§2. Improvement of Beam Optics in the Accelerator with Multi-Slot Grounded Grid

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Since FY2003, the beam accelerator with the multi-slot grounded grid (MSGG) has been applied to the negative ion sources for a beamline of the LHD neutral beam injectors (NBI). As the result, the injection power and energy have exceeded the LHD-NBI design values of 5 MW per beamline and 180 keV, respectively. The accelerator, however, include a disadvantage in its beam focal conditions. In the accelerator with the combination of the grids consisting of the circular aperture and slots, the focal conditions are different in the directions of parallel and perpendicular to the slot long side. The mismatch of the focal conditions induces the loss of the injection power, and the lost beam damages the internal structures of the beamline.

In order to reduce the disadvantage of the focal conditions, we have designed a new accelerator consisting of MSGG and the racetrack-aperture SG (RSG) instead of the previous circular aperture SG (CSG). Using the new accelerator, we confirmed that the minimum beam widths in the directions of parallel to the long and short slot sides were obtained at almost the same focal condition [1, 2].

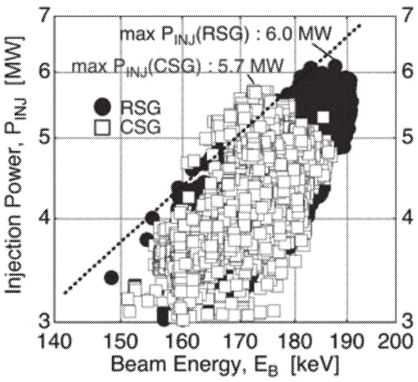

Fig. 1. Beam injection powers using the accelerators consisting of the steering grids (SG) circular apertures (CSG) and racetrack apertures (RSG) as a function of the beam energy (E_B).

The new accelerator has been installed in the negative ion sources for the LHD beamline since the 10th LHD experimental campaign. For comparison, the injection powers using the accelerator with the circular aperture SG and racetrack-aperture SG are shown in Fig. 1. The maximum injection power increased form 5.7 MW (CSG) to 6.0 MW (RSG), while the acceleration electric powers do not change in both cases with CSG and RSG. That is because the beam focal condition is uniquely defined and the beam distribution becomes sharper than the previous case, which we choose the intermediate focal condition to obtain the minimum beam widths parallel to slot long and short sides.

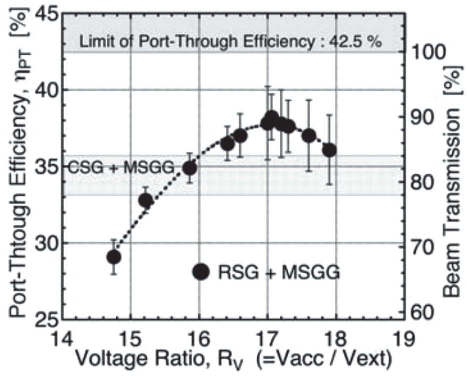

Fig. 2. Port-through efficiency (η_{PT}) with respect to the ratio of acceleration voltage to extraction voltage (R_V=*Vacc/Vext*), which is a maim parameter for beam focus.

Figure 2 shows the port-through efficiency (η_{PT}) with respect to the acceleration-extraction voltages ratio (R_V= *Vacc/Vext*), which is the main parameter to define the beam focal condition. The port-through efficiency is defined as a ratio of the injection power to a product of acceleration electric current times beam energy. In the case of accelerator with CSG and MSGG, the port-through efficiency was 33-36 % as indicated central gray band in Fig. 2. The efficiency increased ~38 % at R_V=17.

The drift tube at the beam injection port is the most far and narrowest part in the beamline. The molybdenum armor tiles protecting the inner wall of the tube have been melted by the exposure of beam formed with the previous

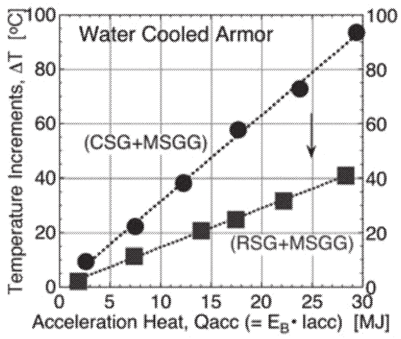

Fig. 3. Temperature increments of the armor plates at the beam injection port with respect to acceleration heat, which is defined as a product of the acceleration current (*Iacc*) , beam energy (E_B), and pulse duration.

accelerator with CSG. The beam heat load onto the armor tiles is indicated as a function of acceleration heat in Fig. 3. After exchanging the CSG to RSG, deposited heat load decreases about a half value. No damage could be observed on the armor tile after the 10th experimental campaign, although the injection powers were higher than ever.

[1] K. Tsumori et al, proceedings of the 10th International Symposium on the Production and Neutralization of Negative Ions and Beams, Kiev, (2004).

[2] K. Tsumori et al, Plasma Science and Technology, Vol. 8 (2006) pp. 24-27.