Terahertz Radiation: Multidisciplinary uses

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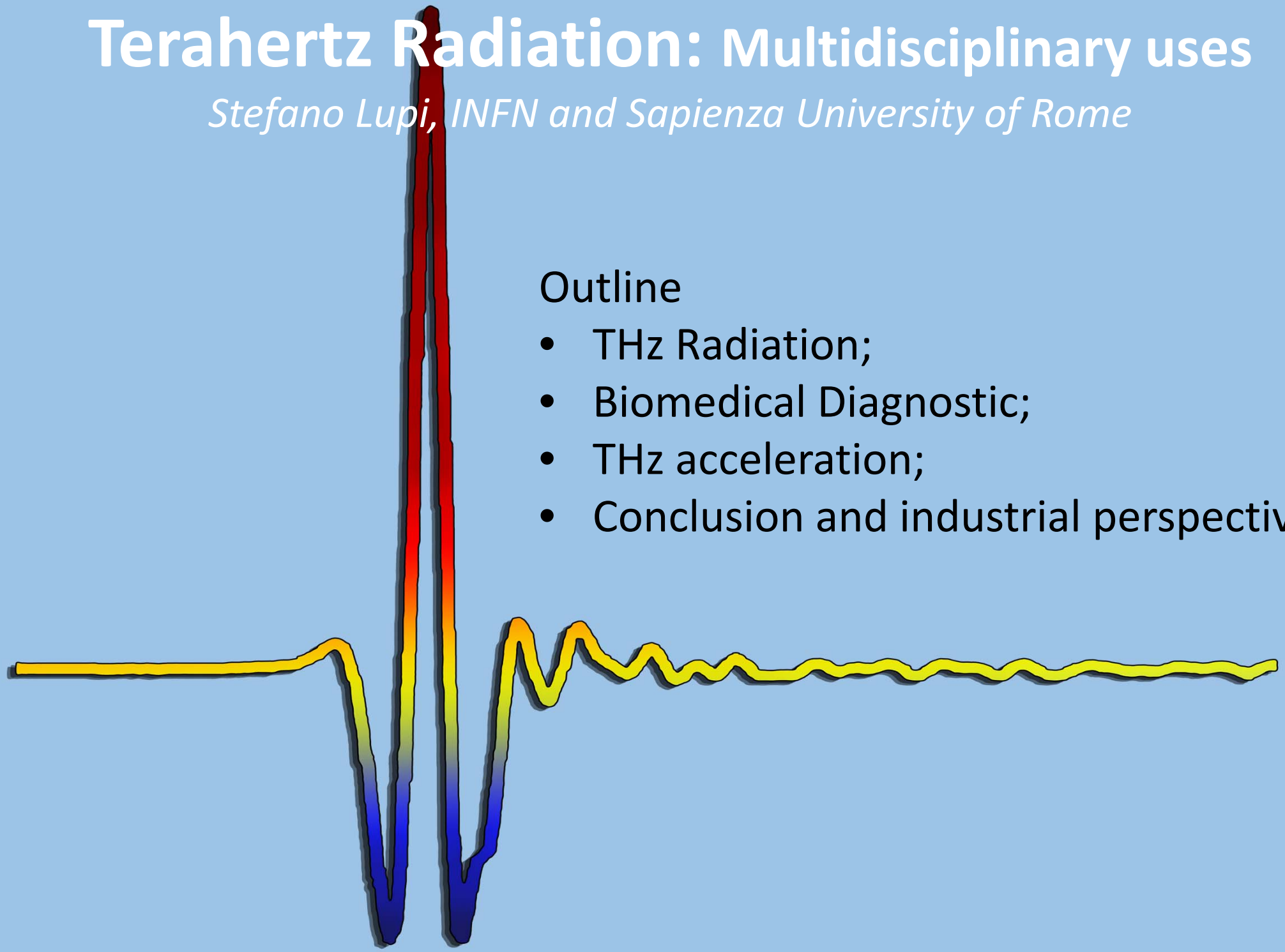
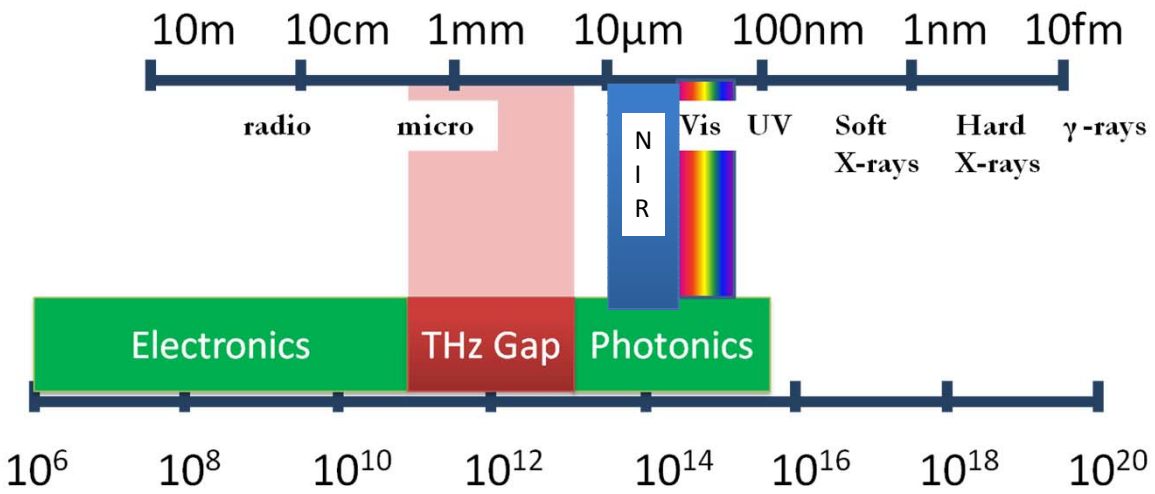


Outline

- THz Radiation;
- Biomedical Diagnostic;
- THz acceleration;
- Conclusion and industrial perspective;

Terahertz Light



THz

Frequency: 0.1 – 10 THz

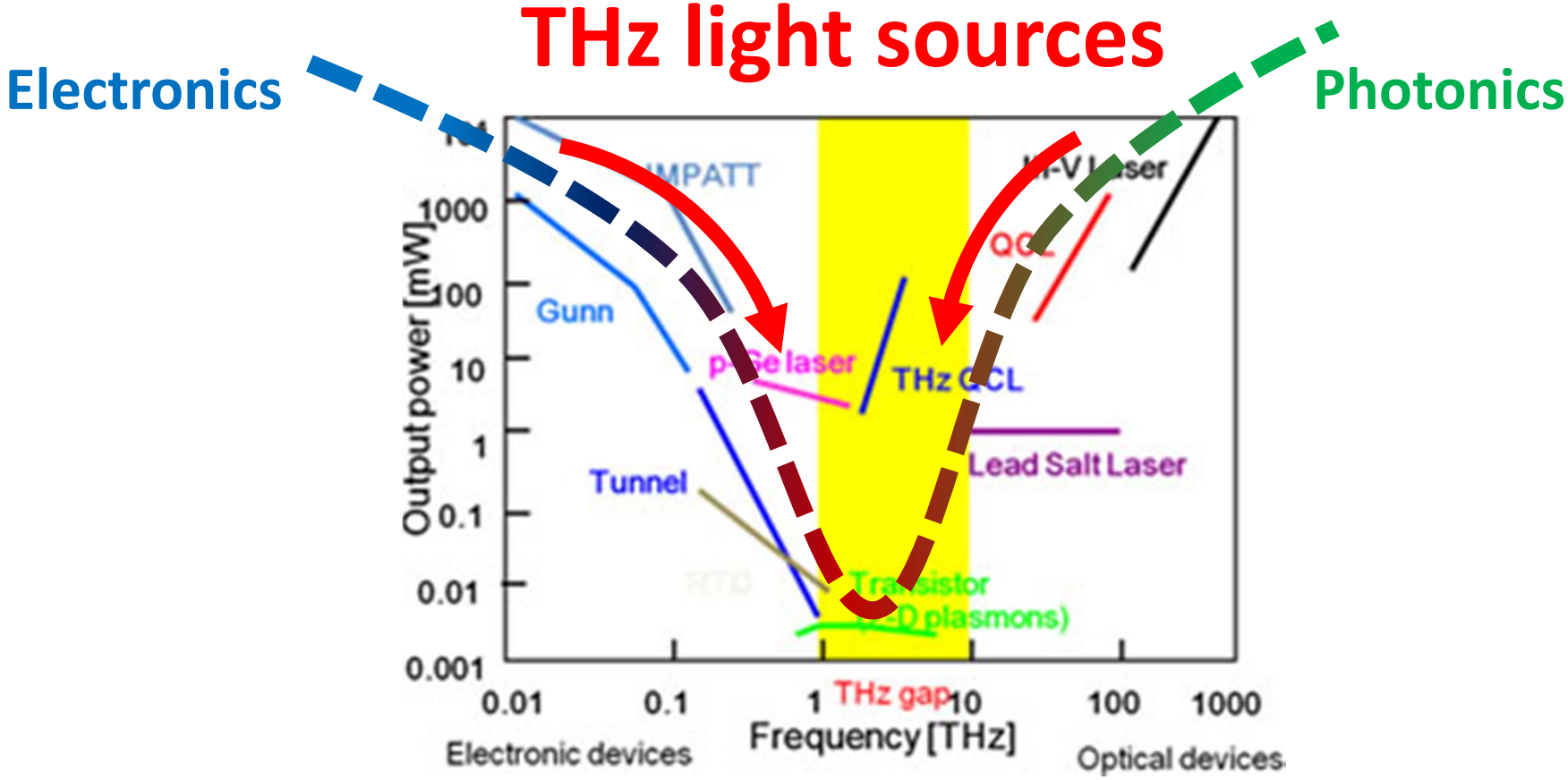
Wavelength: 3 mm – 30 µm

Energy: 0.4 – 4 meV

Wavenumber: 3 – 300 cm^{-1}

Terahertz radiation (0.3-20 THz, 1 THz = 4 meV = 300 µm), is the most important portion of the electromagnetic spectrum in terms of multi disciplinary use in basic science and technology, as defined by the **European THz road map** in 2017.

THz light sources



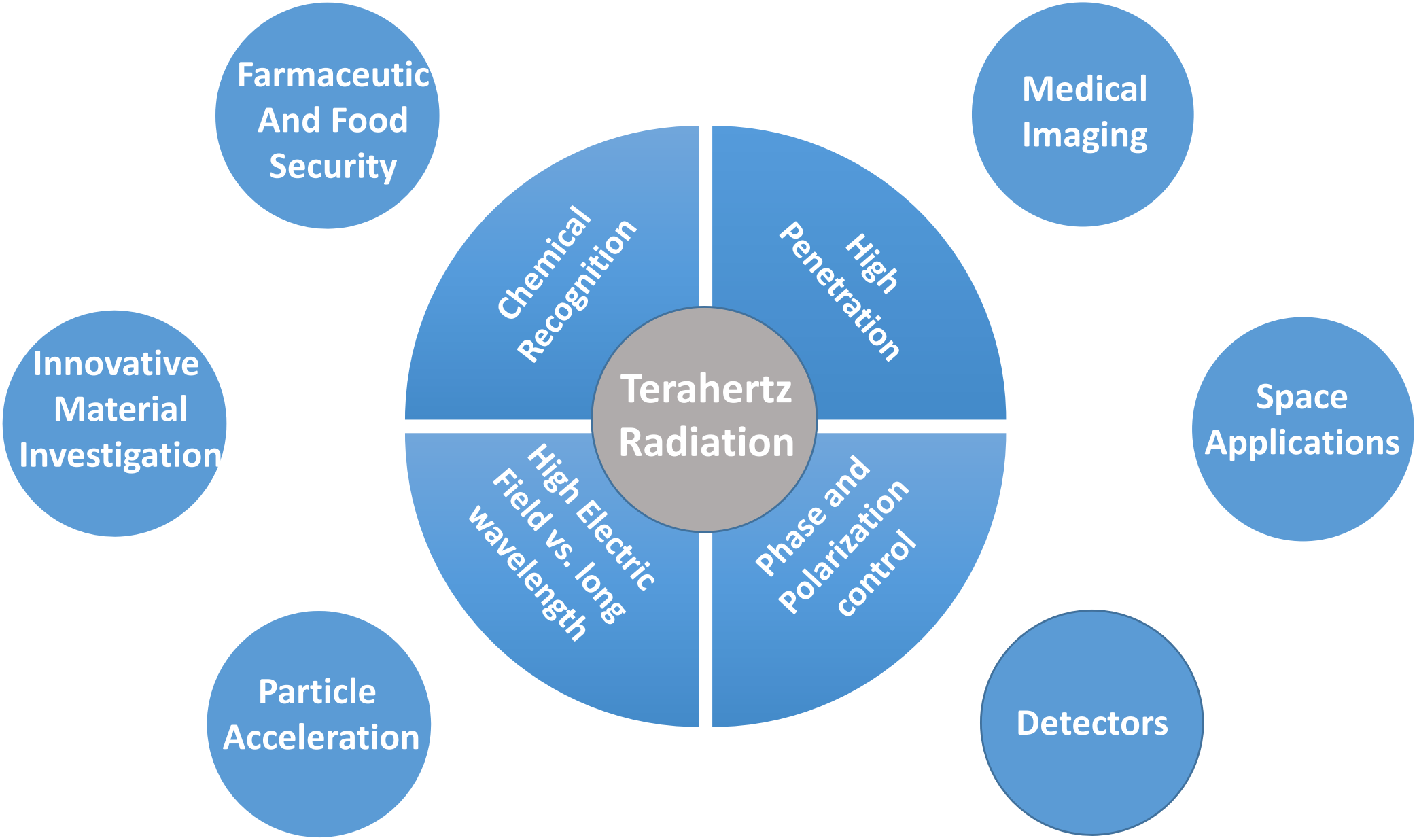
- Solid State Oscillators
- Gas and Quantum Cascade Lasers
- Free electron based sources:
  - Free Electron Laser (FEL)
  - Back Wave Oscillator (BWO)
  - Coherent Transition Radiation (CTR)
  - Coherent Synchrotron Radiation (CSR)

- Laser Based THz sources:
  - **Optic Processes:**

  Optical rectification, Cherenkov Radiation (Organic/Inorganic Crystals)
  - **Optoelectronic Processes:**

  Photoconductive, Photoconductive Mixing

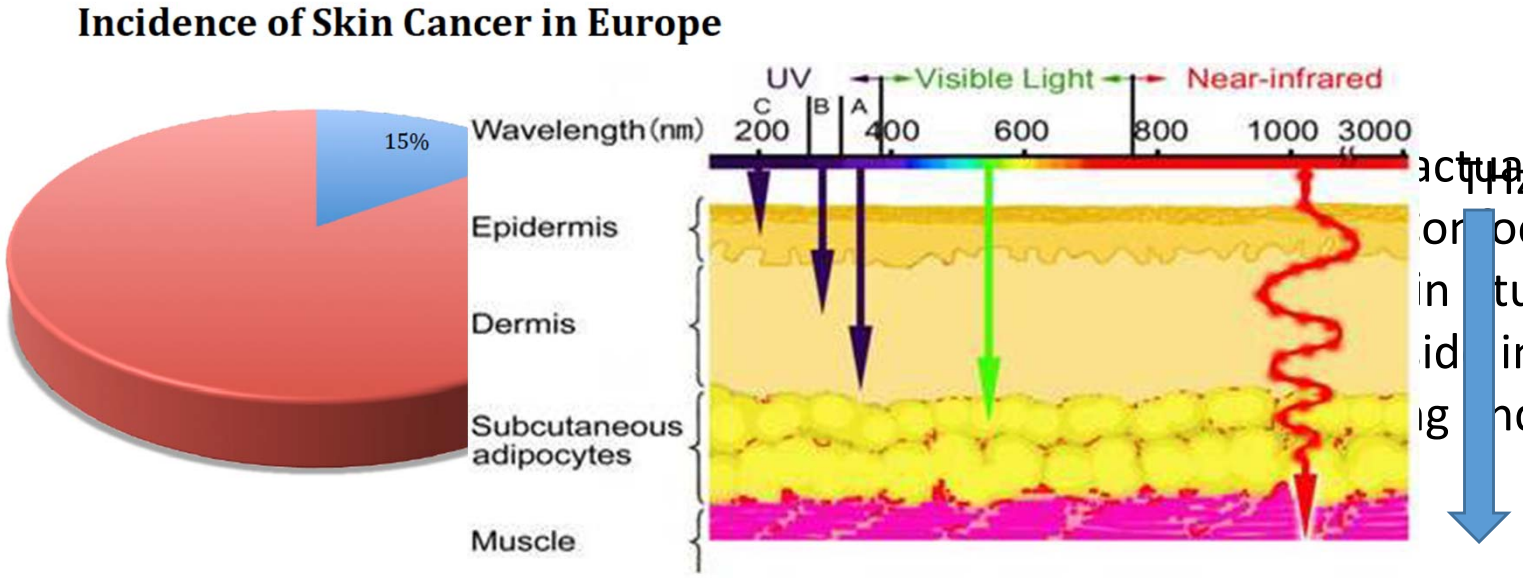
THz Multidisciplinarity



On going THz Activities

1. **THz and Near-Infrared Imaging for Biomedical Diagnostic (TMAGIC: THz-iMAGIng for Clinics);**

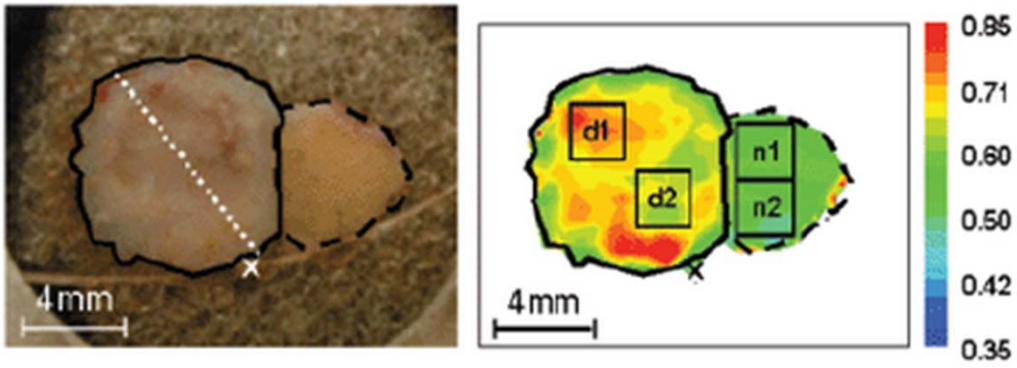
2. **THz Technology for Particle Acceleration (TERA: THz-ERA);**

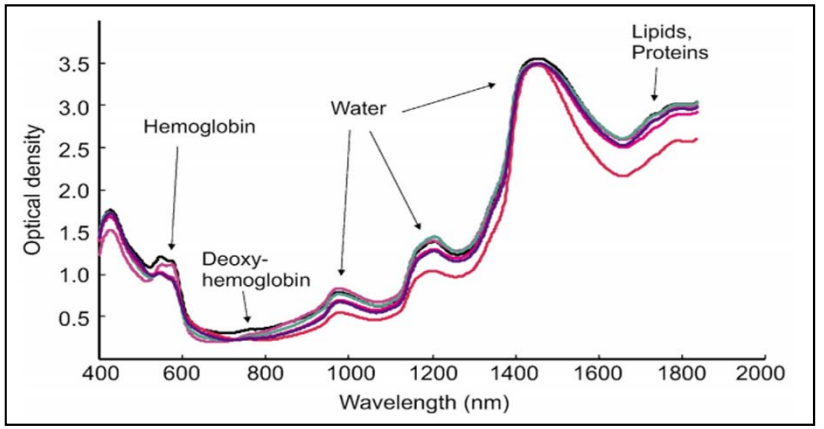


actual "optical techniques": or ocal Microscopy and in tudying skin (potentially id in the practically absence g nd volume penetration.

A good diagnostic technique should recognize chemical composition of skin and deep tissues and having imaging and reconstruction capability → THz for water and density mapping+ NIR for chemical recognizing

THz Imaging + NIR Spectroscopy





THz radiation evaluates cutaneous regions (nevi and lesion), their *depths* and their *shape* through *phase and amplitude constrast* → Tomographic reconstruction;

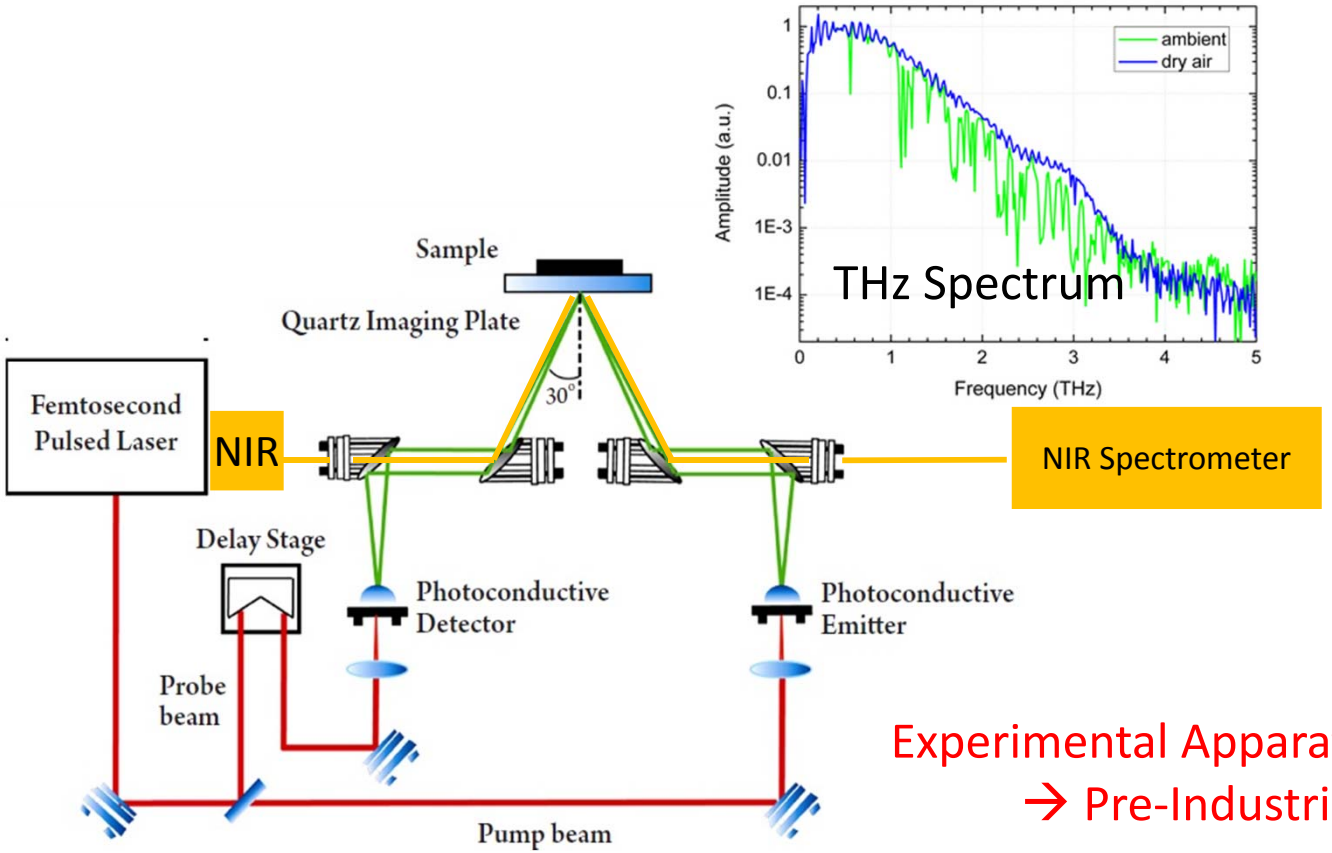
Near-IR radiation evaluates the chemical composition of cutaneous regions through absorption bands related to costituent chemical groups

λ=1000-50 μm (50 GHz to 5 THz)

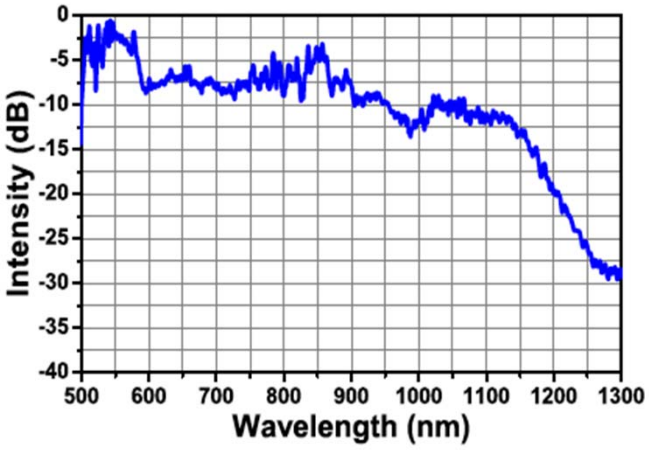
λ=500 nm - 2 μm

Advantages of THz and NIR Combination

Both non Ionizing Radiations
Good (a few mm) bulk penetration of tissues
THz sensitive to tissue water content/NIR to vibrational fingerprints
THz radiation is scarcely influenced by Raylegh scattering → Good imaging capability
→ Biomedical Imaging combined with local chemical information

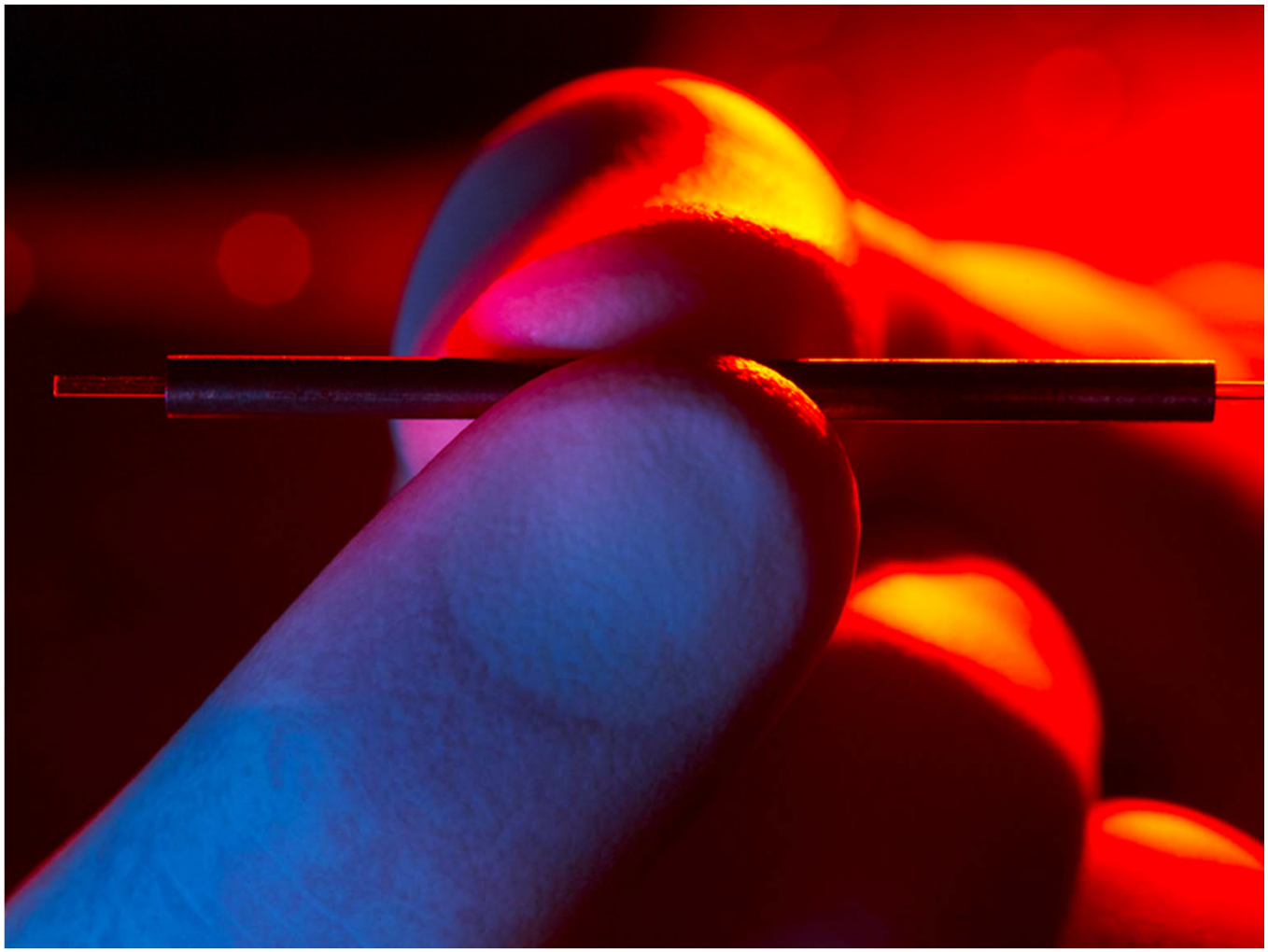


NIR SPECTRUM



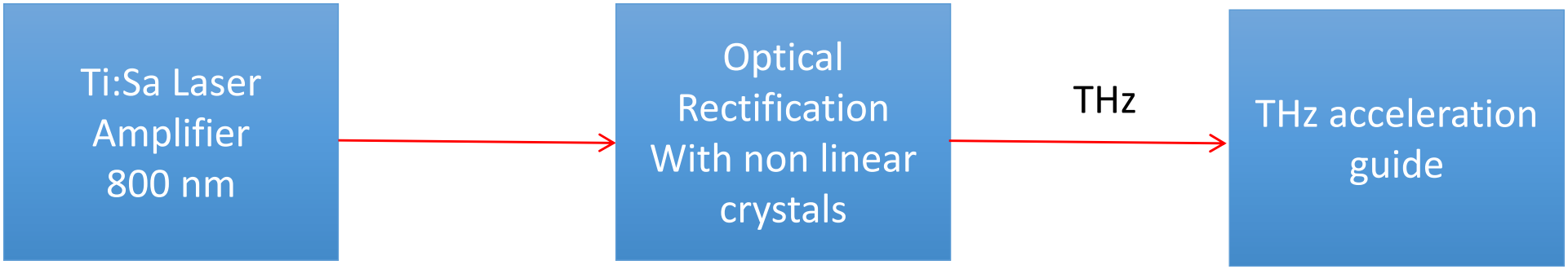
Experimental Apparatous developped in TMAGIC
→ Pre-Industrial Portable equipment

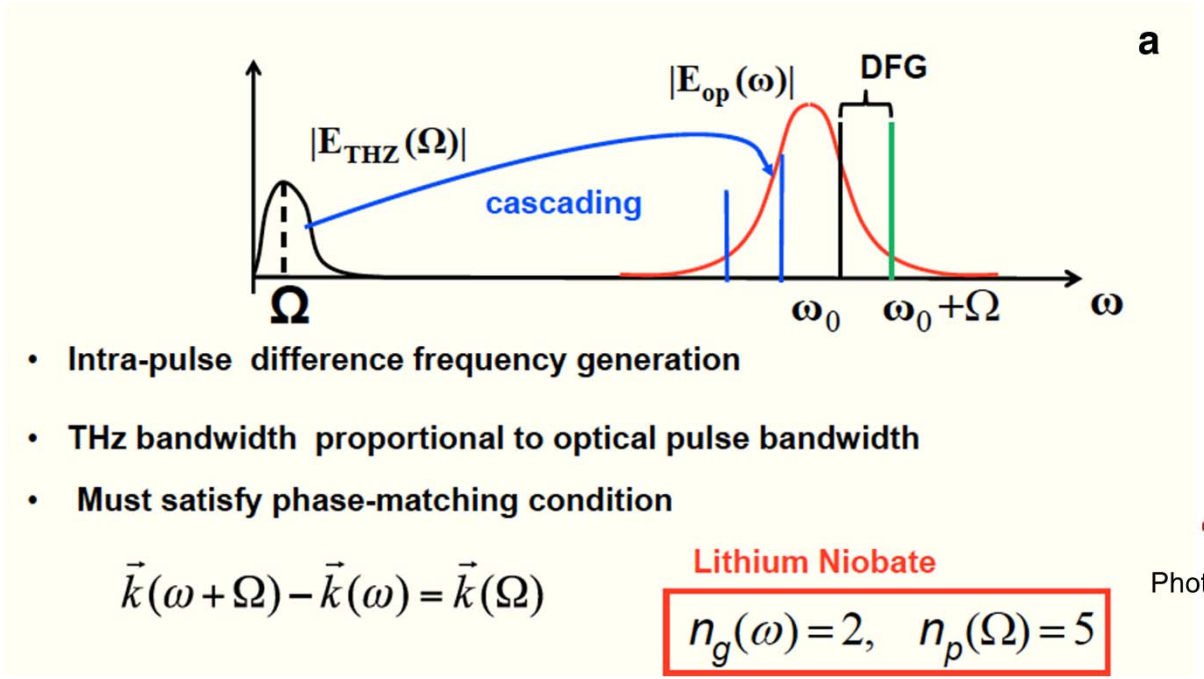
A THz accelerator



Terahertz accelerator modules easily fit into two fingers
DESY/Heiner Müller-Elsner

Acceleration Scheme



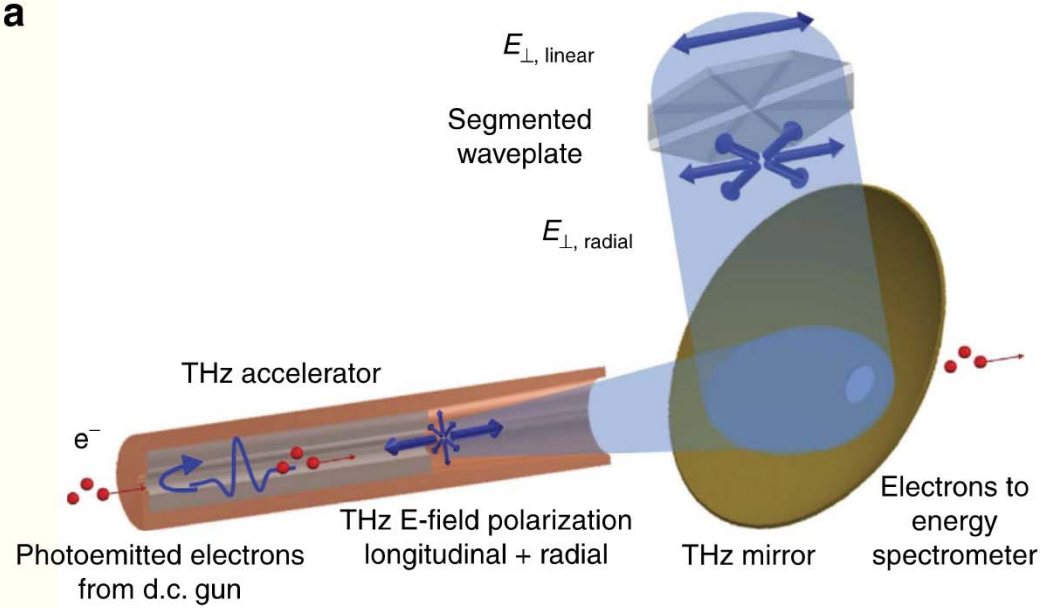


- Intra-pulse difference frequency generation
- THz bandwidth proportional to optical pulse bandwidth
- Must satisfy phase-matching condition

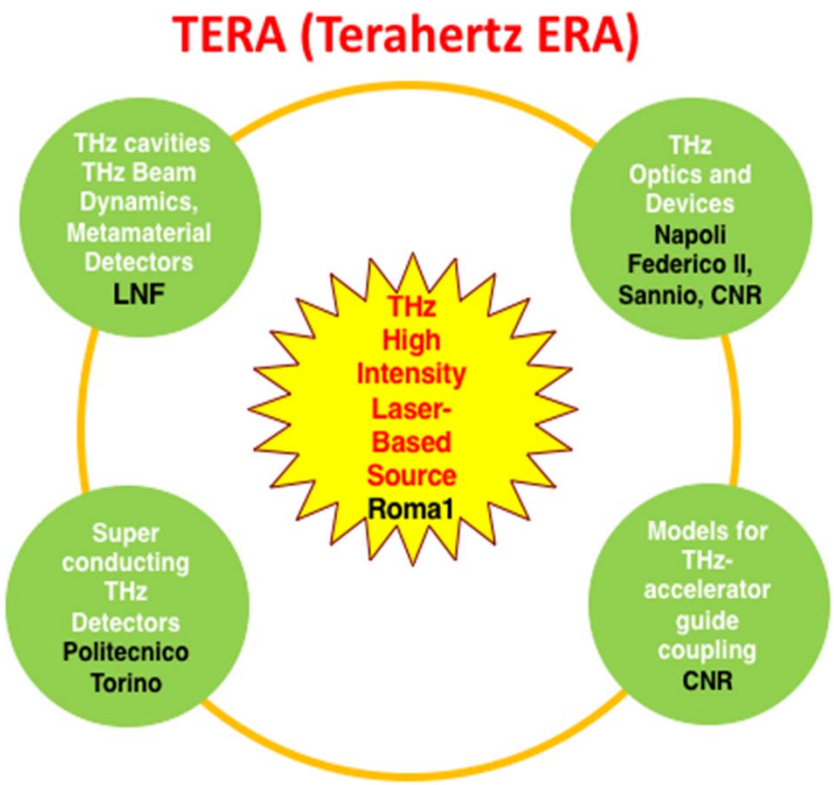
$$\vec{k}(\omega+\Omega)-\vec{k}(\omega)=\vec{k}(\Omega)$$

Lithium Niobate

$$n_g(\omega)=2,\quad n_p(\Omega)=5$$

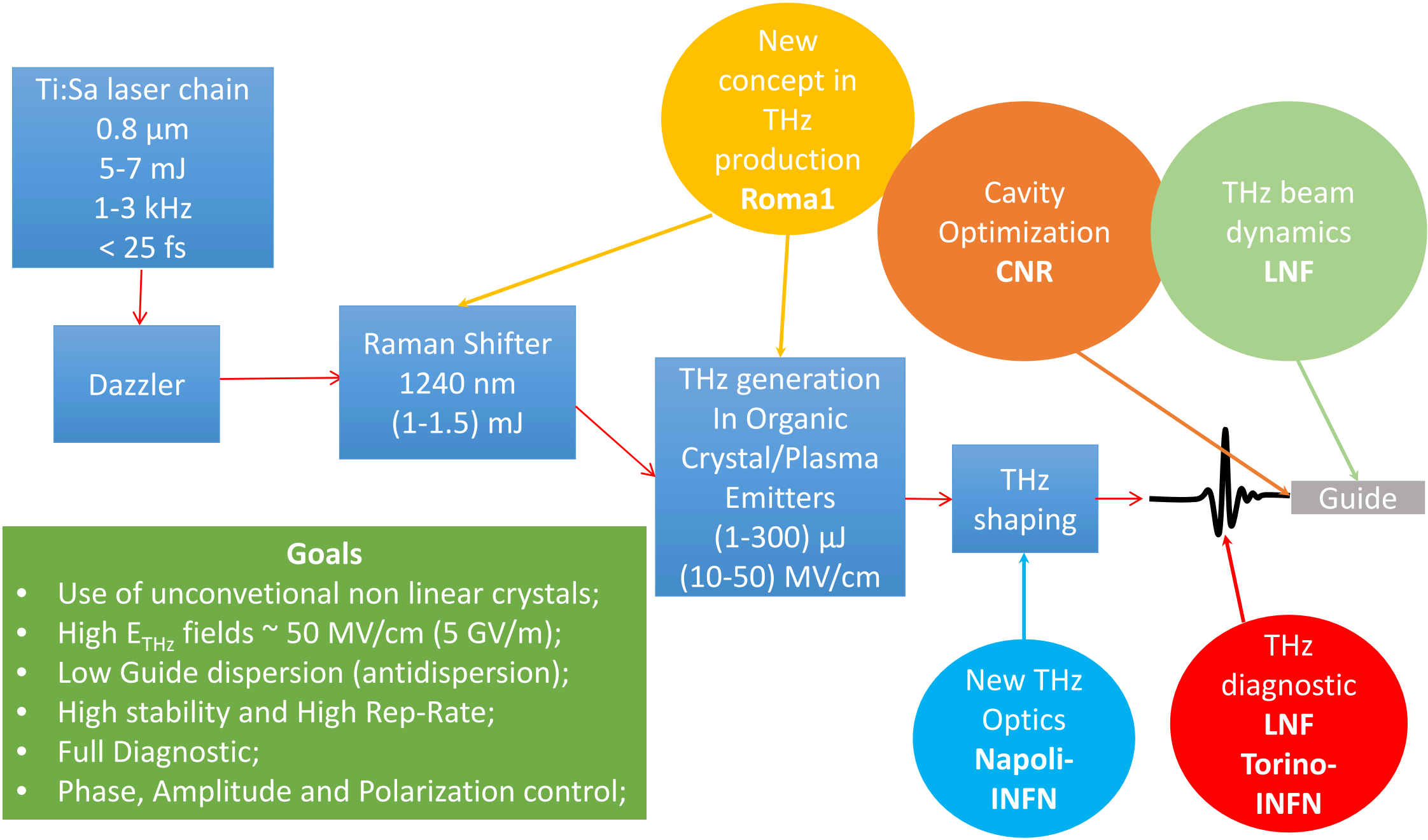


TERA (THz-ERA) Call-INFN: Scientific Goals



Requirements	TERA
THz source	We will develop an innovative laser-based broadband flexible and table-top THz source.
Novel accelerator technology	We will develop THz cavities to optimize THz transport and acceleration process.
Novel THz optics technology	We will develop THz optics to optimize THz transport, to shape and detect the THz E-field and intensity.
THz Detectors	We will develop detectors for measuring THz radiation emitted by the source.

TERA



Goals

- Use of unconvetional non linear crystals;
- High E_{THz} fields ~ 50 MV/cm (5 GV/m);
- Low Guide dispersion (antidispersion);
- High stability and High Rep-Rate;
- Full Diagnostic;
- Phase, Amplitude and Polarization control;

Acknowledgement

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https://www.terahertz.academy/

Many Thanks for your attention