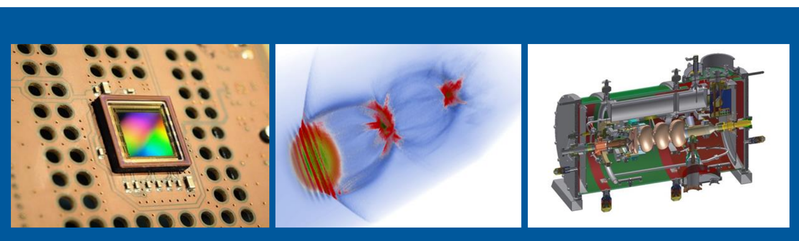
Programme Matter and Technologies

Advancing Thomson sources to optical undulators and medical applications

ARD-ST4 Novel Acceleration Concepts



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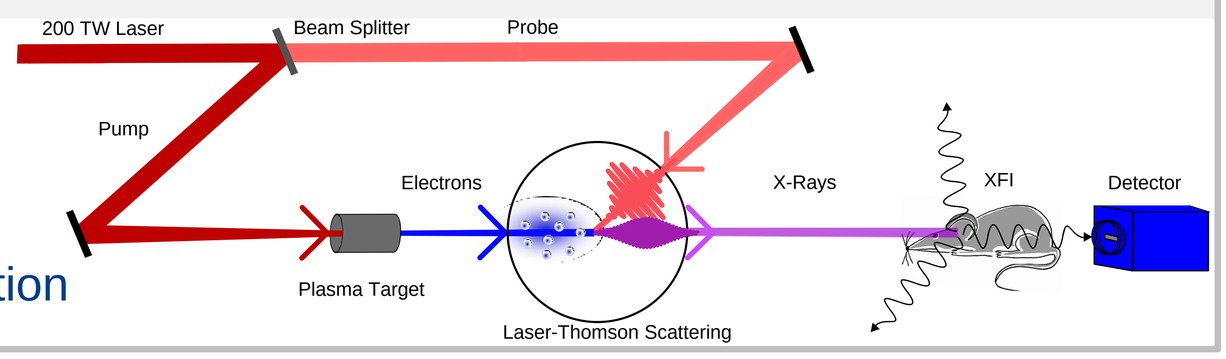
Motivation

- Intense, ultrashort, finite bandwidth X-ray pulses:
  - single-shot X-ray spectroscopy on complex or destructive processes
  - in-vivo X-ray fluorescence imaging (XFI) of diagnostic agents
- Complementary to existing and planned X-FEL facilities
- Laboratory for strong field physics and nonlinear interaction

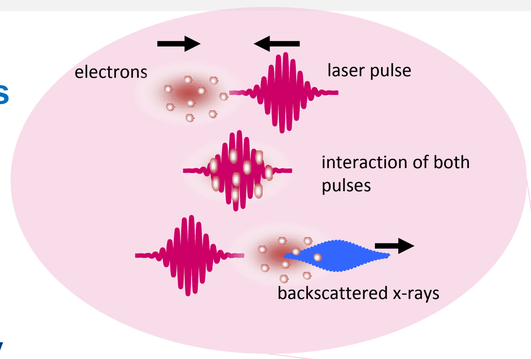


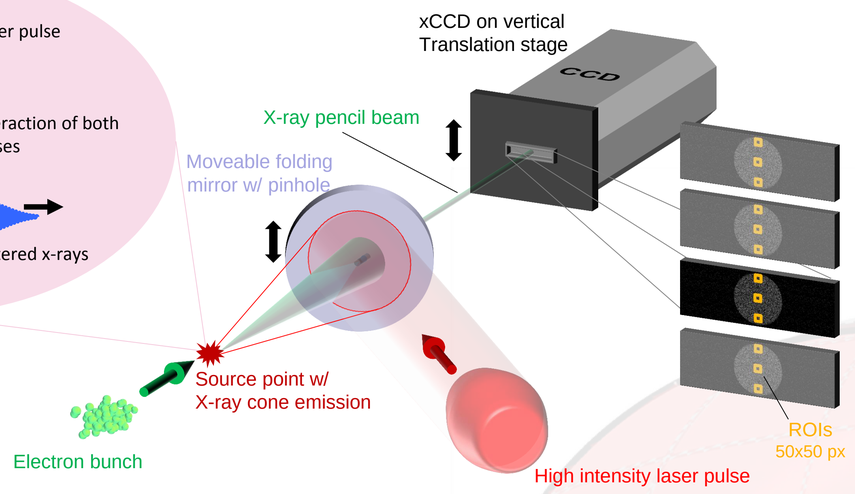
Demonstration of a Laser-Thomson backscattering X-ray source

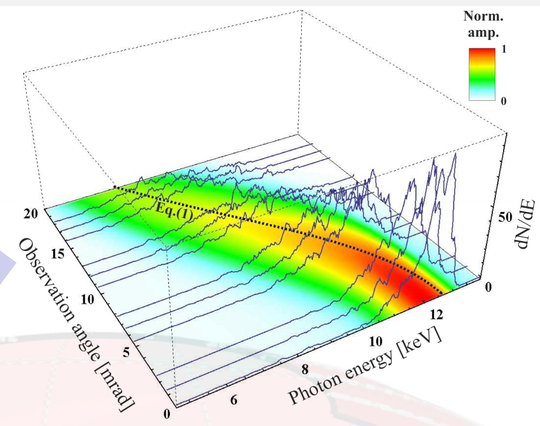
Principle of the scattering process

$$\omega_{sc} = \frac{4\gamma^2 \cdot \omega_0}{1 + a_0^2/2 + \gamma^2\theta^2}$$

- Tunable X-ray spectrum
- Modest required electron energy
- Ultra-short X-ray pulses
- Finite bandwidth and spatially confined
- X-ray polarization is adjustable.







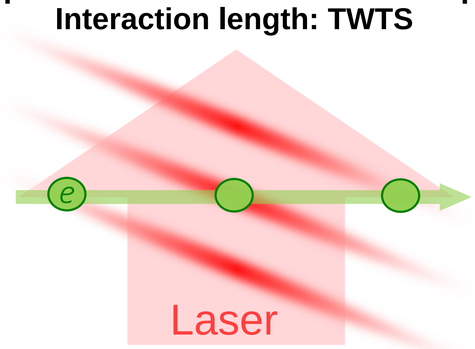
Spectrally and spatially resolved measurement at ELBE. (underlying numerical prediction)

Exploring Compact High-Brightness X-ray Sources Analytically and Computationally

Thomson-Scattering

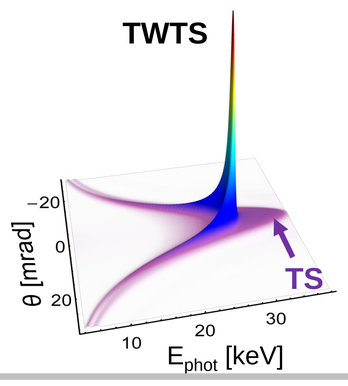
Interaction length: Head-on

Interaction length: TWTS



Traveling-Wave Thomson-Scattering

$$N_{photons} \propto L_{int}$$



Realistic simulations with experimental parameters

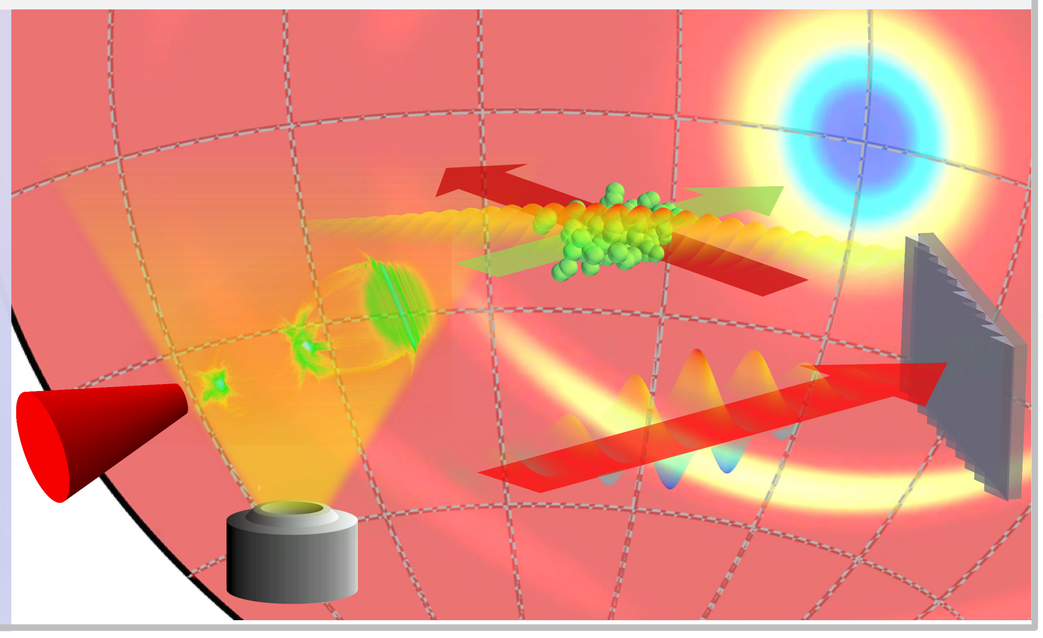
Including all particles and fields

Highly parallel code PIConGPU enables feedback from theory to experiment within beamtime

Start-to-end Simulations with PIConGPU+CLARA

Open source

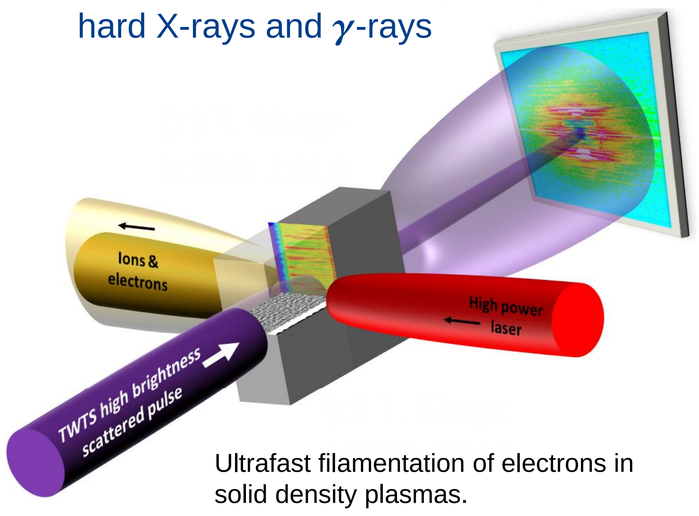
Validated analytically and experimentally



Ultrafast Plasma Pump-Probe Experiments

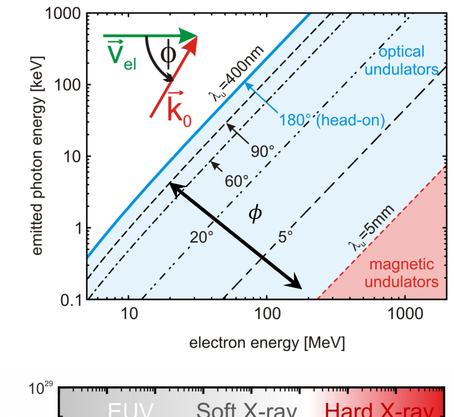
Pilot experiments for XFEL facilities (e.g. European-XFEL):

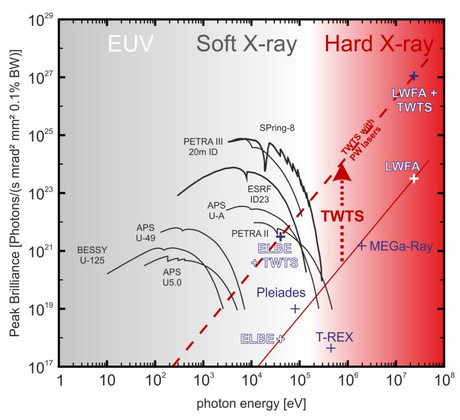
- develop and mature techniques for future experiments
- Extend accessible energy range to hard X-rays and γ-rays



Ultrafast filamentation of electrons in solid density plasmas.

Time scale for oscillations: 30fs.



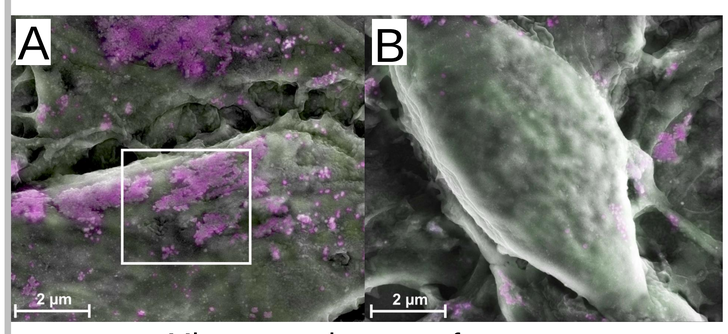


Medical Application of TS

Marking cells with gold nanoparticles (Au NPs)

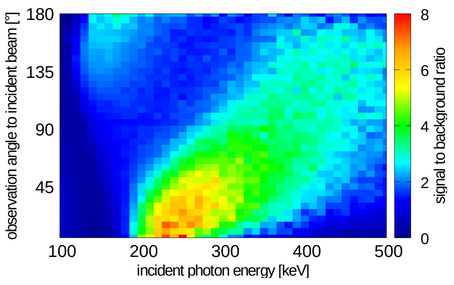
- Functionalized Au NPs (purple) couple to neural receptors
- Detect neural damage using X-Ray Fluorescence Imaging

Functionalized Au NPs Non-functionalized Au NPs



Microscopy images of neurons

X-Ray Fluorescence Imaging



Best signal-to-background ratio @ E_{in}>200 keV

Prospects

- In-vivo imaging
- Ultra-high sensitivity
- Low radiation dose

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