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PhD PROPOSAL 2009

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Title : Self consistent non-linear modelling of radio-frequency wave propagation and of peripheral magnetized plasmas.

Summary :

In order to heat the fuel mix and drive current in magnetic Fusion devices, high power radio-frequency (RF) waves are used. Excited at the periphery of the reactive medium, they propagate to the centre of the discharge where they are damped, giving their energy (heating) and momentum (current drive) to the plasma. Among the types of waves, those in Ion Cyclotron Range of Frequencies (ICRF – 30-80MHz) represent an essential means to heat the plasma on Tore Supra (TS), JET and later ITER.

ICRF waves being evanescent in vacuum and below a critical density, they need to be excited in the immediate vicinity of the well confined plasma and are very sensitive to the properties of the peripheral plasma. Conversely the presence of intense near RF fields tends itself to modify the peripheral plasma in the immediate vicinity of the wave launchers. This non-linear interaction is likely caused by the presence of sheaths, with a non-linear electrical behaviour, at the plasma-wall interface. Recently several physical processes of non-linear interaction were evidenced experimentally: self-biasing of the plasma, peripheral power dissipation and RF-specific heat fluxes, local density modifications, electric current circulation, destabilisation of edge transport barriers (H mode). These processes are potentially harmful to the wave launchers themselves, but also to the magnetically connected objects as well as the edge plasma itself. These still badly known physical processes need first to be understood and then reduced as far as possible in next step devices.

In the current state of our knowledge, the various physical processes observed have been at best studied individually. Some of them have not received yet a satisfactory explanation. For example, some theoretical predictions about the radial extension of RF-induced plasma modifications seem in contradiction with measurements. The circulation of DC currents around active wave launchers was so far neglected. The self-biasing processes were so far estimated on the basis of near RF fields evaluated in absence of bias. This at best provides an order of magnitude for their amplitude and a qualitative estimate for their topology. A self-consistent treatment of the coupled RF waves and DC plasma appears necessary, in particular by introducing RF sheaths in the boundary conditions of the model.

From recent theroretical advances, obtained in particular in collaboration with Nancy I University, the PhD work will establish the equations of the physics model and then implement it numerically in view of explaining the experimental observations, and then test suggestions of next step antenna design and operation with plasmas. Collaborations can be envisaged with Ecole Royale Militaire (Bruxelles) and with Politecnico Torino.

Skills : with the profile of a physicist, the successful candidate will have special skills for analytical calculations and their numerical implementation. He/she will be able to communicate with engineers.