Investigation of Broadband-laser-induced Plasma Interaction and ablation properties

Inertial Confinement Fusion (ICF) is one of the critical technical approaches to achieving controlled fusion energy. The successful achievement of ignition at the National Ignition Facility (NIF) has further confirmed the technical feasibility of ICF. However, although the ignition has been achieved, research into higher gains and lower driving conditions remains an important next step. Laser plasma interaction (LPI) and laser ablation properties are the key issues in laser-driven inertial confinement fusion ignition (ICF), as it may affect target compression and fusion energy gain [1]. Broadband laser technology is one novel option that may inhibit the related processes of LPI and thus enhance the absorption efficiency.

One broadband double-frequency laser facility (named as Kunwu) with an output energy of hundreds of joules (532nm, Δω/ω: 0.6%, 700J) by using the superluminescent diode (SLD) technology has now been built by the researchers from Shanghai Institute of Laser Plasma [2]. Based on kunwu facility, several preliminary experiments into broadband-laser-driven laser plasma instabilities were carried out by our group. Through direct comparison with the LPI results for the traditional narrowband laser, the actual LPI-suppression effect of the broadband laser was shown. The former work shows that broadband laser had a clear suppression effect on both the back-stimulated Raman scattering and the back-stimulated Brillouin scattering at laser intensities below 1×10^{15} Wcm^{-2}[3-4]. Furthermore, The results also show that the target coupling absorption efficiency of broadband laser is higher than that of narrowband laser[5].

In a follow-up experiment, we observed a new phenomenon. We tested the laser transmission energy with target of different thickness driven by broadband laser or narrowband laser. Figure 1(a) shows the transmission energy. we've found that it has significantly higher transmission energy for the target driven by broadband laser than narrowband laser.

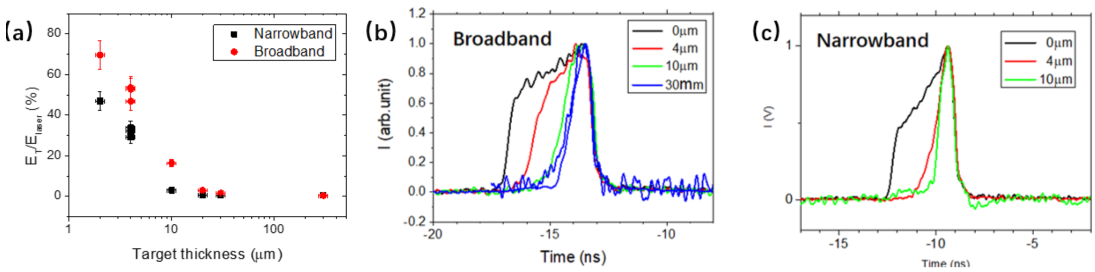

Figure 1(a) The transmission energy of C_8H_8 with different thickness. The time waveform of the transmission signal of C_8H_8 with different thickness for (b) broadband and (c) narrowband laser.

Figure 2 shows the time-resolved spectral signals results of generated LPI backscattered signals for C_8H_8 target of different thicknesses. It can be clearly seen that the broadband laser burns through targets faster.

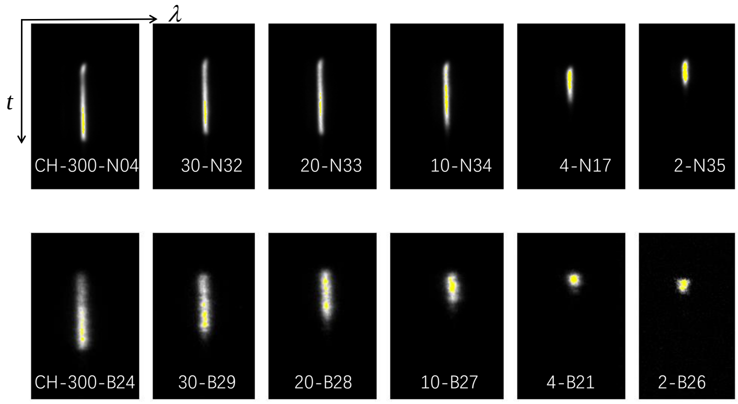

Figure 2 The time waveform of the transmission signal of C_8H_8 with different thickness.

The plasma generated and coupled by laser incident on target can be such important. As it directly determines the efficiency and quality of the energy conversion. Higher transmission energy may indicate less energy loss during the laser interact with the plasma corona of the imploding capsule. Furthermore, tn our experiment, the ablation pressure of aluminum was also measured under narrowband and broadband laser condition, with the results presented in Figure 3. The results show that, compared with traditional narrowband laser, broadband laser effectively enhanced the ablation pressure.

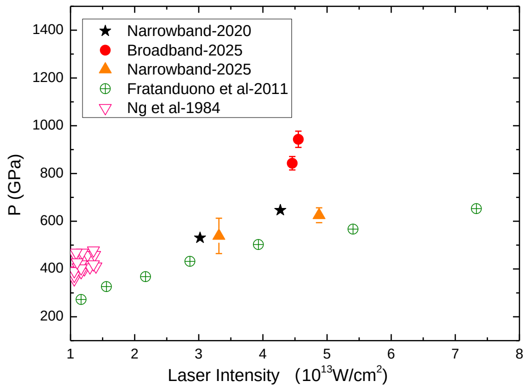

Figure 3 The ablation pressure of aluminum under narrowband and broadband laser condition.

Thus, this interesting and valuable experimental phenomenon may have influence on the fundamental understanding of the related processes of laser plasma interaction of novel broadband low- coherence laser facility.

References:

[1] J. D. Lindl, et al., Phys. Plasmas. 11, (2004) 339.
[2] Y.Q. Gao, et al., Matter Radiat. Extremes. 5, (2020) 065201.
[3] A.L. Lei, et al., Phys. Rev. Lett, 132 (2024) 035102.
[4] P.P. Wang, et al., Matter Radiat. Extremes. 9, (2024) 015602.
[5] N. Kang, et al., Nucl. Fusion 65 (2025) 026042.