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Design of Test experimental negative Ion source for HL-2M

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According to the plasma electron density range 2~10×10^{13}/cm3 of HL-2M tokamak and the injection angle of neutral beam, the particle energy range of neutral beam injection (NBI) for HL-2M tokamak is 45~240 keV for deuterium beam. With the beam energy increasing, neutralization efficiency of positive deuterium ion beam decreases fast, less than 50% when beam energy is higher than 100 keV, while neutralization efficiency of negative deuterium ion beam decreases first then goes saturated at about 60%. From this point of view, not only positive ion source but also negative ion source should be considered as ion sources for neutral beam injection systems of HL-2M device.

In the world, negative ion sources can be classified to RF-Driven negative ion source, mainly used in Germany IPP, and Arc-Driven negative ion source, mainly used in JAEA, NIFS of Japan. The first Negative-NBI system was operated on JT-60U in 1996. Three Negative-NBI beamlines were used in LHD since 2001.

A test negative ion source has been designed with almost the same size as the positive ion source of 80kV/45A/5s on HL-2M. The 3D model of this test N-ion source is shown in Fig.1

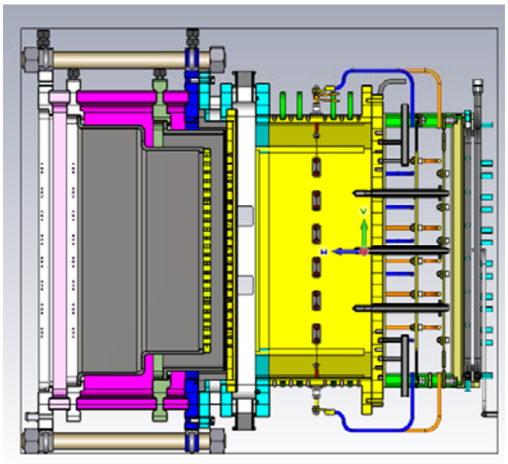

Fig.1 **3D model of the test N- Ion source.**

This negative ion source is a hot cathode arc-driven negative source. The discharge chamber of the source is a water-cooled, oxygen-free copper rectangular column with dimensions of 56 cm in length, 26.6 cm in width and 24 cm in depth. The 16 hair-pin-shaped tungsten filaments, which are 1.5 mm in diameter and 15 cm in length, are attached to the filament holders at the side wall of the chamber. The arc chamber wall serves as an anode, which is surrounded by 6 circles of Co-Sm permanent magnets to produce axial line-cusp magnetic field. The extraction system consists of 4 grids including plasma grid, extraction grid, inert grid and ground grid with extraction area of 130mm×412mm and 168 apertures with 12 mm in diameter. The plasma grid is made of molybdenum and other grids are made of oxygen free copper.

Three kinds of magnet have been applied to the negative ion source: cusp permanent magnets for confinement of arc plasma with surface strength of about 4 kG, filter permanent magnets for decreasing electron temperature with surface strength of about 5 kG, deflection permanent magnet for deflecting the co-extracted electron with surface strength of about 3 kG. The magnetic configuration and trajectories of initial electrons from filaments in the negative ion source have been simulated with CST software, which is a little different from that of the positive ion source of HL-2M.

With designed sizes of extraction grids, the extracted ion beamlet trajectory is simulated for different extraction voltage with CST software. By the simulated trajectory results for negative hydrogen beam and electron beam, beam can be extracted well when extraction voltage is less than 10 kV. The gaps between neighboring grids are also considered during the beamlet trajectory simulation.

The whole engineering design of the test N-Ion source has finished, and it is being manufactured. The bias and extraction power supplies, the diagnostic systems for the test experiments for the test negative source are also being produced. The experiments including discharge and beam extraction for the N-Ion source will be started soon. The design of the NNBI system for HL-2M is in progress.