Gas Excitation with High Perveance Electron Beams ◇

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A tabletop electron beam system has been set up to investigate beam excited dense gases at energy loads of up to several kJ/g. A high perveance electron beam is focussed down to a 1 mm^2 spot size and sent through a thin ceramic foil into the target gas. Perveance is defined as $I/U^{3/2}$; space charge effects cannot be neglected at typically more than 0.1 $\mu A/V^{3/2}$ [1]. Low acceleration voltages U and high beam currents, focussed to a small spot, however, have to be used to achieve high stopping values and excitation densities.

A 0.8 A, 12 keV electron beam of 0.6 μperv, focussed to 1 mm^2, has been used for gas excitation. Power densities of several MW/g in 1bar Ar are achieved. Electron beam excitation is routinely used in large volume excimer lasers with electron energies ranging from 200 keV to 2 MeV. Here, the electron energy could be reduced by more than an order of magnitude. This has become possible by the enabling technology of extremely thin ceramic foils used as entrance windows for the electrons, as described in ref. [2]. Reducing the electron energy reduces the range of the electrons in the medium. This in turn increases the pumping power density for a given beam current. Energy deposition calculations for a 1 A, 12 keV gaussian beam with 1mm FWHM, focussed through a 300 nm thick SiN_x membrane into 1 bar Ar gas, have been performed using the CASINO Monte-Carlo program [3]. Using 500 ns beam pulses, a temperature increase of the membrane of 1500 K is predicted, with an energy density in the gas peaking at 2.5 J/cm^3, as is shown in Fig. 1. Note that the power density increases after the entrance foil due to higher stopping at lower electron energies, leading to an about four-fold increase of temperature a few hundred micrometer behind the entrance foil. Thus, temperatures up to 8000 K would be expected under these excitation conditions.

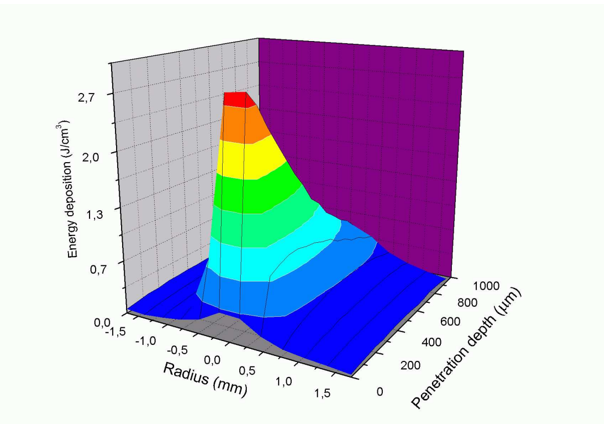

Fig. 1: Energy deposition of a 500 ns, 1 A, 12 keV electron beam focussed with a FWHM of 1mm through a 300 nm SiN_x membrane into 1bar argon gas. Calculations have been perfomed using the CASINO software [3].

In a first experiment, up to 0.8 A, 12 keV electron beam pulses were sent through a square 1 mm^2, 300 nm thick silicon nitride foil into 600 mbar argon gas. Rectangular pulses of 10, 20, and 50 ns were applied to the extraction grid of the electron gun, using a cable pulser with a fast solid state switch. Wavelength spectra were recorded in the 110 to 200 nm range with a gated, intensified diode-array camera. The spectra are dominated by the so called second excimer continuum (Fig.2).

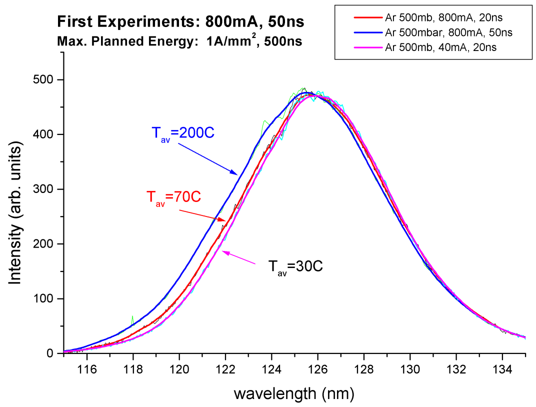

Fig. 2: Electron beam excitation of Ar using three different energy loads. Average gas temperatures of 470 K, 340 K, and 300 K, respectively, could be deduced from the width of the excimer continua.

Average gas temperature has been measured using the widths of the recorded excimer spectra [5]. A maximum average gas temperature of 200 °C could be deduced for the 0.8 A, 50 ns beam pulse, while essentially no temperature increase was measured for the 40 mA, 20 ns beam pulse situation. Taking into account that the temperatures, measured, are mean temperatures, averaged over the entire excited volume, a good agreement between simulation and experiment was achieved.

In a next step, longer elctron beam pulses shall be applied, increasing the energy load and thus the temperature of the excited gas. In particular the transition between a cold recombination plasma, spectrally dominated by excimer radiation, and a hot regime, where excimer molecules can not be formed and thermal ionization is increasingly dominant, shall be studied.

References

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