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Katherine E. Weimer Award: X-ray light sources from laser-plasma and laser-electron interaction: development and applications[1]

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Bright sources of x-rays, such as synchrotrons and x-ray free electron lasers (XFEL) are transformational tools for many fields of science. They are used for biology, material science, medicine, or industry. Such sources rely on conventional particle accelerators, where electrons are accelerated to gigaelectronvolts (GeV) energies. The accelerated particles are wiggled in magnetic structures to emit x-ray radiation that is commonly used for molecular crystallography, fluorescence studies, chemical analysis, medical imaging, and many other applications. One of the drawbacks of these machines is their size and cost, because electric field gradients are limited to about 100 V/M in conventional accelerators. Particle acceleration in laser-driven plasmas is an alternative to generate x-rays via betatron emission, Compton scattering, or bremsstrahlung. A plasma can sustain electrical fields many orders of magnitude higher than that in conventional radiofrequency accelerator structures. When short, intense laser pulses are focused into a gas, it produces electron plasma waves in which electrons can be trapped and accelerated to GeV energies. X-ray sources, driven by electrons from laser-wakefield acceleration, have unique properties that are analogous to synchrotron radiation, with a 1000-fold shorter pulse. An important use of x-rays from laser plasma accelerators is in High Energy Density (HED) science, which requires laser and XFEL facilities to create in the laboratory extreme conditions of temperatures and pressures that are usually found in the interiors of stars and planets. To diagnose such extreme states of matter, the development of efficient, versatile and fast (sub-picosecond scale) x-ray probes has become essential. In these experiments, x-ray photons can pass through dense material, and absorption of the x-rays can be directly measured, via spectroscopy or imaging, to inform scientists about the temperature and density of the targets being studied.

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