Physics for laser power from 1 PW to 100 PW

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We present recent progress and planed experiments in our group with the laser facilities from 1 PW to 100 PW.

Proton acceleration, pair production, and gamma ray generation are studied with 1 PW laser at SIOM. We present experimental studies on ion acceleration using an 800 nm circularly polarized laser pulse interacting with an overdense plasma that is produced by a laser prepulse ionizing an initially ultrathin plastic foil. The proton spectra exhibit spectral peaks at energies up to 9 MeV with energy spreads of 30% and high fluxes. Two-dimensional particle-in-cell simulations reveal that collisionless shocks are efficiently launched by circularly polarized lasers in exploded plasmas, resulting in the acceleration of quasimonoenergetic proton beams. Furthermore, this scheme predicts the generation of quasimonoenergetic proton beams with peak energies of approximately 150 MeV using current laser technology, representing a significant step toward applications such as proton therapy.

For 10 PW laser at SULF, we consider proton acceleration to more than 200 MeV and its application in laser nuclear physics, muon and anti-proton production. Generation of high energy monoenergetic positron beam is proposed. Antiproton beam generation is investigated based on the ultra-intense femtosecond laser pulse by using two-dimensional particle-in-cell and Geant4 simulations. A high-flux proton beam with an energy of tens of GeV is generated in sequential radiation pressure and bubble regime and then shoots into a high-Z target for producing antiprotons. Both yield and energy of the antiproton beam increase almost linearly with the laser intensity. Compared to conventional methods, this new method based on the ultra-intense laser pulse is able to provide a compact, tunable, and ultrafast antiproton source, which is potentially useful for quark-gluon plasma study, all-optical antihydrogen generation, and so on.

Radiation reaction and QED effect in plasma are discussed.For 100 PW laser at SHINE, we discuss the QED effect in vacuum. We introduce the planed experiment for vacuum birefringence. A new experiment design on wave mixing is also discussed. In a two-beam head-to-head colliding of an ultra-fast–super-strong optical laser and a hard X-ray free-electron laser (XFEL), we reveal that the photons, which are created by a partially phase-matched wave-mixing, are scattered into off-axis directions besides the on-axis one. Moreover, if the XFEL beam is focused narrowly enough, the scattered photons will be concentrated in an off- axis ring. This process is analytically demonstrated based on the effective-field model of photon-photon scattering. We estimate the scattered photon number under the parameters of upcoming facilities with 100-PW optical laser and intense XFEL. Since a part of the signal appears in a distinguishable direction with X-ray background, this process will improve the signal-noise ratio in future measurements.

In this talk, we also present our rencet progress on intense vortex laser plasma interaction.

References

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