4-2 Improvement of Reflectivity of Relativistic Flying Mirrors

— Demonstration of Efficient Reflection of Laser Light from Plasma Waves —

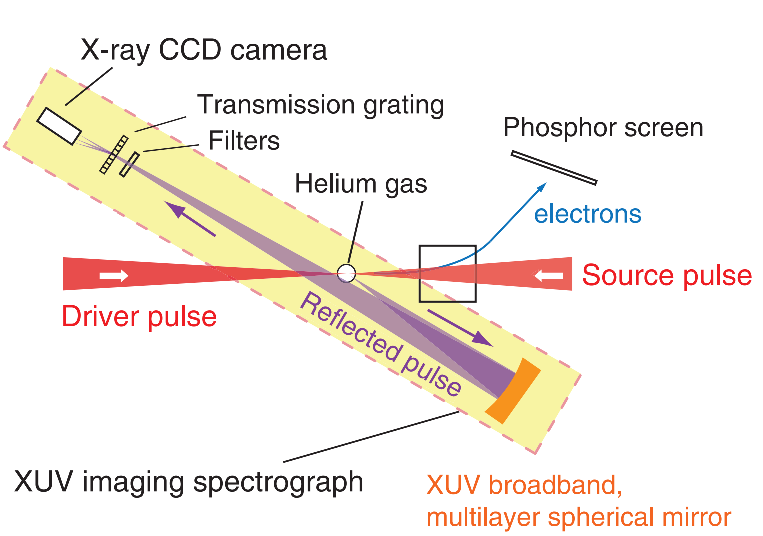

Fig.4-4 Setup of the counter-propagating flying mirror experiment
The driver (source) pulse has an energy of 400 mJ (42 mJ) and a pulse duration of 27 fs (34 fs). They are focused onto He gas with spot diameters of ~30 μm. An extreme ultraviolet (XUV) imaging spectrograph covering the wavelength range from 12.5 to 22.0 nm is used to measure the reflected light from the flying mirrors. The spectrograph consists of a broadband multilayer spherical mirror, a transmission grating, filters, and an X-ray CCD camera.

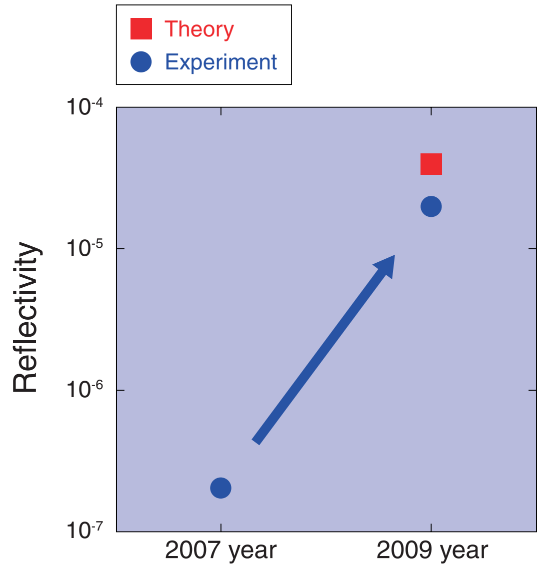

Fig.4-5 Improvement of the reflectivity of the flying mirrors
In the first proof-of-principle experiment (2007), the reflectivity of the flying mirrors was 1000 times smaller than that the theoretical estimate. However, this time (2009), it is close to the theoretical estimate, which indicates high efficiency.

We invented flying mirrors that propagate in plasma almost at the speed of light by using intense laser pulses. The flying mirror is a dense plasma electron shell whose velocity is equal to the group velocity of laser pulses propagating in the plasma. Because it can be used as a mirror that reflects light, the flying mirror is expected to be an effective device for increasing the intensity of the laser and converting it to ultrashort, coherent X-rays. In 2007, we demonstrated that such a flying mirror was produced and that it could reflect incoming laser pulses. However, the number of reflected photons was smaller than the theoretical estimate.

To improve reflectivity, we improved two major points in our experiment. In the first experiment, the laser used was relatively weak, just 3 TW. Therefore, we used the 10 TW J-KAREN laser at our institute. In addition, we changed the experimental configuration. In the first experiment, the source pulse (pulse to be reflected) was directed at an angle, but we adopted a counter-propagating setup.

In the counter-propagating setup, a laser pulse that produces flying mirrors (driver pulse) and the source pulse should be overlapped within 30 μm. For this purpose, we have developed a new monitoring system that samples a part of the returning laser pulses. In addition, we have implemented an extreme ultra-violet (XUV) imaging spectrograph with a wide acceptance angle range to measure the reflected light in the counter-propagating setup as shown in Fig.4-4.

After careful adjustment of the collision of the two laser pulses in plasma, we observe a broad spectrum ranging from 12.5 to 22.0 nm in the XUV spectrograph. This corresponds to the flying mirror velocity that is 98%~99% of the light speed. This value is consistent with the one calculated from the plasma density. The obtained photon number is 7.9×10^9, and the reflectivity is 2×10^{-5}. The reflectivity, as shown in Fig.4-5, is half of the theoretical estimate. Thus, we have proved that the flying mirror has a high reflectivity as predicted theoretically. The photon number is higher than that in 2007 by 10^6. This result verifies the realization of high-brightness X-ray sources based on flying mirrors.

Reference
Kando, M. et al., Enhancement of Photon Number Reflected by the Relativistic Flying Mirror, Physical Review Letters, vol.103, issue 23, 2009, p.235003-1-235003-4.