Profile measurement of laser microbeam produced by glass capillaries: tilt dependence

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Tapered glass capillaries can simultaneously produce ion and laser microbeams with diameters of several tens of μm.[1,2] In the irradiation experiments at the RIKEN Pelletron facility, for example, H and He ions with energies of a few MeV are used. Their ranges are only about 100 μm in water at most. Since it is difficult to confirm incidence on the target by using detectors, the use of a μm-order laser sight system prior to the ion irradiation plays an important role in avoiding mis-shootings.[3] The μm-order laser sight through a capillary was demonstrated with visible light and then extended to UV in 2018.[4] This may be applicable to shorter wavelengths such as X-rays. Moreover, a multi-quantum beam (laser + ion) or (laser + laser) transmission through a capillary will be feasible. However, the transmission property is different between lasers and ions. Here, a laser beam bending along the tilted capillary axis is reported, which is known as the guiding effect for keV-energy ion microbeams through the capillaries without any magnetic field.

Figure 1 shows the experimental setup. A UV laser 375 nm in wavelength was extracted from a semiconductor laser source (THORLABS L375P70MLD; max.70 mW), and it entered a capillary mounted on a precise stage after reflection on two mirrors. The power of the laser microbeam was measured at a photodiode (OPHIR PD300) after a slit, which shields the scattered light from the taper part of the capillary. The microbeam was cut by a knife edge attached on a motorized stage (SURUGA SEIKI XYCV620-G-N) with a scan length and minimal step of 2 mm and 0.5 μm, respectively. The knife edge was located 3 mm downstream of the capillary outlet, of which the corresponding distance from the center of the tilting (θ) was 72 mm for a capillary with an outlet of 18 μmϕ.

The profiles were obtained by differentiating the beam power as a function of the knife-edge position. The peak shift according to θ is shown in Fig. 2. A steeper decrease for the $\theta(+)$ tilting, *i.e.*, an asymmetry of the profiles in the $\theta(+)$ and $\theta(-)$ tilting, can be found and may be attributed to the slightly asymmetric shape of capillaries. Satellite peaks are due to higher-order rings of the Fraunhofer pattern.[1] The angles reconstructed from the measured peak positions are summarized for five outlet sizes, as shown in Fig. 3. The reconstructed angle is found to be nearly proportional to θ. The solid line shows $y = x$ as a guide to the eye. Most of the reconstructed angles are less than the tilting angles, especially for the outlets of 53, 63, and 80 μmϕ. Such a phenomenon is not found in ion experiments.[5,6] This is considered a result of different transmission mechanisms of ions and light in capillaries. Because ions lose their energies during scattering at the inner wall, they cannot penetrate the capillary window, and only those parallel to the capillary axis contribute to the output beam. However, light does not lose its energy during scattering and always contributes to the output beam. We concluded that the knife-edge method is capable of measuring the laser microbeam profile. Further, laser light is possibly guided by the capillary tilting. The next step will be to test the dependence on the divergence of the initial laser beam.

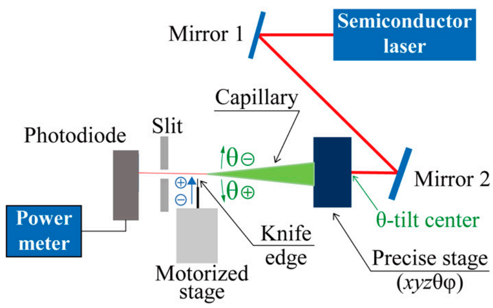

Fig. 1. Experimental setup with the knife-edge method.

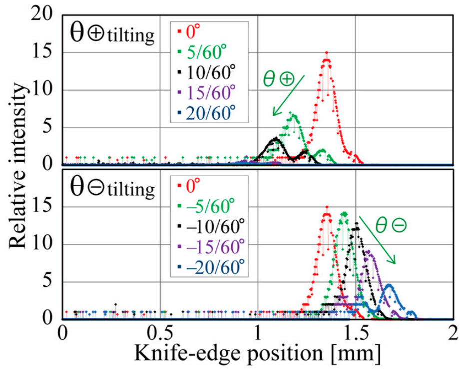

Fig. 2. Laser microbeam profiles measured by tilting the capillary in the $\theta(+)$ and $\theta(-)$ directions.

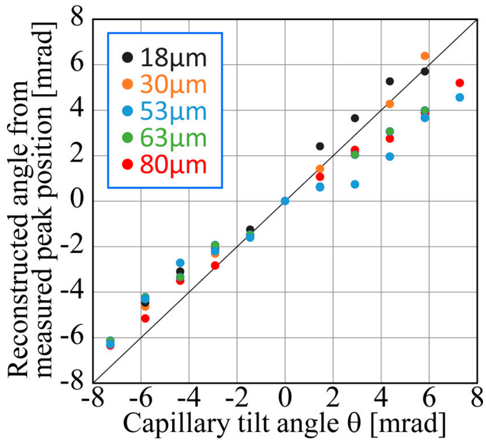

Fig. 3. Reconstructed angles as a function of θ.

References
1) K. Sato *et al.*, RIKEN Accel. Prog. Rep. **51**, 21 (2018).
2) T. Ikeda *et al.*, Quantum Beam Sci. **4**, 22 (2020).
3) T. Ikeda *et al.*, RIKEN Accel. Prog. Rep. **51**, 245 (2018).
4) S. Kawamura *et al.*, J. Phys. Soc. Jpn. **89**, 055002 (2020).
5) M. Ikekame *et al.*, RIKEN Accel. Prog. Rep. **52**, 164 (2019).
6) T. Ikeda *et al.*, Nucl. Instrum. Methods Phys. Res. B **470**, 42 (2020).

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