

Profile measurements of laser beam for the aiming system of ion microbeam irradiation with glass capillaries

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Ion beam irradiation on biological objects has played an important role in applications such as cancer therapy, mutation induction in plants, etc., which are based on DNA damaging. The mechanism of DNA repair can be investigated by performing microbeam irradiation to a small area of the nucleus in order to artificially induce accumulation of proteins for repairing. One of the methods for producing the microbeams for irradiation on cell nuclei involves the use of tapered glass capillary optics whose beam inlet and outlet diameters are ~ 1 mm and several micrometer, respectively. A microbeam irradiation system employing a glass capillary and MeV H/He ions generated by Pelletron accelerator has been developed at RIKEN.¹⁾ So far, irradiation experiments have been performed on HeLa cells,²⁾ *E-coli.* cells,³⁾ and medaka embryos. To maintain a high accuracy while shooting the targets, we introduce an aiming system that utilizes laser μm -spot for a cell and sub-mm-spot for insects. The laser spotlight is generated by the glass capillary, which is also used to produce the ion microbeam, because the capillary can transmit both ions and laser at the same time. In the case of the aiming system, the transmitted laser is used to spotlight the target prior to ion irradiation. When the wavelength of the laser is selected as the excitation energy of a specific fluorescent protein or fluorescent dye, only the labeled target to be irradiated will be recognized.

The laser transmission experiments have been carried out with tapered glass capillary optics in Toho University. The transmission characteristic was studied by comparing the transmitted laser powers of the experimental and simulated results. The simulation, including the real capillary shape, showed good agreement with the experimental data.⁴⁾ In order to apply this technique to the aiming system for a sub-mm-sized target on the surface of a small live insect in air, profile measurements of the laser spot should be performed to define the spot size as the area having a power density larger than the threshold density to detect the fluorescence from the target. In this case, the irradiation distance will be several millimeter.

The profiles of the laser beams extracted from the glass capillaries were measured at Quantum Electronics Lab. in Toho Univ. The laser beam from an Ar⁺ laser source (wavelength = 488 nm, CW power = 15 mW) was introduced into an aperture having a diameter of 1 mm, followed by a tapered glass capillary. The glass capillaries with a beam inlet of 1.8 mm in diameter were fabricated by the authors so that the outlet sizes range from 5.7 to 21.5 μm . The capillary entrance surface was

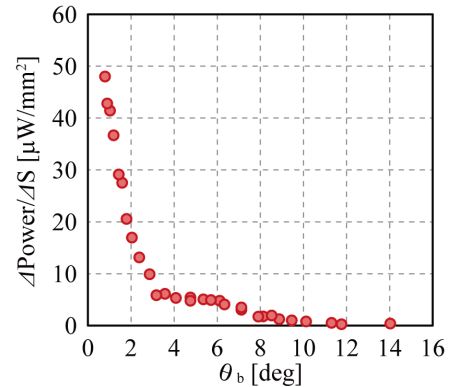


Fig. 1. Extracted laser profile. The vertical axis represents the power density when the target is located 14 mm downstream of the capillary outlet whose diameter is 21.5 μm .

covered with silver paste to prevent the laser from transmitting through the glass wall. Due to refraction, some fraction of the laser beam in the capillary penetrates the inner wall and travels outside toward the downstream, which forms a serious background in the power measurement of the beam extracted only from the capillary outlet. To avoid the background, the bottle shaped region of the capillary, which has the maximum taper angle, is also covered with the silver paste. The power of the extracted beam was measured using a power meter based on a photodiode.

For the first time, the power densities of the developed aiming laser at the 21.5 and 11.7 μm capillary outlets were obtained as 0.40 and 1.26 $\mu\text{W}/\mu\text{m}^2$, respectively, which were 104 and 327 times larger than those at the inlets, where the input power was measured to be 9.8 mW. Figure 1 shows the laser microbeam profile for the capillary outlet with a diameter of 21.5 μm , employing apertures of various sizes to cut the beam profile. The horizontal axis represents the angle with respect to the capillary direction, and the vertical axis represents the power density when the target is located 14 mm downstream of the capillary outlet. The density map was measured, also for the first time, to estimate the spot size at the target in terms of sufficient excitation light area. The plot shows that the effective spot area is limited to within about 3° with respect to the spot center. The calibration measurement of the center position difference between the ion microbeam and the laser spot using the Pelletron accelerator is in progress.

References

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