Profile measurements of dual-microbeams generated by glass capillaries

M. Mori,[*2,*1] T. Ikeda,[*1,*2] and W. -G. Jin[*2]

Tapered glass capillary optics is known to be a simple and reliable microbeam generator for ion/laser beams.[1,2] The DNA of living cells is seriously damaged by not only ion-beam irradiation but also UV light. However, to avoid mis-hitting of a target cell nucleus, a laser sight of a visible micrometer-sized spot is needed prior to the UV microbeam shooting, where the visible light never damages the DNA. We have proposed a dual-microbeam system of visible light + ion beam (produced at Pelletron in RIKEN Nishina Center) and visible + UV light because any quantum beams can be transmitted through the capillary optics. The transmission characteristics and the microbeam profiles of visible laser were investigated until 2017,[3] followed by the similar study for UV microbeams.[4] To realize the system of visible + UV laser, the two microbeam spots should be on the same position. In this report, the displacement between the two spots as a function of possible mis-alignment of the input beam is described, although a laser beam is well-guided by the capillary optics.

Figure 1 shows the setup in Toho University. A UV laser with a wavelength λ = 375 nm from a source (THORLABS L375P70MLD) entered a glass capillary with an outlet diameter of 60 μm, where the capillary was aligned with an accuracy better than the smallest scale of 0.34 mrad in the mirror tuning. The microbeam profile approximately 3-mm downstream of the capillary was obtained as shown in Fig. 2 by a knife-edge method employing a motorized stage (SURUGASEIKI XY620-G-N) and a photodiode (OPHIR PD300) connected to a power meter display. The central sharp peak like an airy disk, which is known in Fraunhofer diffraction for a circular aperture, was used to extract the full width at half maximum (FWHM) as the spot size after Gaussian fitting. A visible light laser (λ = 488 nm) from a source (Photochemical Research Associates Inc. LA15R) also entered the capillary with a half mirror, which was tilted horizontally to emulate the mis-alignment with a step of 0.68 mrad. The peak position and the spot size of each laser were measured according to the tilting angle θ, where θ = 0 when the UV and visible laser entered coaxially.

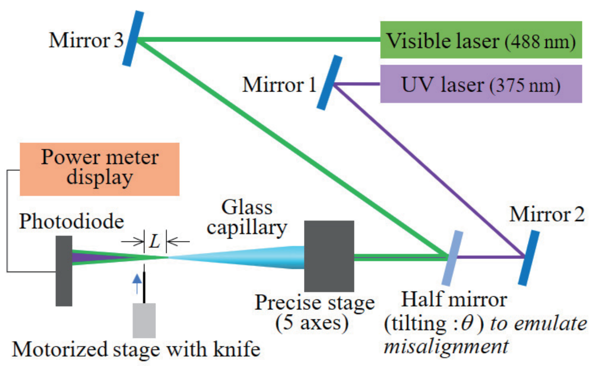

Fig. 1. Experimental setup with a knife-edge method to obtain the beam profiles. The distance $L \sim 3$ mm.

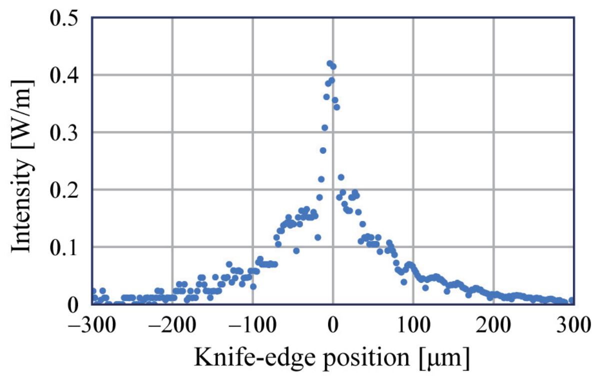

Fig. 2. Horizontal profile of a UV microbeam. The spot size is defined as the FWHM of the central sharp peak.

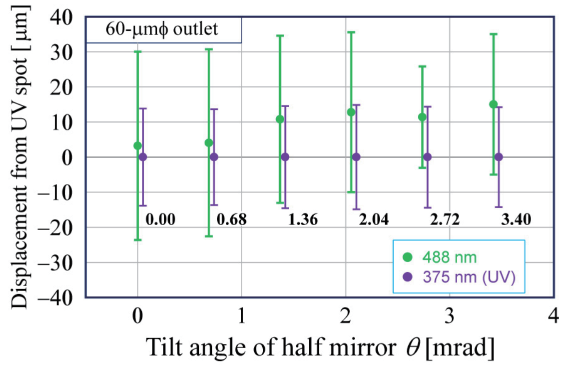

Fig. 3. Displacement of the visible spot from the UV spot as a function of θ, along with the spot sizes.

The displacements of the visible laser spot from the UV spot as a function of θ are plotted in Fig. 3. The green and purple symbols show the peak positions of visible and UV lasers, respectively, where the UV peak positions were set to zero. The vertical bars correspond to the spot sizes, which depend on the initial beam divergences. As expected, the UV spot sizes were almost constant. We confirmed that the visible laser peak positions were measured to be constant in the larger θ region ($\geq$1.36). The guiding effect of the laser beam through the capillary optics is clearly proven.[5] However, for UV spot sizes of $\sim$30 μm, the mis-alignment θ should be suppressed to less than 1.36 mrad to obtain the same spot positions so that the mis-hitting in the UV microbeam irradiation is avoided.

*1 RIKEN Nishina Center
*2 Department of Physics, Toho University

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