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INSTITUT DE RECHERCHE SUR LA FUSION PAR CONFINEMENT MAGNETIQUE (IRFM)
CEA/Cadarache - 13108 St Paul-lez-Durance Cedex - France

PhD PROPOSAL 2014

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Title : Characterization and modelling of the secondary emission properties for high power RF systems. Applications to controlled nuclear fusion and spatial domains.

Summary:
The goal of the magnetic fusion research is to demonstrate the scientific and technological feasibility of fusion power for peaceful purposes. To achieve this, very hot plasma with temperature exceeding 100 million degrees must be generated and sustained for long durations. For long pulse operation in a tokamak, additional heating and current drive are required. The most efficient method to generate additional current drive is currently by Lower Hybrid (LH) waves. These waves, whose frequency is between 1 and 8 GHz, are carried through rectangular waveguides from the high power sources to the antenna. These waveguides are generally gas-pressurized, then under the vacuum of the machine. One must therefore have a window at the interface between the gas-pressure and the vacuum, which is sealed for the gases but transparent to RF waves. The ITER tokamak under construction in Cadarache plans to build a 5 GHz system to lengthen the plasma discharges from 400 to 3000 seconds. This system may couple 20 MW and the available space to accommodate the antenna on the tokamak requires having to transmit 500 kilowatts per window. There is a significant technological leap between what was tested on the Tore Supra tokamak CEA (300 kW at 3.7 GHz) and what is needed for ITER (500 kW at 5 GHz).

The power handling of the transmission line is limited by vacuum "multipactor" effect that occurs when the kinetic energy (gained in the RF wave field) of the electrons striking the surfaces of the guides or the window is sufficiently high. Phenomenon of "electron avalanche" is created and generates a breakdown (arc) in the residual gas at low pressure, which can damage the structures. The critical parameter that will adjust the maximum RF electric field (and thus RF power) is the secondary emission ratio. This rate depends on the material of the target and its topology (roughness) as well as adsorbed gas and the treatments carried out on its surface. This rate is higher for ceramics than for metals and it is critical to assess the limits of power expected from these windows in real experimental conditions (temperature annealing, static magnetic field, effect of ultrathin metal film...).

Some “recipes”, resulting from the experience of the manufacturers without any baseline study has been undertaken, leading to empirical laws often pessimistic. In general, there are very few studies in the literature on the emission properties of ceramics and in particular beryllium oxide and the effect of a “anti-multipactor” layer'. The aging of this very thin film is also not well known.

The physical mechanisms leading to breakdowns by electron avalanche of insulation materials (especially ceramics) are complex: secondary emission and elastic scattering / inelastic of the electrons. The student will measure the quantities related to these mechanisms, in conjunction with the detailed

characterization of surfaces. This experimental work will be carried out by controlling the relevant physical parameters (thermal treatment layer "anti-multipactor").

From a curve giving the secondary emission ratio depending on the energy of the incident electron, it is possible to calculate the gain factor of the population of electrons and therefore predict the power from which the breakdown appears. This was done in simple geometries for the metal guides. We propose to conduct this study in the case of more complex geometries (RF antenna elements, RF window) taking into account the DC static magnetic field in the vicinity of a tokamak.
To do this, the student will use numerical simulation codes with the experimental curves determined from experiments as input parameters. He will accurately verify the beneficial effect of the increase of frequency (3.7 GHz to 5 GHz) and secondly the baking at high temperature (~ 300 ° C) on the multipactor effect threshold.

The student will give recommendations for the size of the BeO ceramic disk of the window but also waveguides (rectangular and circular) connected to the disk. For applications related to space, he will give recommendations for size ranges to meet in the microwave components studied. This work will be conducted in collaboration with industry partners to integrate manufacturing constraints.

Skills : radiofrequency, material physics