

Study of the mutual dependence between Lower Hybrid current drive and heavy impurity transport in tokamak plasmas

Global energy consumption has significantly increased during the last century, e.g. from 6,000 million tons of oil equivalent in 1973 to more than 13,200 million tons of oil equivalent in 2016. Global energy needs will continue to grow in the nearest future. Fossil fuels represent our current dominant source of energy with about 80% of our total primary energy supply. However, fossil fuels reserves are limited and are renewed at a very slow rate, negligible at the human scale. Therefore, controlled thermonuclear fusion can be a prime candidate for energy production in the future.

The tokamak device is currently the most advanced solution to control the fusion reaction and to harvest energy in the future. In this torus-like device, thermonuclear plasma is confined using a strong toroidal magnetic field induced by external coils and a poloidal magnetic field self-generated by the plasma current. However, there are still several scientific and technological challenges on the way to construction of the fusion power plant. One of them is the efficient control of the plasma current profile to ensure stable steady-state plasma conditions. Among several techniques, the Lower Hybrid current drive (LHCD) is a key heating method to control this current profile by optimizing the power deposition of the electromagnetic wave in the fusion plasma. Another issue comes from the fact that future fusion devices - like the International Thermonuclear Experimental Reactor (ITER) - will have to use heavy metallic elements like tungsten (W) as the plasma-facing components, in order to limit tritium retention (tritium is a radioactive reactant of the fusion reaction). The heavy impurities generated by physical sputtering can then cool down the plasma and thus strongly degrade the fusion reaction by radiation in the soft X-ray (SXR) range.

Therefore, efficient impurity mitigation methods must be developed and should include the effect of the heating systems on the impurity distribution. However, in case of LHCD the interaction between the induced energetic electron population and the heavy impurities remains unclear, while it could compromise both the control of the current profile and the mitigation of impurity accumulation in future fusion reactors. The Tore Supra tokamak recently upgraded in WEST - for W Environment in Steady-State Tokamak - is a unique device to perform such studies in ITER-relevant plasma conditions. Thus, the main objective of this project is to investigate the interplay between heavy impurity transport and the shape of the LHCD power deposition profile during Tore Supra / WEST tokamak plasma discharges.

The goals will be achieved first by performing preliminary investigations on the available database of past Tore Supra plasma discharges. Then experimental analysis will be conducted on the new WEST platform to identify the mutual dependence between LHCD and heavy impurity transport in ITER-relevant plasma conditions. For this purpose, X-ray measurements and tomographic reconstructions will be performed to study simultaneously the energetic electrons and heavy impurities behavior and observe the interaction between these two populations. An important modelling work will be also performed with the numerical codes (LUKE, C3PO) to simulate the Lower Hybrid wave propagation and absorption in the plasma and understand the interplay between energetic electrons and impurities.

The results obtained in the framework of the proposed project will allow to choose efficient methods of control of the plasma current profile and impurity mitigation techniques in magnetic confinement devices. These topics play a crucial role for the development of methods for plasma control in the International Thermonuclear Experimental Reactor ITER and future thermonuclear power plant DEMO. Both ITER and DEMO are currently ones of the largest international scientific endeavors of our time.