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RECENT PROGRESS AT IMFM ON EXCIMER LASERS AND THEIR APPLICATIONS

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Abstract - Recent progress made at IMFM on excimer lasers and their applications is presented. It mainly concerns high power and pulse rate frequency discharge excimer lasers, high energy E-Beam pumped excimer lasers, new excitation schemes, photolysis excitation of uv-visible lasers by sliding discharges, new vuv sources using ionic excimers and processing or elaboration of materials with excimer lasers.

1.- Introduction

Numerous potential applications, in particular in the fields of material processing and photochemistry and more generally in energy transfer, 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. Moreover there is presently a need in shorter wavelength (vacuum ultraviolet) high power pulsed laser sources. In parallel, progress on excimer laser sources has induced studies on specific applications of these sources⁽¹⁾.

IMFM has been strongly involved since twenty years in studies of high power pulsed lasers and their applications. Current researches of New Lasers and Laser Matter Interactions Groups on excimer lasers and related studies concern: a) high power and pulse rate frequency discharge excimer lasers, b) high energy E-Beam pumped excimer lasers, c) new excitation schemes to increase efficiency and pulse length of these sources, d) photolysis excitation of uv-visible lasers by sliding discharges, e) new vuv sources using ionic excimers (isoelectronics with classical excimers), f) processing and elaboration of materials with excimer lasers.

2.- High power and pulse rate frequency discharge excimer lasers

A program to investigate the key parameters which may limit scaling of the XeCl excimer laser ($\lambda = 308 \text{ nm}$) to very high average power ($\overline{P}_1 \approx 1 \text{ kW}$) has been undertaken. This program is developed in the frame of EUREKA EU 205 program (Eurolaser-excimer lasers), with the aim to optimize such a laser in terms of energy per shot, efficiency and pulse rate frequency. Experiments are made on the advanced test-bed LUX (Laser Ultraviolet préionisé par rayons X) developed at IMFM, for conditions of very high average power ($\overline{P}_1 \approx 100\text{-}1000 \text{ W}$) and repetition rate ($> 1 \text{ kHz}$). The study includes theoretical, numerical and experimental investigations on possible advanced excitation schemes in order to increase laser pulse length and system efficiency (C-L-C, Double discharge, phototriggering). Behavior and damping of induced waves and couplings between discharge, flow and laser beam at very high PRF are also actively studied. Important advance has been obtained on reduction of laser pulse to pulse fluctuation and energy per shot decrease at high PRF by waves damping and inductive discharge stabilisation⁽²⁻⁴⁾. It has also been possible to run a photoswitched XeCl laser up to 400 Hz (power supply limited⁽⁵⁾). Fig. 1 shows pulse to pulse energy change measured on LUX test bed with 2rd generation laser head including a porous segmented electrode.

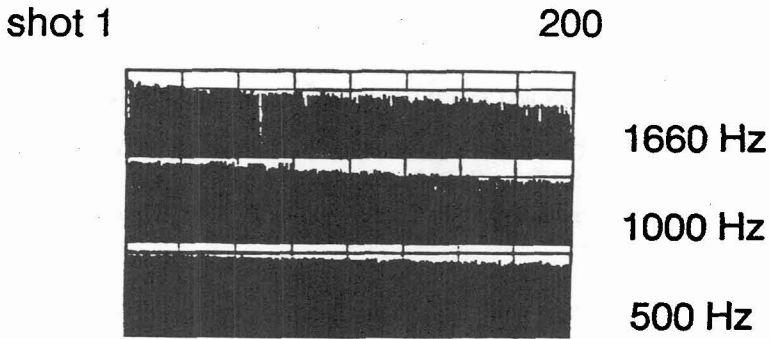


Fig. 1 Pulse to pulse laser energy change on LUX v.s. P.R.F.

3 - High energy E-Beam pumped excimer lasers

A high energy E-Beam pumped KrF laser called KIR for KrYpton Intense Radiation has been designed and constructed for high energy pulsed uv laser applications. The laser cell with a volume of $100 \times 22 \times 22 \text{ cm}^3$ and $21 \times 21 \text{ cm}^2$, is excited by two electron guns (600 kV, 50 kA, 500 ns)(double sided pumping scheme). Numerical simulations of the electron energy deposition (Monte-Carlo method)⁽⁶⁾ and the laser kinetics⁽⁷⁾ have allowed to optimize this system in term of efficiency. A detailed experimental study of energy deposit in the laser cell has shown a uniform distribution of E-Beam current of about 10-12 A/cm². This oscillator delivers routinely 160 J in 400ns (5,1 J/l) at $\lambda = 248 \text{ nm}$ using a confocal unstable resonator. Very recent improvements in cathod design allows to obtain over 200 J of laser energy per shot from this laser. Fig. 2 shows typical diode voltage, diode current, diode pumping power and laser pulse time variations, while, in Table 1 are presented characteristics of KIR.

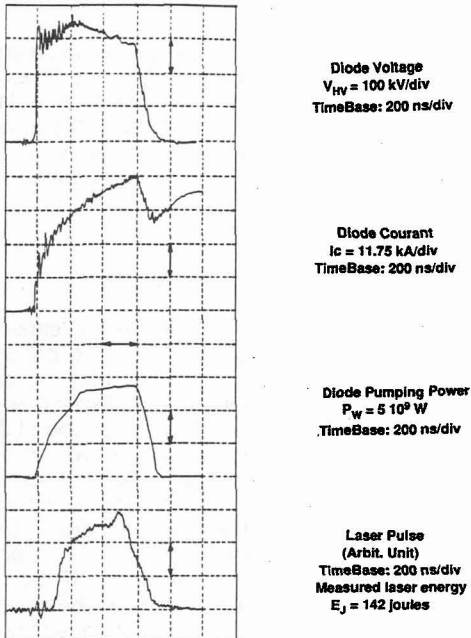


Fig. 2 Typical electrical and optical waveforms from KIR KrF laser

OUTPUT ENERGY	160 J	OUTPUT INTENSITY	$I_0 = 1.2 \text{ MW/cm}^2$
PULSE DURATION	400 ns	INTRINSIC EFFICIENCY	4 %
OUTPUT FLUENCE	0.6 J/cm^2	OVERALL EFFICIENCY	0.3 %

T. 1 Kir excimer laser Characteristics ($\lambda = 248 \text{ nm}$)

4.- New excitation schemes for efficiency and pulse length increase

An experimental and numerical study of a small volume long pulse X-ray preionized XeCl laser using a double discharge with a fast ferrite magnetic switch has allowed high efficiency X-ray preionized discharge XeCl laser excitation with Ne/Xe/HCl mixture in 50 cm³ active volume (25*2*1 cm³) at relatively low pressure (2,5 atm.). A 3,2 % efficiency in energy and 4% in power at maximum with up to 140 mJ extracted optical energy in a 150 ns (FWHM) laser pulse, has been measured, for single shot, with this not optimized device⁽⁶⁾. A complete model of long pulse XeCl laser excited by double discharge with ferrite magnetic switch has been made for Ne/Xe/HCl active medium⁽⁹⁾.

5.- Photolysis excitation of uv-visible lasers by sliding discharges

Recent works⁽¹⁰⁾⁽¹¹⁾ have shown interest of photolytic sources for laser medium excitation.

An experimental and numerical study of possibility to use the high efficiency uv-vuv emission from a sliding discharge on formed ferrites has started in 1990. The objectives are to understand the physics of the excitation process, to characterize the emitted energy spectral distribution and to evaluate the possibilities of this excitation scheme for laser pumping and soft X-Ray production.

6.- New vuv sources using ionic excimers

It as been observed that the recently discovered rare gas-alkali and alkali-halogene ionic excimers, which are isoelectronics to classical neutral excimers are very strong emitters in the VUV spectral range⁽¹²⁻¹⁵⁾.

Theoretical, numerical and experimental study of possibility to obtain strong fluorescence and laser emissions in the vuv-euv by use of rare gas-alkali ionic excimers is presently in progress at IMFM. A mixture of rare gas and alkali at high temperature and high pressure is excited by a pulsed E-Beam. Strong fluorescence emissions from Xe⁺Rb (164 nm) and Kr⁺Rb(134 nm)(first observation with E-Beam pumping) have been observed⁽¹⁶⁾. Table 2 represents ionic and neutral excimers isoelectronicity as well as present pumping methods.

Ionic excimer	Neutral excimer	Final state	Pumping process
Alkali - Rare gas Rg ⁺ A - Kr ⁺ Rb	Rare gas - Rare gas Rg ₂ [*] - Kr ₂ [*]	RgA ⁺ KrRb ⁺	Laser produced plasma Ion beam Electron beam
Alkali - Halide A ²⁺ X ⁻ - Cs ²⁺ Cl ⁻	Rare gas - Halide Rg ⁺ X ⁻ - XeCl ⁺	A ⁺ X Cs ⁺ Cl	Laser produced plasma Ion beam
Diatomic Rare gas Rg ₂ ²⁺ - Ne ₂ ²⁺	Halide - Halide X ⁺ X ⁻ - F ₂ [*]	Rg ⁺ + Rg ⁺ Ne ⁺ + Ne ⁺	Laser produced plasma Ion beam Electron beam
Rare gas - Halide Rg ²⁺ X ⁻ - Xe ²⁺ I ⁻	Halide - Halide X ⁺ X ⁻ - I ₂ [*]	Rg ⁺ + X Xe ⁺ + I	no observation

T.2 Ionic and neutral excimers isoelectronicity

7.- processing and elaboration of materials with excimer lasers

Applications using high average power, high PRF or high energy excimer lasers specificities are developed at IMFM. the sources are either LUX or KIR and also industrial lasers from SOPRA.

In situ growth of high temperature superconductors thin films using XeCl excimer without post-annealing is studied with LUX, in collaboration with specialists of condensed matter physics. Focus is made on effects of PRF, pulse length and wavelength on superconductor characteristics and on hydrodynamics of the plasma. High quality superconductor films with transition at $T_c=90\text{ K}$ and interesting results concerning ablation and deposit processes have been obtained very recently⁽¹⁷⁾.

Surface processing and cleaning of metals by XeCl and KrF laser radiations is studied in collaboration with metallurgists. Effect of PRF at $\lambda = 308\text{ nm}$ is investigated with LUX.

Cleaning of various materials with low PRF industrial excimer lasers is investigated in collaboration with industrial partners.

Medical applications of excimer lasers, in particular photoablation of calcite atheroma in periferials are studied *in vitro* with XeCl and KrF lasers⁽¹⁸⁾.

8.- Conclusion

At IMFM-UM34 CNRS, New Lasers and Laser-Matter Interaction Groups are strongly involved in researchs on excimer lasers and their applications, with the support of DRET, EUREKA, CNRS, MRT, PACA and industriel partners. Focus is made on very high average power and PRF and high energy single shot lasers and also on specific applications of these photon sources. Advances have been recently achieved in these fields at IMFM. These researches will be developed in the future.

9.- Acknowledgments

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References

1. See, for example, papers on Excimer Lasers and Applications in Technical Digests, Conference on Lasers and Electrooptics (Optical Society of America, Washington, DC, 1985-91).
2. M.L. Sentis, Ph. Delaporte, B.M. Forestier and B.L. Fontaine, J. Appl. Phys. **66**, 1925 (1989).
3. M. Sentis, Ph. Delaporte, B. Forestier and B. Fontaine, IEEE J. Quant. Electr., to be publ. (1991).
4. Ph. Delaporte, B. Fontaine, B. Forestier, M. Sentis, 8th GCL, Madrid, Sept. 1990, SPIE, **1397**, 485 (1990).
5. M.L. Sentis, B.M. Forestier, J.P. Truong, B. Lacour, H. Brunet, Technical Digests, Conference on Lasers and Electrooptics (CLEO 91)(OSA), Baltimore, May 1991, paper CThE4, 376 (1991).
6. M.A. Aminou, Thesis, Aix-Marseille III University (1988).
7. A. Fornier, Thesis, Aix-Marseille III University (1990).
8. J.M. Hueber, B. Fontaine, B. Forestier, Ph. Delaporte, M. Sentis, Opt. Comm., to be publ. (1991).
9. M.N. Kobhio, B. L. FONTAINE, J.M. Hueber, Ph. Delaporte, B.M. Forestier, and M.L. Sentis, E.C.O.4, The Hague, Mars 1991, SPIE, **1503**, (1991); also Proc. M2P, J. Physique C (1991).
10. V.S. Zuev, G.N. Kashnikov, V.V. Kirilenko, S.B. Mamaev, V.A. Sorokin, V.F. Shukorukov, So. J. Quant. Electr., **19**, 748, (1989)
11. R.W.F. Gross, L.E. Schneider, S.T. Amimoto, Appl. Phys. Lett. **53**, 2365 (1988)
12. J. Fiedler, L. Frey, F. Steigerwald, H. Langhoff, T. Griegel, K. Petkau, W. Hammer, Z. Phys. D, **11**, 141 (1989)
13. P.S. Milar, G. Warwar, P.J. Wisoff, R. Sauerbrey, Appl. Phys. Lett. **55**, 2176 (1989)
14. Da Xing, K.I. Ueda, H. Takuma, Japan. J. Appl. Phys. L, **30**, L365 (1991)
15. T.T. Yang, V.T. Gyls, D.G. Harris, J. Opt. Soc. Am. B, **6**, 1536 (1989)
16. Ph. Delaporte, Th. Chauvet, B.L. Fontaine, B.M. Forestier, Technical Digests, Quantum Electronics Laser Science Conf. (QELS 91 (OSA), Baltimore May 1991, paper CThE4, 376 (1991)
17. W. Marine, M. Gerry, J.M. Scotto d'Aniello, M. Sentis, Ph. Delaporte, B. Forestier, B. Fontaine, Appl. Surf. Sci., to be published (1991)
18. Ph. Piquet, Ph. Bournot, Ph. Caminat, J.F. Pellissier, C. Mercier, Lasers.in Medical Science, to be Publ. (1991)