Exploratory studies on 1MeV Negative Ion Beam Neutralization by Laser Photodetachement

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The ignition of D-T fusion reactions in ITER requires the injection of high-power neutral D° beams into the core of the plasma. The neutral beam penetrates the tokamak plasma without deflection by the confining magnetic fields, transferring the particle kinetic energy to the plasma by collisions. Two D° injectors will be used in ITER; each one will supply the reactor with 17MW of D° at 1MeV energy. The system NBI (Neutral Beam Injection) system is composed of a negative ion source delivering 40A of D^- to a 1 MV electrostatic accelerator, followed by a neutralizer which converts part of the beam (about 60%) into high energy neutrals by collisions with gas (D_2), and finally the beam crosses the residual ion dump (RID) system, where the remaining charged beam particles, no-neutralised particles of about 20% D^- and 20% D^+, are deflected and dumped on actively cooled electrodes.

High rate of electron stripping occurs in the accelerating channel due to collisions of the negative ions with the background gas; beside the corresponding reduction of negative ion current (about 30%), this reaction is a source of stray particles (electrons, D°) generating troubles and heavy heat load on the accelerating electrodes. A special effort is underway on the ion source and neutraliser levels in order to minimize the operating pressures.

The research program proposed here resumes the old idea of using laser photodetachment to neutralize the negative ion beam which, obviously represents an interesting solution to the problems we exposed, since it doesn't need any gas injection. Nevertheless, due to the smallness of the photodetachment cross section, a simple design would require several hundreds of MW for full neutralization. The research program aims at a study of the method feasibility by an in-depth investigation of the photodetachment physics, and the optical system design.

On the one hand, the fundamental research should follow the possibility of increasing the photodetachment cross section by bringing to light the magnetic resonances corresponding to the occurrence of Landau levels in the continuum of photoelectron free states. On the other hand, the optical system design should combine a multi reflexion laser system and Fabry-Perot cavities which could increase significantly the laser power seen by the negative ions. The mechanical stability of such a system must be taken into account. As a first step, problems due to using optics in a plasma environment are put aside.

The photo-neutralization of negative ion beams is a very seducing and advantageous method, but several issues have to be addressed to fit with the injector environment. This research program should conclude on the interest of proceeding with studies on negative ions beam photo-neutralization for the neutrals injector of ITER. This interest shown, an experimental program should be conducted in order to confirm the proposed ideas.