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Progress of positive-ion-based NBI system in LHD

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Neutral beam injection system of LHD consists of three negative-ion-based beamlines (N-NBI) and one positive-ion-based beamline (P-NBI). The N-NBI system is assembled to inject beams tangentially, one is clockwise and other two are anticlockwise. They provide about 14 MW of port-through power with 180 keV hydrogen beams for 2 seconds at their best condition so far.

The P-NBI system was introduced recently so as to heat plasma ions directly, and to measure ion temperature profile by using Charge Exchange Recombination Spectroscopy. The specific features of this P-NBI are its low energy of 40keV and injection angle that is almost radial. Although perpendicular injection was considered to be ineffective in helical system due to bad confinement of high energy ions, it was found that the confinement of trapped particles becomes very good in some magnetic configuration of LHD. In fact, the initial results of P-NBI in FY2005 by 3MW injection were better than expected from Monte Carlo simulation. Therefore, we decided to increase the power of P-NBI in FY 2006.

The vacuum vessel of P-NBI beamline was designed and fabricated to possess four ion sources. Because only two of them were used in FY 2005, we have added two more ion sources, in-vessel components, and power supplies for increasing power. At the same time, we tried to fix two major problems of P-NBI system that are (1) the excess gas flow into the LHD vacuum vessel during beam injection by which plasma production is impeded sometimes, and (2) locally focused heat deposition on the ion beam dump. The design of the ion source also has been reviewed and improved for fabricating new ion sources.

As a result, the injection power has been increased more than twice as before (maximum injection power of 7MW was achieved successfully), and the gas inflow has been reduced. These contributed to enhance the performance of LHD plasma, such as highest plasma volume-averaged beta value of 5%, and high central hydrogen ion temperature of 5keV with the density of 1.2×10^{19} m^{-3}. Unfortunately, the change of cooling pipes of beam dump to swirl tubes was not perfect to solve the problem, and the beam pulse length is still limited to two seconds under the full beam power operation.