Current status of development of ion microbeam device to fatally damage the small active organs of insects

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In the bodies of living organisms, there exist left-right-symmetric organ structures, or repetitions as in the spine and ribs. The structures are generated by genes that work only in a specific phase during the development of the organism. The study of identifying these genes is considerably important in developmental biology including the field of medicine. One of the methods to specify the gene in an organ corresponding to morphogenesis (the development of the structure or shape) involves damaging the candidate gene before the gene works actively. For example, *Drosophilidae* (fruit fly) has a bristle that can be seen from outside. The growth of this bristle is realized by genes having their corresponding RNA and proteins localized at small parts (~1 μm) of the bristle. If the bristle growth is stopped after one of the parts is damaged by ions with an energy of a few MeV, the RNA and proteins are found to play an important role in the growth. For this purpose, a micrometer-sized He ion beam with an energy of a few MeV energy is used as a tool for causing precise damage within a volume of ~μm^3 order because of the Bragg peak in the stopping-power distribution. Alternatively, if the target is damaged thermally or physically, no further development can be expected because of cellular necrosis.

Before the experiment above, *C. elegans* (nematode) will be targeted because it is easier to irradiate a relatively larger area (~50 μm) by H^+ beams and to observe real-time changes in pharyngeal pumping activity. An experiment with carbon-ion microbeams (18.3 MeV/u) was reported but not yet performed with light ions of a few MeV. We developed a device to damage a small part near pharynges using microbeams of H ions with MeV energies generated by the Pelletron accelerator at RIKEN. The pin-point damaging is provided by tapered glass capillary optics, as shown by a blue thin object in Fig. 1. [1-4] A glass capillary is the same as an injection needle used for biological experiments. Ions with MeV energy can be transmitted through a total capillary length of ~100 mm. Its inlet diameter is typically 0.8 mm. The outlet can have a thin end-window (1-200 μm in diameter and a few to 15 μm in thickness) for targets in liquid or air. We employ a combination of MeV energy H / He ions from the Pelletron accelerator and glass capillary optics because of the following advantages: the Pelletron facility has a beam port accessible during the irradiation, a H / He ion with MeV energy stops at a low depth in the target, and the capillary makes pin-point damaging possible. In the cases of H (He) ions, the stopping power of 80 (240) keV/μm with a short range of ~130 (~20) μm in the target is expected. In order to realize the above advantages, some points should be taken into account. For reliability, the acceleration voltage (1-1.5 MV) should be stabilized with a fluctuation less than 0.1%. Furthermore, beam divergence should be known to avoid mis-hitting any object neighboring the target.[5] The acceleration voltage of the Pelletron was found to be 0.31% in April 2016. After modification including overhaul, it became 0.095%, which is at the level of our requirement. The microbeam divergence was examined using MeV H^+ and pieces of the solid track detector CR-39 for each capillary. The beam profile was analyzed by comparing with the simulation data to estimate the mis-hitting probability. Moreover, usability, such as the method to irradiate, observe, manipulate, etc. must be considered. Figure 1 shows the setup installed at the West 30° beam line in the Pelletron room. The capillary axis is aligned to the initial beam axis by the linear motion of X and Y as well as the rotational motion of θ and ϕ. A microscope is located around the target. The orientation of the microscope will be determined according to the sample. When the sample is transparent, the microscope view will be obtained from the downstream. The method to fix the target is discussed in detail with a group from the QST Takasaki institute.[6]

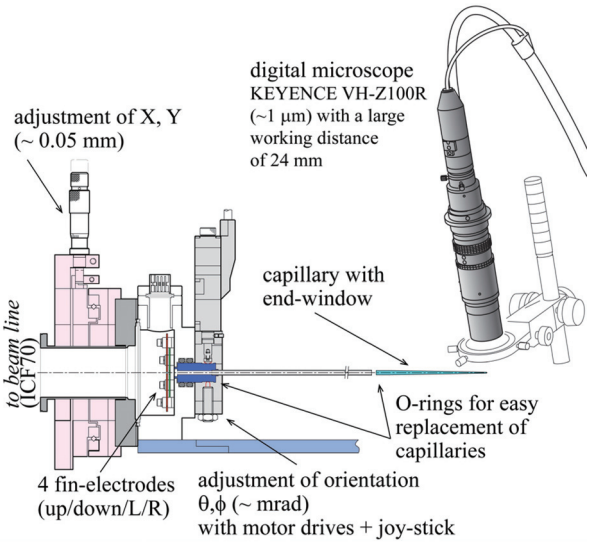

Fig. 1. Experimental setup with the irradiation sample below the microscope.

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