An experimental study of the gas-phase ion-neutral reaction by merged-beam collisions

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The gas-phase reaction in the low-temperature interstellar clouds is predominated by ion-neutral reactions without reaction barrier. While the understanding of the interstellar chemical reaction has dramatically progressed by the radio astronomical observations and the large-scale reaction network calculations, experimental studies are still limited due to the technical difficulties in controlling the cold collision of ions and neutrals.

Merging beams is one of the promising approach to access such processes, in which energetic particle beams are merged in a collinear configuration and the particles collide with each other in extremely low relative velocities corresponding to the thermal energies below 100 K (Figure 1 (Left)). As well as translational collision energies, internal temperature of the molecules are also important that dictates the chemical reaction processes. Cryogenic ion storage rings are suitable apparatus to realize the precise control of both translational and internal degree of freedom in the gas-phase collision experiments. An in-ring merged-beam experiment is being carried out at RIKEN Cryogenic Electrostatic ring (RICE) [1], using the rovibrationally cooled molecular ion beam and the neutral atomic beams. Preparation of the cold molecular beam is already tested in the RICE and the experimental developments in the neutral beam production are ongoing. The neutral beams are produced by a laser-induced photo-detachment of negative ion beams, for which a duoplasmatron and Cs sputter ions sources have been installed, after the acceleration and focusing/defocusing by electrostatic field. Figure 1 (Right) shows the photograph of the photo-detachment chamber, in which a high-power cw diode laser (808nm, 5 kW) is irradiating the negative ion beam through a fused silica window. The effective laser intensity is to be enhanced by a multi-pass optics installed inside the vacuum chamber.

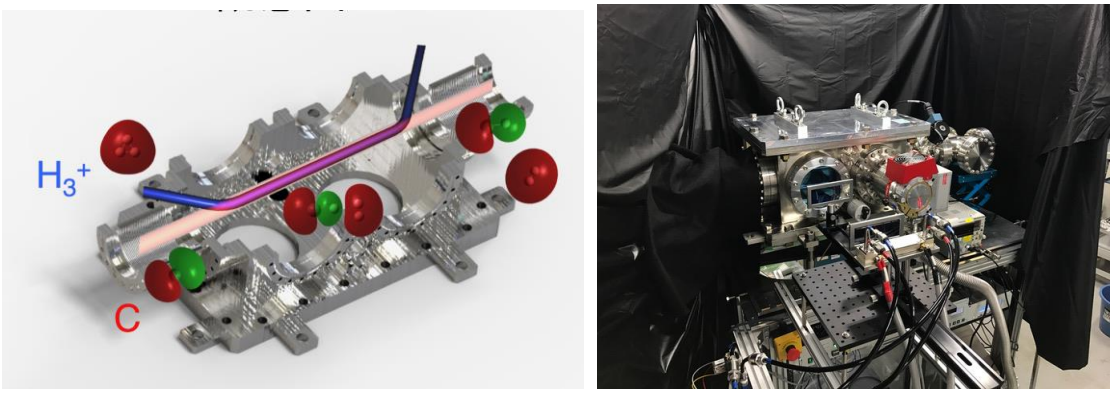

Figure 1: (Left) Schematic image of merged beam collisions. (Right) Photograph of the vacuum chamber for photo detachment of negative ion beams.

References

[1] Y. Nakano, et al., Rev. Sci. Instrum. 88, 033110 (2017).