User opportunities at ELI-ALPS

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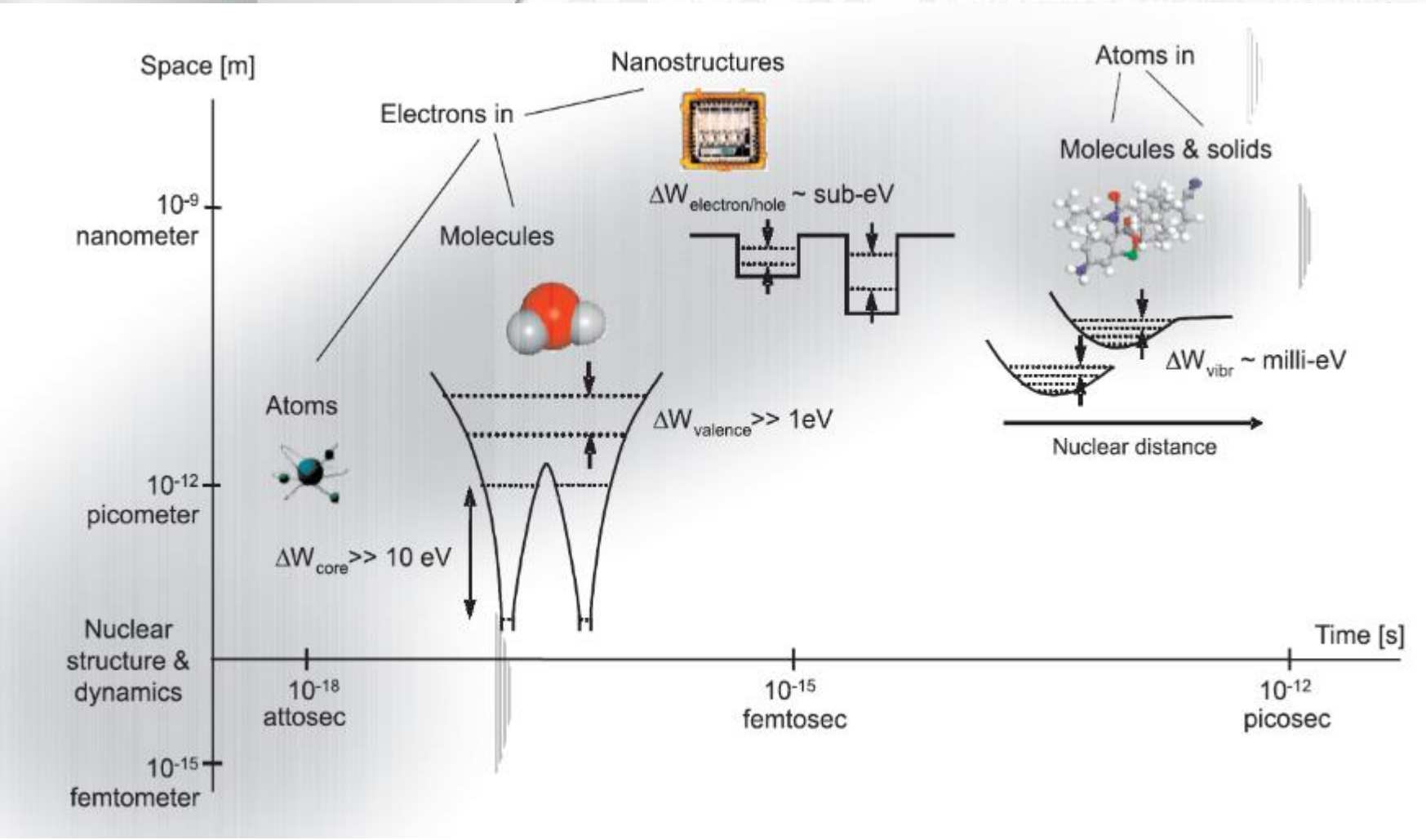
SZÉCHENYI 2020
HUNGARIAN GOVERNMENT
European Union
European Regional Development Fund
INVESTING IN YOUR FUTURE

ELI facilities as complementary pillars

Mission of ELI-ALPS in Hungary:

- to generate **femtosecond and attosecond pulses**,
- for temporal investigations of electron **dynamics in atoms, molecules, plasmas and solids**

Characteristic sizes – characteristic times



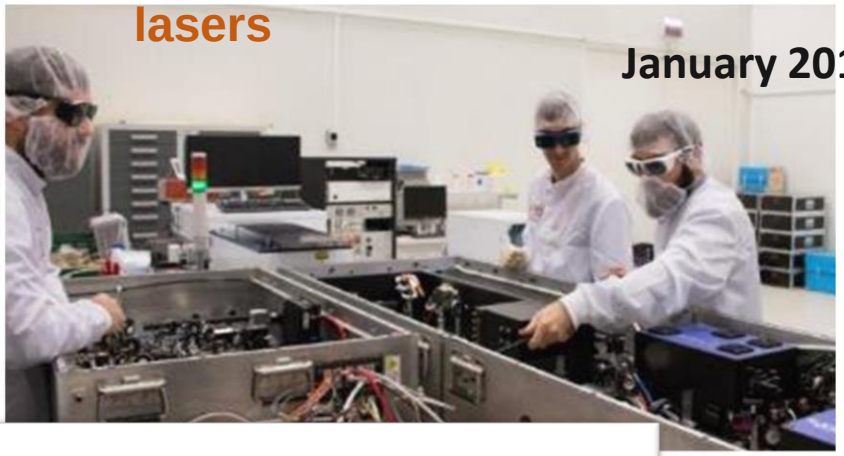
light emission

transport of biological signals

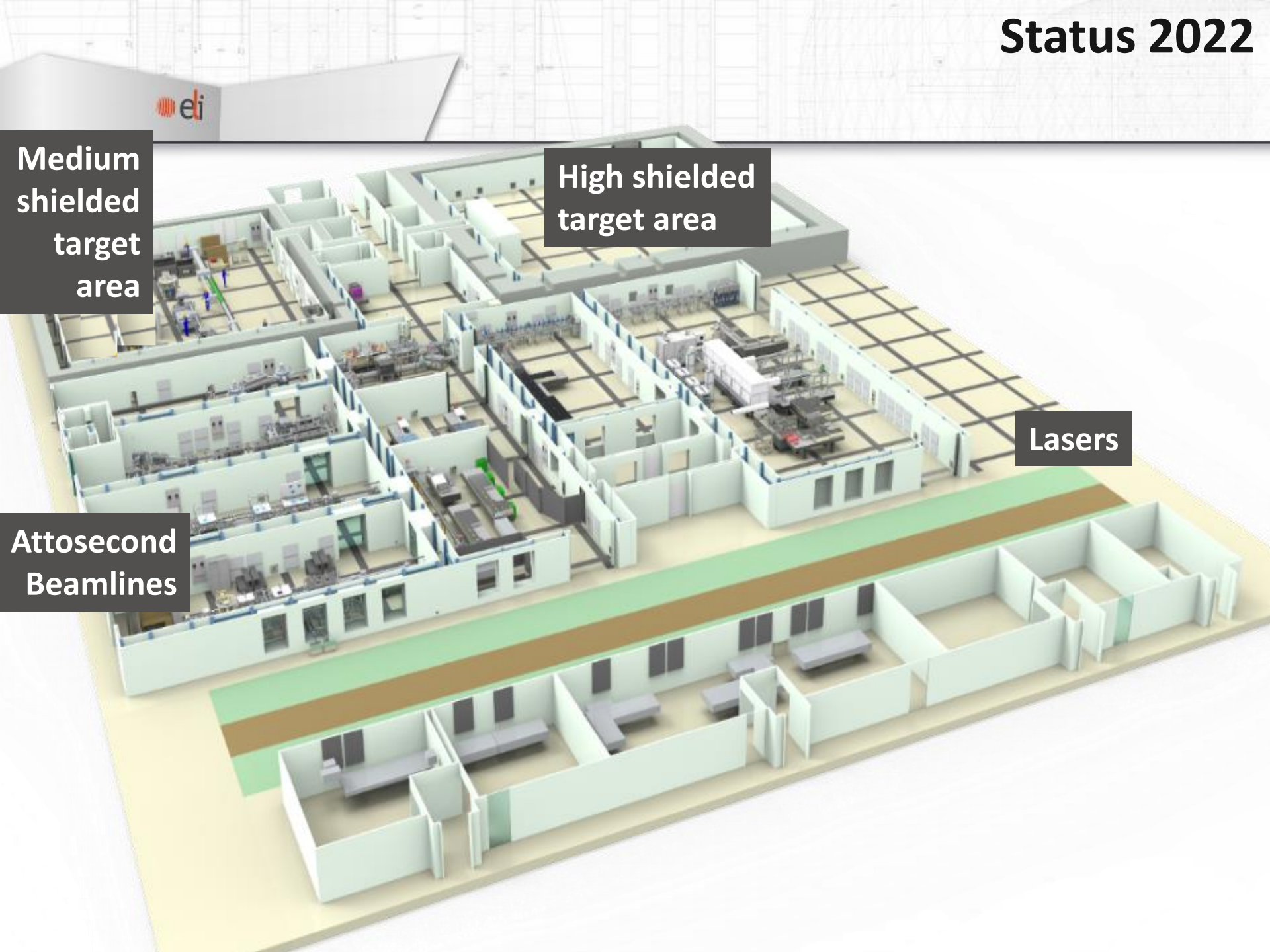
manipulation of chemical bonds / structure

informatics

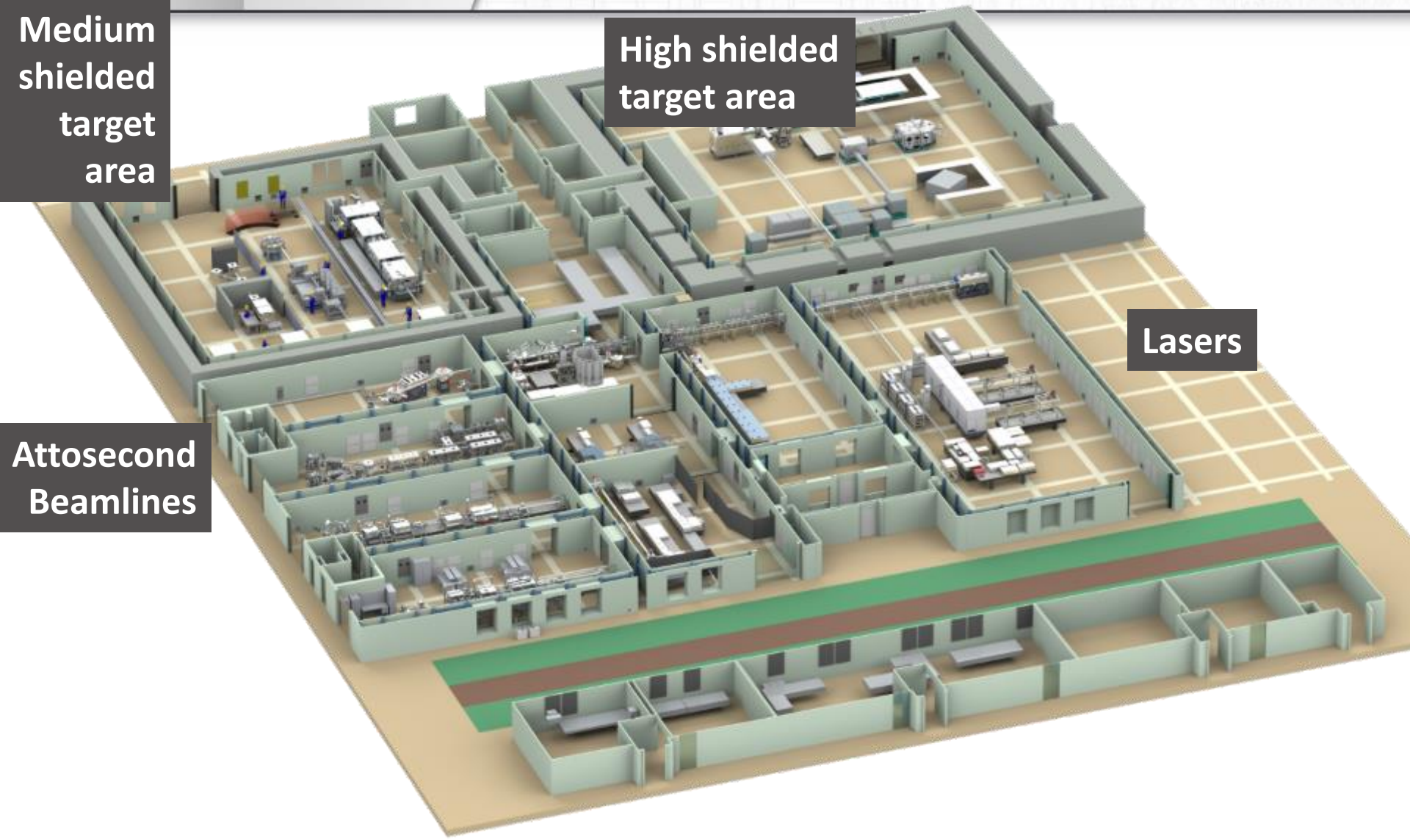
ELI-ALPS history: construction



Status 2022


Medium shielded target area
High shielded target area
Lasers
Attosecond Beamlines

To be achieved by Q4 2023



ELI-ALPS user opportunities

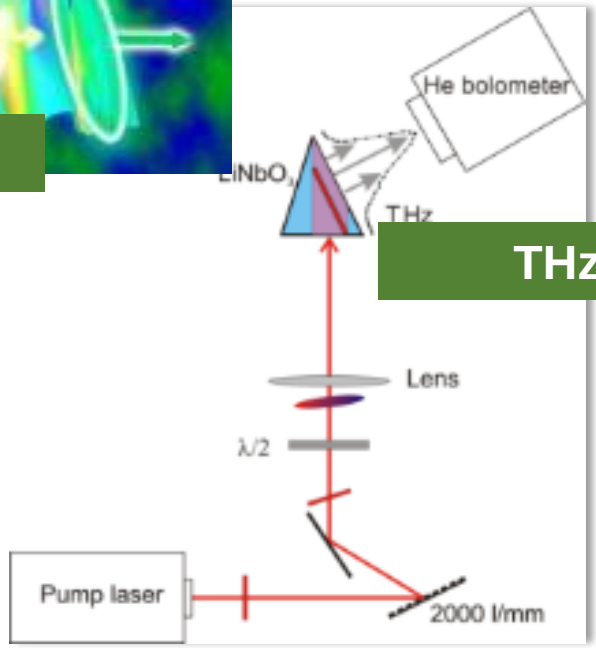
Primary sources
(laser pulses)

Secondary sources

Experiment / User stations

particles

XUV by HHG



THz

Laser parameters & status

	Parameters	Status	Operation
HR1	*100 kHz, 30 fs, 1.5 mJ* *100 kHz, <7 fs, 1 mJ*	*CEP issue unresolved*	*since Dec 2017* *since Aug 2021*
HR2	100 kHz, <6 fs, 5 mJ, CEP<200 mrad	Currently at 9 fs	by Q2 2023
MIR, 3 µm	*100 kHz, <40 fs, 0.15 mJ, CEP<100 mrad*	*Operational*	*since October 2017*
MIR-HE, 3 µm	*1 kHz, <50 fs, 20 mJ, CEP stable*	*Contracted*	*by Q2 2023*
SYLOS 2	*1 kHz, <7.5 fs, >30 mJ, CEP<250 mrad*	*Operational*	*since May 2019*
SYLOS 3	1 kHz, <8 fs, >120 mJ, CEP<250 mrad	In development	by Q4 2023
SYLOS alignment	*10 Hz, <12 fs, >40 mJ, ~850 nm*	*Operational*	*since Jan 2019*
HF PW	10 Hz, <17 fs, 34 J (2.5 Hz, 25 fs, 7 J)	Installation	by 2025 (2023)
THz Pump	*1 kHz, 100 fs, 4 mJ* *50 Hz, <0.5 ps, 0.5 J, synchronized*	*Installed*	*since Jun 2021*

ELI-ALPS Secondary Sources

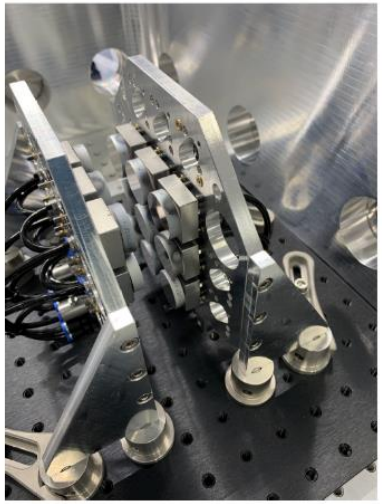
Secondary Source	Specs Achieved	Status	Date for user access
GHHG HR1 & 2 GAS (LTA4)	*>270 pJ @ generation, >50 pJ on target; 166 as; @100 kHz; 30-70 eV*	train of atto pulses, CEP of driver not resolved	**Available to users** with HR1 Q2 2023 (HR2)
GHHG HR1 & 2 CONDENSED (LTA3)	*current status 170 pJ @ generation XUV monochromator installed*	train of atto pulses XUV mono resolution 100-400 meV	**Available to users** with HR1 Q2 2023 (HR2)
GHHG SYLOS COMPACT (LTA2)	*400 nJ @ generation in Ar, ~1 µJ in Xe*	2-photon XUV process observed pol gating in development setting up Flagship proj	**Available to users** Q4 2022
GHHG SYLOS LONG (LTA1)	*400 nJ @ generation in Ar, ~1 µJ in Xe*	in commissioning (XUV flux studies)	by Q1 2023
SHHG SYLOS (MTA)		Under construction on site	by Q3 2023
SHHG PW (HTA)		Under construction on site	by Q3 2023
MIR HE GEN ATTO		Under development	by Q3 2023
NLTSF / THz SPECTROSCOPY (THz)	*energy: 10 µJ at source, 5 µJ at sample useful spectral content: 0.15-2 THz peak THz field at sample: ≥450 kV/cm*	recommissioned in new lab, pump-probe schemes THz – THz – white light – green	**Available to users**
THz HIGH ENERGY (THz)	*energy ~ 1 mJ, @50 Hz useful spectral content 0,15 – 1,5 THz*	pump-probe schemes in development	**Available to users**
ELECTRON- SYLOS (MTA)		Under construction on site	by Q3 2023
ELECTRON PW (HTA)		Under development	by Q4 2023

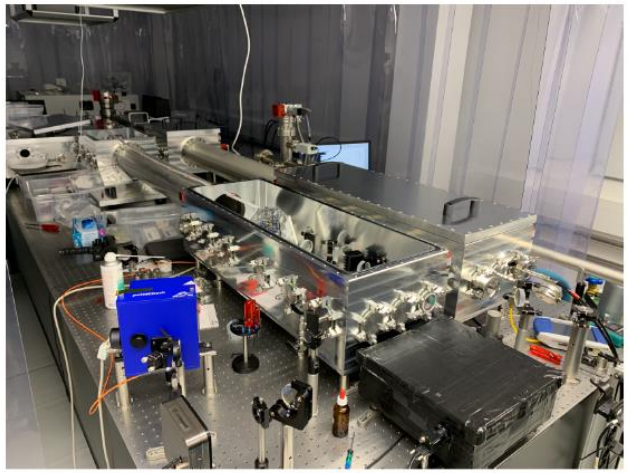
100 kHz laser systems

- fiber laser technology
- double MPC concept for postcompression to <7fs

S. Haedrich et al., Optics Letters **47**, 1537 (2022)

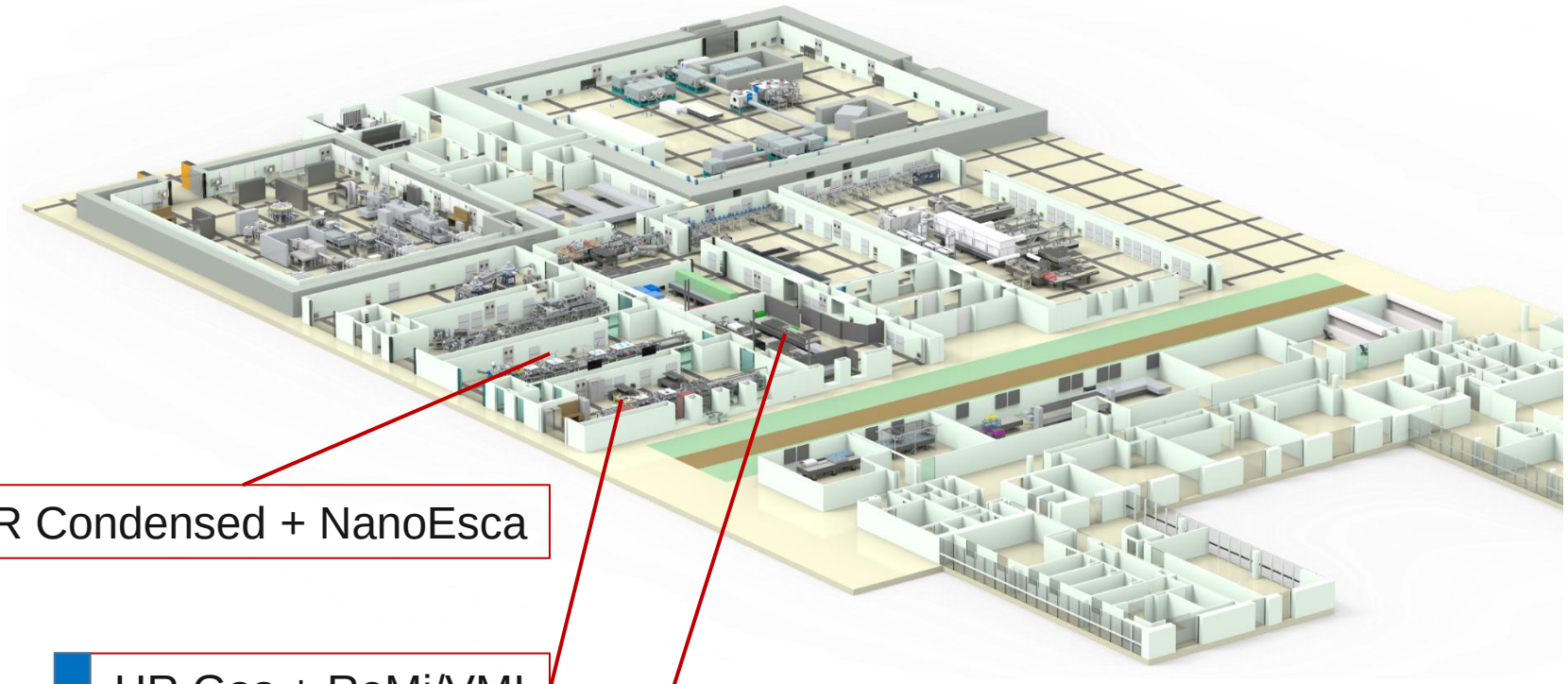
activefiber systems





	Parameters	Status	User readiness
HR1	***100 kHz, 40 fs, 1.5 mJ*** ***100 kHz, <7 fs, 1 mJ, CEP***	***Operational***	***since Dec 2017*** ***Aug 2021***
HR2	100 kHz, <6 fs, 5 mJ, CEP	In development	by Q3 2023

HR (100 kHz) beamlines and instruments



HR Condensed + NanoEsca

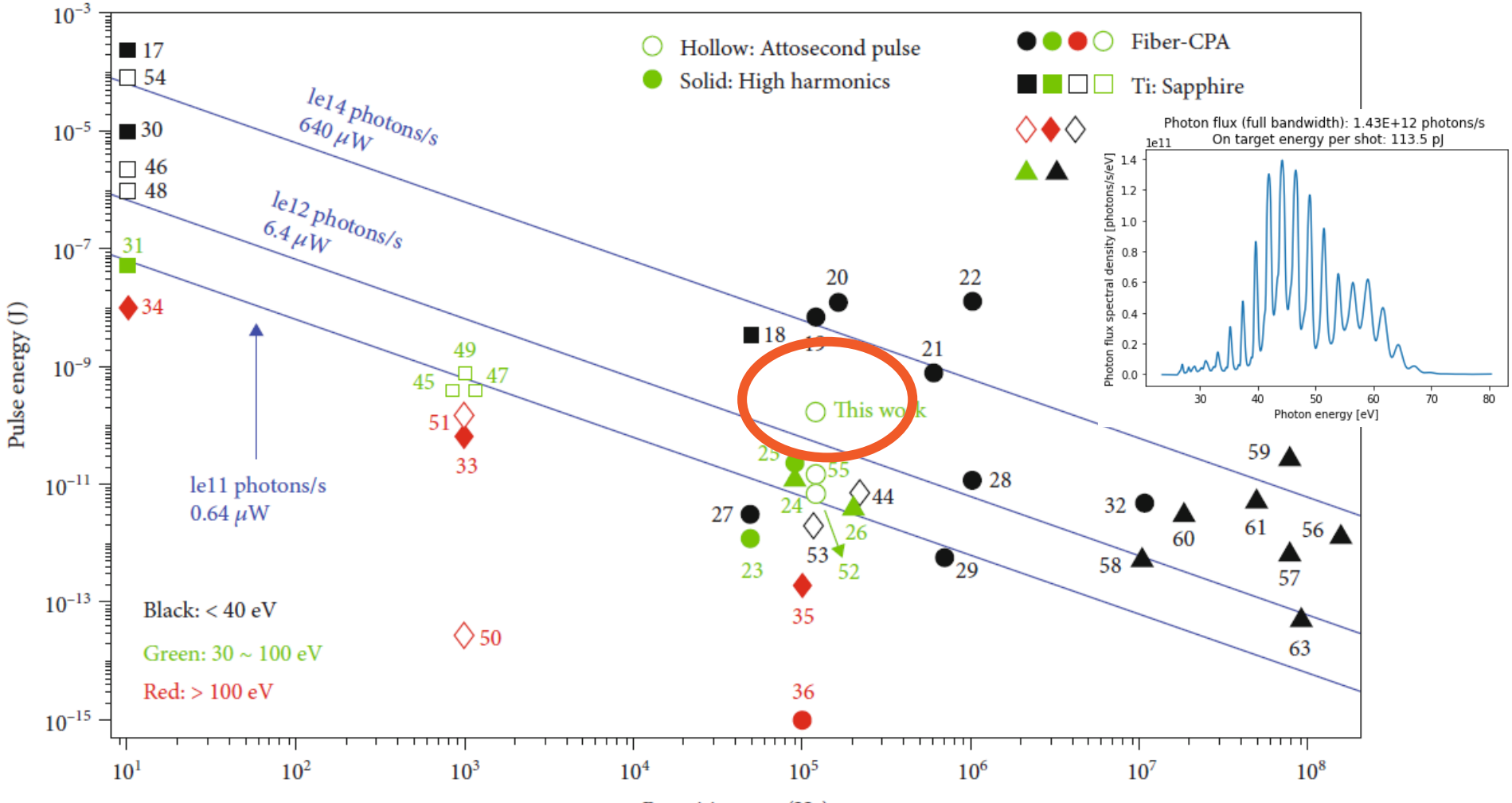
HR Gas + ReMi/VMI

HR1&HR2
100 kHz, 7 fs, 1 mJ
100 kHz, 7 fs, 5 mJ

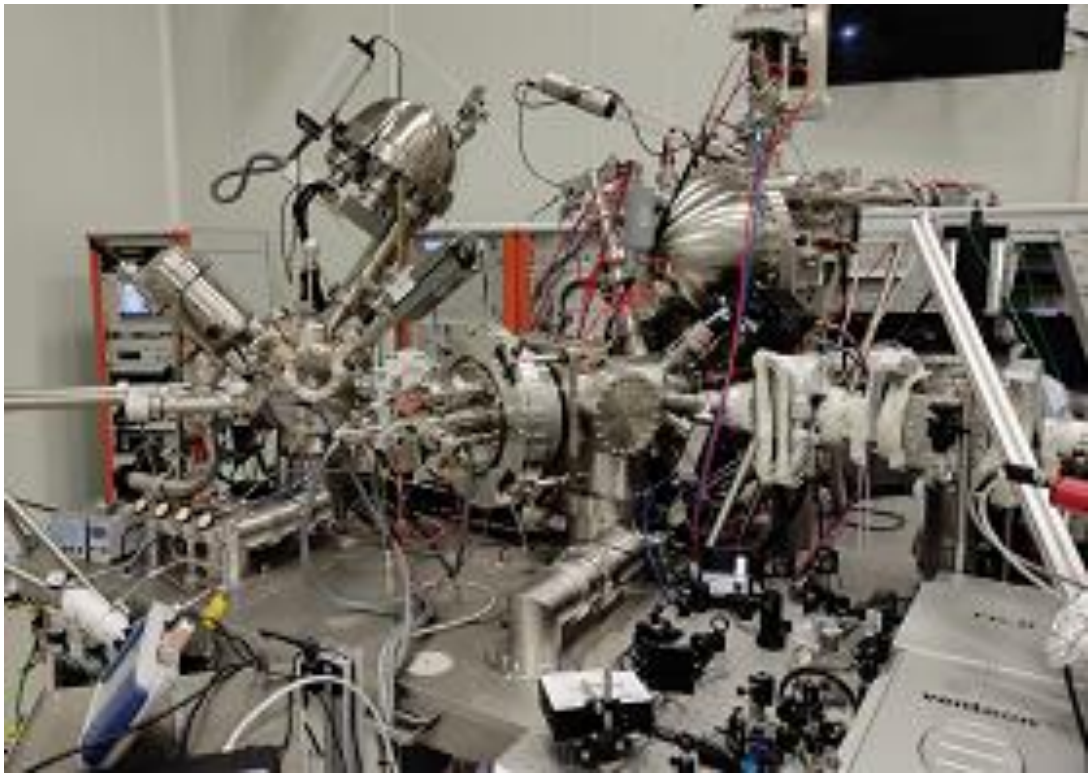
High harmonics @ 100 kHz
Performance

Highest flux, temporally characterized attosecond pump-probe beamline running at 100 kHz

- **~20%** transmission from generation to target
- **>100 pJ** APT on target (**~500 pJ** at generation), 30-70 eV, with XUV monochromator



The NanoESCA end-station



Light sources:

Internal (CW) sources:

- Hg arc lamp (5.2 eV – 238 nm)
- **He VUV lamp** (He I mode: 21.22 eV – 58 nm; He II mode: 40.81 eV – 30 nm)

Short pulsed sources:

- Venteon CEP5 oscillator

(6 fs, 830 nm)

GHHG coming up, 20-90 eV, time-resolved

Modes:

PEEM: Photoemission electron microscope (35 nm res.)

ToF-PEEM: Time of flight + DLD analyzer (delay line detector)

Spectroscopy of selected area: Channeltron detector after first hemisphere (20 meV res.)

k-space imaging of band structure: ESCA mode (0.03 Å-1 res.)

Imaging spin filter: spin selective mirror: gold coated Ir(100) crystal

eli attosecond

NanoESCA prep chamber

Cleaning: (sample cleaning)
- Ar^+ ion sputtering
- Annealing (heat- and coolable manipulator)

Preparation:
- **e-beam evaporator** for metal deposition
- **gas dozer** based on a capillary array (adsorption of vapourable liquids)
- **magnetizer**
  - Helmholtz coil
  - B field: up to 43 mT

Characterization (laterally averaged):
- **LEED-AES** (Low Energy Electron Diffraction – Auger Electron Spectroscopy): determination of surface structure and composition

- **XPS** (X-ray photoelectron spectroscopy):
  - quantitative chemical analysis of the surface
  - **monochromatic** Al K_α X-ray source @ max. 300 W
  - 128 detection channels

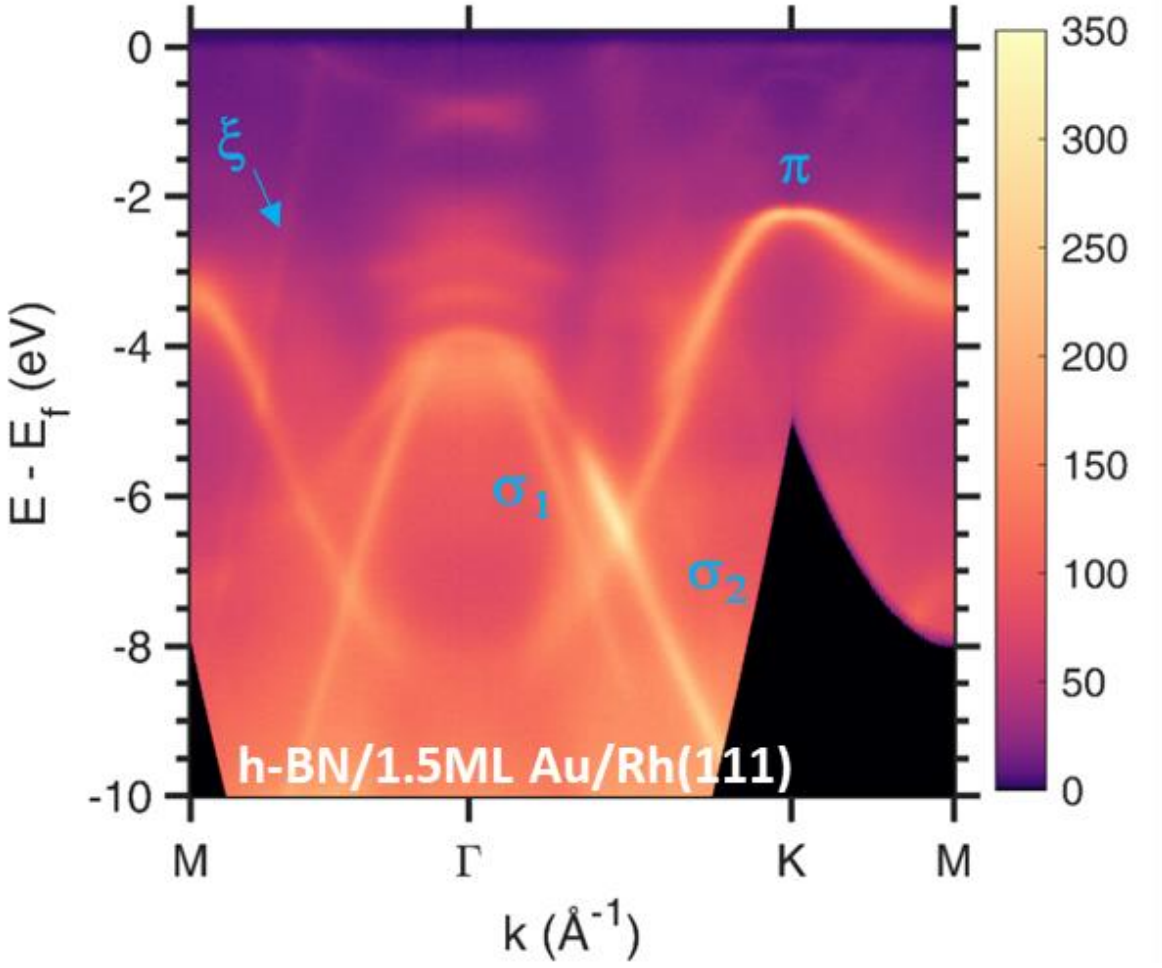
- **RGA** (Residual Gas Analyzer) by quadrupole mass spectrometer

Nano ESCA spin-filter

Fig. 6 Demonstration of the spin contrast on a polycrystalline iron sample in real space mode (FOV 130 µm).

attosecond

The surface band structure of 2D hexagonal boron nitride on Au/Rh(111) surface alloy



Nonlinear THz Spectroscopy Facility (NLTSF)

NLTSF Parameters					
Pump THz pulse parameters		**Electro-optic sampling**		**Sample parameters**	
Pulse energy	10 μJ at source 5 μJ at sample position	Spectral resolution	50 GHz	Minimum sample clear aperture	2 mm
Spectral maximum	0.5 THz	Useful spectral coverage	0.1-2.5 THz	Temperature range	6 K – 800 K
Useful spectral coverage	0.1-2.5 THz	S/N ratio (depends on measurement time)	>300:1	Measurement modes	❑ THz transmission ❑ THz pump - THz probe ❑ Optical pump - THz probe ❑ Optical pump - THz control - white light probe (in development)
Energy stability	< 2% RMS				
Peak THz field	450 kV/cm				

NLTSF - results

Ultrafast carrier dynamics in n – doped germanium

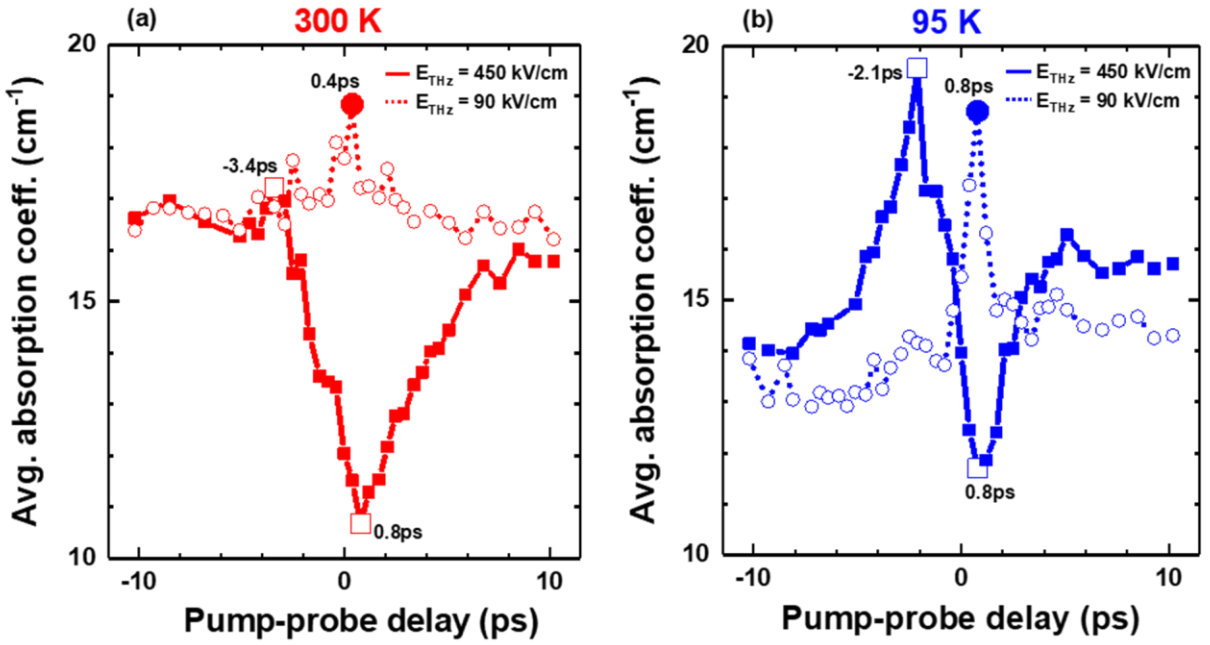


Fig. 5. (a), (b) Spectrally averaged free carrier absorption with respect to pump - probe delay

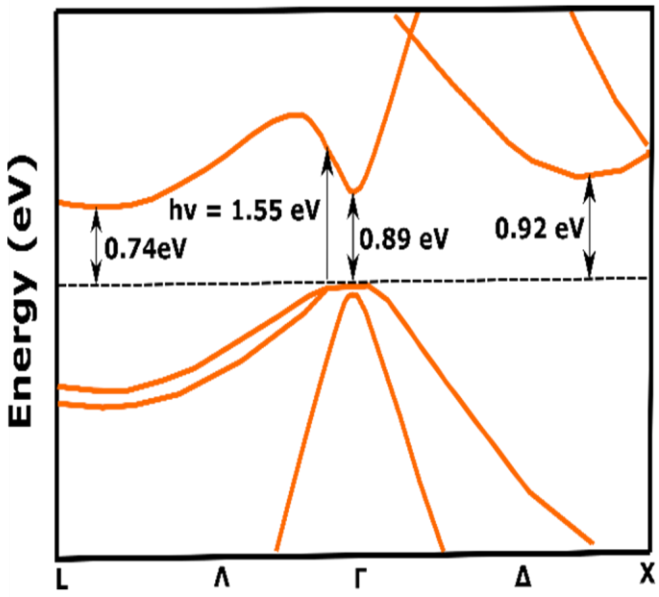


Fig. 6. Schematic band structure of germanium [3

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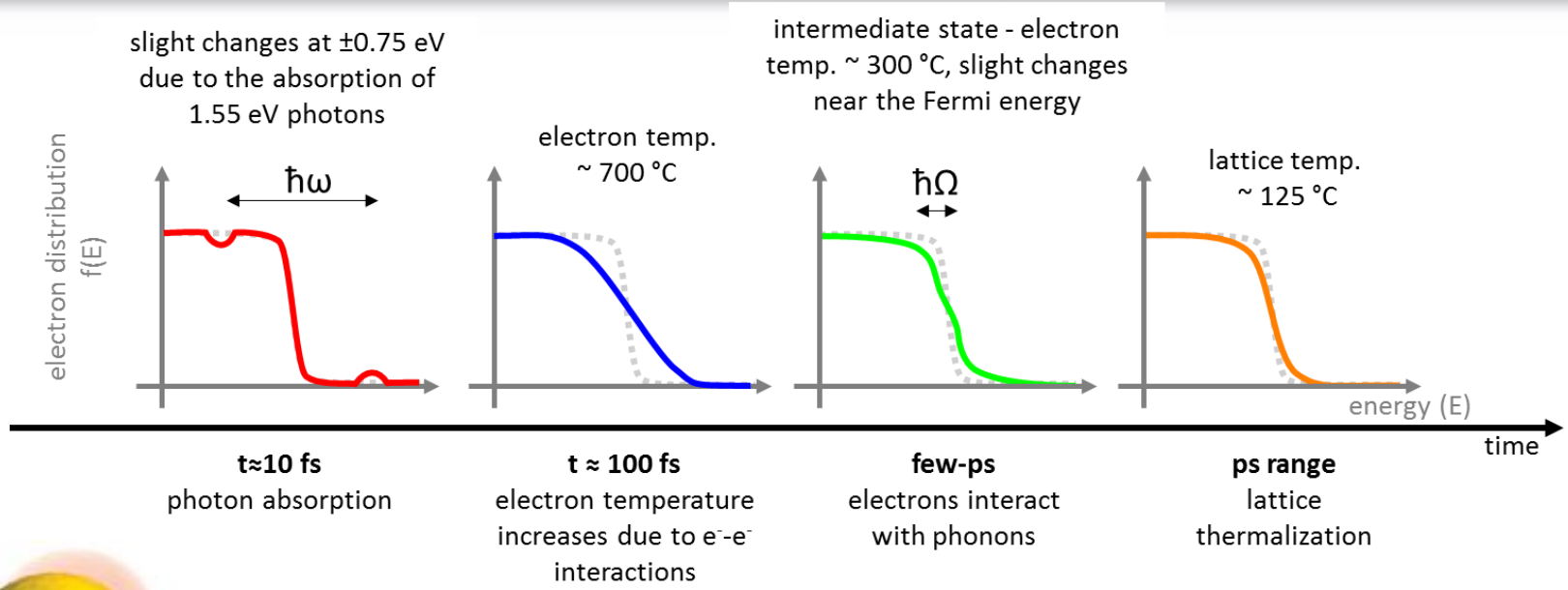
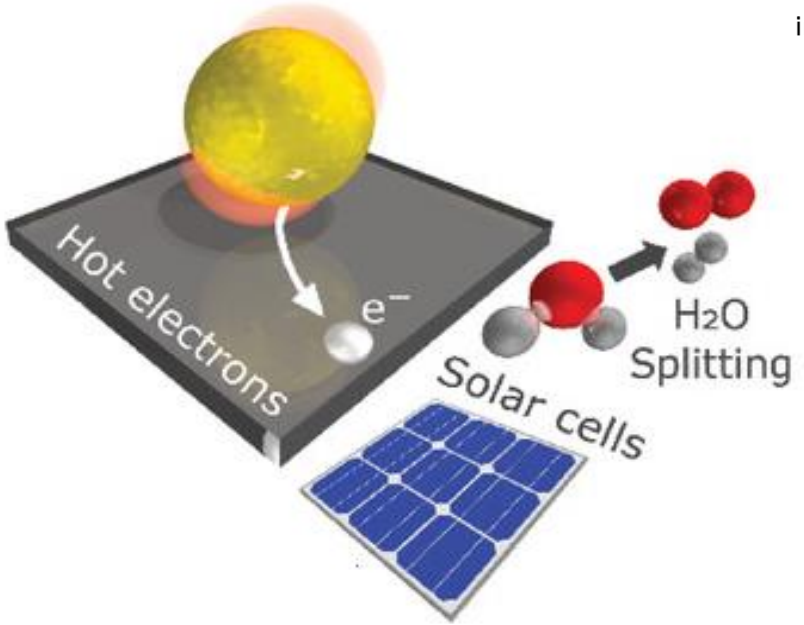
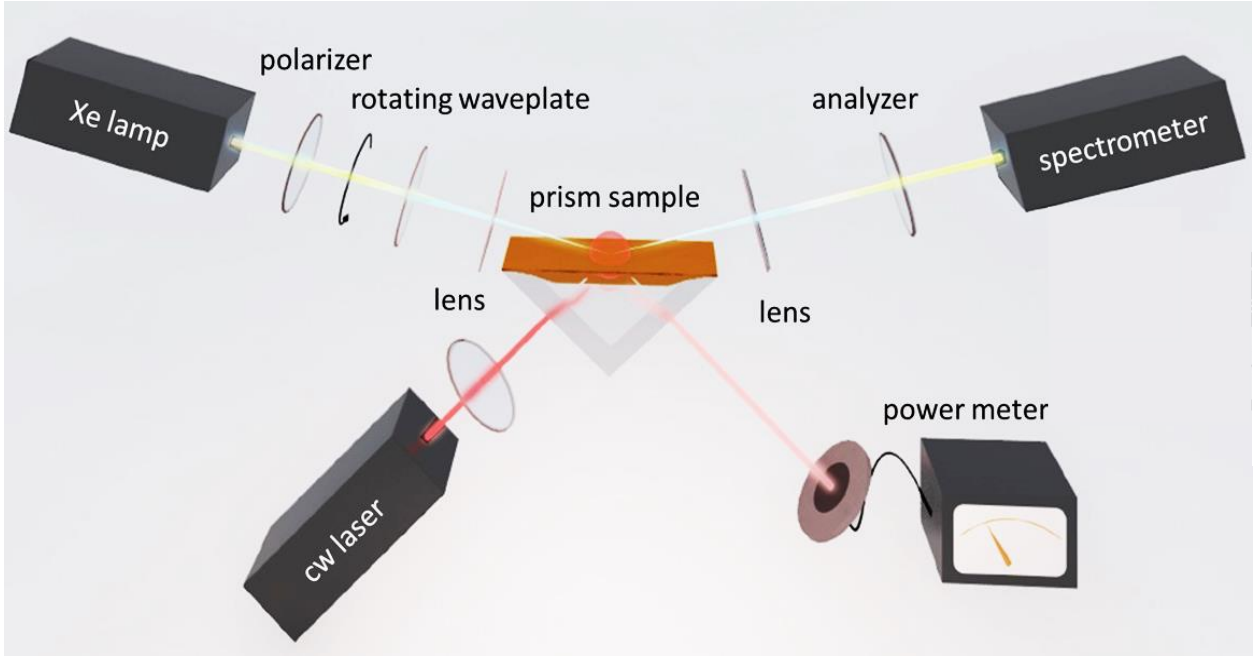
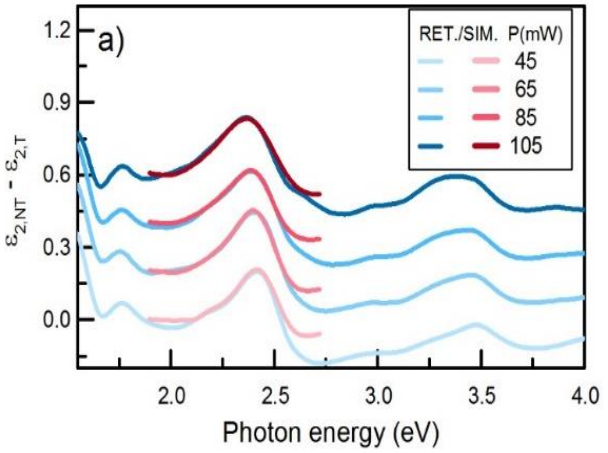
Ultrasensitive probing of plasmonic hot electron occupancies

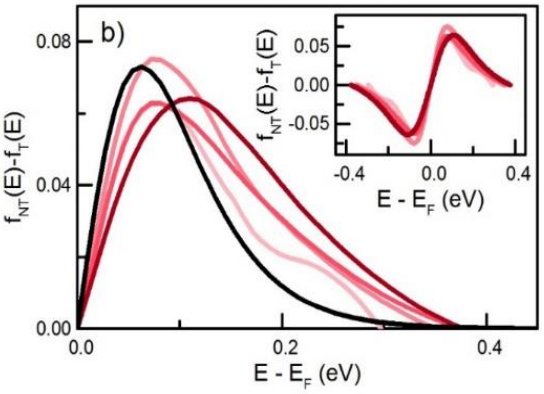


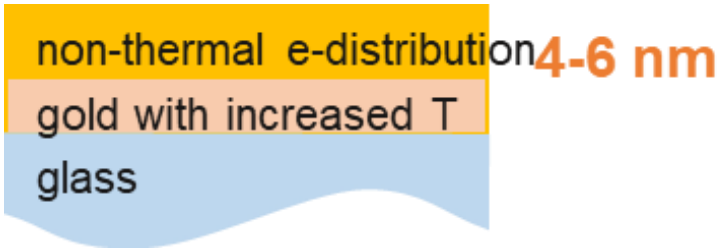


Ultrasensitive probing of plasmonic hot electron occupancies







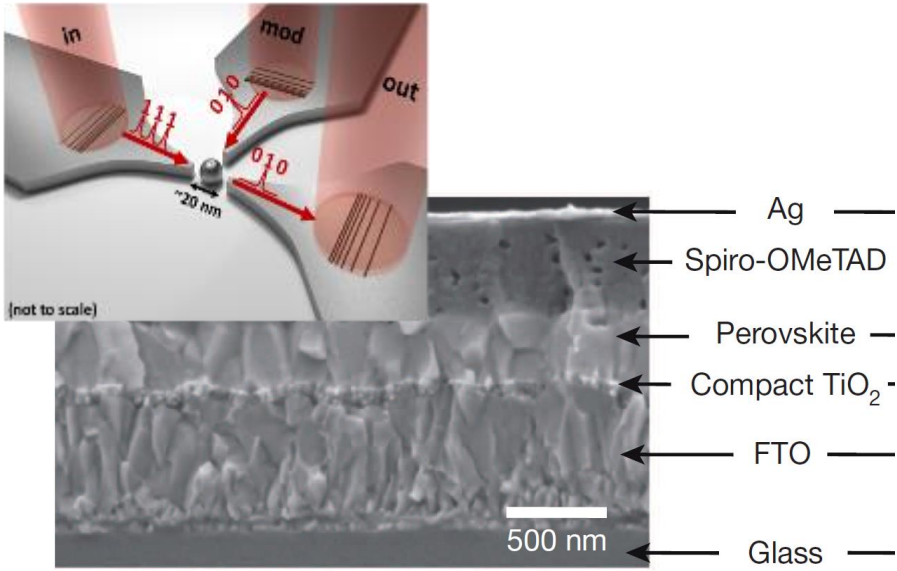


J. Budai, Z. Pápa, P. Petrik & P. Dombi: Nature Comm. 13, 6695 (2022)

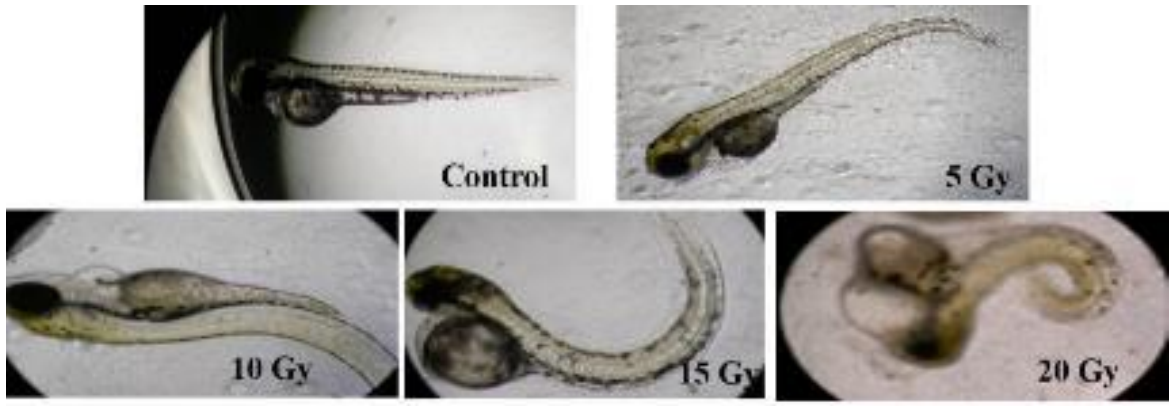
In-house user services

Optical workshop / custom coatings (incl. advanced metrology)

Nanofabrication EBL+FIB

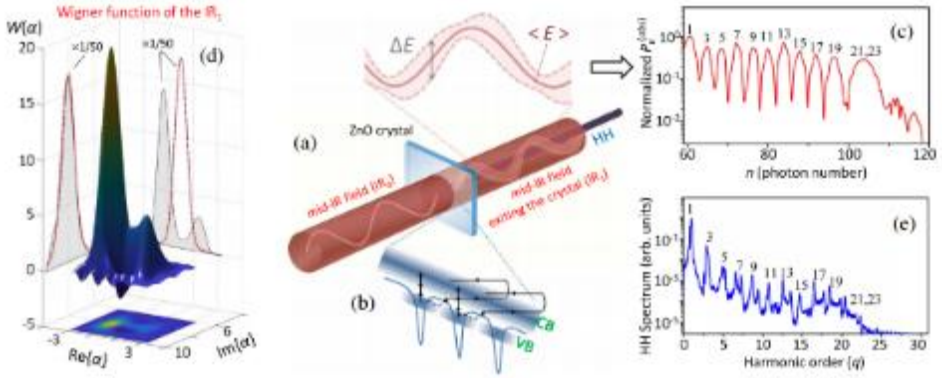


(Radio)biology lab



ELI-ALPS
facts and figures

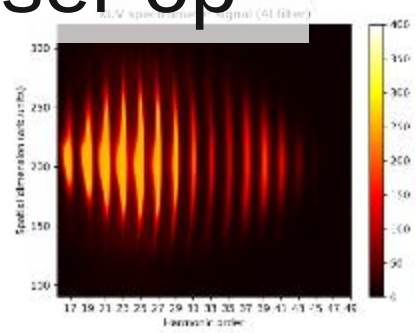
5 of 9 lasers
user operational



first attosecond pulses generated

7 user papers published

3 of 9 secondary
sources user op



25 completed
collaborative user
campaigns
3000+ user hours

ELI-ERIC User Calls & Research Technology Information

www.eli-alps.hu

www.eli-laser.eu

user ready
by Q2 2023
by Q4 2023

Experimental stations implementation status

Experimental Stations	Status	Date for user access
REACTION MICROSCOPE / COLTRIMS	*installed on HR GHHG*	*available to users*
VMI SPECTROMETER ENDSTATION	*tested on HR GHHG, adaptation to MIR ongoing*	*available to users*
CONDENSED MATTER STATION (NANOESCA)	*internal VUV source, CEP stable oscillator, HR GHHG source*	*available to users*
MAGNETIC BOTTLE e SPECTROMETER (IMPULSE) – *collab FORTH*	*under development*	*Q1 2024*
NANOSCIENCE & NANOFABRICATION	*electron beam lito + focused ion beam*	*available to users*
NANOSCIENCE: time resolved ELLIPSOMETRY	*under internal development*	*Q3 2023*
NANOSCIENCE: Scanning Nearfield Microscope	*under procurement*	*Q3 2023*
CHEMICAL REACTION CONTROL STATIONS (GPRC; TAS)	*transient absorption setup for condensed samples on HR, gas phase reaction control on SYLOS*	*available to users*
RADIOBIOLOGY / BIOMEDICAL LAB	*standard biology toolset* *zebrafish embryo test model for radiobio studies* *Radiobiology toolset (irradiator, dosimetry setup)*	*available to users*
eSYLOS IRRADIATION FACILITY (for biol, *chem, phys samples, dosimetry*)	*under internal development*	*Q3 2023*
eSYLOS X-RAY GENERATOR	*under internal development*	*Q3 2023*
HIGH FIELD PHYSICS STATION (PW)	*under internal development*	*Q3 2023*
THz PUMP – XUV PROBE	*under internal development*	*Q2 2023*