

Active discharging method for stable sub-micron sized beams of slow highly charged ions using tapered glass capillary with electrodes

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Synopsis Stable transmission of a 0.75 μm -sized Ar^{8+} beam of 10–100-keV energy through glass tandem optics was achieved. The optics consisted of a 4-electrode tapered capillary and a sub- μm -sized tapered capillary tip, arranged in series. To actively discharge the capillary, and thus obtain stable transmission, an electrode was applied with a mechanical relay closing at a 0.01–0.1 Hz frequency.

Slow (10–100 keV) highly-charged ion (HCI) beams have been widely used for processing and analysis of materials. In order to use the slow HCI in microscopic analysis and modification, small and stable micro-HCI beam generators are required. In 2006, we demonstrated a simple and convenient method for producing microbeams using a single tapered glass capillary with an outlet diameter of 24 μm . The beam transportation is based on self-organized charge patches on the inner surface of the capillary, which are induced by the incident beam itself [1]. However, transmitted microbeams sometimes become unstable and their transmission can be blocked or suddenly increased.

In order to solve the problem, a tandem glass-made optics consisting of a 4-electrode capillary, from Hamamatsu Photonics K.K. (Fig.1(a)), and a tapered capillary tip with a sub- μm sized outlet (Figs. 1(b)) was developed. The larger capillary had 4 ring-electrodes on its outer surface. The unstable transmission was expected to be due to too much charge-up around the position marked by a circle *S* in Fig.1(a). The outlet surface of the larger capillary and the inlet surface of the smaller one touched each other and were connected to *electrode-A*, so that the excess charge is removed toward the ground level periodically through a mechanical relay (active discharging, Fig.1(c)). The relay was controlled by TTL signals with a frequency $f_{\text{TTL}} \sim 0.1$ Hz [2]. Figure 1(d) shows the number of transmitted ions per second N_{transmit} for a 104-keV Ar^{8+} beam at the Slow Highly Charged Ion Facility in RIKEN. During a period (3050–3350s) without relay operation, the transmission became gradually blocked and eventually stopped. When the TTL sending re-

started, the transmission also started again and remained constant until the input beam stopped.

When only a 4-electrode capillary was used, the density of the extracted beam became up to 14 times larger than that of the input beam. A transmission efficiency up to 70% was observed with good reproducibility when the electrodes were biased with appropriate voltages.

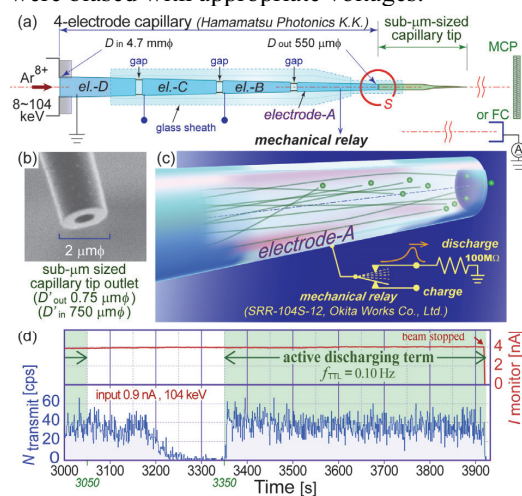


Figure 1. (a) A 4-electrode capillary (larger capillary) and a sub- μm -sized capillary tip (smaller one) were in series. (b) A magnified view of the tip outlet. (c) Charge flow around a circle *S* in Fig. 1(a). (d) The time evolution of the transmission with or without the active discharging. Regarding the stable I_{monitor} (red curve) measured at an entrance aperture of the experimental chamber, input current to the larger capillary was estimated to be stable.

References

- [1] T. Ikeda *et al.* 2006 *Appl. Phys. Lett.* **89** 163502
- [2] T. Ikeda *et al.* 2016 *Appl. Phys. Lett.* **109** 133501

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