Examples and highlights from the E1 Experimental Hall and Auxiliary labs

MAC:
Multipurpose station for Atomic, Molecular and Optical (AMO) science and Coherent Diffractive Imaging (CDI)

Plasma X-ray source (PXS), 3-30 keV, 8 keV
End station for X-ray science (TREX)
- X-ray diffraction
- X-ray spectroscopy

In commissioning

E1 Ultrafast Optical spectroscopy
- Time resolved spectroscopic ellipsometry (trELIps)
- Transient Current Technique (TCT)

High Harmonics Generation (HHG)
- EUV/XUV, 10-120 nm

- mid-IR to hard X-ray
- fs to ms dynamics

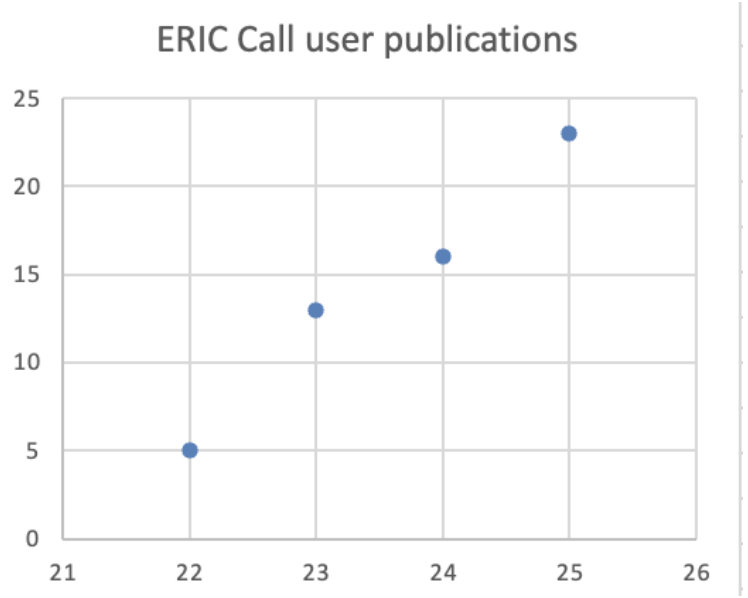
Biolab optical: Femtosecond Stimulated Raman and Tranient Absorption

User statistics: E1 Experimental Hall and Auxiliary labs

Call	Nr of applications	Nr of experiments performed or planned
ERIC call 6 (2025)	28	25
ERIC call 5 (2024)	33	25
ERIC Call 4 (2024)	34	21
ERIC Call 3 (2023)	17	16
ERIC Call 2 (2023)	39	23
ERIC Call 1 (2022)	17	16
BL Call 2 (2021)	29	24
BL Call 1 (2020)	22	22
Covid call	0	1
BL Call 0 (2019)	22	19
sum	**241**	**192**

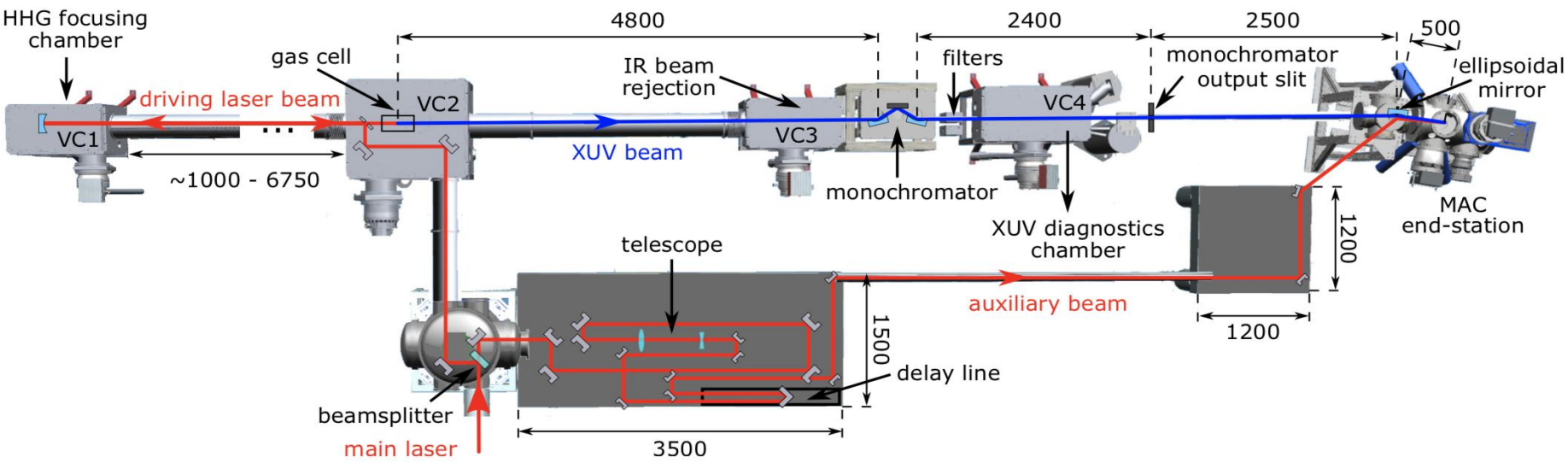
Formation of ERIC

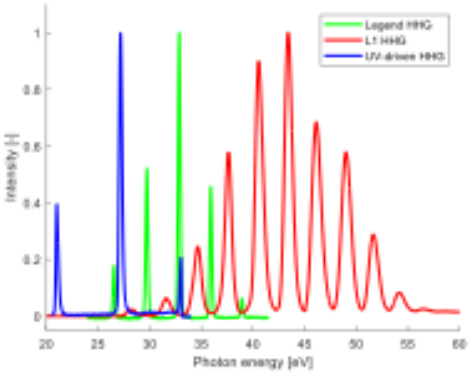
+ 22 experiments scheduled from call 7

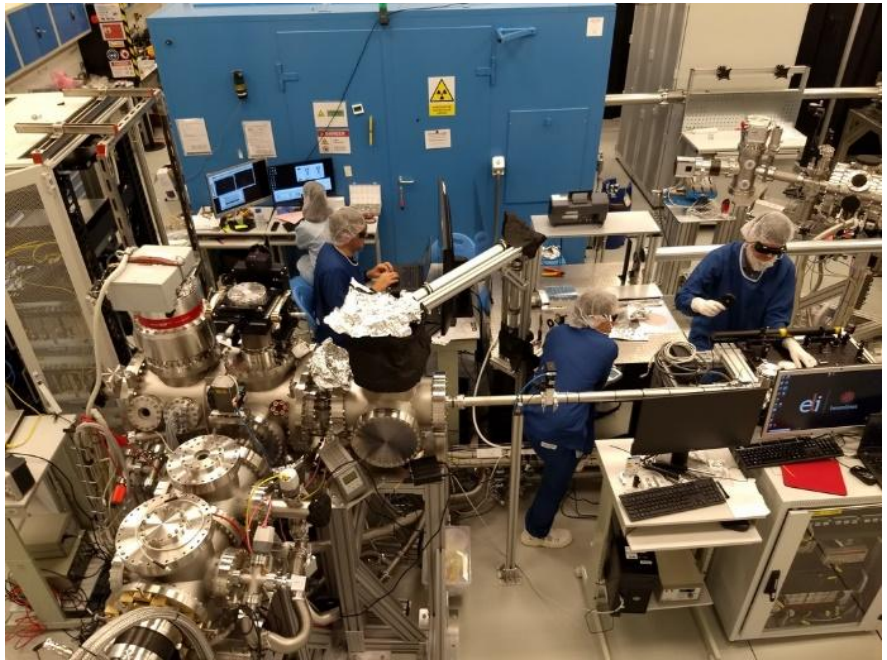


Total number of user publications: 87
Of which 59 are from ERIC user calls
(includign also publications from 2026)

XUV science: HHG source and MAC station



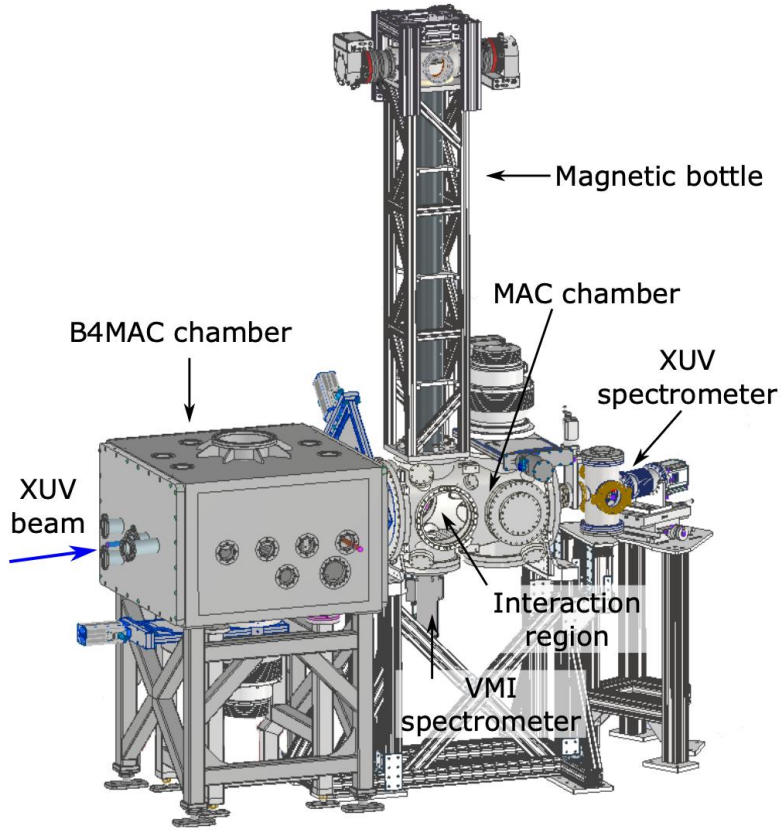




High-flux source of coherent XUV pulses for user applications, O. Hort, et al., Optics express 27 (6), 8871-8883 (2019)

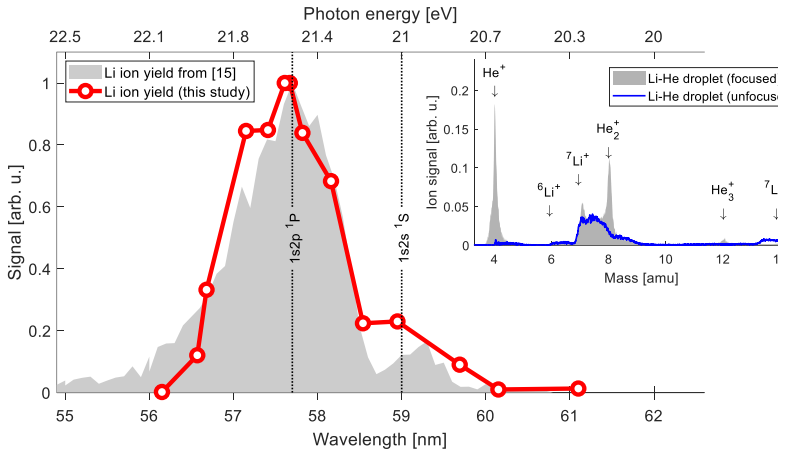
E Klimešová, et al., Eur. Phys. J. Spec. Top. 1-12 (2021) https://doi.org/10.1140/epjs/s11734-021-00192-z

Drive lasers
L1 ALLEGRA or Coherent Legend

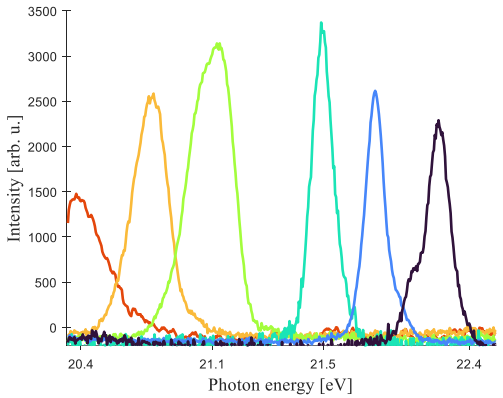


HHG/MAC beamline, recent highlights/user publications

Bright continuously-tunable VUV source for ultrafast spectroscopy
L. Jurkovičova, et al., Communications Physics 7 (1) 26 (2024)

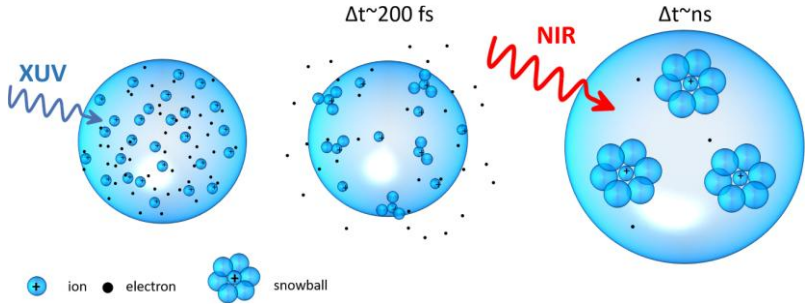


Li+ ion yield (red) from Li-doped He nanodroplets excited by a spectrally tuned 7th order harmonic radiation



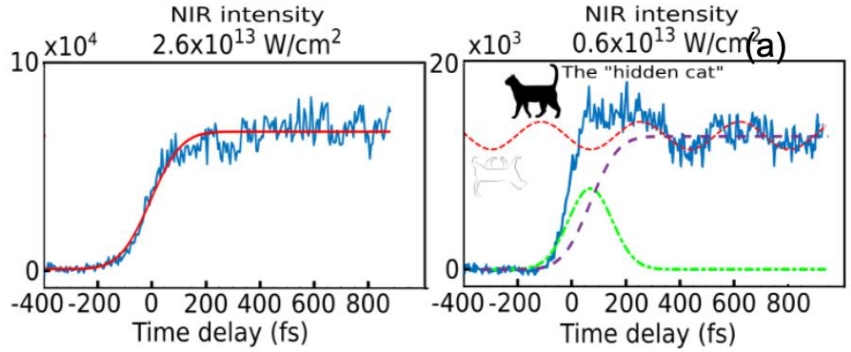
HHG tuning around the peak of the He 1s2p 1P resonance at 21.5 eV

Long-lasting XUV activation of helium nanodroplets for avalanche ionization, C. Medina, et al., NJP 25 (5), 053030 (2023)



With nanodroplets first irradiated by a weak EUV pulse, nanoplasma ignition by the infrared pulse becomes much more efficient. An effect lasting up to many nanoseconds.

Electron correlation dynamics in atomic Kr excited by XUV pulses and controlled by NIR laser pulses of variable intensity
Andreas H. Roos, et al., New J. Phys. 25 013038 (2023)



Probing quantum oscillations of an excited electron wavepacket in a superposition of excited states by tuning the NIR intensity.

XUV fluorescence as a probe of the relaxation dynamics of resonantly excited He nanodroplets, Keshav Sishodia, et al., Scientific Reports
DOI: https://doi.org/10.1038/s41598-025-34677-x

Studies of ultrafast dynamics in substrate-free nanoparticles at ELI using Timepix3 optical camera, D. Ševaev*a*. Et al., http://arxiv.org/abs/2510.05855

Demonstration of a kHz-repetition-rate extreme ultraviolet laser at 41.8 nm
F. Tissandier, et al., Optics Letters 49 (21), 6321-6324, https://doi.org/10.1364/OL.538340

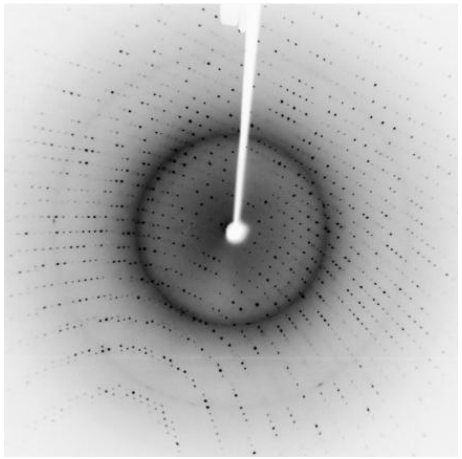
Phase-matched high-order harmonic generation in pre-ionized noble gases
O. Finke et al. Sci Rep 12, 7715 (2022). https://doi.org/10.1038/s41598-022-11313-6

Nanoparticle-assisted acceleration of laser-irradiated low-density He ions
Eva Klimešová, et al.,
Physical Review A 104 (6), L061101 (2021)

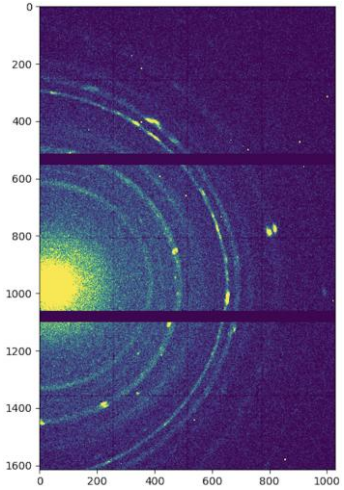
Plasma channel formation in NIR laser-irradiated carrier gas from an aerosol nanoparticle injector, Eva Klimešová, et al., Sci Rep 9, 8851 (2019)

X-ray science: Towards time-resolve X-ray difraction with a Cu tape Plasma X-ray Source

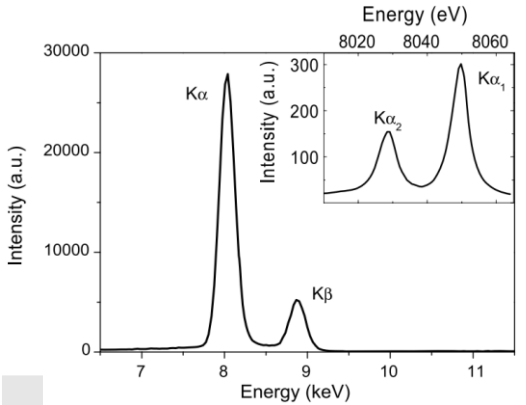
In commissioning



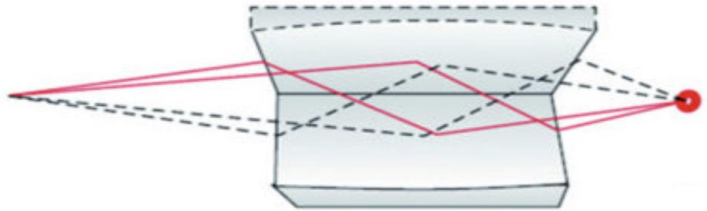
Single crystal X-ray diffraction pattern of lysozyme at room temperature (B. Yorke)



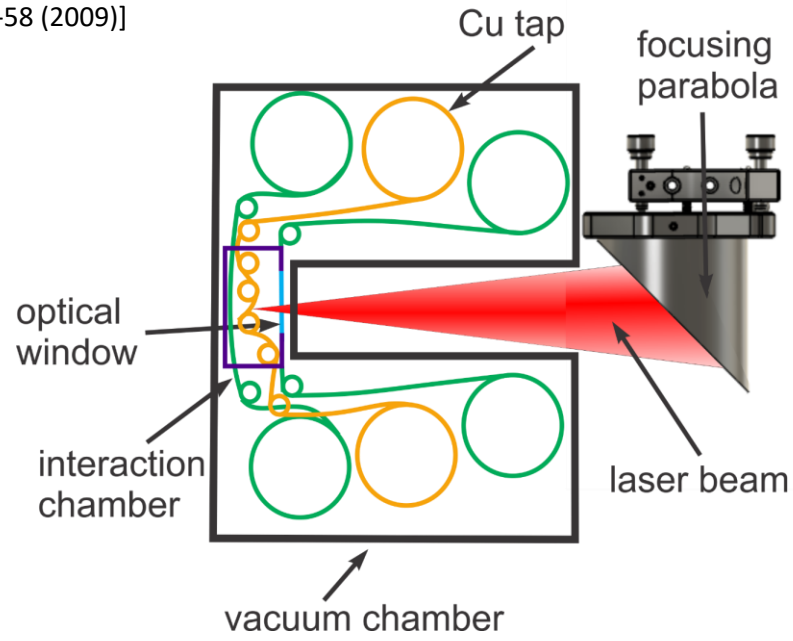
Diffraction patterns from azobenzene with flux of ~ 270 photons/pulse

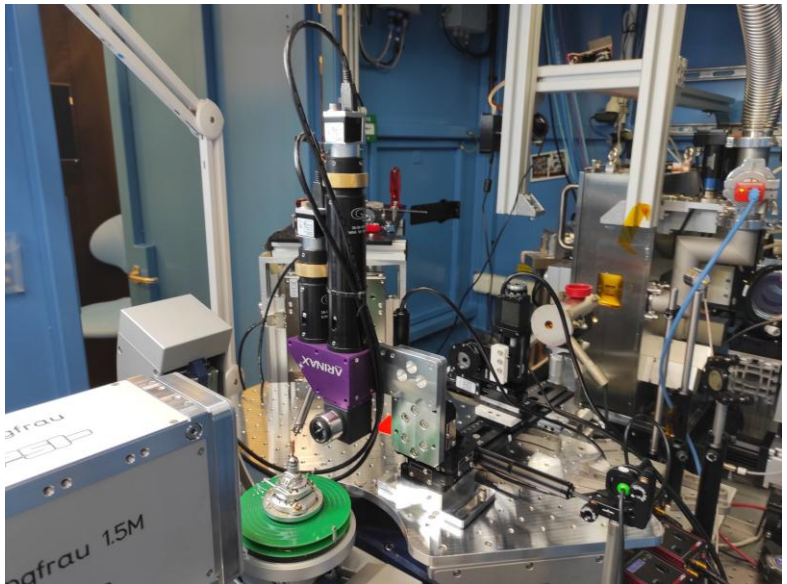


X-ray spectrum of Cu-tape PXS [F. Zamponi et al., Appl. Phys. A, 96, 51-58 (2009)]



Montel optic: Multilayer coatings on curved substrates





Drive lasers
L1 ALLEGRA or Coherent Legend

Targeted early research areas:

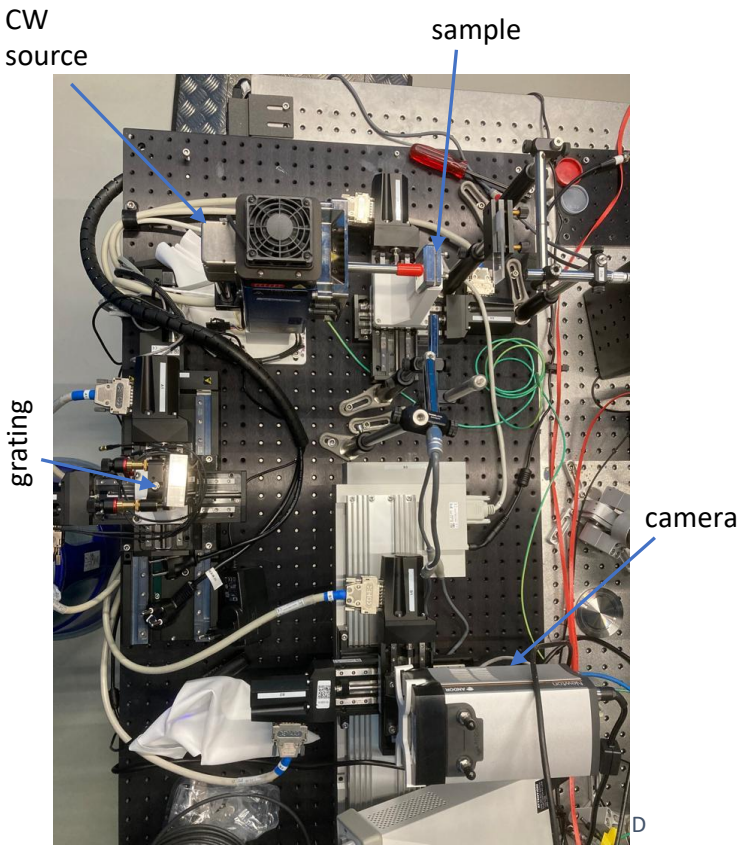
- **Optically driven phase transitions**
- **Charge-transfer dynamics**

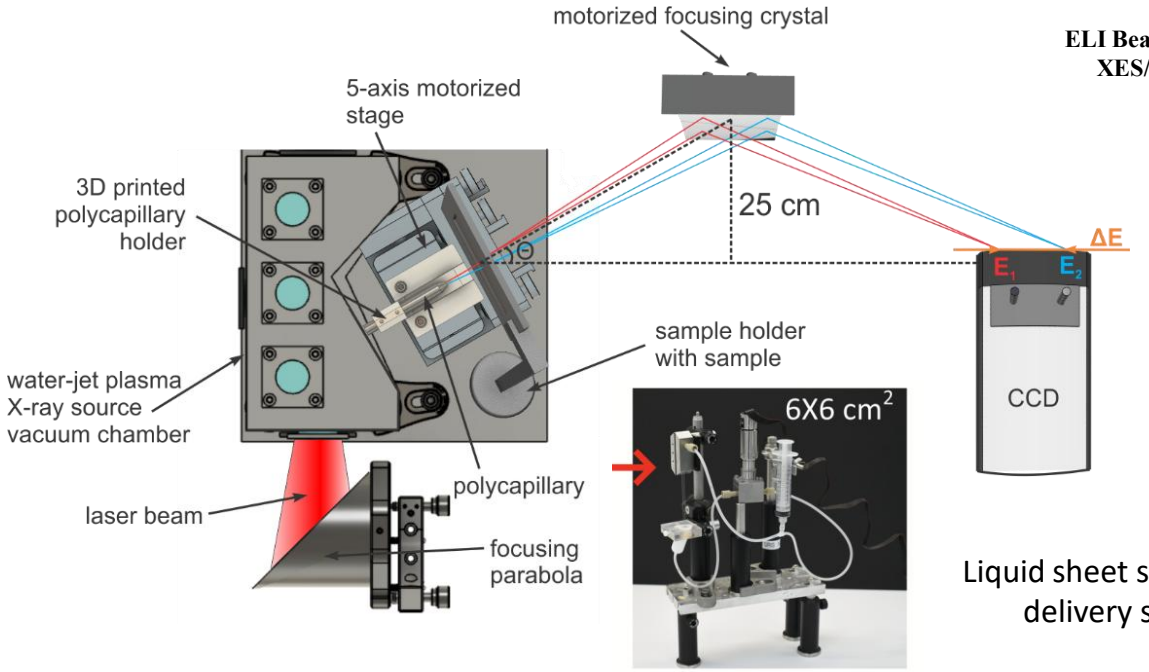
First user publication on Xray imaging

Sampling requirements in near-field ptychography
Luca Fardin, et al.,
Optics Express 33 (7), 15614-15623
https://doi.org/10.1364/OE.544490

X-ray spectroscopy module

- Von Hamos Geometry
- Motorized and automated
- Modular and adaptable, X-ray tube, Water jet source, Cu tape, **Betatron**, …
- Configurations for absorption and emission spectroscopy
- Moveable between locations (PXS, E1, E4, Betatron in E2. ….)





ELI Beamlines von Hamos XES/XAS spectrometer concept
Visegrad collab:
J, Szlachetko
G. Vanko
J. Sa
et al.

Liquid sheet sample delivery system

Recent Publications

X-ray spectroscopy station for offline sample pre-characterization at ELI-Beamlines
A. Zymaková, et al., Scientific Reports 13 (1), 17258 (2023)
https://doi.org/10.1038/s41598-023-43924-y

First experiments with a water-jet plasma X-ray source driven by the in-house developed L1 Allegra laser at ELI-Beamlines,
A. Zymaková, *et al.,* Journal of Synchrotron Radiation, Volume 28, Part 6, pages 1778-1785 (2021),

Implementation of a crossed-slit system for fast alignment of sealed polycapillary X-ray optics
Anna Zymaková, *et al.,* Journal of Synchrotron Radiation 27 (6), 1730-1733,

A fast-integrated X ray Emission spectrometer dedicated on the investigation of the Pt presence in gold Celtic coins (3rd -1st century BCE)
A. Zymaková, et al., X-Ray Spectrometry (2023), DOI: 10.1002/xrs.3354

Both diffraction and spectroscopy development of importance also for experiments on the E2 Betatron source

Ultrafast Optical Spectroscopy 1: Time resolved Spectroscopic Ellipsometrey (trELIps),

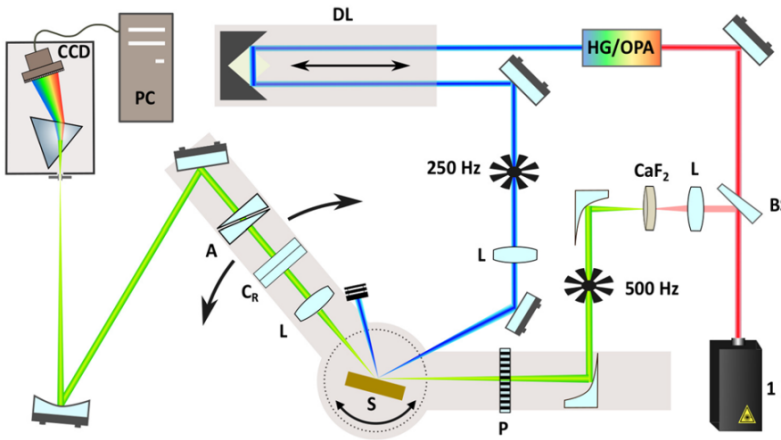
Laser	Energy	Pulse duration	Repetition rate
Coherent Astrella	7 mJ	40 fs	1 kHz

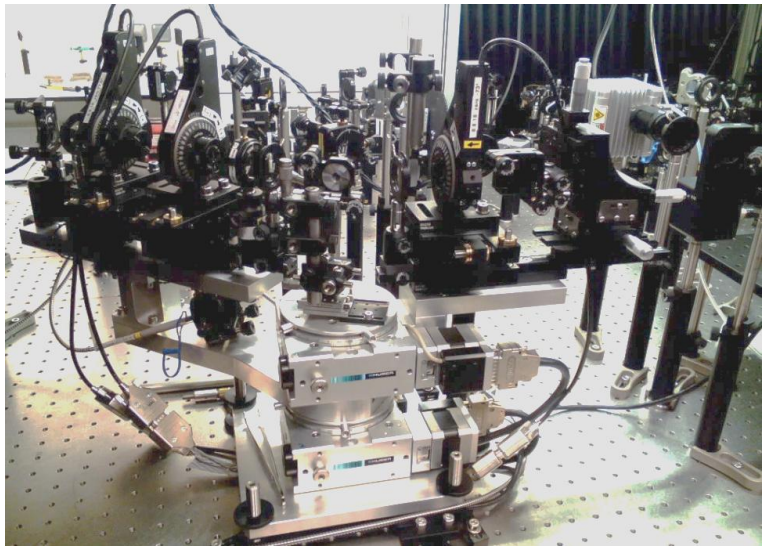
Instrument Responsible

- trELIps: Shirly Espinoza

trELIps

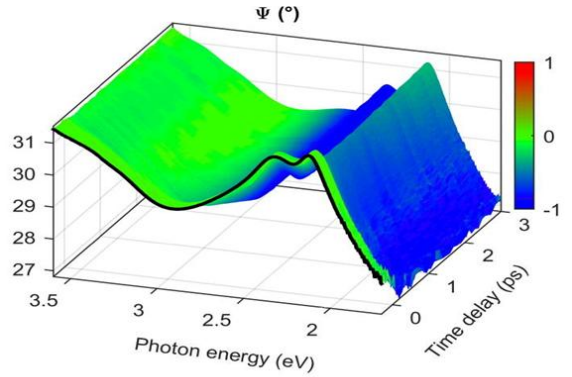
Rev.Sci.Instrum. 92 (2021) 033104

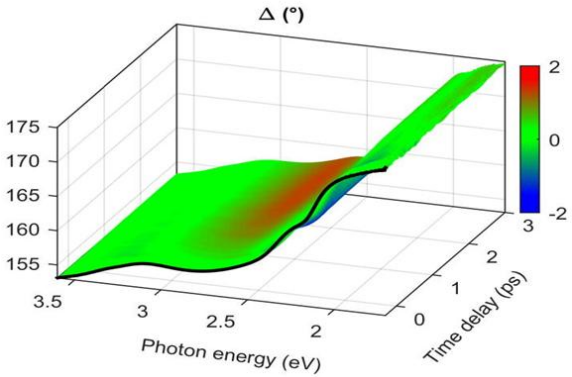




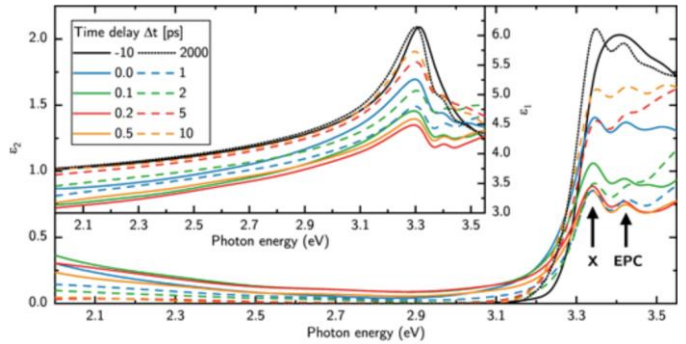
ψ and Δ (λ,t)

transient ellipsometric parameters





Modeling gives dielectric function



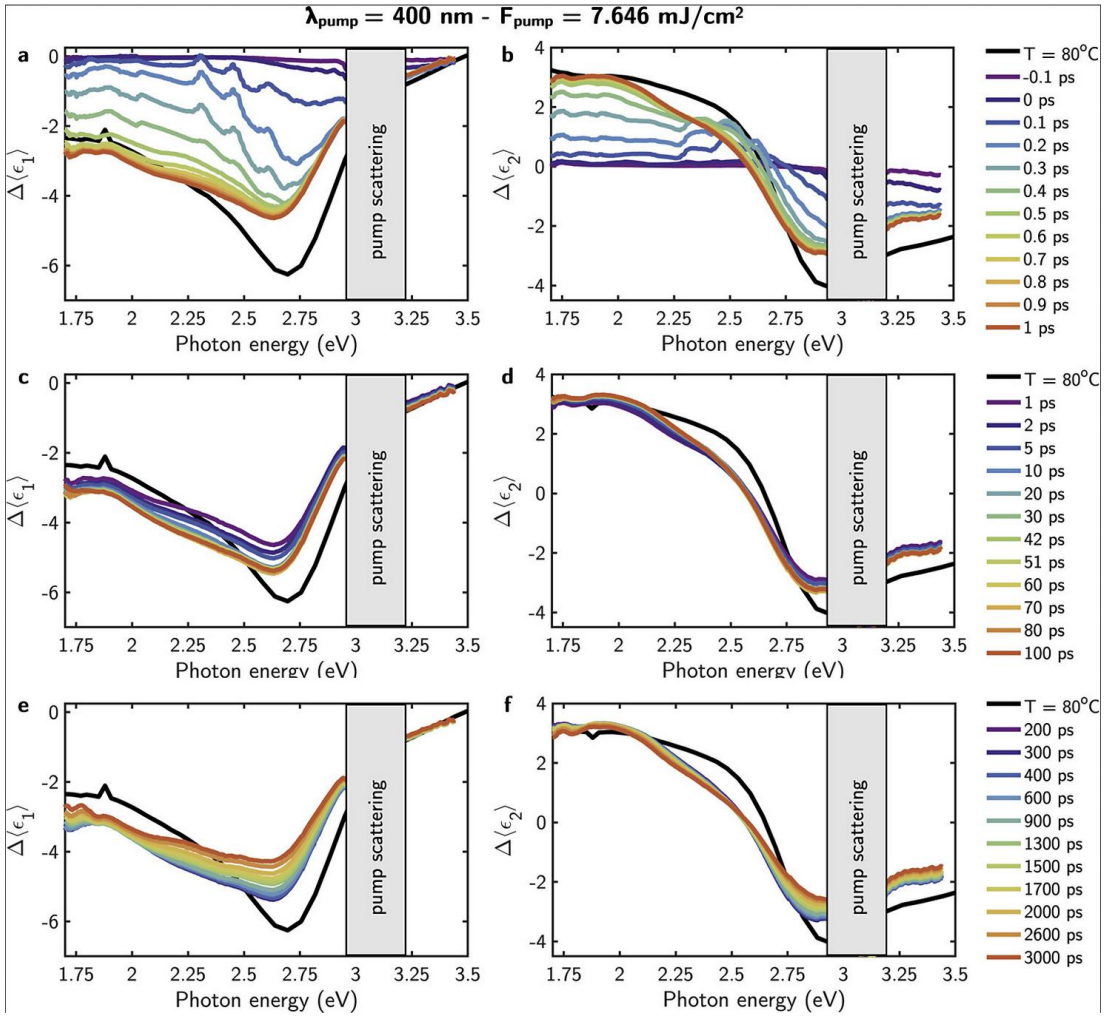
Band gap renormalization
Exciton dynamics
Electron-phonon coupling
Phase transitions, Metal/insulator
..

Ultrafast dynamics of hot charge carriers in an oxide semiconductor probed by femtosecond spectroscopic ellipsometry
S Richter, et al., New Journal of Physics 22 (8), 083066 (2020)

Recent highlights, ELI Beamlines: E1 Optical (trELIps)

Photoinduced metal to insulator transition in phase change material VO_2

Colored lines: Optically driven (ultrafast) insulator-to-metal phase transition

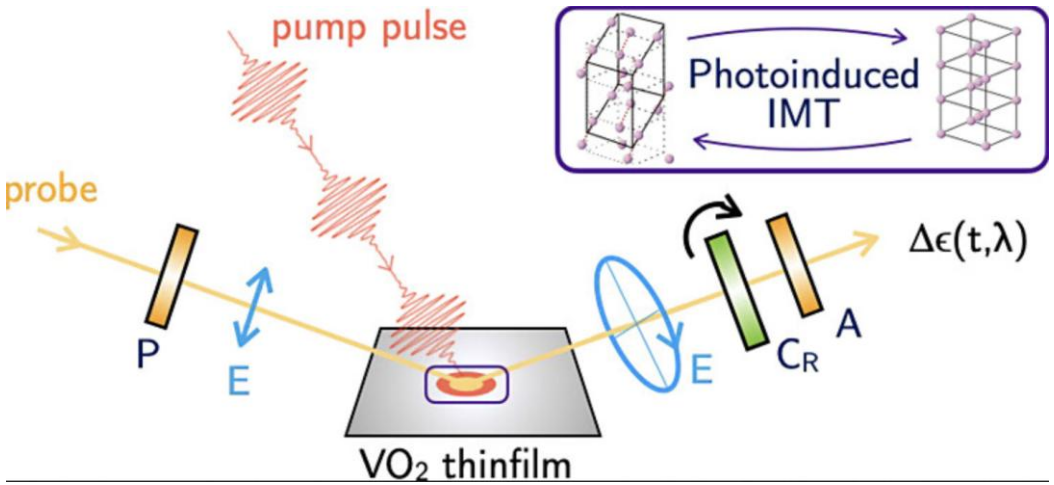


Black line: Thermally driven (slow) insulator-to-metal phase transition (reference)

Subpicosecond Spectroscopic Ellipsometry of the Photoinduced Phase Transition in VO2 Thin Films

ACS Photonics: https://doi.org/10.1021/acsphotonics.4c01414 (2024)

Comparison between thermally and photo-induced IMT
Ideal candidate fro complementary tr X-ray diffraction studies



Transient (a, c, e) real and (b, d, f) imaginary part of the pseudo dielectric function in the time delay intervals of [−0.1, 1], [1, 100], and [200, 3000] ps. As a reference, the plots also show the maximum modulation of $\Delta\langle\epsilon_1\rangle$ and $\Delta\langle\epsilon_2\rangle$ achieved thermally by heating the thin film to T = 80 °C.

Ultrafast Optical Spectroscopy 1: Transient Current Technique (TCT)

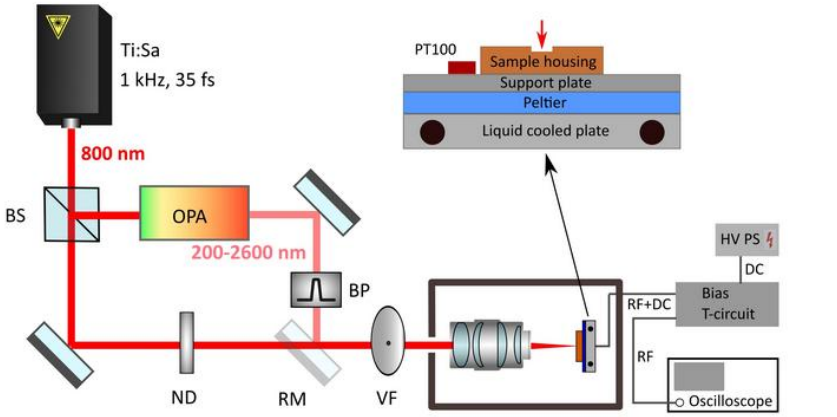
Laser	Energy	Pulse duration	Repetition rate
Coherent Astrella	**7 mJ**	**40 fs**	**1 kHz**

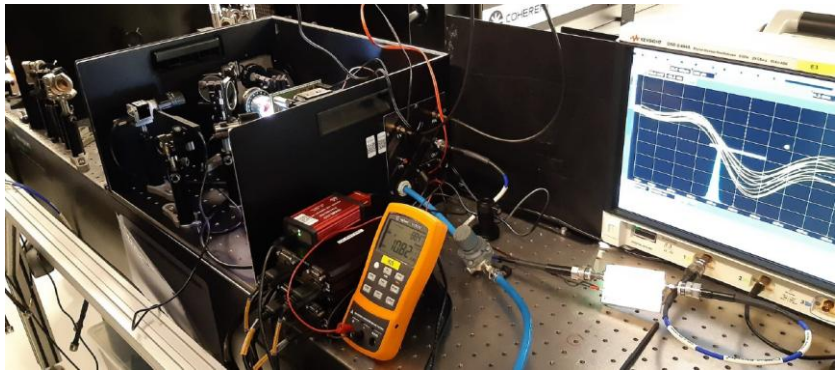
Nucl.Instrum.Meth.A 1041 (2022) 167321

Instrument Responsible

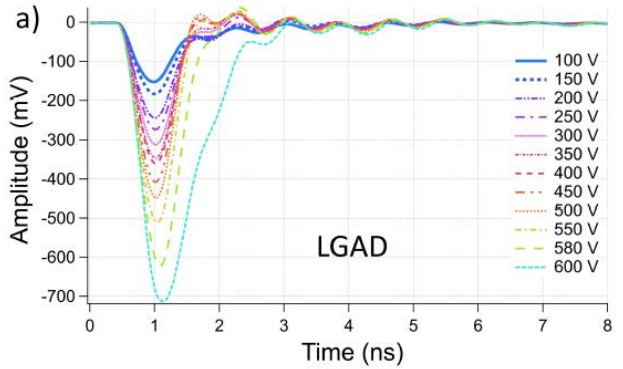
- TCT: Mateusz Rebarz

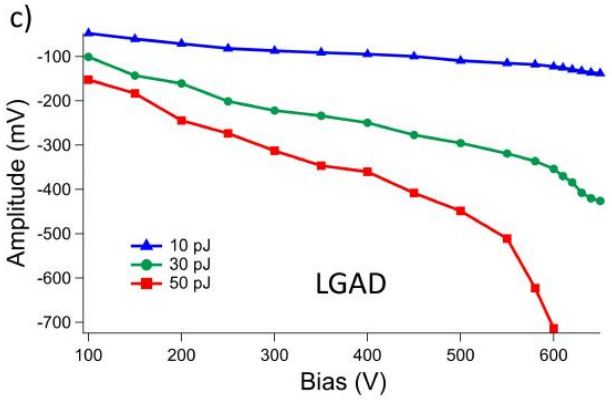
Transient Current Technique (TCT) employs ultrashort laser pulses to characterize different parameters of the semiconductor detectors (sensor response vs. bias, pulse energy, position, temperature)

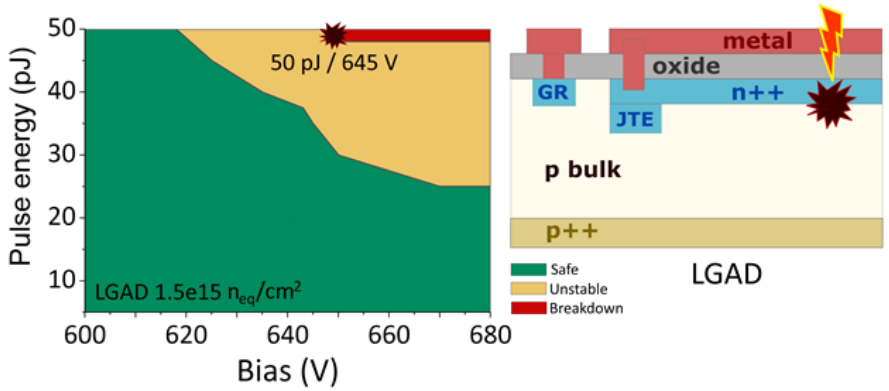




The signal waveforms for LGAD at different fluences and bias voltage







Irradiated LGAD detectors

Mapping of the "safe operation" and "irreversible damage" regimes for irradiated LGAD and corresponding PIN detectors. Data were obtained for SPA at 800 nm

Optical spectroscopy, E1: Selected user publications

trELIps:

Transient dielectric function and carrier related processes in doped cubic GaN determined by femtosecond pump-probe spectroscopic ellipsometry
Elias Baron, et al., Journal of Applied Physic, 138 (2025) 125702
DOI: https://doi.org/10.1063/5.0281902

Optical transitions between entangled electron–phonon states in silicon
Yael Gutierrez, et al., Applied Physics Letters 127 (2025) 141102
DOI: https://doi.org/10.1063/5.0288893

Time-resolved Spectroscopic Ellipsometry in Solid-state Thin Films of Thio-diketopyrrolopyrrole-based Organic Semiconductor
Martin Zahradnik, et al., Optical Materials Express 15 (8), 2066-2078

Femtosecond pump-probe absorption edge spectroscopy of cubic GaN 1 and II
Elias Baron, et al., Journal of Applied Physics 134 (7), http://arxiv.org/abs/2206.02223

Coherent acoustic phonon oscillations and transient critical point parameters of Ge from femtosecond pump-probe ellipsometry
C. Emminger, et al., Phys. Status Solidi RRL2022,16, 2200058
https://doi.org/10.1002/pssr.202200058

Transient birefringence and dichroism in ZnO studied with fs-time-resolved spectroscopic ellipsometry
O Herrfurth, et al., Physical Review Research 3 (1), 013246 (2021)

Photo-induced insulator-to-metal transition and excited states in LaCoO3 using femtosecond pump-probe ellipsometry
M. Zahradnik, et al., Physical Review B, 105 (2022) 235213
https://doi.org/10.1103/PhysRevB.105.235113

Ultrafast dynamics of hot charge carriers in an oxide semiconductor probed by femtosecond spectroscopic ellipsometry
S Richter, et al., New Journal of Physics 22 (8), 083066 (2020)

Transient dielectric functions of Ge, Si, and InP from femtosecond pump-probe ellipsometry
S Espinoza, et al., Applied Physics Letters 115 (5), 052105 (2019)

TCT:

Timing parameters of 3D Si sensors characterized by Two Photon Absorption-Transient Current Technique
JINST 20 C08020 (2025)
DOI 10.1088/1748-0221/20/08/C08020

Gain suppression in LGAD detectors under focused and defocused femtosecond laser beam
Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 1081, January 2026, 170844
https://doi.org/10.1016/j.nima.2025.170844

Ghosts in irradiated trench isolated LGADs
Journal of Instrumentation, 2025 JINST 20 C07015
DOI 10.1088/1748-0221/20/07/C07015

Exploring the Interpad Gap Region in Ultra-Fast Silicon Detectors: Insights into Isolation Structure and Electric Field Effects on Charge Multiplication
Sensors 2023, 23(15), 6746 (2023)
https://doi.org/10.3390/s23156746

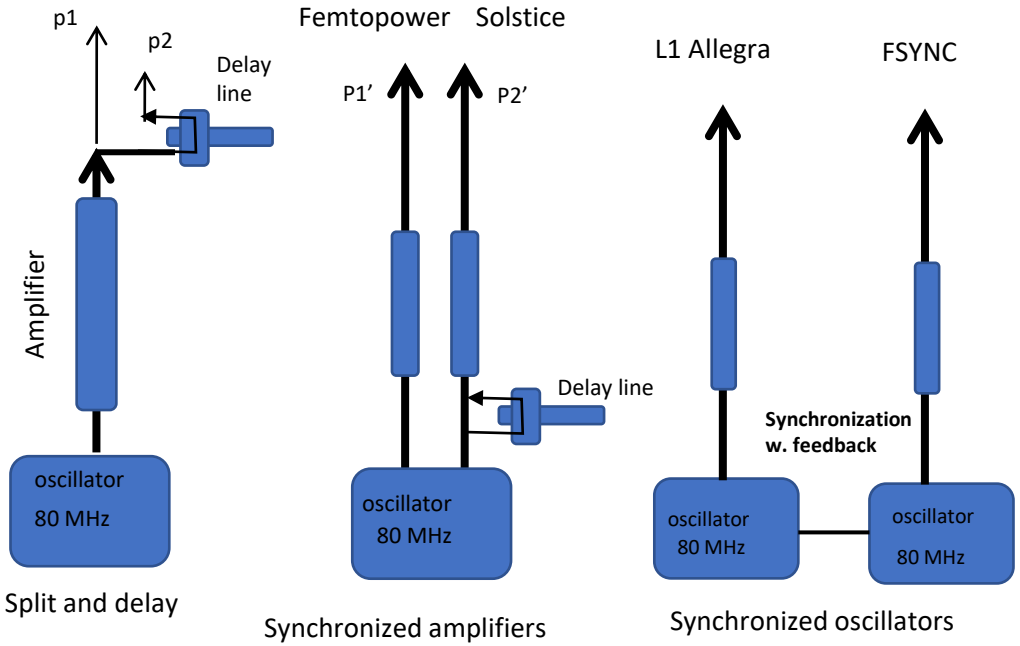
Femtosecond laser-based TCT-TPA and IBIC microscopy: two powerful depth profiling characterization tools for testing the micron-sized sensitive volumes in micro-strips or pixeled detectors for microdosimetry and hadron therapy
Eur. Phys. J. Spec. Top. 232, 1501–1511 (2023) https://doi.org/10.1140/epjs/s11734-023-00892-8

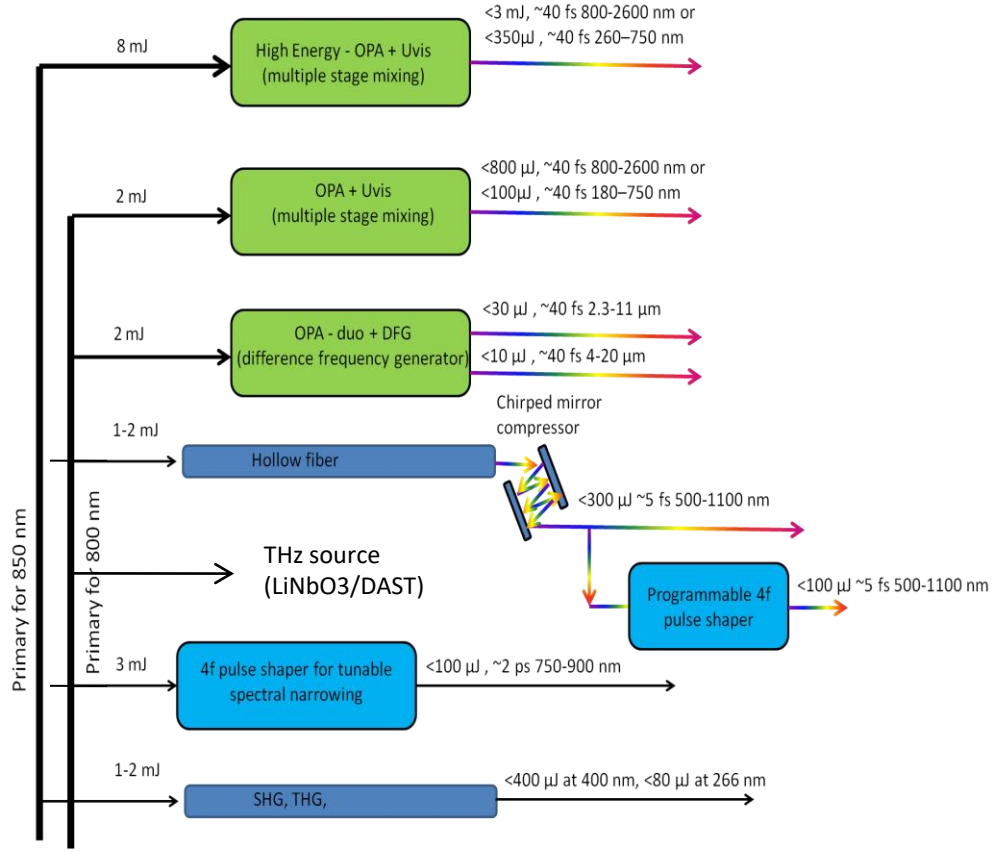
Studies of LGAD performance limitations, Single Event Burnout and Gain Suppression, with Femtosecond-Laser and Ion Beams
Nuclear Inst. and Methods in Physics Research, A (NIMA), DOI:
https://doi.org/10.1016/j.nima.2022.167388

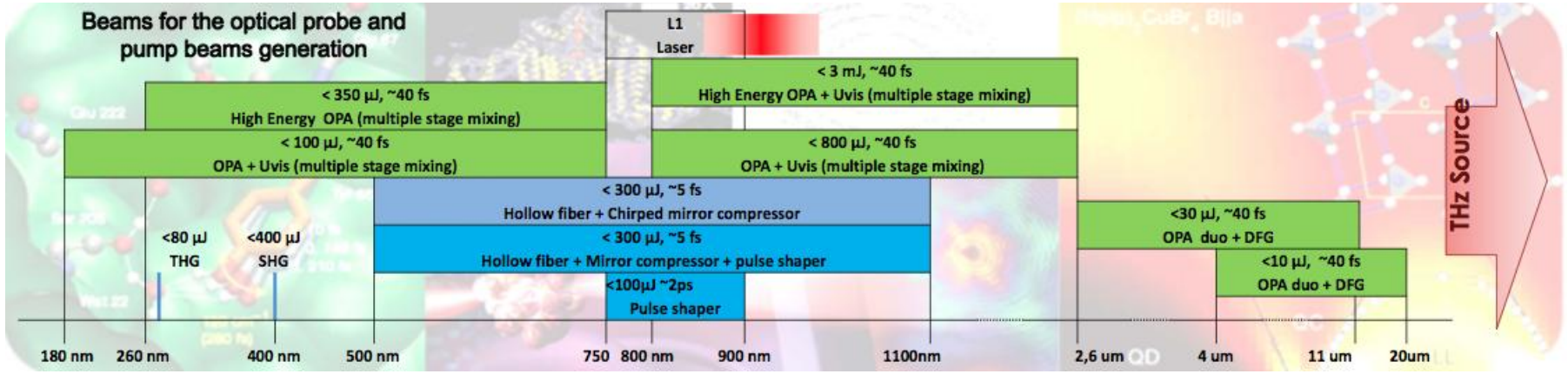
Femtosecond laser studies of the Single Event Effects in Low Gain Avalanche Detectors and PINs at ELI Beamlines
Nuclear Inst. and Methods in Physics Research, A (2022),
doi:https://doi.org/10.1016/j.nima.2022.167321.

Delays and optical pulse conversion

0 fs to 1 ms delay with fs precision







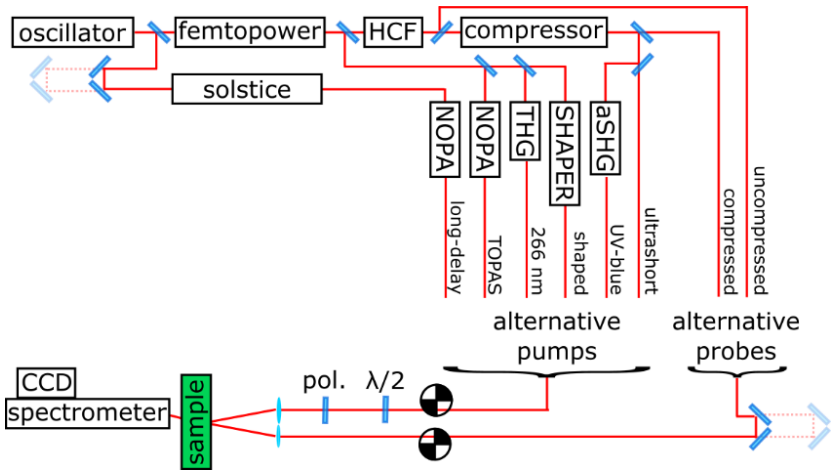
Ultrafast Optical Spectroscopy 2: Femtosecond Stimulated Rmana Spectroscopy (FSRS) and Transient Absorption (TA)

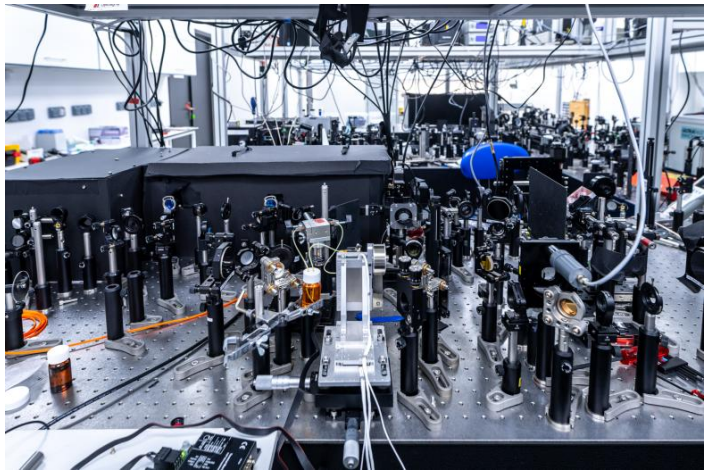
Lasers	Energy	Pulse duration	Repetition rate
Spectra Physics Doublet /Femtopower	4.5 mJ	30 fs	1 kHz
Spectra Physics Doublet/ Solstice	7 mJ	40 fs	1 kHz

Instrument Responsible

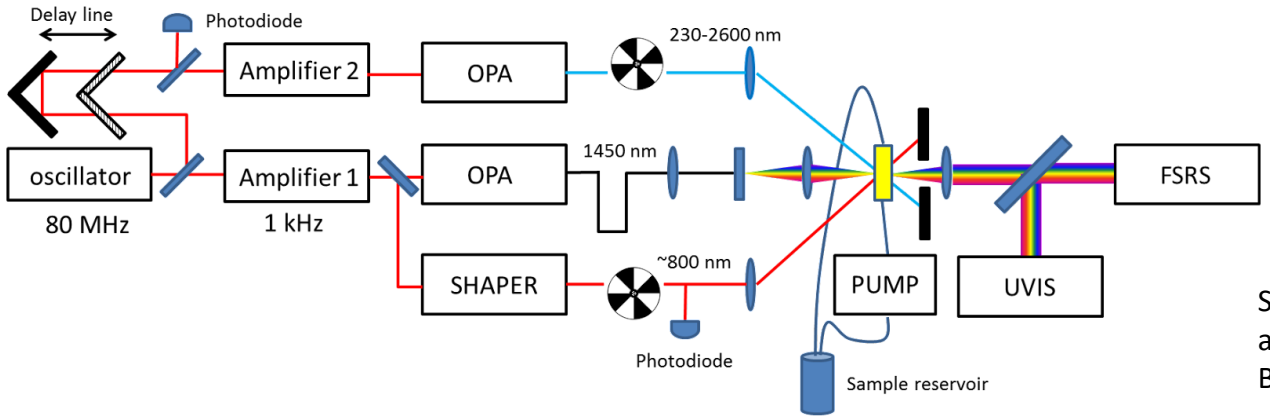
- FSRS: Miroslav Kloz
- TA: Jakub Dostal

TA

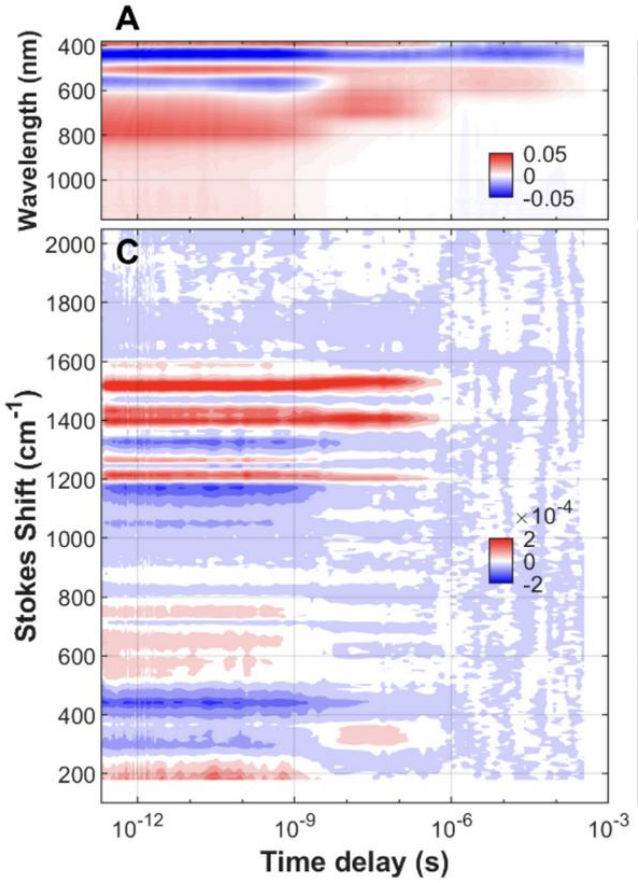




FSRS



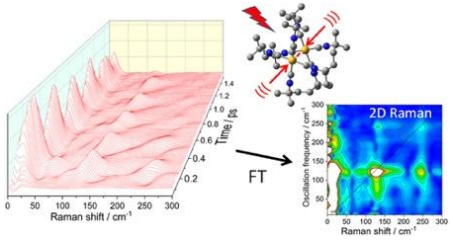
Can be measured simultanelously



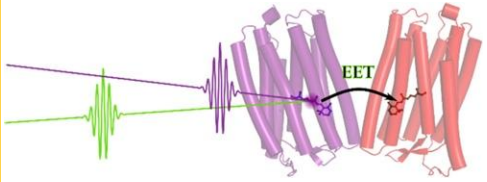
Sub-Millisecond Photoinduced Dynamics of Free and EL222-Bound FMN by Stimulated Raman and Visible Absorption Spectroscopies
Biomolecules, 13(1) (2023) 161 DOI: https://doi.org/10.3390/biom13010161

Selected user publications and recent highlights: TA and FSRS

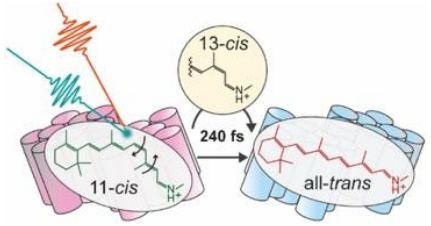
Recent highlights (three JACS in 2025)



Real-Time Tracking of Photoinduced Metal–Metal Bond Formation in a d8d8 Di-Iridium Complex by Vibrational Coherence and Femtosecond Stimulated Raman Spectroscopy
M Kloz, et al., **Journal of the American Chemical Society 147 (11), 9810-9824**

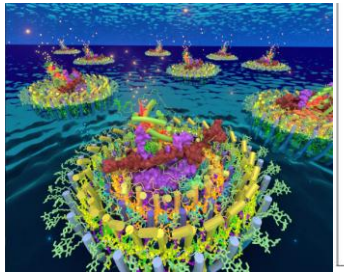


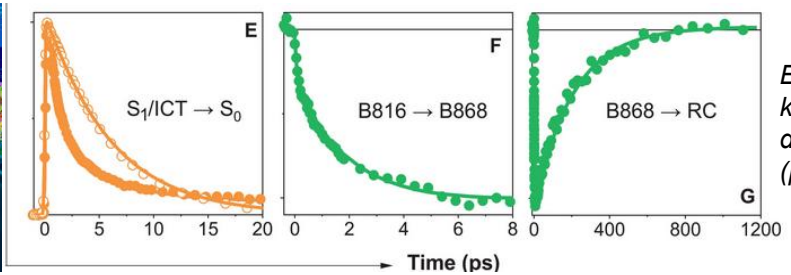
Retinal to Retinal Energy Transfer in a Bistable Microbial Rhodopsin Dimer
IHM van Stokkum, et al., **Journal of the American Chemical Society 147 (17), 14468-14480**



Multistep 11-cis to All-trans Retinal Photoisomerization in Bestrhodopsin, an Unusual Microbial Rhodopsin
M Broser, et al., **Journal of the American Chemical Society 147 (29), 25571-25583**

2.4-Å structure of the double-ring Gemmatimonas phototrophica photosystem
Science Advances • 16 Feb 2022 • Vol 8, Issue 7





Electron transfer kinetics in the RC-dLH1 complex. (part of full figure).

Selected user publication (FSRS and TA) 2020-2025

Excited-State Pathways in Near-Infrared Emitting DNA-Stabilized Silver Nanoclusters with Different Geometries
Nano Lett. 2025, 25, 10010−10016
https://doi.org/10.1021/acs.nanolett.5c01754

Vibrational signature of 11B+u and hot 21A–g excited states of carotenoids revisited by femtosecond stimulated Raman spectroscopy
Phys. Chem. Chem. Phys., 2025, 27, 20313
DOI https://doi.org/10.1039/D5CP02711J

Multiple Retinal Isomerizations during the Early Phase of the Bestrhodopsin Photoreaction
PNAS, March 13, 2024 121 (12) e2318996121

Excited States Mixing in the LOV Domain Proteins: Possible Physics Behind the Difference in the Transient Absorption and Transient Stimulated Raman Spectroscopy
The Journal of Physical Chemistry Letters 16, 4072-4080
https://doi.org/10.1021/acs.jpclett.4c02978

Site-specific vibrational spectroscopy with non-canonical amino acids containing frequency-resolved labels
Biophysical Journal 122 (3), 190a-191a
DOI: https://doi.org/10.1016/j.bpj.2022.11.1168

Quantitative Energy Transfer in Organic Nanoparticles Based on Small-Molecule Ionic Isolation Lattices for UV Light Harvesting
ACS Appl. Nano Mater. (2022); https://doi.org/10.1021/acsanm.2c01899

Photochemistry of (Z)-Isovinylneoxanthobilirubic Acid Methyl Ester, a Bilirubin Dipyrrinone Subunit: Femtosecond Transient Absorption and Stimulated Raman Emission Spectroscopy
J. Org. Chem. 2022, 87, 5, 3089–3103

Optical and Infrared Spectroelectrochemical Studies of CN-Substituted Bipyridyl Complexes of Ruthenium(II)
Inorg. Chem. 2021, DOI: 10.1021/acs.inorgchem.0c03579 (2021)

Spectroscopy and excited state dynamics of nearly infinite polyenes
Phys.Chem.Chem.Phys., 2020, 22, 17867

Femtosecond-to-nanosecond dynamics of flavin mononucleotide monitored by stimulated Raman spectroscopy and simulations
Physical Chemistry Chemical Physics 22 (12), 6538-6552 (2020)

Thank You !