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Inverse Compton Scattering from Laser accelerated electrons and its application for Stand-off Detection III

レーザー加速電子によるレーザー光の逆コンプトン散乱エックス線発生と遠隔透視応用III

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Interactions between ultra-intense laser and plasma can provide a compact laser-driven electron accelerator. We have demonstrated inverse Compton X-rays from laser-accelerated multiple quasi-mono energetic electrons. The main laser beam accelerate electrons to energies of 14 and 23 MeV, which inversely scattered the secondary laser beam into 6 and 12 keV X-rays, respectively. This quasi-mono energetic electron has divergence of less than 5 mrad and resulting x-lay photons have 30^{o} angular distribution. This demonstrates a novel source of monoenergetic directional ultra-short X-ray pulses in principle. Such directional X-ray can be applied for a stand-off detection in the future.

1. Introduction

Ultra-intense laser technology since 1990s has contributed rapid progresses in physics on interactions between ultra-intense photons and plasma. For example, by using laser wake-field acceleration scheme [1], we can achieve mono-energetic electron beams from energy of 10 to a few GeV within a few-cm acceleration length [2-4]. Laser-plasma acceleration scheme is now on the stage for developing its applications. In order to introduce such innovative technologies into industrial applications, we have compared differences between laser plasma accelerators and conventional RF accelerators. Our conclusion is movability in the future. Using laser-accelerated electrons, a novel source of mono-energetic directional ultra-short X-ray pulses is possible in mobile. This pulse is accomplished by inverse Compton scattering of laser-accelerated electrons with energy range of 100 MeV. This novel X-ray pulse has energy of a few hundred keV, the divergence within 5 mrad, and the pulse duration of less than ps. This directional X-ray pulse can be applied for a stand-off detection in the future. In which, we can prove the inside of stand-off object by detecting the back scattering photons from the object [5]. This manuscript describes present status of inverse Compton Scattering from Laser accelerated electrons.

2. Experimental Results

The blue line in Fig. 1 represents the inverse Compton X-ray spectrum calculated from the experimental electron spectrum. The three calculated peaks at 5, 13, and 22 keV are derived from the multiple quasi-monoenergetic peak of the accelerated electrons; they agree well with the

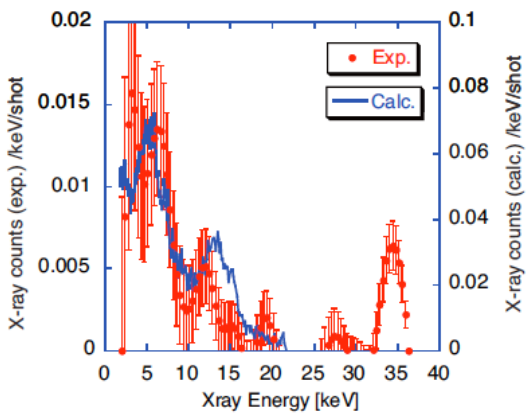

Fig.1. Scattered photon spectrum at θ=0: Red points are experiment data and blue line is calculated from the electron beam spectrum.

experimentally observed photon peaks at 6, 11, and 19 keV. The peaks at 27 and 34 keV are also likely inverse Compton signals from higher energy which beyond our ESM detection range.

Figure 2 shows the angular distribution of inverse Compton scattering counts. Theory predict the beam divergence within 2°, however, the data is spread over 30°. The reason for this may be that the electron beam is not aligned with an angle of zero degrees, but it is slightly shifted due to the dipole magnet. The huge error bar comes from the background bremsstrahlung.

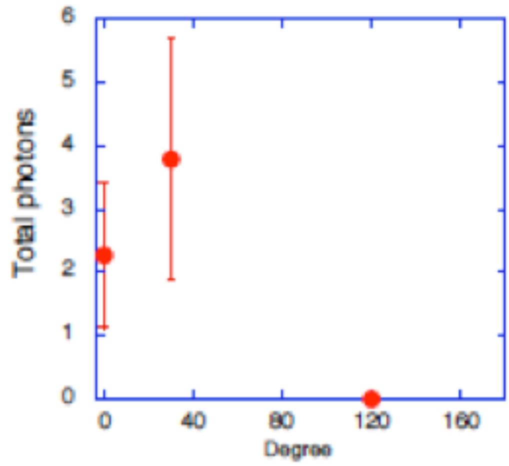

Fig.2. Angular anisotropy of inverse Compton scattering: total number of photons summed over the whole spectrum. Vertical axis is in units of counts/1000 shots.

3. Perspective for stand-off detection

Figure 3 shows the photon energy and divergence of inverse Compton scattering as a function of electron energy. The solid-circle and solid-triangle are from experiments. The X-ray energy E_x scattered from the laser photon energy ε_L is given from the Klein-Nishina formula [6] by:

$$E_x \sim 4\gamma^2 \varepsilon_L \quad (1)$$

where γ is the Lorentz factor of the electron and ε_L is 1.55 eV in our experiments. The angle is defined as 0 in the electron beam direction (i.e., the inverse direction). The scattering angle θ is also given by:

$$\theta \sim 1/\gamma \quad (2)$$

when we achieve X-ray beams with energy beyond 200 keV and divergence within 5 mrad at source point, it becomes 5 cm diameter on the stand-off object which 10 m apart from the source. Such beam is suitable for the application of stand-off detection for human relief in the disaster field.

In conclusion, the experiments shown here is on the way to improve the photon energy and beam divergence of inverse Compton scattering for the application of stand-off detection.

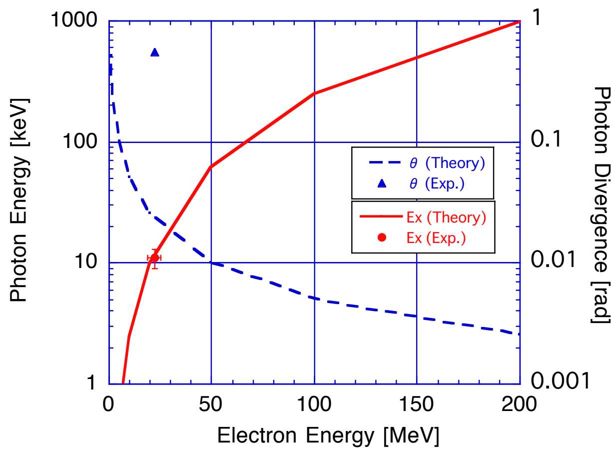

Fig.3. Photon energy and divergence of inverse Compton scattering as a function of electron energy.

Acknowledgments

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