Current status of development of ion microbeam device with tapered glass capillary for biological use

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A microbeam irradiation system based on single tapered glass capillary optics with thin end-window has been developed at a beam line of the Pelletron tandem accelerator in the Nishina R&D Building. The microbeam is extracted through a several-μm diameter outlet. The previous system (FY2006-2015) was used to investigate only the cellular response to ion microbeam hitting.[1–4] The new system will irradiate samples of not only (1) cells (transparent target), but also (2) the surfaces of small insects (not transparent). The corresponding aims are (1) investigation of the mechanism of repair of DNA by microbeam irradiation to a small area in the nucleus to artificially induce accumulation of proteins for the repairing, and (2) search for a specific gene that corresponds to an active organ (horn, wing *etc.*) to develop its structure or shape. The system will employ H^+ ions of up to 3 MeV and He^{2+} ions of up to 4.5 MeV, whose ranges after the end-window are approximately 130 μm and 20 μm in water, respectively. For the irradiation of cells, the ion energy is selected such that the ion can be stopped inside the nucleus or can penetrate the cell. For the irradiation of an insect that is alive in air, the distance from the capillary outlet is several mm for both H^+ and He^{2+} beams, since air is about 1000 times thinner than water. One can select the ion species according to their linear energy transfer (LET) of up to about 80 and 230 keV/μm for H^+ and He^{2+} in the target, respectively. This means that single ion hitting can cause a serious damage in the DNA. This year, the following parts were installed or are in progress:

(a) Laser alignment system for capillary axis: a green (wavelength = 532 nm, 1 mW max. for output) laser source is positioned at the counter part of the capillary beam line on the analyzing magnet so that the ion beam axis can be visualized as the laser beam. The laser is transmitted through the capillary optics. The system allows users to reduce the alignment time from a few hours to a few minutes. The inset photo in Fig. 1 shows a diffraction ring pattern that is obtained when a capillary is aligned precisely. The capillary is seen at the bottom left part as a shining cone by the green laser.

(b) Prototype of vertically bending magnet of MeV ion beams using neodymium magnets located in the vacuum chamber: the magnetic field in the gap was measured to be 6.4 kGauss. The gap will be tuned so that the optimum bending angle of the ion beam will be obtained.

(c) Capillary holder with a remote-control tilt system (Fig. 2): the actuators (SGSP-13ACTR-B0, SIGMAKOKI Co., LTD) for the horizontal and vertical tilting are controlled by Windows Tablet PCs through Ethernet.

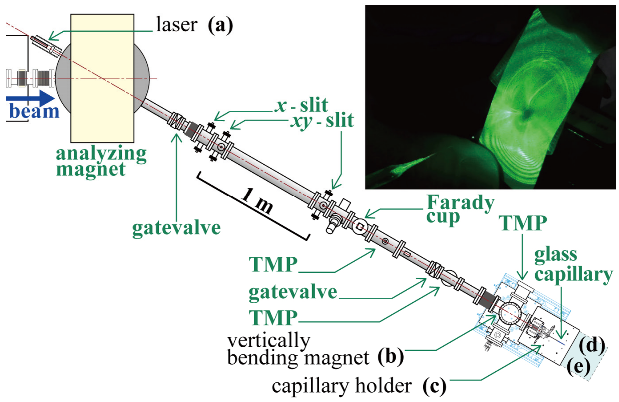

Fig. 1. The beam line of the new microbeam system. The symbols (a)–(e) are explained in the text. The degree of vacuum level is kept better than 10^{-5} Pa.

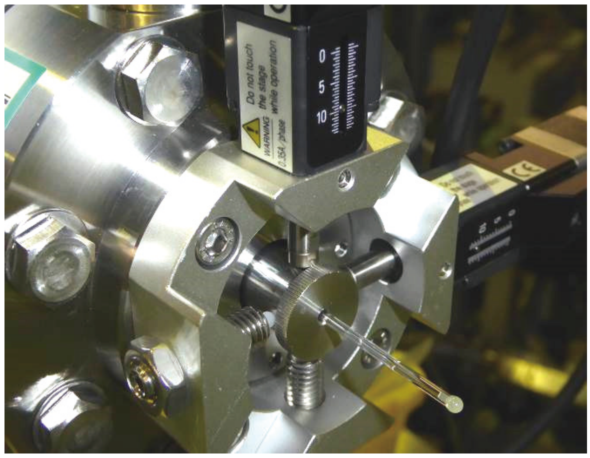

Fig. 2. Capillary holder with a remote tilt system controlled through Ethernet. The glass tube will be replaced with a tapered glass capillary optics to produce microbeams.

(d) Ion counting system to estimate the dose for the irradiation: PIN photodiode sensor (S3590-09, Hamamatsu) is connected to a charge-sensitive pre-amplifier whose output signals are processed by NIM modules.

(e) An inverted microscope (IX73, OLYMPUS) and a motorized XY stage system (BIOS-225T-OL, SIGMAKOKI Co., LTD) were purchased. The working distances of the stage are 110 and 75 mm for the X (left-right) and Y directions, respectively, with a position resolution of 0.1 μm.

The next step is the irradiation to biological target for the aims mentioned in the introduction section.

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