League of European Accelerator-based Photon Sources

Coherent and cost-effective multi-THz superradiant light source for standalone and THz pump-FEL probe experiments, compatible with high-repetition rates.

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Driven by user requirements

- Requirements come from diverse areas of applications
- Ultrafast phenomena in condensed matter
  – New materials: low-dimensional, high T_c superconductors, “THz transistors”, …
  – Exotic phases and phase transitions; electronic and lattice
  – Spin dynamics
- Chemistry / Physical-Chemistry
  – Control and triggering of chemical reactions / electronics distributions
  – Catalysis
- Biology
  – Cellular mechanisms in high E-fields
- In the context of pump-probe experiments // Probes: X-ray, VUV, IR-Vis, UED

From - User workshops, science cases, white papers, in person discussions …

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Summary

- Accelerator-based THz-IR sources are well established within the FEL user community
  – Standalone IR-THz FEL facilities
  – Pump-probe experiments at short-wavelength FELs

- The user communities present a challenging set of requirements for future experiments
  – pulse energies: increase by few 100 (few 100 µJ/pulse are needed)
  – frequency range: extension to 30 THz (10 µm)
  – broadband (single-cycle) and narrowband (few %) are required
  – repetition rate: to match short-wavelength FELs, or 100 kHz – 1 MHz CW sources

- In many cases, to provide the required performance improvements, new techniques or radiation source schemes are needed

- **Use of longitudinally modulated beams and better bunch compressors to increase the longitudinal brightness by a few orders of magnitude**

$$I_{coherent}(\omega) \approx I_{e-}(\omega) \cdot N_e^2 \cdot |\mathrm{b}(\omega)|^2$$

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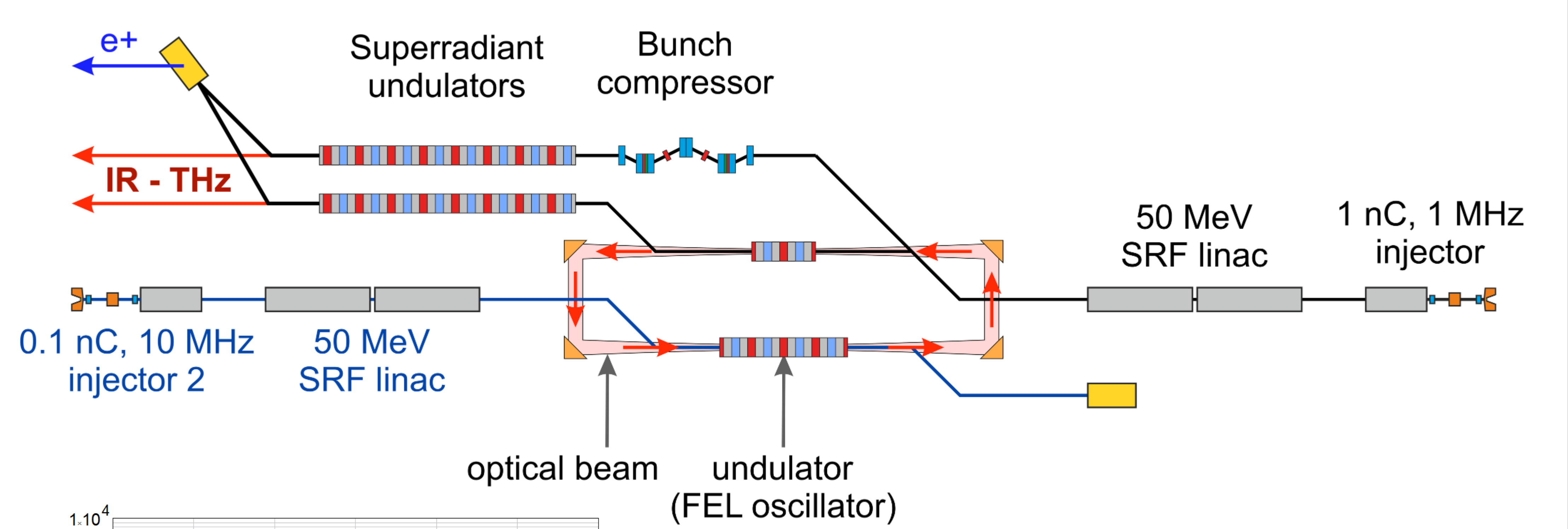
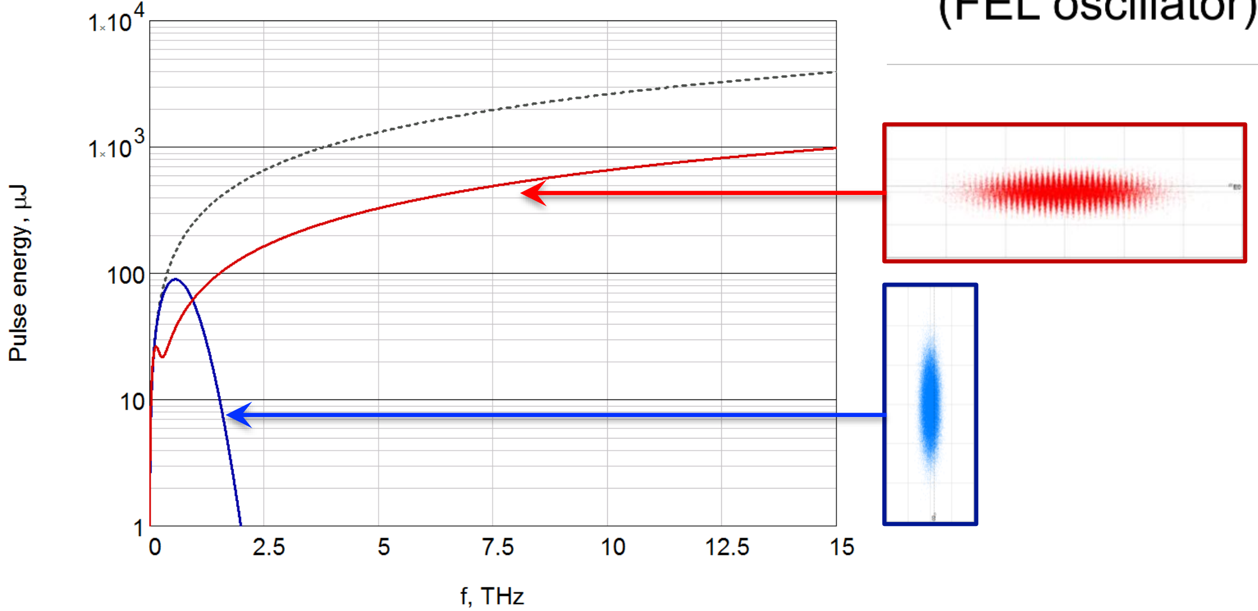
New IR-THz Source Architecture





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Work Breakdown Structure, Org.

Work packages (tentative)

- Corrugated structures for e-modulation at GeV beam energies
- 2nd order magnetic bunch compressor: high $Q_{b,}$ E_b few 10 MeV
- Optimized dispersions sections for converting e-modulation to density-modulation

3 execution phases for each WP

- Physics design: modeling, simulations, etc.
- Engineering design, construction of prototypes
- Beam tests at existing facilities

Participating institutions

- Elettra Sincrotrone (FERMI)
- ELBE, Helmholtz-Zentrum Dresden-Rossendorf (HZDR)
- MAX-IV
- DESY (PITZ)

Elettra Sincrotrone Trieste

HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

DESY.

MAX IV

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Backup

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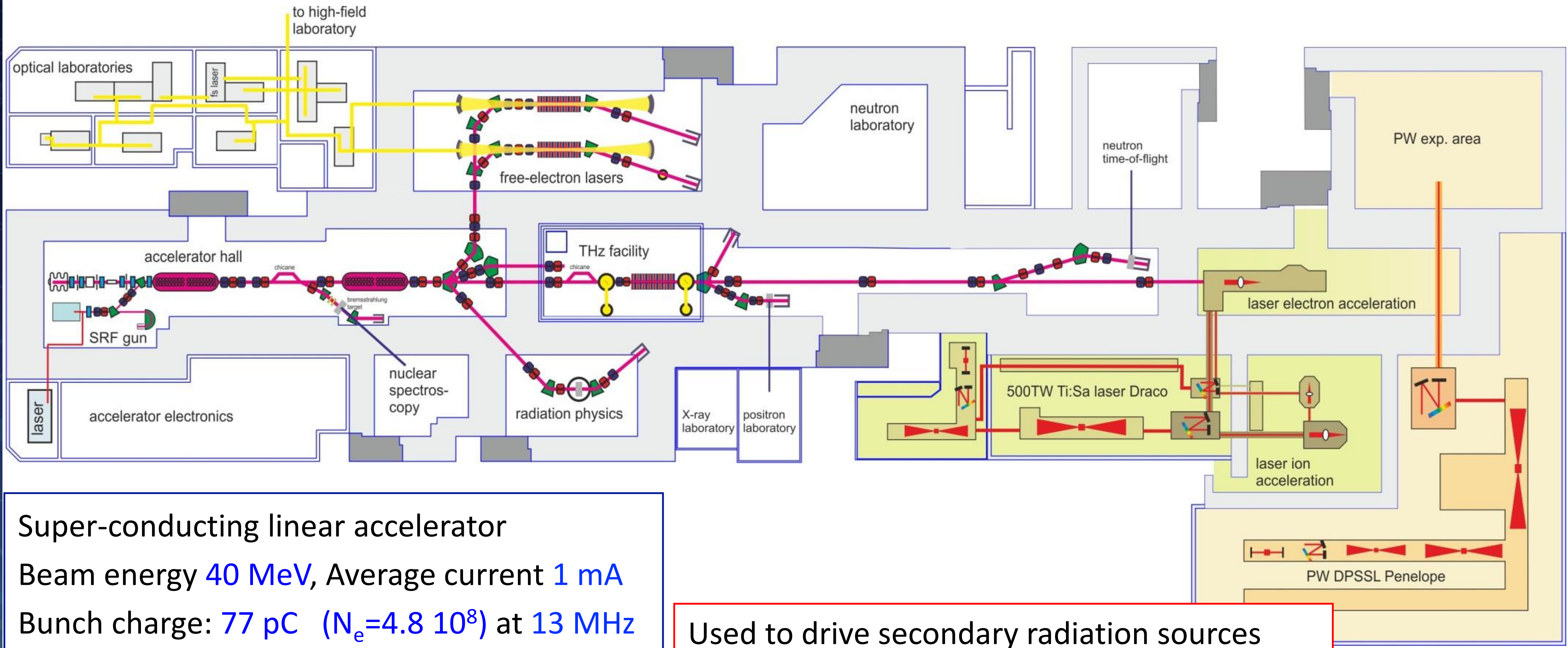
Radiation Source ELBE - user facility @ HZDR



Super-conducting linear accelerator

Beam energy 40 MeV, Average current 1 mA

Bunch charge: 77 pC (N$_e$=4.8 10^8) at 13 MHz

250 pC (N$_e$=1.6 10^9) at 250 kHz

User operations:

- 95.4 % reliability: (used/scheduled)
- 70 % external users
- 6000 hours/year

Used to drive secondary radiation sources

2 free-electron laser (FEL) oscillators: **MIR**, **FIR**

Super-radiant undulator, CDR: **THz**

Positron Source: **e^+**

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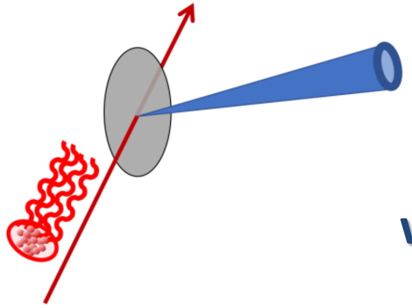
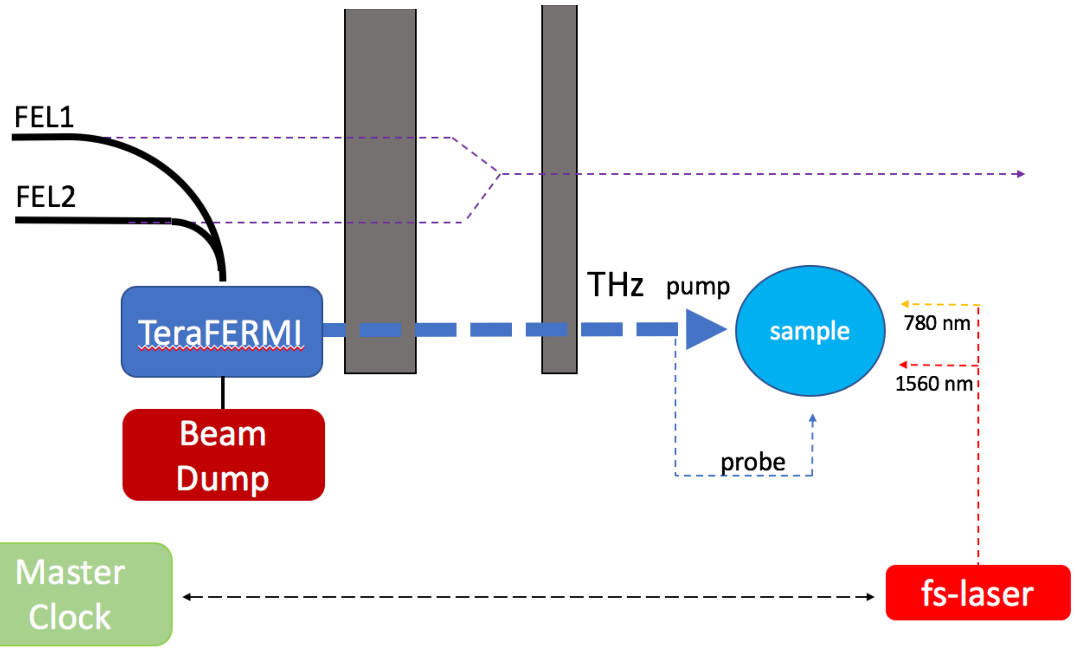
TeraFERMI at FERMI@Elettra

Coherent Transition Radiation occurs when relativistic electrons cross the boundary between two media of different dielectric constant:



ultra-short, high-power broadband THz pulses with 100 fs-electron structures.



	Measured parameters
Wavelength range	0.3 mm – 20 mm 0.1 – 15 THz
THz pulse energy	100 μJ @ source 40 μJ @ sample
Spot size at focus	400 μm
Peak Field	<MV/cm
e-beam operation	0.9-1.8 GeV (FEL1/FEL2)
Rep. rate	50 Hz

Available set-ups

- Michelson interferometer
- EOS sampling
- THz pump - NIR probe (780 and 1560 nm)
- THz pump – Kerr rotation
- THz pump – THz probe

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