High-energy proton generation from nanometer targets driven by a petawatt laser

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Irradiating nanometer targets with a petawatt laser is promising to produce ultrashort high-energetic protons[1]. Acceleration of laser-driven protons over 100 MeV is still a worldwide challenge for the ultra-intense laser community. Further enhancing the proton energy necessitates a thorough understanding of the regime of laser-plasma interaction, of which direct detection is quite challenging but may be derived by measuring the energy, beam profile and spectrum of the transmitted light.

Here we report the proton acceleration results when irradiating a petawatt laser with a peak intensity over 10^{21} W/cm^2 on a nanometer plastic (F8BT) target at an incident angle of 36°. Highly efficient double plasma mirrors[2] were utilized to ensure a laser contrast high enough for nanometer targets. As shown in Fig. 1(a), a systematic measurement of the energy and profile of the transmitted laser was performed on-line based on a CCD camera and a Teflon screen installed downstream the target. The linearity of this method was first validated by varying the laser energy in the case of empty targets. Then a positive correlation between the proton energy and the laser transmittance was measured during the scan of laser focal position, since a larger transmittance represents a higher laser intensity. The target thickness was also scanned indicating an optimal thickness of around 30 nm with the maximum proton cut-off energy, as displayed in Fig. 1(b). Besides the laser transmittance, the profile of the transmitted light on the screen was also analyzed. Elliptical transmitted spots were measured for almost half of the shots, with the eccentricity and the angle of slope varied shot by shot.

To uncover the underlying physics of the measured transmitted light, particle-in-cell (PIC) simulations were performed. Here a long-standing challenge is to relate the small-scale (tens of micrometers) PIC simulations to the large-scale (tens of centimeters) transmitted spots, as their sizes span four orders of magnitude. We developed a method based on the angular spectrum method and the rescaled Fourier transform to realize a near-field and far-field transform. As shown in Fig. 1(c), the simulated laser transmittance and proton cut-off energy fit well with the experimental measurements. Detailed analyses on the profiles and spectra of the transmitted light were also performed by varying the laser parameters in simulations to speculate the real experimental conditions.

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References

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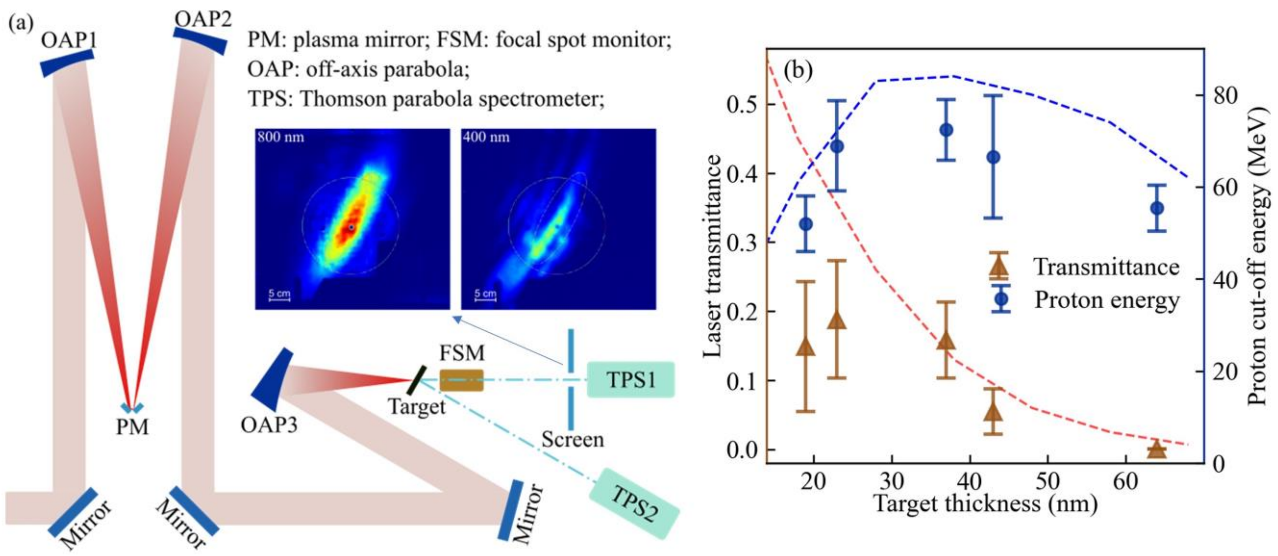

Figure 1. Experimental lay-out and results. (a) Schematic diagram of the experimental set-up. (b) Comparison of experimental (solid dots) and simulated (dashed lines) results for different target thicknesses.