ELI Beamlines Presentation of Available Instruments

Jakob Andreasson

ELI Beamlines

Department for Structural Dynamics

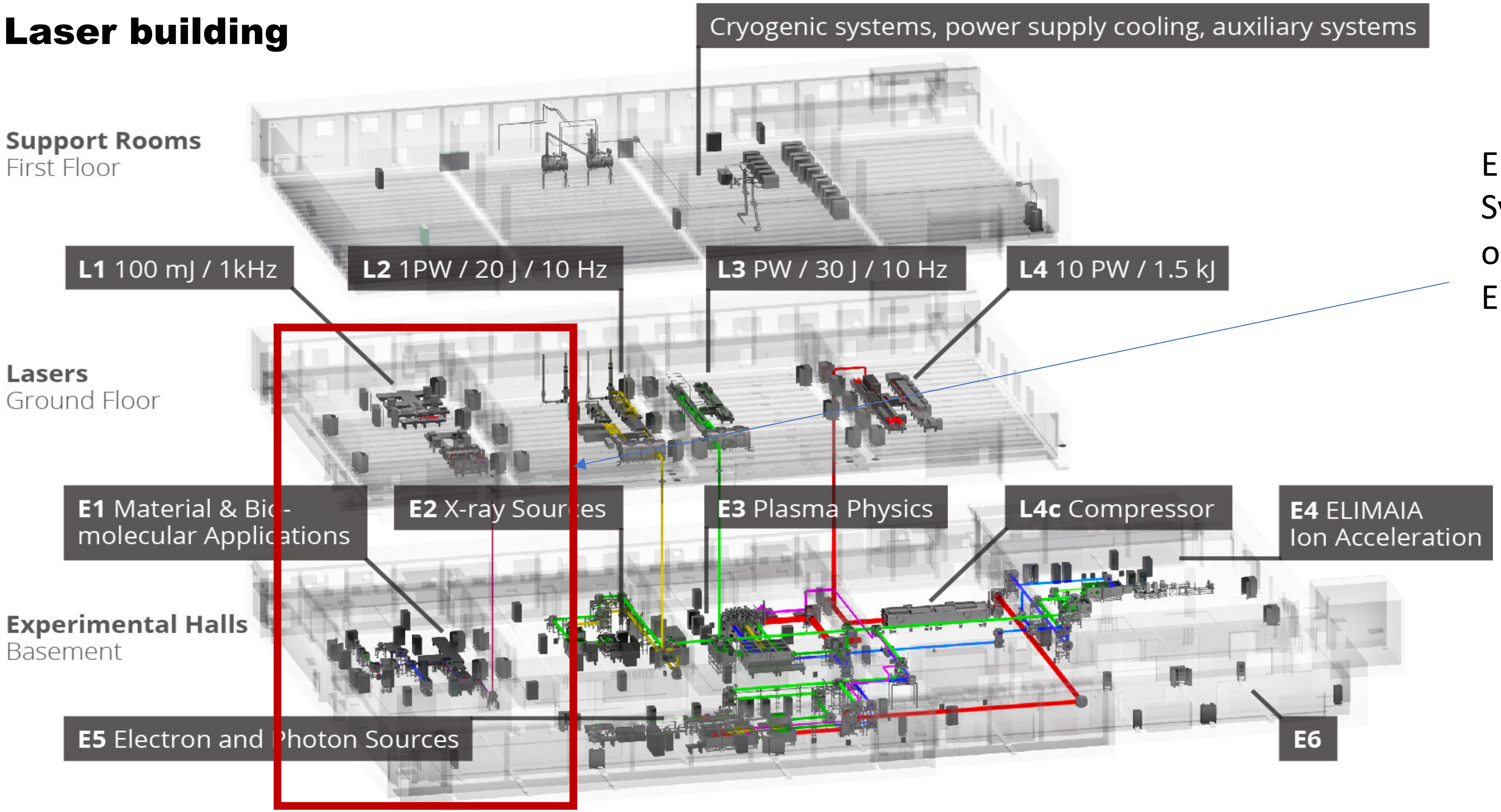
ELI User Call Webinar

18 July 2022

Welcome to the ELI Beamlines research facility

Objective: Use high power lasers to generate and study new states of matter and the generation of beams of photons and particles for science and applications

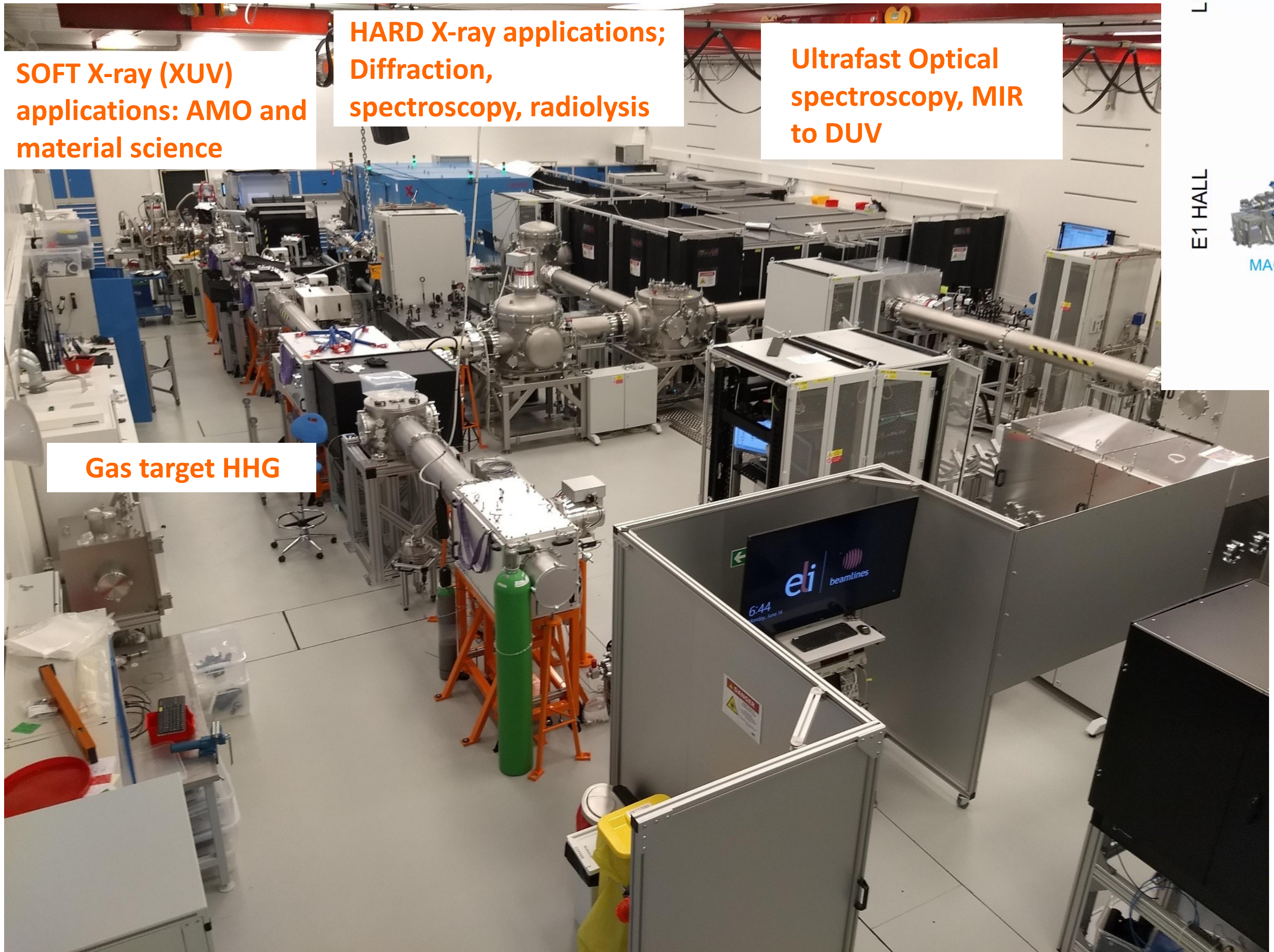
Facility general layout

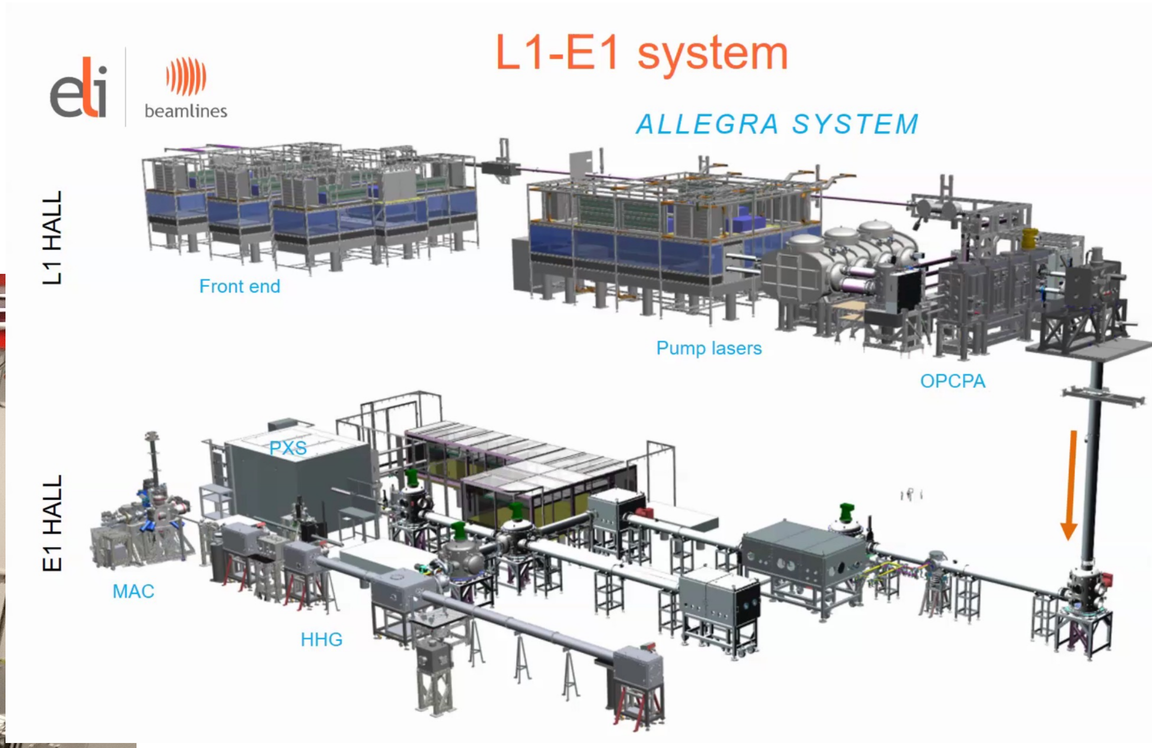


ELI Beamlines Systems in operation for ELI Call 1

Overview; ELI Beamlins E1 experimental hall overview and the L1 Allegra laser

Contact person: Jakob Andreasson,
Head of Department for Structural Dynamics

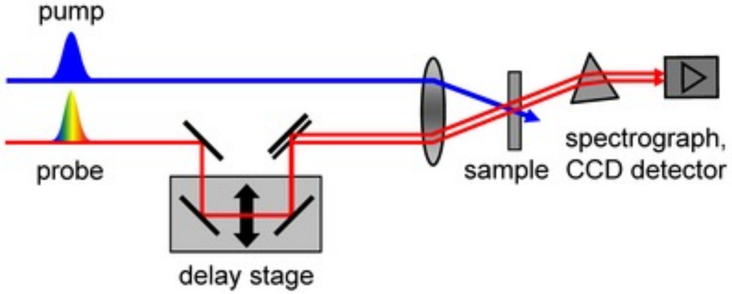




***Function* is fundamentally related to dynamics!**

In the E1 experimental hall, and its support laboratories, we have developed beamlines and stations for photon science experiments in the mid IR to Hard X-ray range

These are used for time resolved experiments using pump-probe techniques to study femtosecond to millisecond dynamics



ELI Beamlines kHz laser sources

L1 Allegra

The L1 Allegra laser is based on amplification of picosecond pulses in broadband OPCPA and compression to <20 femtosecond using chirped mirrors. The pump lasers are based on Yb:YAG thin disk technology. The central wavelength is 860 nm, beam profile is Gaussian-like and the polarization is linear s-polarization. Pre-pulse temporal contrast (up to 5 ps before pulse) is 10^-10. More information on the system can be found here (https://www.eli-beams.eu/facility/lasers/laser- 1-allegra-100-mj-1-khz/)

Energy, compressed Pulse duration at target, Repetition rate

4 to 25* mJ, <16 fs, 1 kHz

*Higher pulse energies can be provided but at the potential risk of reduced reliability in delivery. Contact the ELI BL staff for a detailed discussion.

Optional drive laser for HHG and MAC experiments

The following lasers are available for HHG source operation together with the MAC station.

Coherent Legend Duo Elite

Energy, compressed Pulse duration at target, Repetition rate:

12 mJ, <35 fs, 1 kHz

Drive lasers for optical spectroscopy

For user experiments in optical spectroscopy (FSRS, TA and time resolved ellipsometry) the following lasers are available:

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:

Femtopower : 4.5 mJ, 30 fs, 1 kHz

Solstice: 7 mJ, 40 fs, 1 kHz

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

HHG and MAC; XUV AMO science (1)

High-order Harmonic Generation (HHG) beamline

Parameter HHG	Available now
Repetition rate	1kHz
Pulse duration	<15fs
Dl/l	up to 10^-2
Wavefront	<l/10
Divergence	<2mrad
Source type	Variable length cell or EL pulsed valve
Pulse energy (Min-Max range)	10^9 - 10^12 ph/shot
Central wavelength	
Spectral bandwidth	~10nm - 120nm
Polarization	Lin / Circ / Ellipt
CEP stabilization	NA
Near field intensity distribution	Gaussian
Beam size	

O Hort, et al.
Optics express 27 (6), 8871-8883 (2020)

XUV monochromator

Frassetto, *et al*
Single-grating monochromator for extreme ultraviolet ultrashort pulses
Opt. Express 19, 19169–19181 (2011).

Pulse duration after monochromator (simulated), 35 to 100 fs

Grating (lines/mm)/spectral region (eV)
Flat mirror
G1 (86) / 10-28
G2 (158) / 25-54
G3 (600) / 51-98
G4 (985) / 86-121

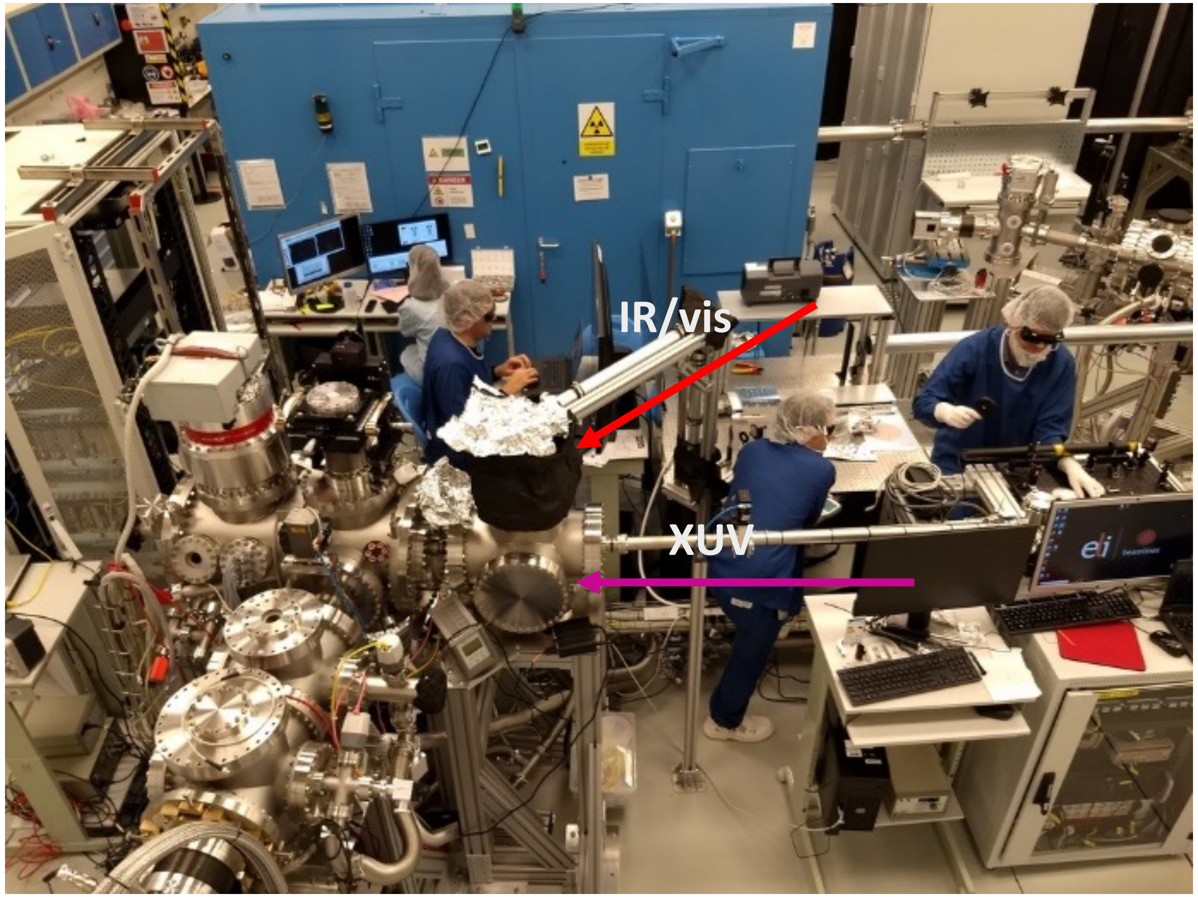
Throughput: >30% between 15th and 29th harmonic

Refocusing with mono.:
5:1 ellipsoidal mirror.
Spot size about 40*70 um

Back focusing geometry: Alternatively the elements of the XUV monochromator are removed from the beam path and the XUV beam is refocused by a spherical mirror.

Three different coatings are available: (1) centred at 21.5 eV (narrow bandwidth), (2) centered at 26.6 eV (narrow bandwidth), (3) around 15-27.5 eV (broad bandwidth).

HHG and MAC; XUV AMO science (2)



MAC station for AMO science

-Cryo-cooled Even-Lavie valve, maximum pulsed repetition rate of 500 Hz, or continuous valve option

-Cluster source with doping ability

-Molecular source with an Amsterdam Piezo Valve, model ACPV2-100 with a repetition rate up to 5 kHz (on demand/commissioning)

-4-axes fixed sample stage for CDI and fixed targets

Available spectrometers, detection and observation systems

-Electron and ion Time of Flight spectrometers (in house development). Up to 1 kHz shot to shot readout.

-Velocity Map Imaging (VMI 75 mm MCP with a phosphor screen imaged by a camera with 166 fps 1936 x 1216 pix Sony CMOS 1/1.2" sensor 72 dB (~ 12 bit resolution)) with ns gated imaging detector (Velocitas/Photek)

-PI MTE in vacuum XUV CCD

-Microscope for sample observation and optimization

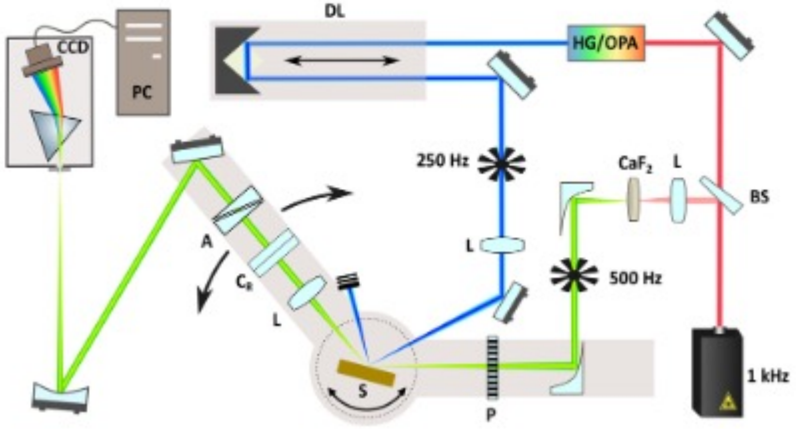
Core publications

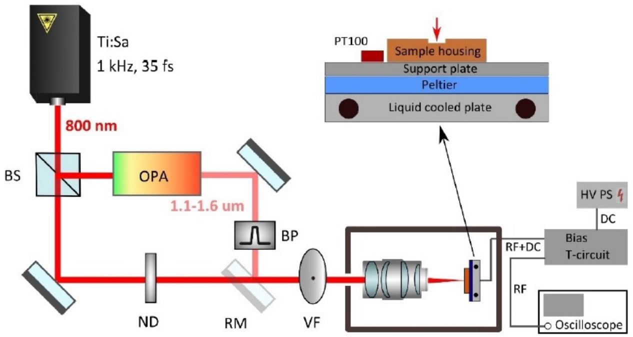
- E Klimešová, et al., The European Physical Journal Special Topics, 1-12 (2021)
- E Klimešová, , et al., Physical Review A 104 (6), L061101 (2021)
- E Klimešová, et al.: Sci. Rep. 9, 8851 (2019)

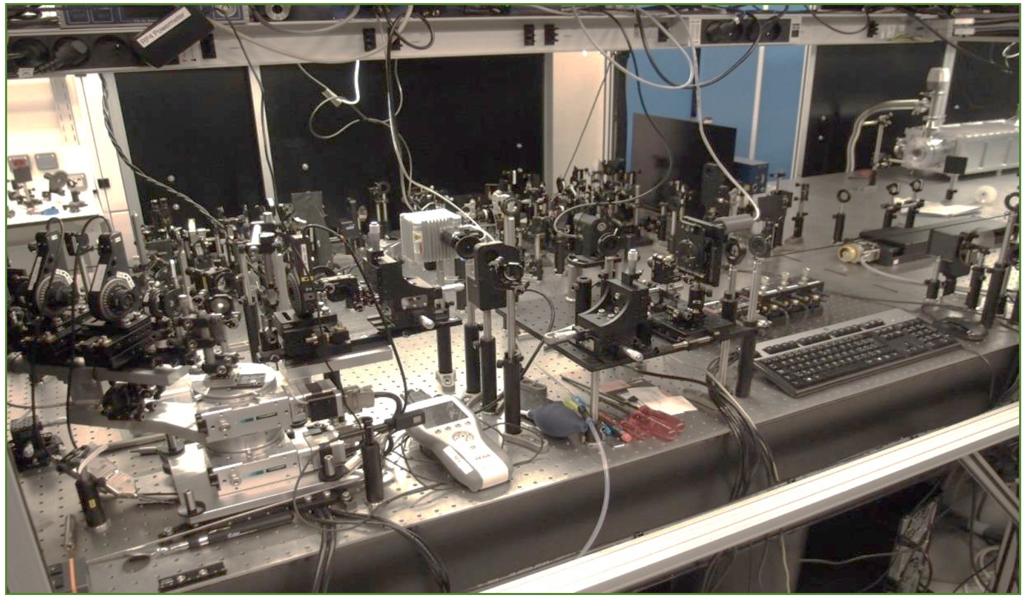
Optical spectroscopy: trELIps and TCT (E1)

Time resolved ellipsometry (trELIps)

- Wavelengths pump beam: 266 nm, 400 nm or 800 nm generated by a third harmonic generation kit or to pump with any wavelength between 350 -2000 nm generated by an Optical Parametric Amplifier
- Spectral range probe: 350 nm - 750 nm (1.65 eV - 3.54 eV) based on supercontinuum generation.
- Probe spot size at the sample: ~100 µm
  Time range: 5 ns
- Time resolution: 100 fs - 200 fs
- Angle of incidence of the probe: 0-90 degrees
- Magnet with bipolar field of up to 0.8T for magneto-optical measurements in transmission. Variable distance between the magnet poles, 8 mm axial holes for light entry and exit.







Transient Current Technique (TCT)

Operational modes: Single and two photon absorption (SPA and TPA)
Wavelength: 800 nm (SPA), 1550 nm (TPA)
Pulse energy on sample: Variable by ND filters (accuracy: 0.2 pJ)
Focus waist radius: 0.85 um (SPA), 1.5 um (TPA)
Rayleigh length: 3.31 um (SPA), 7.74 um (TPA)
Sample cooling: Down to -25 deg. C
Sample movement: X, Y, Z
Bias voltage: variable, up to >720 V
Detection: 6 GHz (20 GSa) oscilloscope and leakage current measurement (accuracy: 0.1 uA)

Core publications, trELIps

- Herrfurth O., et al., Phys. Rev. Research 3, 013246 (2021)
- S Richter, et al., Review of Scientific Instruments 92 (3), 033104 (2021)
- S Richter, et al., New Journal of Physics 22 (8), 083066 (2020)
- S Espinoza, et al., Applied Physics Letters 115 (5), 052105 (2019)

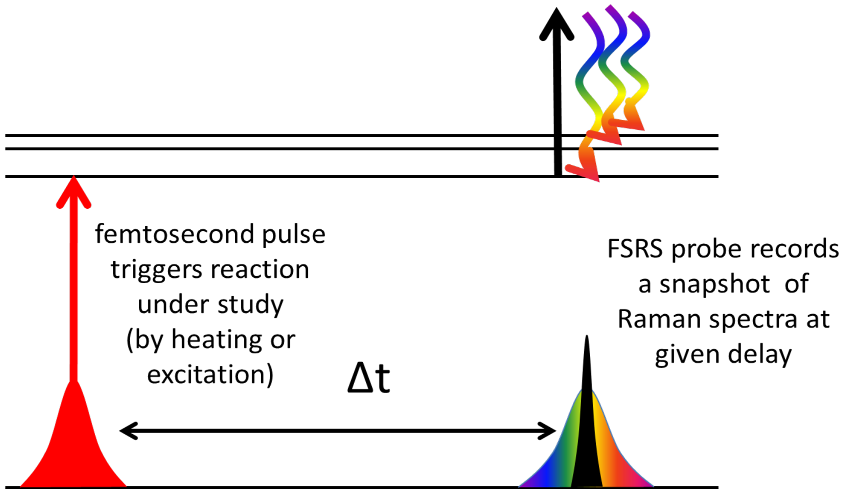
TCT

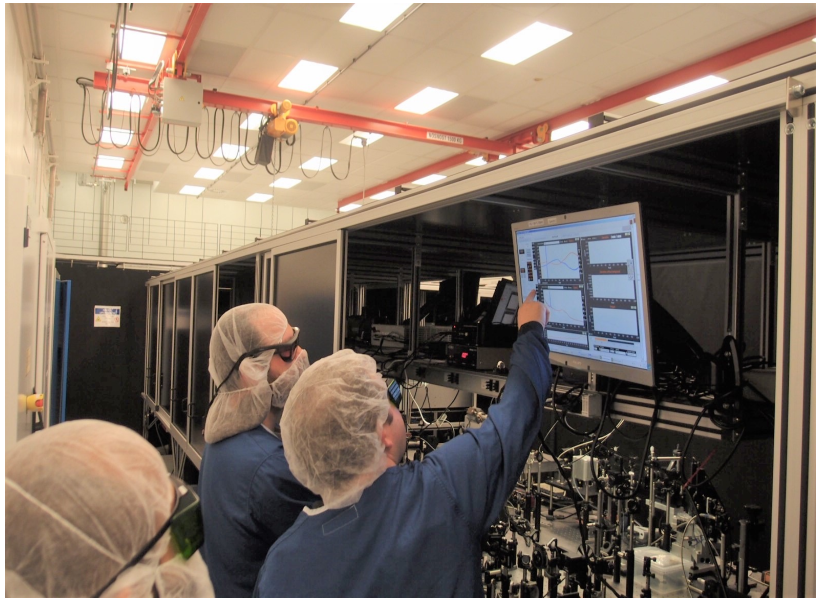
- Gordana Lastovicka-Medina, *et al.,* Femtosecond laser studies of the Single Event Effects in Low Gain Avalanche Detectors and PINs at ELI Beamlines, Nuclear Inst. and Methods in Physics Research, A (under review)

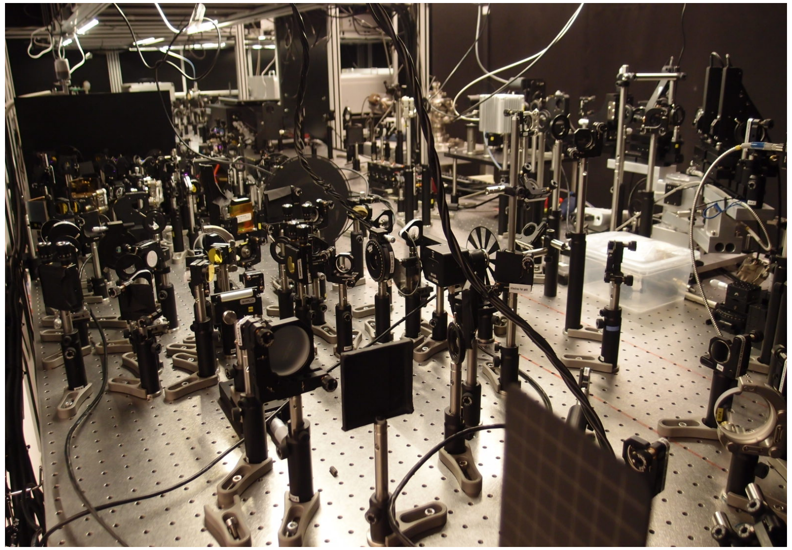
Optical spectroscopy: SRS and TA (ELIBIO laserlab)

FSRS
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)

Transient optical absorption (TA)
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
(Coherent Astrella as drive laser)
Pump-probe delay: 0 – 1 ms, 10 fs resolution
(Femtopower/Solstice doublet as drive laser)







Core publications, TA and SRS
- Qian *et al*., 2.4-Å structure of the double-ring Gemmatimonas phototrophica photosystem, Science Advances • 16 Feb 2022 • Vol 8, Issue 7 (2022)
- PC Andrikopoulos, et al., Physical Chemistry Chemical Physics 22 (12), 6538-6552 (2020)
- M Naumova, et al., Chemical Physics 20 (9), 6274-6286 (2018)
- M. Pižl, et al., Journal of Physical Chemistry A, 2020 Feb 20; 124(7):1253-1265 (2020)
- V. Kuznetsova, et al., Biochimica et Biophysica Acta (BBA) - Bioenergetics Volume 1861, Issue 2, 1 February 2020, 148120 (2020)

PXS and TREX (source development/commissioning)

TREX, X-ray diffraction and spectroscopy

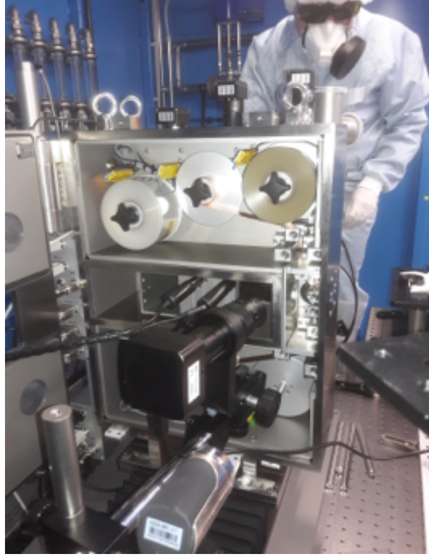
Sealed tube X-ray beam parameters
Anode materials: Cu and Mo
Flux on the sample: 10^8 ph/sec
Beam size: 145 micrometers
Beam divergence: 4.8 mrad
Beam polarization: 40%
Wavelength CuKa: 1.54 Angstroms

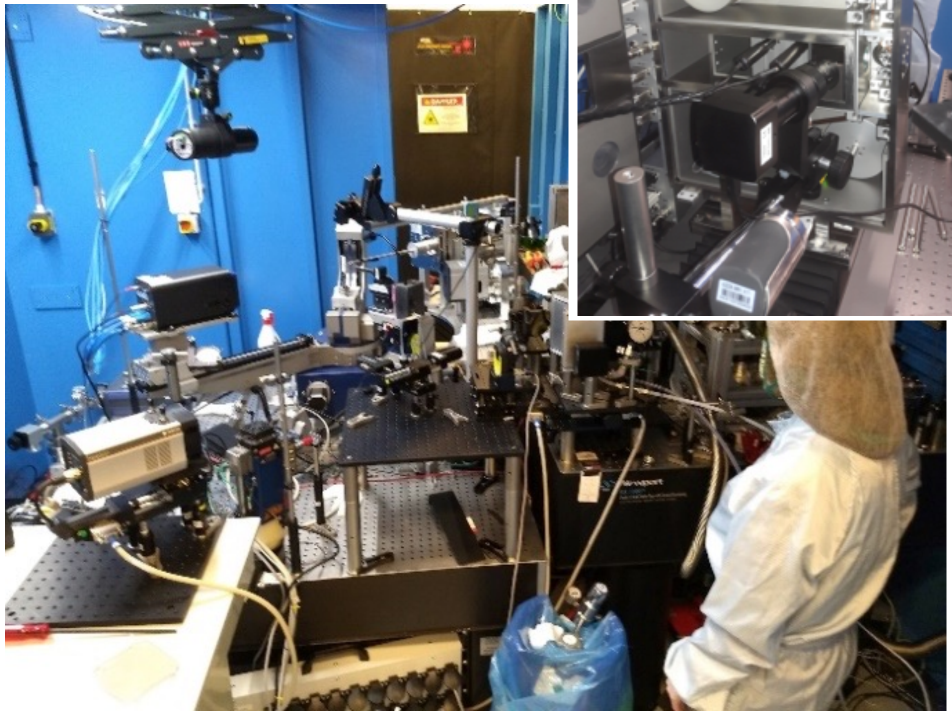
Eiger X 1M Detector parameters
Pixel size [µm2]: 75 x 75
Sensitive area (width x height)
[mm2]: 77.2 x 79.9
Total number of pixels: 1030 x 1065 = 1,096,950
Maximum frame rate [Hz]: 3000
Frame dead time: 3 µs
Point-spread function: 1 pixel
Sensor thickness [µm]: 450
Threshold energy [keV]: 2.7-18
Maximum 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

Complementary X-ray CCD
Andor Newton X-ray CCD camera with an e2v CCD30-11 front illuminated, deep-depletion chip

Cu tape source parameters

Energy range	1-40 keV
Photon number	1e9 ph/(shot*sr) @ 1 keV BW **10^4 ph/shot, monochromatized on sample**
Spectrum	Ka-Line & Bremsstrahlung
Pulse duration @ source	ca. 100 fs
Divergence	4p
Source size	10-30 µm





Experimental/diagnostics capabilities

Diffraction	Diffractometer station
Spectroscopy	Von Hamos spectrometer

Core publications

- First experiments with a water-jet plasma X-ray source driven by the in-house developed L1 Allegra laser at ELI-Beamlines, Journal of Synchrotron Radiation, Volume 28, Part 6, pages 1778-1785 (2021), A. Zymaková, *et al.*
- Kilohertz Macromolecular Crystallography Using an EIGER Detector at Low X-ray Fluxes, Crystals 2020, 10(12), 1146; https://doi.org/10.3390/cryst10121146, Khakurel K. P., et al.
- Implementation of a crossed-slit system for fast alignment of sealed polycapillary X-ray optics, Journal of Synchrotron Radiation 27 (6), 1730-1733, Anna Zymaková, *et al.*

ELI Beamlines E1 and auxiliary labs and instrument contact persons

Contact persons for sources and instruments (email: N.N)

- HHG source: Dr. Ondrej Hort
- PXS source: Dr. Dong Du Mai
- MAC station (AMO science): Prof. Dr. Maria Krikunova
- TA and FSRS stations: Dr. Miroslav Kloz
- ELIps station: Dr. Shirly Espinoza
- TCT station: Dr. Mateusz Rebarz
- X ray Diffraction station: Dr. Borislav Angelov
- X ray Spectroscopy station: Dr. Anna Zymakova

Available support systems/services

- Rapid prototyping: 3D printing
- Bio/Chem sample preparations: Well equipped Bio-lab (300 m2, in collaboration with the ELIBIO project). Including BSL2 capabilities
- Imaging systems: Optical microscopes, ESEM
- Machine shop: Yes
- Data analysis & transfer: Scientific team can assist based on need.

Thank you for your attention

Looking forward to your beamtime applications

We're one week from our webinar on the ELI user call and I'm contacting you with some guidance on the format of the facility presentations. I'm attaching the programme to this email for your convenience.

Each facility will have 30 minutes to present + 5 minutes for questions. In the spirit of this joint call, we'd like to have as much unity and consistency as possible in the content and format of the presentations. I'm stating the obvious, but the orientation and focus of your talks should be really to outline what is our offer to users within the framework of this call. As a consequence, the approach we'd like to suggest for each facility talk is as follows:

- 2-3 slides of introduction of your facility (keeping in mind that Allen, in the ELI ERIC intro talk, will most likely give a very quick overview of the scope of the Facilities)
- For each instrument:
    - 1-2 slides introducing the instrument, including elements on the type of science / techniques enabled by the instrument and a table of user-relevant parameters available within the framework of the call (you may also include laser parameters if you deem them relevant from the user's point of view)
    - 1 slide on metrology with available diagnostics
    - 1 slide including other relevant information regarding the level of user support: targets and supporting labs / workshops + name of contact person (instrument scientist) for further questions.

As time is short and that some of the facilities have to present up to 4 instruments, we suggest that you keep slides on the level of availability, previous commissioning experiments and experimental results as back-up slides. We'll make them available online and you'll be able to use them in case they are useful to respond to questions.