10th Conference on Applications of Femtosecond Lasers in Materials Science

FemtoMat 2025

February 24 - 27, 2025
Mauterndorf Castle, Mauterndorf
Salzburg, Austria
https://esg-nano.ac.at/femtomat

Chair: Wolfgang Kautek
Organization Committee: Oskar Armbruster, Eva-Kathrin Ehmoser, Evgeny Gurevich, Wolfgang Kautek, Thomas Klar, Aida Naghilou

Foreword

The science, technology, and application of femtosecond lasers matured to a level that a critical review of the state of the art is timely and possible to assist in signposting future trends of development.

The success of the series of the Conferences on Applications of Femtosecond Lasers in Materials Science (FemtoMat) with

the 1st FemtoMat 2002, Visegrád, Hungary, October 2002,

the 2nd FemtoMat 2004, Bad Kleinkirchheim, Carinthia, Austria, February 2004,

the 3rd FemtoMat 2007, Vienna, Austria, April 2007, as special session of the
8th International Symposium on Laser Precision Microfabrication (LPM 2007),

the 4th FemtoMat 2011, Mauterndorf, Salzburg, Austria, March 2011,

the 5th FemtoMat 2013, Mauterndorf, Salzburg, Austria, March 2013,

the 6th FemtoMat 2015, Mauterndorf, Salzburg, Austria, March 2015,

the 7th FemtoMat 2017, Mauterndorf, Salzburg, Austria, March 2017,

the 8th FemtoMat 2019, Mauterndorf, Salzburg, Austria, March 2019,

and the 9th FemtoMat 2022, Mauterndorf, Salzburg, Austria, March 14 - 16, 2022,
is the basis of the present

10th FemtoMat 2025, Mauterndorf, Salzburg, Austria, February 24 - 27, 2025.

The FemtoMat conferences represent a topical conference devoted exclusively to the present status and application of femtosecond lasers in materials science. The participants are encouraged to explore the possibilities and problems of the field and exemplify these by their most important new results. The conference features active discussions at the oral and poster sessions, and plenty of time for in-depth discussions in an informal atmosphere amidst the Austrian high alps. Due to the coherent topic of the meeting and to allow full attendance, no parallel sessions are being organized.

Vienna, February 2025

Wolfgang Kautek

Sponsors

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Program

Monday, February 24, 2025

09:00 – 10:00 **Registration & opening**
10:00 – 10:30 **L01** Koji Sugioka
(RIKEN, JP)
Femtosecond laser 3D printing of CYTOP for super-resolution live imaging of cells inside microfluidic channels
10:30 – 12:30 **Posters:** Short lectures and session

12:30 – 16:30 **Free discussion**

16:30 – 17:00 **Break**
17:00 – 17:30 **L02** Leonid Zhigilei
(University of Virginia, US)
Mechanisms of laser ablation: Validation of atomistic modeling by time-resolved optical and X-ray probing
17:30 – 18:00 **L03** Aleksandr Ovsianikov
(TU Wien, AT)
High-resolution 3D printing using fs lasers – upscaling and addressing industrial applications
18:00 – 18:30 **Break**
18:30 – 19:00 **L04** Evgeny Gurevich
(FH Münster, DE)
Laser Induced Periodic Surface Structures in 2D Materials
19:00 – 19:30 **L05** Cyril Mauclair
(University of Angers, FR)
Ultrafast laser spatial beam shaping for material processing: overcoming the modulator limitations

Tuesday, February 25, 2022

09:00 – 09:30 **L06** Peter Balling
(Aarhus University, DK)
Femtosecond laser excitation of dielectric materials

09:30 – 10:00 **L07** Karsten König
(Saarland University, DE)
Femtosecond laser for multiphoton tomography of human skin and low-power nanosurgery

10:00 – 10:30 **L08** Nadezhda Bulgakova
(Institute of Physics of the Czech Academy of Sciences, CZ)
Laser-Assisted Synthesis, Printing, and Functionalization of 2D Materials

10:30 – 11:00 **Break**

11:00 – 11:30 **L09** Xxx Sedao
(Jean Monnet University, FR)
Ultrafast Laser for Biomimetic Surfaces and Their Applications

11:30 – 12:00 **L10** Brian Julsgaard
(Aarhus University, DK)
Luminescence properties of GeSn laser materials: influence of buffered-substrates

12:00 – 12:30 **L11** Gediminas Račiukaitis
(LTS-FTMC, LT)
How does femtosecond laser processing contribute to high-energy research and applications?

12:30 – 16:30 **Free discussion**

16:30 – 17:00 **Coffee**

17:00 – 17:30 **L12** Razvan Stoian
(Jean Monnet University, FR)
Ultrafast laser nanostructuring; the quest for resolution

17:30 – 18:00 **L13** Francois Courvoisier
(FEMTO-ST, FR)
Ultrafast laser-induced extrusion in sapphire

18:00 – 18:30 **Break**

18:30 – 19:00 **L14** János Hebling
(University of Pécs, HU)
Tilted-pulse-front-pumped THz sources for femtosceond material science

19:00 – 19:00 **L15** Georgii Gvindzhiliia
(Johannes Kepler University Linz, AT)
Two-photon lithography of Organic Semiconductor Nanowires

Wednesday, February 26, 2025

09:00 – 09:30 **L16** Jörg Krüger
(Federal Institute for Materials Research and Testing, DE)
X-ray emission during ultrashort pulse laser material processing

09:30 – 10:00 **L17** David Redka
(Munich University of Applied Sciences, DE)
Impact of laser-induced nanomorphology on multi-pulse formation of periodic surface structures

10:00 – 10:30 **L18** Maximilian Spellauge
(Munich University of Applied Sciences, DE)
On the perspective of advancing laser ablation in liquid to the industrial scale: Concept and origin of a fundamental efficiency limit

10:30 – 11:00 **Break**

11:00 – 11:30 **L19** Johannes Heitz
(Johannes Kepler University Linz, AT)
Guidance of osteoblast migration using femtosecond laser induced hierarchical structures

11:30 – 12:00 **L20** Alexander Bulgakov
(Institute of Physics of the Czech Academy of Sciences, CZ)
Non-thermal ultrashort-pulsed laser annealing of semiconductors at the nanoscale: Crystallization without melting

12:00 – 12:30 **L21** Alex Fuerbach
(Macquarie University, AU)
Femtosecond laser induced refractive index changes in fluoride glasses

12:30 – 16:30 **Free discussion**

16:30 – 17:00 **Coffee**

17:00 – 17:30 **L22** Mark Baker
(University of Surrey, UK)
Femtosecond Laser Ablation X-ray Photoelectron Spectroscopy (fs-LA XPS) Depth Profiling

17:30 – 18:00 **L23** Peter Banzer
(University of Graz, AT)
Analysing Free-Space Light with All-Passive On-Chip Photonic Circuits

18:00 – 18:30 **Break**

18:30 – 19:00 **L24** Alexander Pogány
(Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, AT)
Austrian R&D-Policy in Advanced Materials

19:00 – 19:00 **L25** Andreas Falk
(BioNanoNet Forschungsgesellschaft mbH, AT)
The Advanced Materials ecosystem – enabling synergies with cross-sectorial collaboration

Thursday, February 27, 2025

09:00 – 09:30 **L26** Cristian Sarpe
(University of Kassel, DE)
Temporal Airy Pulses as Precursor for Precision Dicing of Thin Glasses

09:30 – 10:00 **L27** Eric Audouard
(Amplitude, FR)
Ablation of batteries materials by femtosecond pulses and burst of pulses

10:00 – 10:30 **L28** Thibault Derrien
(Institute of Physics of the Czech Academy of Sciences, CZ)
Quantum predictions of ultrafast phenomena: strong field effects of crystals and optical response of nanomaterials

10:30 – 11:00 **Break**

11:00 – 11:30 **L29** Wolfgang Husinsky
(TU Wien, AT)
Simulation of Rippleformation under Ultra Short Laser - Surface Interaction

11:30 – 12:00 **L30** Simon Maier
(University of Regensburg, DE)
Attosecond charge transfer in atomic-scale scanning tunnelling microscopy

12:00 – 12:30 **L31** Km Akanksha Dubey
(Sorbonne University, FR)
Selected Continuum Wavefunction Method (SCWF) for Modeling Molecular Photoemission at the attosecond scale

Lecture Abstracts

L01

Femtosecond laser 3D printing of CYTOP for super-resolution live imaging of cells inside microfluidic channels

Koji Sugioka, Mirai Hanzawa, Kotaro Obata, Masatoshi Takagi, Asako Sakaue-Sawano, Satoshi Shimozono, Asako Tosaki, Felix Sima, Hiroyuki Kawano, Takuro Tojima, Akihiko Nakano, Atsushi Miyawaki

RIKEN Center for Advanced Photonics

Live imaging of cell behavior in 3D micro- and nanoenvironment is important to investigate the mechanisms of immune systems or disease progression, and has been attracting much attention, especially to understand cancer cell invasion into other tissues, neutrophil migration at the sites of infection, and axon extension of neurons in brain development, for which microfluidic chips are the attractive tool. A remaining problem of the current microfluidic chips is, however, the refractive-index mismatch between the chip materials and culture media containing cells (typically water), which makes it difficult to capture high resolution images. To solve this problem, we propose to use amorphous fluoropolymer CYTOP as a platform of the microfluidic chips, because it has a refractive index (1.34) very close to that of water (1.33). To fabricate the microfluidic chips, a 3D microstructure of SU8 was first fabricated by two-photon polymerization of SU8 using a femtosecond laser. The fabricated 3D structure was then used as a mold to be filled with liquid CYTOP, followed by thermal treatment for curing CYTOP. Finally, the SU8 microstructure remaining in CYTOP was removed by chemical treatment, resulting in fabrication of the 3D microfluidic structure inside CYTOP. The fabricated microfluidic chips were applied to live imaging of cancer cells migrating in the microfluidic channels. We have confirmed that the cells can enter and then pass through the microchannels with widths of 2.1-3.5 µm. Refractive index match between CYTOP and water enabled capturing clear images of cells even near the channel sidewalls. The fine structures such as nucleolus in the cell nucleus were also clearly observed. We have further demonstrated that the CYTOP microfluidic chips can provide ability of super-resolution live imaging of cells. Thus, the developed technique is expected to be used for fabrication of micro- and nanoenvironment platforms for super-resolution bioimaging.

L02

Mechanisms of laser ablation: Validation of atomistic modeling by time-resolved optical and X-ray probing

Chaobo Chen, Mikhail I. Arefev, Antonios S. Valavanis, Leonid V. Zhigilei

Department of Materials Science and Engineering, University of Virginia

Laser ablation is the process of material removal from a surface exposed to laser irradiation. It is actively used in many applications ranging from synthesis of advanced nanomaterials to surface nanostructuring and functionalization. The practical relevance has motivated experimental, computational, and theoretical efforts aimed at revealing the mechanisms responsible for the material ejection from the irradiated targets. Large-scale atomistic modeling has been playing a prominent role in the exploration of the fundamental mechanisms of laser ablation. In particular, the results of atomistic simulations have revealed the existence of two distinct regimes of laser ablation: the “photomechanical spallation” driven by the dynamic relaxation of laser-induced stresses and the “phase explosion” driven by the rapid (explosive) release of vapor in a part of the target superheated up to the limit of thermodynamic stability of the target material.

To enable direct experimental verification of the computational predictions, we perform calculation of optical properties of transient multiphase structures obtained in the atomistic simulations through the solution of the Maxwell equations describing the interaction electromagnetic wave with the emerging ablation plume. The computational predictions are related to the results of spatially- and time-resolved experimental probing of laser ablation of FeNi targets performed at Munich University of Applied Sciences. The coordinated computational and experimental investigation of laser ablation of FeNi targets enables reliable interpretation of optical signals measured in pump-probe experiments and suggest new ideas for tuning the conditions of laser synthesis of materials in the multi-pulse irradiation regime.

Further insides into the dynamics of nanoscale phase decomposition in laser ablation are provided by probing the ablation dynamics by intense femtosecond X-ray pulses generated by the free electron laser at the SLAC National Accelerator Laboratory. Using the ablation of thin gold films irradiated by femtosecond laser pulses as a test case for the exploration of the emergence of the nanoscale density heterogeneities at the initial stage of laser ablation, we perform atomistic simulations aimed at explaining the evolution X-ray diffraction patterns observed in the SLAC experiments. The small-angle X-ray scattering (SAXS) patterns calculated for transient atomic configurations obtained in the simulations are mapped to the results of experimental SAXS probing. The comparison of the experimental data to the computational predictions has enabled the interpretation complex SAXS signals in terms of the different ablation regimes and the corresponding characteristic pathways of phase decomposition.

L03

High-resolution 3D printing using fs lasers – upscaling and addressing industrial applications

Aleksandr Ovsianikov

TU Wien, Vienna, Austria

Additive manufacturing technologies, often referred to as 3D printing, open exciting perspectives for biomedical applications and tissue engineering. Among the myriad of possible approaches multiphoton lithography (MPL) stands out as a technique enabling true 3D structuring with spatial resolution unmatched by other additive manufacturing technologies [1].

MPL relies on the nonlinear absorption of femtosecond laser pulses to induce photochemical processes, not necessarily limited to photopolymerization alone. An increasing portfolio of available materials enables utilization of the versatile capabilities of MPL, from producing complex volumetric 3D structures by means of cross-linking, to creating void patters within hydrogels already containing living cells, via photocleavage. Among other things, high resolution of MPL recently enabled realization of a novel tissue engineering approach, employing scaffolded spheroids for bottom up assembly of tissue constructs with high initial cell density [2-3]. Our recent breakthroughs on the material development side enabled the use of MPL for direct fabrication of cell-containing constructs, giving rise to High-Definition Bioprinting [4-5].

Recent advances in system and material development allow to substantially increase the throughput of MPL, making this technology highly relevant for industrial applications. In this contribution, the recent progress in this area will be discussed. The presentation is supported by numerous examples.

[1] Multiphoton Lithography: Techniques, Materials, and Applications, J. Stampfl, R. Liska, A. Ovsianikov (Eds.) John Wiley & Sons (2016), [ISBN: 978-3-527-33717-0]
[2] A. Ovsianikov et al., The Synergy of Scaffold-Based and Scaffold-Free Tissue Engineering Strategies, Trends in Biotechnology, 36(4):348-357 (2018) [doi: 10.1016/j.tibtech.2018.01.005]
[3] O. Guillaume et al., Hybrid spheroid microscaffolds as modular tissue units to build macro-tissue assemblies for tissue engineering, Acta Biomaterialia, (165) 72-85 (2022) [https://doi.org/10.1016/j.actbio.2022.03.010]
[4] A. Dobos et al., On-chip high-definition bioprinting of microvascular structures, Biofabrication, 13 : 015016 (2020) [doi: 10.1088/1758-5090/abb063]
[5] T. Zandrini et al., Breaking the resolution limits of 3D bioprinting: future opportunities and present challenges, Trends in Biotechnology, 41 (5) 604-614 (2023) [https://doi.org/10.1016/j.tibtech.2022.10.009]

L04

Laser Induced Periodic Surface Structures in 2D Materials

M.J.M.J. Becher, J.B. Ullrich, J. Jagosz, C. Bock, A. Kostka, E.L. Gurevich

Ruhr University Bochum; University of Applied Science FH Münster

We study the Laser-Induced Periodic Surface Structures (LIPSS) formed in 2-D materials on the example of reduced graphene oxide and ALD-deposited MoS_2 layers exposed to femtsecond laser pulses. We demonstrate the transition from the low- to high-spatial frequency LIPSS upon increase in the laser fluence in the molybdenum disulfide layers. The dependency of the LIPSS formation on the laser pulse duration is also discussed. These results are compared to the LIPSS observed in the reduced graphene oxide. We observe the negative accumulation effect in MoS_2, i.e., deterioration of the ablation when the number of the laser pulses increases. The effect can be explained by pulse-to-pulse modification of the processed layer.

L05

Ultrafast laser spatial beam shaping for material processing: overcoming the modulator limitations

Cyril Mauclair

Laboratoire de Photonique d'Angers (LPhiA)

Spatial laser beam shaping, especially with spatial light modulators (SLMs), enhances processing speed and precision by enabling flexible modification of beam intensity distribution of ultrafast lasers. However, SLMs face inherent optical limitations, such as resolution, fill factor, and phase quantization, which lead to challenges like unintended energy distribution (zeroth order) and irregularities (Speckle effect) that compromise high quality beam shaping. We discuss these limitations on both numerical simulations and a femtosecond laser workstation, focusing on specific phase modulations (e.g., gratings, biprisms, axicons). The findings highlight the negative effects of limited phase resolution and quantization. We discuss several strategies to overcome these limitations by taking advantage of in-situ characterization of the irradiated zone and/or by adapting the phase modulation calculation to the performance of the SLM.

L06

Femtosecond laser excitation of dielectric materials

Peter S. Sneftrup, Søren H. Møller, Venkatesh Mottamchetty, Christoffer Debel Christensen, John L. Hansen, Signe G. Balslev, Brian Julsgaard, Peter Balling

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The investigation of ultrashort-pulse laser excitation of dielectric materials is both interesting and relevant. While the relevance is clear from several demonstrations in a variety of material-processing applications, the fundamental interest lies in the fact that such investigations provide insight into the fundamental mechanisms of material excitation. Electrons are promoted from the valence to the conduction band by strong-field excitation, and the generated carriers can subsequently interact with the light, acquiring kinetic energy and when this energy is high enough, collisional processes may generate additional free carriers.

In this presentation, we will present recent results from combined experimental and modeling investigations in our group. We recently developed a material-excitation model that combines a description of the basic excitation processes in the so-called multiple-rate-equation (MRE) model with light propagation obtained from a direct solution of Maxwells equations (in one dimension) [1]. This model allowed us to interpret the results of laser-ablation experiments carried out on thin (~1 micron) Al_2O_3 films. The ablation is found to originate from the regions of constructive interference inside the film, thus giving rise to ejection of multiple layers from the sample in steps corresponding to the distance between interference maxima [2]. We are currently setting up an experiment to investigate the predicted emission of THz radiation from short-pulse excited dielectrics. Our simulations of carrier transport in the highly excited dielectric showed that the difference in electron- and hole mobilities leads to the fast build-up of a strong electric field (the Dember field), and THz emission would be an experimental signature of this process [3]. We hope to be able to present first results from these ongoing experiments at the conference.

[1] Phys. Rev. B 108, 094307 (2023)
[2] Appl. Phys. A 130, 646 (2024)
[3] Phys. Rev. B 109, L140304 (2024)

L07

Femtosecond laser for multiphoton tomography of human skin and low-power nanosurgery

Karsten Koenig

Saarland University, Department of Biophotonics and Laser Technology

Tunable titan:sapphire laser as well as ultracompact Er:doped fiber laser have been used for multiphoton tomography (MPT) at transient GW/cm2 laser intensities to realize high-resolution non-invasive label-free human skin imaging with subcellular resolution. Using time-resolved single photon counting with 200 ps temporal resolution, two-photon autofluorescence lifetime imaging (FLIM) for optical metabolic imaging (OMI) can be realized. At TW/cm^2 light intensities, multiphoton-induced plasma formation and subsequent photodisruptive effects may occur. These destructive effects can be used for femtosecond LASIK in refractive surgery as well as for cellular nanosurgery to realize targeted transfection and virus-free cellular reprogramming to generate induced pluripotent stem (ips) cells.

L08

Laser-Assisted Synthesis, Printing, and Functionalization of 2D Materials

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The first successful exfoliation of graphene layers by a simple tape technique and demonstration of their unique properties [1] created a boost of research in seeking new 2D materials (2DMs) and exploring their unique features for various applications such as optoelectronics, sensors, bio-imaging, photothermal therapy, etc. Despite great advances in synthesizing and manipulating 2DMs, challenging gaps still exist that call for extensive exploration. This involves cost-effective methods for 2DM synthesis, manipulation of their functionalities, and development of printing methods for assembling 2DM-based devices. In this work, we report on our recent experimental and theoretical studies on the synthesis, characterization, functionalization, and high-precision printing of 2DMs. This includes the pulsed laser deposition (PLD) technique to fabricate single- or multi-layered 2D materials, an original approach to the periodic functionalization of graphene by substrate patterning, and high-precision positioning of 2DM flakes on desired substrates without affecting the properties of transferred material. Additionally, the development of efficient methods of quantum simulations will be discussed which would enable to explore and predict the electronic and optical properties of 2DMs under different conditions and arrangements.

[1] A.K. Geim, K.S. Novoselov, The rise of graphene, Nat. Mater., Vol. 6, pp. 183-191 (2007)

L09

Ultrafast Laser for Biomimetic Surfaces and Their Applications

Sedao

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Over millions of years, the nature has learned to develop a wealth of strategies to fulfill necessary functions and allow their evolution for ever-optimized capabilities, i.e. in energy, recycling, morphology adaptation to function etc. Inspired by nature, artificial materials and surfaces are created to achieve desired properties for applications. Ultrafast laser is one of the potent tools used to create bio-inspired, biomimetic as well as bio-sourced surfaces for targeted applications: i.e. liquid transport, optics, biomedical and vision correction are discussed as examples of functions and applications. Appropriate choice of laser parameter and processing conditions, such as laser pulse duration, wavelength, polarization, burst etc, is key to biomimicry. Optimization of upscaling / process automation strategies are equally important for bringing laboratory demonstrators to economically viable products. To this end, case by case solutions can be developed thanks to various technology bricks such as fast optics, parallel processes, advanced beam shaping, robotics and online visions.

L10

Luminescence properties of GeSn laser materials: influence of buffered-substrates

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3 Pollard Institute, School of Electronic and Electrical Engineering, University of Leeds, UK.

Since the first GeSn laser emission was demonstrated in 2015, the field has been inching ever closer to the goal of achieving an electrically injected CMOS-compatible laser operating at room temperature. The performance deterioration of GeSn as a laser medium above cryogenic temperatures has inhibited this development, and so far the highest reported operating temperature for an electrically injected laser is 140 K. Material defects are an important obstacle in pushing this limit higher, because they limit the carrier lifetime of GeSn.

In device manufacturing, much is done to prevent the active GeSn layer from being impacted by the defects originating at the interface between the underlying silicon substrate and, typically, a germanium buffer layer. Usually this is done by ensuring that the buffer is thick enough, smooth, and with good crystal quality to ensure a relaxed active region with a good interface between them. An example of such a buffer layer is a thick Ge-virtual substrate (GeVS). If the buffer layer is too thin, experience shows that the GeSn sample would not work for laser devices.

In this study, we investigate how a difference in the choice of buffer layer affects the luminescence properties of the GeSn layer. For this purpose, two samples are grown by an industry-compatible reduced-pressure chemical vapor deposition reactor. Both have similar GeSn layer properties in terms of thickness, strain, and tin concentration. The only significant difference is that one sample has the active layer grown on a 2.5 µm GeVS and the other has the active layer grown on a post-deposition-annealed 0.42 µm Ge buffer layer (Ge-PDA). We use time-resolved photoluminescence spectroscopy at varying excitation densities and temperatures from 20 K to 300 K. Using this method, we can establish the behaviour of light emission from the samples in a large parameter space.

Surprisingly, changing the buffered-substrate has almost no influence on the decay time of the photoluminescence, implying that the defects near the interface have a limited impact on the luminescence properties.

The experimentally determined decay times allow us to calculate theoretical time-resolved spectra using k.p-theory. With these, the photoluminescence yield can be estimated as a function of temperature and compared to our experimentally determined values.

The theoretical calculations show the same decrease in the photoluminescence yield as seen in the experimental data and point to the small directness of the GeSn bandgap as the main reason for this. These results further point to the small directness of the bandgap and the short decay time of the carriers as the primary challenges to overcome in order to finally achieve an electrically injected GeSn laser operating at room temperature.

L11

How does femtosecond laser processing contribute to high-energy research and applications?

Gediminas Račiukaitis

FTMC - Center for Physical Sciences and Technology

Extreme Light Infrastructure is intended to be a Laser-CERN, and progress in ultrashort laser development facilitates that. Laser wakefield accelerators are a promising alternative to huge radiofrequency accelerators, enabling us to get as high as GeV energy electrons just in a few centimetres distance. From a more practical point of view, electron bunches with 150-200 MeV energies are needed for Very High Energy Electron radiotherapy. We investigate how to reach such electron energies utilising new kHz-class OPCPA lasers operating at sub-10 fs pulse duration and limited pulse energy just above 50 mJ.

The injection of electrons into a wake and their acceleration take place when the focused laser beam interacts with a gas plasma target. Standard machining technologies, including 3D printing, are limited in the complexity and precision of gas injection nozzles. We utilise a combined laser micromachining technology with ultrashort-pulse burst-mode lasers to manufacture complex gas nozzles in fused silica [1,2]. The process includes mechanical design of the nozzles, optical simulation of the laser beam shaping and Fourier-Bessel Particle-In-Cell (FBPIC) simulation of electron acceleration and a plasma wake, generated inside the plasma target [3] before the real manufacturing.

A stable operation with electron energy around 3 MeV was demonstrated at a 1 kHz repetition rate with a low pulse energy [4]. Our simulations show that electron energy above 100 MeV could be achieved using SYLOS3-type lasers [5]. Flexibility in the 3D shaping of plasma targets, tailored to particular beam profiles of ultra-high intensity lasers, is a way to achieve high energy of accelerated electrons with low energy spread and divergence.

[1] V. Tomkus, V. Girdauskas, J. Dudutis, P. Gečys, V. Stankevič, G. Račiukaitis, Optics Express. 26, 27965, (2018).
[2] V. Tomkus, M. Mackevičiūtė, J. Dudutis, V. Girdauskas, M. Abedivaraki, P. Gečys, G. Račiukaitis, J. Plasma Physics, 90(1), art. no. 965900102, p. 1-11. (2024)
[3] V. Girdauskas, V. Tomkus, M. Abedi-Varaki, G. Račiukaitis, Appl. Sci. 14, 10611 (2024).
[4] L. Rovige, J. Huijts, I. Andriyash, A. Vernier, V. Tomkus, V. Girdauskas, G. Raciukaitis, J. Dudutis, V. Stankevic, P. Gecys, M. Ouille, Z. Cheng, R. Lopez-Martens, J. Faure, Phys. Rev. Accel. Beams., 23, 093401, (2020).
[5] V. Tomkus, V. Girdauskas, M. Abedi-Varaki, G. Raciukaitis, J. Plasma Phys. 89(2), 905890209 (2023)

L12

Ultrafast laser nanostructuring; the quest for resolution

Razvan Stoian

Laboratoire Hubert Curien CNRS-UJM

The employment of ultrafast laser technology for volume nanostructuring of transparent materials shows tremendous potential for 3D photonics. Key in an optical design at the nanoscale is the capability to confine energy to the smallest regions. The nonlinearity of the light-matter interaction, the control of far and nearfield effects as well as of material transients is at the base of refractive index engineering on the nanoscale, enabling new embedded optical functionalities. I will discuss how extreme scales, down to a tenth of the wavelength, can be obtained starting form a self-induced scatterers. Using quantitative optical imaging techniques over the whole relaxation range, a time dynamic perspective will be given over the excitation mechanisms and the relaxation pathways, reconstructing thermomechanical trajectories for the formation of void-like nano-scatterers. Demonstrating nanoscale features, I will pinpoint the potential for the fabrication of complex hybrid micro-nano optical systems, capable of transporting, manipulating and reconstructing optical signals.

L13

Ultrafast laser-induced extrusion in sapphire

F. Courvoisier, V. V. Belloni, M. Hassan, L. Furfaro, R. Giust

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Ultrafast near-infrared laser pulses excel at generating localized and intense material transformations via nonlinear processes such as multiphoton ionization. Tailoring laser pulses, in space, time or polarization offers significant advantages to control light-matter interaction. Most applications of ultrafast laser pulses were hitherto related to ablative processes, removing material or modifying the bulk.

We will present a drastically novel femtosecond laser-induced phenomenon that is neither ablative or subtractive. We have discovered a process where positive structures are generated atop a sample by translating the matter over several micrometers using a single laser pulse, as reported in [1].

The key to this process is inducing a nanometrically-thin liquid layer in the shape of a cylinder inside sapphire, effectively cutting out a nano-rod with a 100 fs laser pulse shaped into a radially polarized zero-order Bessel beam, which features an elongated, hollow cylindrical focus. The pressure gradients generated are capable of pushing the material out, forming 800-nm diameter nano-pillar-shaped positive structures with a height of several micrometers on the surface.

We have identified 3 different regimes which were deeply investigated using Transmission Electron Microscopy (TEM) to provide insights into the effective generation processes. Strikingly, all structures are mono-crystals. The actual generation processes range from material translation without phase change to a jet of liquid undergoing capillary instabilities before resolidification, resulting in a final wavy shape up to 15 µm in height.

From a fundamental perspective, our research shows that ultrafast laser pulses can create extreme temperatures on scales as small as 50 nm. On the applications side, our processing method offers a rapid approach to producing nanostructures with applications in areas such as metamaterials, photonics, phononics, and mechanical systems, supported by the demonstrated capability to create matrices of nano-pillars.

This project has received funding from H2020 European Research Council (ERC) under grant agreement 682032-PULSAR, the European Union's Horizon 2020 research and innovation program under grant agreement No 825246 kW-flexiburst, the French Agence Nationale de la Recherche, projects DENSE (ANR-21-CE08-0005) and EQUIPEX+ SMARTLIGHT platform (ANR-21-ESRE-0040), and the EIPHI Graduate School (ANR-17-EURE-0002). This work was partially supported by the French Renatech network.

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L14

Tilted-pulse-front-pumped THz sources for femtosceond material science

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Femtosecond laser based THz pulse generation and detection make it possible to measure easily the temporal shape of the generated THz pulses, and in this way performing time-domain-terahertz spectroscopy (TDTS). A TDTS measurement can result simultaneously both absorption- and index of refraction spectrum.

Generation of THz pulses having energy on the µJ level [1], made it possible to follow the ultrafast dynamics of electrons and lattice excitations [2-4], and control material excitations [5,6], and material structure [6,7].

THz pulses with mJ energy [8] make it possible to build fs electron guns suitable for material research [9,10]. This talk will summarize the research in the above mentioned fields.

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L15

Two-photon lithography of Organic Semiconductor Nanowires

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Organic semiconductors have gained significant attention in electronics due to their tunable electronic properties, solution processability, and compatibility with flexible substrates. Among them, poly(3,4-ethylenedioxythiophene) (PEDOT) stands out for its high electrical conductivity, environmental stability, and wide applicability in organic electronic devices [1]. Despite these advantages, conventional methods for PEDOT fabrication, such as chemical and electrochemical polymerization, lack the spatial resolution required for nanoelectronic applications. Overcoming this limitation requires high-precision lithographic techniques capable of defining PEDOT structures at the nanoscale while preserving its intrinsic electronic properties.

In turn, multiphoton lithography (MPL) has recommended itself as a powerful tool for high-resolution, three dimensional nanopatterning [2]. Controlling two-photon absorption with low-energy visible or near-infrared femtosecond laser pulses prevents damage to sensitive materials like organic semiconductors or biomaterials. When combined with stimulated emission depletion (STED) inspired lithography [3], which confines the effective excitation volume to its central voxel, it enables the fabrication of structures with feature sizes below 40 nm [4].

In this study, we applied these lithographic techniques to the oxidative polymerization of EDOT. We discovered that 7-diethylamino-3-thenoylcoumarin (DETC), a well-established photoinitiator in STED-inspired radical photopolymerization, can also serve as a photosensitizer for EDOT oxidative polymerization. Additionally, we explored velocity-dependent lithography modes for both two-photon lithography (TPL) and STED lithography, and we discuss the possible physical and chemical mechanisms governing the polymerization process.

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L16

X-ray emission during ultrashort pulse laser material processing

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The unwanted emission of X-rays during ultrashort pulse laser material processing in air was already reported more than 20 years ago for pulse repetition rates in the 1 kHz range [1]. It was stated that an enclosure of the experimental setup is necessary to protect the operator from X-rays. By now, the use of ultrashort pulse laser technology has become established in industry using repetition rates in the multi 100 kHz up to the GHz range and laser average powers up to the kW level. Since 2018/2019, more and more investigations have been carried out on the hazards from X-rays at higher laser pulse repetition rates [2-4]. Recently, maximum X-ray skin dose rates of the order of 1 Sv/h (iron target [5]) and X-ray photon energies of up to 40 keV (tungsten target [6]) were reported. Measures must be taken to shield the unwanted X-rays.

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L17

Impact of laser-induced nanomorphology on multi-pulse formation of periodic surface structures

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Laser-induced periodic surface structures (LIPSS) have been widely applied in ultrashort pulsed (USP) laser processing for surface functionalization, impacting applications such as wettability control, optical absorption enhancement, and tuning of mechanical properties [1]. Despite extensive research, the interplay between processing parameters, material properties, and the mechanisms of LIPSS formation remains not fully understood. Models for metals highlight the necessity of inhomogeneous light coupling of the laser pulse, which can lead to either direct ablation or thermally driven hydrodynamic surface instabilities and melt flow dynamics [2,3]. However, due to the computational costs of large-scale molecular dynamics simulations, existing simulation models are predominantly macroscopic (e.g., hydrodynamic descriptions). The role of nanomorphology, specific to material and process parameters, in LIPSS formation remains underexplored.

In this study, we analyze the pulse-by-pulse behavior of aluminum (Al) and austenitic stainless steel (AISI 304), selected for their contrasting thermophysical properties. Al, characterized by high thermal conductivity and intermediate electron-phonon coupling, develops a rough surface with pronounced nanomorphology after a single pulse. In contrast, AISI 304, with low thermal conductivity and high electron-phonon coupling, results in a smoother surface [4]. Using a USP laser with a wavelength of 1040 nm and a pulse duration of 515 fs, we conducted multi-pulse ablation ranging from 1 to 50 pulses at 1.5 times the single-pulse threshold fluence. Surface morphology and topography were examined using scanning electron microscopy and atomic force microscopy. Finite-difference time-domain (FDTD) simulations modeled electromagnetic field coupling, while two-temperature model simulations provided thermal insights.

Our results reveal stark differences in surface evolution between the two materials. After the first pulse, Al exhibits a rough nanomorphology with frozen jet-like structures. Subsequent pulses lead to chaotic self-organization of coarser structures, which stabilize and remain largely unchanged. FDTD simulations indicate that this rough and random surface inhibits coherent light scattering, leading to chaotic field distributions that preclude LIPSS formation. Conversely, AISI 304 develops low spatial frequency LIPSS (LSFL) oriented perpendicular to the laser polarization after seven pulses, with periodicity decreasing from 650 nm to 600 nm as the structure height increases from 60 nm to 120 nm over 20 pulses. High spatial frequency LIPSS (HSFL), parallel to the laser polarization, appear after three pulses with a periodicity of 250 nm and a height of 40 nm, predominantly located in the valleys of LSFL structures at higher pulse numbers. The formation of LSFL aligns with periodic energy absorption, as calculated via FDTD simulations, and results in a cumulative self-reinforcing process. HSFL, however, do not exhibit an accumulative trend and are suspected to form anew with each pulse.

Our findings highlight that the nanomorphology induced by the first laser pulse plays a crucial role in determining the feasibility of LIPSS generation in a material. Excessive nano-roughness after the first pulse disrupts coherent light scattering, preventing LSFL formation. Thus, further understanding the influence of thermophysical properties on nanomorphology can guide the development of material-specific strategies for optimizing LIPSS formation, particularly for materials with challenging properties.

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L18

On the perspective of advancing laser ablation in liquid to the industrial scale: Concept and origin of a fundamental efficiency limit

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Pulsed laser ablation in liquid is a technique for the generation of nanoparticles from virtually any material. Since its inception more than 30 years ago, the techniques has matured in terms of control over particle properties and throughput, reaching industrial productivity on the g/h scale. This breakthrough was mainly driven by innovations in process design, such as avoidance of critical phenomena within the liquid layer by simultaneous spatial and temporal focusing, bypassing cavitation bubble shielding by fast scanning techniques and efficient removal of scatterers such as nanoparticles and persistent microbubbles by liquid flow reactors. While these efforts ensure efficient energy coupling to the target material, closer attention must be paid to laser ablation in liquid dynamics, which are fundamentally different compared to laser ablation in air due to the presence of the liquid overlayer. This overlayer has a negative effect on the ablation efficiency as it promotes material redeposition. As this redeposition process marks a fundamental limit of productivity, its investigation is of paramount importance to guide further upscaling efforts. In this study we aim to experimentally verify spallation layer redeposition and quantify the magnitude of redeposited material for Au and FeNi. For this pump-probe microscopy and absorption corrected ablation efficiency measurements are carried out in air and water. The time-resolved experiments clearly demonstrate spallation layer redeposition, which up until now was only shown by computational methods. Furthermore, the control of the precise amount of absorbed pulse energy enables a direct comparison of laser ablation in liquid and air and thus allows to determine the significance of spallation layer redeposition, amounting to more than 80 % of the ablated material. Our results clearly show that spallation layer redeposition during laser ablation in liquid fundamentally limits ablation efficiency. Based on this, strategies beyond efficient energy coupling, such as increasing fluence or employing double pulses may be formulated to reduce redeposition, increase ablation efficiency, and further scale up the LAL process.

L19

Guidance of osteoblast migration using femtosecond laser induced hierarchical structures

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The adhesion and alignment of osteoblasts and fibroblasts on titanium alloy (Ti-6Al-4V) surfaces can be adjusted over a wide range by femtosecond laser treatment and anodization. The great differences in cell behavior between different experimental conditions raised further questions about the role of cell migration, which will be addressed in this study. For that, Ti-6Al-4V surfaces were laser-structured to obtain a surface covered with ripples, i.e. laser-induced periodic surface structures (LIPSS), or micro-cones superimposed with ripples. Then, cells were seeded either directly onto the non-structured or laser-structured areas on the titanium alloy samples or besides of such samples where they can reach the surface by cell migration. After two weeks in culture, the cell coverage of the samples was evaluated by scanning electron microscopy (SEM). The results showed that cells directly seeded onto the non-structured or laser-structured areas cover the surface nearly completely, eventually aligned along the ripple direction for the laser-structured areas. In contrast for cell-seeding beside the samples, the laser-structured areas remain nearly cell-free while the non-structured areas were covered with cells in a similar non-oriented manner as for direct cell-seeding.

L20

Non-thermal ultrashort-pulsed laser annealing of semiconductors at the nanoscale: Crystallization without melting

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As-prepared semiconductor nanostructures are usually amorphous and, for most applications, need to be converted into a crystalline form. The most utilized method of furnace annealing is time- and energy-consuming and unsuitable for low-melt substrates. An alternative approach is laser annealing which is fast and highly localized but laser-annealed nanostructures are often destroyed by melting. Here we consider gentle non-thermal annealing of semiconductor nanostructures with low-fluence ultrashort laser pulses in the near- and mid-IR wavelength range [1]. One investigated system is a stack of alternative silicon and germanium nanolayers where selective crystallization of Ge was achieved without affecting the amorphous Si layers. Another laser-annealed sample is amorphous titania nanotubes which are crystallized into the anatase phase, the most desirable for applications. In both cases, the obtained crystalline nanostructures preserve their initial morphology and do not show any sign of melting. A theoretical analysis suggests that the plausible mechanism of the observed melting-free crystallization is the explosive stress-induced solid-phase transformation which can be achieved under stress confinement conditions provided by the action of ultrashort laser pulses.

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L21

Femtosecond laser induced refractive index changes in fluoride glasses

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We report on the fabrication of waveguides and fibre Bragg gratings in mid-infrared transparent fluoride glasses. Using a variety of advanced micro-characterisation techniques, we uncover the physical mechanisms that underpin the observed refractive index changes.

L22

Femtosecond Laser Ablation X-ray Photoelectron Spectroscopy (fs-LA XPS) Depth Profiling

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XPS depth profiling is a widely employed analytical technique to determine the chemical composition of thin films, coatings and multi-layered structures, due to its ease of quantification, good sensitivity and chemical state information. Since the introduction of XPS as a surface analytical technique more than 50 years ago, depth profiles have been performed using ion beam sputtering. However, many organic and inorganic materials suffer from ion beam damage, resulting in incorrect chemical compositions to be recorded during the depth profile. This problem has been resolved for most polymers through the use of argon gas cluster ion beams (GCIBs), but the use of GCIBs does not solve the issue for inorganics. A prototype XPS depth profiling instrument has been constructed which employs a femtosecond laser rather than an ion beam for XPS depth profiling purposes. This novel technique has shown the capability of eradicating chemical damage during XPS depth profiling for all initial inorganic, compound semiconductor and organic materials examined. The technique is also capable of profiling to much greater depths (up to 100 microns) and is much faster than sputter XPS sputter depth profiling. fs-LA XPS depth profiles results will be shown for selected thin films, coatings, multilayers and oxidised surfaces and the outlook for this exciting new technique discussed.

L23

Analysing Free-Space Light with All-Passive On-Chip Photonic Circuits

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Measuring light is a crucial and pivotal task in countless research fields and applications, from optical communications, sensing, microscopy and nano-optics all the way to quantum optics, biophotonics and life sciences. In fact, our day-to-day lives are based on the interpretation of and response to the visual fingerprints of our environment. Hence, also our technological companions are equipped with various light detectors and sensors, from simple to sophisticated, recording the world around us, recognizing and interpreting patterns or monitoring our vital signs. The vast majority of such sensors measure the intensity of light, while additional parameters, e.g., the wavelength, are accessible via simple filters. However, the phase of light, an intrinsic property very sensitive to the interaction with the environment, and thus a valuable resource for sensing the world, is usually harder to detect. Several techniques for phase measurements are well known, while all of them are usually bulky, computationally demanding, limited in the range of accessible parameters or requiring high mechanical stability.

Here, we introduce a novel concept – and prove its principle experimentally as well as theoretically – based on a passive photonic integrated circuit capable of spatially probing intensity and phase distributions of free-space light beams [1]. Phase information is retrieved in a single shot by utilizing compact, all-passive, on-chip interferometers combined with a versatile analysis method. In this presentation, we also highlight recent steps related to the extension of the measurement technique and system to additionally access polarization information, thus fully characterizing a light field [2]. This approach is fast, broadband, and features an inherently small footprint, while paving the way for a wide variety of potential applications.

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L24

Austrian R&D-Policy in Advanced Materials

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Nanotechnology and Advanced Materials are a very important research field in Austria and is funded by several research programms from the Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology with about € 70 million a year. Beside of bottom-up research-programmes projects from the field of nanotechnology are well represented in many thematic and structural programmes. The biggest one is topic field “digital and key enabling technologies” which promotes research into core issues relevant to digital and key enabling technologies within innovative RTD projects, also with the goal of producing competitive products and fostering increases in productivity leading to sustainable economic growth. Topics in the Area of Advanced materials within this programme are not only nanotechnology, but also digital technologies, robotics, photonics, materials, and smart textiles. The BMK is also quite active in the field of Nanosafety by funding projects within a special research programme, the Austrian nano environment, health and safety research program (“Nano-EHS”) dealing with topics like safe-and-sustainable-by-design, worker place protection and risk assessment of engineered nanoparticles. This research program represents the implementation of one of the main recommendations of the Austrian Nanotechnology Action Plan (ÖNAP) and is continuously adapted to current developments in this research area. As an independent discussion platform for ministries, public authorities and other actors active in nanosafety the project has been established. This enables the exchange of views in an objective context.

L25

The Advanced Materials ecosystem – enabling synergies with cross-sectorial collaboration

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The term "advanced materials" (AdMa) is used broadly and in various contexts, however, no definition is commonly agreed. As nanomaterials are understood to be AdMa [1], the Organisation for Economic Co-operation and Development (OECD) in the working party on manufactured nanomaterials (WPMN) has chosen to concentrate on the connections between nanotechnologies and AdMa, aiming to establish a common understanding of the term's scope: “AdMa are understood as materials that are rationally designed to have (i) new or enhanced properties, and/or (ii) targeted or enhanced structural features with the objective to achieve specific or improved functional performance” [2]. On another side, the international standardisation organisation (ISO) runs a study group to prepare a definition of AdMa [3], however, there is no such definition published yet. Based on these developments, the European research and development ecosystem has prepared itself to align their work towards improving the competitiveness of Europe in the global economy related to materials [4]. One of the actions in the coordinated plan is the development of a governance framework, including the setting up of the Technology Council [5]. This shall have strong links with the member states, thus, the demand for national structured initiatives and interconnections from regional, national to European level evolved.

In this intervention, the cross-sectorial collaboration is highlighted, focussing on the goals of the projects coordinated by BNN, on national level ATIMA - Austrian Advanced and Innovative Materials Community [6], as well as the EU-project InnoMatSyn - Innovative Materials Ecosystem to Gain Synergies of regional, national and EU Initiatives [7], will be presented. Furthermore, specific aspects of cross-sectorial connections in the field of AdMa e.g. implementation of the Safe and Sustainable by Design (SSbD) [8] concept as e.g. in HARMLESS project [9], will be shown, as they will be crucial elements in the early stages of the innovation process for the successful translation of AdMa to the market.

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L26

Temporal Airy Pulses as Precursor for Precision Dicing of Thin Glasses

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In recent years, ultrashort pulse lasers have become indispensable tools in the processing of high-bandgap dielectric materials. Their high peak power enables access to nonlinear effects within small areas, producing high-quality structures with minimal side effects. Traditionally, processing systems employ bandwidth-limited pulses with Gaussian temporal and spatial profiles, which primarily create surface ablation craters during interactions with dielectric materials. In previous studies [1], we demonstrated that Temporal Airy Pulses (TAP) - generated by modulating 30 femtosecond pulses from a Ti:Sapphire laser operating at 790 nm - enables the processing of fused silica at scales one order of magnitude beyond the diffraction limit imposed by classical optics. Cross sections of the samples created by focused ion beams revealed that these structures exhibit high aspect ratios, with lateral dimensions in the hundreds of nanometers and depths reaching tens of microns in a single-shot ablation regime [2]. A theoretical model describing the ability of positive and negative TAP to control the interplay between multiphoton ionization and avalanche ionization [1] has been experimentally validated by measuring the transient density of the electron plasma generated during the laser-induced optical breakdown process [3].

In this work, we present results on using three types of pulses (30 fs bandwidth-limited and ±600,000 fs^3 cubic dispersed TAP) as precursors for the precision dicing of ultrathin soda-lime glass plates. Irradiation experiments were conducted at varying fluences with two focusing conditions, achieved using 50× and 20× microscope objectives. The cutting performance was evaluated through breaking force measurements using a custom-built four-point bending stage, and the quality of the lines was assessed via optical microscopy of surface markings and lateral cross-sections post-breakage. Our findings reveal that positively dispersed TAP produced clean, flat-cut edges on the glass samples, significantly outperforming both negatively dispersed and bandwidth-limited pulses [4]. This approach demonstrates a promising alternative to mechanical cutting methods, which often fail to deliver the precision and quality required for thin dielectric and semiconductor materials.

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L27

Ablation of batteries materials by femtosecond pulses and burst of pulses

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AMPLITUDE

The automotive industry has initiated a considerable transition by moving from thermal to electric traction. The laser electrode structuring by femtosecond pulses or burst of pulses is now intensively studied. The electrode production speeds are decisive, and their value depends on the speeds achievable by laser structuring. The laser ablation mechanism of composite materials used for batteries is a key knowledge for the process optimization. Various technical approaches can be applied to improve the laser structuring process, acting on the laser beam itself, such as temporal or spatial shaping of laser pulses. In this work, we will provide new results on fs ablation of materials used for batteries. In particular, the very high value obtained for specific ablations rates of graphite up to 14 mm^3/min/W is rarely reached in fs ablation of any materials (next to 0.2 mm^3/min/W for metals). Moreover, the use of new high-power lasers allows to predict a high throughput of the associated industrial processes. A focus will be made also on electrode cutting to investigate numerous questions raised by recent experimental results on this hot topic.

L28

Quantum predictions of ultrafast phenomena: strong field effects of crystals and optical response of nanomaterials

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Since the development of the density functional theory method [1], considerable progress has been made in describing and even predicting the effect of laser light on materials, for situations that are near or far from equilibrium [2, 3].

In the first part, I will present the results obtained in the latest years via systematic comparison of first principle simulation results with non-equilibrium experiments. Using the example of silicon, I will review non-perturbative effects such as light-induced excitation of carriers [4], high harmonic generation [5,6], and will reveal theoretically predicted control parameters, which subsequently enabled a strong reduction of experimental fluctuations of the materials modification threshold [7,8].

In a second part, using computationally lighter quantum techniques [9] that enable to treat thousands of atoms in a laser field, I will address near equilibrium interaction regimes of more advanced materials, such as graphene and crystalline nanoparticles. Taking into account realistic aspects of experiments such as the presence of a substrate and the effect of temperature on linear optical properties and Fermi energy of nanomaterials thus becomes accessible for the design of novel sensors and qubits.

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L29

Computer Simulations of Rippleformation under Ultra Short Laser-Surface Interaction

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A combination of a finite element simulation of the electric field on a metal target during ultra-short-fs-laser pulses and a Molecular Dynamic MD simulation of the resulting target modifications has been realized. First results yield a strong indication, which processes are responsible for LIPSS development on the surface.

In our lab we have investigated experimentally over many years the growth of laser induced periodic surface structures (LIPSS), in particular for ultra-short fs laser pulses. The "nature" and "physics" of laser ablation - in particular for ultra short laser pulses still poses a lot of puzzles. That´s in spite of the fact of a large number of experiments and also theories. The richness of the physics becomes evident in the understanding of the nature of LIPSS, which have found a wide range of applications. This is due to the small nano - structures one can create below 100 nm. Fig. 1 shows the development of High Frequency Ripples in the 100 nm range.

The laser interacts with a material (surface) due to the electric fields it creates in the material. Program tools like COMSOL i.e. use a finite element approach to solve the Maxwell equations and determine the complex field distribution responsible for LIPSS. It is quite evident, that the xyz-scale on which these fields can be calculated is limited. On the other hand, the "response" of the material to these complex fields happens on an atomic scale and can be addressed i.e. by Molecular Dynamic (MD) simulations. The LAMMPS (Large-scale Atomic/Molecular Massively Parallel Simulator) code is a good choice [1]. In order to simulate reasonable target sizes, the use of an HPC is required. The computations were performed on the Vienna Scientific Cluster (VSC).

Most of the major bottlenecks, which appeared have been solved and a simulation of a LIPSS process is now possible within a reasonable time frame. A discussion will be presented. We are convinced, that a major issue in all simulations is the fact, that only a limited number of physical processes can be included and also often in a simplified manner. It will be demonstrated, that specific processes have to be considered in order to achieve the desired results. This might sound trivial, but we can show that Coulomb-like processes, which have often been neglected over the years (especially in simulations), are essential to be included.

L30

Attosecond charge transfer in atomic-scale scanning tunnelling microscopy

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Understanding and controlling ultrafast elementary dynamics of novel quantum materials is equally important for fundamental science and next-generation technology. Lightwave-driven scanning tunnelling microscopy (LW-STM) has enabled us to record atomic-scale slow-motion videos of single molecular orbitals and defect states on their intrinsic spatio-temporal scales [1,2]. To this end, the oscillating carrier field of terahertz pulses replaces the DC bias voltage across the tip-sample junction. So far, the time resolution (~100 fs) of this approach has not yet been sufficient to trace eV-scale electronic excitations. The necessary single-fs snapshots may move into reach using single-cycle bias pulses at much higher carrier frequencies. Yet this step comes with two caveats: (i) It is unclear whether quasi-adiabatic sub-cycle field-controlled tunnelling is still possible as photon-mediated tunnelling becomes increasingly likely. (ii) Stable imaging requires exceptional stability of the atomically defined tunnel junction. Even subatomic variations of the tip-sample distance cause measurement artefacts. At higher carrier frequencies, the absorption coefficients of metals typically increase, therefore the problem of thermal expansion induced by fluctuations in laser power becomes more prevalent.

Here, we introduce a novel attosecond STM with atomic resolution that explores this uncharted territory. By modulating the waveforms of single-cycle near-infrared pulses, we gain a new control parameter for tunnelling currents while leaving the laser intensity constant. This allows us to measure currents depending only on the carrier-envelope phase and the shape of the synthesized waveform avoiding thermal artefacts. Pronounced sub-cycle features in the light-induced tunnelling current are the hallmarks of tip-sample charge transfer faster than 1 fs. Our data suggest tunnelling processes with an effectively reduced barrier height characteristic of a non-thermal electron distribution. By imaging single Cu adatoms we find a spatial confinement of the attosecond tunnelling current to the atomic length scale. This breakthrough in lightfield-controlled microscopy paves the way to videography of fully coherent electronic motion on intrinsic attosecond and atomic scales. Soon, even electronic wave packet propagation through a single atom may become accessible in actual real-space movies.

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L31

Selected Continuum Wavefunction Method (SCWF) for Modeling Molecular Photoemission at the attosecond scale

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We develop the selected continuum wavefunction (SCWF) method for molecules to model molecular photoemission at the attosecond scale. This is a very efficient method to access ionization dynamics, photoemission time delay, angular photoelectron spectrum, anisotropy

of scattering potential, photoelectron cross-section, dipole density distribution, etc. We develop a real-space grid-based method for evaluating continuum wavefunction of the photoelectron, incorporating realistic three-dimensional molecular potential and multi-electron nature of polyatomic systems. The numerical implementation is provided as a plugin to Quantum Package 2.0, an open-source quantum chemistry software.

Poster Abstracts

P01

High-Field Terahertz Pulses for Cutting-Edge Electron Acceleration

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The generation and application of terahertz (THz) pulses offer transformative potential in particle acceleration, providing compact and efficient alternatives to conventional methods [1,2]. This work allows insights from two cutting-edge approaches: multi-cycle THz pulse-driven dielectric laser accelerators (DLAs) and vacuum-based THz-driven electron acceleration from gas jets [3]. In the first approach, multi-cycle THz pulses, generated through quasi-phase-matched lithium niobate, are coupled by using waveguide structures to amplify electric fields, and optimizing electron acceleration within dielectric microstructures. The second approach explores the direct acceleration of electrons via counter-propagating single-cycle THz pulses in a vacuum, utilizing pre-ionized gas jets. Both methodologies underscore the advantages of THz systems, such as high accelerating gradients and tuneable electron bunch properties, promising scalable and cost-effective solutions for next-generation accelerators. Together, these techniques highlight the versatility of THz-driven acceleration for scientific and industrial applications, from compact accelerators to high-precision beam control.

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P02

Mapping high-density nano-plasmas through wave-turning measurements

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Laser-induced plasmas play a pivotal role in the process of energy deposition within solid dielectrics during ultrafast laser material processing. Its understanding and modeling is key for numerous applications. The plasma density holds significance in fundamental inquiries into the generation of extreme pressures and temperatures in materials, such as those found in warm dense matter—the state of matter found at the core of various celestial bodies, including planets and stars. However, comprehension of these fundamental processes necessitates precisely quantifying the distribution of laser-induced plasma density in space.

In this study, we propose a novel and simple imaging technique to map plasma generated by Bessel beams inside the bulk of dielectrics such as sapphire or glass. Direct imaging is nearly impossible because of the nanometric transverse scale of the laser-induced plasma rod. We use the direct imaging of the laser pump pulse after its interaction with the sample. The plasma dimensions are extracted from the images analyzing the wave-turning phenomenon, in which waves are reflected away from the plasma at a precise density when interacting with a plasma distribution at an angle. Our results allow us to characterize plasmas with scales much smaller than the optical resolution limit. The resulting spatial distributions exhibit excellent agreement with the dimensions expected from advanced numerical simulations based on the Particle-In-Cell approach.

P03

Progress in STED-inspired sub-diffractional lithography of epoxides

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Two-photon lithography, enhanced by stimulated emission depletion (STED) principles, has significantly advanced direct laser writing, primarily benefiting radical polymerization systems [1,2]. However, its application to cationic polymerization, especially in epoxide-based systems widely used in microfabrication, remains largely unexplored, despite the latter's advantages, including lower monomer toxicity, reduced shrinkage stress, improved adhesion, and resistance to oxygen inhibition.

In our recent work [3,4], we investigated a resist containing 3,4-epoxycyclohexylmethyl 3,4 epoxycyclohexanecarboxylate (EPOX) as the monomer, triarylsulfonium hexafluoroantimonate salt as photo-initiator and 2-isopropylthioxanthone (ITX) as a photosensitizer. Using a 780 nm femtosecond laser for two-photon excitation, we successfully produced polymer structures with a feature size of 418 nm. Introducing an additional component to the resist system as a quenching agent [5], Ethyl 4-(dimethylamino)benzoate (EDAB), resulted 70% polymerization quenching. Furthermore, by employing a 450 nm multimode continuous-wave (CW) diode laser for depletion in combination with a half-spaced phase mask, we identified an alternative depletion mechanism in this system, enabling the fabrication of structures with a feature size of 195 nm.

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P04

Influencing the Amorphization Thickness and Fluence-windows for crystalline Silicon <111> with Temporally Shaped Femtosecond Laser Pulses.

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Temporally shaped laser pulses have proven to be a new tool for material processing. By controlling the energy flux and instantaneous frequency of infrared femtosecond laser pulses the excitation dynamics during the laser-matter-interaction and resulting material changes are altered [1].

We now direct this technique towards high-resolution processing of phase-change materials, in particular crystalline silicon, which is at the heart of the technological requirements for the manufacture of various electronic devices. It is known that, in the case of crystalline silicon, irradiation with low fluences generally leads to amorphization due to rapid cooling, since after melting, silicon atoms resolidify quickly into a preferentially amorphous phase. This permanent transition modifies the local etching rate, electric conductivity, hardness, and optical properties such as the refractive index, providing new laser-based fabrication processes for microscopic silicon-based devices [2]. The challenge when processing these materials with short laser pulses lies in preventing the additional unwanted chemical and structural changes that occur during processing.

We employ a home-built liquid crystal modulator based optical synthesizer to tune the temporal shape of the output laser pulses of our Ti:Sa amplified laser system (800 nm, 30 fs) to produce Group Delay Dispersion (GDD) pulses and Temporal-Airy-Pulses (TAP). Compared to the traditional Bandwidth-Limited (BWL) pulse, we observe that shaped pulses shift the fluence thresholds for producing thin amorphous films on c-Si <111>. In addition, the temporally asymmetric Airy-Pulses, when inverted, lead to different amorphous layer thicknesses for a given constant irradiation fluence, meaning that the effect is not merely based on pulse-stretching compared to BWL pulses, but on the actual temporal shape.

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P05

Numerical Simulation of femtosecond laser ablation of Aluminium

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We have developed a novel MATLAB code to simulate femtosecond laser ablation of aluminium by solving the Two-Temperature Model (TTM) equations using finite difference methods. All dependencies of optical and thermal parameters with temperature have been considered, the former were calculated via the Drude+Critical Points (CPs) model for metals, while for the thermal parameters various models were used, including an analytical solution developed by us to model the electron heat capacity in s-band metals. Ablation has been modelled by introducing a normal mesh velocity, which removes material once the surface temperature reaches the phase explosion condition. Predictions from our code have been experimentally validated by conducting our own irradiation experiments using a femtosecond laser on a polished aluminium sample. Our predictions were also compared with previously published research on USP Al ablation. We have found that good agreement exists in all cases for the diameters of ablation spots, which confirms the reliability of the code in simulating laser ablation processes. Moreover, ablation efficiency can also be predicted from our code, by radial integration of the resulting crater shapes.

P06

Femtosecond Laser-Induced Breakdown Spectroscopy for Thin Film Analysis of Cu-Coated Polymer Textiles

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Recently, flexible polymer-based substrates have become popular for making electronic devices like flexible screens, wearable sensors, and energy harvesting systems. However, creating durable conductive elements on these flexible materials remains a challenge.

This study uses a copper-coated polymer textile (lyocell fabric) as conductive tracks for textile electronics. The coating process involves silver seeding for copper electroplating and results in a deep blue color. However, nanoparticles in the passivation layer, primarily composed of Cu_2O, can cause unwanted color changes (brown, orange, yellow) due to localized surface plasmon resonances. To better understand these color variations, we analyzed the passivation layer's composition.

We used femtosecond Laser-Induced Breakdown Spectroscopy (fs-LIBS) system to study the colored regions on the Cu-coated textile. The system employs 30 fs laser pulses at 790 nm, focused to a 3.5 µm beam waist, and operates at 1 kHz. Each laser pulse creates a plasma, and the emitted light is analyzed for chemical composition. The sample was positioned using a motorized XYZ stage with 1 µm resolution. We recorded spectral data from 300-600 nm, averaging results from a 5×5 matrix of ablation spots spaced 25 µm apart. The process was repeated until the underlying polymer substrate was reached. Additional techniques like energy-dispersive X-ray spectroscopy and scanning electron microscopy were used to map the copper coating's depth distribution.

Our results demonstrate that fs-LIBS is an effective tool for characterizing copper coatings on heat-sensitive, soft materials like textiles. The technique requires minimal sample preparation and provides accurate chemical analysis, making it suitable for studying various metallic coatings and substrates.

P07

Enhancing LIPSS Formation and Processing Efficiency on as-cast $AlSi_{10}Mg$, AlMg and pure Al with Temporal Pulse Shaping of Femtosecond Laser Pulses

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Laser-Induced Periodic Surface Structures (LIPSS) are periodic surface modulations that from due to ultrashort pulsed laser irradiation. The structures depend on laser polarization and material properties, with feature sizes ranging from nanometers to micrometers, making them useful for applications such as change of wettability, structural color, and influencing bacterial growth on the surface.

Fabricating LIPSS on aluminum and its alloys is challenging due to the short decay length of excited surface plasmon polaritons. This difficulty increases for alloyed materials, where variations in optical properties at crystal boundaries inhibit continuous plasmon formation. To improve LIPSS formation on as-cast AlSi10Mg, AlMg and pure Al, the laser pulses were formed temporally, while maintaining the Gaussian spatial profile of the beam.

The laser system used was a Ti:Sapphire pulsed laser with a pulse duration of 30 fs, a central wavelength of 790 nm, and 1 kHz repetition rate. Temporal shaping was achieved using an optical pulse shaper, which split the beam spatially with a diffraction grating and manipulated the phases of certain frequencies using a liquid crystal modulator before recombining with a second grating. The pulse shapes included bandwidth-limited (BWL) pulses (30 fs), group delay dispersed (GDD) pulses with positive and negative chirp, and positive/negative temporal Airy pulses (TAP), extending up to 1 ps in pulse duration. LIPSS were generated with line scans at a scan speed of 0.1 mm/s, with a beam waist of 12.2 µm and an effective pulse number of 244.

Processing efficiency was assessed by measuring the marked area for different pulse shapes at constant laser fluence. Optical microscopy, scanning electron microscopy, and atomic force microscopy analyses showed that both the pulse duration and temporal shape influenced LIPSS formation. Longer pulses improved structuring and efficiency, where in particular negative TAPs produced the most defined structures and largest marked area. The study demonstrates the potential of temporal pulse shaping for laser processing in advanced manufacturing.

Bundesministerium
Klimaschutz, Umwelt,
Energie, Mobilität,
Innovation und Technologie

P08

The need to detect and characterise nanocarriers for environmental risk assessment testing

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Nanocarriers are innovative transport and encapsulation systems that enable targeted delivery and release of active ingredients (AIs) to a specific (target) site of action. The nanocarrier systems (NCS) achieve a higher efficacy of the AI and are already used in medicine (e.g. cancer treatment or vaccines), cosmetics or in the food sector [1]. In the last decade, there has been increased research and development into NCS for use in batteries, household products and agrochemicals. Especially the agricultural sector is prospering because NCS can be used for the target delivery of fertilizers and pesticides [2,3]. It is reasonable to assume that production volumes will increase significantly in the near future. Consequently, a comprehensive risk assessment of NCS in the size range between 1 and 1000 nm is essential, encompassing thorough characterisation, along with toxicity and fate assessment of the AI and the nanocarrier [3]. For instance, in the context of environmental risk assessment (ERA), it is imperative to consider detailed nanocarrier information and testing on biodegradability and potential mobility (e.g. in agricultural soils, surface waters, or groundwater), taking into account the release of the AIs depending on the environmental conditions. As many nanocarriers are very innovative, differ in material composition and can also be modified and functionalised on the particle surface (e.g. nanoliposomes stabilised with PEG and functionalised with peptides), there are currently few studies on their environmental behaviour [4]. The authorities are faced with the challenge of having to assess very complex NCS, for which relevant standards for characterisation and testing methods for ERA may not be suitable.

For this reason, the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection and the German Environment Agency (UBA) have commissioned the application of relevant OECD test guidelines to selected NCS. The aim of this project is to check their applicability to such complex advanced materials and provide recommendations for necessary adaptations to assess the environmental behaviour. For example, using the 'OECD TG 318 Dispersion Stability of Nanomaterials', we found in laboratory tests that the characterisation and quantification methods provided therein, such as UV-VIS and ICP-MS, are insufficient to obtain robust and meaningful measurement data regarding the potential mobility of NCS in aqueous environments. According to this international guideline, DLS can be used as a complementary method to make predictions regarding the change in particle size distribution. However, the reproducibility of the results is often not guaranteed because, for example, the refractive index of the nanocarrier outer shell is often not precisely known and the NCS test media are highly polydisperse, in which salts and humic substances are also added in order to simulate environmental conditions. As part of our nanocarrier project and the poster presentation, we want to show a few examples from measurement practice as to why standardised test methods, including the intended analysis methods, need to be revised for application to complex NCS. This in turn should be the groundwork for developing advanced methods for the characterisation and quantification of NCS in terms of chemical risk assessment, which can be used simply, quickly and cost-effectively for regulatory purposes.

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P09

Investigation of nanoparticular abrasion of ceramic dental implants

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In recent years, there has been a trend in dentistry toward the use of metal-free dental implants. Titanium implants, which have been considered the "gold standard" for decades, can now be substituted or even replaced by biocompatible ceramic implants. In addition to the positive aesthetic aspect of a ceramic prosthesis, improved osseointegration and tissue compatibility have been observed in patients who are allergic to individual components of titanium implants or who have pre-existing conditions [1-3]. Consequently, this material offers distinct advantages and novel opportunities in the field of dentistry. However, nanoscale abrasion can occur during insertion, removal, or as a result of accidents and gum disease, which may pose a potential health risk. To date, however, no negative interactions of ceramic dental implants in the human body have been described in the literature, although long-term studies are still lacking. Accordingly, the present study examined a high-performance ceramic (ACERPEDENCO G2 from MKM-Engineering GmbH, Offenbach, Germany) as a potential example for possible immune reactions. The dental implants were provided as sintered, planar surfaces in the form of polished platelets, but also as abrasive dust. This allowed simulation of potential material abrasion or corrosion-induced particle formation during the lifetime of a ceramic implant. Experiments were performed in parallel with TiO2 (NM-105, Joint Research Center, Ispra, Italy) for comparison. Nanoscale abrasion of ACERDENCO G2 and TiO_2 each were dissolved in the cell culture medium in equal amounts and applied to macrophages and human osteoblasts, and the effects on the cells studied were compared. Several critical inflammatory markers were examined at the gene and protein level. Both ACERDENCO G2 and TiO_2 showed only slight differences in the activation of inflammatory markers in the in vitro osteoblast model. Immunological testing as part of a commissioned immunization study also revealed no specific anti-ceramic antibodies, thereby indicating an absence of an inflammatory or immunogenic response to nanoscale ceramic abrasions. However, the findings suggest that ceramic materials exhibit reduced inflammation overall in the experimental models and the inflammation markers selected. This enhanced tolerability would offer a distinct advantage over titanium implants, given the documented cases of allergies to nanoscale impurities. Results of an additional expert survey, also demonstrate that ceramic materials offer several advantages, particularly for patients with chronic pre-existing conditions, and could therefore be a suitable dental implant material of the future.

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P10

Spatial and temporal multiple-pulse beam shaping in pulsed laser ablation in liquid

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Pulsed laser ablation in liquid (PLAL) is an attractive technique for nanoparticle synthesis. It is versatile and produces clean, compositionally controlled, and safe-to-handle products that find applications in multiple fields [1]. The main limitation of the process relies on the formation of a plasma plume and a cavitation bubble after ablation that may block the beam. Thus, industrial applications of PLAL-produced nanoparticles are limited, mainly due to the low productivity of the method. Also, control of nanoparticle size, shape, and homogeneity remains a challenge for PLAL. In this work, we address these limitations using spatial and temporal shaping of ps laser beams.

1) Spatial shaping: beam splitting over the surface.

Using simultaneous laser beams instead of one beam to ablate a larger surface has already shown great potential for the production rate (up to a g/h level) with 2 to 11 separated pulses [2,3]. In this work, high entropy alloy (HEA) and FeNi nanoparticles have been synthesized using a diffractive optical element (DOE) to split a beam into 49 sub-beams. The production rate and the size homogeneity of the nanoparticles obtained will be discussed as a function of the used parameters and the geometry formed on the surface of the multiple beams.

2) Temporal beam shaping: double pulses separated by time delay.

The laser ablation effect is in competition with the energy loss due to the thermal diffusion inside the sample. Thus, getting most of the pulse energy per shot is crucial. Preparing the target using a first non-ablative pulse may optimize the ablation process for a second delayed pulse. Some promising effects have already been demonstrated for similar ablation processes with [4,5] and without [6] liquid media. Here we present a preliminary set-up and ongoing work using two pulses separated by a time delay and consequences on the interaction with the target.

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P11

pyLUMINA: Open-source Python Evolutive Library for Ultrafast Laser Beam Propagation Simulations

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Material processing with femtosecond laser pulses requires a precise knowledge of the laser intensity distribution on or inside the material. In particular, the fluence level cartography is a key parameter to understand and control the result of laser-matter interaction. We propose a collaborative open source simulation code based on the non paraxial approximation: pyLUMINA (Laser Unveiling Modeling Interactive Numerical Application). Based on the Python programming language, and hosted on a public GitHub repository [1], the code is a library of basic functions easily stackable in 'Scenarios' to simulate usual laser processing situations (beam focusing, beam shaping, non diffractive shaping etc.) with clear and nicely rendering figures of fluence distributions (2-3D). We present several results including multispot shaping, Bessel and Airy beam forming. The effect of the nonlinear index on multispot shaping is also qualitatively investigated using the code.

[1] https://github.com/cyril-everlearner/pyLUMINA

P12

Influence of local field enhancements on the incubation effect for ultrashort pulsed laser ablation

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In recent decades, ultrashort pulse (USP) laser ablation has become a key technique in precision material processing. This advancement has been driven by extensive experimental and theoretical studies, leading to a well-established understanding of single-pulse interactions. However, industrial applications invariably rely on multi-pulse processing, where the so-called incubation effect plays a crucial role. This effect, characterized and quantified by a reduction in the ablation threshold with increasing pulse number, is commonly described by a heuristic power-law model introduced in 1988 [1], which has been recently refined in other works by specifically accounting for global properties such as enhanced absorption [2] and material weakening or defect accumulation [3]. However, recent advancements in USP laser ablation have increasingly focused on the influence of nanomorphology on near-field scattering, particularly in the context of laser-induced periodic surface structures (LIPSS) formation [4]. Given trend, our objective is to explore near-field effects and their influence on incubation.

We examine the incubation effect on a pulse-by-pulse basis for two distinct metals, aluminum and stainless steel, each exhibiting unique single-pulse crater morphologies. Our approach combines ablation experiments using an USP laser (1040 nm, 500 fs), pulse-integrated self-reflectance measurements, topographical analysis via confocal microscopy, Finite-Difference Time-Domain simulations, and morphological assessments through scanning electron microscopy.

While the incubation factor is similar for both stainless steel and aluminum, yielding values of 0.76(1) and 0.71(1), respectively, their relationship to absorptance differs fundamentally. For stainless steel, unlike aluminum, total absorption remains constant over the initial five pulses, despite a drastic 35% reduction in the ablation threshold. While material weakening may play a role, the constant ablated depth per pulse suggests that additional mechanisms are involved. Instead, we observe pronounced local field enhancements at the crater edge, further evidenced by the emergence of selectively ablated LIPSS. These near-field enhancements contribute directly to crater widening, which, by definition, characterizes the incubation effect.

Through these insights, we challenge the conventional incubation model, which primarily considers global material modifications, and highlight the possibility to incorporate local field effects for a more comprehensive understanding of the process. This perspective opens prospects for deriving the power-law dependence emerging naturally from an improved model.

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P13

Reflection and Transmission of Femtosecond Laser Pulses in Polymer Target

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High-intensity femtosecond laser pulses interacting with nanostructured polymer-based targets offer valuable insights into laser-driven plasma physics and its potential applications in nuclear fusion [1]. The use of targets with various structures has also been extensively investigated for their roles in laser-driven ion acceleration [2], high-harmonic generation [3], and ultrafast material processing [4]. Recent studies have demonstrated that incorporating gold nanorods into polymer matrices can significantly enhance the kinetic energy and yield of ions due to their strong plasmonic resonance [1]. Specifically, the plasmon resonance peak of 25 × 85 nm gold nanorods is around 800 nm [5], making them highly effective at the emission wavelength of the femtosecond laser system. When a high-intensity femtosecond laser pulse interacts with a target, the absorbed laser energy generates plasma, enabling the study of energy absorption and plasma dynamics. In this work, systematic reflection and transmission measurements have been carried out to analyze the optical response of urethane dimethacrylate (UDMA) polymer undoped and doped with gold nanoparticles under varying laser energies. Experiments were performed using a Ti:Sapphire chirped-pulse amplification laser system in single-shot mode, delivering 40 fs pulses at an 800 nm central wavelength, and a maximum pulse energy of 30 mJ. The peak intensity at the focal point reached 3×10^{17} W/cm^2. The polymer target was irradiated at pulse energies of 5, 10, 15, and 20 mJ to investigate the intensity-dependent optical response. The results demonstrate that higher laser energies reduce reflectivity, enhancing energy absorption into the material. Additionally, minimum reflectivity was observed in the polymer target containing plasmonic gold nanorods, leading to a further increase in laser intensity absorption. These findings provide critical insights into the plasma mirror threshold and energy absorption dynamics in polymers, advancing our understanding of high-intensity laser-matter interactions, and highlighting the potential of nanostructured polymer-based targets for applications in nuclear fusion and high-intensity laser physics.

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P14

STED-Inspired Sub Diffractional Cationic Lithography

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Stimulated emission depletion (STED) broke the diffraction limit of resolution in fluorescence microscopy and it has been proposed that a STED-confined excitation volume should be equally applicable to spatially control chemical reactions on the nanometre scale [1]. Meanwhile, this prediction has been experimentally realized using free radical polymerization of mostly (meth)acrylates [2-5].

In this contribution, we will present concepts of how to achieve sub 100 nm structure sizes in STED-inspired epoxide cationic lithography by using a modified system of photosensitizers and initiators. In particular, we use thioxanthones as sensitizers and a sulfonium salt as initiator. The thioxanthones turned out to be optically depletable within the triplet system by transient state absorption depletion (TAD) [6, 7]. Making use of this depletion mechanism in the outer rim of the excitation focus, we were able to write sub-diffractional, 125 nm wide epoxide features with isopropyl thioxanthone [8], and, most recently, even sub-100 nm features using 2-chlorothioxanthone [9].

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P15

Pump–probe imaging of GHz surface waves for Young's modulus measurement

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Understanding GHz surface acoustic waves (SAWs) is critical for advancing nondestructive testing and material characterization in applications like semiconductor wafers and optical crystals. Traditional SAW measurement methods often rely on time-consuming point-based techniques, requiring multiple scans to capture angularly resolved wave propagation. This study employs a fast, full-field imaging approach using ultrafast pump–probe microscopy with subpicosecond infrared laser pulses in the ablation regime. This method captures angular propagation velocities of Rayleigh SAWs and high-velocity pseudo-SAWs in fused silica and x-cut quartz. Reflectivity modulations were recorded using a high-resolution sCMOS camera, enabling an observation of wavefront dynamics over a time delay range of 6–11.5 ns. The results matched finite element simulations, achieving relative errors between 2–5%. From the measured wave velocities, key material parameters such as Young's modulus and Poisson's ratio were derived in excellent agreement with literature values. This technique demonstrates potential for faster, accurate material characterization.

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	Feb. 24, 2025	**Feb. 25, 2025**	**Feb. 26, 2025**	**Feb. 27, 2025**
9:00 - 9:30	Registration & opening	L06 Balling	L16 Krüger	L26 Sarpe
9:30 - 10:00		L07 König	L17 Redka	L27 Audouard
10:00 - 10:30	L01 Sugioka	L08 Bulgakova	L18 Spellauge	L28 Derrien
10:30 - 11:00	Posters: Short lectures and session	Break	Break	Break
11:00 - 11:30		L09 Sedao	L19 Heitz	L29 Husinsky
11:30 - 12:00		L10 Julsgaard	L20 Bulgakov	L30 Maier
12:00 - 12:30		L11 Račiukaitis	L21 Fuerbach	L31 Dubey

16:30 - 17:00	Coffee	Coffee	Coffee
17:00 - 17:30	L02 Zhigilei	L12 Stoian	L22 Baker
17:30 - 18:00	L03 Ovsianikov	L13 Courvoisier	L23 Banzer
18:00 - 18:30	Break	Break	Break
18:30 - 19:00	L04 Gurevich	L14 Hebling	L24 Pogány
19:00 - 19:30	L05 Mauclair	L15 Gvindzhiliias	L25 Falk