

Ultrafast spectroscopy at ELI Beamlines: capabilities  
for applications in molecular, bio-medical and  
material science

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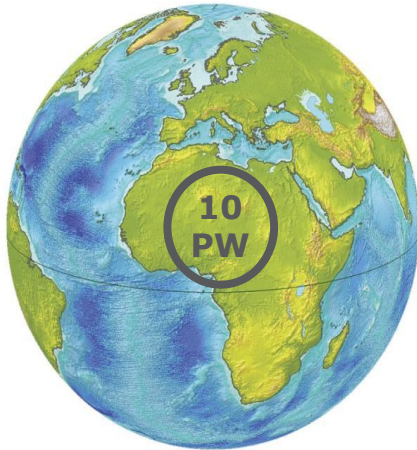
# What is ELI ?

The **E**xtrême **L**ight **I**nfrastructure is the world's largest and most advanced high-power laser infrastructure and a global technology and innovation leader in high-power, high-intensity, and short-pulsed laser systems.

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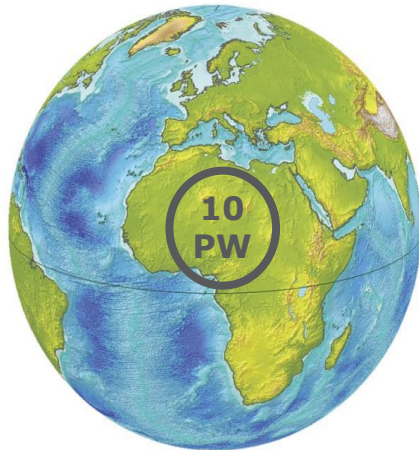
**Ultra-high power**  
**(up to 10 PW)**



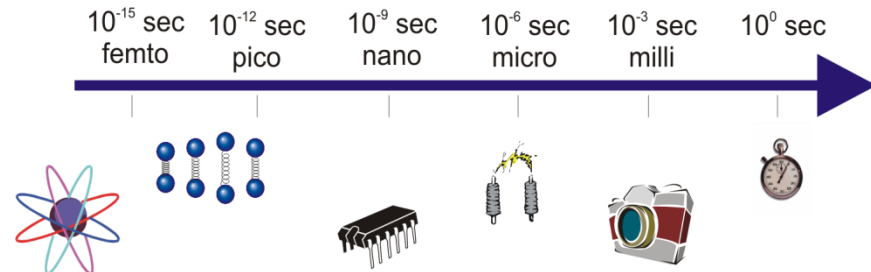
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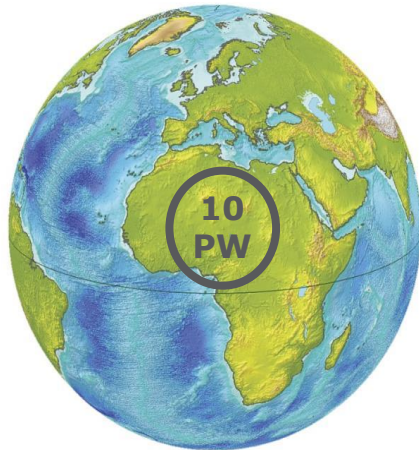
**Ultra-short pulses (down to 100 as)**



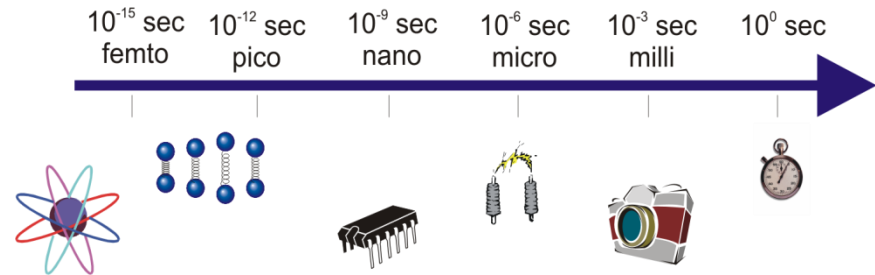
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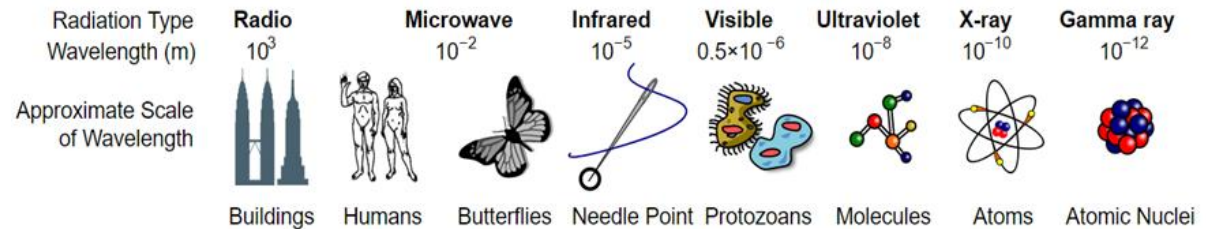
**Ultra-high power**  
(up to **10 PW**)



**Ultra-short pulses (down to 100 as)**



**Ultra-broadband spectrum (THz-Gamma)**



# ELI Facilities

## ELI BEAMLINES



Czech Republic, Dolní Břežany (outskirts of Prague)  
(in ERIC since April 2021)

## ELI ALPS



Hungary, Szeged  
(in ERIC since April 2021)

## ELI NP



Romania, Magurele (outskirts of Bucharest)  
(in ERIC soon)

### Extreme peak power: 10 PW

- Particles acceleration
- X-ray sources

### Extreme pulse duration: 166 as

- Attosecond physics
- Few-cycle pulses from THz to UV

### Extreme photon energy: 19 MeV

- Photonuclear physics
- Gamma sources

# What is ERIC ?

The **E**uropean **R**esearch **I**nfrastructure **C**onsortium (ERIC) is a legal framework created by the European Commission to allow the operation of Research Infrastructures of Pan-European interest.

Construction was possible with **E**uropean **S**tructural **I**nvestment **F**unds

*The Czech Republic,  
Host of Seat*



*Hungary,  
Host*

*Italian  
Republic*



ESIF



*Lithuania*

*Federal Republic of  
Germany  
Observer*



*Bulgaria  
Observer*

*European  
International  
Organisation  
Established  
in 2021*

*Member countries support ELI ERIC jointly with national funding*

# Petawatt-class lasers worldwide

Europe leads the world in laser production and installation, especially state-of-the-art systems

- **Investment** in high-power laser systems in Europe is connected to a **strong and relatively consolidated** community in Laserlab Europe beginning in 2001.
- **The ELI Facilities** are introducing **> 33 PW ( 3x10PW @10Hz systems)**



**SOURCE:** Courtesy of J.L. Collier, CLF RAL, UK



# ELI vs Synchrotrons

## Accelerator based sources



- ⊕ Reliability
- ⊕ Tuneability
- ⊕ Flux
- ⊖ Limited temporal resolution
- ⊖ Synchronization

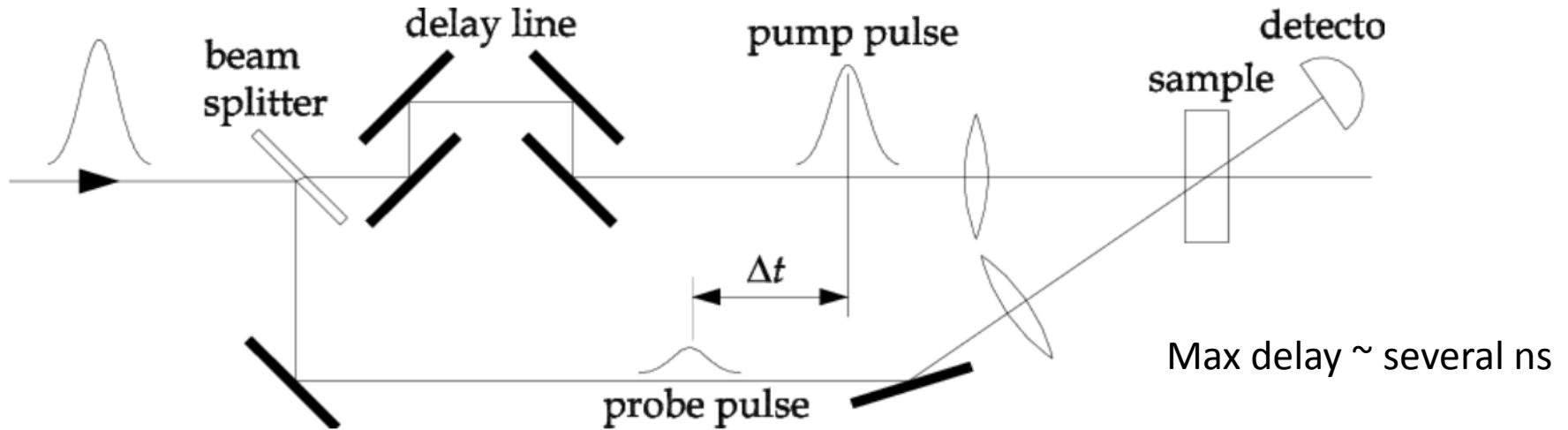
## Laser-driven sources



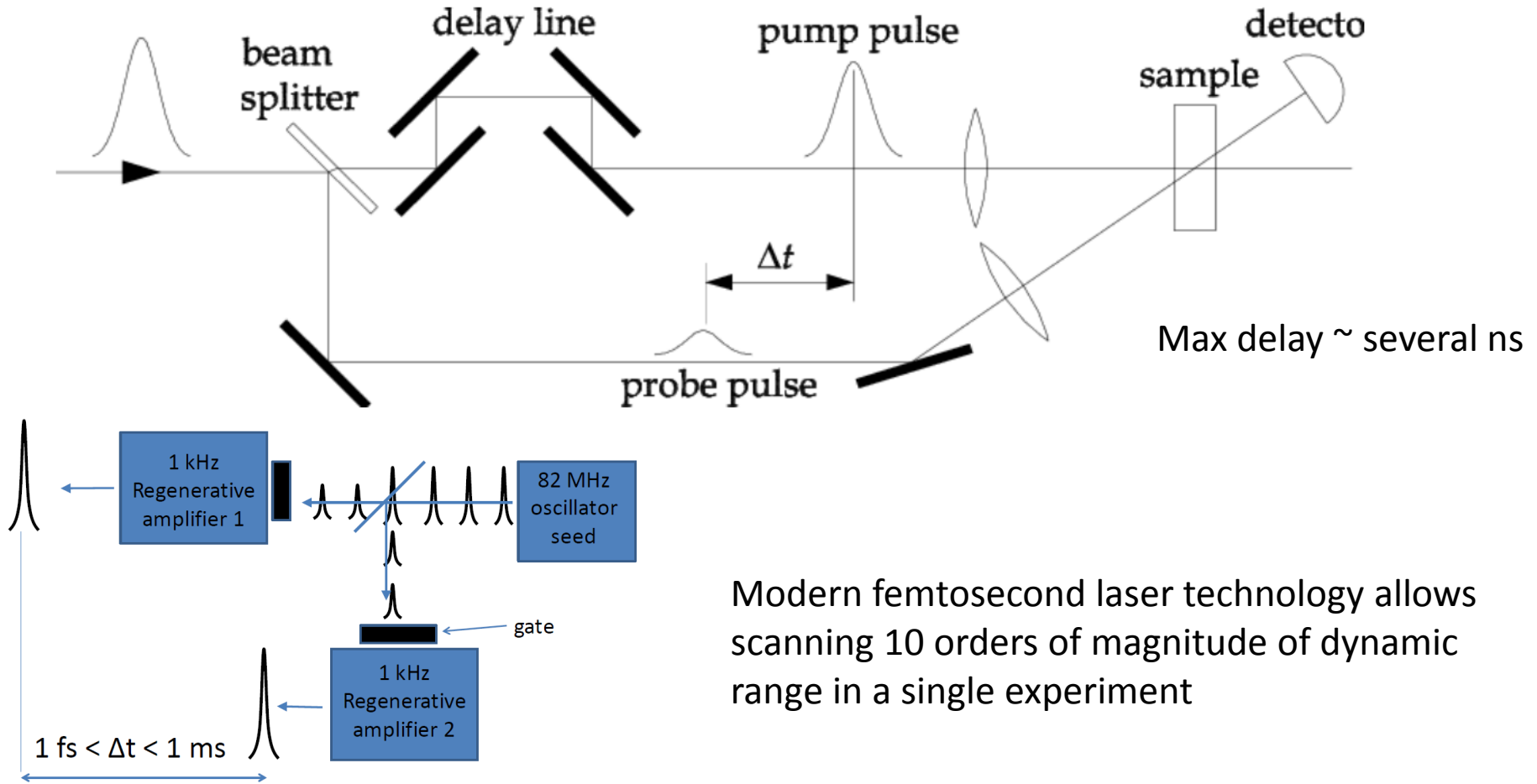
- ⊕ Synchronization
- ⊕ Temporal resolution
- ⊕ Flexibility (pump-probe)
- ⊖ Limited tuneability
- ⊖ Flux

**High complementarity between synchrotrons and ELI infrastructure**

# Pump-probe experiments



# Pump-probe experiments



Modern femtosecond laser technology allows scanning 10 orders of magnitude of dynamic range in a single experiment

# ELI Beamlines

ELI Beamlines is an international user facility for fundamental and applied research using ultra-intense laser and particle beams

## Research Departments

1. Department of Laser Systems
2. Department of Radiation Physics and Electron Acceleration
3. Department of Ion Acceleration and Applications of High Energy Particles
- 4. Department of Structural Dynamics**
5. Department of Plasma Physics and Ultra-high Intensity Interactions

Czech Republic  
Dolní Břežany (on the outskirts of Prague)



[www.eli-beams.eu](http://www.eli-beams.eu)

# ELI Beamlines Lasers



## ELI Beamlines

L1	L2 *	L3	L4
5 TW	100 TW	1 PW	10 PW
100 mJ	2 J	30 J	1.5 kJ
15 fs	25 fs	30 fs	150 fs
1 kHz	50 Hz	10 Hz	0.01 Hz

\* target in 2026

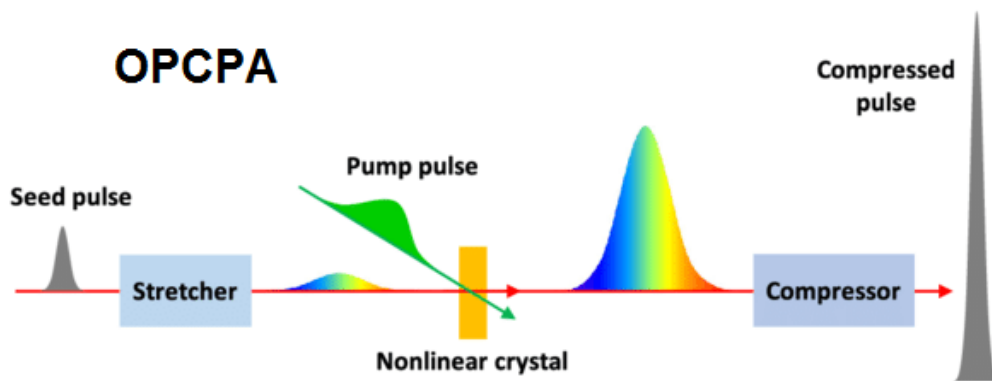
## Technologies

### DPSSL

Diode Pumped Solid State Laser

### OPCPA:

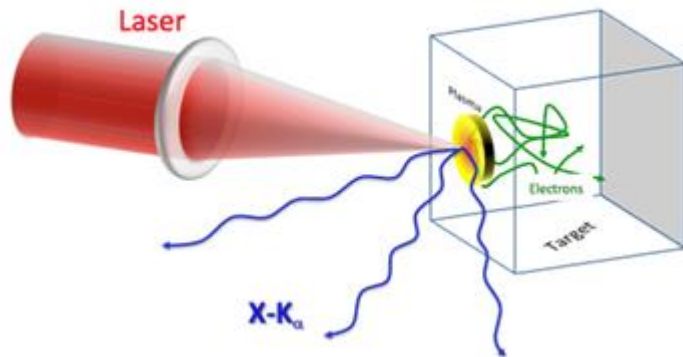
Optical Parametric Chirped-Pulse Amplification



# Laser driven X-ray sources

Focusing laser on the specific target

Plasma Source

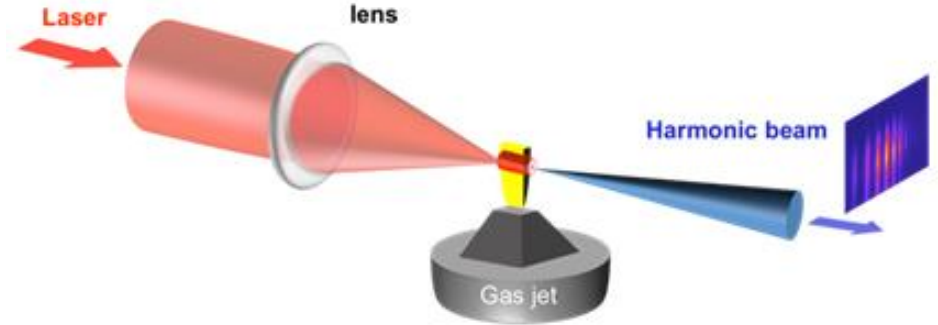


4-30 keV

100 fs

incoherent

High Harmonics

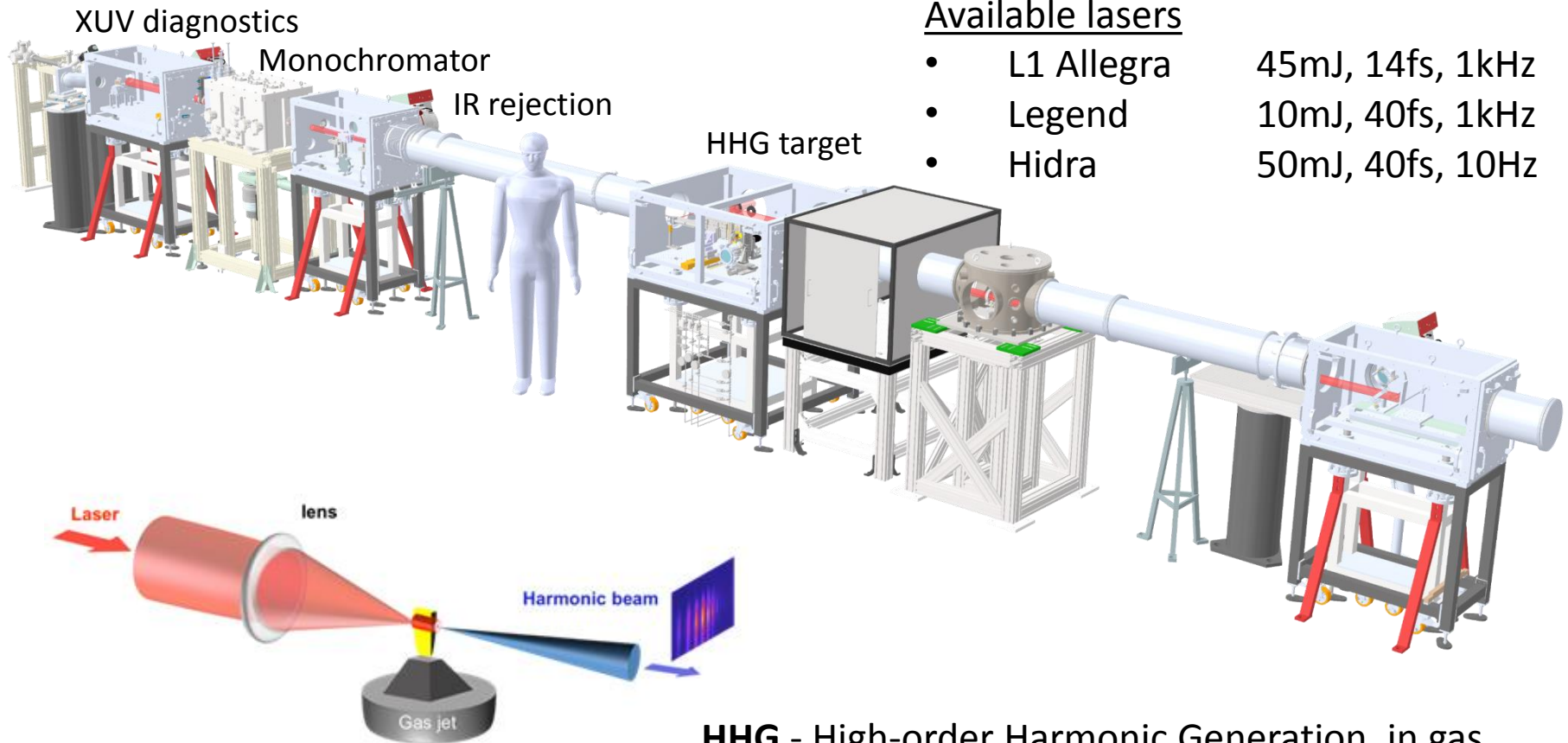


10-250 eV (5 -120 nm)

< 20 fs

coherent

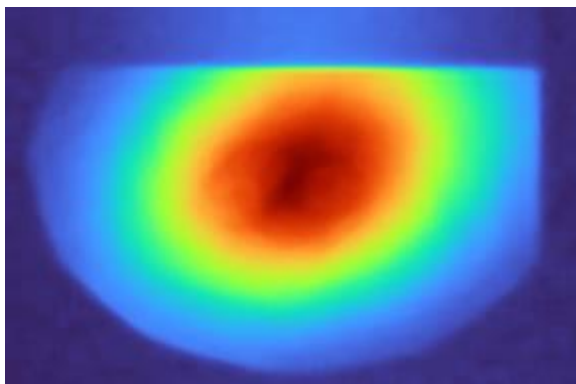
# High Harmonics Generation (HHG)



**HHG** - High-order Harmonic Generation, in gas  
10-120 eV, 20-35 fs, resolution <1 eV

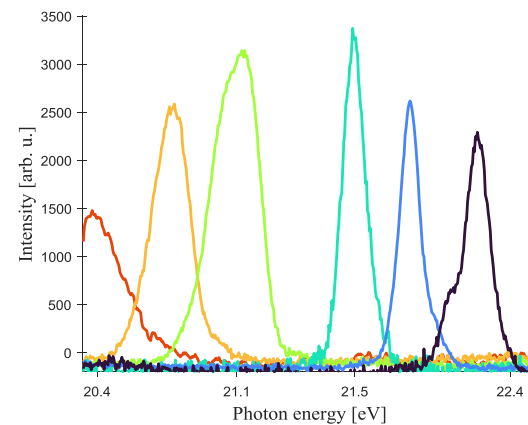
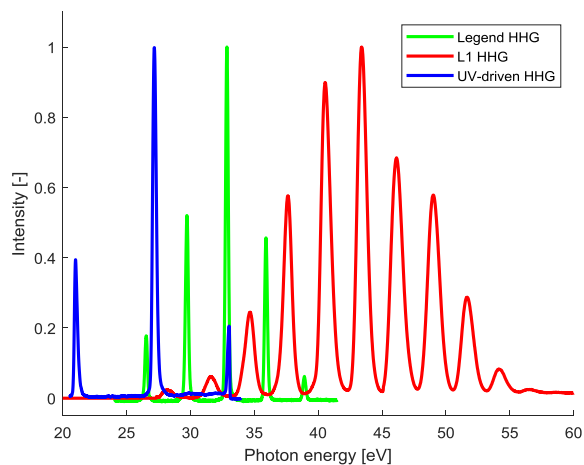
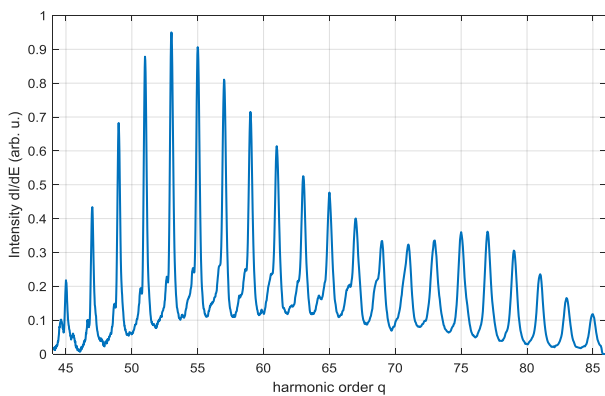
# High Harmonics Generation (HHG)

Measured XUV beam profile



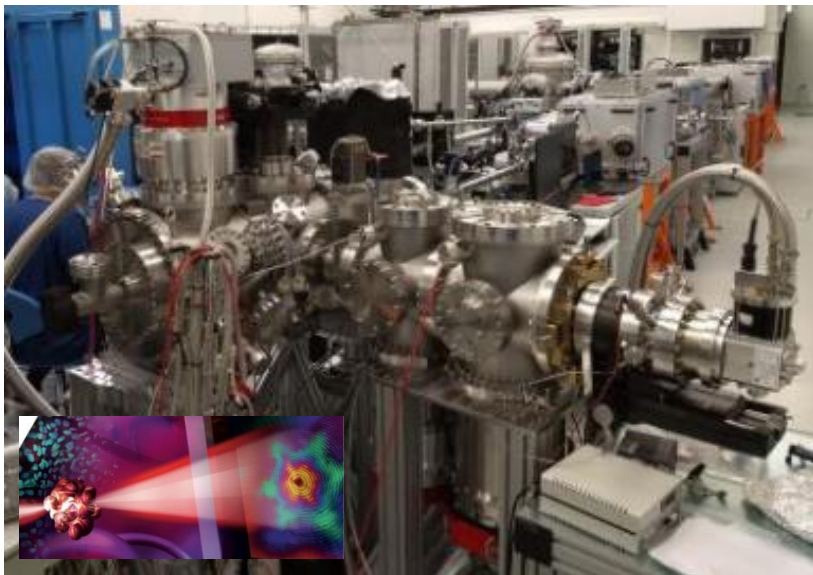
Gas	$\lambda_{\text{XUV}}$ (nm)	Estim. XUV energy ( $\mu\text{J}$ )
Xenon	$\geq 50$	2
Argon	$\geq 30$	0.2
Neon	$\geq 13$	0.02
Helium	$\geq 10$	0.02

neon





# MAC chamber & AMO science

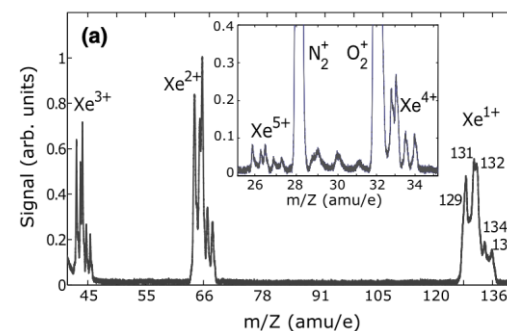
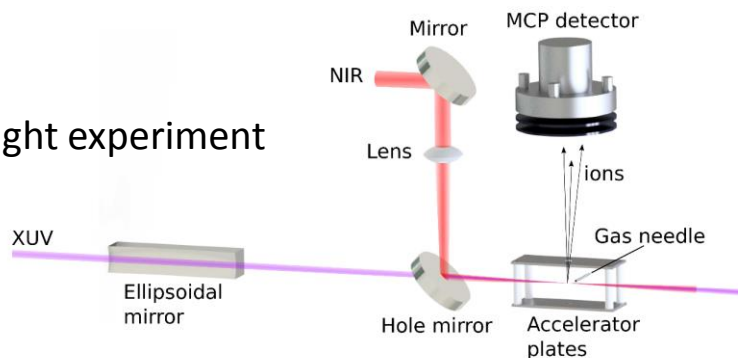


**MAC:** Multi-purpose chamber for AMO (Atomic, Molecular, Optical) and CDI (Coherent Diffractive Imaging) science.

**Detectors:** Electron and Ion Time of Flight spectrometer (in-house development) Velocity Map Imaging (VMI 75 mm MCP with a phosphor screen and ns gated imaging detector )

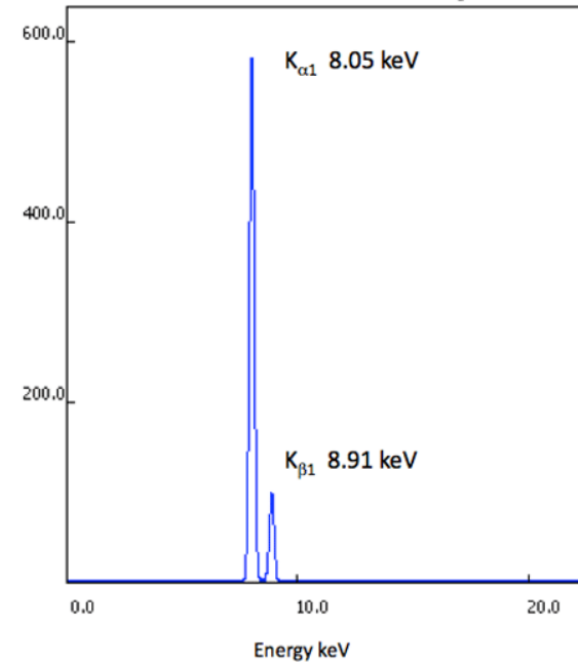
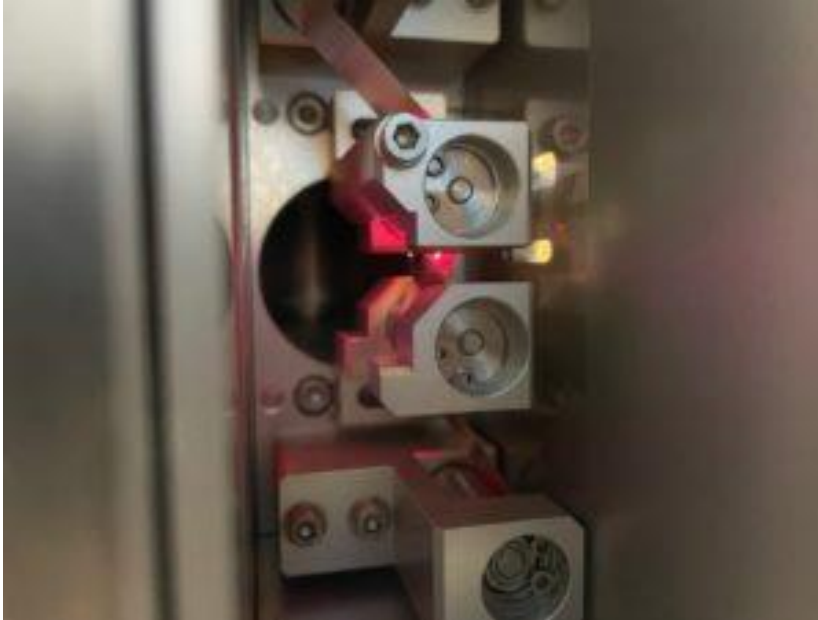
**Samples delivery:** Cluster source – for rare-gas and water clusters with sizes from few to 100 nm. Molecular source (5 KHz), aerosol injection.

Gas phase time of flight experiment



# Plasma X-ray Source (PXS)

Cu-tape source: ~ 8 keV X-rays



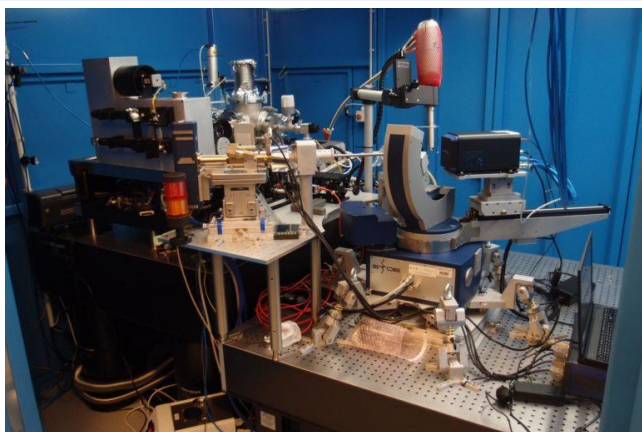
3-30 keV Bremsstrahlung (continuum)

$2.9 \times 10^{10}$  ph/(shot\*sr) @ 1 keV bandwidth

Complementary CW sources: Cu and Mo anodes –  $10^8$  ph/sec

# X-Ray Diffraction & Spectroscopy (XRD/XAS)

## Hard X-ray Diffraction



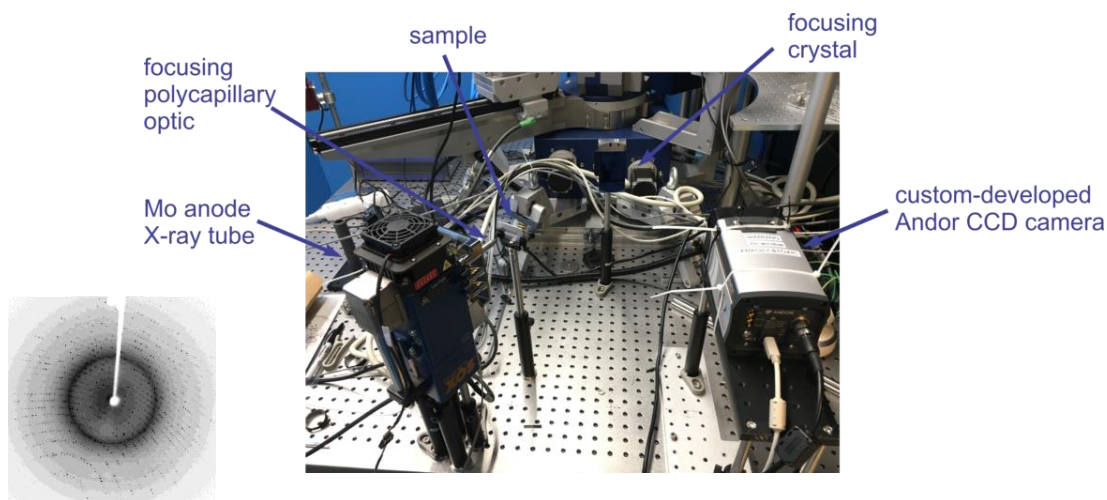
### Euler cradle goniometer

simultaneously rotating the investigated sample at 360° and positioning the X-ray detector at desired angle and distance.

### Detection

recording of the diffracted and scattered X-ray photons by a single photon counting hybrid pixel 3 kHz detector (Eiger X 1M, Dectris)

## Hard X-ray Spectroscopy



### Spectrometer

von Hamos design with gratings from 4 to 12 keV

### Detection

custom designed CCD (Andor) with greater acceptance angles and beryllium window

# Optical Spectroscopy Stations

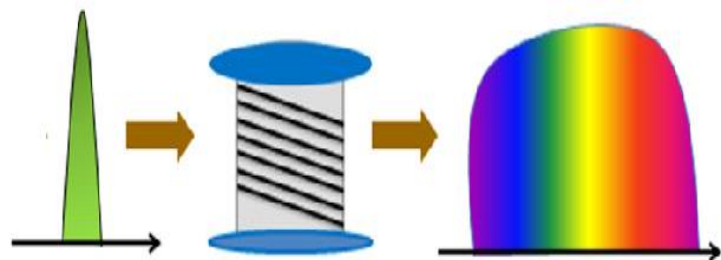


**UV-VIS-IR Transient Absorption:** monitoring excited and transient states of molecules, atoms and materials

**Stimulated Raman Spectroscopy:** monitoring Raman vibrational spectra of molecules to follow structural changes with high time resolution

**TR Ellipsometry:** measures the polarization response of samples providing optical constants of the material in an excited states and during the time evolution of these states

## Light sources

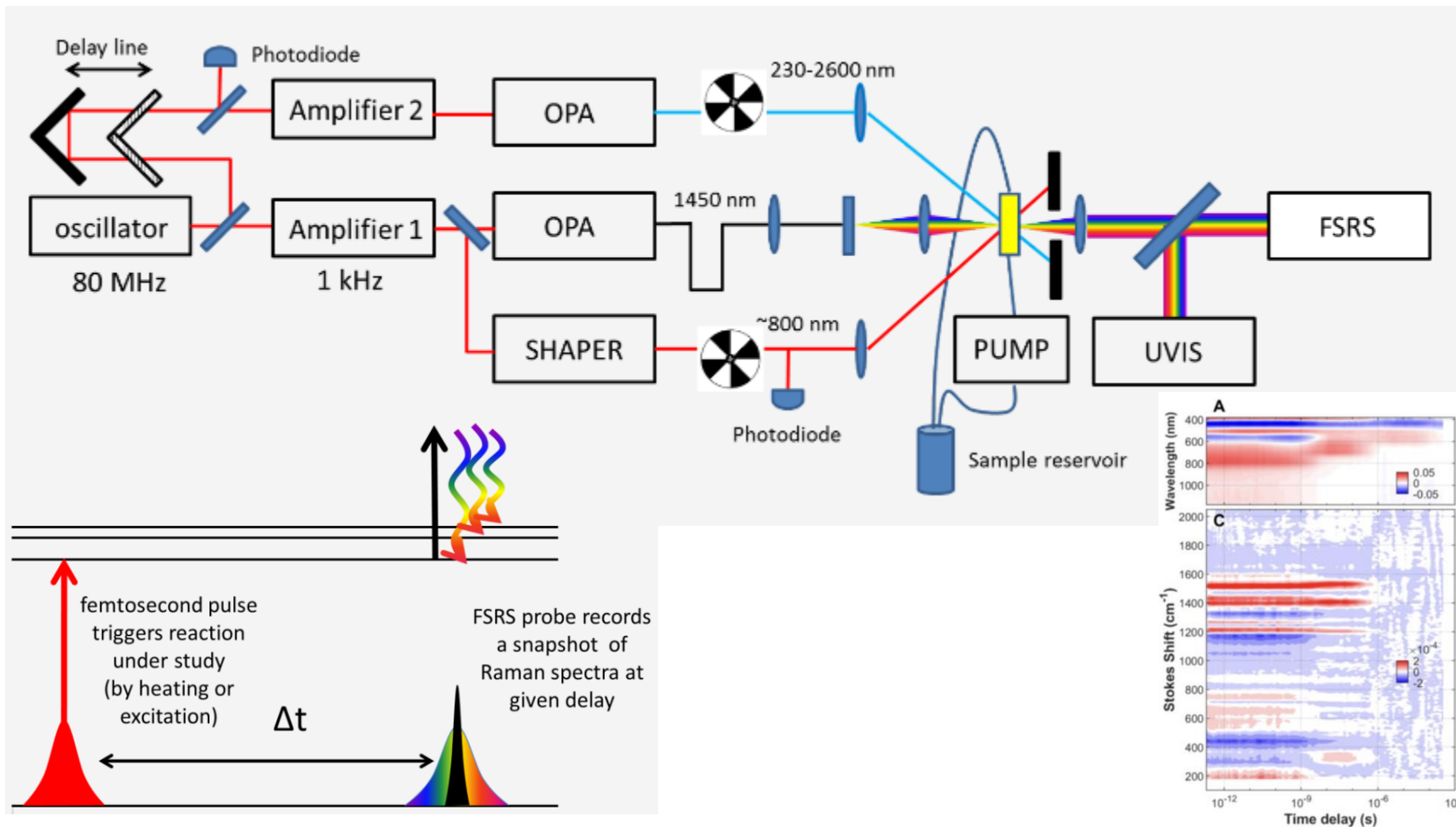


**Ti:saph** - fs lasers (800 nm, 20-35 fs, 1 kHz)

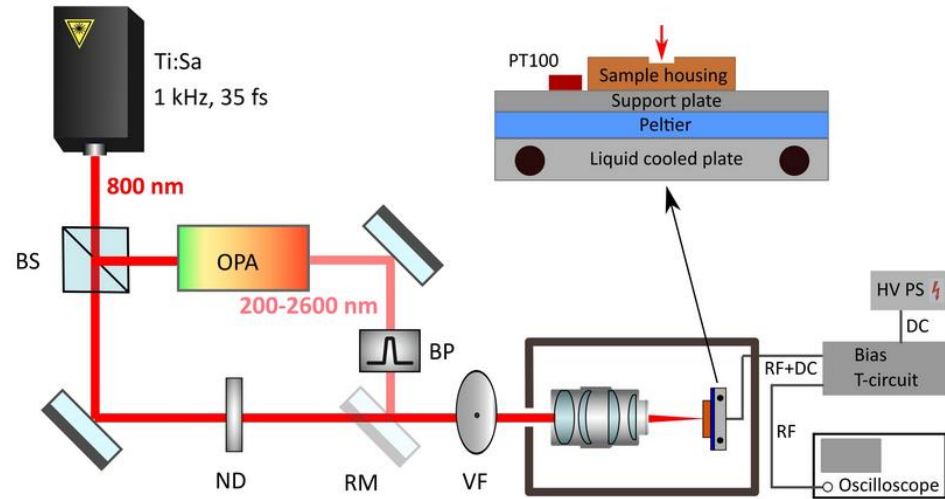
**OPA** - Optical Parametric Amplifiers (0.25-2.5  $\mu\text{m}$ )

**HCF** - Hollow Core Fiber (5 fs, 250 - 1100 nm)

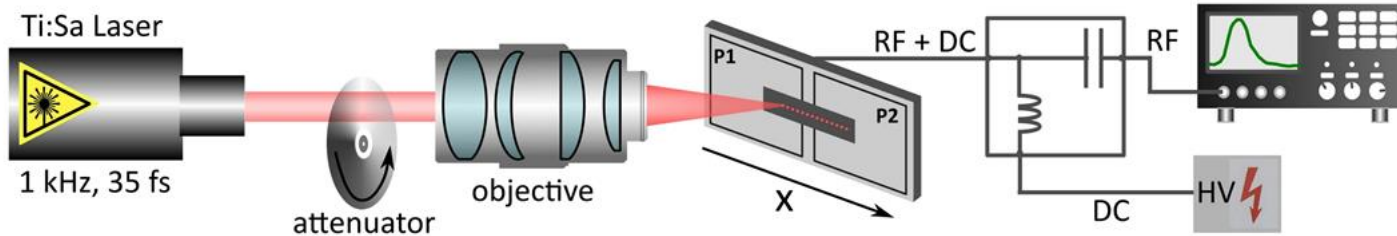
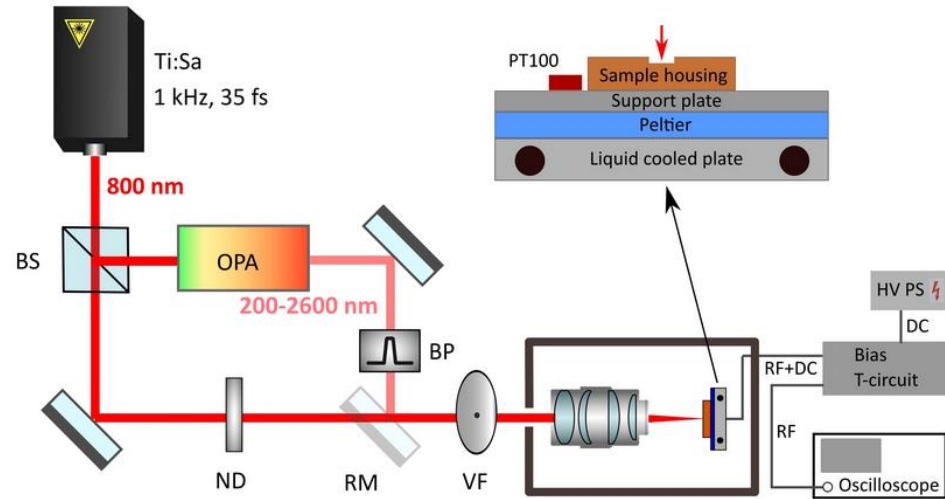
# Stimulated Raman Spectroscopy



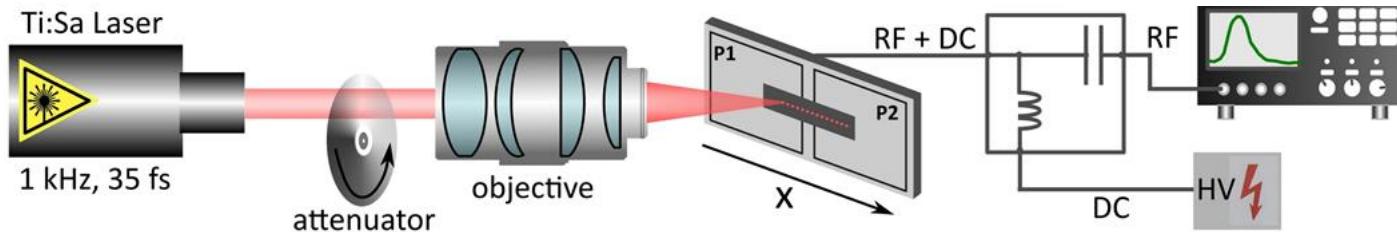
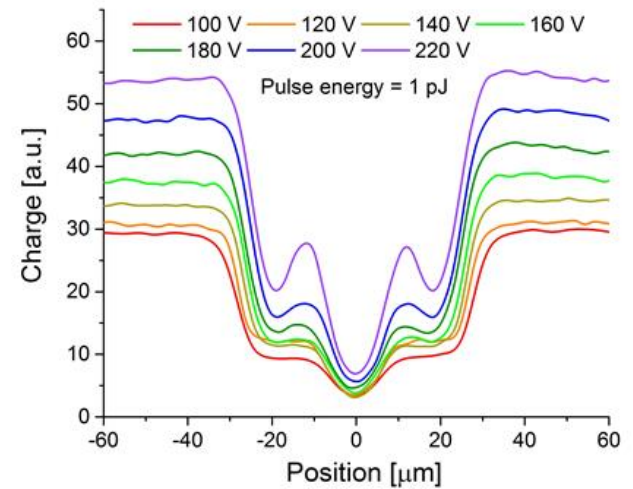
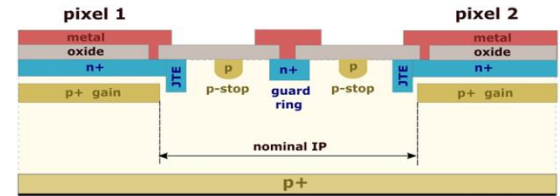
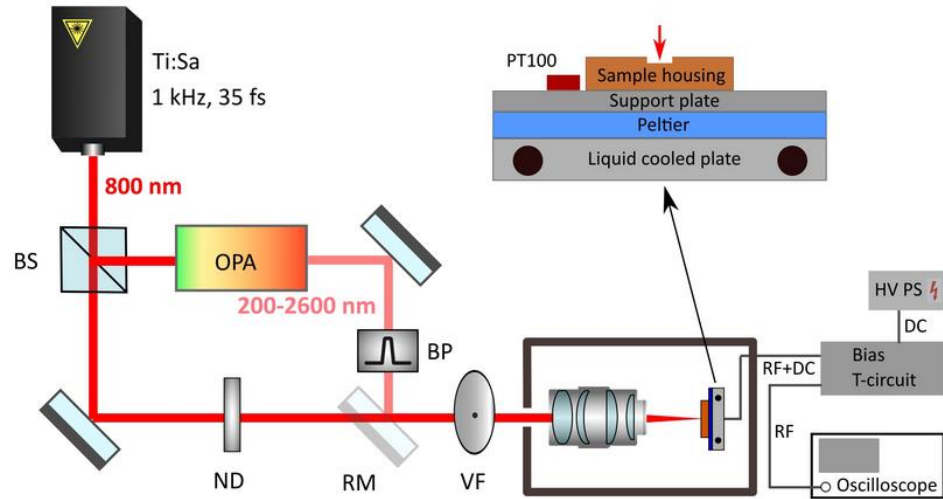
# TCT station at ELI Beamlines



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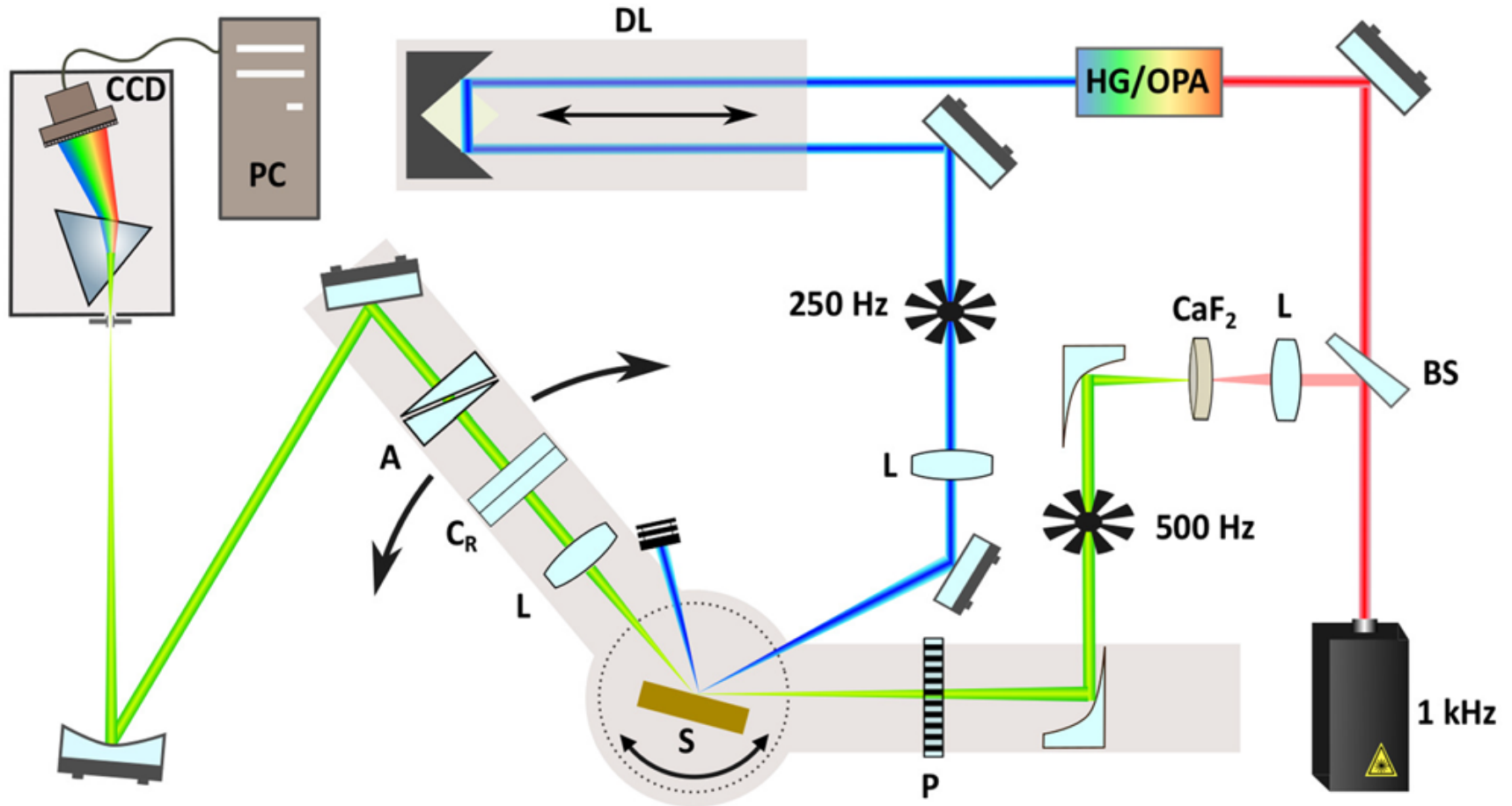


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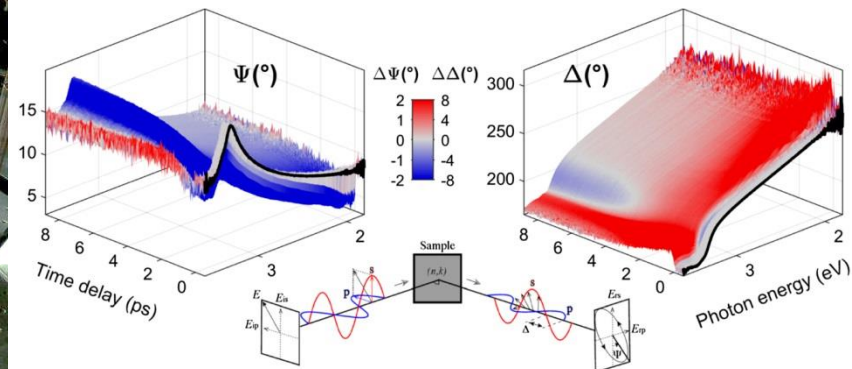
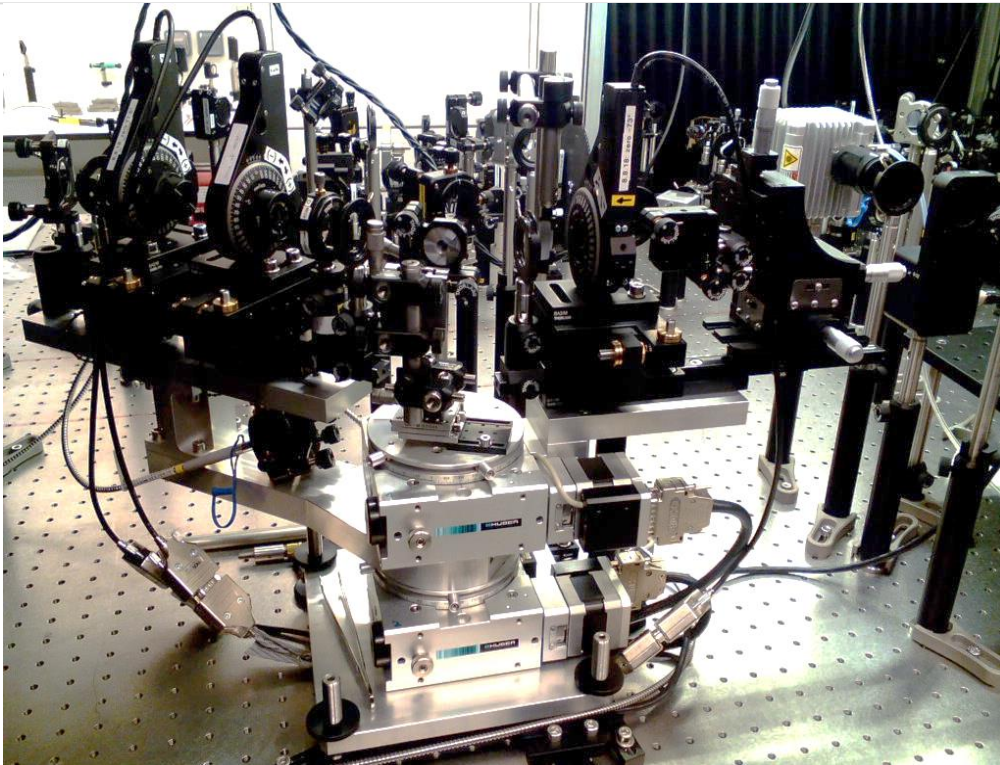




# Femtosecond Broadband Ellipsometer



# Femtosecond Broadband Ellipsometer



New J. Phys. 22 (2020) 083066

**Everything about our setup:**

Broadband femtosecond spectroscopic ellipsometry

Rev. Sci. Instrum. 92, 033104 (2021)

# Available end-stations

## Optical stations

- UV-VIS-IR Transient Absorption
- Stimulated Raman Spectroscopy
- Time-Resolved Ellipsometry
- Transient Current Technique

## Soft X-ray stations

- Electron and Ion Time of Flight
- Coherent Diffractive Imaging

## Hard X-ray stations

- Time-Resolved X-ray Diffraction
- Time-Resolved X-ray Absorption

## Others

- Laser-Plasma Electron Accelerator
- Laser-Plasma Ion Accelerator

# Access to ELI Infrastructure

## ELI ERIC is Open to the World

A user facility with three access modes

- **Excellence-Based Access** – Evaluation of proposals by international peer-review panels. *Results of experiments published and open.*
- **Mission-Based Access** – Thematic research granted on the basis of scientific missions pursuing challenges. Proposals reviewed by international panels. *Results published and open.*
- **Proprietary Access** – Paid access for industrial or other users. *Results are retained by the user,* consistent with ELI ERIC's Data and IPR Policy.



# Calls for Users

User Portal: <https://up.eli-laser.eu/>

 eli User Portal

User calls

Instruments

User guide

Terms and Conditions

Contact

My proposals



Access ELI's world-class lasers,  
instruments and facilities

Extreme Light Infrastructure provides international  
scientific teams with access to the world's most intense  
lasers

Browse instruments

Apply for beamtime

**3rd Joint Call for Users**  
**Proposal Submission Deadline:**  
**16 October 2023; 23:55 CEST !**

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 eli

 beamlines

project supported by:



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

  
MINISTRY OF EDUCATION,  
YOUTH AND SPORTS

**Thank you for your attention!**

