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Optimisation of Inverse Compton Scattering via spatio-temporal tailoring of the scattering pulse

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All-optical high-energy X-ray (HEX) beam sources based on Inverse Compton Scattering (ICS) are a promising and innovative alternative to conventional sources, enabling the generation of X-ray beams with percent-level bandwidth. These X-rays are generated by colliding a laser pulse with relativistic electron beams from a laser-plasma accelerator. Although a low HEX bandwidth is essential for many applications, current all-optical ICS sources still exhibit bandwidths of tens of percent. In this work, we present experimental results demonstrating the use of a 'Flying Focus' scheme to achieve spatio-temporal shaping of the scattering pulse. In this scheme, a chirped laser pulse and a chromatic focusing system are combined to make different frequencies focus at different positions. This allows the high-intensity region of the laser to interact with the electron beam over distances longer beyond previously published limits. Such focus optimisation—crucial to precisely match the laser pulse with the electron beam—can lead to a significant reduction in the X-rays bandwidth and an increase in the photon yield. This advancement paves the way for tunable, compact X-rays sources applicable in fields such as non-destructive testing of large or dense objects and k-edge subtraction imaging.

Primary author: MARIANI, Cristina (Deutsches Elektronen-Synchrotron DESY)

Co-authors: PODER, Kristjan (DESY); MARTELLI, Lorenzo (Deutsches Elektronen-Synchrotron DESY); MEISEL, Martin (Deutsches Elektronen-Synchrotron DESY)

Presenter: MARIANI, Cristina (Deutsches Elektronen-Synchrotron DESY)

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