



HAL
open science

XeCl laser pumped by an electron beam and X-ray assisted discharge

B. Forestier, B. Fontaine, T. Solenne

► **To cite this version:**

B. Forestier, B. Fontaine, T. Solenne. XeCl laser pumped by an electron beam and X-ray assisted discharge. *Journal de Physique Lettres*, 1981, 42 (10), pp.211-213. 10.1051/jphyslet:019810042010021100 . jpa-00231911

HAL Id: jpa-00231911

<https://hal.science/jpa-00231911>

Submitted on 4 Feb 2008

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Classification
 Physics Abstracts
 42.55H — 47.40K

XeCl laser pumped by an electron beam and X-ray assisted discharge (*)

B. Forestier, B. Fontaine and T. Solenne

Institute of Fluid Mechanics of Aix-Marseille University, 13003 Marseille, France

(Reçu le 20 février 1981, accepté le 31 mars 1981)

Résumé. — Une émission laser de longue durée (200 ns) et de rendement élevé a été obtenue à 3 080 Å à partir de l'excimère XeCl* à la suite de l'excitation de mélanges Ne/Xe/HCl à température ambiante et à très basse température par une décharge en régime d'avalanche assistée par un faisceau d'électrons et de rayons X. L'énergie apportée au milieu actif par la décharge était de plusieurs ordres de grandeur supérieure à celle apportée par le faisceau de préionisation. L'énergie spécifique laser maximale obtenue était de 3 J/l à température ambiante pour une longueur de gain de 16 cm et une énergie apportée au milieu actif par la décharge égale à 150 J/l.

Abstract. — Long pulse (200 ns) XeCl excimer laser emission ($\lambda = 3\,080\text{ \AA}$), has been obtained when Ne/Xe/HCl mixtures are excited by an electron beam and X-rays assisted discharge either at room temperature or at very low temperature. Absorbed discharge energy is several orders of magnitude higher than the absorbed beam energy. Maximum specific laser energy is 3 J/l at room temperature for a 16 cm gain length and an absorbed discharge energy of 150 J/l.

There are presently intensive researches in Europe and U.S.A. Laboratories towards development of high average power short wavelength lasers [1, 2]. These systems have numerous potential applications in photochemistry, telecommunication and controlled fusion. These needs have motivated the researches made for several years at IMFM on rare-gas halide lasers.

We report here about new experimental results on XeCl laser related to the potential pumping of large volumes at high repetition rate. Owing to technological difficulties (particularly for commutation) actual pumping systems for rare-gas halide lasers (e-beam, e-beam stabilized discharge and u.v. preionized fast discharge) are not fully convenient for this aim.

1. Experimental. — The experimental apparatus which has been described in part previously [3] has already allowed to obtain new results on laser and fluorescence emissions of rare-gas halides excited by an electron beam [4, 5] for conditions of very low temperature (active medium in supersonic flow) and also at room temperature without flow.

The apparatus mainly consists of a high pressure tank followed by a Laval nozzle initially isolated from it by an aluminium diaphragm. The nozzle is

followed by a constant area channel made with permaglass (fiberglass and epoxy) and by a dump tank. The channel is 3 cm high and 16 cm wide. Flow starts with diaphragm opening and its duration is generally a few milliseconds. Various nozzle profiles permit to achieve in the channel a flow with the following characteristics : Mach number 1.75, 2.5 or 3; temperature 120, 80 or 65 K, density up to 2 amagats. It is also possible to work with a room temperature, no flow, gas mixture in the channel; the working pressure is then up to 3 atmospheres.

The gas mixture previously excited by an electron beam is now excited by an avalanche discharge assisted either by e-beam and X-rays or only by X-rays. Relatively long pulses of low intensity are used for preionization. A cold cathode electron-gun permits to preionize the gas by means of electrons ($E \leq 300\text{ keV}$) with a density of $20\text{ mA}\cdot\text{cm}^{-2}$ to $1.6\text{ A}\cdot\text{cm}^{-2}$. The time duration of the e-beam can be varied between 0.4 and 2 μs . The e-beam reaches active medium through a 25 μm thick titanium window and a tungsten grid which plays the role of cathode for the main discharge. The anode which faces the cathode is made of a copper plate ($2 \times 14\text{ cm}^2$) with slightly smoothed edges. Anode and cathode are flush mounted in the upper and lower wall of the channel to reduce the aerodynamic disturbances. Unfortunately that does not permit to achieve a spatially constant electric field. A voltage up to 11 kV

(*) La version française est proposée pour publication dans les Comptes Rendus de l'Académie des Sciences.

is applied to the electrodes through a triggered spark gap by means of a capacitor bank ($C = 0.5 \mu\text{F}$). The circuit inductance of 100 nH limits the current rise time. This inductance value could be reduced only by setting current returns in the channel (and thus in the flow).

Laser cavity is formed of MDL hard coating quartz concave mirrors ($R = 2 \text{ m}$); one has a transmission coefficient of 10^{-3} at $\lambda = 3080 \text{ \AA}$ and the transmission coefficient of the other may be varied between 10^{-3} and 0.66 at the same wavelength. The useful cavity volume, defined as a cylinder whose cross section is the laser beam area at the extracting mirror and length is the distance between side channel walls, is equal to 11 cm^3 .

2. e-beam and X-ray assisted laser operation. — A first set of experiments with the optimization of extracted energy in a single pulse as the main objective, has been performed. When an Ne/Xe/HCl (9 100/260/14) mixture at a pressure of 2 000 torrs and a temperature of 300 K (no flow) was excited

by a discharge ($V_{\text{capacitor}} = 11 \text{ kV}$) assisted by an electron beam of $1.6 \text{ A}\cdot\text{cm}^{-2}$ transmitted current density ($V_{\text{gun}} = 270 \text{ kV}$) the laser pulse characteristics were, for a coupling mirror of 0.20 transmission, the following ones : energy : 31 mJ (3 J/l), duration : 200 ns , peak power : 200 kW (20 MW/l). To achieve these laser energy and laser power it was necessary to apply the voltage to the electrodes after e-beam firing. This need of initial preionization before discharge starting for maximum laser energy and power was the rule for all the experiments described here. Figure 1 shows for the above conditions, time variation of e-gun voltage (a), transmitted e-beam current density (b), discharge anode voltage (c), discharge current (d), and XeCl laser power (e).

A second set of experiments has been performed in order to determine conditions favouring generation of long pulse high repetition rate high average power XeCl laser emission. The current density of the transmitted preionization electron beam has been varied from $20 \text{ mA}\cdot\text{cm}^{-2}$ to $1.6 \text{ A}\cdot\text{cm}^{-2}$ by changing the Marx generator charging voltage. The constant parameters for these experiments were as follows : discharge capacitor charging voltage (10 kV); Ne/Xe/HCl mixture (5 300/190/10); pressure (1430 torrs), temperature (300 K), coupling mirror transmission coefficient (0.20). On figure 2 are shown the variations of laser energy *versus* Marx generator voltage. Two scales are added to the voltage scale : one indicates the corresponding transmitted electron beam current density j_e , while the other gives the ratio $R = E_D/E_C$ between discharge and e-beam energies absorbed by the active medium. This figure shows that conditions exist where energy deposited in the active medium originates essentially from the discharge whilst maintaining high laser efficiency. Laser energy undergoes only a threefold decrease when preionization e-beam energy is decreased by a factor 60. Nearly constant specific energy and peak

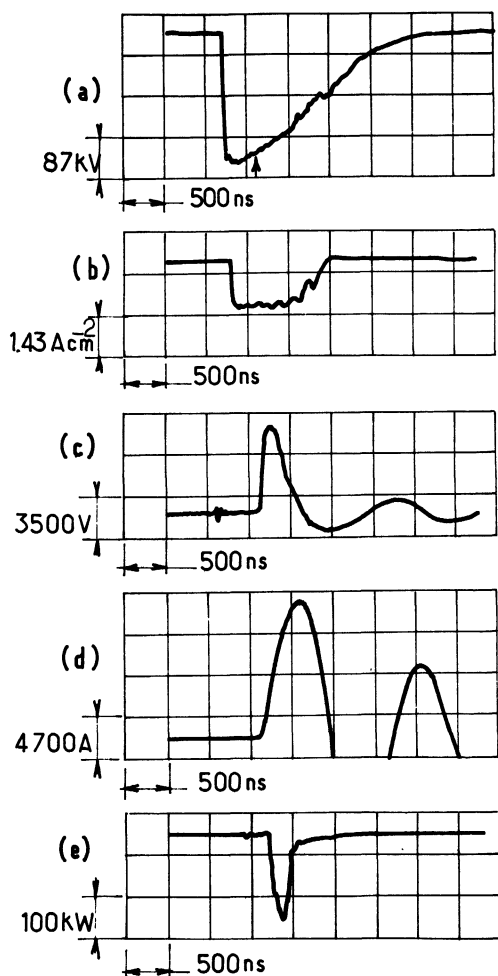


Fig. 1. — Temporal profiles from a typical experiment. (a) Marx generator voltage; (b) transmitted e-beam current density; (c) discharge electrodes voltage; (d) discharge current; (e) laser power. Arrow on figure 1a indicates starting of discharge voltage application. Ne/Xe/HCl (9 100/260/14), $p = 2000 \text{ torrs}$; $T = 300 \text{ K}$, $V_{\text{Marx}} = 270 \text{ kV}$, $V_{\text{discharge capacitor}} = 11 \text{ kV}$, $T_{\text{mirror}} = 0.20$.

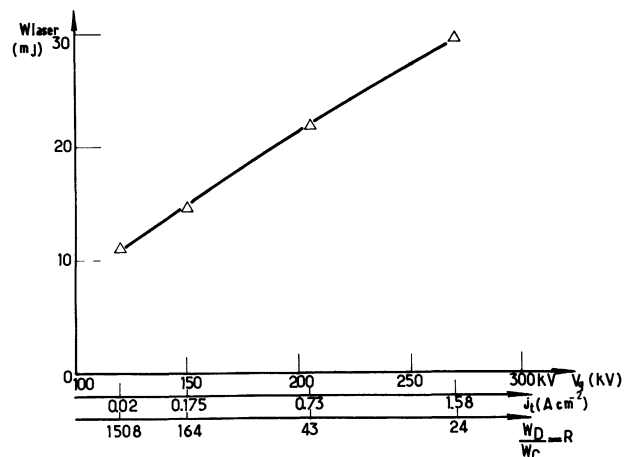


Fig. 2. — Laser energy *versus* maximum Marx generator voltage. In abscissae are also given the transmitted e-beam density and the ratio R between discharge and e-beam absorbed energy before lasing termination. Ne/Xe/HCl (5 300/190/10); $p = 1430 \text{ torrs}$, $T = 300 \text{ K}$; $V_{\text{discharge capacitor}} = 10 \text{ kV}$; $T_{\text{mirror}} = 0.20$.

power of respectively 150 J/l and 500 MW/l were added to the mixture by means of the discharge during these experiments. Intrinsic laser efficiency varied from 2 to 0.7% and seems to have been limited mainly by the short gain length (16 cm) of the present device. The results obtained compare favourably with those obtained from experiments where the ratio R was lower than 10 [6, 7].

This slow decrease of laser energy when the beam current density was strongly lowered could indicate the existence of another mechanism controlling preionization at very low e-beam electron density. Very recently S. C. Lin has shown, with very different experimental conditions, the ability to efficiently preionize an excimer laser active medium with X-rays [8]. A third set of experiments has been performed with the same device for conditions where the preionization was made by means of an X-rays beam produced by the interaction of e-beam with gun window. The e-beam was totally absorbed by a 1.5 mm thick aluminium plate before entering the channel. In order to enhance X-rays emission, a tantalum foil 12.5 μm thick was set inside the gun, immediately in front of the titanium window. Though preliminary, these experiments have enabled the achievement of laser action at $\lambda = 3\,080\text{ \AA}$ from XeCl excimer when Ne/Xe/HCl mixtures at a temperature of 300 K and a pressure of 1 atm. were excited by an X-ray assisted avalanche discharge ($V_{\text{gun}} = 270\text{ kV}$). However laser emission had an energy weaker by an order of magnitude and a duration 3-4 times shorter than for the case of e-beam assisted discharge experiments. Nevertheless this result, obtained with a device not particularly adapted, is interesting because the possibility of using X-rays can strongly facilitate the development of high repetition rate high average power large volume laser systems : a) X-rays penetration range is much higher than the electrons one

and could permit homogeneous excitation of large volumes ; b) difficulties associated with gun window heating could be strongly reduced. Optimization of experimental conditions is in progress and will be the object of a forthcoming letter.

3. Laser operation with supersonic flow. — A last set of experiments has been performed for conditions where a supersonic very low temperature and high density flow was excited by an electron beam assisted discharge. These experiments have allowed to achieve, for the first time, lasing on the $\lambda = 3\,080\text{ \AA}$ XeCl excimer transition in a supersonic flow excited by an e-beam assisted discharge. The experimental conditions were as follows : Ne/Xe/HCl mixtures, $M = 1.75$; $\rho = 1$ and 2 amagats ; $T = 120\text{ K}$; $V_{\text{gun}} = 270\text{ kV}$; $j_i = 1.6\text{ A.cm}^{-2}$; $V_D = 6\text{ kV}$. However, laser emission was, at the opposite to the case of e-beam excitation [5], noticeably weaker than when using room temperature mixtures for the same excitation conditions. This preliminary result shows however the possibility of using supersonic flows to replace gas in very high repetition rate e-beam assisted discharge laser systems.

In conclusion, the present experimental results show, apparently for the first time, the ability to achieve long pulse and high specific energy lasing at $\lambda = 3\,080\text{ \AA}$ with a high specific energy when Ne/Xe/HCl mixtures are excited by a discharge assisted by a low intensity electron beam. Relatively high efficiency is obtained for conditions where absorbed energy from the discharge is several orders of magnitude higher than that from the preionization beam. The preionization can also be made partially or entirely by means of an X-ray beam. These results could allow development of repetitive u.v. laser systems with high average power. Specific average laser power of a few kilowatts by liter for a repetition rate of a few hundred hertz seems possible.

References

- [1] BRAU, C. A., *Rare gas halide lasers* in Excimer Lasers, C. K. Rhodes, Editor, (Springer-Verlag, Berlin) 1979.
- [2] LAKOBA, I. S. and YAKOVLENKO, S. I., *Sov. J. Quantum Electron.* **10** (1980) 389.
- [3] FORESTIER, B. and FONTAINE, B., *Rev. Sci. Instrum.* **50** (1979) 421.
- [4] FORESTIER, B. and FONTAINE, B., *Appl. Phys. Lett.* **32** (1978) 569.
- [5] FONTAINE, B. and FORESTIER, B., *Appl. Phys. Lett.* **36** (1980) 185.
- [6] NIGHAN, W. L. and BROWN, R. T., *Appl. Phys. Lett.* **36** (1980) 498.
- [7] FORESTIER, B., FONTAINE, B. and GROSS, P., *3rd International Symposium on Gas Flow and Chemical Lasers*, Marseille 8th-12th September 1980, *J. Physique Colloq.* **41** (1980) C9-455.
- [8] LIN, S. C. and LEVATTER, J. I., *Appl. Phys. Lett.* **34** (1979) 505.