ELI Beamlines COVID call, Lasers and experimental stations

Drive lasers for the Scientific cluster for advanced ultrafast optical spectroscopy

Coherent Astrella

Energy - compressed	Pulse duration at target	Repetition rate
7 mJ	<40 fs	1 kHz

Spectra Physics Femtopower/Solstice doublet

Energy - compressed	Pulse duration at target	Repetition rate
4.5 mJ (Femtopower)	30 fs (Femtopower)	1 kHz
7 mJ (Solstice)	40 fs (Solstice)	1 kHz

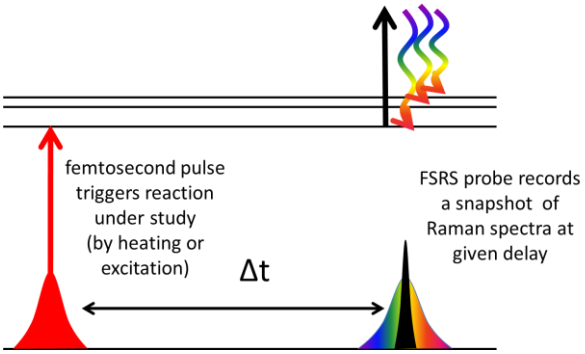
Delays between Femtopower/Solstice doublet lasers can be controlled between 0 fs to 1 ms.

Available experimental techniques/stations within the Scientific cluster for advanced ultrafast optical spectroscopy and X-ray diffraction

Femtosecond Stimulated Raman scattering (FSRS)

Contact person: Miroslav Kloz, miroslav.kloz@eli-beams.eu

Femtosecond stimulated Raman spectroscopy is an experiment that allows monitoring Raman vibration spectra of molecules with sub-ps time resolution. When used with reactions that can be triggered, ideally photo-triggered, it is powerful tool to follow reaction dynamics and structural changes with high time resolution and high acquisition speed.



Stimulated Raman probe:

Time resolution	~100fs
Spectral resolution	~1 cm^{-1}
Observed spectral window	30 - 4000 cm^{-1}
Raman pulse wavelength	760-840 nm

Triggering pulse pump:

Time resolutions	~ 30fs
Spectrum	~ 50 nm
Available wavelengths	266 nm, 400 nm, 800 nm (being extended to 230-2600 nm)
Pump-probe delay	0 – 6 ns, 10 fs resolution (Coherent Astrella as drive laser)
Pump-probe delay	0 – 1 ms, 10 fs resolution (Femtopower/Solstice doublet as drive laser)

FZÚ

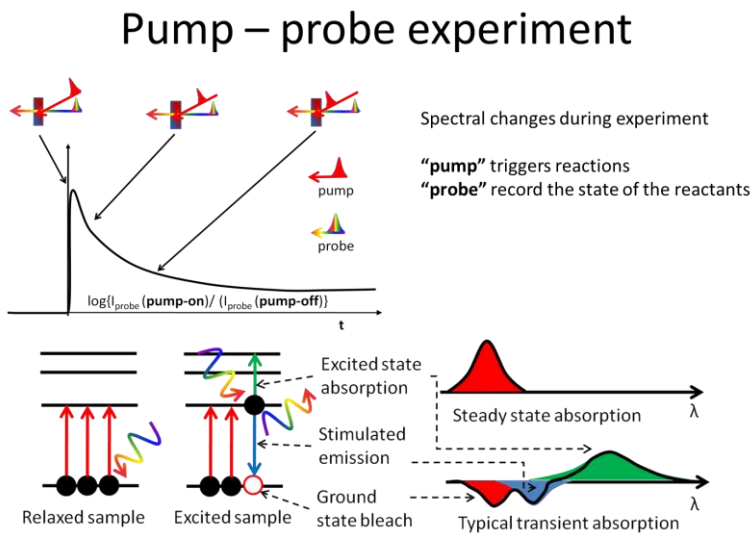
EUROPEAN UNION
European Structural and Investing Funds
Operational Programme Research,
Development and Education

MINISTRY OF EDUCATION YOUTH AND SPORTS

Optical transient absorption

Contact person: Miroslav Kloz, miroslav.kloz@eli-beams.eu

Optical transient absorption is an experiment where changes in the sample absorbance are recorded with high time resolutions. It is very robust technique for characterization of excited and transient states of molecules, atoms and materials.



Probe pulse:

Time resolution	~20fs
Spectral resolution	~1 nm
Observed spectral window	266 – 2500 nm

Triggering pulse pump:

Time resolutions	~ 30fs
Spectrum	~ 50 nm
Available wavelengths	266 nm, 400 nm, 800 nm (being extended to 230-2600 nm)
Pump-probe delay	0 – 6 ns, 10 fs resolution

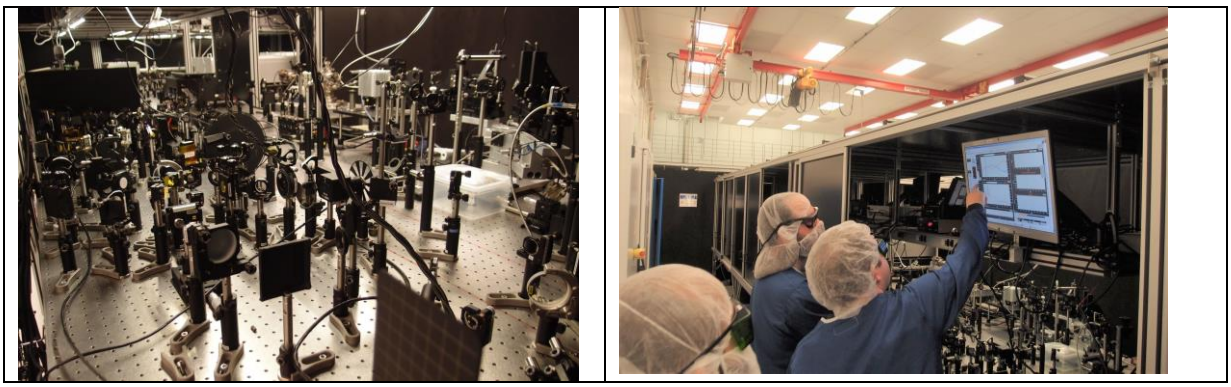


Fig: Set up for fs Stimulated Raman Scattering in operation in the E1 experimental hall.

FZÚ

EUROPEAN UNION
European Structural and Investing Funds
Operational Programme Research,
Development and Education

MINISTRY OF EDUCATION
YOUTH AND SPORTS

Pump-probe spectroscopic ellipsometry and reflectance

Contact person: Shirly Espinoza, ShirlyJosefina.EspinozaHerrera@eli-beams.eu

Ellipsometry and reflectance are methods used for studying changes in bio layers [1-4]. The femtosecond pump-probe ellipsometer setup at ELI Beamlines measures changes on reflectance and polarization responses of planar samples, in the scale of femtoseconds to nanoseconds after a reaction has been initiated by photons of a known energy. The ellipsometer is a P_R-S-C_R-A_R ellipsometer.
Other characteristics of the systems are:
Wavelengths pump beam: 266 nm, 400 nm or 800 nm
Spectral range probe: continuous from 350 nm to 700 nm
Probe spot size at the sample: <200um
Time range: 0-5 ns
Time resolution: <100 fs
Dynamic range: 10000:1
Characteristic of the pulses from the laser: <35 fs, 1 KHz rep.rate. (Coherent Astrella)
Angle of incidence: variable from 20 to 90 degrees
Sample requirements:
Sample size: >50 um
Roughness < 350 nm
For this call for the use of the pump-probe ellipsometry advanced supporting labs are available, including an enviromental SEM microscope (https://www.thermofisher.com/us/en/home/electron-microscopy/products/scanning-electron-microscopes/quattro-esem.html) and a Hirox digital microscope (https://www.hirox-usa.com/)

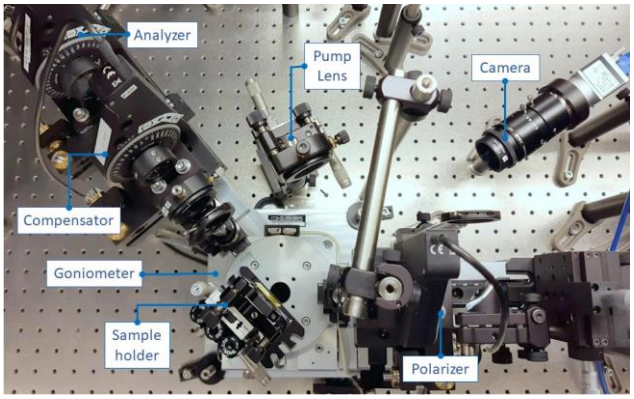


Fig: Setup for pump-probe spectroscopic ellipsometry in operation in the E1 experimental hall.

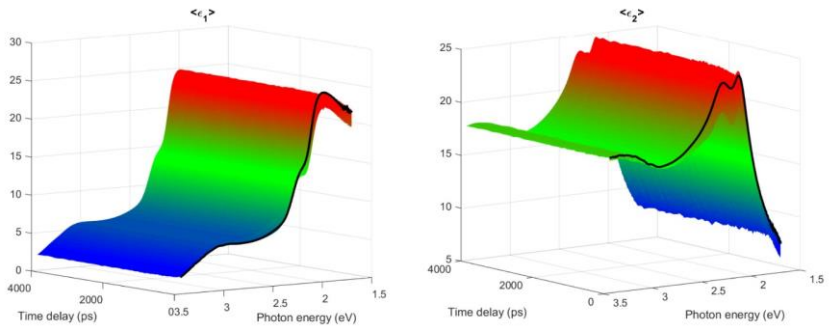


Fig. Pseudo dielectric functions. Results of pump-probe ellipsometry experiments on a sample of bulk germanium.

References:

FZÚ
EUROPEAN UNION
European Structural and Investing Funds
Operational Programme Research,
Development and Education
MINISTRY OF EDUCATION
YOUTH AND SPORTS

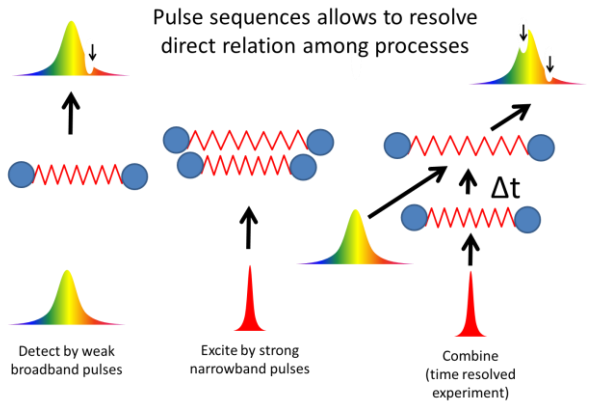
1. Casquel, R., Holgado, M., Laguna, M.F. et al. 2020. Engineering vertically interrogated interferometric sensors for optical label-free biosensing. Anal Bioanal Chem. https://doi.org/10.1007/s00216-020-02411-3
2. Fujiwara H. 2007*Spectroscopic ellipsometry: principles and applications.* Chichester, UK. John Wiley & Sons, 287-294. ISBN: 978-0470016084
3. Rafique S., Idrees M., Bokhari H. et al. 2019. Ellipsometric-based novel DNA biosensor for label-free, real-time detection of Bordetella parapertussis. *J Biol Phys* 45, 275–291. https://doi.org/10.1007/s10867-019-09528-2
4. Rath C., Burger J., Norval L. et al. 2019. Comparison of different label-free imaging high-throughput iosensing systems for aptamer binding measurements using thrombin aptamers. Analytical Biochemistry 583, 113323. https://doi.org/10.1016/j.ab.2019.05.012

IR spectroscopy

Contact person: Miroslav Kloz, miroslav.kloz@eli-beams.eu

Femtosecond mid IR spectroscopy is a tool for study of bond structure of molecular and solid state systems. Vibrations spectra are recorded with fs time resolutions. That allows following conformational changes such as isomerization, bond braking, bond formation, solvent dynamics etc.…

2D IR spectroscopy is technique for observing cross-talk between individual bonds. Such experiment is analogue of 2D NMR experiments. In the same way it produces data that are richer in structure-related information, but with possibility to record them with femtosecond time resolution.



Probe pulse:	
Time resolution	~100fs
Spectral resolution	~0.1 cm-1
Observed spectral window	2600 nm – 10000 nm
Triggering pulse pump:	
Time resolutions	~ 30fs
Spectrum	~ 50 nm
Available wavelengths	266 nm, 400 nm, 800 nm (being extended to 230-2600 nm)
Pump-probe delay	0 – 6 ns, 10 fs resolution

FZÚ

EUROPEAN UNION
European Structural and Investing Funds
Operational Programme Research,
Development and Education

MINISTRY OF EDUCATION
YOUTH AND SPORTS

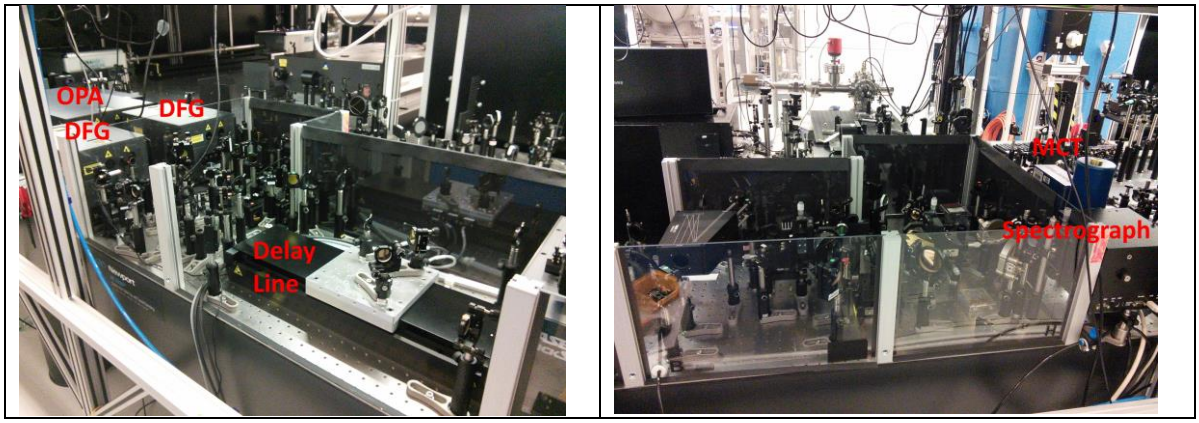


Fig. TRIR end-station in E1 experimental hall

Available sample delivery systems for optical spectroscopy

-Quartz and borosilicate cuvettes with various path lengths (0.5 to 10 mm).
-Custom quartz flow cells, 0.5- and 1-mm path length, for high repetition rate lasers and minimized volume (few dozen ul)
-Temperature controlling holder, from 5°to 95°C for quartz cuvettes and flow cells.
-Windows-less closed-loop wire-guided flow jet:
Picchiotti, *et al*. https://doi.org/10.1063/1.4929860
-IR cells with CaF2 windows.
-Peristaltic pump (volume > 5 ml), syringe pump (< 1 ml), and micro-fluidic gear pumps (volume < 1 ml).

X-ray diffraction and scattering

Contact person: Borislav Angelov, Borislav.Angelov@eli-beams.eu

The X-ray diffractometer is based on a custom modification of a commercial STOE STADIVARI goniometer. It has the same functionality as the commercial analog plus in addition an extended range for the detector movement going up to 400 mm sample to detector distance. The main module of the diffractometer is the so called Euler cradle goniometer, which is capable of simultaneously rotating the investigated sample at 360 degree and at the same time to position the X-ray detector at desired angle and distance from the sample. It comes with a computer controlled video microscope and dimmable led light. The cryo cooling for the fragile biological sample is implemented via a commercial cryo stream cooler from Oxford Cryosystems. The recording of the diffracted and scattered X-ray photons is accomplished by a single photon counting hybrid pixel detector model Eiger X 1M from Dectris company. Another module is the X-ray microfocus sealed tube with Montel optics and JJ X-ray pinhole collimation. The instrument for hard X-ray science is outlined in the figure below.

FZÚ

EUROPEAN UNION
European Structural and Investing Funds
Operational Programme Research,
Development and Education

MINISTRY OF EDUCATION
YOUTH AND SPORTS

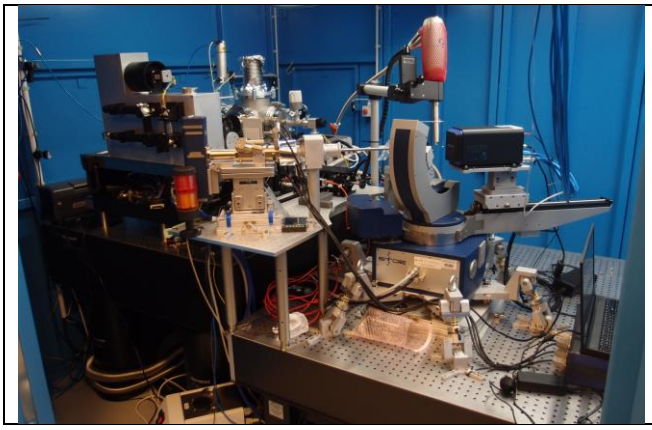
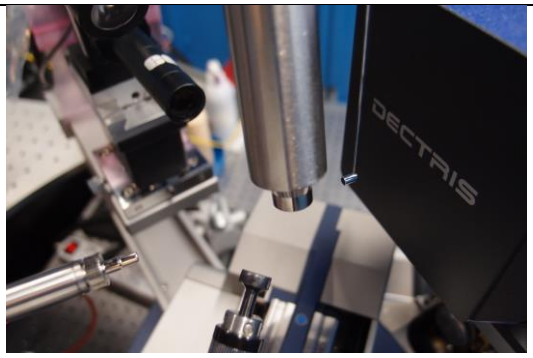



Fig. Left: Diffraction station available for the COVID call with the sealed tube Cu-anode X-ray source. Right: detail of the diffractometer sample environment when optimized for protein crystallography with the cryostream cryocooler.

Technical Data

Sealed tube X-ray beam parameters	
Flux on the sample	10^8 ph/sec
Beam size	145 micrometers
Beam divergence	4.8 mrad
Beam polarization	40%
Wavelength	CuKa 1.54 Angstroms
Detector parameters	
Pixel size [µm2]	75 x 75
Sensitive area (width x height) [mm2]	77.2 x 79.9
Total number of pixels	1030 x 1065 = 1,096,950
Maximum frame rate [Hz]	3000
Frame dead time	3 µs
Point-spread function	1 pixel
Sensor thickness [µm]	450
Threshold energy [keV]	2.7-18
Maximum count rate [phts/s/mm2]	5x10^8
Counter bit depth [bit]	12
Image bit depth [bit]	16 or 32
Photon processing time per pixel	180 ns
Data format	HDF5
Sample to detector distance	40-400 mm

EUROPEAN UNION
European Structural and Investing Funds
Operational Programme Research,
Development and Education
MINISTRY OF EDUCATION
YOUTH AND SPORTS