ELI Beamlines COVID call, Lasers and experimental stations

Drive lasers for the Scientific cluster for advanced ultrafast optical spectroscopy

Coherent Astrella

<table>
<thead>
<tr>
<th>Energy - compressed</th>
<th>Pulse duration at target</th>
<th>Repetition rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 mJ</td>
<td>&lt;40 fs</td>
<td>1 kHz</td>
</tr>
</tbody>
</table>

Spectra Physics Femtopower/Solstice doublet

<table>
<thead>
<tr>
<th>Energy - compressed</th>
<th>Pulse duration at target</th>
<th>Repetition rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5 mJ (Femtopower)</td>
<td>30 fs (Femtopower)</td>
<td>1 kHz</td>
</tr>
<tr>
<td>7 mJ (Solstice)</td>
<td>40 fs (Solstice)</td>
<td>1 kHz</td>
</tr>
</tbody>
</table>

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 \(\sim 100\) fs
- Spectral resolution \(\sim 1\) cm\(^{-1}\)
- Observed spectral window 30 - 4000 cm\(^{-1}\)
- Raman pulse wavelength 760-840 nm

Triggering pulse pump:
- Time resolutions \(\sim 30\) fs
- Spectrum \(\sim 50\) 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)
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 a very robust technique for characterization of excited and transient states of molecules, atoms and materials.

**Pump – probe experiment**

1. **Probe pulse:**
   - Time resolution: ~20 fs
   - Spectral resolution: ~1 nm
   - Observed spectral window: 266 – 2500 nm

2. **Triggering pulse pump:**
   - Time resolutions: ~30 fs
   - 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.
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 Pr-S-Cr-Ae 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:


**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.

![Diagram](image)

**Probe pulse:**
- Time resolution: ~100fs
- Spectral resolution: ~0.1 cm
- 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
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°C to 95°C for quartz cuvettes and flow cells.
- 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, Borislag.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.
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

<table>
<thead>
<tr>
<th>Sealed tube X-ray beam parameters</th>
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<tr>
<td>Flux on the sample</td>
<td>$10^8$ ph/sec</td>
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<tr>
<td>Beam size</td>
<td>145 micrometers</td>
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<td>Beam divergence</td>
<td>4.8 mrad</td>
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<td>Beam polarization</td>
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<tr>
<td>Wavelength</td>
<td>CuKa 1.54 Angstroms</td>
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</table>

<table>
<thead>
<tr>
<th>Detector parameters</th>
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<tbody>
<tr>
<td>Pixel size [µm2]</td>
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<tr>
<td>Sensitive area (width x height) [mm2]</td>
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<tr>
<td>Total number of pixels</td>
<td>1030 x 1065 = 1,096,950</td>
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<tr>
<td>Maximum frame rate [Hz]</td>
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<tr>
<td>Frame dead time</td>
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<td>Point-spread function</td>
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<tr>
<td>Threshold energy [keV]</td>
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<tr>
<td>Maximum count rate [phts/s/mm2]</td>
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<tr>
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<td>Image bit depth [bit]</td>
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<td>Photon processing time per pixel</td>
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<td>Data format</td>
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<td>Sample to detector distance</td>
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