ELETTRA SINCROTRONE TRIESTE

Elettra Sincrotrone Trieste

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Funded by the European Union

- **Address**

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- **Scientist in charge**

Carlo Callegari (experiments)

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Luca Giannessi (machine physics)

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Useful Links

https://quatto.eu/

Home Institution

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Elettra – Sincrotrone Trieste S.C.p.A. is an international research center operating two advanced light sources: **FERMI** and **Elettra**. FERMI is a high-performance free-electron laser producing ultrashort, fully coherent pulses from the ultraviolet to soft X-rays.

Its seeded design ensures superior spectral stability, enabling time-resolved studies of ultrafast reactions and structural dynamics with femtosecond precision.

On July 2, 2025, after more than thirty years of operation, Elettra was switched off to allow for the construction of Elettra 2.0, a fourth-generation synchrotron based on a multi-bend achromat lattice. This design will reduce emittance to tens of pm·rad, yielding photon beams of unprecedented brightness and transverse coherence. Such performance will support real-time investigations at the atomic scale, expanding research in structural biology, nanoscience, quantum materials, and energy technologies.

Together, FERMI and Elettra 2.0 provide complementary, cutting-edge tools positioning Trieste at the forefront of photon science.

Group Leader

Carlo Callegari

- **Graduation:** Degree in Physics from the University of Pisa and Scuola Normale Superiore, in Pisa, Italy. Master thesis on laser ablation of pure and doped fullerenes (1993).
- **PhD**: PhD in Chemistry from Princeton University, USA, on molecular rotation and dynamics in superfluid helium nanodroplets (2000).
- **Current Position**: Head of the Low Density Matter beamline at the FERMI Free Electron Laser at Elettra Sincrotrone Trieste, Italy.
- I received my PhD in 2000 from Princeton University, USA, under the supervision of Giacinto Scoles, one of the pioneers of molecular beams. I then moved to Pasadena, as a postdoc at Caltech, where I learned the art of nanomechanical resonators and applied it to sensitive detection of neutral species. In 2003, I joined the Institute of Experimental Physics at the TU Graz as a research assistant, and I established the concept of optically detected magnetic resonance in superfluid helium droplets; this is when optical coherence started to be real fun. In 2009, I moved to Trieste, where the seeded Free Electron Laser was under completion: I was the local coordinator, and later the head, of the Low Density Matter beamline. My research interests are focused on the longitudinal coherence of seeded free-electron lasers, on its application to nonlinear phase-controlled experiments and, separately, on the study of the photodynamics of molecules with time-resolved charged-particle spectroscopy.

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Useful Links

https://www.elettra.eu/lightsources/fermi/fermi-beamlines/ldm/ldmhome-page.html

Group Leader

Luca Giannessi

- **Graduation:** Degree in Physics at University of Rome "La Sapienza" (1989). Research on the spectral characteristics of radiation emitted by ultrarelativistic electron beams in undulators.
- **Current Position**: Head of the FERMI machine at Elettra-Sincrotrone Trieste and senior scientist at the INFN Laboratory in Frascati, Italy
- I began my activity in the 1980s at the ENEA laser power division at Frascati and at the Mark III FEL at Stanford, studying harmonic generation mechanisms, and later contributed to the first lasing of DELTA (Dortmund, 2000), the Elettra storage-ring FEL (Trieste, 2001), and SPARC (Frascati, 2009), where I coordinated international efforts on seeded and cascaded FEL configurations. I served as Head of Machine Physics at the FERMI facility of Elettra–Sincrotrone Trieste, contributing to the first lasing and commissioning of FERMI FEL-1 (2010) and FEL-2 (2012).
- My research focuses on high-brightness electron beams, radiation emission from ultra-relativistic particles, and the physics of free-electron lasers (FELs). I have contributed to the understanding of beam–radiation interaction, the modeling of charged-particle dynamics, and the development of simulation tools for space-charge–dominated beams, including the TREDI code. I have investigated FEL saturation processes in both linac- and storage-ring–based oscillators, as well as the interplay between FEL dynamics and longitudinal beam instabilities. More recently, my work has focused on the dynamics of seeded FELs at saturation, leading to innovative configurations for harmonic generation, cascaded amplification, superradiance, and coherence control. At FERMI, I was among the main drivers of the study, implementation, and experimental validation of advanced multicolor FEL emission schemes, which today represent a central element of the Qu-Atto activities on coherent control of ultrafast dynamics.

Useful Links

https://www.elettra.eu/lightsources/fermi.html

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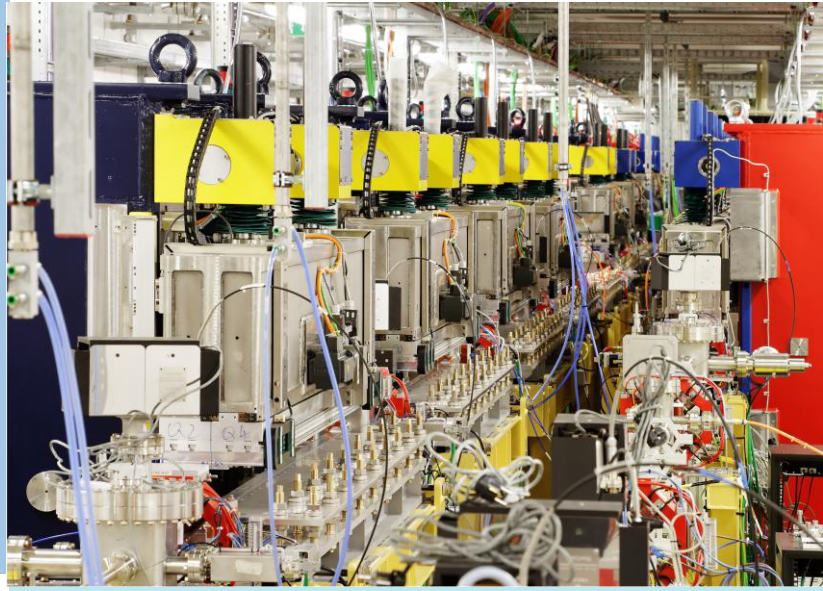
Research Training Modules



Generation of synchrotron and FEL radiation

Synchrotron radiation, based on the oscillatory motion of bunches of relativistic electron traveling through magnetic structures, is a powerful spectroscopic tool spanning a wide, fully tunable wavelength range from the infrared to the hard x-rays. Its applications range from static spectroscopy of atoms and molecules, to the investigation of protein structures, heterogeneous chemical reactions, the study of nanomaterials, cultural heritage, and medical applications.

Free Electron Lasers (FELs), based on the same concepts and devices add amplification to the game, resulting in short, intense pulses to investigate dynamical processes on their natural (atomic) length and time scales. A seeded FEL such as FERMI possesses in addition the property of temporal coherence, pushing the time resolution from the pulse duration down to a fraction of the radiation period. Multiple, phase-locked harmonics can be generated, and their phase becomes a control parameter of the process under study. The combination of three or more harmonics corresponds to a train of attosecond pulses.

Our goal is on the one hand to understand and perfect the generation of these exotic pulses, on the other hand to apply them to study the electronic and nuclear dynamics of atoms or small molecules. Further possibilities are offered by the presence of a synchronized optical field (infrared, visible or near-uv), in which case correlation techniques must be applied to reconstruct the shot-to-shot synchronization. The experiments are mostly based on photoelectron spectroscopy, and the concurrent development of new spectrometers or new detection schemes is an essential part of our research.

Useful Links

https://www.elettra.eu/lightsources/index.html

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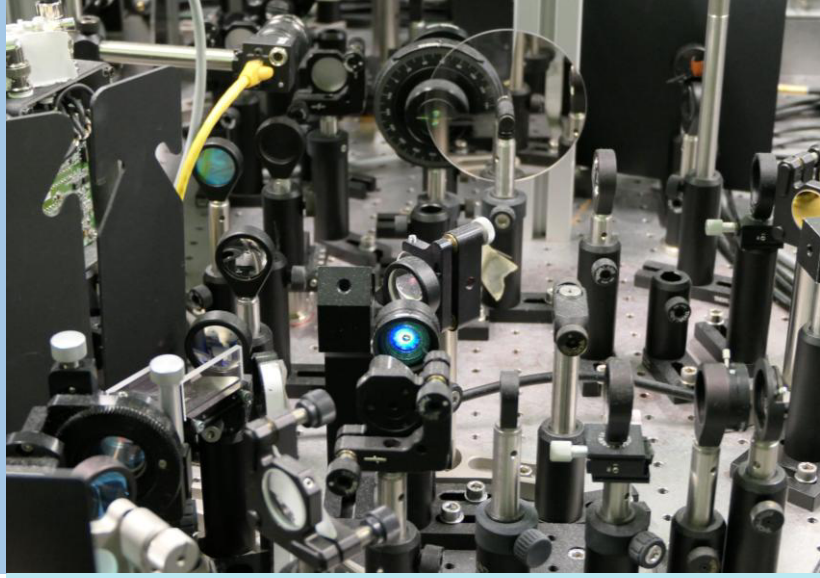
Scientific courses of the Physics Department



UNIVERSITÀ DEGLI STUDI DI TRIESTE

Dipartimento di
Fisica
Dipartimento d'Eccellenza 2023-2027

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The PhD program in Physics at the University of Trieste is integrated into a research and higher education system that is unique in Italy for its exceptional concentration of physics research institutions forming the so-called "Sistema Trieste". The spectrum of research activities is very broad and lies at the forefront of many relevant fields in physics. Next to a significant theoretical and computational research activity, a wide community of experimental physicists belongs both to the University and to public and private research bodies who are actively engaged in a variety of relevant fields. The synergy between the experimental activities and the theoretical and computational ones at the University, as well as with those in all laboratories in Trieste, provide the students of the PhD School of Physics with a very rich and stimulating environment, full of learning opportunities and characterized by an exceptional range of research activities to join which is rare to find elsewhere.

A variety of courses cover advanced topics in:

- nuclear and particle physics
- astrophysics and cosmology
- theoretical and experimental condensed matter physics
- fundamental quantum mechanics,
- field theory and quantum information theory
- quantum optics and AMO physics
- imaging techniques.

Useful Links

https://phd.units.it/en/dot1333595

Transferable skills modules

Elettra - Sincrotrone Trieste offers several courses and workshops per semester (often on-demand or as a partnership with other local institutions), covering the following domains of core competencies and transferable skills:

- Synchrotron/FEL Radiation: Fundamentals, Methods and Applications (biennial school)
- Communication
- Grant Acquisition and Fundraising
- Radiofrequency electronics
- Data management (hardware/ software) and data protection
- Use of generative AI
- Language Courses

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Life in Trieste

Trieste lies at the northernmost tip of the Adriatic Sea in north-eastern Italy, at the head of the Gulf of Trieste on a narrow strip of Italian territory near the border with Slovenia. It is the capital of the autonomous region of Friuli Venezia Giulia.
Thanks to its deep-water port, Trieste is the maritime gateway to Northern Italy, Germany, Austria and Central Europe. It is also an important research centre in Europe and hosts many international organisations and institutions.

It is a city rich in beauty and culture, with a cosmopolitan character influenced by a unique mix of languages, peoples and religions. For centuries it has been a bridge between Central Europe and the Mediterranean, at the crossroads of Latin, Slavic and Germanic cultures. The heart of the city, Piazza Unità d'Italia, is Europe's largest seafront square, surrounded by monumental buildings. It's view from the Molo Audace, a pier extending 200 metres into the sea, is particularly spectacular. Nearby you can admire the majestic Canal Grande and the Greek Orthodox Church of San Nicolò. In the distance, the white silhouette of Miramare Castle gazes out over the gulf. The romantic residence of Maximilian and Charlotte of Habsburg, it now welcomes the public to explore its collection of original furnishings and stroll through its lush park.

Watching the sun set over the sea of Trieste is an exquisite experience, where the golden hours dance on the waves, creating a breathtaking symphony of colours and emotions.

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