Photoionization experiments in UVSOR-III for study of divertor plasmas in a nuclear fusion reactor and of interstellar plasmas in a context of astrobiology

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In nuclear fusion reactors, density of plasmas and neutral hydrogen in the divertor region will increase by more than one order of magnitude compared to the present-day devices due to the increasing plasma pressure in the scrape-off layer (SOL) as well as to the high ratio of divertor size to ionization mean free path of hydrogen [1]. At the same time, the photon emission from plasmas in confinement region (Bremsstrahlung) and in the SOL (line emissions from highly charged ions) will increase in wide wavelength range, from EUV to visible and infrared regions, because of the higher plasmas density required to sustain nuclear fusion reaction. Such situation leads to enhanced interaction between hydrogen atoms/molecules and the photons in the divertor region, such as photoionization, photoexcitation (electronically, vibrationally, and rotationally). While the effects have not received much attention until now due to the negligible interaction in the present nuclear fusion experiments, the atomic/molecular processes will be altered under the influence of the increased numbers of photons especially in very low temperature range below ~10 eV [2, 3].

There exist partially ionized plasmas in an interstellar space, where ionization is caused by cosmic rays or by interstellar radiation field [4]. In this circumstance, photon-induced processes, such as photoionization, photoexcitation, photolysis, photodissociation etc, also play important roles in chemical evolution of prebiotic molecules related to the origin of life in space [5]. It is also noted that collective phenomenon of plasmas under the effects of magnetic fields will provide additional effects on the evolution. Characteristics and roles of the photoionized plasmas are, however, not yet fully understood.

To address these issues, we attempt to generate photoionized plasmas by using the synchrotron radiation source UVSOR-III [6] to simulate the above mentioned plasmas in the divertor region in nuclear fusion reactors and in the interstellar space. The beamline BL7B is used to generate beam from 30 to 500 nm. A gas cell has been installed inside the irradiation chamber to maintain high pressure of sample gas while keeping a good vacuum condition for the beamline. A high gas pressure is necessary to enhance the photoionization events through an interaction between the photons and neutral atoms/molecules. Fig.1 shows the gas cell used in the present experiments. The beam from BL7B is injected to the cell through a hole at the front end (ϕ 2 mm and 60 mm length). The beam is damped at the end of the gas cell. An off-axis parabolic mirror is installed at the front end to collect emission from the gas along the beam axis. An electrode of Langmuir probe is situated at the center of the cell and biased to +/- 18 V to measure saturation current of the plasmas. The gas is fed to the cell through the input terminal at the top of the cell.

As a sample gas, Argon (ionization potential of 14.5 eV) was introduced. The gas pressure inside the gas cell could be increased to an order of 1 Pa while the ambient pressure outside of the cell was kept at an order of 10^{-4} Pa and the pressure at the upstream of the beamline was at an order of 10^{-6} Pa. The photon flux of the beam was measured with a photodiode, and was estimated at an order of 10^{15} ~ 10^{16} photons/s/mm^2. At the conference the detail plan of the research and the experiments will be presented.

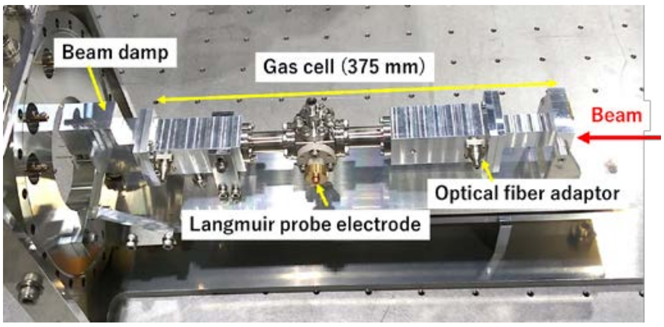

Fig.1: Photo of the gas cell for photoionization experiments.

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References

[1] M. Kotschenreuther et al., Physics of Plasmas, **14** (2007) 072502.
[2] K. Sawada et al., Contributions to Plasma Physics, **60** (2020) e201900153.
[3] M. Kobayashi et al., Contributions to Plasma Physics, **60** (2020) e201900138.
[4] E.F.van Dishoeck et al., Faraday Discuss **133** (2006) 231.
[5] K. Kobayashi et al., Astrobiology **21** (2021) 1479.
[6] H. Ota et al.,J. Phys.: Conf. Ser. **2380** (2023) 012003.