§7. A Basic Experiment on a Compact High Power Electromagnetic Plasma Accelerator

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To achieve compact high power beam injector, we studied why an energetic coaxial gun turns into less energetic spheromak producing mode in a quasi-steady longer time operation; note that, if the fast energetic mode were exported to quasi-steady mode, beam power density greater than ~10^3 times as large as that of a usual electrostatic system would be realized. The origin of this phenomena is ascribed to the fact that at the initial state of the plasma just after ionization of the inlet gas the flow must always be in subsonic state, because the electromagnetic force is shown to accelerate the plasma in super sonic state but to choke the subsonic plasma flow [1,2]. We therefore interpret the spheromac producing mode is the state that the plasma is pushing the magnetic field instead of vice versa. This adverse state is cured if super sonic plasma flow is supplied, and thereby we started the development of "the super sonic ion source (SSIS)" for injecting into the accelerating system.

Because entropy acceleration is the most common basic process for subsonic flow, we firstly tested a wall constricted arc jet as the ion source [3]. We gave the SSIS-1 the wall constrictor bore of 1 mmø to maximize the thermal pinch effect, but the SSIS-2 in Fig.1 the larger bore of 2.5 mmø and higher operating pressure of 100 kPa so as larger the ion flux of 500~1000 A equivalent be extracted.

Figure 1 shows the full plasma accelerating system made of two major parts: the SSIS and the 3-staged Faraday accelerator. Non single staged system is preferable for energetic beam yield, because the Hall field is shorted out on the electrode.

The pole piece magnet capable of responding rapid field change is made of 25 μm thick laminated ion core and has the 22 mm gap length and the cross-section of 30×30 mm^2. Using the dummy coil simulating the plasma driving current, we observed that the pole piece generates rapidly raising field and also the field profile in Fig.2, which is quite similar to the one observed in energetic coaxial gun.

The test of the SSIS-2 has done at the arc current of 700 A. Quite an accurate arc ignition is confirmed at the deuterium filling pressure of 50 kPa. At 100 kPa case however, ignition of ~30% shots showed poor behaviors. The arc voltage is observed to be 400 V so that power input into the SSIS-2 marks 280 kW. In spite of such a huge power input into quartz arc constrictor, no serious damage was evident, which is very encouraging.

Estimate of ejecting plasma velocity was done by measuring $\vec{v} \times \vec{B}$ motive force in the accelerator. The results give 3000 m/s, which is far below the sonic velocity. This tells that only a simple straight arc constrictor is not enough but we need more effective design utilizing such as the Laval nozzle.

References :

[1] Hirano,K.,Journal of Plasma and Fusion Research 69 (1993) 684
[2] Hirano,K.,Journal of Plasma and Fusion Research 69 (1993) 806
[3] Hirano,K., Sugisaki,K., et al, Fusion Engineering and Design 26 (1995) 529

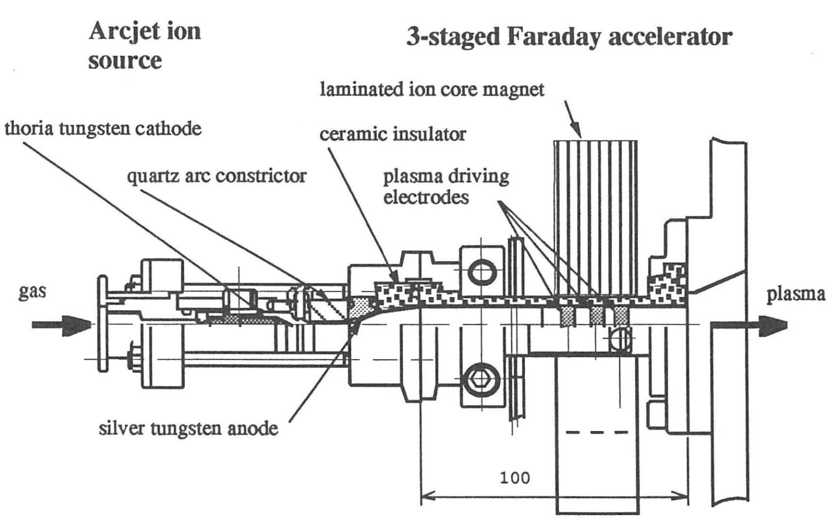

Fig.1 Major structure of the accelerator system

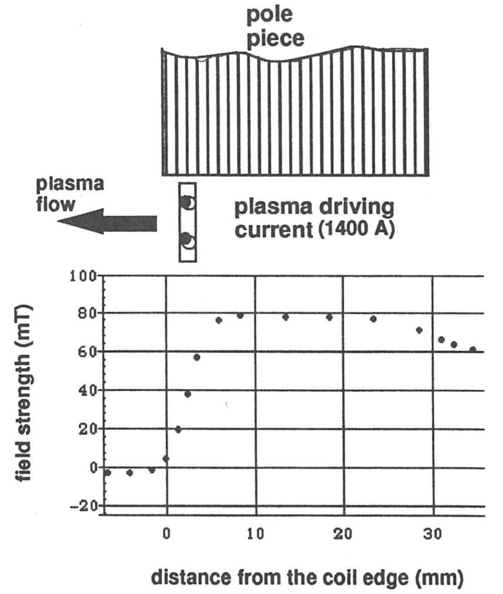

Fig.2 Plasma driving field distribution