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Thesis Topic Proposal

Institute of Physics, Czech Academy of Sciences
ELI Beamlines laser center

Degree Level: MSc
Starting date: October 1st 2022

Experimental study of gamma-ray generation in high-intensity laser-plasma interactions

Topic Characteristics/Abstract:

Based on an agreement with the student, the thesis will focus on providing much needed experimental insights into physics of extreme magnetic field generation and the resulting efficient production of dense gamma-ray beams in dense laser-irradiated plasmas.

Development of efficient gamma-ray sources for fundamental studies, such as two-photon pair-production, and applications, such as active interrogation, nuclear waste analysis/characterization and medical isotope production, requires an in-depth understanding of the underlying mechanism that this project aims to provide.

The emission of MeV photons can be achieved by driving a multi-Giga Gauss quasi-static azimuthal magnetic field inside a dense plasma that is rendered transparent by an ultra-high-intensity laser pulse. Plasma electrons serve as a mediator in the conversion of the laser energy into a dense beam of energetic gamma-rays.

The confining azimuthal magnetic field facilitates electron energy gain from the laser, while, at the same time, the electron deflections within the magnetic field cause the electrons to emit MeV gamma-rays in the direction of the laser propagation.

The extreme magnetic field strength and high electron energy boost the quantum nonlinearity parameter characterizing the photon emission to the level where a single photon can carry an appreciable fraction of the emitting electron's energy, which ensures high efficiency of gamma-ray emission.

Scope:

The aim of the project is to advance the understanding of ultra-high-intensity laser-plasma interactions by experimentally demonstrating efficient generation of multi-MeV photons via the mechanism that leverages strong plasma magnetic fields.

Both aspects are critical to probing, in the laboratory, phenomena that are currently accessible only in extreme astrophysical environments. Specifically, the project will pave the way to creating matter and antimatter from light alone in laboratory by developing an efficient mechanism for creating dense gamma-ray beams.

None of the existing photon sources are capable of creating electron-positron pairs through gamma-gamma collisions due to low photon density in the MeV energy range.

Methodology/Approach:

This thesis project will depend upon the following research methods for garnering results. The student will first study the topic through a detailed bibliographic study of existing books and articles. The collaborations already established with international colleagues working on the topic will also be an important source of knowledge for the project.

The student will develop new diagnostics in close collaboration with our technical teams. These will then be used during several experimental campaigns at ELI Beamlines. Each campaign will bring new insights to this research so that the student develops the topic and really appropriates it to himself for all the duration of the thesis.

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