

High current electron generation by Fundamental/Second harmonics mixed LFEX

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Energetic electrons generated by intense lasers are used in a wide range of experimental plasma physics scenarios, such as an electron or ion generation, X-ray sources in plasma physics and fast ignition inertial confinement fusion.

An improvement of electron generation efficiency brings a great progress in all of these researches. We describe here investigations of a new method of greatly improving the efficiency of laser-driven electron generation by modifying the harmonic structure and polarization of laser light before it strikes the conversion target. In this study, LFEX laser which has a wavelength of 1053 nm was converted to second harmonics with a wavelength of 527 nm with a conversion efficiency of up to 23% for over 100 J input energy, and create a two waves mixture of them. A unique optical layout was utilized; a thin LBO ($\text{Li}_2\text{B}_3\text{O}_5$) frequency converting crystal converts LFEX beam having 1053-nm wavelength to a second harmonics having 527-nm after focal optics just before a target.

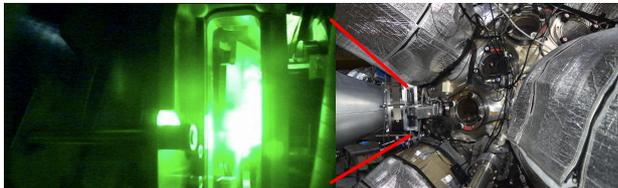


Figure 1 LFEX-Frequency converting system installed on GEKKO-XII system

Figure 1 shows a photo of frequency converting crystal system installed on LFEX. The crystal can be installed and removed easily by a shot to a shot. Frequency converting of focusing beam was technically difficult since which contains various angle to the frequency converting crystal, and usually only a fraction of the laser beam is converted to second harmonics where crystal angle is matched to the laser axis, however by selecting LBO crystal and designing a thin (1.5mm) thickness, we realized the conversion of entire part.

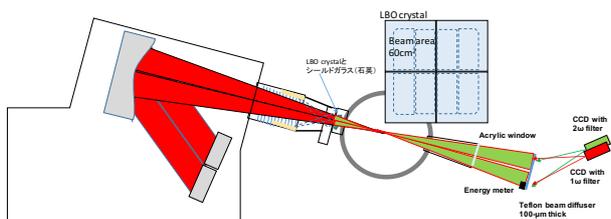


Figure 2 Experimental setup to measure the frequency

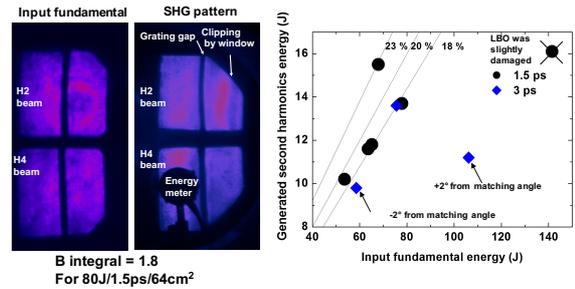


Figure 3 Left: The near field pattern of fundamental injecting LFEX to the LBO and that of second harmonics showing entire beam was successfully converted. Right the frequency conversion efficiency resulted in the experiment.

conversion efficiency. As shown in Fig2, the frequency conversion efficiency and damage limit of the system was evaluated. It resulted in frequency doubling at an efficiency of up to 23 % and produced a laser beam with a mixture of 1053-nm and 527-nm wavelength. The damage threshold was 140J/beam at LBO crystal for 1.5ps pulse duration. A theoretical calculation predicted that up to 50% conversion is possible with 0.5-mm thick (three times thinner than this time) LBO crystal thickness, and which can increase the damage threshold. As shown in Fig3 left, the input beam pattern was successfully converted entirely to second harmonics.

Besides the laser engineering, a new electron acceleration behavior physics was also found out by using the laser. A combination of two beams improved a number of electron detected was more than twice in less than 1 MeV energy region.

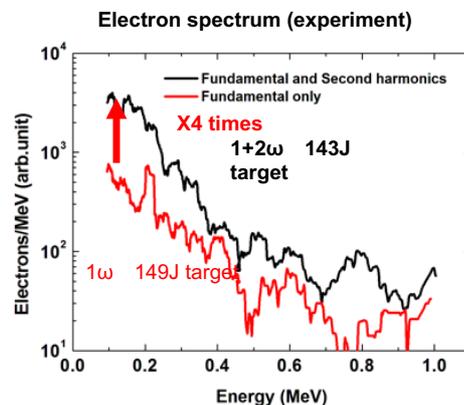


Figure 4 Electron energy spectrum for 1ω only and $1+2\omega$ mixing condition.

This result was agreed with proton energy spectrum and hard X-ray spectrum which confirmed the number of electron (current) was surely improved. The phenomena were explained theoretically; the second harmonics beam created high density plasma at laser –plasma interaction surface the fundamental beam can also interacted with the high density plasma. In addition, by mixing two color beams “8” motion circular polarization was created. These two unique conditions were considered to realized such excellent results.

Outcomes

1. Invited talk on international conference IFSA 2019 Osaka, Y. Arikawa, et al., “Second harmonics generation on LFEX”,
2. Funding; Grant in Aid B, “Study on efficient plasma heating by mixing of two-color lasers”

Acknowledgement

We greatly appreciated the support of LFEX team for developing of second harmonics generation system. We also thank Dr. Tsubakimoto developed a theoretical simulation code for expect laser frequency conversion of this situation.