rate of 70 Hz. In addition, a smaller scale experiment, Nano-PSI, provides a versatile platform to study ion irradiation-induced nano-structuring of surfaces.

The experimental program was supported with numerical simulations of impurity transport in a high-density low-temperature hydrogen plasma (using the ERO code) and a kinetic model for the neutral hydrogen species (using the EUNOMIA code). Specific attention was paid to the drag exerted by the fast flowing beam on the impurities and to validation of EUNOMIA against visible spectroscopy.

Program leaders

G.C. De Temmerman, P.C. de Vries, W.J. Goedheer

Funding

FP-75 - PSI-lab, an integrated laboratory on plasma-surface interaction, EFDA, ITER service contract

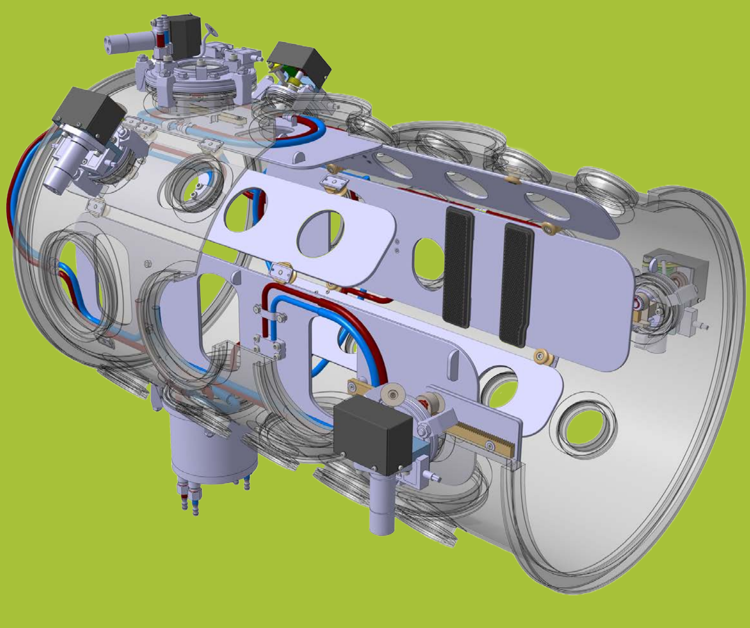
Grants

Thomas Morgan - European Fusion Researcher Fellowship (EFDA)

Collaborations

ASIPP, Hefei, China; ANSTO, Sydney, Australia; ANU, Canberra, Australia; Beihang University, Beijing, China; CEA Cadarache, France; CIEMAT, Madrid, Spain; Dalian University of Technology, China; Delft University of Technology, NL; EPF Lausanne, Switzerland; FZJ, Jülich, Germany; German University Cairo, Egypt; Heriot-Watt University, Edinburgh, UK; IPP Garching, Germany; ITER IO divertor section, Cadarache, France; Jefferson Laboratory, Newport, US; MIT, Boston, USA; Nagoya University, Japan; NIFS, Toki, Japan; Tartu University, Estonia; INFLPR, Bukarest, Romania; Oak Ridge National Laboratory, USA; Osaka University, Japan; PPPL, Princeton, USA; Purdue University, West Lafayette, USA; SCKCEN, Mol, Belgium; Sichuan University, Chengdu, China; VTT, Finland; TEKES, Finland; Tsinghua University, Beijing, China; TU/e, Eindhoven, NL; Twente University, Enschede, NL; University of Basel, Switzerland; University of Illinois, Urbana Champaign, USA; UCSD San Diego, USA

Windows in the plasma experiment Magnum-PSI provide ample diagnostics access to the hot, dense plasma. A custom designed and constructed set of remotely controlled shutters protect windows which are not in use from stray plasma particles.



Strongly reduced penetration of deuterium in tungsten

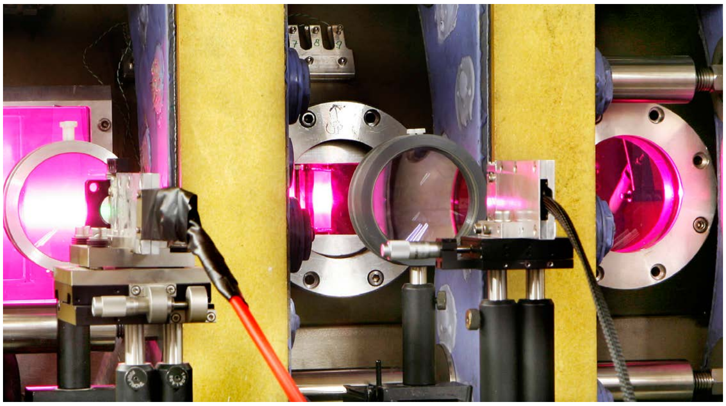
In a fusion reactor, the hydrogen isotopes deuterium and tritium will fuse into helium. The exhaust of the reactor or divertor must be able to withstand large quantities of heat and particles. For safety reasons, only a limited amount of hydrogen (tritium) may be present in the reactor wall.

The divertor of ITER will consist of tungsten with its high melting point and good thermal conductivity. Tungsten is known to retain little hydrogen, although the retention can rise by several orders of magnitude under the influence of neutrons from the fusion reaction. Recent experiments together with IPP Garching have shown that the penetration of hydrogen in tungsten can be strongly reduced as compared to the incoming plasma flux.

The experiments were carried out on the linear plasma generator Pilot-PSI where intense reactor-like deuterium plasmas were produced. It was observed that only a very small fraction, in the order of one millionth, of the deuterium plasma flux penetrates the exposed tungsten. It was also found that this fraction strongly depends on the local surface temperature. The results strongly suggest that the deuterium forms a protective chemisorbed layer on top of the tungsten surface. Deuterium atoms arriving at the surface collide with the atoms in this layer, thereby losing large part of their kinetic energy and preventing direct penetration. The chemisorbed deuterium atoms need to cross an energy barrier of 1-2 eV to penetrate bulk tungsten, explaining the small influx of deuterium and the strong temperature dependence.

Strongly reduced penetration of atomic deuterium in radiation-damaged tungsten, Phys. Rev. Lett. 111 (2013) 225001

Max-Planck-Institut für Plasmaphysik



Fusion plasmas produce carbon nanostructures

Materials exposed to high flux plasmas are driven far out of equilibrium by constant bombardment of the surface and high amounts of energy transferred to it. Such treatment is harsh, but nevertheless favorable for synthesis of self-organized structures. Using Pilot-PSI a great variety of carbon nanostructures, including graphene sheets and carbon nanotubes, was formed on different untreated substrates. Research of nanosynthesis under these extreme plasma conditions is directed at the discovery of novel nanostructured materials.

Spontaneous synthesis of carbon nanowalls, nanotubes and nanotips using high flux density plasmas, Carbon Volume 68, March 2014, Pages 695–707

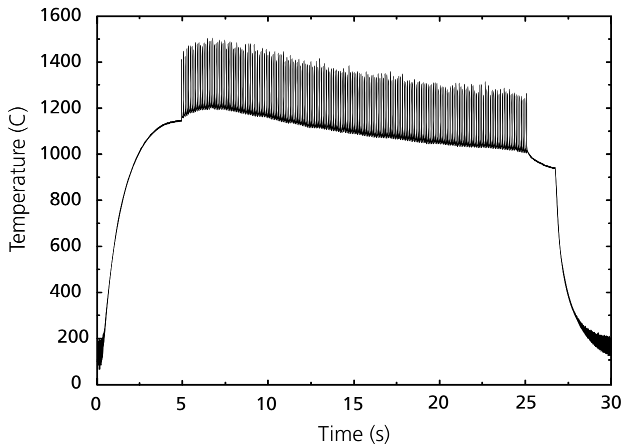
Carbon nanostructures developed during bombardment of graphite with a fusion-relevant plasma

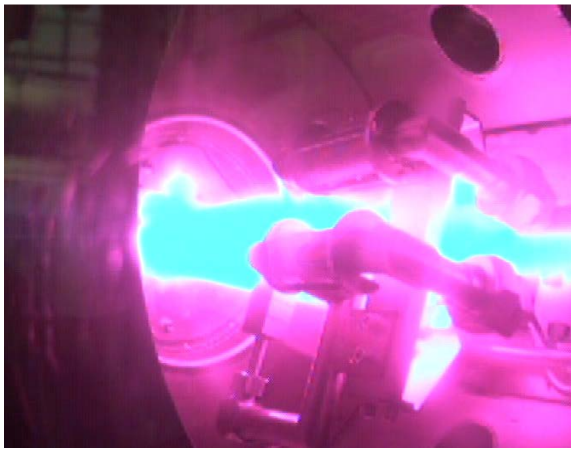
Plasma pulses test ITER wall material

The tungsten exhaust of future fusion reactors such as ITER faces punishing plasma conditions, with short energy bursts (ELMs or Edge Localised Modes) on top of a continuous high temperature and density plasma. DIFFER's plasma experiment Magnum-PSI is the first laboratory setup able to mimic those conditions, thanks to a modular capacitor bank designed and built by the in-house high power electronics group.

In 2013, the ITER International Organization placed a service contract to study transient melting and recrystallisation of tungsten by the repeating ELMs. Magnum-PSI's pulsed plasma system can mimic Edge Localized Modes (ELMs), transient instabilities which can develop at the edge of a fusion plasma. Each pulse lasts up to a millisecond and reaches a peak power density of 150 MW m^{-2}. During each pulse, the surface temperature rises by approximately 300 degrees Centigrade.

Helium effects on tungsten under fusion-relevant plasma loading conditions, J.Nucl.Mater. (2013) Volume 438, Supplement, July 2013, Pages S78–S83





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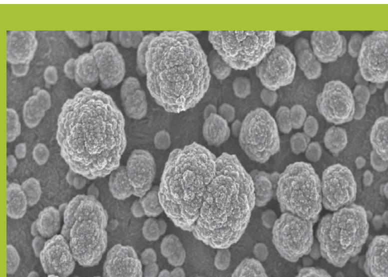
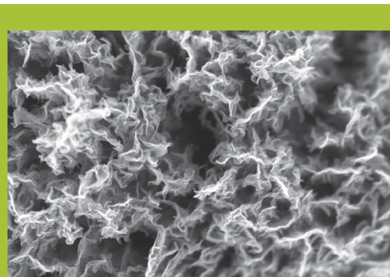
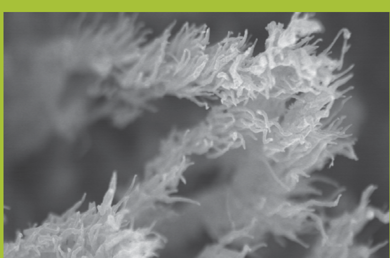
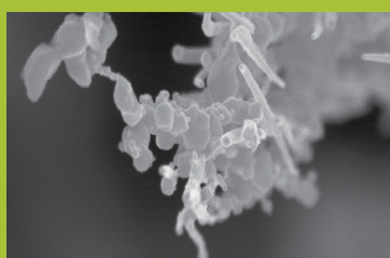
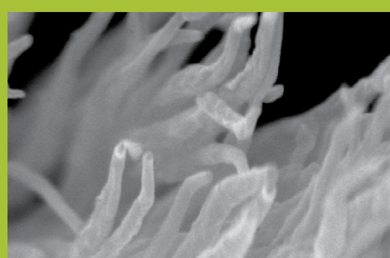










2.2 Fusion

Control of burning plasma

Fusion research aims to develop a clean, safe and sustainable energy source based on the process powering the sun and stars. With the construction of the ITER experiment in Cadarache in France, a global effort is underway to build the first ever fusion reactor to produce more power from fusion than the device requires: a so-called burning plasma.

In the burning ITER plasma, which will be the first reactor dominated by alpha particle heating, magnetohydrodynamic (MHD) instabilities arise which can both enhance and decrease the reactor performance. Active control of the MHD instabilities will allow tuning of the plasma and reaching the planned tenfold greater power output from the fusion process than is injected via the reactor's heating and control systems.

The research groups in the program Control of burning plasmas study the physics underlying the active control of instabilities in burning plasmas and are directly involved in the design of ITER components. The development of high resolution multi-channel diagnostics allows the measurement of small scale structures in hot magnetized plasmas. These novel diagnostics concepts lead to new insights in plasma physics, which feed into the development of sensors, actuators and models for the control of MHD instabilities. The diagnostics and control work are supported and inspired by mathematical and numerical modelling of MHD instabilities and their real-time control.

Partners

The experimental work of the division is largely focused on the ASDEX-Upgrade tokamak in Garching (Germany) and the Joint European Torus (UK), with some smaller activities ongoing at the tokamaks TCV (Switzerland), MAST (UK) and Tore Supra (France). The instrumental work for ITER is organized within the framework of ITER-NL, a consortium consisting of four Dutch research institutes: TNO, DIFFER, NRG and Eindhoven University of Technology. ITER-NL aims to facilitate front-line participation of Dutch researchers in the scientific exploitation of ITER and additionally to enable Dutch companies to have strong participation in ITER.

Together with HIT and Dutch Space, DIFFER exploits a state of the art virtual reality simulation of ITER to validate remote handling maintenance procedures.

Program leaders

M.R. de Baar, P.C. de Vries, E. Westerhof

Grants

Jonathan Citrin - Young Energy Scientist Fellowship (4 years post-doc at CEA/DIFFER)
Dmitry Moseev - European Fusion Researcher Fellowship (2 years post-doc at IPP)
Matthijs van Berkel - Japan Society for the Promotion of Science Fellowship (1 year stay at NIFS)

Funding

FP-120 - Advanced Control of Magnetohydrodynamic Modes in Burning Plasmas, ITER-NL2, EURATOM, EFDA, EFP, NWO, NWO-RFBR CoE, TU/e, US-DOE

Collaborations

ASIPP, Hefei, China; CCFE, Culham, UK; CEA, Cadarache, France; CWI, Amsterdam, NL; DTU, Risø, Denmark; EPFL-CRPP, Lausanne, Switzerland, ERM-KMS, Brussels, Belgium; FZJ, Jülich, Germany; IAP, Nizhny Novgorod, Russia; Ioffe St., Petersburg, Russia; IPP Garching, Germany; IPF Stuttgart, Germany; ITER IO, Cadarache, France; KIT, Karlsruhe, Germany; Kurchatov Institute, Moscow, Russia; NFRI, Daejon, Korea; NIFS, Toki, Japan; NRG, Petten, NL; SWIP, Chengdu, China; TNO, Delft, NL; TU/e, Eindhoven, NL; UC-Davis, US; University of Pohang, Korea

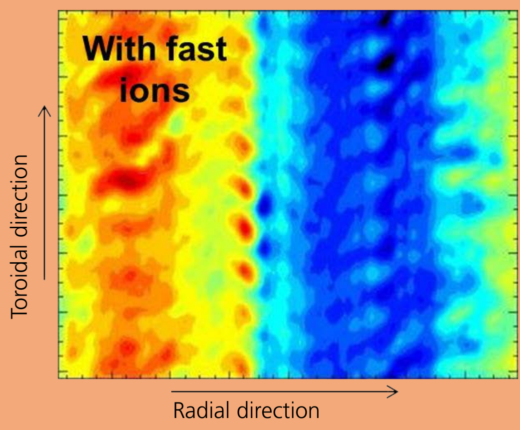
Fast ions, and not rotation stabilise fusion turbulence

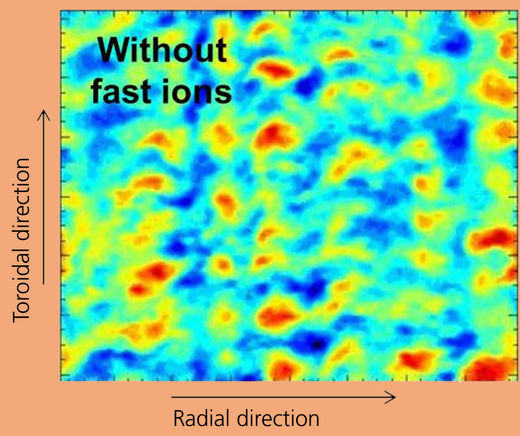
Turbulence in the hot plasma at the heart of a fusion reactor or tokamak can leak heat from the plasma, degrading the reactor performance. In the Joint European Torus tokamak (JET) a plasma regime exhibits improved heat confinement of ions in the plasma core.

Electromagnetic stabilization of ion temperature gradient (ITG) microturbulence is found to be significantly enhanced by fast ions. This effect is key to understanding a hitherto unexplained improved core ion heat confinement regime in JET L-mode, previously attributed to concomitant high rotational shear and low magnetic shear, The new findings show that rotational flow shear cannot fully explain the improved confinement. Rather, increased fast ion suprathermal pressure - co-correlated with the increased flow shear – can explain the observations. These results were achieved through extensive non-linear simulation scans with the GENE gyrokinetic code. The simulations included both electric and magnetic field fluctuations and multiple ion species including fast ions induced by neutral beam injection and ion cyclotron heating. The inclusion of this physics was key to resolve the stabilization effects. This extended simulation capability was possible due to the recent expansion of available supercomputing power.

A total of approximately 8 million CPU hours (at the HPC-FF and NERSC supercomputers) were used for this work. These results have positive ramifications for ITER and future reactors, which are not expected to have significant flow shear but which will have a significant suprathermal pressure fraction due to the fusion α-particles. The extrapolation may particularly improve for so-called "hybrid" advanced scenarios, which are expected to have an even greater suprathermal pressure fraction compared with standard scenarios due to reduced density. Presently, the analysis is being extended to high power JET hybrid scenarios in H-mode, to increase confidence on the extrapolation of this effect.

Nonlinear stabilization of tokamak microturbulence by fast ions, Phys. Rev. Lett. 111 (2013) 155001

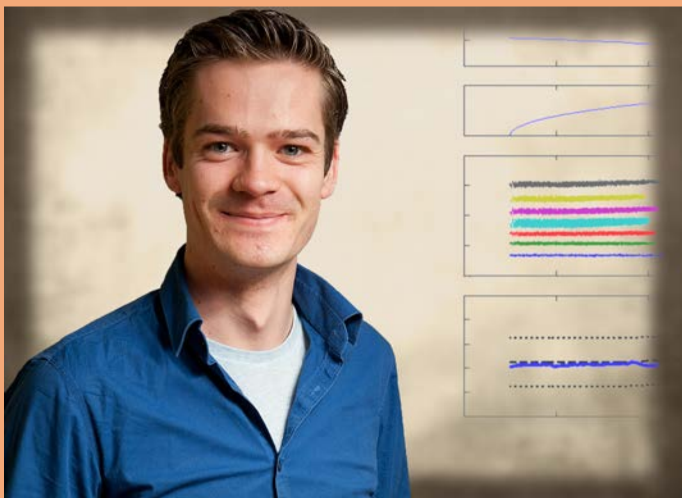




Comparison of electrostatic potential fluctuations in GENE nonlinear gyrokinetic simulations of a JET discharge, when including and neglecting the impact of fast ions. With fast ions, the radial stratifications introduced by zonal flows are much more pronounced, which leads to a reduction of the fluxes responsible for the leakage of particles and heat from the system.

Diagnostics to detecting rotating magnetic islands in ITER

Detection and localization of metastable, rotating magnetic islands is an important requirement for control of the plasma in the ITER fusion reactor. To analyze different detection and localization algorithms, PhD student Hugo van den Brand (photo) developed a simulated electron cyclotron emission (ECE) radiometer in collaboration with Eindhoven University of Technology. The optimal IF bandwidth of the radiometer is determined at 300 to 400 MHz. This allows both a timely detection (within 1 second after the initial destabilization of the island) and an accurate localization (within 0.5% of the tokamak minor radius) of the island.

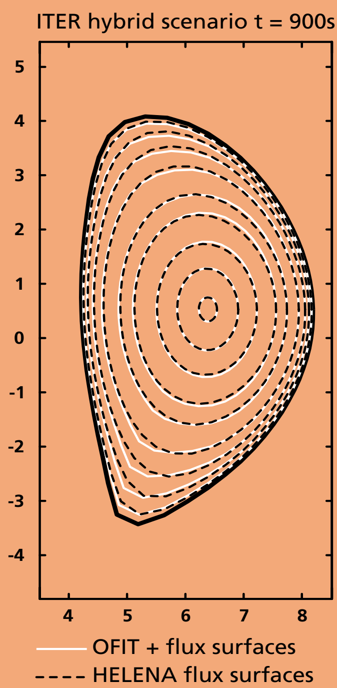


Evaluating neoclassical tearing mode detection with ECE for control on ITER, Nucl. Fusion 53 (2013) 013005

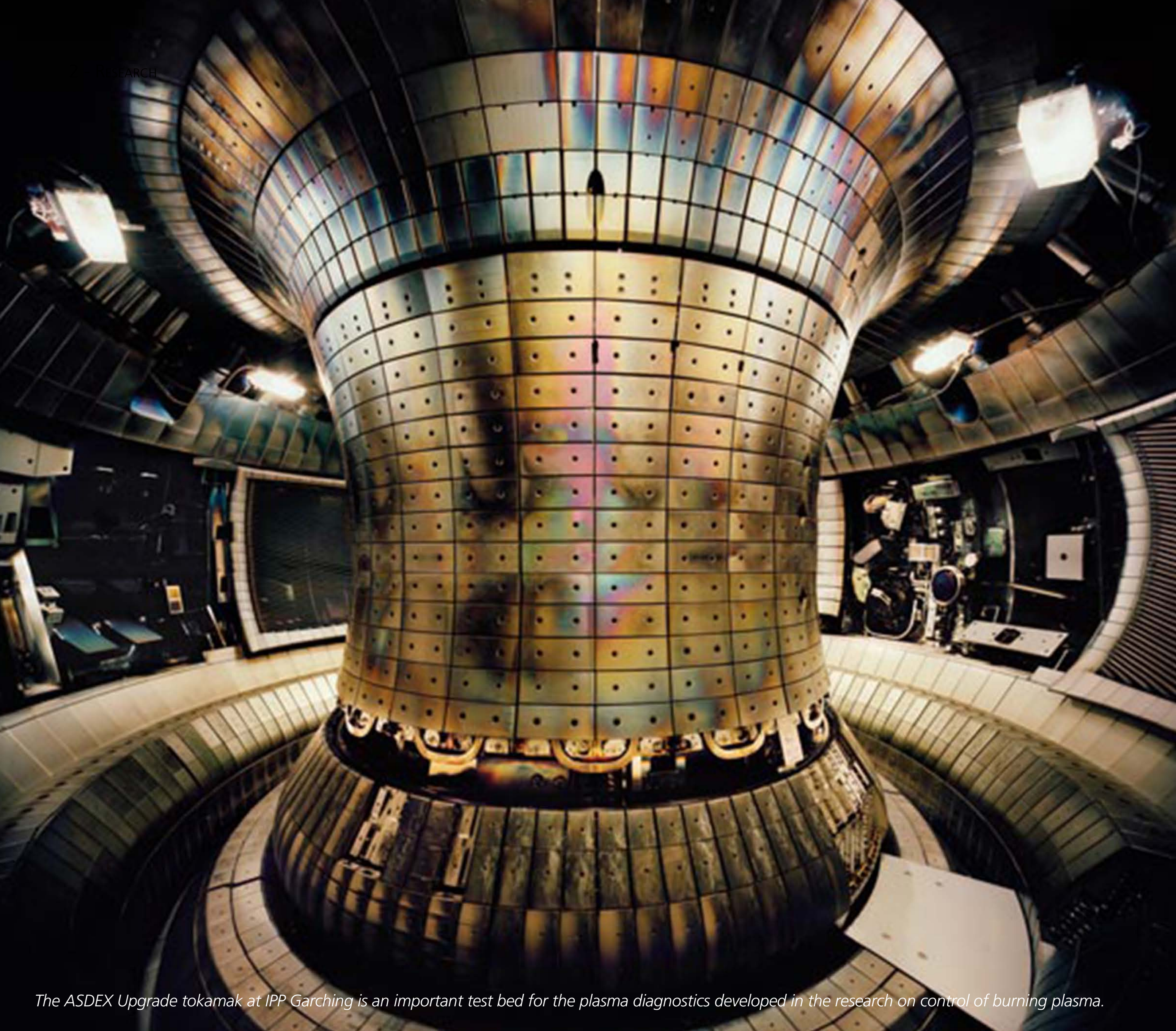
TU/e Technische Universiteit Eindhoven University of Technology

Optical inspection reveals invisible plasma layering

In a tokamak fusion reactor, the winding magnetic fieldlines and layered flux surfaces are important quantities for the performance and stability of the plasma. Normally, these quantities are iteratively derived by solving plasma equilibria. PhD student Gillis Hommen now demonstrates a new optical technique which quickly infers the invisible plasma structures from the visibly glowing plasma edge at a fraction of the computational cost. Comparisons with the CRONOS code for the plasma regimes in the tokamaks ITER, JET and MAST yielded better than 1% agreement for the flux surface positions, and better than 10% agreement with the inferred profiles for magnetic field winding. The Optical FIT (OFIT) technique will be tested further on the Swiss TCV tokamak at EPFL.



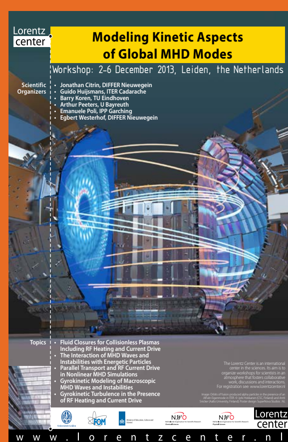
A fast, magnetics-free flux surface estimation and q-profile reconstruction algorithm for feedback control of plasma profiles, Plasma Phys. Control. Fusion 55 (2013) 025007



The ASDEX Upgrade tokamak at IPP Garching is an important test bed for the plasma diagnostics developed in the research on control of burning plasma.

Novel Thomson scattering systems on multiple tokamaks

In 2013 the diagnostics group within DIFFER has participated in many developments in Thomson scattering (TS) systems. Contributions include; the correction to JET core LIDAR TS calibration via ray tracing, participation in the optical design and performance analysis for divertor Thomson scattering on MAST Upgrade, proving a new method for characterization of dust particles in TEXTOR using TS, and also contributions to develop the first Thomson Scattering system to measure bootstrap current density profiles at ASDEX Upgrade.



Workshop

In December 2013 a workshop on Modeling Kinetic Aspects of Global MHD Modes was organized at the Lorentz Centre in Leiden. The fact that a fusion plasma is almost collisionless poses intricate problems when one wants to combine a fluid description of the plasma with kinetic effects. The goal of the workshop was to bring together experts from the different fusion plasma modeling communities to discuss how to simultaneously implement their approaches.

2.3 Solar fuels

Sustainable energy storage

Large scale implementation of renewable energy sources in our current energy infrastructure involves balancing the differences in time and location of energy generation and consumption. Efficient storage and transportation is essential to overcome these supply-demand mismatches of particularly wind and solar energy. An attractive solution is energy storage in chemical bonds, for example by using CO_2 and H_2O as feedstock for the production of CO_2-neutral solar fuels.

The DIFFER solar fuels research and development program is driven by the need for cost-effective production of solar fuels and the use of abundantly available materials. The central theme is to achieve power efficient dissociation of CO_2 or H_2O (or both). Subsequently, established chemical conversion methods (Fisher-Tropsch, Sabatier, etc.) may be applied to convert the resulting CO and H_2 into the fuel of choice. Specifically, DIFFER is exploring the use of plasma for efficient CO_2 conversion, materials for photo-electrochemical water splitting, and membranes for fuel conversion applications.

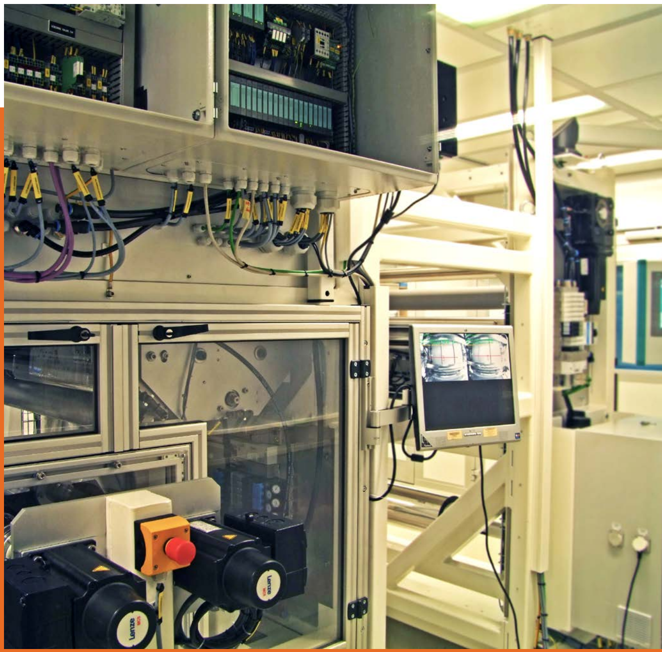
Most of the worldwide research efforts in solar fuels are directed at the splitting of water into hydrogen and oxygen. The quest is to develop a scalable, earth abundant catalyst for this process. DIFFER contributes in this area with research on alternative metal oxide materials and structures as well as the investigation of the electrochemistry of so-called photo-electrochemical cells. Such devices provide the photocatalytical dissociation of water into hydrogen and oxygen, opening directly the storage of solar energy in molecular hydrogen.

Teaming up with Fujifilm

A new FOM industrial partnerschip programme (IPP) between DIFFER and Fujifilm investigates the production of silica-plastic systems with atmospheric pressure plasma processing. A potential application of such systems is as membrane to separate solar fuel relevant mixtures such as CH_4 and CO_2 or CO_2 and N_2.

A promising route for CO_2-neutral fuel production involves the dissociation or activation of CO_2 by means of plasma, possibly combined with catalysis. The essence of the current plasma CO_2 conversion research is understanding and controlling the non-equilibrium between translational and vibrational degrees of freedom of the feedstock molecules (CO_2). Ultimate energy efficiencies become viable by directing the input power preferentially into vibration of the molecules, in effect into bond breaking.

Instrumentation for thin layer deposition with atmospheric plasma at Fujifilm Research in Tilburg, NL



Program leaders

M.A. Gleeson, G.J. van Rooij, H.W. de Vries

Funding

NWO program CO_2-neutral fuels; TKI Gas, Topsector Energy

Collaborations

Fujifilm Research, Tilburg, NL; IPP Stuttgart, Germany; Radboud University Nijmegen, NL; TU/e Eindhoven, NL; University of Antwerp, BE; University of Leiden, NL; University of Twente, Enschede, NL

Awards

Christine Verbeke, BSc research prize 2013 of the VSNU - Dutch Universities Association

Topsector project for plasma production of hydrogen

In a collaboration with Alliander, Energy Valley, and Nederlandse Gasunie, DIFFER is investigating an alternative to electrolysis of water by producing hydrogen out of water and CO_2 via plasmolysis. This project is the first awarded to DIFFER out of the Dutch Topsector initiative, which is designed to stimulate public-private collaboration on key societal challenges.

In-house at Fujifilm: investigating atmospheric plasma deposition

How to harness flickering plasma channels for the creation of functional films with applications in sustainable energy? To tackle this question, tenure track group leader Hindrik de Vries will head a new scientific group within DIFFER. The research is funded by a new public-private Industrial Partnership Programme between DIFFER and Fujifilm and De Vries' research group will be stationed at the Fujifilm site in Tilburg, the Netherlands. There, the two partners will investigate the fundamental behaviour of plasma in the context of large scale advanced materials production using atmospheric plasma deposition. This will lead to a powerful technology platform for the creation of functional foils with a large spectrum of applications.

The research in the new research group will focus on atmospheric plasma processing of functional films, a specialty of industrial partner Fujifilm. Fujifilm Manufacturing Europe has developed a novel atmospheric pressure plasma that can deposit silica layers on plastic substrates. These silica layers are dense and smooth and have excellent moisture barrier properties. The silica layers can meet the moisture barriers requirements for thin film solar cell applications. Since the moisture permeation is governed by a nano-porous structure, the silica layers may also be exploited as gas selective membranes, for applications such as CH_4 / CO_2 or CO_2/N_2 separation.

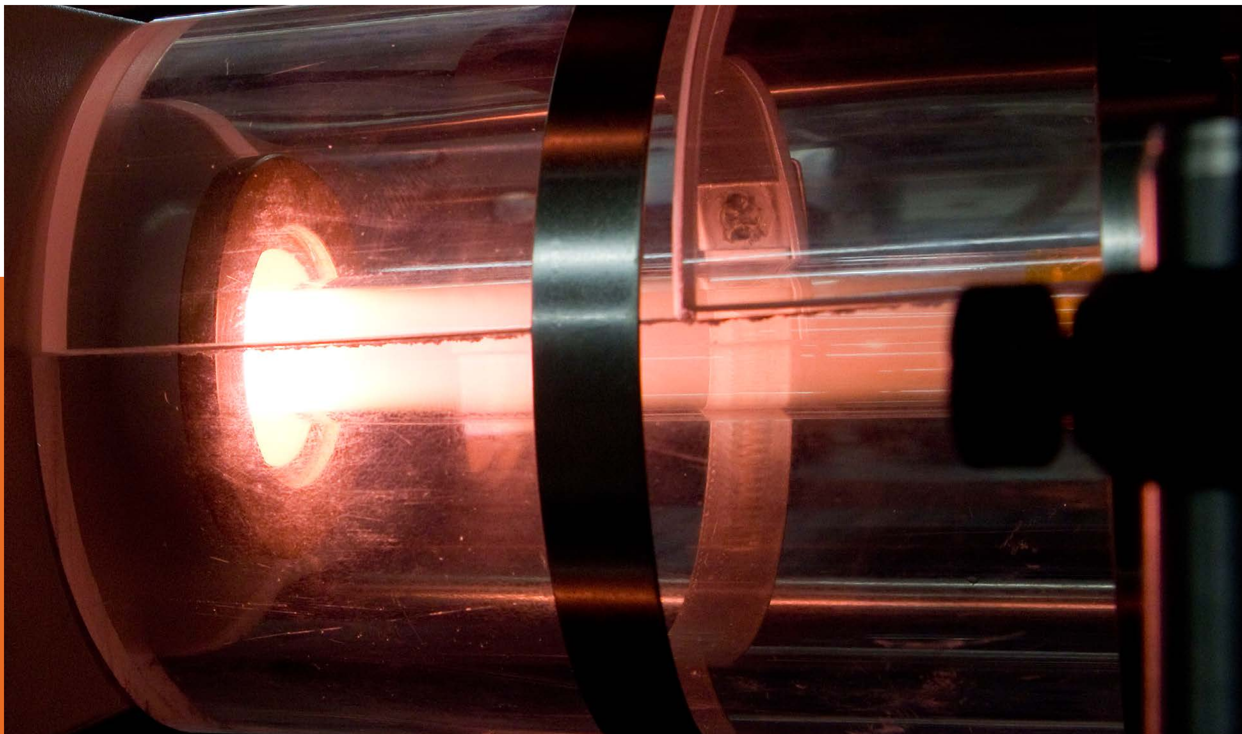
Aiming to convert intermittent sustainable energy into fuels that match the existing infrastructure

Three projects on CO_2-neutral fuels awarded

Mike Gleeson and Gerard van Rooij from DIFFER's solar fuels research theme, together with colleagues from four Dutch universities, are starting three research projects on the clean production of fuels from water and CO_2. The research is financed by Shell, FOM and NWO and is part of the NWO program CO_2-neutral fuels. In total, seven research projects received funding within this program, which is coordinated by DIFFER.

Gleeson's project "Direct Production of Fuels from Captured CO_2" aims to integrate plasma-enhanced CO_2 conversion with its release from a solid capture material. In collaboration with the University of Twente (L. Lefferts) he seeks for substantial process enhancement at both the macroscopic (integration) and the molecular (enhance chemistry) levels. The other project in which Gleeson is involved is "Surface Reactivity of Activated CO_2", together with the University of Leiden. Here, the influence of material properties (structure and composition) on the surface reactivity of plasma-excited CO_2 molecules will be studied. Molecular beams with controlled excitation of specific vibration modes will be combined with state distribution analysis on plasma excited CO_2 beams to disclose pathways of enhanced CO_2 conversion.

Van Rooij's project "Plasma Chemistry at Work: efficient plasma-assisted fuel conversion through control of vibrational excitation" concerns a collaboration with Eindhoven University of Technology (R. Engeln) and the Radboud University Nijmegen (G. Berden). In this project, the intrinsic CO_2 vibration excitation in the plasma will be perturbed through resonant infrared pulses. Probing the evolution of these perturbations will elucidate the role and dynamics of vibrational excitation in plasma chemical reduction of CO_2.



Above: Solar fuels plasma. Opposite: Plasma reactor at DIFFER used to study efficient plasma conversion of CO_2 to CO, one of the ingredients for the production of hydrocarbon, e.g. methane

Solar fuels control system

The new solar fuels setup at DIFFER uses a CODAC tool for Control, Data Access and Communication. This system is based on the control system designed and built in-house for DIFFER's linear plasma generator Magnum-PSI. From a common code base, the ICT department has now derived separate branches for the solar fuels and plasma surface interactions experiments.

2.4 Nanolayer Surfaces and Interfaces

Transition to University of Twente

The nSI division aims to perform high-quality scientific research in the fields of surface science and thin film and interface physics. The research includes photo-chemical phenomena, photo-conversion processes, and the solid state and interface physics of short-wavelength optics. The latter primarily concerns multilayered reflective coatings relevant for the 'XUV wavelength band' ranging from the soft X-ray to the VUV. In particular, the division studies the boundary areas between these topics: the use of XUV optics, for instance, generates exciting research questions in the field of photo-induced surface chemistry, as in Extreme UV-induced optics contamination.

A key feature of the research in the nSI division is its industrial and societal relevance: the investigations are usually motivated by application of the knowledge in plasma surface interaction phenomena as e.g. in advanced photo-lithography optics or in the utilization of multilayer reflective optics for radiation sources with highest brightness.

The industrial relevance formed the basis for a new activity, which has been formulated in the frame of the national innovation policy by the Dutch government: the establishment of the industrial-related research group 'XUV Optics', being founded at the MESA+ Institute for Nanotechnology at the University of Twente. This is a brand new type of organization of research, directly linked to the new governmental 'Topsectoren' innovation policy.

The division's research is carried out in three research groups. Research on the behaviour of thin single and multilayered films down to atomic scale processes provides the foundation of the departments research. The development of physics and technology for XUV and soft X-ray multilayer optics for various applications builds on this basic research. Of special mention is the extramural EUV Lab research group within ASML Research, which focusses on the photochemistry at surfaces upon EUV illumination up to intensities causing non-linear processes.

Transition to University of Twente

Upon the successful establishment of the Industrial Focus Group XUV Optics by late 2012, the division started its relocation to MESA+ at Twente. The experienced permanent staff committed itself to moving to this nationally leading institute in the Netherlands, with great prospects for accelerating the XUV Optics research. Running PhD projects are being continued with minimal interruption and new staff has been appointed to reinforce the XUV Optics group at Twente. A 500 m^2 laboratory was built, including an over 4 M€ investment in new, state-of-the-art equipment. Much of the existing, thin film instrumentation was transported from Nieuwegein to Enschede, and arranged in the new

Division leader

F. Bijkerk

Program leaders

C.J. Lee, E. Louis, A. Yakshin

Funding

FOM Industrial Partnership Programmes FP-I10 and FP-I23, AgentschapNL, ASML, Carl Zeiss SMT, CATRENE programme of the EC, FOM, M2i, NanoNext, STW

Collaborations

ASML Research, Veldhoven, the Netherlands; Carl Zeiss SMT GmbH, Germany; Delft University of Technology, the Netherlands; DEMCON, Oldenzaal, the Netherlands; Eindhoven University of Technology, the Netherlands; Institute for Plasma Physics, Warsaw, Poland; Institute for Spectroscopy, Troitsk, Russia; Institute of Crystallography, Moscow, Russia; Lawrence Berkeley National Laboratory, USA; Lebedev Physical Institute, Russia; MESA+ Institute for Nanotechnology, University of Twente, the Netherlands; Moscow State University, Russia; PANalytical, Almelo, the Netherlands; Physikalisch Technische Bundesanstalt Berlin, Germany; SolMateS, Enschede, the Netherlands; SRON Space Research, Utrecht, the Netherlands; TPD/TNO, Delft, the Netherlands

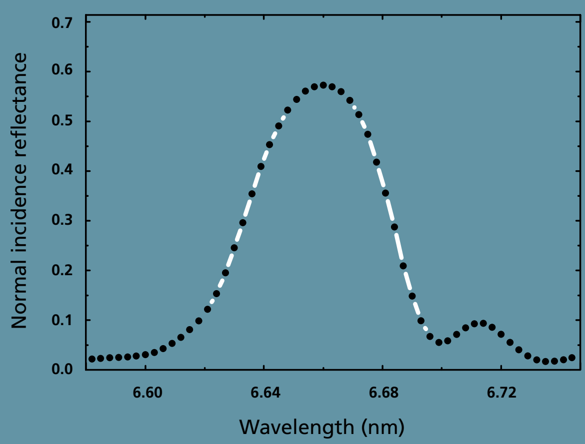
Part of the new 500 m² large XUV laboratory at MESA+ dedicated to thin film and multilayer research

laboratory. The full move is ahead of schedule by about 4 months with respect to the formal completion by 1 July 2014. The Focus Group is funded by a consortium of industrial participants, the regional government and the MESA+ Institute for Nanotechnology. Industrial parties include ASML, Carl Zeiss SMT, PANalytical, DEMCON, SolMateS, and others. Together they raised the funding for an eight year research programme with a 20M€ budget. In return, the industrial participants have aquired a right in the intellectual property developed in the Focus Group. The parties are selected based on their complementary industrial competence so that new innovations can be developed jointly right from the very initial stages of know how.
The themes in the Focus Group are selected on basic physics aspects of thin film and multilayer systems within the areas of the applications. Clever choices allow both the fundamental research and high quality scientific output as well as a high probability of industrial spin-off.

World reflectivity record beyond the EUV wavelength range

nSI has demonstrated a new world record of normal incidence reflectivity of 57.3% at 6.6 nm wavelength, the next candidate lithography wavelength. This record, up from the previous value of 45%, was achieved with a state-of-the-art LaN/B multilayer mirror containing 175 layer periods. To this end the LaN layer deposition was optimized, while for further progress a unique feedback method is inserted between the analysis of the structure of deposited multilayers and their deposition process.

Short period La/B and LaN/B multilayer mirrors for ~6.8 nm wavelength, Optics Express, 2013, 21(24): p.29894-29904



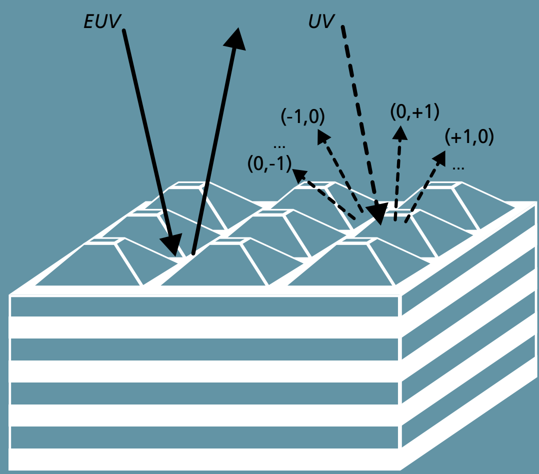
Nanopyramids on multilayer mirror clean up extreme UV light

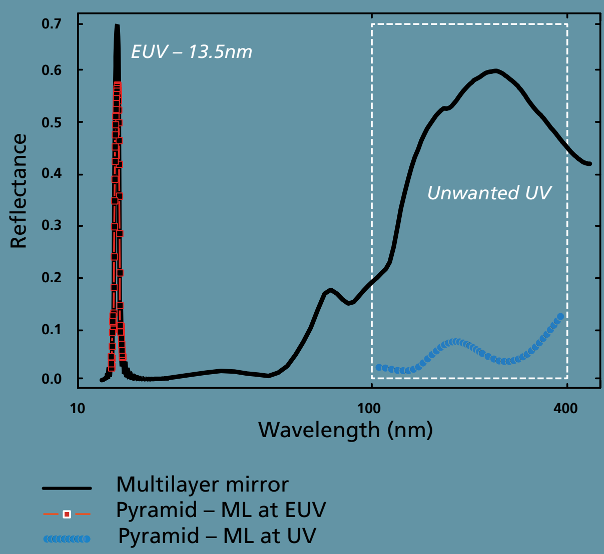
The combination of multilayer mirrors with diffraction structures provides new freedom to modify the spectral response of XUV optics. It allows the control of the spatial distribution of different wavelengths with high efficiency so that a higher spectral selectivity or higher spectral resolution can be achieved compared to a standard multilayer mirror. For example, a UV spectral filter for broadband XUV sources is demonstrated through combining novel diffraction pyramid structure with a multilayer mirror. This is of particular importance for EUV photolithography, as the typical light source used there emits a large amount of UV light (λ=100-400nm) which will cause a loss of image contrast.

The EUV-transparent but UV-reflecting material silicon was used to make the pyramid structure on top of the multilayer. The EUV light is reflected by the multilayer underneath, while the broadband UV light will be diffracted to higher orders away from the reflection direction of the multilayer. A top flat area was included in each pyramid structure to generate destructive interference and further suppress the UV reflection.

A pilot device of 100nm-high Si pyramids was fabricated by using a straightforward deposition scheme. The reflectivity measurements show an effective suppression of 14 times over the whole UV band with a maximum of >300. Moreover, the EUV reflectivity of this pyramid-multilayer system still reaches a good value of 56.2% which is better than alternative approaches. This broad suppression effect is not sensitive to the incident angle (up to 40 degrees to normal) so it can be applied to large XUV mirrors in industrial applications. This novel scheme of spectral filter is applicable to a variety of XUV sources with a broadband emission spectrum, like plasma sources, high harmonic generation, or solar irradiation, in order to select the target wavelength with high efficiency and purity. With the synergy of the XUV group and MESA+ Nanolab, more possibilities on multilayer-diffraction optics with unprecedented spectral properties will be explored.

UV spectral filtering by surface structured multilayer mirrors, Optics Letters 2014, Vol. 39, No. 5

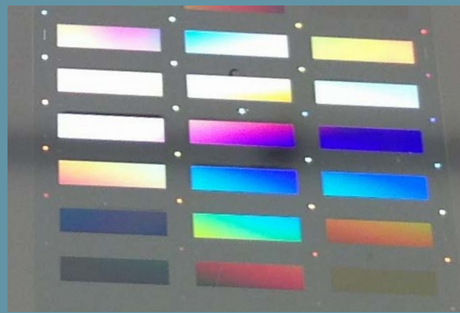




Geometry of an UV diffractive pyramid structure to clean up EUV light beams from parasitic UV light. The reflectance plot shows a 14x suppression of unwanted UV

Integrated infrared spectral filter for Extreme UV mirrors

The novel XUV group at Twente managed to successfully fabricate a powerful new diagnostic for the XUV wavelength band: high resolution transmission gratings with line densities as small as 10.000 lines per millimeter. Extensive clean room processing and the use of nano-imprint lithography (NIL) was used to arrive at the free-standing transmission gratings with bar structures down to 50 nanometer. This activity involved two SMEs and included MESA+ member Dr Bastiaens.

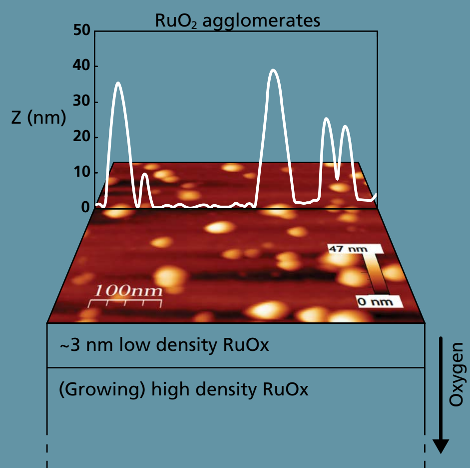


Transmission grating spectroscopy in the EUV and VUV, P-SO-63, Sematech International Symposium on EUVL, Toyama (2013)

Silicon chip holding 21 transmission gratings with line densities ranging from 500 up to 10.000 lines/mm, reproducibly fabricated by nanoimprint lithography

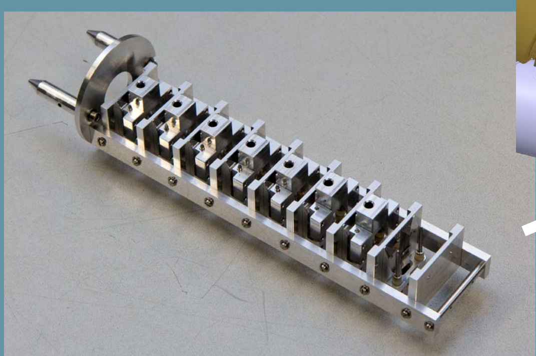
Surface and sub-surface thermal oxidation of ruthenium thin films

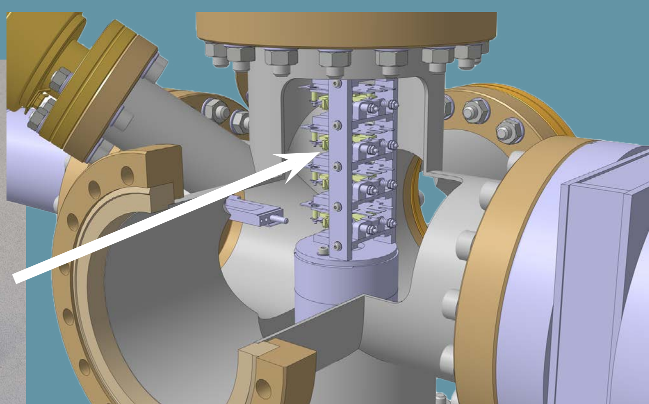
Oxidation of Ru thin films is important for many applications including catalysis, electronics and optical coatings. Above a temperature of ~200°C, high surface mobility of oxygen leads to formation of polycrystalline RuO_2 agglomerates at the Ru surface. At the same time, oxygen diffusion into the Ru layer leads to growth of sub-surface low density, and buried high density RuO_x layers. These results can be used to optimize growth conditions of Ru and RuO_x thin films.



Sample holder

The nSI division's multilayer coating and diagnostics equipment is connected via a transfer system in vacuum. To enable temporary 'parking' of samples without breaking vacuum, the in-house drawing office and workshop produced this sample holder, which will be installed in the group's new laboratory at the University of Twente.





3

Community building

The transition to a fully sustainable energy infrastructure is one of the grand challenges facing us this century. For the Netherlands to tackle this task, it needs a strong and coherent national research program. DIFFER wishes to play a national role in basic energy research by helping develop a multidisciplinary community focused on science for future energy.

A well-connected and collaborative network of researchers working on energy-related topics is a promising soil for scientific collaboration and breakthroughs. Equally important to universities, research institutes and industries, it provides new opportunities for collaboration to strengthen and extend one's own research. Moreover, innovative breakthroughs are prone to arise on the cutting-edges of the scientific disciplines brought together in such a research community.

As of May 2013, DIFFER has appointed a research development officer to organize activities in close collaboration with other institutes, research schools and universities to spark the formation of a this energy community. Dr. Erik Langereis works to connect to and cross-link existing networks, but also to organize new activities in order to attract a multidisciplinary audience from research, small to medium enterprise and industry.

To strengthen the position of the Netherlands in the international field of energy research, two FOM focus groups have been established at the University of Groningen and at the research institute AMOLF. As part of the DIFFER network, they contribute to building a community of researchers working on fundamental aspects in the global energy challenge.

Workshop series: Science & the Energy Challenge

DIFFER helps to build an energy research community on the basis of scientific content. To this end the workshop series "Science & the Energy Challenge" is initiated as a format to discuss various aspects of the global energy challenge. The common nominator of each workshop is the strive to formulate the fundamental research challenges in such way that those working in and out of that field (almost) feel it as a missed opportunity not to attend.

The workshop series is chosen to be an open format to encourage those interested to adopt it for future workshops to be organized. Besides bringing researchers together, the intention is to give each of the workshops a relevant outcome, such as preparation of a white paper for new research programs, a kick-off event of national programs (e.g. NWO program CO_{2}-neutral fuels) or defining

Facilitating workshops to build a community on energy research

www.scienceandtheenergychallenge.nl

Developing a multidisciplinary community focused on science for future energy

use-inspired research questions in close collaboration with SMEs and industries. In national and international research networks, DIFFER represents the Dutch energy research community. We intend to contribute to the agenda for energy research and to (scientific) preparation of future project calls, such as for the Dutch Top Sectors and the European Horizon 2020 programs. By connecting to and collaborating with SMEs and industry, we address and contribute to use-inspired innovation challenges.

Fusion

Over the years, DIFFER has built up a strong track record on scientific excellence in the field of fusion energy. DIFFER fulfills a coordinating role as a recognized member in various organization bodies related to fusion energy, such as within EUROfusion (the Horizon 2020 successor of the European Fusion Development Agreement EFDA), Fusion for Energy (F4E) and EURATOM. Nationally, DIFFER and its industrial liaison officer (ILO) are active in the ITER-NL consortium of SME and industry (see section 4), which has among others aligned its activities within the Top Sector High-tech systems and materials (HTSM).

Solar fuels

Nationally, DIFFER is representing basic research on energy storage in chemical form in the top sectors Energy and Chemistry, especially in the top consortia for knowledge and innovation (TKI) Institute for Sustainable Process Industry (ISPT), Bio-based economy (BBE) and lastly Gas, where DIFFER's director Richard van de Sanden was appointed to the governing board as representative of NWO. In October 2013, DIFFER organized a session together with ISPT for representatives of several large industries in order to define economically and technologically promising routes for CO_2 re-use in processing industries.

Internationally, DIFFER became a member in the divisions Energy Storage and Advanced Materials and Processes for Energy Application (AMPEA) of the European Energy Research Alliance (EERA). Here we are contributing to a Horizon 2020 project proposal on chemical storage routes. As a new partner to the UK-based CO_2CHEM network on carbon capture and utilization, we contributed to the formation of a separate cluster on plasma technology. Currently, we are forming a consortium to submit a proposal for the Future and Emerging Technologies (FET) sector in Horizon 2020.

The DIFFER network of organizations and research collaborations

The growing network for energy-related R&D is a promising soil for scientific collaboration and breakthroughs

4

Knowledge transfer to society

One of DIFFER's strategic goals is transfering knowledge to society at large. The institute focuses its outreach efforts on secondary to higher education and the general science-interested public, matched by a strong outreach effort to SME's and industry.

Connecting to industry

DIFFER strongly pursues contact with industry to both inspire its research and as the pathway to turning fundamental energy research into practical applications. The research on nanolayer surfaces and interfaces is of high industrial relevance to e.g. advanced photo-lithography optics. In 2013 the group started its relocation to Twente University as the core of the new Industrial Focus Group on XUV Optics (see page 20).

In its solar fuels theme, the institute is building consortia of companies that can develop the diverse technologies needed for large-scale conversion of sustainable energy into fuels.

In the fusion theme, DIFFER helps optimise Dutch scientific and industrial participation in the international ITER project as part of the Dutch consortium ITER-NL. The consortium organises industrial missions and conference representation for companies interested in participating in ITER. As part of its ITER-NL activities, DIFFER employs the national Industrial Liaison Officer (ILO) to inform interested companies about ITER-related opportunities via workshops, a newsletter and the ITER-NL website.

Education

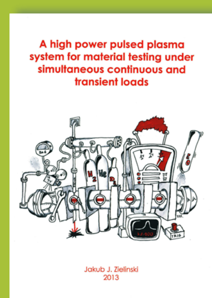
DIFFER is keen to play a role in educating the next generation of energy scientists and PhD students are an integral part of the institute's scientific staff. In 2013, 39 PhD candidates performed research at DIFFER and eight of them successfully defended their PhD thesis at a Dutch university. The average PhD period at DIFFER is 4.5 years, slightly shorter than the national average. DIFFER's science staff both supervises the PhD candidates and serves on thesis defense committees at home and abroad.

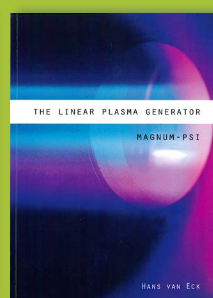
The institute also welcomes higher education interns for three to twelve month MSc or BSc research projects. Six staff members held a part-time professorship at a Dutch university, and together with five more scientific staff (co-) taught twenty courses at the BSc or MSc level.

At the secondary school level, DIFFER supports an elective lessons module for the science subject NLT (nature, life and technology). Students explore the design steps leading to a fusion reactor, and can experiment with a dedicated Paschen curve setup at DIFFER.

Prizes

Bachelor student Christine Verbeke (left) received the VSNU 'best bachelor research' prize for her theoretical work on plasma dissociation of CO_2. Verbeke was the first student to do a research project within DIFFER's new solar fuels theme.





Students at DIFFER

39	10	2
PhD students	University students	Technical apprentices

Fusion Road Show

For a different take on fusion, schools can book the Fusion Road Show. This dynamical performance showcases the principles of fusion and explains how fusion can help tackle the energy challenge. In 2013, the Fusion Road Show reached over 4000 high school students at Antwerp University's biennual Fusion Days, via school visits and during DIFFER's two open days. The show also featured as the 'closing 'act' of the Woudschoten chemistry teachers' conference. Custom versions were performed at the Robeco Investors Day 'Energy Revolutions' and at KIJK Live!, a science café hosted by the Dutch popular-science magazine KIJK.

General public and media

In 2013 the research on fusion and on CO_2-neutral fuels was covered in national newspapers and popular-science magazines. As the national centre for fusion research, DIFFER was approached for reactions on the ongoing ITER construction and Dutch industrial involvement, and for comments on work at the U.S. National Ignition Facility. Finally, the start of construction of the new building in Eindhoven generated a new and continuing stream of radio and newspaper articles in the Eindhoven region.

DIFFER organised two open days for secondary to university level students and for the general public. See the online Appendix for the full list of outreach activities.

The national television science programme Labyrint explored the concept of re-using CO_2, with a prominent role for DIFFER in interviews with researchers Waldo Bongers and Richard van de Sanden.

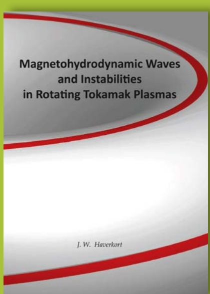
http://goo.gl/hhuDH4

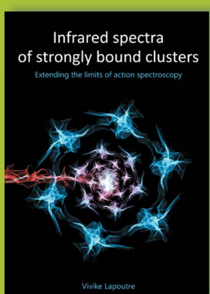
On January 15th 2013, PhD researcher Willem Haverkort (DIFFER and CWI) was interviewed on fusion energy in prime time science talkshow "De Wereld Leert Door", hosted by Matthijs van Nieuwkerk.

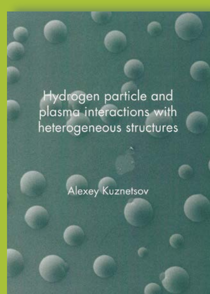
http://goo.gl/BBeFhl

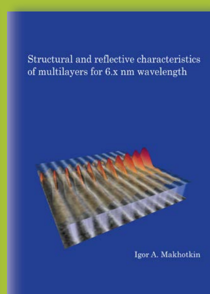
PhD theses 2013

Eight PhD students conducted their research at DIFFER and successfully defended their thesis in 2013: Jakub Zielinski, Hans van Eck, Willem Haverkort, Vivike Lapoutre, Jeroen Bosgra, Alexey Kuznetsov, Igor Makhotkin and Bircan Ayten.









News clippings

Fuji: drie miljoen voor onderzoek

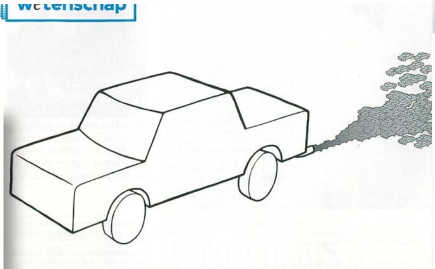
Een bijzondere samenwerking tussen wetenschap en bedrijfsleven krijgt vorm in de vestiging van Fujifilm in Tilburg.

door **Johan van Grinsven**

TILBURG – Fujifilm in Tilburg gaat samenwerken met energie-instituut Differ om efficiënter energiezuinige folies te kunnen produceren. Fujifilm steekt drie miljoen euro in deze samenwerking, die vijf jaar duurt. Volgens prof. dr. ir. Richard van de Sanden, directeur van Differ, is het bijzonder dat een Japans bedrijf kennis deelt met Nederlandse wetenschap-

stituut uit Nieuwegein bij Fujifilm. Het is de bedoeling dat het Tilburgse bedrijf en Differ samen geavanceerde plasmatechnologie gaan ontwikkelen voor materialen met uiteenlopende toepassingen. „Het is een project voor de lange termijn. Meestal kijken bedrijven maar een paar jaar vooruit, in dit geval hanteert Fujifilm een lange-termijnvisie", aldus Van de Sanden. Volgens de Tilburger past deze

de zogeheten topsectoren. Energie is zo'n topsector. Met ongeveer 850 werknemers is Fujifilm Tilburg een van de grootste productievestigingen van Fujifilm buiten Japan. Hier worden fotopapier en offsetplaten geproduceerd. Ook verricht Fujifilm onderzoek om producten te vernieuwen en nieuwe producten te ontwikkelen, zoals materialen voor energietoepassingen. Het Dutch Institute for Fundamental Energy Research (Differ) in Nieuwegein telt zo'n 150 medewerkers en verricht onderzoek naar fusie-energie en brandstof uit zonne-energie. Over twee jaar verhuist Differ naar de campus in Eindhoven. Fuji en Differ delen de rechten op wat de samenwer-



Van uitstoot naar brandstof

Zonne- en windenergie opslaan door brandstof te maken uit kooldioxide? Het klinkt bijna te mooi om waar te zijn, maar ...

Bits&Chips

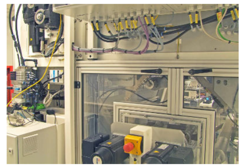
AUTOMOTIVE MEDISCH CE SEMICON SOLAR
CHIPS DRAADLOOS ELEKTRONICA SOFTWARE

Fujifilm en Differ starten onderzoeksgroep

Auteur: Paul van Gerven

4 juni 2013

Fujifilm in Tilburg start samen met energie-instituut Differ een nieuwe onderzoeksgroep voor functionele films gemaakt met atmosferische plasmadepositie. 'Functionele folies zijn enorm interessant, maar om ze grootschalig toe te passen hebben we fundamenteel begrip en controle nodig over het grillige plasma tijdens het productieproces. Samen met Differ bouwen we die noodzakelijke fundamentele kennis uit om de technologie van functionele films grootschalig en kosteneffectief te introduceren', zegt senior onderzoeker Jan Bouwstra van Fujifilm.



De samenwerking komt niet uit de lucht vallen. Fujifilm ontwikkelde eerder al een plasmadepositietechniek met de Eindhovense groep 'Plasma and Materials Processing'. De hoogleraar die daar de leiding had, Richard van de Sanden, werd in 2011 directeur van Differ, dat voortkomt uit een strategische heroriëntatie van het Fom-instituut voor Plasmafysica Rijnhuizen.

18 ECONOMIE

Differ ontwikkelt de energie

Wetenschappelijk instituut Differ komt naar Eindhoven om te werken aan de energie van de toekomst.

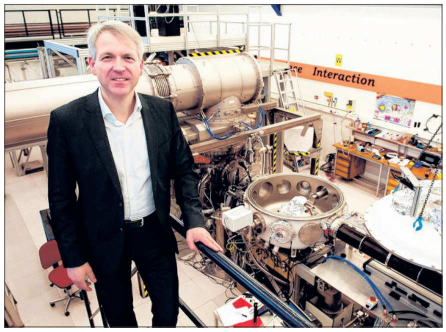
door **Harrie Verrijt**
e-mail: **h.verrijt@ed.nl**

Grote stalen vaten, een spaghetti van buizen en kabels en enorme elektrische apparaten. De hoge hal en de aangrenzende ruimtes van Differ in Nieuwegein staan er vol mee. „Het wordt een hele klus om dit allemaal naar Eindhoven te verhuizen", zegt Wim Koppers, manager van het instituut Differ. „De ervaring bij de opbouw van deze machine, die wij de Magnum noemen, hebben we gebruikt bij het ontwerp van de laboratoriumhal in ons nieuwe gebouw in Eindhoven. Bijvoorbeeld bij de constructie van de stalen wand van vijf centimeter die deze machine moet afschermen. Dat is om het supermagnetische veld waarmee hij werkt tegen te houden."

De verhuizing staat al lang gepland, maar de aanbesteding van de bouw aan aannemer Dura Vermeer brengt deze nu dichtbij. „Er is natuurlijk veel discussie als je een instituut met 125 mensen ver- miskenbaar als we kunnen aansluiten bij het energie-onderzoek dat al in Eindhoven plaatsvindt. Ook Amsterdam, Leiden, Delft en Twente hebben overigens aan ons getrokken. Ongeveer 100 van onze 125 werknemers gaan mee over naar Eindhoven. Er is er al een verhuisd naar Helmond. Er staan verhalen in ons personeelsblad van mensen die een hotel in Eindhoven nemen om de sfeer te proeven en te kijken of je het beste in of buiten de stad kunt wonen."

Het nieuwe gebouw komt op het bedrijvengedeelte van de Technische Universiteit (TU/e) aan De Zaale. „Dat is mooi tussen bedrijven en universiteitsgebouwen, waarmee we via een loopbrug zijn verbonden. We willen ook materialen testen in opdracht van bedrijven. Dat doen we naast het funderend onderzoek dat onze hoofdtaak is."

Dat funderend onderzoek is voor al voor het internationale project Iter, dat kernfusie als toekomstige energiebron aan het ontwikkelen is. „Voor de fusiereactor die Iter bouwt ontwikkelen we het mate-



Instituutmanager Wim Koppers van Differ in de grote laboratoriumhal waar zich de Magnum machine bevindt. „Het wordt een hele klus om dit allemaal naar Eindhoven te verhuizen." foto Marnix Schmidt

de binnenzijde wordt bekleed. Kernfusie speelt zich in extreem heet, in een magnetisch veld gevangen plasma af. Daar springen men uit, die dan de wand kunnen bereiken. In de Magnum, die enorme machine die het hart van ons laboratorium is, kunnen wij en zo de invloed op de wandbekleding testen. Het project van de Magnum kost ongeveer 15 miljoen euro. Daarvan wordt 40 pro-

BRABANTS DAGBLAD

Fujifilm investeert fors in duurzame energie

28 november 2013 | Laatste update: 28 november, 16:10

Drie van de vijf windmolens, gezien vanuit De Moer. foto John Schouten/PV

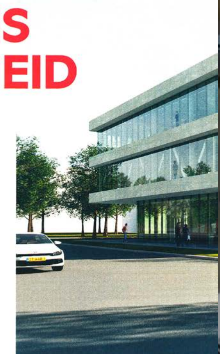
TILBURG - Een bijzondere samenwerking tussen wetenschap en bedrijfsleven krijgt vorm in de vestiging van Fujifilm in Tilburg. Fuji investeert daar 3 miljoen euro in.

Fujifilm in Tilburg gaat samenwerken met energie-instituut Differ om efficiënter energiezuinige folies te kunnen produceren. Differ detacheert vijf jaar lang enkele wetenschappers ...

42 | DUURZAAMHEID

"DOOR BREEAM-NL IS DUURZAAMHEID HANDEL GEWORDEN"

Duurzaam ontwerp voor DIFFER krijgt vier sterren



Aan de nieuwbouw van DIFFER (Dutch Institute for Fundamental Energy Research) in Eindhoven wordt het certificaat BREEAM-NL 'Excellent' toegekend. De Dutch Green Building Council ontwikkelt en beheert BREEAM-keurmerken voor de beoordeling van gebouwen op hun duurzaamheidsprestaties. Directeur Stefan van Uffelen vertelt over de achtergrond van BREEAM-NL. Koen Klijn, projectarchitect van het nieuwe gebouw voor DIFFER en BREEAM-expert bij Ector Hoogstad Architecten, stelt hem kritische vragen.

Fotografie **EDITH VERHOEVEN**

DE ITER-BOUWPUT IN HET FRANSE CADARACHE

HOLLANDS GLORIE

Nederland heeft tot nu toe bijna 9,5 miljoen euro aan contracten en subsidies voor ITER in de wacht gesleept. Het Noord-Hollandse bedrijf DeMaCo bijvoorbeeld maakt onderdelen voor de cryogene koelinstallatie. Deze order, ter waarde van een miljoen euro, voert het bedrijf uit als onderaannemer voor het Indiase ITER-agentschap. 3D Metal Forming uit Flevoland maakte in 2008 al een prototype van een dubbelgekromd paneel voor het vacuümvat. Nu werkt het bedrijf met Italiaanse partners aan een verbindingstechniek om de roestvrij stalen onderdelen in het vacuümvat te bekleden met een koperlaag. Heemskerk Innovative Technology en Dutch Space zijn in de race voor *remote handling*-opdrachten.

Van de Europese landen trekt Italië veel van de grote klussen naar zich toe vanwege de lagere loonkosten, zoals de productie van de zeven secties van het 300 miljoen euro kostende vacuümvat. Nederland moet het vooral van kleinere opdrachten hebben. 'Tot nu toe zijn we een tikje teleurgesteld', vertelt *industrial liaison officer* ir. Toon Verhoeven. Zijn taak is om het Nederlandse bedrijfsleven bij ITER te betrekken. 'Maar er staan nog tientallen miljoenen op de plank.' Ook de Nederlandse wetenschap ontwikkelt mee aan de fusiereactor. Zo onderzoekt energie-instituut DIFFER in Nieuwegein hoe de wand van de reactor zich gedraagt onder extreem hoge temperaturen en ontwikkelt het controletechnieken voor de beheersing van het plasma.

www.iter-nl.nl

De eerste fase van de fundering van de fusiereactor. De 1,7 m hoge betonnen pilaren hebben een aardschokbestendige bovenkant.

...transport naar de bouwput van ITER, ...ton aan betonblokken.

...amak bestaat uit ongeveer een miljoen ...llende onderdelen. De grootste zijn ...oo ton wegend vacuümvat waarin de ...eactie plaatsvindt, daaromheen een ex...koud koelsysteem van 3500 ton en aan ...lerkant een 700 ton wegende divertor ...e en heliumsysteem op de bodem van het va...vat moet afvoeren. De divertor bestaat ...cassettes van wolfraam, een me...rt die bestand is tegen de hitte van de ...hietende neutronen. De miljoen puzzel...s moeten minutieus in elkaar passen. ...n dure, hoogtechnologische onderde...s niet elk technisch bedrijf heeft de ex... in huis om die te maken. Mede daar-

om is ITER een samenwerkingsproject van de EU, China, India, Japan, Zuid-Korea, Rusland en de VS. Zij bouwen allemaal mee aan de puzzel en leggen daar ruim veertien miljard euro voor neer.

Het hart van de machine, het vacuümvat, wordt door Italië en Zuid-Korea gemaakt. Het zijn negen D-vormige dubbelwandige roestvrij stalen secties. Italië maakt er zeven, Korea twee. 'Ze produceren niet allemaal exact volgens het ontwerp', verzucht dr. Rem Haange, de Nederlandse adjunct-directeur van het technische departement van ITER. 'De Italianen hebben het ontwerp aangepast. Zij gebruiken een andere lastechniek, terwijl de Ko-

reanen min of meer het originele ontwerp volgen.' De Italianen hebben een nieuwe lastechniek ontwikkeld, op basis van elektronenbundels. Deze techniek is sneller en efficiënter, werkt met lagere temperaturen en geeft minder vervormingen. Maar er ging wel een lang ontwikkeltraject aan vooraf en het benodigde materieel is duurder. De Koreaanse las-

techniek is niet nieuw en daarom goedkoper, maar wel langzamer en minder efficiënt. Dit verschil in aanpak bezorgt de ITER-organisatie in Frankrijk kopzorgen. Want uiteindelijk moeten de Italiaanse en Koreaanse secties aan elkaar worden gelast tot een feilloos vacuumvat. Haange: 'Het is eigenlijk ondoenlijk om de componenten zo onafhankelijk van el-

11 OKTOBER 2013 • DE INGENIEUR • 16 ... 25

[C2W] LAB NEWS

HOME NIEUWS PRODUCTEN LABTECHNOLOGY VACATURES

[Fusiereactor wordt grafeenfabriek]

Extreem plasma genereert onverwacht subtiele koolstofnanostructuren

28 november 2013 • Arjen Dijkgraaf

Fusiereactoren kunnen op een heel exotische manier verkolen. Als je niet uitkijkt krijg je een

OMROEP BRABANT

Hoogleraar Richard van de Sanden van TU Eindhoven lid van KNAW

STAD & REGIO 35

'Het draait in de wetenschap steeds meer om 't maatschappelijk belang'

INTERVIEW Prof. dr. ir. Richard van de Sanden uit Tilburg zet zich in zijn werk en privé in voor een duurzame samenleving.

Eindh. Dagblad - Buitenkatern 17-09-2013

Gerennomeerd instituut Differ naar TU/e

EINDHOVEN – De TU/e krijgt er in 2015 een gerenommeerd instituut bij. Het gaat om het *Dutch Institute for Fundamental Energy Research* (Differ), een van de drie onderzoeksinstituten van de Stichting voor Fundamenteel Onderzoek der Materie (FOM).

Gisteren werd op het TU/e-terrein het startschot gegeven voor de nieuwbouw van het complex. Het gebouw wordt volgens de nieuwste technieken zo duurzaam mogelijk gebouwd. Differ is nu nog gevestigd in Nieuwegein. Differ houdt zich bezig met het zoeken naar oplossingen voor het wereldwijde energievraagstuk. Want naarmate de fossiele brandstofvoorraden opraken, wordt de noodzaak om over te schakelen op duurzame energie steeds urgenter. Behalve onderzoek naar methoden om duurzame energie op te wekken, wordt ook onderzocht hoe deze kan worden opgeslaan.

Voortgekomen uit het FOM-instituut voor Plasmafysica Rijnhuizen, het Nederlandse centrum voor onderzoek naar kernfusie, zal Differ ook in Eindhoven dit onderzoek voortzetten. Kernfusie, in tegenstelling tot kernsplitsing, wordt gezien als een schone, veilige en duurzame energiebron. Het doel is het samensmelten van lichte atoomkernen, zoals dat ook op de zon gebeurt, in te zetten als energiebron op aarde.

Ook onderzoekt Differ de mogelijkheid om duurzame energie de vorm van *solar fuels* (vloeibare brandstoffen op basis van CO_2) op te slaan. Verder ontwikkelt Differ optieken voor extreem UV-licht, het hart van de fotolithografie-machines van ASML.

De aftrap van de nieuwbouw van het Differ-instituut. Rechts: het ontwerp van het complex. foto Bart van Overbeeke / inzet: Ector Hoogstad Architecten

STUDIO 040

Home Nieuws 040Kiest Sport Radio Televisie Webcam 040Gemist Over ons

Start bouw nieuw energielab TU/e

Op de campus van de TU/e is vandaag de nieuwbouw begonnen van Differ, het nieuwe energie-instituut van de Stichting FOM.

Richard van de Sande – Differ

Wetenschappers en technici van de TU/e en Differ doen daar gezamenlijk onderzoek om de energie van de toekomst te ontwikkelen. DIFFER is nu nog gevestigd in Nieuwegein. Dat het prestigieuze instituut naar de universiteitscampus komt betekent een toevoeging voor Eindhoven.

Kernfusie, weer een hobbel genomen

tekst Bart van den Dikkenberg
beeld ornl.gov

Het klinkt veelbelovend: energie opwekken zoals de sterren dat doen. Kernenergie zonder gevaarlijk afval zou met het ITER-project voor het grijpen liggen. Van een leien dakje ging het echter niet: een fors probleem met een kabel had het project zomaar in gevaar kunnen brengen.

Met kernfusie zouden de grootste nadelen van kernenergie in een klap zijn opgelost: de brandstof is onbeperkt voorradig, er komt veel energie bij vrij en het levert nauwelijks kernafval op. Simpel gezegd: er gaat waterstof (in de vorm van deuterium en tritium) in en er komt ongevaarlijk helium uit. Schone kernenergie ligt daarmee binnen handbereik.

Na allerlei kleine projecten in allerlei landen steken de Europese Unie, Japan, Zuid-Korea, China, India, de Verenigde Staten en Rusland de koppen bij el…

„ITER staa… de kwalite… supergelei…

Superkoud

Gewoon koperdraad heeft de eigenschap dat de weerstand toeneemt met de stroomsterkte; de draad wordt warmer en verliest energie. Zou er in een kernfusiereactor gewerkt worden met koperdraad, dan moet bijna alle opgewekte energie gebruikt worden om het koperdraad te koelen en is het rendement nul. Supergeleidende draden hebben een heel bijzondere eigenschap. Ze worden met vloeibaar helium gekoeld tot 4,5 Kelvin (-268,7 graden Celsius). Bij die temperatuur treedt er tot een bepaalde stroomsterkte geen energieverlies op. Dankzij supergeleiding gebruikt ITER in theorie slechts 10 procent van de opgewekte energie zelf.

Kernfusiecentrale ITER

Specificaties

Vermogen:	500 megawatt	Plasmavolume:	850 kubieke meter
Economisch rendement:	90 procent	Diameter tokamak:	12 meter
Hoogte:	24 meter	Hoogte plasmakamer:	8 meter
Doorsnede:	34 meter		

Kernfusie

Waterstofionen deuterium en tritium smelten samen bij 15 miljoen graden Celsius en vormen een heliumatoom en een vrij neutron.

Dit is het eerste artikel in een tweeluik over de kernfusiecentrale ITER. Morgen op pag. 2 van Puntkomma deel 2.

TW TECHNISCH WEEKBLAD

Home Nieuwsarchief Opinie Rubrieken Dossiers Tabellen Agenda

Technisch Weekblad / Nieuwsarchief / Natuurkundigen 'blazen' glas op plastic

Natuurkundigen 'blazen' glas op plastic

22 juni 2013 • Henk Klomp

FOM ontwikkelt samen met het Japanse elektronicabedrijf Fujifilm plasmadepositietechniek om in de toekomst in de productiehallen van Fuji in Tilburg op grote schaal industriële membranen te kunnen maken.

5

5.1 Governance

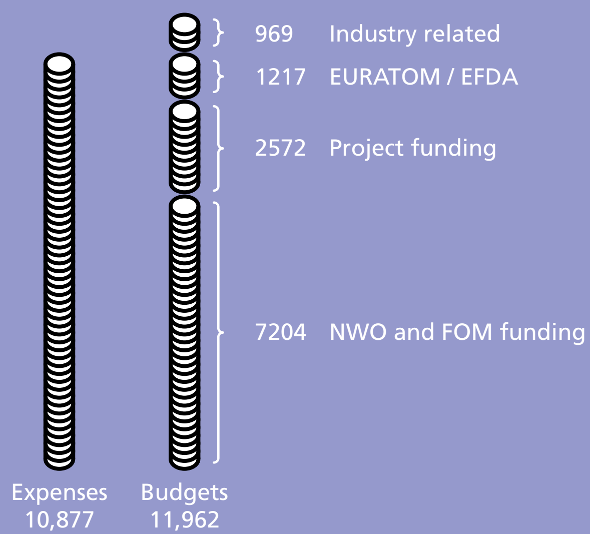
DIFFER is undergoing a major transition: starting up a completely new research theme alongside the existing fusion research, transferring two activities to Dutch universities, and relocating to a new building in Eindhoven. These changes influence the organization on many levels and in order to tackle them optimally, we strive to become a flatter organization that supports an optimal communication between all levels of the institute. To help achieve this ambition, in 2013 a new governance model was adopted, in which group leaders have more freedom and responsibility to shape their individual research programs within the overarching research themes.

Tenure track positions

Attracting top talent to DIFFER is essential to grow the institute into a world-class level in fundamental energy research. To that end we offer young scientists a five year tenure track program with attractive research and carreer opportunities such as a permanent position as head of a research group. Tenure trackers are challenged to set up a research group and position it within the broader research community. A research proposal with well-defined milestones coupled to regular coaching by senior researchers and evaluations by an external committee provide an optimal environment for the tenure trackers to set up their own research groups.

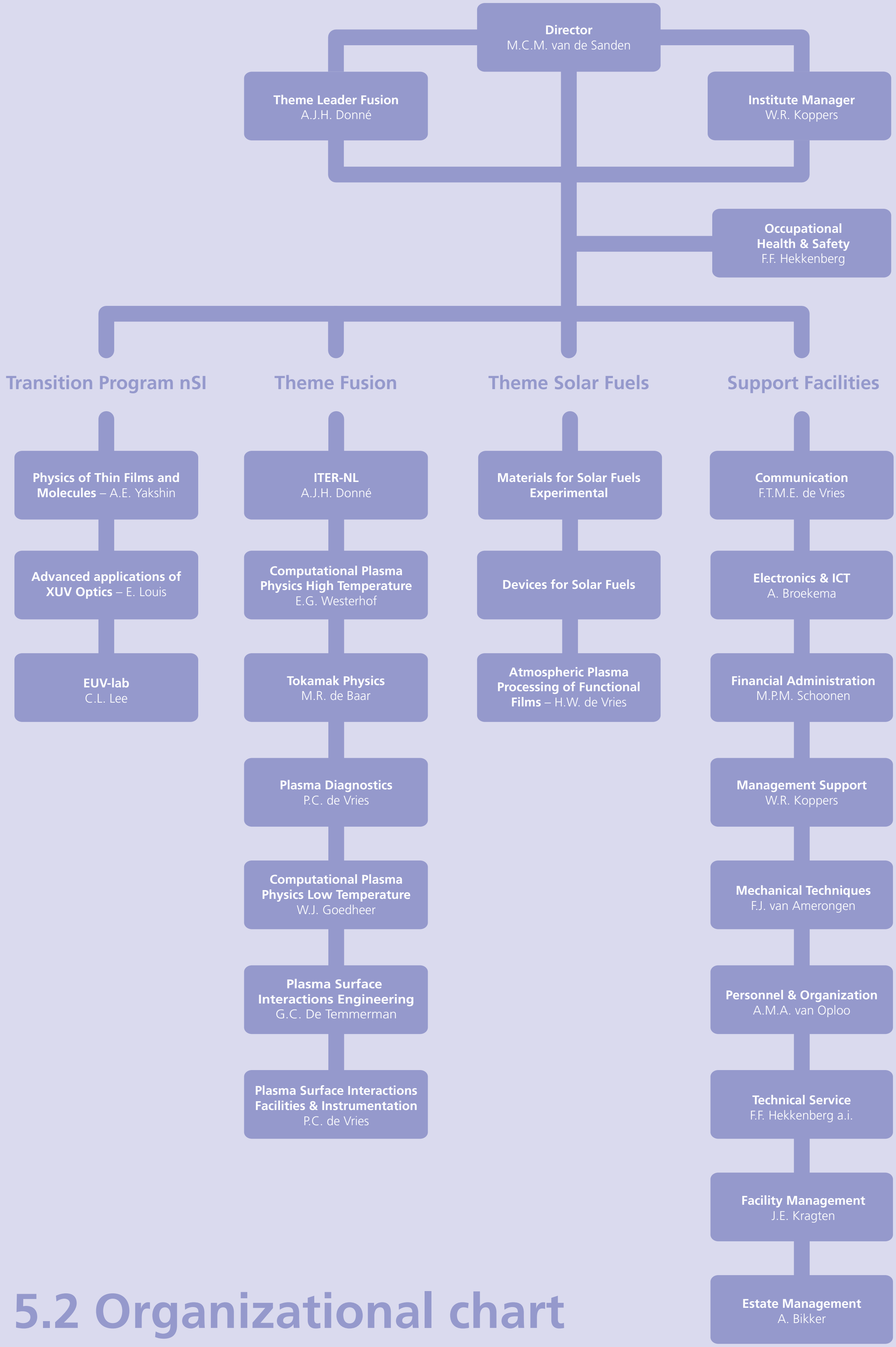
Staff overview (ppy)

Funding vs expenses (k€)



Output 2013

5.2 Organizational chart



5.3 List of committees

Management Team

M.C.M. van de Sanden (institute director; chairman)
F. Bijkerk (program leader nSI)
A.J.H. Donné (program leader fusion)
W.R. Koppers (institute manager)

Scientific Advisory Committee

G. van der Steenhoven (University of Twente; chairman)
D.J. Campbell (ITER)
A. von Keudell (Ruhr-University Bochum)
D. Lincot (Institut de Recherche et Développement sur l'Energie)
E.B. Stechel (Arizona State University)
Y. Ueda (Osaka University)
H. Werij (TNO)

Employees Council

G. Kaas (chairman)
F.J. van Amerongen
B.S.Q. Elzendoorn
J.W. Genuit
M.H.J. 't Hoen
H.J. van der Meiden
A.P. Visser

Please see for a full list of employees per group, the online appendix, http://www.differ.nl/en/annual_reports

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DIFFER is one of the three research institutes of the Foundation for Fundamental Research on Matter (FOM).
FOM is part of the Netherlands Organisation for Scientific Research (NWO).