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Advanced Laser-driven Betatron X-ray Generation

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Ultrafast high-brightness X-ray pulses have proven invaluable for a broad range of research. Such pulses are typically generated via synchrotron emission from relativistic electron bunches using large-scale facilities. Recently, significantly more compact X-ray sources based on laser-wakefield accelerated (LWFA) electron beams have been demonstrated. In particular, laser-driven betatron sources, where the radiation is generated by transverse oscillations of electrons within the plasma accelerator structure can generate highly-brilliant ultrashort X-ray pulses using a comparably simple setup. Here, we present experimental and simulation data that demonstrate significant enhancement of and control over the parameters of LWFA-driven betatron X-ray emission. With our novel Transverse Oscillating Bubble Enhanced Betatron Radiation (TOBER) scheme, we show a significant increase in the number of generated photons by specifically manipulating the amplitude of the betatron oscillations. We realize this through an orchestrated evolution of the temporal laser pulse shape and the accelerating plasma structure. This leads to controlled off-axis injection of electrons that perform large-amplitude collective transverse betatron oscillations, resulting in increased radiation emission. Our concept holds the promise for a method to optimize the X-ray parameters for specific applications, such as time-resolved investigations with spatial and temporal atomic resolution or advanced high-resolution imaging modalities, and the generation of X-ray beams with even higher peak and average brightness.

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