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Bright MeV-energy x-ray beams from a compact all-laser-driven inverse-Compton-scattering source

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Bright MeV energy x-ray beams produced by conventional inverse-Compton-scattering sources are used for nuclear physics research, but their large size (>100-m) restricts accessibility and utilization for real-world radiological applications. By developing a method to integrate a compact laser-driven accelerator with Compton scattering, we have developed a source that produces MeV energy x-rays, but with a four orders-of-magnitude increase in peak brightness, and yet has a size (< 10 m) small enough to fit in a hospital laboratory, or even on a portable platform. Our design employs two independently adjustable laser pulses—one to accelerate electrons by means of a high-gradient laser wakefield, and one to Compton scatter. The use of two separate pulses from the same high-peak-power laser system allowed us to independently optimize the electron accelerator and the Compton scattering process. It also allowed the electron bunch and scattering laser pulse to be spatially overlapped on the micron scale, and be synchronized with femtosecond timing accuracy. The resulting x-ray photon energy was peaked at 1 MeV, and reached up to 4 MeV, which is twenty times higher than from an earlier all-laser-driven Compton source with a different design [K. Ta Phuoc *et al.*, *Nature Photonics* **6**, 308 (2012)]. The total photon number was measured to be 2×10^7; the source size was 5 μm; and the beam divergence angle was $\sim$10 mrad. The measurements were found to be consistent with a theoretical model that included realistic beams. We also discuss the results of the first application of the source, namely, the diagnosis—with micron resolution—of both the radiation source size and the emittance of a laser-wakefield-accelerated electron beam. Ultrafast nuclear science can also be enabled by MeV x-ray energy combined with ultrashort pulse duration (fs).