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Abstract

Recent success in high efficiency and high energy laser extraction of tunable radiation in the blue-green C-A transition of XeF under intense, short-pulse electron beam excitation has renewed interest in the possibility of similar performance in avalanche discharges. We present preliminary results of discharge excited fluorescence studies in a variety of devices having different degrees of energy loading.

Introduction

The recent work by Tittel, Sauerbrey, Nighan and co-workers[1] on the XeF C-A transition laser under intense, short pulse (10ns) electron beam excitation at pump energies of 135 Joules per liter has shown efficiencies of 3 percent and energy extraction as high as 4 joules per liter. These results are obtained with very complicated five component gas mixtures that include argon as buffer with xenon, krypton, NF_3 and F_2. The most important addition is believed to be that of substantial amounts of krypton which tend to lower the absorption in the blue-green from argon species [$Ar_2^+(\Sigma_u^+)$ and Ar_3^+], to drop the population of the B-state due to enhanced B-C state mixing by krypton[2] and to increase absorption at the B-X transition wavelength region due to the formation of Kr_2F^*. In addition, there is increased gain on the blue side of the C-A band due to trimer emission from Kr_2F. Under e-beam excitation the B-X fluorescence steadily decreases with increasing krypton pressure. The C-A fluorescence remains relatively constant as kinetic code calculation shows that at room temperature over ninety percent of the population starts off in the C-state. Time resolved gain measurements show that during the e-beam excitation pulse there is net absorption with net gain taking place only in the afterglow of the discharge. (Recently, results at Avco Everett Research Laboratory has shown that at lower energy deposition rates substantial gain is observed throughout the e-beam pump pulse using such five component gas mixtures as described by the Rice University and United Technology work.)

Discharge Fluorescence Studies

The results of pumping with intense electron beams tend to indicate that to successfully implement similar results we need to deposit energies of the order of 10 Mwatts/cm^3 in 10 nanoseconds and this needs to be done in gas mixes containing high concentrations of krypton and at static filling pressures of 6 atmospheres. Several fluorescence studies have been undertaken on the XeF C-A transition in a number of different discharge devices. This includes a long-pulse inductively stabilized laser head at relatively low power deposition (500 kw/cc), a commercial Lambda Physik EMG-50 laser at power deposition estimated in the region of 1 to 2 MW/cc, and a high power deposition device with deposition densities measured higher than 20 MW/cc.

Some initial data was obtained in a long-pulse inductively stabilized device. The power deposition is relatively low (approximately 500 KW/cc). Figure 1 summarizes the B-X and C-A fluorescence data with a gas mixture of 6 torr F_2, 8 torr Xe, 3 Atmospheres Ne and varying concentrations of Kr. Stable self sustained discharge was obtained up to 200 torrs of Kr with 100ns long electrical pulse widths. The limitation on stability in this situation is believed due to the weak corona type of pre-ionization. The rise in C-A and the drop in B-X fluorescence as a function of krypton pressure confirms the initial expectations of discharge laser pumping kinetics as indicated by the electron beam pumped laser systems.

A series of studies was undertaken in a commercial laser device (Lambda Physik EMG 50) at relatively moderate energy deposition rates which are estimated at 1-2 MW/cc. This device uses arc type pre-ionization and is capable of sustaining stable discharges with krypton partial pressures up to 500 torrs. The electrical pulse width is 25ns and He buffer is used in these studies. Figure 2 presents a typical time integrated fluorescence spectrum. Figure 3 shows the fluorescence variation as a function of krypton partial pressure in a gas mix of F_2/Xe/Total=5/20/2500mB with He buffer. This device unfortunately is limited in both its pressure and power deposition rate capabilities. Note that the results of Fig.3 shows rather rapid quenching of the B-X fluorescence as expected and relatively slow decrease also in the C-A fluorescence. The relative insensitivity of the C-A fluorescence as a function of Kr partial pressure is in keeping with the explanation given in electron-beam systems that most of the excited state population resides in the C state. The gradual overall decrease in the total upper state density is an indication of increased quenching as a function of krypton pressure and is an unfortunate observation and not in keeping with the data of the inductively stabilized long pulse device using Ne buffer.

A device capable of high pressure operation but still with relatively short gain length is equipped with an inductively stabilized electrode and operated with a peaking capacitor pulse power setup that we hope will be able to operate in the 10MW/cc power deposition range. Using corona pre-ionization this device could sustain a stable discharge with 3 atmospheres. Ne buffer gas only to 50 torrs of krypton partial pressure. It was necessary to utilize an alternate form of pre-ionization. In the following fluorescence studies the discharge is pre-ionized with a krypton fluoride laser operating at 248nm as shown in Fig.4 and with the addition of trace amounts of fluoro-benzene in the gas mix. Under this technique of pre-ionization we were able to control the discharge up to 300 torrs of Kr partial pressure and at total operating pressures of over 6 atmospheres using Ne buffer. The voltage and current measurements (Fig.5) give a power deposition into a 30cmX.5cmX1cm discharge volume of 20 MW/cc. at the peak of the current pulse. Under this degree of power deposition the behavior of the C-A fluorescence with 10 torrs F_2, 10 torrs Xe as a function of varying Ne buffer pressure and varying partial Kr pressure is given in Fig.6. In this case we observe steadily increasing C-A fluorescence as a function of increasing krypton pressure. However, the C-A fluorescence dropped precipitously beyond 4 atmospheres of Ne buffer gas. The charging voltage for all these studies were kept at 25Kv. It is not clear presently if this turn around in the C-A fluorescence can be overcome if higher charging voltages are used.

Discussion

The data presented in the above studies are a preliminary look into the possibility of obtaining high laser outputs of tunable blue-green radiation using the C-A transition of XeF with complicated multi-component gas mixtures and under the conditions of intense power deposition. As can be seen the fluorescence behavior appears to be different using neon and helium buffers. Of course, the behavior of different buffers need to be compared in the same device which up to this point have as yet to be done. The observation of increasing C-A fluorescence as a function Kr partial pressure in the neon buffer discharges at low and very high power deposition rates imply that the C and B state populations are much more evenly distributed then in the case of electron-beam excitation although the He buffer studies seem to be in accord with the e-beam excitation studies. We are presently setting up experiments to look at the gain at the argon ion laser wavelengths and to see if we can successfully obtain blue-green lasing in the high pressure device. We, however, do not look toward very strong lasing outputs because of the relatively short gain lengths of the devices under study. We need to built a laser with relatively long gain lengths using strong ,uniform pre-ionization with either x-ray or arc type sources and at power deposition rates that have been reported here in order to see if strong blue green lasers in the XeF C-A transition is a possibility.

Acknowledgements

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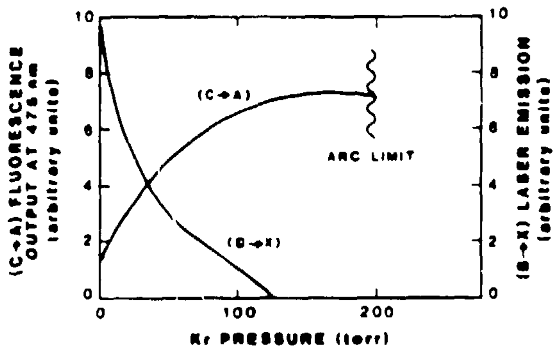

Figure 1. Fluorescence (C-A) and (B-X) versus Krypton partial pressure in a long pulse inductively stabilized long pulse laser with gas mix of 4 torrs F_2, 8 torrs Xe and 3 atmospheres of Ne.

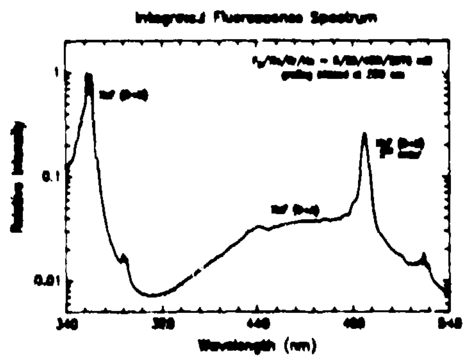

Figure 2. Integrated fluorescence spectrum from a commercial laser device (Lambda Physik EMG 50) using helium buffer with gas mixture given by F_2/Xe/Kr/He=5/20/400/2075 mB.

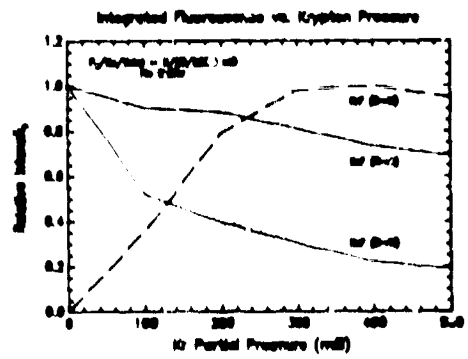

Figure 3. Fluorescence XeF(C-A, B-X), and KrF(B-X) as a function of Kr partial pressure in a gas mix of F_2/Xe/Total=5/20/2500 mB.

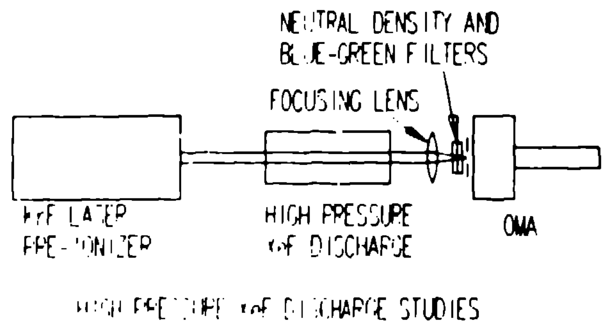

Figure 4. Schematic of high pressure XeF discharge cell with KrF laser pre-ionization.

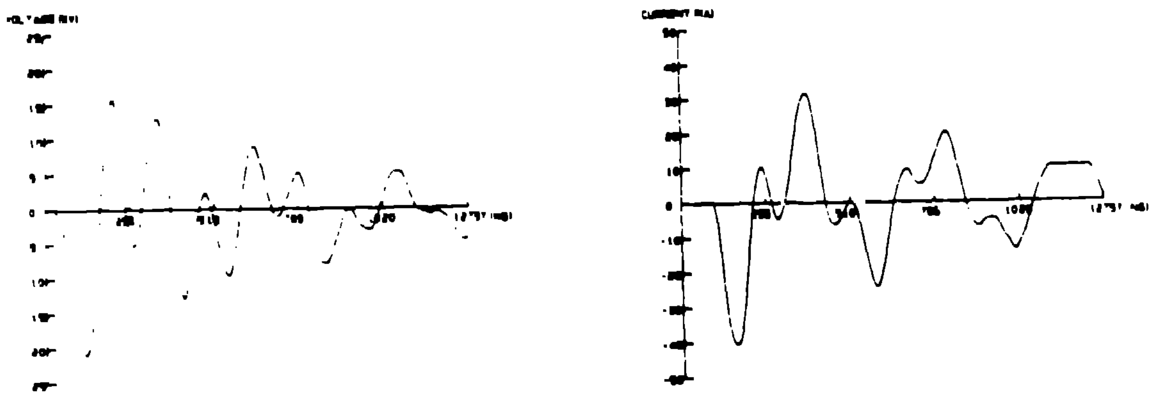

Figure 5. Voltage and Current Temporal behavior with 25 KV charging voltage and a gas mix of $F_2/Xe/Ne=10/10/2280$ torr with no Kr.

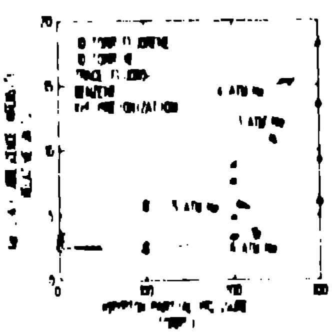

Figure 6. Fluorescence XeF(C-A) as a function of Kr partial pressure and as a function of total filling pressure using 10 torr F_2 and 10 torr Xe and Ne as buffer gas.