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13. ABSTRACT (Maximum 200 words) Detailed molecular structural information is of enormous significance to the medical and biological communities. Since hydrated biologically active structures are small delicate complex three-dimensional (3D) entities, it is essential to have molecular scale spatial resolution, high contrast, distortionless, direct 3D modalities of visualization of specimens in the living state in order to faithfully reveal their full molecular architectures. An x-ray holographic microscope equipped with an x-ray laser as the illuminator would be uniquely capable of providing these images. The findings presented in this report (1) experimentally demonstrate at $\lambda \cong 2.9 \text{ \AA}$ the operation of a new concept capable of producing the ideal conditions for amplification of multikilovolt x-rays and (2) prove the feasibility of a compact x-ray illuminator that can cost-effectively achieve the mission of x-ray biological microholography and likewise serve an array of other applications involving the fabrication and measurement of solid state nanostructures. An estimate of the peak brightness achieved in these initial experiments gives a value of $\sim 10^{29} \gamma \cdot s^{-1} \cdot mm^{-2} \cdot mrad^{-2} (0.1\% \text{ Bandwidth})^{-1}$ , a magnitude that is $\sim 10^5$ -fold higher than presently available synchrotron technology.				
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**FINAL PROGRESS REPORT**  
**DAAG55-97-1-0310**

**Studies of Dynamically Enhanced Electromagnetic Coupling in Self-Trapped Channel**  
**Award End Date: 4 May 2000**

**(1) FOREWORD**

Ideal conditions for x-ray amplification in the multikilovolt spectral region combine an exceptional set of circumstances. They are summarized by the production of cold, low opacity, spatially directionally organized, and vigorously ( $10^{19}$ – $10^{20}$  W/cm<sup>3</sup>) inner-shell state-selectively excited high-Z matter. The results reported below establish that the alliance of two recently studied phenomena, ( $\alpha$ ) the direct multiphoton excitation of hollow atoms from clusters with ultraviolet radiation and ( $\beta$ ) a nonlinear mode of confined propagation in plasmas resulting from relativistic/charge-displacement self-channeling, can successfully produce the union of this demanding set of requirements. Experimental evidence and corresponding theoretical analyses have led to the conclusion that the hollow atom Xe(L) emission at  $\lambda \cong 2.9$  Å generated by 248 nm excitation of Xe clusters in a self-trapped channel closely represents the ideal conditions sought for x-ray amplification. Specifically, on the basis of (a) a detailed examination of Xe(L) spectral data, (b) theoretical analyses of the mechanisms of cluster excitation and channeled propagation, and (c) calibrated measurements of the Xe(L) energy yield, the exponential gain constant  $g_L$  is estimated to reach a value of  $g_L = 60 \pm 20$  cm<sup>-1</sup>, a range approximately two orders of magnitude above the competing absorptive losses. The measurements described herein confirm these assessments.

Detailed molecular structural information is of enormous significance to the medical and biological communities. Since hydrated biologically active structures are small delicate complex three-dimensional (3D) entities, it is essential to have molecular scale spatial resolution, high contrast, distortionless, direct 3D modalities of visualization of specimens in the living state in order to faithfully reveal their full molecular architectures. An x-ray holographic microscope equipped with an x-ray laser as the illuminator would be uniquely capable of providing these images [1,2]. The findings presented in this report (1) experimentally demonstrate at  $\lambda \cong 2.9$  Å the operation of a new concept capable of producing the ideal conditions for amplification of multikilovolt x-rays and (2) prove the feasibility of a compact x-ray illuminator that can cost-effectively achieve the mission of x-ray biological microholography and likewise serve an array of other important applications involving the fabrication and measurement of solid state nanostructures. An estimate of the peak brightness achieved in these initial experiments gives a value of  $\sim 10^{29}$  γ·s<sup>-1</sup>·mm<sup>-2</sup>·mrad<sup>-2</sup>(0.1% Bandwidth)<sup>-1</sup>, a magnitude that is  $\sim 10^5$ -fold higher than presently available synchrotron technology [3].

**(2), (3) NA.**

**(4) STATEMENT OF PROBLEM STUDIED**

The development of methods for the compression of power in materials is one of the oldest endeavors of mankind with an origin that precedes the Stone Age. From the use of a wooden club to the contemporary production of vigorous thermonuclear environments, the achievable power density (W/cm<sup>3</sup>) has been advanced by approximately a factor of 20 orders of magnitude ( $\sim 10^{20}$ ). New processes, involving the nonlinear interaction of intense ( $\sim 10^{18}$ – $10^{21}$  W/cm<sup>2</sup>) fs pulses of radiation with matter were explored to enhance further the controlled production of these environments to a new ultrahigh level ( $\sim 10^{19}$ – $10^{21}$  W/cm<sup>3</sup>), a range that can approach  $\approx 100$  W/atom.

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**(5) SUMMARY OF THE MOST IMPORTANT RESULTS**

See attached paper.

**(6) LIST OF PUBLICATIONS**

1. "Energetic Electronic Ensembles: New Rules for the Interaction of Radiation with Matter," C. K. Rhodes and G. Marowsky, *Appl. Phys.* B66, 475 (1998).
2. "Theoretical/Experimental Studies of Ultraviolet High-Power Density Self-Trapped Channels," A. B. Borisov, B. D. Thompson, A. McPherson, F. Omenetto, T. Nelson, W.A. Schroeder, K. Boyer, and C. K. Rhodes, in *Superstrong Fields in Plasma*, edited by M. Lontano et al. (American Institute of Physics, New York, 1998) p.322.
3. "Stable Relativistic/Charge Displacement Channels in Ultrahigh Power Density ( $\sim 10^{21}$  W/cm<sup>3</sup>) Plasmas," A. B. Borisov, J. W. Longworth, K. Boyer, and C. K. Rhodes, *Proc. Natl. Acad. Sci. USA* 95, 7854 (1998).
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5. "Pump Laser Wavelength-Dependent Control of the Efficiency of Kilovolt X-Ray Emission from Atomic Clusters," W. Andreas Schroeder, F. G. Omenetto, A. B. Borisov, J. W. Longworth, A. McPherson, C. Jordan, K. Boyer, K. Kondo and C. K. Rhodes, *J. Phys. B* 31 5031 (1998).
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8. "Study of Plasma Channel Bifurcation in the Propagation of Intense Ultraviolet Pulses with the Relativistic/Charge-Displacement Mechanism," Alex B. Borisov, S. Cameron, Yang Dai, W.A. Schroeder, James W. Longworth, Keith Boyer, and Charles K. Rhodes Proceedings of the International Conference on Electromagnetics in Advanced Applications, edited by R. Graglia (Politecnico di Torino, Torino, Italy, 1999) p.15.
9. "Hollow Atom Production By a Shell-Selective Collisional Ejection Process in Clusters and Solids Xe(L) and Ba(L)," Thomas R. Nelson, A. B. Borisov, S. Cameron, J. W. Longworth, T. S. Luk, W. A. Schroeder, J. Santoro, A. J. VanTassel, and C. K. Rhodes, X-Ray and Inner-Shell Processes, Chicago, 1999.

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10. "An Efficient, Selective Collisional Ejection Mechanism for Inner-Shell Population Inversion in Laser Driven Plasmas," W. A. Schroeder, T. R. Nelson, A. B. Borisov, J. W. Longworth, K. Boyer, and C. K. Rhodes, submitted to *J. Phys. B*.
11. "Bifurcation Mode of Relativistic and Charge-Displacement Self-Channeling," A. B. Borisov, S. Cameron, T. S. Luk, T. R. Nelson, A. Van Tassle, J. Santoro, W. A. Schroeder, Y. Dai, J. W. Longworth, K. Boyer, and C. K. Rhodes, submitted to *J. Phys. B*, May, 2000.

**(7) PARTICIPATING SCIENTIFIC PERSONNEL**

Thomas R. Nelson

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**(8) INVENTIONS**

No inventions reported.

**(9) BIBLIOGRAPHY**

See attached paper.

**(10) NA.**