RIKEN ion-beam irradiation platform with glass capillary optics as a member of the Japanese microbeam facility network

T. Ikeda*[1]

Ion-beam irradiation is used for material analysis, modification, pattern fabrication of sample surfaces and so on. When a sample surface has a structure on the order of micrometers, the beam size must also be on the same order. Such a beam is called a microbeam. Japan has several microbeam facilities operated at research institutions such as QST-Chiba, QST-Takasaki, KEK-PF (X-rays), Tohoku Univ., Univ. of Tsukuba, and Kyoto Univ. Some of them form a network for microbeams to provide users with better solutions. RIKEN Nishina Center Detector Team is also a member of the network and has built dedicated beam ports for ion microbeams at the Pelletron accelerator facility (up to 1.7 MV). The RIKEN microbeam irradiation platform began the user machine time (MT) with MeV ions in 2024. This report describes the advantage points of RIKEN microbeam and its activities.

Figure 1(a) shows a microbeam generator utilizing a tapered glass capillary optics with a plastic end-window at the beam exit.[1] The window is 20 μm in diameter (D) and 10 μm thick and is vacuum tight even in liquid. Additionally, it is sufficiently thin to allow H^+/He^{2+} of a few MeV energy to pass through, whose range is less than 100 μm in water. Through selecting the ion initial energy and window thickness, the ion stopping position (Bragg peak) in depth is controlled, where the stopping power is larger than 60 keV/μm, which is sufficient for DNA damage (Fig. 1(b), (c)).

The following MT's were performed in 2024: (1) Development of calibration method of position resolution for a high-speed position sensitive detector.[2] (2) Back-trace of ion trajectories using a new-type emulsion detector with 3D sub-μm resolution. (3) Observation of beam spot structure within a several μm diameter employing a SiC target. (4) Pin-point irradiation to a *C. elegans* sample with video recording.

To provide the users with beam profile information as shown in Fig. 2, we used a 2D semiconductor array detector, MINIPIX (ADVACAM, Czech Republic) before each MT (Fig. 1(d)). Although the typical position resolution of 55 μm is larger than that of CR-39 detector, online monitoring via a USB interface improves the alignment feedback of the glass capillary optics. The spectra in Fig. 2 were obtained for a capillary ($D = 3$ μm) without end-window as a trial, changing the irradiation distance (L) between the capillary outlet and the sample surface in air. This small D enables a differential pumping of the beam line to keep the vacuum of the order of 10^{-5} Pa. The capillary without end-window can be used for a sample with a dry surface, such as SiC. Comparing with the SRIM/TRIM simulation results for 1.3 MeV H^+ ions, the equivalent air thickness in the capillary was found to be 4 mm. The distance L is usually set shorter than 1 mm.

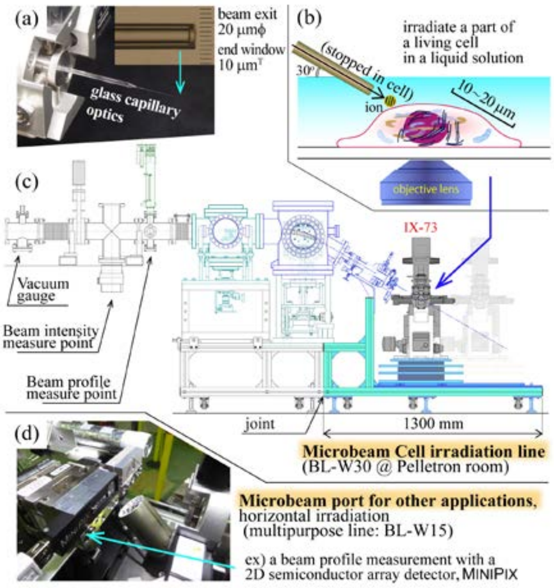

Fig. 1. (a) Microbeam generator utilizing glass capillary optics. (b) Microbeam irradiation for a living cell in a liquid solution. (c) Cell irradiation beam line in Pelletron room. (d) Beam profile measurement using the MINIPIX detector in air.

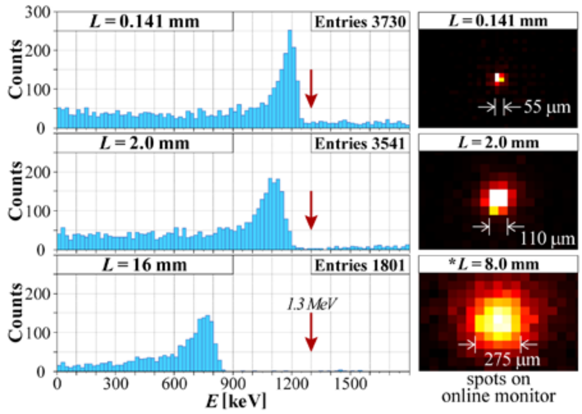

Fig. 2. Left: Energy spectra measured using the MINIPIX detector with $L = 0.141$, 2.0, and 16.0 mm, respectively. The arrows show the initial energy of H^+. Right: Corresponding beam spot images. The spot for $L = 16$ mm was measured to be much larger and replaced with that for $^*L = 8$ mm.

References
1) T. Ikeda, Quantum Beam Science **4(2)**, 22, 1–30 (2020).
2) N. Itoh *et al.*, Nucl. Instrum. Methods Phys. Res. A **1073**, 170244 (2025).

*1 RIKEN Nishina Center

DOI:10.34448/RIKEN.APR.58-220