Three dimensional analysis of beamlet deflection in a MeV accelerator for ITER NBI

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In order to realize a high power negative ion accelerator (1 MeV, 40 A D^- for 3600 s) in a neutral beam injector (NBI) of ITER, numerical approaches have been carried out in parallel to negative ion acceleration tests in JAEA. To investigate negative ion beam trajectories more precisely, a three dimensional (3D) beam analysis has been progressed by combination of a commercial 3D beam code and numerical codes developed in JAEA [1]. In a negative ion acceleration test for long pulses up to 30 s in JAEA, molten parts were observed around apertures of the grids. In order to examine whether or not direct interception of negative ions caused the meltdown, the beamlet deflection was examined in the 3D beam analyses.
The calculation model was composed of a plasma grid, an extraction grid (EXG), three intermediate acceleration grids and a grounded grid (GRG), simulating a JAEA MAMuG accelerator used in the long pulse test. The H^- negative ion beams were extracted from fifteen apertures (14 mm in a diameter) drilled in a lattice pattern of 3 x 5. In the beam path in the accelerator, there are transverse magnetic filter fields generated by permanent magnets installed in the ion source and dipole magnetic fields generated by electron suppression magnets installed in the EXG. Those were precisely simulated in the present analyses and the beamlets were deflected due to the space charge repulsion and the magnetic fields.
The 3D beam analyses were carried out utilizing OPERA-3d supplied by Vector Field Co. Ltd. As an input of OPERA-3d for initial positions of beam particles, a 2D beam code developed in JAEA, BEAMORBT, was utilized. The BEAMORBT calculates beam emitter surfaces according to a Child-Langmuir law. In order to take into account the stripping loss of ions, the background gas density in the accelerator was calculated utilizing a 3D Monte Carlo gas flow code developed in JAEA.
The figure below shows power density around one aperture on the GRG surface and a picture of the GRG surface. In the calculation, the acceleration voltage was set to a typical value in this test, 600 kV. The extracted negative ion density was 140 A/m^2. A H_2 gas pressure was 0.17 Pa in the ion source and 0.1 Pa at the accelerator exit. The stripping loss of ions was 34 %. The beamlets were deflected upward by the filter field and to left by the dipole magnetic field and space charge repulsion. The deflection angle at accelerator exit was 3.5 mrad upward and 11 mrad to left. This deflected beam caused high power loading of over 20 kW/cm^2 along the aperture edge. This shows a good agreement with the molten parts. Thus the grid melt could have been caused by the beam deflection followed by the direct interception of negative ions. Toward a next long pulse test, an offset aperture grid to compensate the beamlet deflection will be installed.

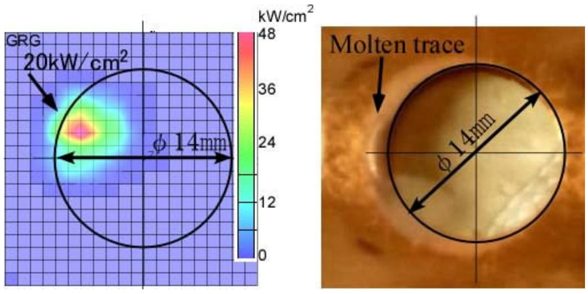

Figure: Calculated power density (left) and molten parts (right) on the GRG surface.

[1] M. Kashiwagi et al., AIP conf. proceedings 1097 (2008) 421.