Measurement of the gain in a XeF (C→A) laser pumped by a coaxial e-beam

H.M.J. Bastiaens, P.J.M. Peters and W.J. Witteman

University of Twente, Department of Applied Physics,
P.O. Box 217, 7500 AE Enschede, The Netherlands

ABSTRACT

A XeF (C→A) excimer laser with a specific output energy of 1.4 J/l has been demonstrated. The laser was pumped by a coaxial e-beam with an intermediate pulse length (≈ 175 ns) and pumping rate (~ 1 MW/cm^3). The small signal gain in this system was measured at λ = 488 nm for different gas compositions and under various pumping conditions. A peak gain of 3.3% cm^{-1} was found in the usual five component gas mixture.

1. INTRODUCTION

Excimer lasers are well known as powerful sources of UV radiation. They normally operate on the B→X transition of the molecule. This transition has a relatively large cross-section for stimulated emission and a maximum bandwidth of several nanometers. Bandwidths of several tens of nanoseconds are possible with trimeric molecules (e.g. Xe_2Cl, Kr_2F) or on the C→A transition of the dimeric excimer molecules. Obviously these transitions have a much smaller cross section for stimulated emission and consequently also a lower gain coefficient compared to the dimeric species. Consequently special optics with a high reflectivity at the broad band transition and a very low reflectivity at the B→X transition is needed. For the XeF (C→A) laser significant progress was made by Nighan et al[1),2)] using a five component laser gas mixture.

Initially only short pulse (≈ 10 ns) high current density electron beams have been used to excite the XeF (C→A) laser. Recently Litzenberger et al[3)] reported on a XeF (C→A) laser which was pumped by an e-beam with a moderate pump power of 290 kW/cm^3 and a long pulse with a duration of 600 ns. In a separate paper we described the output energy measurements we carried out with our coaxial e-beam apparatus[4)]. It produces an intermediate pulse length (≈ 175 ns) and pumping rate (≈ 1 MW/cm^3).

In this paper we will present the results of our gain measurements on this XeF (C→A) laser.

2. EXPERIMENTAL CONFIGURATION

The coaxial e-beam device used in our gain measurements is described elsewhere[4)]. Briefly it consist of a low inductance five stage Marx generator which is directly connected to a coaxially shaped vacuum diode. Inside the cylindrical anode tube a pumping pulse length of about 175 ns and a maximum current density of about 100 A/cm^2 was measured. The pumped length of the anode tube was 50 cm.

For the output energy measurements an optical cavity with two dielectric coated mirrors separated by 96 cm was used. The radius of curvature of the first mirror was 10 m with a reflectivity of 99.8% at 485 ± 20 nm and a transmission of more than 90% at 350 nm. The other mirror was plane-plane and had a reflectivity of 85% at 485 ± 20 nm and a transmission of more than 90% at 350 nm. The laser output beam passed through a color glass filter (GG 385) and was detected by a GenTec ED 500 energymeter. For the gain measurements two uncoated suprasil windows were mounted instead of the dielectric mirrors.

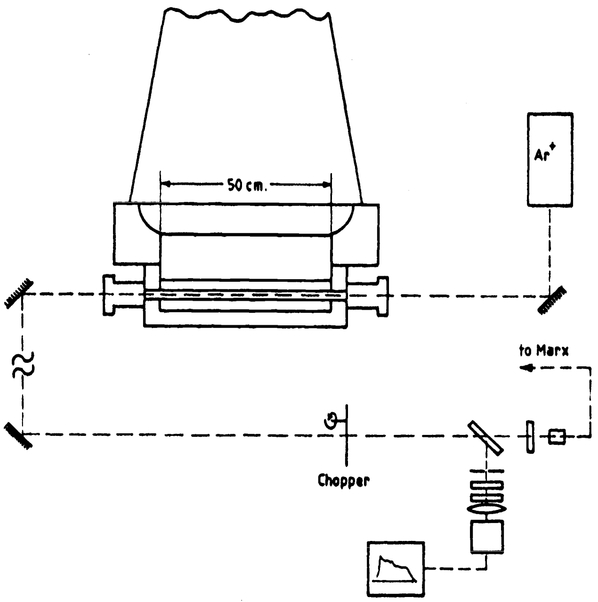

Fig. 1 Schematic diagram of the experimental layout.

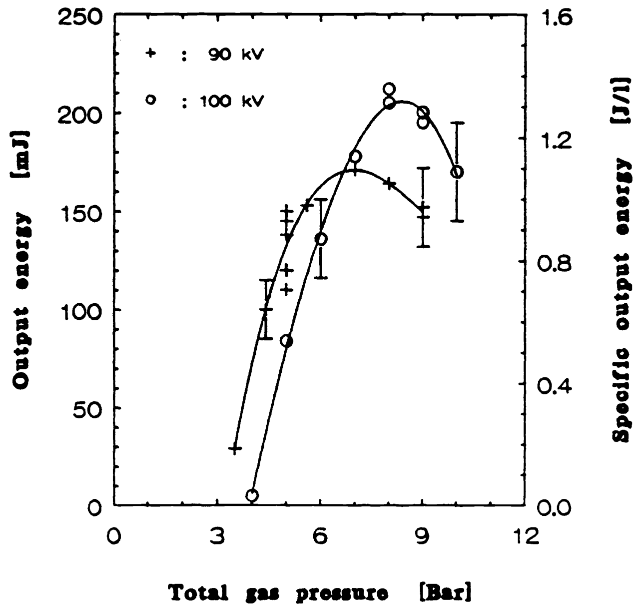

Fig. 2 XeF (C→A) laser output energy as a function of the total gas pressure for two different load voltages (active volume: 157 cm^3).

An Ar^+ ion laser (λ = 488 nm) was used as probe beam. In order to avoid saturation of the FND 100 Q photodiode the probe beam was chopped and the Marx generator was fired when the chopper was open. In fig. 1 a schematic layout is given from the experimental configuration. To minimize the contribution of amplified spontaneous emission an iris was placed in front of the colour glass filter and the neutral density filters. Behind the filters the photodiode was placed. The distance between the laserhead and photodiode was either 5 or 10 m.

3. EXPERIMENTAL RESULTS AND DISCUSSION

For the output energy measurements we used a five component laser gas mixture containing 0.02% F_2, 0.16% NF_3, 0.18% Xe, 6.1% Kr and 93.5% Ar. The maximum output energy of 215 mJ (1.4 J/l) was obtained at a total gas pressure of 8 bar as can be seen from fig. 2. Increasing the pump rate further the output energy decreased again. For all measurements a fresh gas mixture was used for each shot.

The gain was measured under different pumping conditions and with several experimental configurations. As already mentioned before, we changed the pathlength of the amplified beam (5 or 10 m), the probe beam diameter (1 or 12 mm) and the excitation length (20 or 50 cm). Comparing the results obtained by these various methods we found a reproduceability of about 5%. In order to estimate the gain we did two shots with the laser under the same excitation conditions. From the first shot the amplified probe signal and from the second one only the spontaneous emission of the laser was recorded. From the difference of these two signals the gain signal was calculated and plotted by a computer. A typical example obtained for the same load voltage of the Marx generator at four different total gas pressures is shown in fig. 3. At 2 bar only absorption occurred but at a higher total gas pressure (and consequently a higher pumping density) an increasing gain was measured. The gain signal shows a strong initial peak followed in time by a lower and broader shoulder. We measured the peak and shoulder gain for different gas compositions as a function of the total gas pressure.

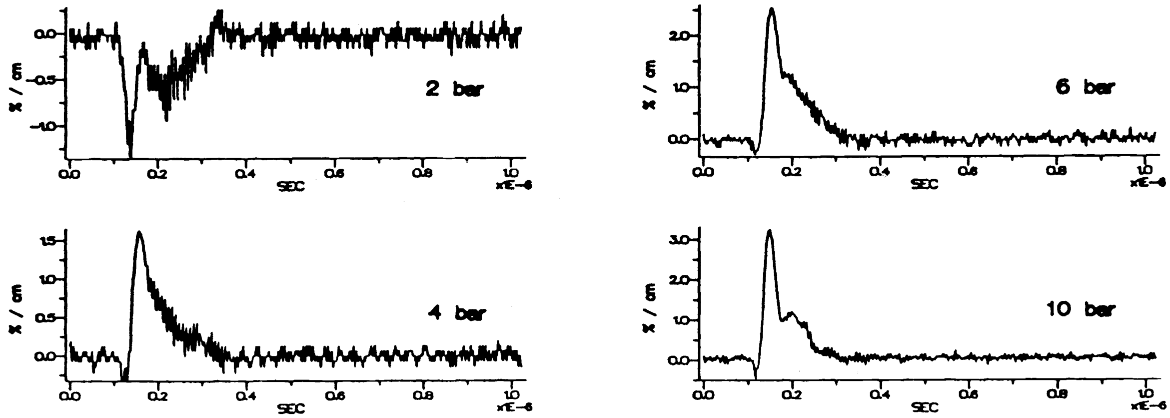

Fig. 3 Small signal gain signals at λ = 488 nm for 4 different gas pressures (load voltage: 100 kV, standard gas mixture).

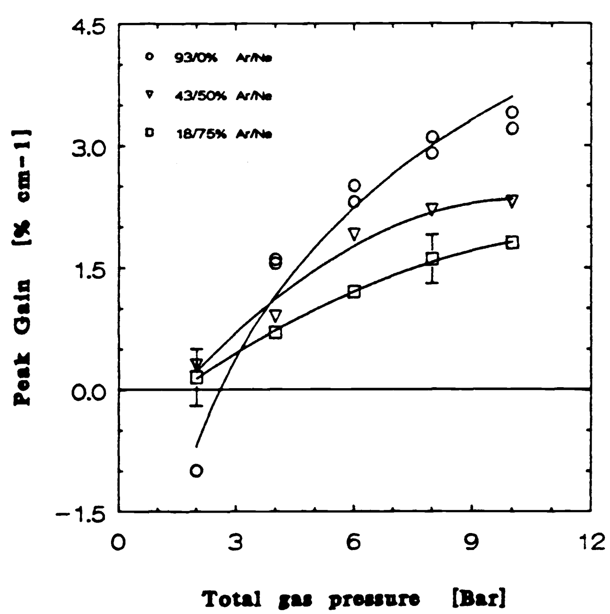

Fig. 4 Peak gain as a function of the total gas pressure for various buffergas concentrations (100 kV, 50 μm Ti tube).

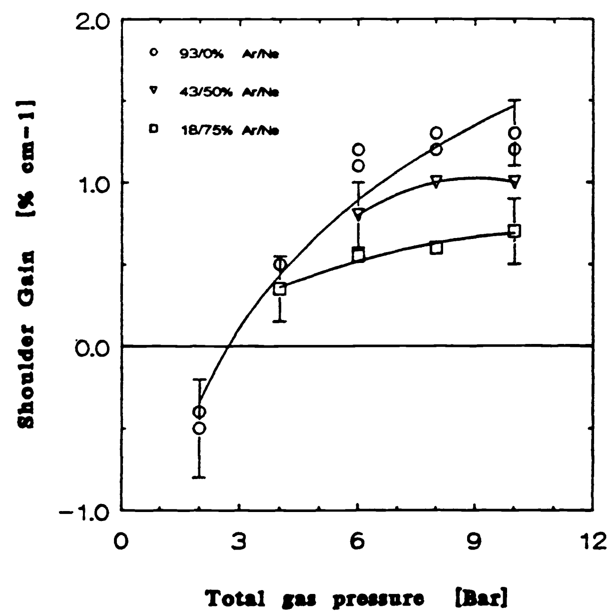

Fig. 5 Shoulder gain as a function of the total gas pressure for different buffer gas concentrations (100 kV, 50 μm Ti tube).

In fig. 4 the peak gain is plotted for three laser gas mixtures. The highest peak gain of 3.3% cm^{-1} was obtained with the above mentioned five component gas mixture at a total gas pressure of 10 bar. Replacing 75% of the Ar buffergas by Ne caused a decrease in peak gain of roughly a factor two at the highest total gas pressures.

From the energy deposition measurements in pure Ar and Ne it appeared that under the same excitation conditions the ratio of the energy deposition in Ar and Ne was 1.6 at 2 bar and decreased to 1.2 at 10 bar. Obviously it is not a matter of energy deposition but the kinetics is changed in a bad way by replacing Ar by Ne. The same behaviour is seen for the gain in the shoulder following the peak gain signal. These results are plotted in fig. 5. These gain results are in good agreement with the output energy measurements which we carried out on Ne rich laser gas mixtures[5] where we found that with 75% Ne a higher reflectivity of the outcoupling mirror was needed and that the output energy decreased from 170 mJ to 55 mJ at 10 bar.

4. ACKNOWLEDGEMENTS

These investigations in the program of the Foundation for Fundamental Research on Matter (FOM) have been supported by the Netherlands Technology Foundation (STW).

5. REFERENCES

1. W.L. Nighan, Y. Nachshon, F.K. Tittel, and W.L. Wilson, "Optimization of electrically excited XeF (C→A) laser performance", Appl. Phys. Lett., 42, 1006, 1983
2. W.L. Nighan, F.K. Tittel, W.L. Wilson, N. Nishada, Y. Zhu and R. Sauerbrey, "Synthesis of rare gas-halide mixtures resulting in efficient XeF (C→A) laser oscillation", Appl. Phys. Lett., 45, 947, 1984
3. L.N. Litzenberger and A. Mandl, "Improvements in long-pulse, e-beam pumped XeF (C→A) laser performance", J. Appl. Phys., 68, 1465, 1990
4. P.J.M. Peters, H.M.J. Bastiaens, W.J. Witteman, R. Sauerbrey, C.B. Dane and F.K. Tittel, "Efficient XeF (C→A) laser excited by a coaxial electron beam at intermediate pumping rates", IEEE J. Quant. El., QE-26, Sept. 1990
5. P.J.M. Peters, H.M.J. Bastiaens, W.J. Witteman, R. Sauerbrey, C.B. Dane and F.K. Tittel, "Effects on variation of buffergas and pumping rate on the behaviour of the e-beam pumped XeF (C→A) laser", Tech. Digest CLEO, Anaheim, 1990, paper CTH F4.