ULTRA-BRIGHT X-RAY GENERATION USING INVERSE COMPTON SCATTERING OF PICOSECOND CO_2 LASER PULSES

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Abstract

Laser-Compton scattering with picosecond CO_2 laser pulses is proposed for generation of high-brightness x-rays. The interaction chamber has been developed and the experiment is scheduled for the generation of the x-rays of 4.7 keV, 10^7 photons in 10-ps pulse width using 50-MeV, 0.5-nC relativistic electron bunches and 6 GW CO_2 laser.

1 INTRODUCTION

Laser Compton scattering can generate x-rays or γ-rays with high brightness and controlled polarization by applying high-peak-power laser pulses to relativistic electron bunches. We propose to use laser this method for generating circularly polarized γ-rays which, by pair-creation, produce circularly polarized positrons for JLC (Japan Linear Collider) project [1]. In this scheme, a picosecond CO_2 laser will be used as a photon source for Compton scattering. This choice is based on the wavelength proportional increase of laser photon flux per joule of the laser energy, the average power scalability, high wall-plug efficiency, and a capability to the high-repetition rate operation. In general, Compton scattering with CO_2 laser has a promise to become a compact, high-intensity, monochromatic, femtosecond x-ray source for a variety of applications beyond the polarized positron source [2].

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2 EXPERIMENTAL SETUP

We have developed a laser-Compton scattering chamber for the proof-of-principle experiment, in which counter-propagating electron and CO_2 laser pulses collide at the focal point. Fig. 1 shows the conceptual drawing of the Compton chamber to be installed in the linac beamline of the Accelerator Test Facility at Brookhaven National Laboratory. Picosecond CO_2 laser beam is introduced through the side window and focused by an off-axis parabolic Cu mirror of the 50 mm diameter with the focal length of 15 cm. The Cu mirror has 5 mm diameter hole along the electron beam axis to let electrons pass through. An axicon telescope is placed on the CO_2 beam axis just before the Compton chamber. This telescope serves to modify the Gaussian spatial profile of the incident laser beam into the "donut"-shaped profile, as is shown in Fig. 2-(a). This allows the laser radiation to bypass the hole in the focusing parabolic mirror. Fig. 2-(b) represents a numerically calculated CO_2 beam profile at the focal point. The estimated beam waist size is about 100 μm (FWHM), that corresponds to the electron beam size at the colliding point. Diverging after the focal point the spent laser beam is recollimated by another parabolic Cu mirror and is extracted from the chamber through the output window.

The diagram of the experimental setup is shown in Fig. 3. Picosecond YAG laser pulses are split and delivered to the photo-cathode of the RF gun and for the CO_2 pulse slicing to the 180 ps FWHM by the optical semiconductor optical switching method. The sliced CO_2 pulses are amplified up to 6 GW by the high-pressure TE CO_2 regenerative laser amplifier [3].

Electron bunches with the charge of about 0.5 nC are generated by a photo-cathode RF gun. They are accelerated up to 50 MeV in the RF linac and focused by quadrupole magnets at the center of the chamber.

Since the same mode-locked YAG laser controls both processes of the CO_2 pulse slicing and photo-cathode illumination, the timing jitter between the CO_2 laser and

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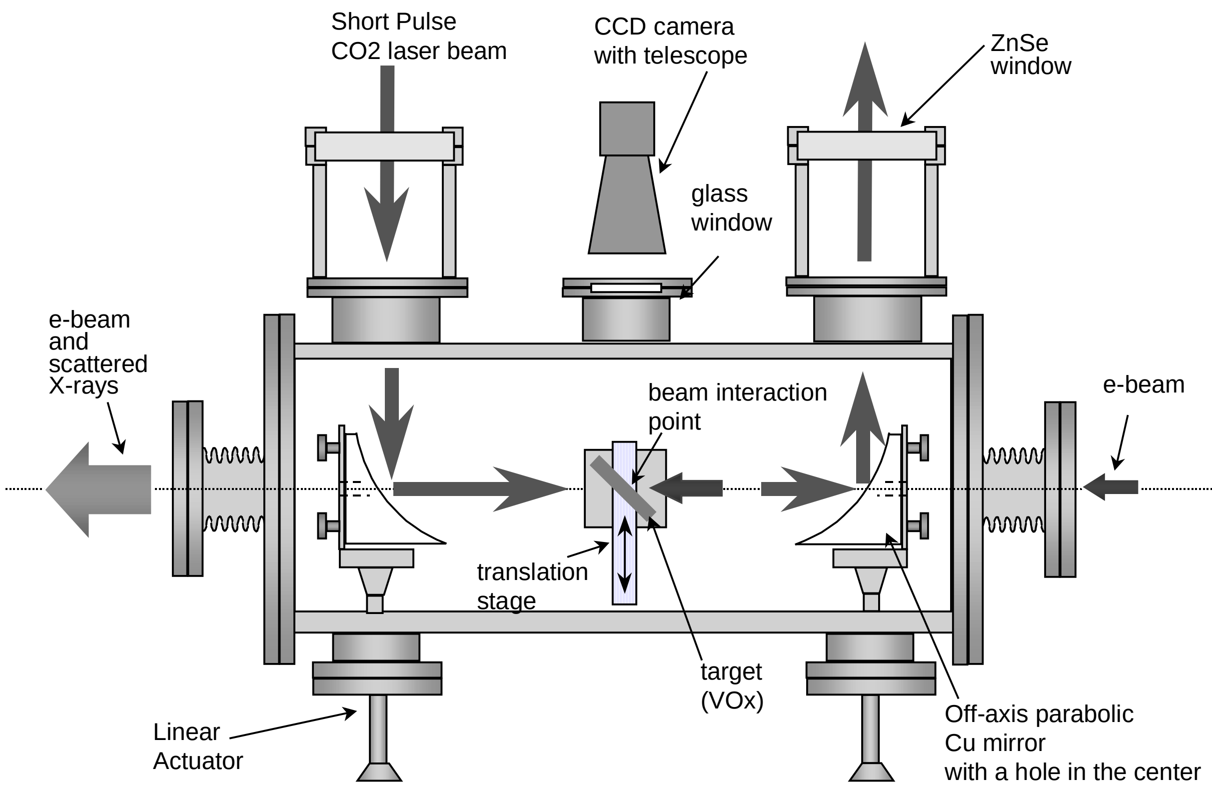

Fig. 1 Top view of the Compton chamber

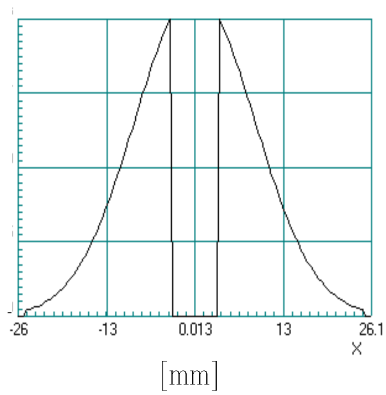

Fig. 2-(a) CO_2 beam profile
at the entrance window

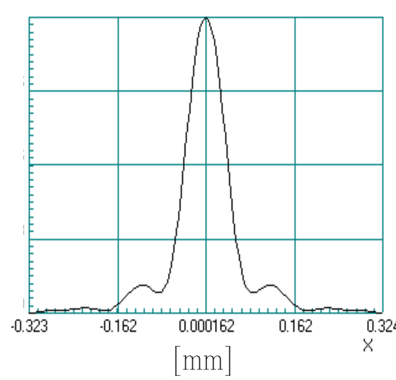

Fig. 2-(b) CO_2 beam profile
at the focal point

electron bunches is negligible to compare with the pulse duration.

For fine alignment of the laser and electron beams at the colliding point and the observation of their spatial profiles, we use a target composed of the vanadium oxide thin film coated on a mica substrate. This coating is sensitive to both electron and mid-infrared beams. In the preliminary test with a focused picosecond CO_2 laser pulse, beam profile image was clearly visible as about 100 μm wide blackened spot. The image capture for the mid-infrared beam is physically based on the film reflectivity change in the visible region due to the phase transition in the oxidized vanadium crystal structure heated by the laser beam. Since the reflectivity shows hysteresis nature in the response to the temperature, the laser spot image can be "grabbed" by maintaining the target temperature around 55^0C.

Upon interaction of the 0.5 J laser pulse with the 0.5 nC electron bunch, we expect to observe up to 10^7 of the Compton scattered x-ray photons with the maximum energy of 4.7 keV and the angular divergence of 10 mrad. The x-ray pulse width will be 10 ps, which is approximately the same as the electron bunch length. The scattered x-rays will be detected by a silicon photodiode placed behind the Be window downstream of the dipole magnet that serves to separate electron and x-ray beams.

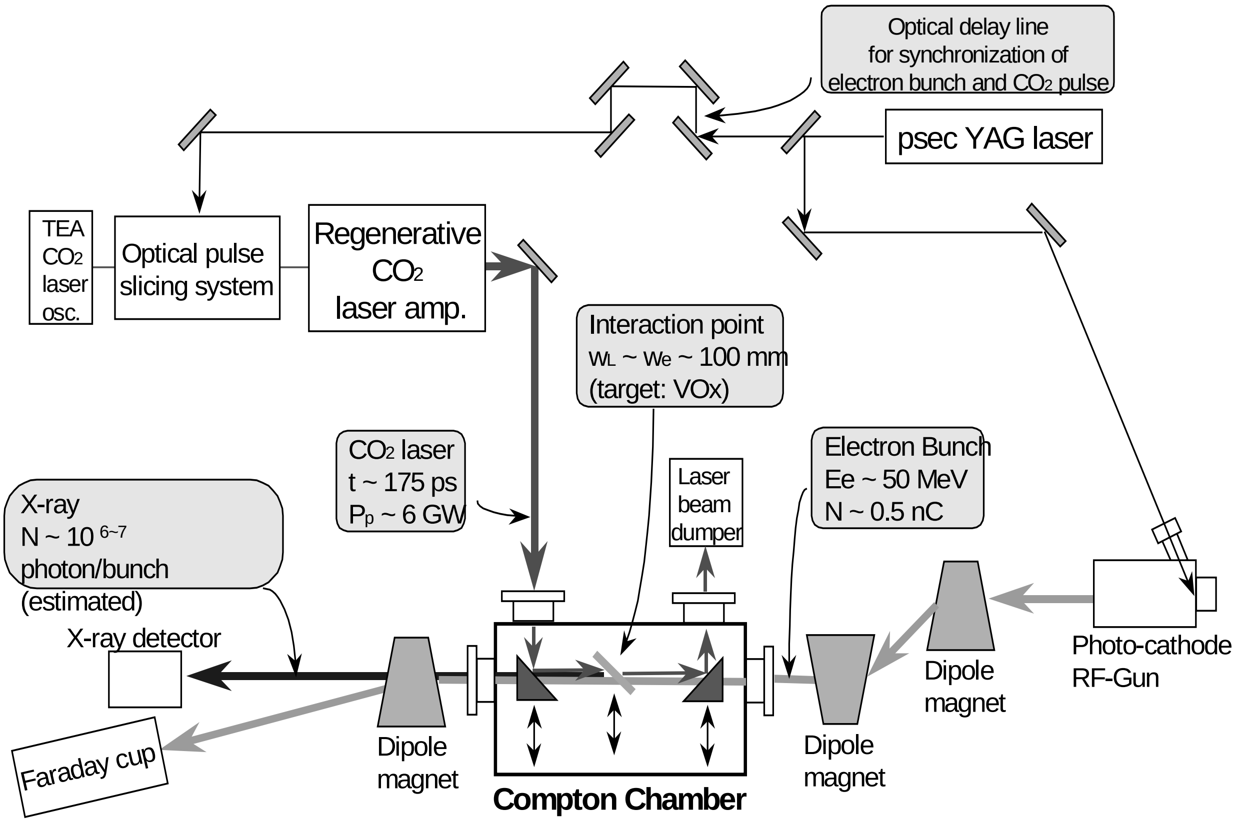

FIG. 3 EXPERIMENTAL SETUP

3 SUMMARY

The experiment to observe high-brightness x-ray generation using Compton scattering of the relativistic electron beam with the picosecond CO_2 laser is scheduled at the BNL Accelerator Test Facility.

The laser pulse to be applied to this experiment has about 6 GW peak power and the 180 ps pulse width, which is longer than the laser waist length at the interaction region. In order to decrease the laser pulse length, multi-step pulse slicing system will be assembled and applied in the future experiments. In addition, 10-atm TE CO_2 power amplifier is planned to be installed to increase the laser peak power up to the 1 TW level.

4 REFERENCES

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