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Towards gamma-ray free-electron lasers

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Driven by an electron accelerator and equipped with an undulator, the free-electron laser (FEL) is known for its capability to produce x-ray pulses at unprecedented brightness. As of early 2025, five FEL facilities operate at wavelengths in the hard x-ray regime: European XFEL in Germany, LCLS in the USA, PAL-XFEL in Korea, SACLA in Japan and SwissFEL in Switzerland. The present work illustrates the potential to shorten the wavelengths further to the gamma-ray regime.

By means of numerical simulations, a new scheme is demonstrated which utilises the higher harmonics of an x-ray FEL and delivers gamma rays with a good signal-to-background ratio. The new scheme would enable existing x-ray FELs to be operated as gamma-ray lasers, despite the constraints of the electron beam energy and the undulator tuning range.

The gamma-ray laser, with its coherence and spatial resolution, would be a new tool for studying nuclear processes and could open the door to many new discoveries. In his lecture as the 2003 Nobel Laureate in Physics, Vitaly Ginzburg described the gamma-ray laser as one of the 30 most important and interesting problems in physics*.

Footnotes

- V. L. Ginzburg, Rev. Mod. Phys.76, 981 (2004). doi:10.1103/RevModPhys.76.981

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