

Betatron Radiation Compact Sources: Tapping Opportunities in Cultural Heritage and Life Sciences

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When an intense laser (driver) pulse is focused into a plasma, it can accelerate electrons to GeV-scale energies over short distances, causing them to wiggle at relativistic speed emitting an intense, focused radiation. This phenomenon, known as Laser Wake-Field Acceleration (LWFA) [1], provides a compact and cost-effective avenue to produce a relatively coherent X-ray source with the brightness and spectral characteristics of synchrotron light, combined with a pulsed temporal structure, typical of Free-Electron Lasers (FELs).

The EUPRAXIA Advanced Photon Source (EuAPS), currently under development at the Frascati National Laboratory (LNF, Italy), aims to establish experimental capabilities by the end of 2025 (see Fig. 1a). The driver pulse is generated by the Frascati Laser for Acceleration and Multidisciplinary Experiments (FLAME) system, delivering 25 fs width pulses at 200 TW peak power with a 1-5 Hz repetition rate. This configuration is designed to deliver X-ray pulses with $\sim 10^9$ photons per pulse, a brightness of $\sim 10^{21}$ photons/s/mrad²/mm²/0.1% BW, a beam size of a few μm , and photon energies spanning 1-10 keV (see Fig. 1b) [2].

Commissioning of a preliminary experimental beamline is underway, featuring a 3-meter-long experimental chamber equipped with motorized slits and interchangeable filters, a XYZ- ω sample stage, a movable 2048 \times 2048 pixels CCD X-ray detector, and various sample environment [3]. The chamber is modular in design, permitting additional integration of optical components and detectors for forthcoming applications.

Limited to structural sciences, such source shows promise for crystallographic studies of organic and biological structures, benefiting from the 1–10 keV photon range, as well as in phase contrast imaging and X-ray absorption spectroscopy. Additionally, the micron-sized beam is ideal for spatially resolved investigations of heterogeneous specimens, with potential applications in cultural heritage science where non-destructive analysis of small features is often required.

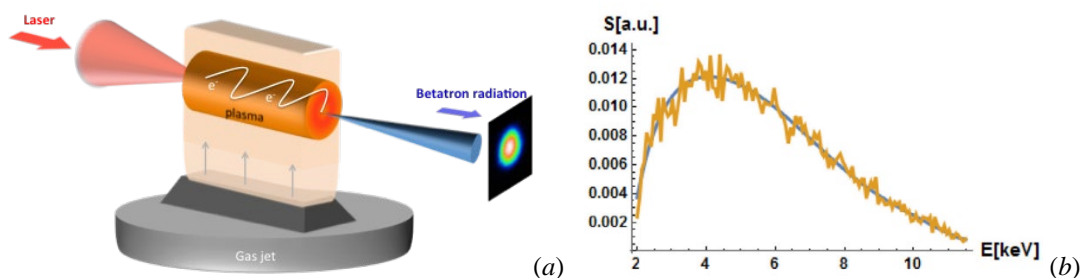


Figure 1. (a) Scheme behind betatron radiation production at FLAME laser facility. (b) Energy profile of EuAPS betatron source.

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