coupled in the four-fluid model. In this paper, for simplicity, a formal radial ohm law is assumed to determine the radial electric field, and the specific mechanism to form the ambipolar electric field is dodged on purpose.

From above results, we can easily find that the profile of toroidal velocity and radial electric field can be adjusted by controlling tangential injection of neutral beam. As we know, this is very important in the research of the improvement of plasma confinement. Furthermore, because the distribution of radial field is related to the toroidal momentum diffusivity, maybe it could offer a new way to explain the formation and sustentation of transport barrier.

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3. 10 The Extraction and Acceleration System of 60 kV, 70 A, 2 s Ion Source

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Key words Extraction and acceleration system of ion source Ion beam optics characteristic

The 60 kV, 70 A ion source adopts 4 electrodes extraction and acceleration system that consists of plasma grid, gradient grid, acceleration grid and ground grid. Such a system usually is used in a higher energy ion source, the ions are extracted at lower energy and are post-accelerated to higher energy. Advantages of such a system are that it can extract higher ion beam density and can obtain better beam optics characteristic by means of adjusting the electric field strength ratio between extraction gap and acceleration gap.

The large area multislit extraction system is used to obtain high current beam. The area of each electrode grid is 45 cm × 16 cm, each and all consist of three modules. The area of each module is 15 cm × 16 cm. There are 18 slits at each module. Thus, the sum total of the slit is 18 × 3 = 54 slits at each electrode grid. The extraction slit size of the plasma grid is 0. 35 cm × 16 cm, its transparency is about 42%.

To change the large beam cross section into 30 cm × 22 cm at 4. 5 m away from the source, "focusing" is accomplished by inclining the outer two modules[1] (0. 96° for 4. 5 m focus). The beamlet optics characteristic extracted from the grid slit is still very important in spite of like that. For a slit type of ion extraction system, the ion beam divergence in direction parallel to the slit is effected mainly by the plasma ion temperature, but the divergence in direction perpendicular to the slit is caused by two factors of the ion temperature and the system aberration. Therefore, it is necessary to decrease ion temperature of ion source plasma as far as possible and to reduce the aberration by optimizing the system.

The extraction and acceleration system is optimized and designed by means of numerical simulation. The physics model for the numerical simulation include many practical physics processes during the ion extraction and acceleration, such as the effect of plasma density, electron temperature and ion temperature on the ion initial emission condition, the effect of plasma electron diffusion, the ion beam space charge itself, the system geometry and electric field profile on beam optics characteristic[2]. Each slit is shaped to obtain good beam optics and reduce grid heat loading. The shapes of the plasma and gradient grids are determined to make the fringing field small, and that of the suppressor grid is determined to reduce backstreaming electrons. The numerical simulation research for the 4 electrodes extraction and acceleration system shows:

(1) There is a match ion beam density for a determined 4 electrodes extraction and acceleration system, at this current density the beam divergence is the most small, as showed in Fig. 1.

(2) The beam optics characteristic is affected seriously by the ratio of electric field strength between extraction gap (first gap of the system) and acceleration gap (second gap of the system).

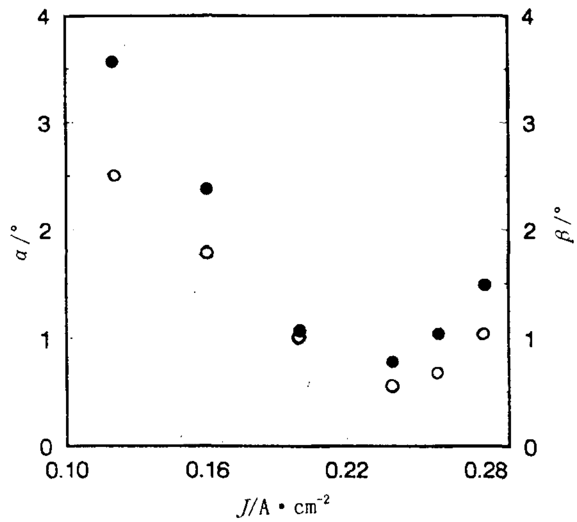

Fig. 1 The effect of ion current density on the rms divergence angle α and 85% beamlets divergence angle β for the optimized extraction extraction and acceleration system

○—— α, ●—— β.

(3) Because ion temperature of ion source plasma expresses the ion initial random heat velocity, as ion temperature increases, the ion beam optics characteristic can change into no fine.

(4) The ion beam optics characteristic is very sensitive to the plasma grid slit geometry.

The grid slit geometry of the system electrodes optimized by numerical simulation is obtained. The potential of the plasma grid, gradient grid, acceleration grid and ground grid is 60 kV, 46 kV, −2 kV and 0 kV, respectively. The size of the first, second and third gap is 0. 3 cm, 0. 6 cm and 0. 2 cm, respectively. The electric field strength ratio between extraction gap and acceleration gap is 0. 53. Assuming extracted ion beam density J_{ext} = 0. 24 A · cm^{-2}(H_1^+:H_2^+:H_3^+ = 0. 7: 0. 2: 0. 1 in the beam), and ion temperature

$T_i = 1$ eV, the rms divergence angle α of all beamlets extracted from each slit is 0.492°, the divergence angle β of 85% beamlets is 0.72°, the largest beam divergence angle ω is 0.915° (in the direction perpendicular to the slit).

According to the electric field profile near the emission surface, the extraction ability is inspected, demonstrating the extracted ion current density J_{ext} is equal approximately to the emission ion current density J_i, i. e. $J_{ext} \approx J_i \approx 0.24$ A · cm^{-2}. Because the effective extraction area is 302.4 cm^2, the total extracted ion current can attain 72.6 A.

The oxygen-free copper with fine conductivity is selected as electrode material. Because the ion beam pulse duration is 2 s, water cooling pipes are silver brazed between each row of slits.

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