Power Density Limits in Dense Gases for Low Energy Electron Beam Excitation

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Low energy electron beam excitation of dense gases holds the potential for producing very high power densities in the target gas. This is due to the short range of the electrons in the gas and the consequently small volume ($\sim 1mm^3$) in which the beam power is deposited. Therefore we develop concepts to pump short wavelength lasers with this technique. A model device of a very compact, low energy electron beam pumped laser working successfully in the near infrared is described in ref. [1]. Here we present the limitations for a system which uses a similar technique. The goal was to determine whether a 172 nm Xe_2 excimer laser could be realized in such experiments. However, the results show clearly that a geometry with an elongated beam pumped volume produced by a pulsed, high current, elliptically shaped, 12 keV electron beam will have to be used for successful laser experiments [2].

A laser cell with a high current Pierce-type electron gun has been used for the experiments. This electron gun with 12 keV acceleration voltage provided pulsed beams of up to 2 A beam current. The current could be pulsed via a control voltage applied to a grid in front of the heated cathode. The beam was focused through a 300 nm thick, $2 \times 2\ mm^2$ ceramic membrane into the gas target. The technology of the membrane used as an entrance foil for the electron beam is described in more detail elsewhere [3]. A stable optical cavity with highly reflective (96% at 172 nm) mirrors was installed. The light output on the laser axis and the spontaneous light emission was detected by photodiodes and a VUV monochromator with a gated, intensified diode array camera, respectively. The optical path between the cell and the detection systems was flushed with helium to avoid absorption of the VUV light by the oxygen content in air.

A series of experiments for various xenon pressures and xenon containing mixtures with other, lighter rare gases has been performed in order to get above laser threshold for the 172 nm excimer laser on the so called second continuum of xenon, which actually was the first excimer laser to be studied, historically [4], but without success. The diagnostic technique was similar to a successfull particle beam pumped excimer laser experiment performed at GSI Darmstadt [5].

However, other important results were obtained using this setup. A practical limit was found for the operation of pulsed, high current experiments using the 300 nm ceramic foil technique. It was observed that the foils are destroyed when a 12 keV, 2 A beam is applied for more than about 50 ns. In combination with a transmissivity study [6] this corresponds to an energy deposition on the order of 0.1 mJ in the membrane. The threshold found experimentally is consistent with estimates based on the heat capacity of the membrane and corresponds to a transient temperature increase of the foil of about 700 K.

The heating effect of the high intensity beam was also qualitatively observed via a change in the shape of the spectral excimer emission of xenon [1]. An intensity increase at the short wavelength side of the emission indicates an increased population of the higher lying vibrational levels of the excimer molecule due to gas heating.

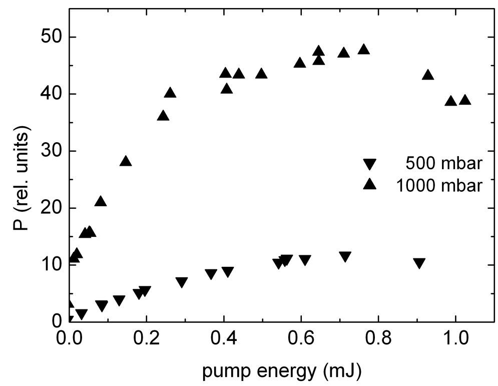

Fig. 1: Second excimer continuum light output of Xenon vs. energy of the pumping pulses.

In a series of measurements the beam intensity was systematically increased and the intensity of the Xe_2^* second continuum was recorded. The result is shown in Fig. 1. The experiment was performed for a target gas pressure of 500 and 1000 mbar, respectively. The output power saturated in both cases at a beam energy value on the order of 0.5 mJ. From a practical point of view this demonstrates the limit for experiments with xenon using the present setup. The exact reason for this saturation still has to be investigated in forthcoming experiments. An instrumental effect which could limit the output might be a limitation of the beam energy which can be transported into the target gas. This could either be due to a broadening of the beam diameter due to space charge in the beam or by a charging effect of the target gas which might lead to repulsion and/or deflection of the electrons. An effect which would limit the emission of excimer light would be an overpumping of the target gas. It is known that an increase in the density of excimer molecules leads to a destruction of these molecules via collisions among these molecules.

References

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