HIGH-POWER ULTRASHORT TERAHERTZ PULSES GENERATED BY A MULTI-FOIL RADIATOR WITH LASER-ACCELERATED ELECTRON PULSES

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Abstract

Terahertz (THz) wave is an attractive source for a variety of research including imaging, spectroscopy, security, etc. We proposed a new scheme of high-power and ultrashort THz generation by using the coherent transition radiation from a cone-shaped multi-foil radiator [1] and a rectangle-shaped multi-foil radiator. To perform the proof-of-principle of the multi-foil THz radiator, we used 80~100 MeV electron bunches from laser-plasma acceleration. While a cone-shaped multi-foil radiator has a circular polarization with a conic wave, we made a rectangle-shaped multi-foil radiator that has a linear polarization in a plane-like wave, which can be used more widely for various applications. We can easily control the power of multi-foil radiator by adjusting the number of foils. We compare the THz power ratio between 2 sheet and multi sheets using cooled bolometer. We will measure the pulse duration and bandwidth of the THz wave from the multi-foil radiators in a single-shot by using electro-optic sampling and cross-correlation method [2].

INTRODUCTION AND BACKGROUND

Since THz wave has different property to existing the electromagnetic wave, it is expected to be critical source in medical industry, security and various researches. But, the THz power from photo conductive antenna, Electro-optics and transition radiation is not sufficient to comercialize the item using the THz wave so far. It is dilemma in the THz industrial region. The new multifoil radiator may achieve gigawatt-level peak power using short electron bunch (70~100MeV, 25fs) [1].

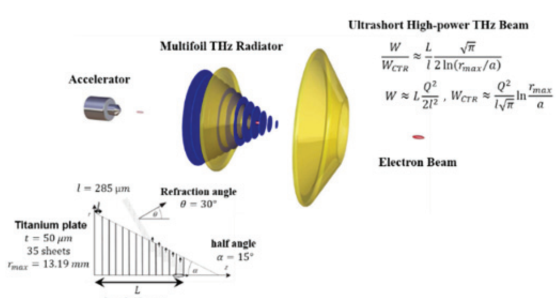

Figure 1: Radial polarization type multifoil radiator.

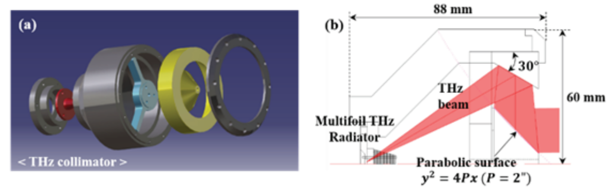

Figure 2. (a) 3D scheme of THz collimator with radiator, (b) The cross-sectional view of THz collimator.

Figure 1 is a THz generation process scheme of the radial polarization type multifoil radiator. 50 µm thickness Circular flat 35 sheets Ti plates with successively decreasing radii are stacked as a truncated cone. The gaps between Ti plates are filled with air and are equal. When short electron bunch propagate through Ti plates along z-axis, transition radiation is generated and is transferred to the edge of radiator along gap of Ti plate as waveguide. At edge of plate, all the transition radiation form one of the wavefront in phase. Then, the coherence wave pulse propagate outward with donut beam shape and it's collimated by special type collimator mirror in Fig. 2.

Figure 3 is linear polarization type radiator, it's consist of a half of the radial polarization type radiator with 5 µm thickness, 70 sheets Ti plates and collimation mirror. In the case that transition radiation by short electron bunch propagate upwards, it is radiated outward without collimation. Other case that transition radiation propagate downwards, it is collimated by parabolic reflector. This reflected and collimated beam is propagated along Ti plate. Finally, it is radiated outward with linear polarization as same process radial type radiator.

Figure 4 shows real image of the radial polarization type multifoil radiator and the linear polarization type multifoil radiator.

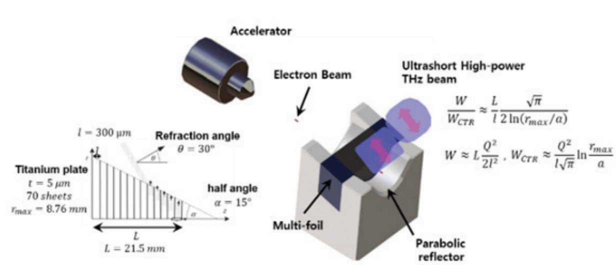

Figure 3: Linear polarization type multifoil radiator.

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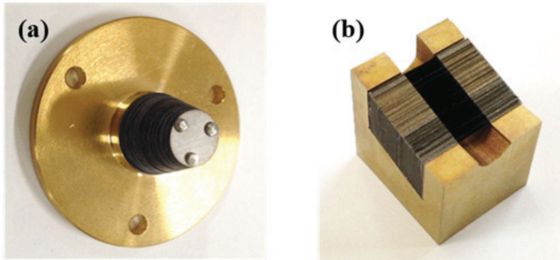

Figure 4: Real image of (a) Radial polarization type multifoil radiator, (b) Linear polarization type multifoil radiator.

Figure 5 is THz single pulse measurement scheme. We use 800 nm, 250 ps, 2.8 mJ and 10Hz chirped pulse amplification (CPA) laser. It is divided into two parts. One of ray is for probe beam. It has phase modulation by Electro-optics (EO) effect when THz beam and probe beam co-propagate through EO crystal temporally and spatially. We can distinguish modulation using two crossed polarizers system (near zero optical transmission). Other beam is for cross-correlation beam such as gating beam. Firstly, its 250ps pulse duration is converted to 50fs narrow pulse beam by two grating compressing system for high resolution in cross-correlation system. When gating beam and modulated probe beam are crossed at Beta Barium Borate (BBO) crystal temporally and spatially, some part of energy is converted to 400nm second harmonic beam (SHB) along bisectional angle of two beam line.

$$I_{SHG}(x) \propto \int_{-\infty}^{+\infty} I_{EO}(t+\tau) I_{gate}(t-\tau)\, dt \qquad (1)$$

Finally, we can get the signal by subtracting probe beam from modulated probe beam and calibrate it by delay line for time difference between probe and gating beam. [2].

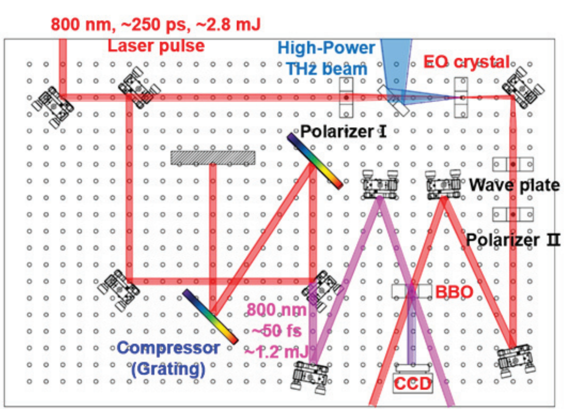

Figure 5: Single pulse measurement system.

RESULT

Figure 6 is the comparison of the power of 2 sheets and 70 sheets Ti plates with 5 µm thickness and 300 µm gap of linear polarization type multifoil radiator. The ratio of multi foil and single foil radiator is

$$\frac{W}{W_{CTR}} \approx \frac{L}{l} \frac{\sqrt{\pi}}{2\ln(r_{max}/a)}, \qquad (2)$$

where L is the radiator total height along z-axis, l is the gap size between Ti plates, r_{max} is the radius of the Ti plate and a is the cross-sectional diameter along x-axis. The theory ratio is 27.23 and experiment ratio is 11.8. The reason of the difference is the diffraction of the edge of 2 sheet Ti plates radiator. Therefore, it is not properly collimated to cooled bolometer. In order to reduce this experiment error, we will use common 1 sheet Ti plate radiator.

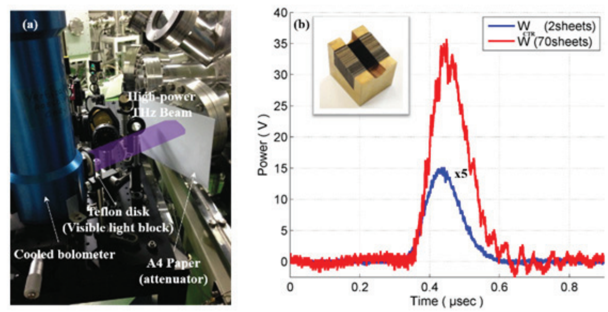

Figure 6: (a) THz power measurement system with cooled bolometer, visible light block and attenuator, (b) Comparison of the power for 2 sheets Ti plate and 70sheets Ti plates of linear polarization type multifoil radiator.

We use cross-correlation method for studying THz pulse from multifoil radiator and to match pulses timing between THz generation beam (30 fs), gate beam (50 fs) and probe beam (300 ps). Figure 7 are second harmonic beam between beams. Figire 7(a) is for matching pulse timing between THz pulse and probe pulse at EO crystal. Figure 7(b) is for matching pulse timing between modulated beam and gate pulse at BBO crystal. In the case that probe beam is modulated by electric field at EO crystal, we can find different part from SHB without unmodulated probe beam.

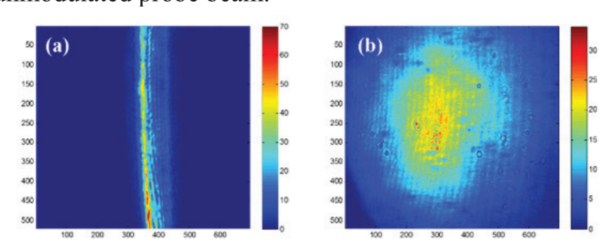

Figure 7: SHB Images of (a) THz generation beam (30 fs) and gate beam (50 fs), (b) Probe beam (300 ps) and gate beam (50 fs).

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