Development of UV microbeam irradiation system by glass capillary optics

S. Kawamura,[*1,*2] T. Ikeda,[*1,*2] M. Mori,[*1,*2] M. Ikekame,[*1,*2] Y. Hikima,[*1,*2] T. Minowa,[*1] and W. G. Jin[*1]

The tapered glass capillary is known to be a powerful tool for producing ion microbeams. Many studies on ion microbeam produced by the glass capillaries as well as its application of irradiation to a living cell have been reported.[1)] Several years ago, a group from Toho university and RIKEN started studies on the visible-light microbeams by glass capillaries.[2)] Recently, we have developed an ion microbeam irradiation system with a visible-laser microbeam.[3–5)] Another irradiation setup based on UV-laser microbeams will be newly introduced to a beam line of RIKEN Pelletron accelerator so that the ion and UV-laser microbeam irradiations can be switched quickly without any changing around the sample stage. This time, we will report the details on the UV-laser microbeam profiles and the estimation of the beam energy per pulse ([J]) by the glass capillary optics.

The glass capillary was fabricated from a straight glass tube made of borosilicate, whose inner and outer diameters are 1.8 mm and 3.0 mm, respectively. The glass capillaries were made using a puller (Narishige PE-22) by heating a straight glass tube and pulling both ends with a constant force. The outlet diameter a of the capillary was determined using a microforge (Narishige MF-900).

Figure 1 shows the experimental setup for beam profile measurement. In this measurement, we used a diode laser with wavelength (λ) of 375 nm. A fluorescent screen was used to obtain the spot shape at the distance L, called irradiation distance, from the capillary outlet. The spot pictures were taken by a digital camera that is installed behind a fluorescent screen. Generally, the spot shapes for $L > 1$ mm and $L < 100$ μm are like a Fraunhofer diffraction pattern and a Fresnel pattern, respectively, which are known as spot images for a parallel beam entered a small circular aperture. In previous study, the spot pictures with Ar^+ laser with $\lambda = 488$ nm were analyzed for $L > 1$ mm and $L < 100$ μm.[4)] We will support the pin-point irradiation to the nucleus in a living cell. Therefore, we defined the irradiation distance ($L = 17$ μm) and obtained spot diameters D(FWHM) for the microbeam. Figure 2 shows the results of D as a function of a at $L = 17$ μm. In this experiment, we obtained smaller spots for smaller outlet capillaries without high-order rings like a Fraunhofer diffraction pattern. The spot shapes are good for irradiating a small target like the nucleus in a living cell.

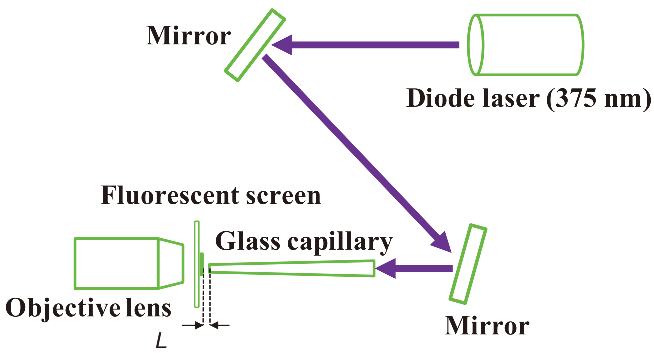

Fig. 1. Experimental setup for beam profile measurement.

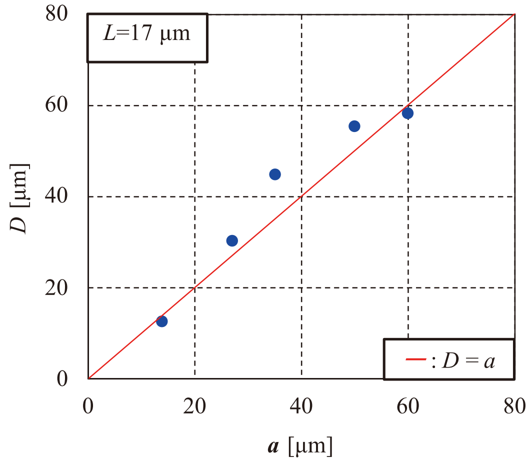

Fig. 2. Spot diameters D(FWHM) for glass capillaries with different outlet diameters a. The input laser wavelength was 375 nm. L is the irradiation distance.

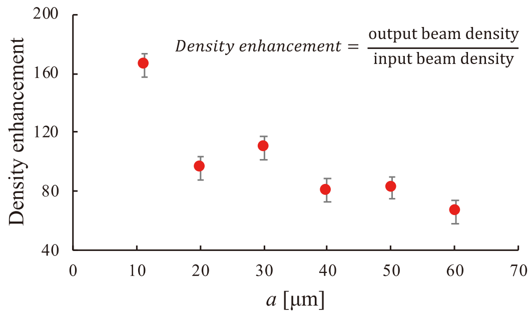

Fig. 3. Density enhancement of the extracted laser beam for $\lambda = 375$ nm with different outlet diameters a.

Using a power sensor (Ophir PD-300) and photodiode (HAMAMATSU S2281), we measured the beam power for different glass capillaries, and estimated the focusing ability. To estimate the focusing ability of the capillaries, we introduced density enhancement, which is the ratio between the output beam density at the outlet and the input beam density at the inlet.

Figure 3 shows the density enhancement for glass capillaries that have different outlet diameters. This result means that the tapered glass capillary has a strong focusing ability even for UV-laser beam ($\lambda = 375$ nm). In the near future, we will install this system to the beam line of the Pelletron accelerator and for biological irradiation.

*1 Toho University
*2 RIKEN Nishina Center

References

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