KINETIC ENERGY DISTRIBUTION OF SLOW MULTIPLY CHARGED ARGON IONS TRANSMITTED THROUGH A CYLINDRICAL GLASS CHANNEL

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Guiding of slow multiply charged ion beams using insulator capillaries or tubes has attracted attention since discover [1] of the effect. Slow multiply charged ions can transmit thin capillaries or tubes even if they are tilted or bent with respect to ion beam axis due to electrical charge accumulation on insulator surface upon impingement with multiply charged ions. More secondary electrons than the charge state of incident ions results in positive charge accumulation on the surface. Coulomb repulsive force from positive charge patch prevents the following incident ions from colliding with the surface atoms. This guiding of a multiply charged ion beam has a high potential for pioneering novel ion beam technologies. Simpler, smaller, and cheaper devices may be developed by applying these phenomena to various ion beam technologies, e.g., surface analysis, coating, lithography, milling, modification, implantation, and bio imaging.

However, controlling shape and conditions of inner wall surface in capillaries or tubes is difficult. Such difficulties have been a barrier for stable and accurate handling of the ion beam using insulator capillaries or tubes. Thus, we previously proposed a new method to guide the ion beam using a pair of cylindrical optical glass lenses [2] (Fig. 1). Cylindrical glass channel (CGC), the device used in the previous study, has a narrow gap between a cylindrical convex glass and a cylindrical concave glass. The cylindrical glasses are optical borosilicate glass (BK7) lenses with a common curvature of 155.7 mm and a focal length of 300 mm for green

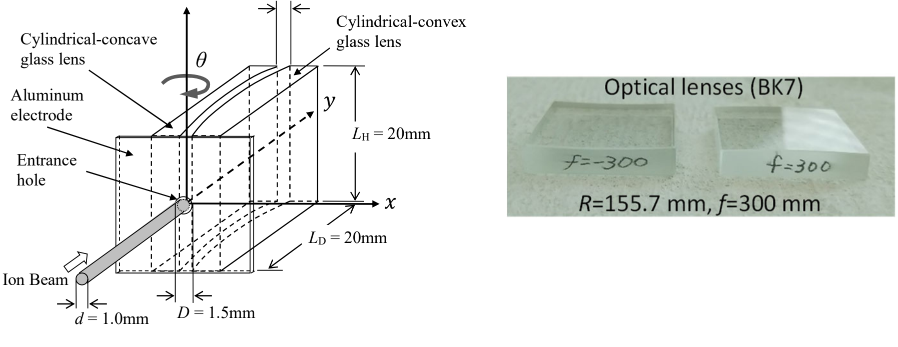

Fig. 1 Schematic (left) and photo of optical lenses (right) of cylindrical glass channel (CGC).

light. It is easy to choose curvature, gap width, roughness, and other physical properties for the CGC. In this study, I attempted to evaluate the guide effect of the slow multiply charged Ar ion beams using the CGC.

There is also another aim in this study. It's a successful measurement of kinetic energy of transmitted ion through the CGC. To my knowledge, kinetic energy distribution of transmitted or guided ions has never been measured because of its technological difficulties. Long thin insulator capillaries or tubes prevent researchers from measuring kinetic energy of each transmitted ion using usual electrical and time-resolved methods. To opposite that, present experimental method described below can measure kinetic energy of each transmitted ion because of the short channel and large exit hole. Figure 2 depicts a schematic illustration of the experimental setup [3] used in this study. Mass-to-charge ratios (*m/q*) of ions were analyzed upon their exit from the narrow gap of the CGC at various tilt angles, θ, when a pulsed $2.5 \times q$ keV-Ar^{q+} ($q = 3$ and 4) ion beam entered the front hole (diameter of 1.5 mm) of the CGC. *m/q* of the ions that were transmitted through the CGC were measured using a time-of-flight, T, via the displacement, y, on a position sensitive ion detector with a microchannel plate (MCP-PSD), according to Equation (1):

$$\frac{m}{q} = \frac{eLE_{\mathrm{PP}}}{y}\left(\frac{L}{2} + \ell_5\right)\left(\frac{T - \frac{\ell_1 + \ell_2}{v_0}}{\ell_3 + \ell_4 + \ell_5 + L}\right)^2 , \tag{1}$$

where E_{PP} (= 53 V/cm) is the electric field in the parallel plate, e is the elementary electric charge, and v_0 is the initial speed of the Ar^{q+} ion beam. The lengths of $\ell_1, \ell_2, \ell_3, \ell_4, \ell_5,$ and L were 31, 98, 20, 35, 529, and 40 mm, respectively. Ar^{q+} ion beam was extracted from a compact electron beam ion source.

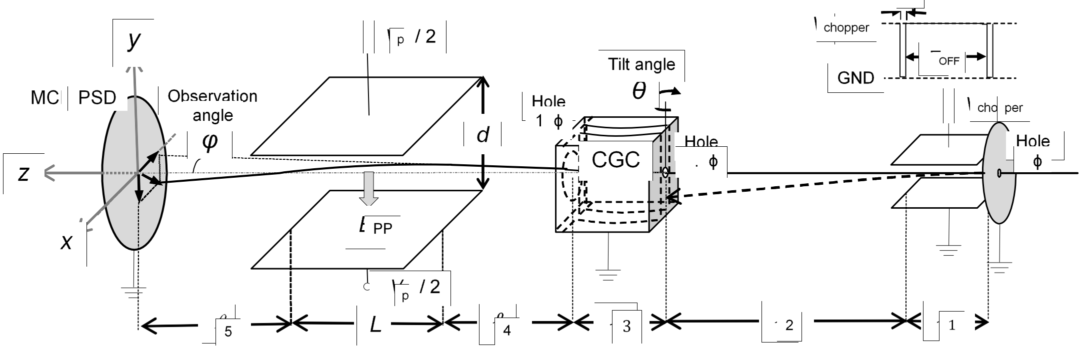

Fig. 2 Schematic illustration of the experimental setup

Figure 3 shows (a) x distributions and (b) kinetic energy distributions of the ions transmitted through the CGC at various tilt angles in incidence of the 7.5 keV-Ar^{3+} ion beam. The kinetic energies of the transmitted ions were calculated from the mass (m) and the time of flight, T.

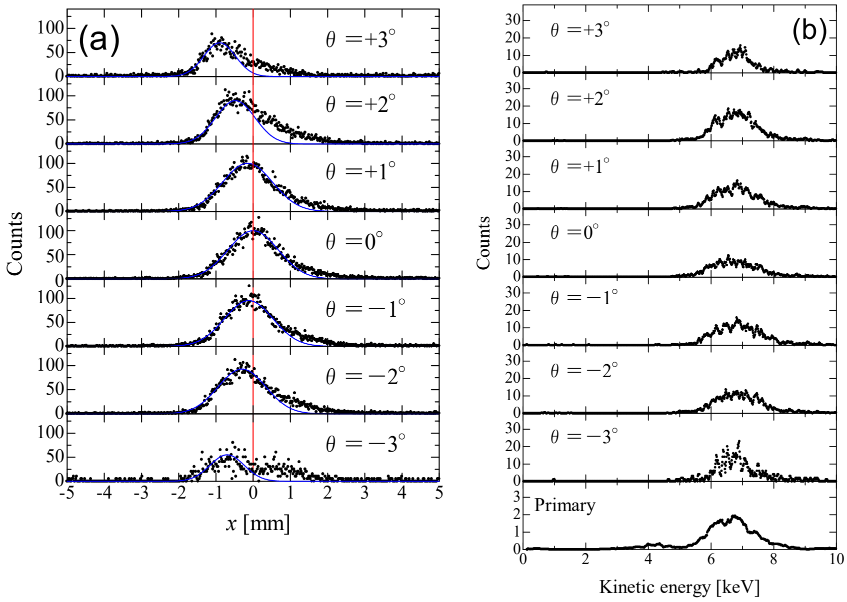

Fig. 3 x distributions (a) and kinetic energy distributions (b) of the ions transmitted through the CGC at various tilt angles in incidence of the 7.5 keV-Ar^{3+} ion beam.

Peak positions for the x distribution also shifted to the negative direction at both positive and negative tilt angles. Thus, the CGC deflected the ion beam. Furthermore, the kinetic energy distributions of all tilt angles almost preserved their initial distributions of the primary 7.5 keV-Ar^{3+} ion beam through the peak located at approximately 6.8 keV because of the insufficient position calibration of the MCP-PSD. Therefore, the CGC guided the Ar^{3+} ion beam. Thus, guiding of the 7.5keV-Ar^{3+} ion beam was clearly demonstrated in this study.

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