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Turbulent magnetic reconnection generated by intense lasers and electron acceleration

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Turbulent magnetic reconnection is believed to occur in astrophysical plasmas, and it has been suggested to be a trigger of solar fares. It often occurs in long stretched and fragmented current sheets. Recent observations by the Parker Solar Probe, the Solar Dynamics Observatory and in situ satellite missions agree with signatures expected from turbulent reconnection. However, the underlying mechanisms, including how magnetic energy stored in the Sun's magnetic feld is dissipated, remain unclear.

With the development of high-power lasers, efforts to experimentally simulate astrophysical processes in the laboratory are increasingly being made. In one example, loop-top X-ray source and reconnection outflows in solar flares are being modelled experimentally by intense lasers[1] at Shenguang (SG) II laser facility. It has also been found that electrons can be accelerated to the relativistic regime in a laser-driven benchtop experiment for the laboratory simulation of solar flares[2].

Here we demonstrate turbulent magnetic reconnection in laser-generated plasmas created when irradiating solid targets. Turbulence is generated by strongly driven magnetic reconnection, which fragments the current sheet, and we also observe the formation of multiple magnetic islands and fux-tubes. Our fndings reproduce key features of solar fare observations. Supported by kinetic simulations, we reveal the mechanism underlying the electron acceleration in turbulent magnetic reconnection, which is dominated by the parallel electric feld, whereas the betatron mechanism plays a cooling role and Fermi acceleration is negligible[2]. Figure 1 shows Laser-driven turbulent magnetic reconnection experiments. This work is supported by the National Key RD Program of China (grant nos. 2022YFA1603200 and 2022YFA1603203) and the National Natural Science Foundation of China (grant nos. 12175018, 12135001, U1930108, 12075030 and 11903006) and the Strategic Priority Research Program of the Chinese Academy of Sciences (grant no. XDA25030700).

References

[1] Jiayong Zhong *et al*, Nat. Phys. 6, 984–987 (2010).
[2] Jiayong Zhong *et al*, Astrophys. J. Suppl. 225, 30 (2016) .
[3] Yongli Ping *et al*, Nat. Phys. 19, 263–270 (2023).

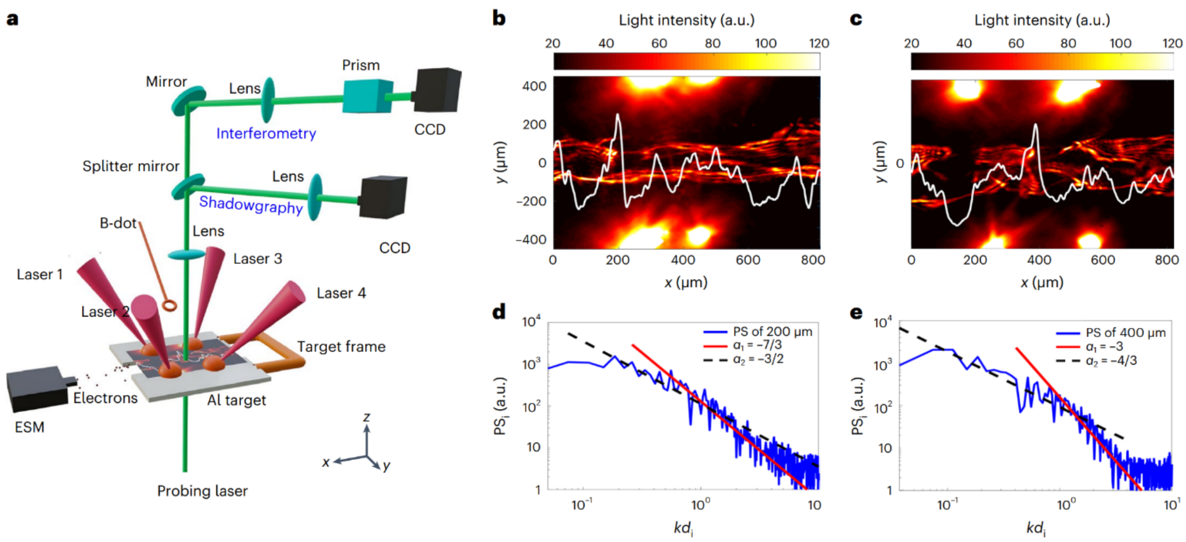

Fig. 1 | Laser-driven turbulent magnetic reconnection experiments. a, The experimental set-up. Four beams of long-pulse (1 ns) lasers are focused on two aluminium (Al) foil targets, which are separated by a 600-μm-wide slit. Shadowgraphy and interferometry measurements with a 60-ps green laser beam are used to observe the evolution of the plasma. One electron spectrometer (ESM) is positioned along the slice midplane to face the outflow. The magnetic field is monitored by a B-dot probe, which is located 45 mm from the centre of the targets. CCD, charge-coupled device. **b**,**c**, Optical shadowgraphy results, 1 ns after laser irradiation on the targets, for cases I (**b**) and II (**c**). The colour bar indicates the light intensity from the target. The darker areas of the shadowgraphy images indicate higher refractive index, corresponding to high plasma-density gradients, the brightest spots are the laser irradiation positions, and the white lines show the light intensity of shadowgraphy measurements averaged over the current sheet width. **d**,**e**, Power spectra of the average light intensity, PS$_i$, obtained by a fast Fourier transform of the white lines of **b** and **c** in cases I (**d**) and II (**e**), fitted by two power laws (red solid and black dashed lines). Here, k is the wavenumber along the current sheet in the x direction and d_i ($=c/\omega_{pi}$) is the ion inertial scale with $\omega_{pi} = \sqrt{4\pi n_i e^2/m_i}$, e is the element charge and m_i is the ion mass with $m_i = 1{,}836m_e$ in experimental analyses. n_i is the number density of ion.