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13. ABSTRACT (Maximum 200 words)

Efforts to trump bioterrorism can be sharply advanced by the development of new modalities for the rapid measurement and quantitative classification of protein structural and regulatory information. This report (1) states the experimental status of a new concept for an ultrabright, wavelength tunable, coherent, multikilovolt source ($\lambda \sim 2.71 - 2.93 \text{ \AA}$) suitable for single-molecule microimaging and (2) introduces a cryptographic analogy connecting physical and biological phenomena that speaks to the development of a powerful modular mode of bioinformatics organization that embraces both regulation and structure.

14. SUBJECT TERMS

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Multikilovolt Coherent X-Ray Generation for Protein Analysis and Biological Threat Reduction

Award End Date: 3 August 2003

(1) FOREWORD

Detailed molecular structural information of the living state 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 naturally functioning specimens 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. A concordance of physical evidence, that includes (a) the observation of strong enhancement of selected spectral components of several Xe^{q+} hollow atom transition arrays (q = 31, 32, 34, 35, 36, 37) radiated axially from confined plasma channels, (b) the measurement of line narrowing that is spectrally correlated with the amplified transitions, (c) evidence for spectral hole-burning in the spontaneous emission, a manifestation of saturated amplification, that corresponds spectrally with the amplified lines, and (d) the detection of an intense narrow ($\delta\theta_x \sim 0.2$ mr) directed beam of radiation, (1) experimentally demonstrates in the $\lambda \cong 2.71\text{--}2.93$ Å range ($h\omega_x \cong 4230\text{--}4570$ eV) the operation of a new concept capable of producing the ideal conditions for amplification of multikilovolt x-rays and (2) proves the feasibility of a compact x-ray illuminator that can cost-effectively achieve the mission of biological x-ray microholography. The measurements also (α) establish the property of tunability in the quantum energy over a substantial fraction of the spectral region exhibiting amplification ($\Delta h\omega_x \sim 345$ eV) and (β) demonstrate the coherence of the x-ray output through the observation of a canonical spatial mode pattern. An analysis of the physical scaling revealed by these results indicates that the capability of the x-ray source potentially includes single-molecule microimaging, the key for the *in situ* structural analysis of membrane proteins. An estimate of the peak brightness achieved in these initial experiments gives a value of $\sim 10^{31}\text{--}10^{32}$ photons \cdot s⁻¹ \cdot mm⁻² \cdot mr⁻² (0.1% Bandwidth)⁻¹, a magnitude that is $\sim 10^7\text{--}10^8$ -fold higher than presently available synchrotron technology.

(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/cm³) has been advanced by approximately a factor of 20 orders of magnitude ($\sim 10^{20}$). New processes, involving the nonlinear interaction of intense ($\sim 10^{18}\text{--}10^{21}$ W/cm²) fs pulses of radiation with matter were explored to enhance further the controlled production of these environments to a new ultrahigh level ($\sim 10^{19}\text{--}10^{21}$ W/cm³), a range that can approach ≈ 100 W/atom. Bright x-ray production is an automatic consequence of establishing these conditions.

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(5) SUMMARY OF THE MOST IMPORTANT RESULTS

See three attached papers:

1. “Ultrabright Multikilovolt Coherent Tunable X-Ray Source at $\lambda \sim 2.71 - 2.93 \text{ \AA}$ ” Alex B. Borisov, Xiangyang Song, Fabrizio Frigeni, Yevgeniya Koshman, Yang Dai, Keith Boyer, and Charles K. Rhodes, *J. Phys. B* **36**, 3433 (2003). [b31714.pdf:]
2. “Saturated Multikilovolt X-Ray Amplification with Xe Clusters: Single-Pulse Observation of Xe(L) Spectral Hole Burning,” Alex B. Borisov, Jack Davis, Xiangyang Song, Yevgeniya Koshman, Yang Dai, Keith Boyer, and Charles K. Rhodes, *J. Phys. B* **36**, L285 (2003). [b31606.pdf]
3. “Cryptographic Unification of Mass and Space Links Neutrino Flavour (ν_e, ν_μ) Transformations with the Cosmological Constant Λ ,” Yang Dai, Alex B. Borisov, James W. Longworth, Keith Boyer, and Charles K. Rhodes, *International Journal of Modern Physics A* **18**, 4257 (2003.) [cryptog.pdf]

(6) LIST OF PAPERS

Published

1. “Ultrabright Multikilovolt Coherent Tunable X-Ray Source at $\lambda \sim 2.71 - 2.93 \text{ \AA}$ ” Alex B. Borisov, Xiangyang Song, Fabrizio Frigeni, Yevgeniya Koshman, Yang Dai, Keith Boyer, and Charles K. Rhodes, *J. Phys. B* **36**, 3433 (2003).
2. “Saturated Multikilovolt X-Ray Amplification with Xe Clusters: Single-Pulse Observation of Xe(L) Spectral Hole Burning,” Alex B. Borisov, Jack Davis, Xiangyang Song, Yevgeniya Koshman, Yang Dai, Keith Boyer, and Charles K. Rhodes, *J. Phys. B* **36**, L285 (2003).
3. “Cryptographic Unification of Mass and Space Links Neutrino Flavour (ν_e, ν_μ) Transformations with the Cosmological Constant Λ ,” Yang Dai, Alex B. Borisov, James W. Longworth, Keith Boyer, and Charles K. Rhodes, *International Journal of Modern Physics A* **18**, 4257 (2003).
4. “Ultraviolet-Infrared Wavelength Scalings for Strong Field Induced L-Shell Emissions from Kr and Xe Clusters,” Alex B. Borisov, Xiangyang Song, Fabrizio Frigeni, Ynag Dai, Yevgeniya Koshman, W. Andreas Schroeder, Jack Davis, Keith Boyer, and Charles K. Rhodes, *J. Phys. B* **35**, L461 (2002).
5. “Observation of Directed Emission and Spectral Narrowing on Xe(L) Hollow Atom Single-(2p) and (2s2p) Double Vacancy Inner-Shell Transitions at 2.8–2.9 Angstroms,” A. B. Borisov, K. Boyer, A. Van Tasse, X. Song, F. Frigeni, M. Kado, and C. K. Rhodes, Proceedings of the Second International Conference on Superstrong Fields in Plasmas (Varenna, Italy, 2001), AIP Conference Proceedings Vol. 611, edited by M. Lontano, G. Mourou, O. Svelto, and T. Tajima (American Institute of Physics, Melville, NY, 2002) p. 346.
6. “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, *J. Phys. B* **34**, 297 (2001).
7. “Bifurcation Mode of Relativistic and Charge-Displacement Self-Channeling,” A. B. Borisov, S. Cameron, T. S. Luk, T. R. Nelson, A. Van Tasse, J. Santoro, W. A. Schroeder, Y. Dai, J. W. Longworth, K. Boyer, and C. K. Rhodes, *J. Phys. B* **34**, 2167 (2001).
8. “Determination of Supersymmetric Physical Masses and Attributes with Genetic Divisors,” Yang Dai, Alexey B. Borisov, Keith Boyer, and Charles K. Rhodes, Sandia National Laboratories, *Report SAND2001-1608*, June 2001.

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9. "Quadratic Reciprocity and the Group Orders of Particle States," Y. Dai, A. B. Borisov, J. W. Longworth, K. Boyer, and C.K. Rhodes, Sandia National Laboratories, *Report SAND2001-1534*, June 2001.
10. "A p-Adic Metric for Particle Mass Scale Organization with Genetic Divisors," Y. Dai, A. B. Borisov, K. Boyer, and C. K. Rhodes, Sandia National Laboratories, *Report SAND2001-2903*, December 2001.
11. "Computation with Inverse State in a Finite Field \mathbb{F}_p : The Muon Neutrino Mass, the Unified Strong-Electroweak Coupling Constant, and the Higgs Mass,"^g Yang Dai, Alexey B. Borisov, Keith Boyer, and Charles K. Rhodes, Sandia National Laboratories, *Report SAND2000-2043*, August 2000.

Pending

1. "Amplification of Multikilovolt Xe(L) Hollow Atom Transitions with Xe Clusters in Confined Plasma Channels," Alex B. Borisov, Xiangyang Song, Yevgeniya Koshman, Jack Davis, Yang Dai, Keith Boyer, and Charles K. Rhodes, *Ultrafast Optics IV: Selected Contributions to the 4th International Conference on Ultrafast Optics, Vienna Austria*, ed. by Ferenc Krausz, George Korn, Paul Corkum, and Ian Walmsley, (Springer-Verlag, NY, in press).
2. "High-Intensity Applications of Excimer Lasers," Alex B. Borisov, Jack Davis, Keith Boyer, and Charles K. Rhodes, *Excimer Laser Technology*, ed. by Gerd Marowsky (Springer-Verlag, NY, manuscript in preparation).
3. "Was Ist Leben?," Charles K. Rhodes, lecture presented at the Bozner Treffen, Bozen, Italy, 5–7 October 2001, publication pending.

(7) PARTICIPATING SCIENTIFIC PERSONNEL

Charles K. Rhodes
Keith Boyer
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(8) INVENTIONS

New patent disclosure made, "Ultrabright Multikilovolt X-Ray Source: Saturated Amplification on Noble Gas Transition Arrays from Hollow Atom States," (Application No.: 09/954,635, filed 09/14/2001).

(9) BIBLIOGRAPHY

See bibliographies of attached papers in (5) above.

(10) NA.