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SMALL VOLUME LONG PULSE X RAY PREIONISED XeCl LASER WITH DOUBLE DISCHARGE AND FAST FERRITE MAGNETIC SWITCH

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Abstract - Experimental results obtained with a high efficiency small volume long pulse X-Ray preionised XeCl laser with double discharge and very fast ferrite magnetic switch are presented and compared with the results given by a new XeCl laser numerical self consistent model. The model takes into account most recent kinetic data and time variation of discharge impedance and switch inductance. There is a good agreement between experiment and model on electrical and laser parameters for typical conditions.

1.- Introduction

Potential applications of high power pulsed ultraviolet lasers have recently stimulated considerable interest in the scaling of excimer lasers to higher output energy, pulse length, pulse repetition frequency, average laser power and efficiency⁽¹⁾. Discharge pumped excimer lasers are extensively used in various domains of scientific research and industrial processing. Recent developments of long pulse high efficiency self sustained discharge excimer lasers provide a number of opportunities in terms of lower stress on electrical components, lower heat and acoustic load by extracted photon, higher energy transmission capability through optical fiber, and better control of laser beam divergence, polarization and line-width⁽²⁾⁻⁽⁵⁾.

A program to extensively investigate the key parameters which may limit scaling of the XeCl laser ($\lambda = 308 \text{ nm}$) to very high average power ($P_1 \approx 1 \text{ kw}$) has been undertaken at IMFM⁽⁶⁾⁽⁷⁾. This program includes theoretical, numerical and experimental studies of possible advanced excitation schemes in order to increase both laser pulse length and whole system efficiency.

This paper presents results of a parametric experimental and numerical study of a small volume long pulse X-ray preionized XeCl laser using double discharge with a fast ferrite magnetic switch. This system allows both long pulse, high efficiency and high PRF capabilities ($\approx 1 \text{ KHz}$).

2.- Experimental set-up

The experimental set-up⁽⁸⁾ has allowed high efficiency X-ray preionized discharge XeCl laser excitation with a Ne/Xe/HCl mixture in a 50 cm³ active volume (25*2*1 cm³) at relatively low pressure (2,5 atm.). A Schematic diagram of laser electrical circuit is shown on fig 1. A fast high voltage (30-40 KV) and low energy spiker pulse is applied across laser electrodes to initiate a uniform discharge. Peaking capacitors are set in a low inductance configuration. Main discharge is energized by a 100-200ns electrical time pulse charged double sided solid state PFL of much lower voltage (5-10 KV) which is automatically applied to electrodes through a low inductance path after magnetic switch saturation by spiker current. The magnetic switch is made of several coaxial structures set in parallel, each of them including many high frequency Ni-Zn ferrite cores in serie.

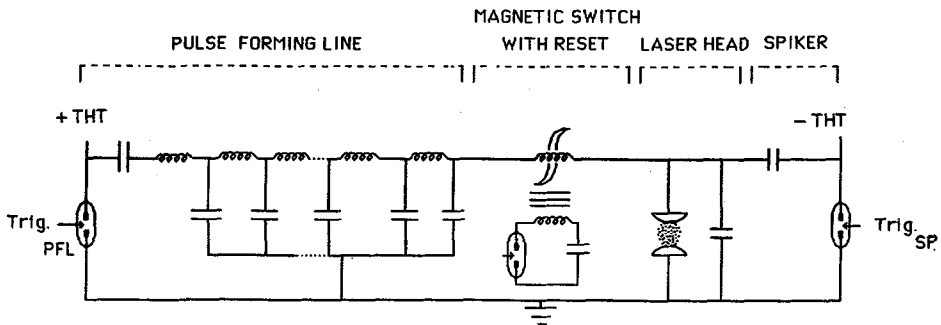


Fig. 1 : Schematic diagram of double discharge laser electrical circuit.

3.- XeCl laser numerical model

A complete self-consistent model of long pulse XeCl excimer laser excited by a double discharge with fast ferrite magnetic switch has been established at IMFM for a Ne/Xe/HCl active medium^{(9),(10)}. The model organization is shown schematically in Fig. 2. Model includes rate equations for 23 species with most recent available rate constant values for 72 reactions⁽¹¹⁾, circuit equations with time dependant ferrite switch inductance and plasma impedance and rate equation for laser emission taking into account absorptions. The model takes into account delay time beetwen spiker and sustainer, low value of sustainer field and dynamics of magnetic switch.

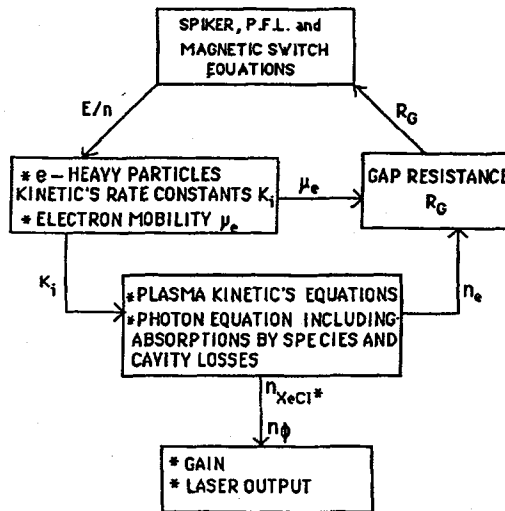


Fig 2 : Numerical model organisation.

4. Results

A small volume long pulse X-ray preionised XeCl laser with double discharge and fast ferrite magnetic switch as been studied. The effects of ferrite material has been taken into account. An efficiency of 3,2 % in energy and 4% in power at the maximum with up to 150 mJ extracted optical energy in a 130 ns (FWHM) laser pulse length, has been demonstrated experimentally, for single shot conditions, with this not optimized device⁽⁶⁾.

Comparison between numerical modeling and experimental results with the I.M.F.M.set-up shows, for various PFL charge voltage conditions, a good quantitative agreement for electrical parameters behavior as well as for laser power and energy. Fig. 3 shows calculated and experimental electrical and optical waveforms for a sustainer voltage of 7 KV and a magnetic switch made of two coaxial structures set in parallel ($\mu = 200$). Model simulates very well spiker-sustainer delay time as well as time needed to reach lasing threshold and laser pulse length. Difference between computed and measured values of laser energy, for same working conditions, is typically 30%.

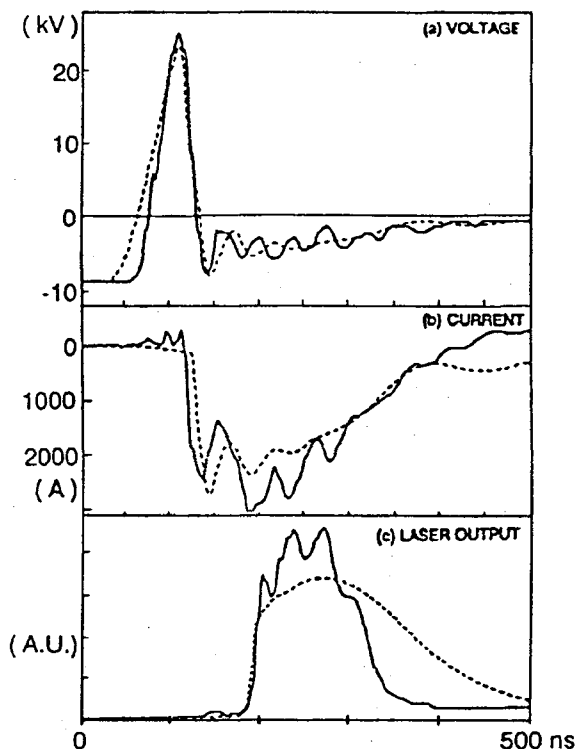


Fig 3 : calculated and experimental waveform of (a) time variation of magnetic switch voltage, (b) current through the switch and (c) laser emission.

A parametric study of the XeCl laser with double discharge and magnetic switch has been fulfilled as well as a comparison with both experiments and numerical results of excitation by a C-L-C classical circuit for the same geometric and gas conditions and the same input energy. As an example a comparison of calculated laser power and gain for double discharge and C-L-C discharge excitation is shown in Fig. 4 ($W_{el} = 6,8$ joules). One observes that for C-L-C excitation initial gain is much higher and of much shorter duration than for double discharge. Laser pulse is very short (40 ns to be compared to 150-200ns for double discharge excitation) and does not reach stationary conditions. It is important to note that electrical energy added to active medium is typically 50% of stored energy for the C-L-C case and 85% for the double discharge case.

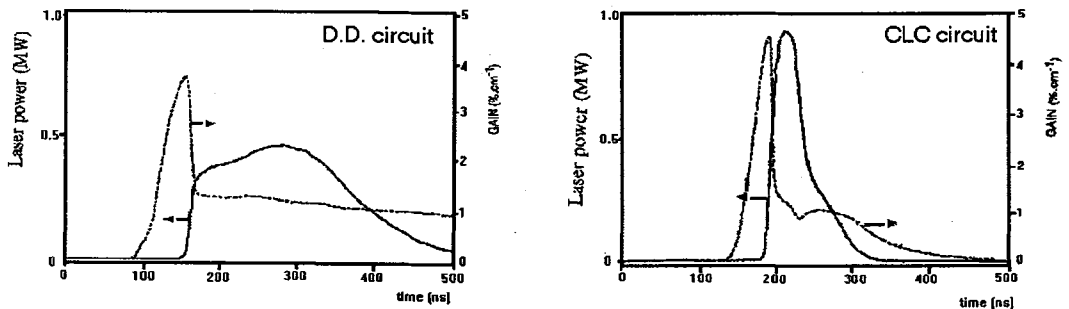


Fig 4: Calculated laser power and gain for double discharge and C-L-C discharge excitation systems.

5.- Conclusion

The present study shows a good agreement between experiments and a new model developed at IMFM for small volume long pulse X-ray preionised XeCl laser with double discharge and fast magnetic switch.

Future experimental and numerical work is planned at IMFM on XeCl laser with double discharge and magnetic switch, in the frame of EUREKA EU 205 program (Eurolaser-excimer lasers), with the aim to optimize such a laser in terms of energy per pulse and efficiency. Experimental part of this study will be made on LUX test-bed for conditions of very high average power ($P_1 \approx 100\text{-}1000\text{ W}$) and repetition rate (PRF > 1 kHz) ⁽⁶⁾⁽⁷⁾.

6.- Acknowledgments

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