Measurements on a high pressure inductively coupled light source

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Measurements on a high pressure Inductively Coupled Light Source

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Introduction

The use of electricity for lighting purposes is a considerable part of the total consumption of power. Therefore, research on light sources with a high efficacy is an important approach in reducing the total energy consumption. One of the future light sources might be an inductively coupled high pressure plasma, which has the feature of an effective energy coupling into the plasma. However, the reason why this light source is so very efficient is not yet well understood. In this project fundamental research is carried out on an argon plasma. Although this gas is not the optimal gas compound for lighting sources, insight in the fundamental processes could give an indication of the origin of the high efficacy and this result might be useful for other types of light sources as well.

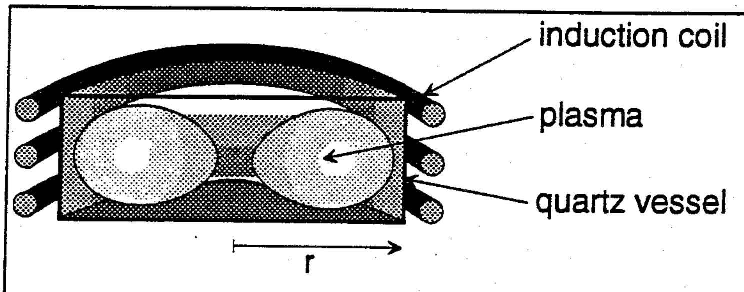

Figure 1. Cross-section of the inductively coupled light source.

Experimental

Plasma

The plasma is created in a coil with three windings fed by an effective power of typical 100 W. In this coil a cylindrical quartz vessel is positioned with an inner radius of 9 mm and a height of 10 mm. A cross-section of the plasma is depicted in Figure 1. The fillings of the vessel that are under study have filling pressures of 10^3, $5\ 10^3$ and 10^4 Pa. During operation these values are a factor of ten higher due to the temperature increase.

Diagnostics

Since the plasma is driven by the energy transfer from the EM-field to the electrons, the electron temperature (T_e) and density (n_e) are important parameters. Also the heavy particle temperature (T_h) is an interesting parameter. To obtain information on T_h and n_e diode laser absorption experiments are carried out[1]. A current and temperature controlled diode laser system with a wavelength corresponding to the $4s^3P_2$-$4p^3D_3$ transition in argon (811.531 nm) is applied to measure the absorption profile by changing the current through the laser, i.e. changing the wavelength slightly. This profile is broadened by Doppler and Stark effects. These components can be obtained by fitting the profile with a Voigt profile and can be used to calculate the T_h and n_e respectively. To estimate T_e we used the method of power interruption combined with emission experiments. This method[2] can be used to measure the ratio T_e/T_h. It requires a set of (relative) line emission measurements during the power interruption for several argon lines and the assumption that the corresponding levels are populated to according Saha and is based on the fact that after switching the power off, the electron temperature drops down to the heavy particle temperature. Using the heavy particle temperature measured with diode laser absorption we are able to calculate the electron temperature.

Results

Here we present the results measured for three different filling pressures. In Figure 2 the heavy particle temperature T_h is shown as a function of radius.

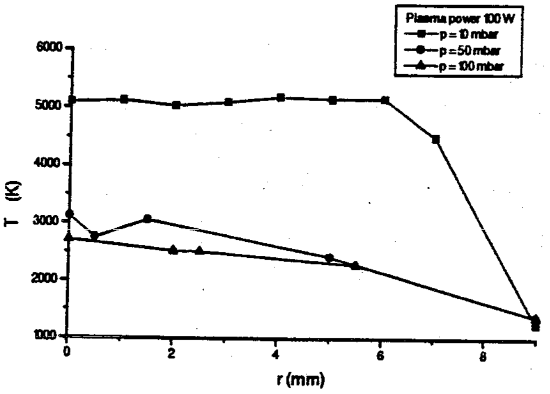

Figure 2. Heavy particle temperature (T_h) for 3 filling pressures as a function of radius at 100 W.

The temperature at 9 mm from the center, the wall temperature, is measured with an IR-pyrometer. The figure clearly show a dependence of the heavy particle temperature on the filling pressure. The higher the filling pressure, the lower the heavy particle temperature. Nevertheless, inaccuracies are large (25%), due to problems induced by the interference of the laser light with the windows of the vessel.
In Figure 3 the electron density is depicted as a function of radius.

Here, the accuracy is in the order of 30%, so no accurate radial information is obtained.

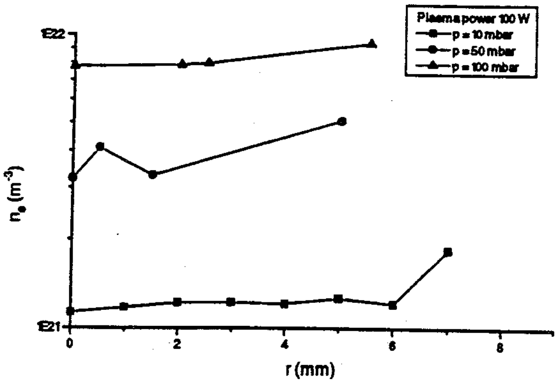

Figure 3. Electron density (n_e) for 4 3 filling pressures as a function of radius at 100 W.

However, the order of magnitude of the electron density allows us to conclude that the higher the filling pressure, the higher the electron density will be.
The power interruption experiments show that the higher the filling pressure, the lower the difference between T_e and T_h, see Figure 4. This is not surprising since at higher pressure more particles are available for energy transfer, resulting is less differences.

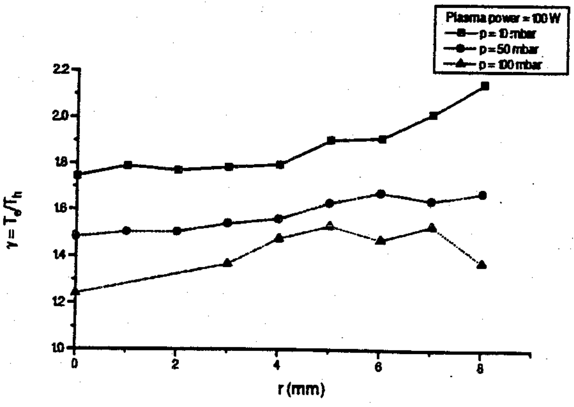

Figure 4. T_e/T_h for different filling pressures at 100 W as a function of radius.

Acknowledgments

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