Heavy Ion Beam Pumping of VUV Excimer Lasers ◇

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Experiments to pump the VUV excimer-lasers of Ar_2, Kr_2, and Xe_2 using intense heavy ion beams from the SIS accelerator are performed. The laser transition is the decay of the first excited state of rare gas molecules to the repulsive ground state (second continuum). A first experiment with a high beam intensity on the order of 1.5x10^9 Ne-ions per micro-puls has been described in the last annual report [1]. Dense xenon gas is used as a laser medium since liquid and solid rare gases which could be used alternatively show light diffraction or permanent damage of the material. Optical gain has already been measured in dense rare gas which was evaporated from a solid using intense low energy beams from the GSI RFQ-accelerator [2]. In a static gas target, however, attenuation of the 172nm VUV excimer radiation of Xe_2 in the laser medium exceeded optical gain in the experiment at SIS mentioned above so that a laser effect could not be observed. Here we describe the various contributions to this light attenuation which could now be clearly resolved. Ways to reduce or eliminate these effects are presented.

In order to stop 300MeV/amu neon ions in xenon within the focal depth of about 10cm of the SIS-beam behind the fine focusing lense at the HHT target station requires a density of more than 2g/cm^3 which corresponds to a xenon pressure of 100bar and a particle density of 9x10^{21}/cm^3. The dense gas is prepared by circulating xenon in a titanium gas purifier at about atmospheric pressure. Then the gas is condensed in a high pressure gas system using liquid nitrogen as a coolant. High pressure is then obtained by heating the condensed gas to room temperature. A cold trap was used to remove water vapor from the system.

Now another high pressure cell has been developed in which the gas handling procedure can be improved using VUV absorption spectroscopy as a diagnosis. Light from a deuterium lamp is sent through a 6.7cm long path inside the cell and then analysed using a VUV monochromator with a VUV sensitve multichannel-plate image intensifier and an optical multichannel analyser . Transmission spectra of dense xenon are shown in Fig. 1. Light attenuation is due to scattering and absorption processes. Rayleigh scattering and absorption in xenon itself have been studied by Gerado and Johnson [3] up to 30bar. In the temperature/density region around the critical point at 289.7K and 1.11g/cm^3 (p_{kr}=58.3bar) scattering is the dominant mechanism for light attenuation. At 300bar this scattering which is determined by the slope of the eqation of state $\rho * (\frac{\partial \rho}{\partial p} |_T)$ should be reduced again to the value at 30bar assuming the index of refraction scales linearly with density ρ. Photoabsorption in xenon appears as an asymmetric broadening on the long wavelength side of the first resonance line at 147nm due to beginning molecule formation. This explains the broad and deep absorption dip in Fig. 1.

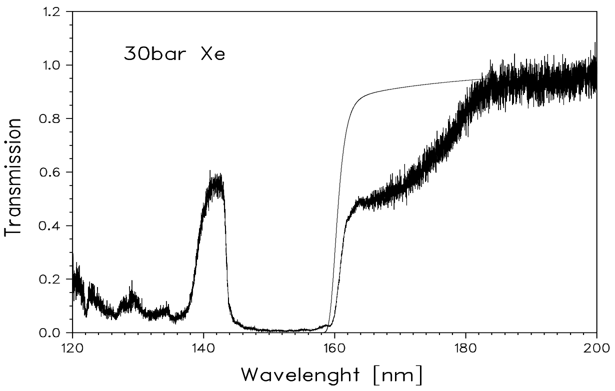

Fig. 1: Absorption spectrum of a Xe-sample with 21ppm water vapor in comparison with theory (thin line)[3].

The process, however, which was found to be critical for successful 172nm excimer laser operation at very high densities is photoabsorption by impurities in the gas. It was found that despite the elaborate gas handling procedure described above too much water vapor ends up in the cell and outgases from the walls after the cell being filled. Water vapor was identified as an absorber by comparing absorption spectra with the wavelength dependence of the optical absorption cross section [4]. The other impurity which may have to be taken care of is oxigen [5] which showed up in some experiments as an absorber when water vapor was removed by placing molecular sieve directly into the high pressure cell. Oxigen can be removed by chemical reactions with hot titanium. An electrically heated Ti-wire which was found to work well at atmospheric pressure can e.g. be tested for that purpose. Another approach for improving the optical quality of the laser medium is to dilute the laser medium with lighter rare gases. This is possible because effective collisonal processes transfer the excitation energy from the lighter gas to the second excimer continua of the heavier ones.

References

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