Void behavior and profile using Laser Induced Fluorescence

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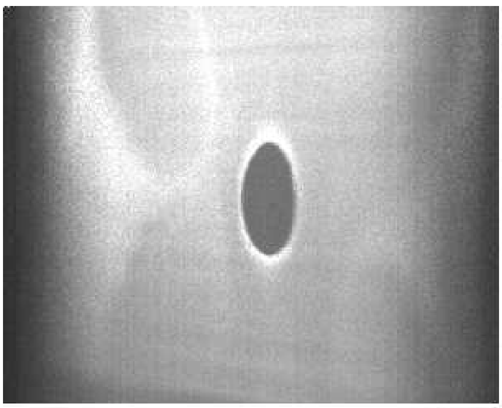
In a plasma, dust particles can be easily grown, either by injecting reactive gases (like silane or acetylene), or by sputtering materials [1]. This work is performed in the PKE-Nefedov reactor, a capacitively coupled discharge with a rf (13.56 MHz) power of about 3 W and a gas pressure between 1 and 2 mbar (100 – 200 Pa). A polymer layer deposited on the electrodes is sputtered by an Ar plasma [2] leading to the injection of molecular precursors in the plasma volume. These molecules are at the origin of the dust particle growth through a complex succession of chemical and physical reactions. Using this method, a huge density of small dust particles can be grown and trapped in the plasma [3]. The trapping is mainly due to the fact that dust particles attach plasma free electrons and acquire a negative charge. This loss of electrons can strongly disturb the plasma equilibrium and can give birth to complex unstable phenomena [4, 5, 6]. In our experimental conditions, dust particles stay small enough (a few tens - a few hundreds nm) to be little affected by gravity. Therefore, three-dimensional clouds can be obtained in on-ground experiments. An interesting characteristic of the dust cloud structure is the appearance of a central dust-free region: the void, as observed in Fig. 1 left. This region is due to an equilibrium between two opposite forces: an outward ion drag forces that pushes the negatively charged dust particles out of the plasma center, and an inward electrostatic force that attracts them toward the void center [7]. The void is a place where the plasma characteristics are different from the rest of the plasma containing the dust particles. This particularity is easily observed by the naked-eye as the light emission is strongly enhanced in the void [8, 9] as seen in Fig. 1 right.



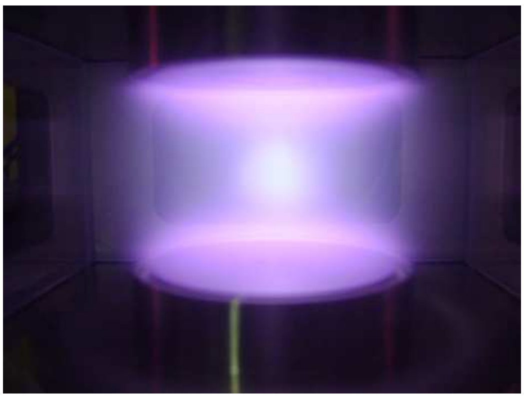


Figure 1: Left: A typical void is a dust-free region in the plasma center. Right: The void corresponds to a plasma region with an enhanced light emission

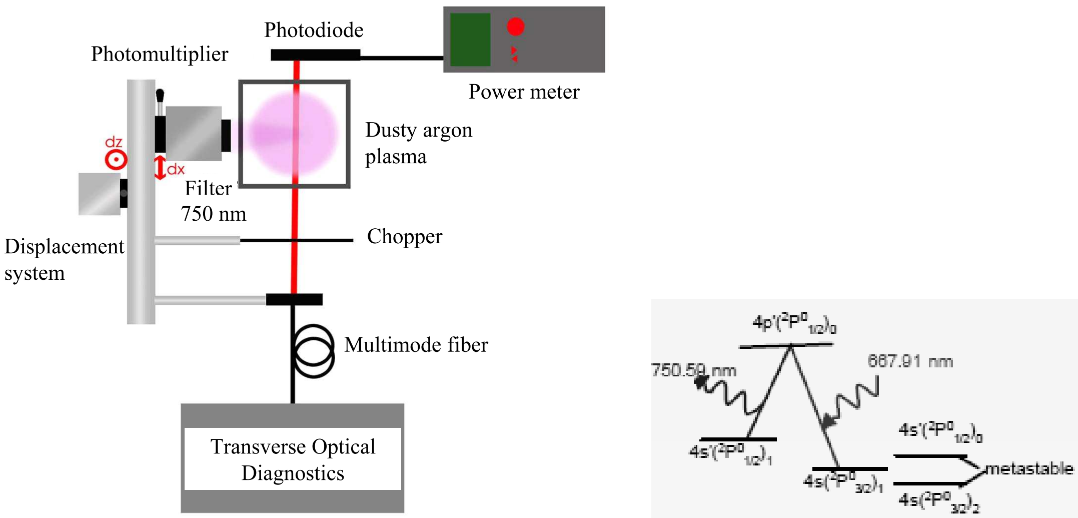


Figure 2: Left: Experimental setup with the LIF platform installed on the PKE-Nefedov setup. Right: Excitation scheme used for LIF

In order to get some insights on the void properties without disturbing the inner plasma, non intrusive diagnostics are more appropriate. Therefore, the LIF diagnostic has been used to obtain horizontal and vertical profiles of the excited neutral atom density. A LIF platform currently developed in GREMI, has been installed on the PKE-Nefedov setup as shown in Fig. 2 left. LIF measurements were performed with a laser of central wavelength $\lambda_0 = 667.9125$ nm in order to pump the $4s[3/2]_1$ level of the neutral Ar to the $4p'[1/2]_0$ level [10]. The de-excitation to the $4s'[1/2]_1$ level corresponds to the emission of a photon at 750.5934 nm. This excitation scheme is shown in Fig. 2 right. The laser is continuously probing the wavelength region around λ_0 with a triangular scan, i.e. with a cycle from $\lambda_0 - d\lambda$ up to $\lambda_0 + d\lambda$ and then down to $\lambda_0 - d\lambda$. At the end of a scan cycle, the photomultiplier is moved to analyze another plasma location. By repeating this procedure, LIF signal as a function of λ can be recorded for different locations as shown in Fig. 3. From these measurements, the maximum LIF signal amplitude is obtained as a function of the plasma location. It gives the horizontal (from the void center toward the plasma edge) and vertical (from the void center toward the electrode) profiles of the relative excited neutral density.

The obtained horizontal profile is shown in Fig. 4 left. A clear enhancement of the excited neutral atom emission is observed in the void center. The emission is continuously decreasing when moving toward the plasma edge. The transition between the void and the dusty plasma region is not well-marked as it could be expected. It could be due to the too large size of the region observed by the photomultiplier. Indeed, as the light is integrated on a region of a few mm it leads to a smoothing of the emission gradient. The vertical profile has a slightly different

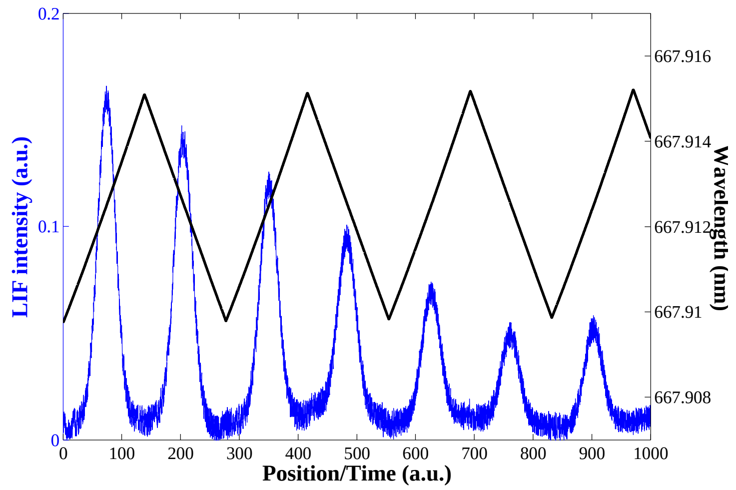


Figure 3: LIF measurements as a function of the laser wavelength for different horizontal positions in the plasma, from the void center toward the plasma edge

behavior as shown in Fig. 4 right. Indeed, in this direction the plasma is strongly confined by the electrodes. It leads to the formation of well-defined sheaths in front of each electrode. It is well-known that a region of enhanced emission appears at the transition between the plasma and the sheath. This is the place where plasma electrons gain energy [11]. This region is well-evidenced in Fig. 4 right, that shows three main regions. The first one is the void with and enhanced excitation. In comparison with the horizontal profile, the void is clearly marked between 0 and 0.4 cm. Indeed, for the vertical profile, the integration region is reduced because it is limited by the laser width. The second region is the plasma bulk with a rather constant emission. The last region is the presheath where the excitation steeply increases.

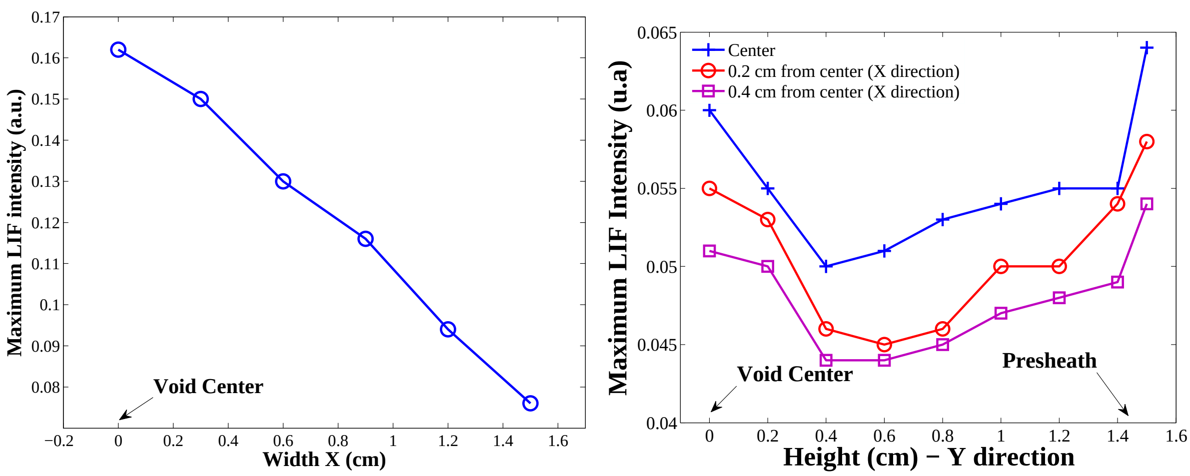


Figure 4: Left: Horizontal profile for LIF maximum intensity from the void center toward the plasma edge, Right: Vertical profile for LIF maximum intensity from the void center toward the electrode for 3 different horizontal positions

In this contribution, we briefly presented preliminary results on the void characteristics using a Laser Induced Fluorescence platform currently under improvement in GREMI. It has been shown that the excited neutral density is higher in the void than in the rest of the plasma bulk containing dust particles (except the presheath regions). Some improvements will be performed as for example an increase of the spatial resolution. The neutral gas temperature can also be estimated from LIF measurements. Nevertheless, uncertainties on the temperature were rather important during our experimental campaign and no clear conclusions can be drawn for the moment on this interesting parameter.

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