Influence of Water Vapor on the $1.73\mu m$ ArXe-Laser System ◇

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The development of efficient near infrared gas lasers is of continuing interest for scientific and industrial applications [1]. In particular, the ArXe laser at a wavelength of $1.73\mu m$ is being studied using rf-discharge [1], electron beam excitation [2], and so called nuclear pumping [3]. The laser line is the $5d[3/2]_1 - 6p[5/2]_2$ transition in Xe*. The laser species is mixed with a rather dense (100mbar to a few atmospheres) buffer gas such as argon or helium. The pumping scheme is complex and includes several gas kinetic processes with dissociative recombination of ArXe$^+$ and Xe_2^+ being important for obtaining population inversion.

Athough efficiencies up to 8% can be observed for the ArXe laser [1], long pulse (ms) pumping often shows premature termination of the laser pulse compared with the pumping pulse [3,4]. Both outgassing of water vapor from the walls of the laser cell and an influence of gas temperature, which rises due to the energy deposited during the pumping pulse, on the complex pumping scheme are discussed as potential reasons for this deficiency.

Using a 100MeV ^{32}S beam from the Munich Tandem accelerator for pumping, we have studied both effects seperately and under controlled experimental conditions. Here we describe the influence of water vapor. Beam pulses of $50\mu s$ duration, long enough for obtaining steady state pumping conditions and short enough to avoide significant heating of the laser gas, were used. The ion beam was sent into a 500mbar Ar, 0.5% Xe laser gas mixture through a 4mm diameter, $1mg/cm^2$ Titanium entrance window. Pumping power density was on the order of 100W/cm^3 which is comparable with typical nuclear pumped laser experiments.

An almost longitudinal geometry [5] was used for the laser cavity with a flat laser mirror mounted next to the entrance window of the particle beam and one external mirror with 1.5m radius of curvature. Both mirrors were dielectrically coated for maximum reflectance at $1.73\mu m$. They were mounted at a distance of 65cm, forming a stable resonator. Laser light reflected off the Brewster window, installed at the end of the laser cell, was detected using a Germanium photodiode.

The laser was operated using a gas mixture which was highly purified by circualting the gas through a hot (800^oC) titanium gas purifier. Then water vapor was deliberately added. By opening a valve to a water containig section of the cell, water vapor diffused into the laser gas. It was observed that the laser intensity decreased and the laser went off after a few minutes. Water concentration in the laser gas was measured using a sensitive electrical hygrometer. Using the gas purifier the water vapor was again removed from the laser gas step by step and its concentration and the corresponding laser power were measured. The result of this measurement is shown in fig. 1.

Two processes were considered for describing the influence of water vapor on the laser power P. One is collisional quenching of the upper laser level by water and the other is attachment of free electrons to water, which reduces the rate of dissociative recombination of the molecular ion precursors and thereby the pumping rate into the upper laser level.

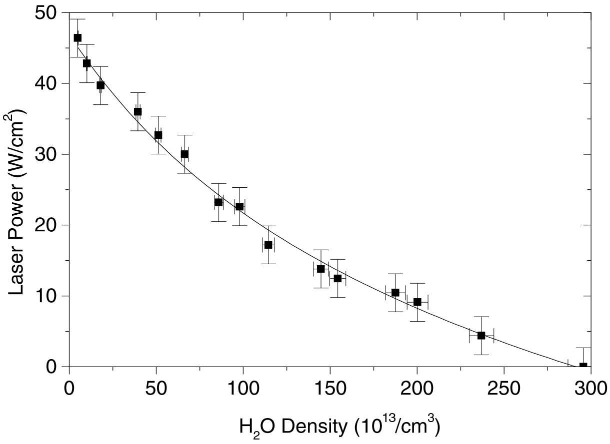

Fig. 1: Water vapor dependence of laser power in the optical cavity. The solid line was obtained using the fit described in the text.

By modelling the corresponding steps in the pumping scheme it can be shown that collisional quenching leads to a linear decrease of laser power with increasing water vapor concentration x, whereas the electron attachment process reduces the laser power in a 1/x dependence. It was found that only a combined model including both effects can describe the data shown in fig. 1 correctly. The laser threshold at $[H_2O] = 300 \times 10^{13}/cm^3$, in particular, can only be reproduced if the quenching process is included. The following formula was fitted to the data:

$$I([H_2O]) = \frac{h\nu}{\sigma} * \left(\frac{const}{p_1[H_2O]+1} - (A_{ik} + \tau_Q^{-1} + p_2[H_2O])\right)$$

From the fitting parameters a quenching rate constant of $5.4 \times 10^{-11} cm^3/s$ could be deduced. The electron attachment rate constant k can be derived only in comparison with the total recombination rate R as $k/R = 5 \times 10^{-16} cm^3$. Multiplying with the number of water molecules per cm^3 results in the ratio of both rates.

Finally it should be noted that the water content given as the number of water molecules per cm^3 does not necessarily mean that water can be treated as an ideal gas under these condidtions. In contrary, as was recently discussed in the literature, a large fraction of the water is bound in rather large clusters containing about 30 molecules [6].

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◇ Work supported by INTAS Grant 96/351 and NATO Grant 921215