Highlights from FEL conference

Frank Stephan, Mikhail Krasilnikov, Georgi Georgiev, Raffael Niemczyk
PPS
Zeuthen, 06.10.2022

HELMHOLTZ

DESY.

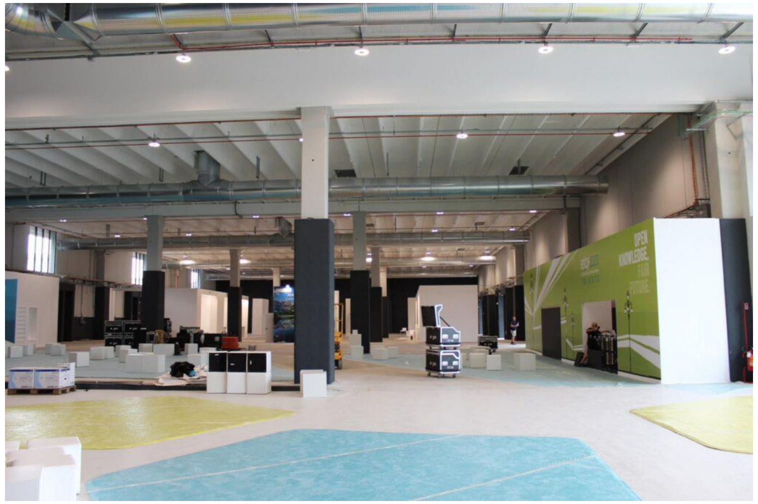
Trieste

Before conference dinner

FEL2022 in Trieste

Conference site & organisation

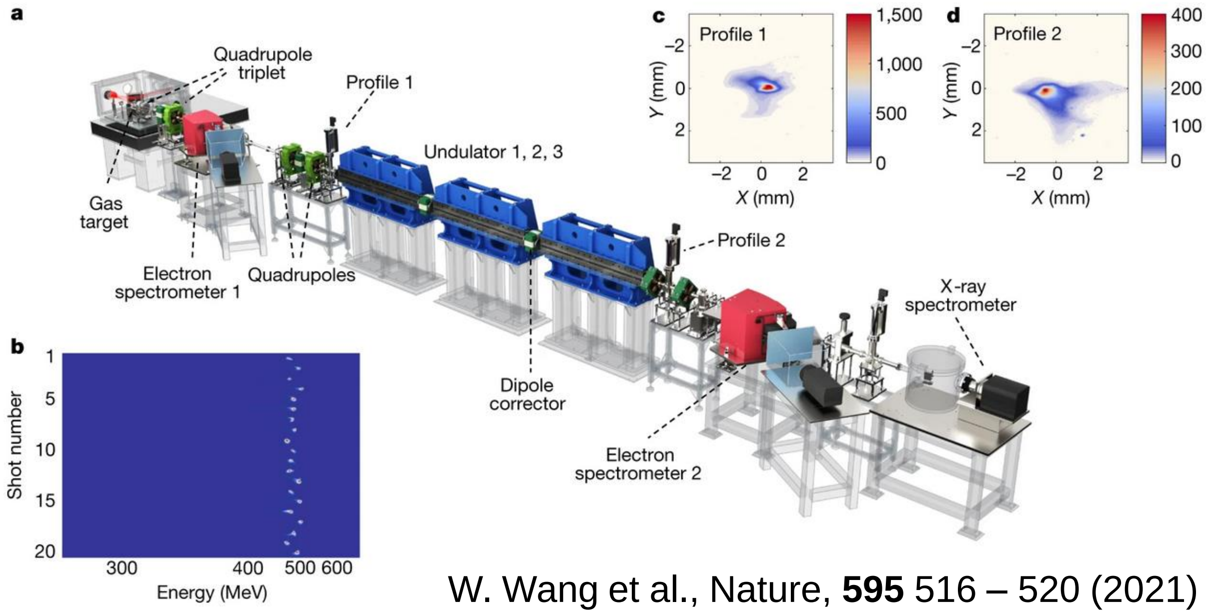
- No parallel sessions, 4.5 days
  - Quite a lot of program
  - But sufficiently long breaks
- Modern venue side, excellent organisation
- Visit of Elettra & FERMI



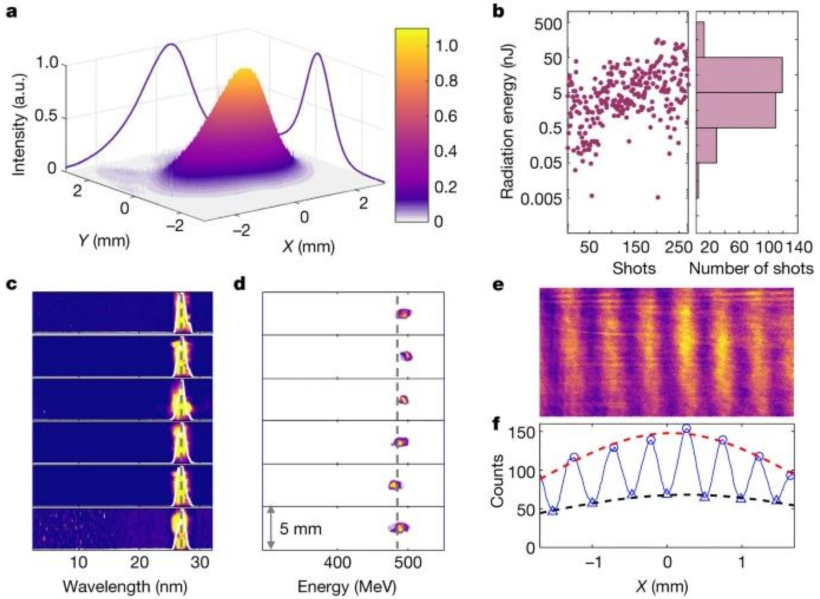
Highlights

Free-electron Lasing Based on a Laser Wakefield Accelerator

- Acceleration in plasma
  - Quadrupole triplet after plasma
  - Quadrupole doublet before undulator
- Lasing in three undulators
  - 27 nm wavelength
  - Measured gain length by opening undulators



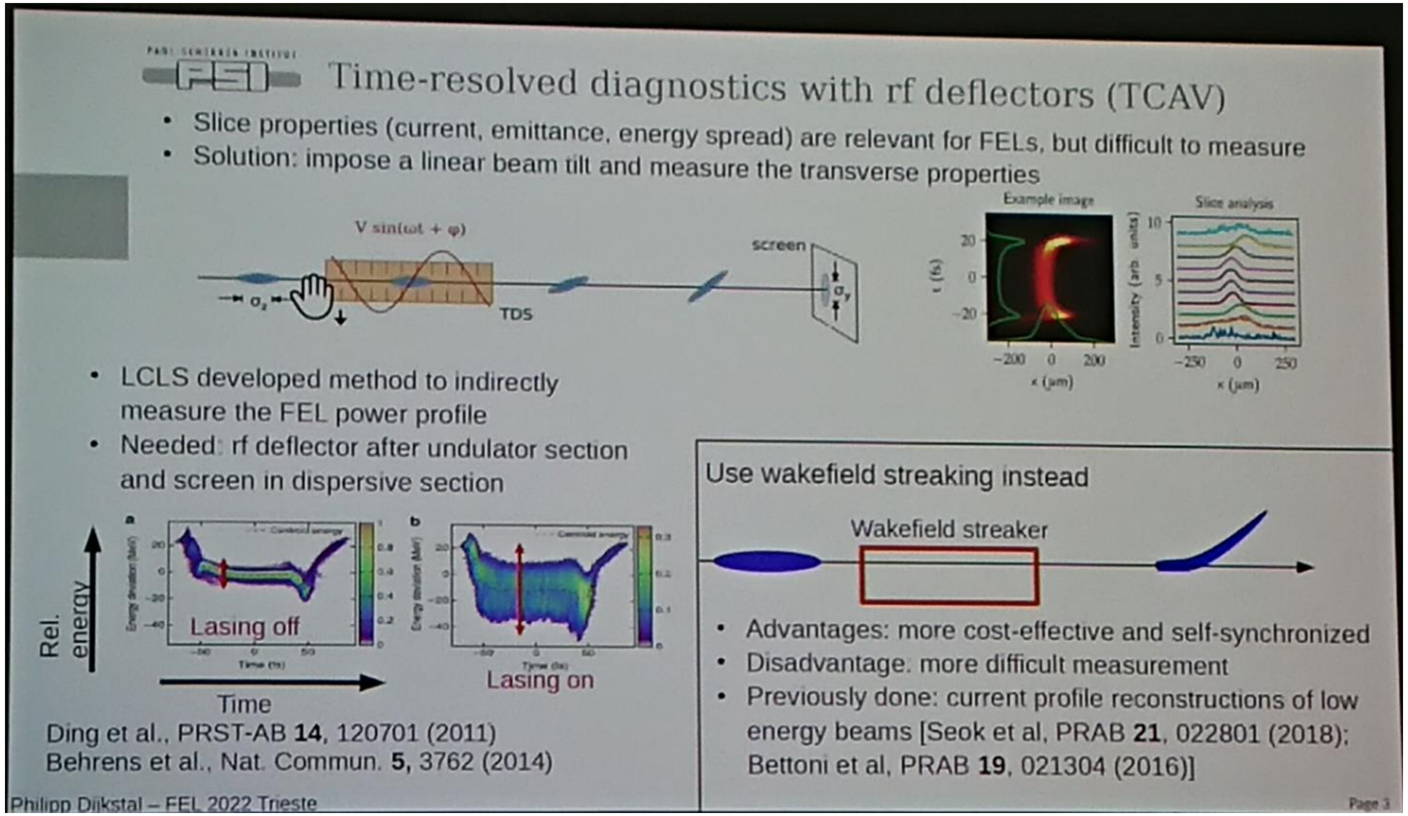
W. Wang et al., Nature, **595** 516 – 520 (2021)



Highlights

Self-synchronized and cost-effective time-resolved measurements at x-ray FELs with femtosecond resolution

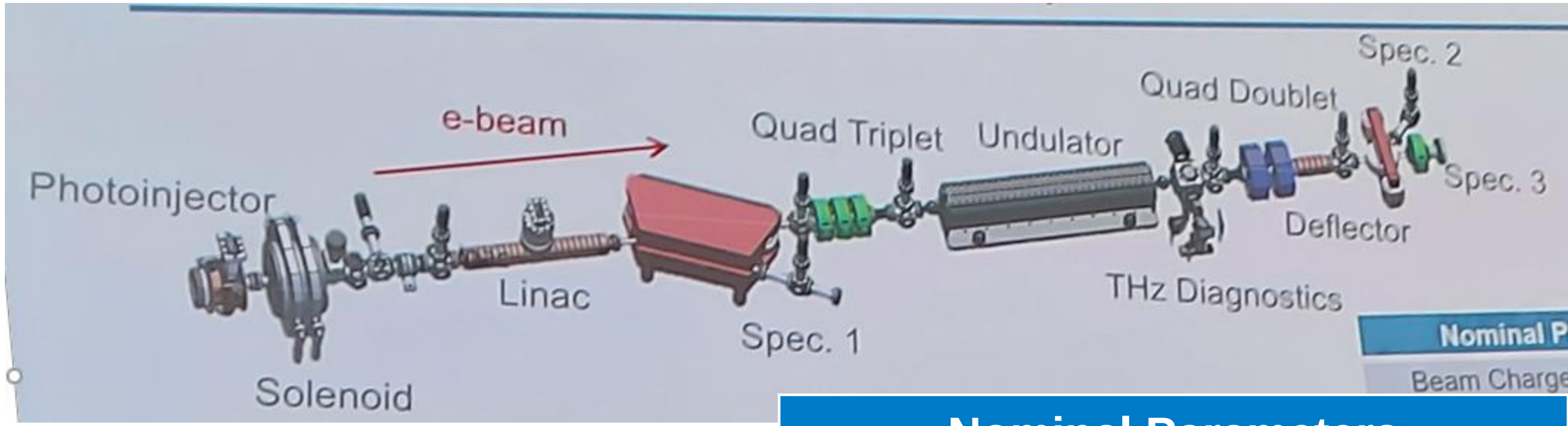
- Wakefield leads to transverse deflection
- However:
  - Head is not deflected
  - Deflection generally nonlinear
  - Iterative reconstruction procedure needed



Pietro Musumeci, First Lasing of UCLA High Efficiency THz FEL

Here we report on the first lasing of the high efficiency THz FEL operating at the UCLA Pegasus laboratory. The FEL is operated in the zero-slippage regime where a circular waveguide is used to match the radiation and electron-beam velocities in a 0.96 m long tapered helical undulator, allowing resonant interaction with the ultrashort 200-pC 5.5-MeV electron beam from the RF photogun over an extended region. Electron-beam spectrum measurements, supported by energy and spectral measurement of the terahertz FEL radiation, indicate an average energy efficiency of ~10%, with some particles losing >20% of their initial kinetic energy.

Pegasus beamline (UCLA)

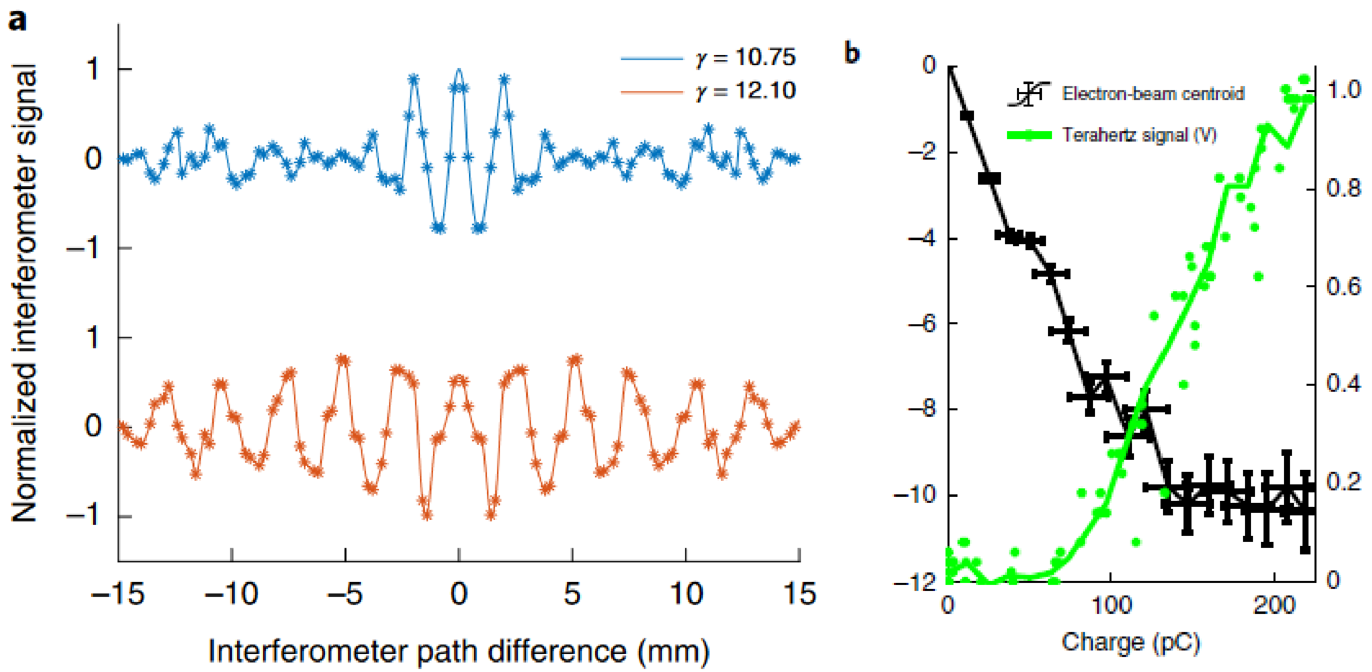


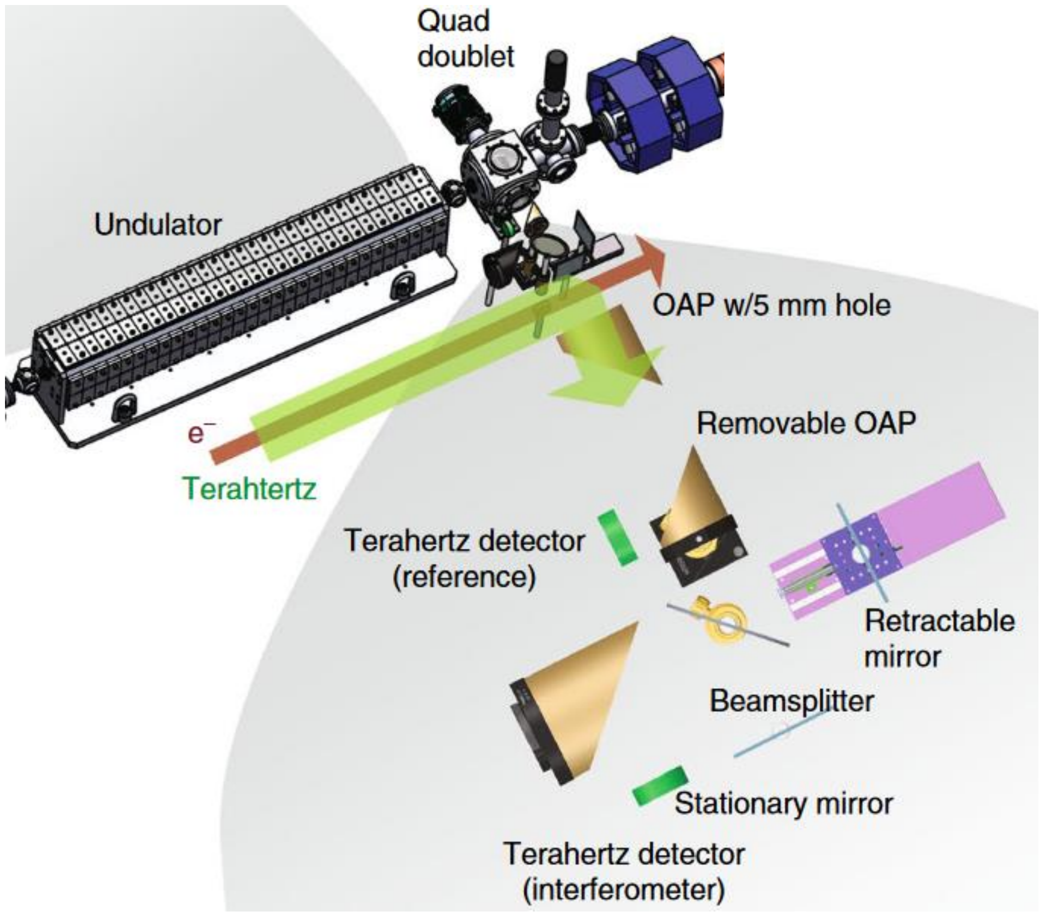
Nominal Parameters	
Beam Charge	200 pC
Norm. Emittance	2 mm-mrad
Beam Energy	5.5 MeV
Undulator Field	0.73 T
Undulator Period	3.2 cm
Waveguide Radius	2.27 mm
Frequency	160 GHz

THz at Pegasus (UCLA)

THz Diagnostics

- THz Diagnostics
  - Able to measure total energy and spectrum
- Energy measurement consistent with spectrometer data
- THz losses

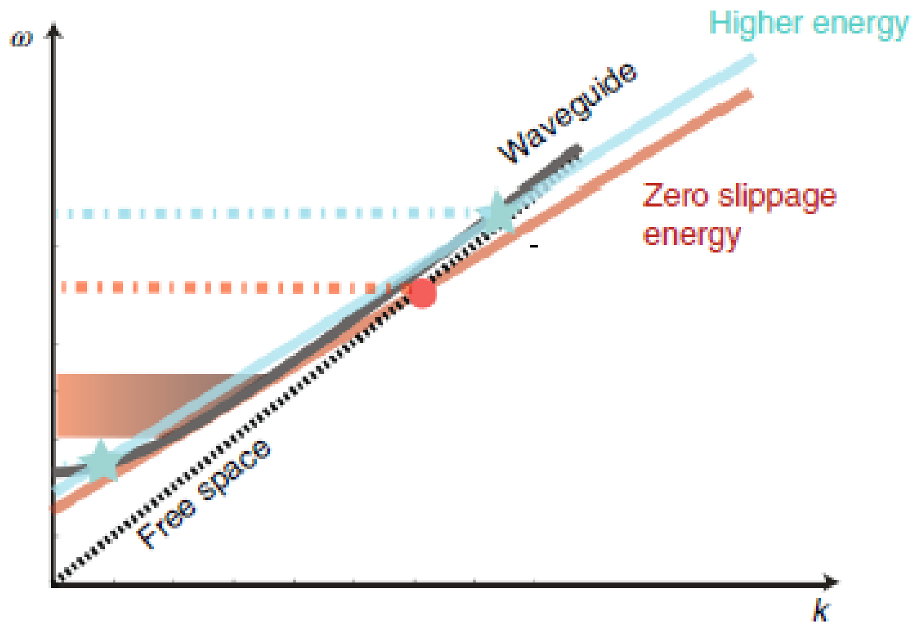


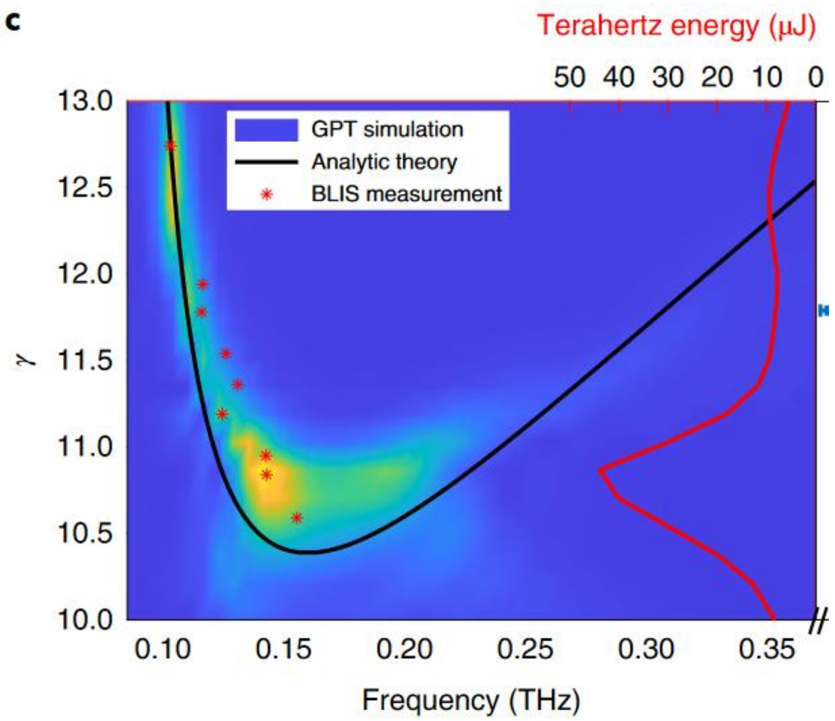


THz at Pegasus (UCLA)

Energy Resonance

- As energy ***increases,*** frequency ***decreases***
- Energy detuning
  - Energy spread and transverse emittance

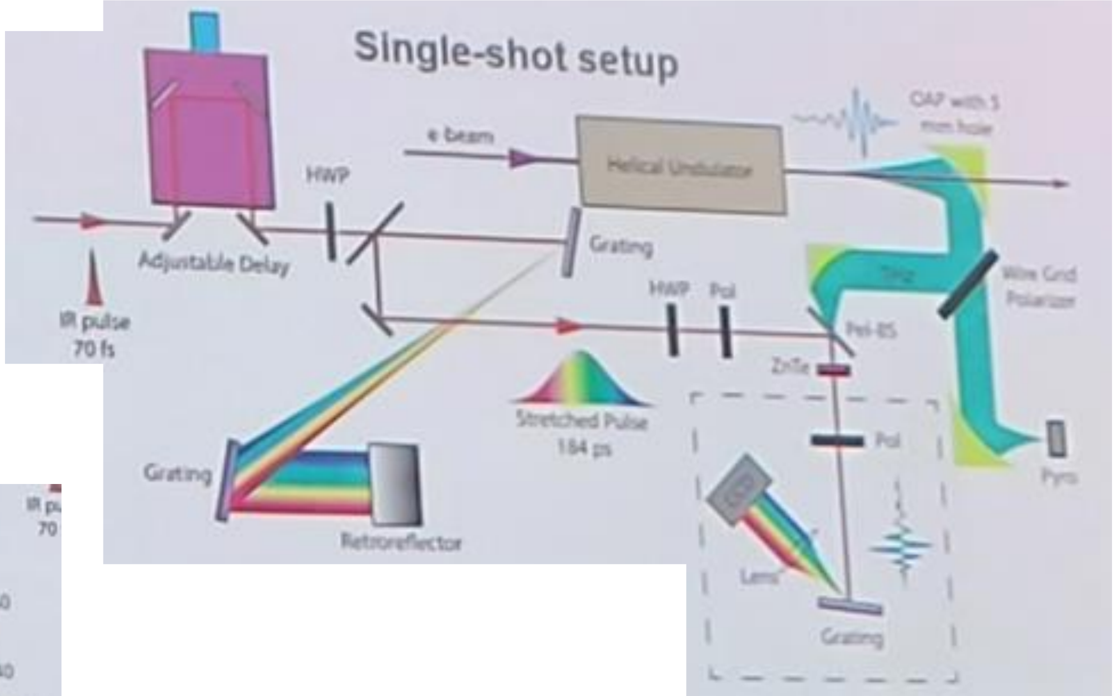


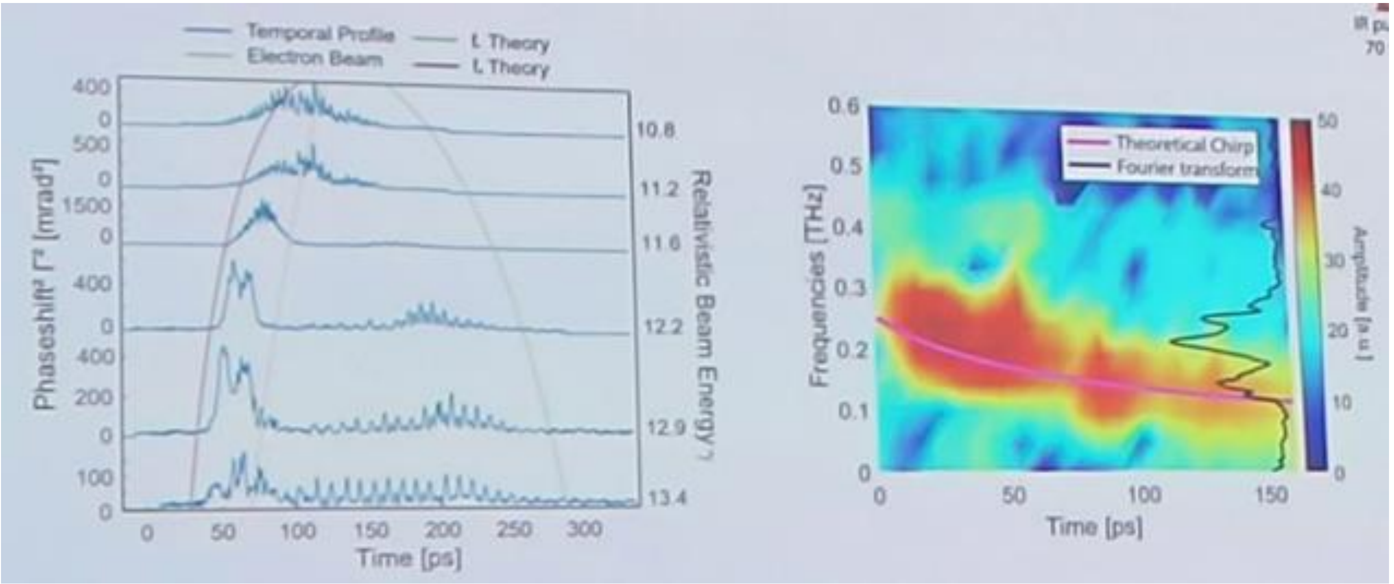


THz at Pegasus (UCLA)

Electro-optic Sampling (EOS)

- Utilizes crystal birefringence induced by an applied electric field
- Measure pulse in time domain
  - Multi-shot with short IR pulse
  - Single-shot with stretched IR pulse





THz at Pegasus (UCLA)

nature photonics

ARTICLES

https://doi.org/10.1038/s41566-022-00995-z

Check for updates

Single-pass high-efficiency terahertz free-electron laser

A. Fisher[1]✉, Y. Park[1]✉, M. Lenz[1], A. Ody[1], R. Agustsson[2], T. Hodgetts[2], A. Murokh[2] and P. Musumeci[1]✉

The terahertz gap is a region of the electromagnetic spectrum where high average and peak power radiation sources are scarce while at the same time scientific and industrial applications are growing in demand. Free-electron laser (FEL) coupling in a magnetic undulator is one of the best options for radiation generation in this frequency range, but slippage effects require the use of relatively long and low-current electron bunches to drive the terahertz FEL, limiting amplification gain and output peak power. Here we use a circular waveguide in a 0.96-m strongly tapered helical undulator to match the radiation and electron-beam velocities, allowing resonant energy extraction from an ultrashort 200-pC 5.5-MeV electron beam over an extended distance. Electron-beam spectrum measurements, supported by energy and spectral measurement of the terahertz FEL radiation, indicate an average energy efficiency of ~10%, with some particles losing >20% of their initial kinetic energy.

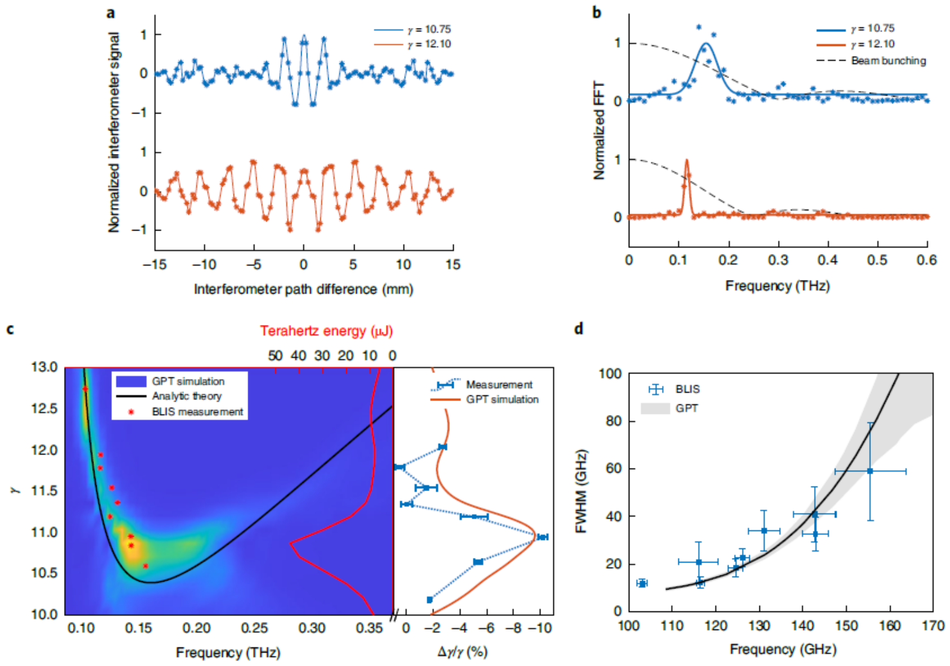


Fig. 3 | Interferometry measurements. a, Interferometer traces for input beam energies near (blue) and above (orange) the zero-slippage condition. **b**, Power spectrum of the emitted radiation, computed from a fast Fourier transform (FFT) of the interferometer traces and plotted together with the beam bunching factors obtained from beam dynamics simulations. **c**, The interferometer peak frequency measurements are compared to general particle tracer (GPT) simulations and to the theoretical phase-resonance curves. The simulated pulse energies show a maximum interaction at a slight positive energy detuning. Measurements of FEL efficiency versus input electron-beam energy are plotted against GPT results. The error bars in the energy loss data represent the r.m.s. of the distribution calculated over ≥10 images. The charge in these simulations is scaled by the observed transmission through the undulator. **d**, Terahertz spectrum bandwidth (FWHM) shown as a function of the peak radiation wavelength for measurements and simulation. Errors bars represent 95% confidence intervals of Gaussian fits to the spectral peaks, like those shown in **b**.

Facility tour

Brief visit of Elettra and extensive visit of FERMI

- FERMI
  - 500 pC bunch charge
  - 1.3 GeV design energy
  - 10 Hz – 50 Hz operation
- Two FEL beamlines
  - Photon energy (eV): 12.4 – 65 & 65 – 310
  - Wavelength: 100 nm – 20 nm & 20 nm – 4 nm