Spectral characterization of dusty plasma - Application to ITER edge-plasma monitoring

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Abstract

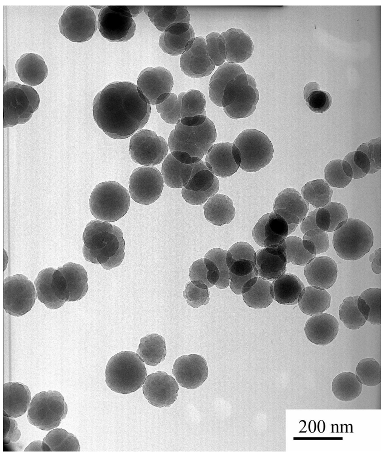
The poster proposed here deals with the spectral characterization of carbon dusty plasma. This study is related to the "International Thermonuclear Experimental Reactor" project ITER. This one is now initiated and several problems have to be solved before an efficient fusion power reactor will be designed. Among the numerous technically challenging issues arises the question of plasma magnetic confinement question. Experiments have shown that interactions between the edge-plasma and the reactor walls may happen. ITER walls should be built with carbon material that can be able to resit to high energy fluxes such as those occurring when the magnetic confinement is broken. However, if the hot edge-plasma (T≃10000K) impinges the carbon wall, dust production is observed. This carbon dust production is problematic because it might induce the interruption of the fusion process. Furthermore the produced particles are radioactive and they can fall away at different locations in the reactor, generating new radioactive wastes that must be treated.

In order to understand these phenomena, experimental setups with a lower scale have been designed at the LPMIA. Among them a low pressure reactor is used to produce discharges by means of a carbon electrode. Infrared transmission measurements of the induced plasma show that the scattering phenomenon occurs as carbon particles are produced and aggregate. Samples taken from the reactor reveals that these particles are spheres with radius ranging from 50nm to some microns, according to the way dust is produced. Two cases have been tested, plasma with a carbon cathode which generate very small particles (Figure 1(a)) or discharge with argon-acetylene mixture providing larger spheres. Hence, absorbance measurements achieved in the plasma discharge at different times vary as scattering evolves from the Rayleigh regime to the Mie regime with a forward phase function. Therefore, the challenge is to estimate size distribution and volume fraction by inversion techniques of the spectral data (achieved between 400cm^{-1} and 4000cm^{-1}).

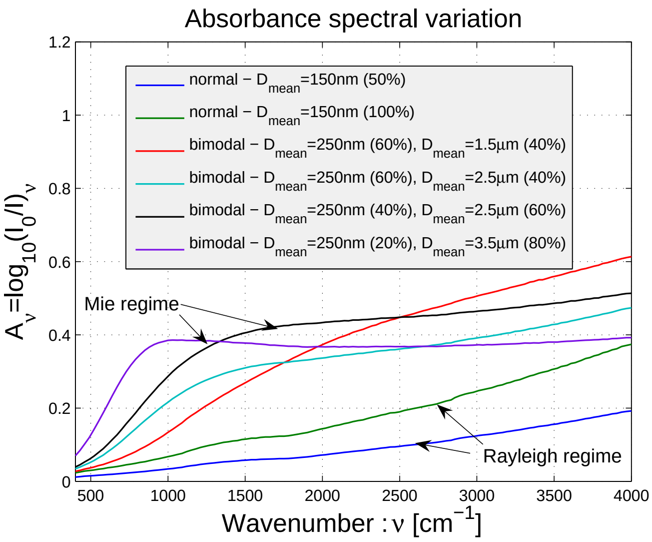
In parallel to these measurements, a companion numerical study has been done at the LEMTA. Reproducing the geometry of the experimental reactor, we have developed a Monte Carlo model that tracks quanta from the emission point of the spectroscopic device to the MCT detector, through the absorbing and scattering plasma

discharge. A complete Mie calculation pre-processing step is achieved for sphere diameters in the range 50nm$<D<$5μm, using amorphous carbon optical properties in the wavenumber range 400cm$^{-1}<\nu<$4000cm^{-1}. Polydispersions (normal and bimodal distributions) are tested in order to compute absorption and scattering properties at different moment of the experiment, trying to fit the carbon dust growth. Then the Monte Carlo procedure is achieved using an energy partitioning technique. Numerical results give trends similar to the experimental ones, especially in what concerns the transition between the isotropic and the forward scattering regimes (Figure 1(b)). The shape of the polydispersion distribution being the key parameter.

Further investigations are going to be carried out. First we will try to optimize the estimation of carbon dust properties (size and concentration), and we will also achieved calculation in the visible range for small particles (d$<$1μm). In a second time, experimental procedure can be adapted in order to accurately control the carbon dust mass and size distribution production in order to adjust the numerical procedure. Besides, other type of plasma discharges, including magnetic confinement are also planed.



(a) Carbon dust electron microscopy sample



(b) Monte Carlo absorbance calculation for a argon-acetylene mixture

Figure 1: Spherical carbon dust sample and Monte Carlo absorbance calculation

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