Contribution ID: **58** Type: **Oral presentation**

Exploring new possibilities in Compton sources based on free-electron lasers

Tuesday, October 7, 2025 9:45 AM (30 minutes)

Compton sources based on free-electron lasers (FELs) have a long history and have been successfully implemented for practical use, notably as gamma-ray sources utilizing storage rings. A prominent example is the High Intensity Gamma-ray Source (HIGS) facility at Duke University, which delivers tunable gamma-ray beams in the energy range of 1–100 MeV for nuclear physics experiments.
In this presentation, we explore new possibilities for Compton sources employing FELs.
One promising direction is the generation of narrow-band GeV photons using an X-ray FEL oscillator (XFELO). With recent advancements in superconducting accelerator technology, XFELOs are being actively pursued at major facilities such as the European XFEL and SLAC's LCLS-II. Unlike conventional self-amplified spontaneous emission (SASE) XFELs, XFELOs offer highly monochromatic spectra and excellent temporal coherence. In our previous work [1], we proposed a scheme to generate narrow-band GeV photons via Compton scattering of hard X-ray photons from an XFELO. The resulting photon beam exhibits a sharp spectral peak with a bandwidth of approximately 0.1% (FWHM), attributed to the significant momentum transfer from electrons to photons. For typical parameters based on a 7-GeV electron beam operating at a 3-MHz repetition rate, the expected spectral photon density is on the order of 10^2 ph/(MeV·s).
Another potential application is a compact X-ray source utilizing a superradiant infrared FEL oscillator. Infrared FEL oscillators can be operated in the superradiant regime, generating few-cycle optical pulses with high conversion efficiency from the electron beam to the laser pulse. In our experimental work at KU-FEL [2], we successfully demonstrated the generation of superradiant FEL pulses. In this experiment, 19-mJ FEL pulses (peak power of 0.13 TW) were circulated in an optical cavity at a repetition rate of 30 MHz. A compact X-ray source can be realized by leveraging intra-cavity Compton scattering between these FEL pulses and the electron beam to drive the FEL. We will discuss the expected performance of the X-ray source.
[1] R. Hajima, M. Fujiwara, Phys. Rev. Acc. Beams, 19, 020702 (2016).
[2] H. Zen, R. Hajima, H. Ohgaki, Sci. Rep. 13, 6350 (2023).

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Session Classification: Session I