§23. Magnetic Confinement of Cryogenic Plasma in Super-Fluid Liquid Helium

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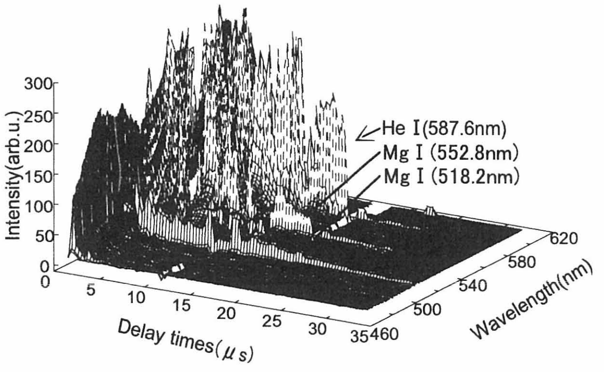
The purpose of the present study is to create transient cryogenic plasma in super-fluid liquid helium (LHeII) [1]. At a temperature below 2.17 K, LHeII at 1 atm includes a super-fluid component (Bose-Einstein condensate) that has little viscosity against impurity ions, namely, electron bubbles and He clusters because of ion super-fluidity. Previously, one of the authors (K. M.) measured spectral line emissions from high density localized plasma created by high voltage pulsed discharges between needle electrodes in LHe [2]. We are planning to measure the effect of strong magnetic field on the localized plasma in LHeII. For that purpose, we fabricated a small separate type super-conducting solenoid coils with outer and inner diameters, respectively, 68 and 20 mm, total length 138 mm. The maximum magnetic field was measured to be 2.5 T. The coils are connected to mirror or cusp configuration of magnetic fields by changing the electrical connections outside the Dewar bottles. The experiments of confinement are under way in 2002.

We describe here the preliminary experiments carried out in 2001. High voltage pulse of 20 kV, 180 A and duration 0.5 microsec is applied between the needle electrodes immersed in LHe. First, we carry out measurement of spatial changes in light intensity from the source, when the focal point on the entrance slit of the spectrometer is moved by using the lens on a precision 3-D movable holder. Measurements of plasma density from Stark broadening are made for two cases that the common axis of the electrodes is horizontal or vertical. The schematic shape of the localized plasma is a rotated ellipsoid around minor axis that coincides with the common axis of the needle electrodes.

Next, we measured the spectral lines of impurity Mg atoms in LHe after the pulsed discharge, when Mg electrode is used instead of W. It is successful to introduce Mg atoms and ions into LHe by means of pulsed discharges. During the discharge, a gas bubble is formed between the electrodes in which high density plasma including Mg atoms is produced. When discharge is over, the gas bubble is crushed because of cooling effect by surrounding LHe. Plasma is extinguished quickly, and Mg atoms are implanted into LHe. An example is shown below.



Here, the temporal changes in lines HeI 587.6 nm, MgI 552.8 nm and MgI 518.2 nm are given. The HeI line at 587.6 nm is extinguished at delay time T_d=20 microsec. On the other hand, MgI 518.2 nm line survives until T_d=33 microsec. This fact suggests that Mg ions or atoms are implanted into LHe after the pulse discharge.

It is emphasized that the cryogenic plasma in the present study involves various unknown phenomena such as cluster and electron bubble formations, ion super-fluidity, strongly coupled plasma and quantum magnetohydrodynamics.

References

[1] K. Minami, S. Watanabe, W. Qin, F. Tomimoto, S. Kuwabara, M. R. Amin, and T. Satow, *Jpn. J. Appl. Phys.* vol. 34, Part 1, pp. 271-276, 1995.

[2] W. Qin, K. Minami, A. W. DeSilva, F. Tomimoto and K. Sato, *Jpn. J. Appl. Phys.* vol.36, Part 1, pp. 4474-4480, 1997.