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Form Approved  
OMB No. 0704-0188

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1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 10 Jul 1990	3. REPORT TYPE AND DATES COVERED Final Report/15 Jan 87-14 Jul 90	
4. TITLE AND SUBTITLE Energetic X-Ray Processes in Atoms			5. FUNDING NUMBERS 61102F/2301/A4 (2)	
6. AUTHOR(S) Bernd Crasemann			8. PERFORMING ORGANIZATION REPORT NUMBER AFOSR-TR-90 0835	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Oregon Dept of Physics & Chemical Physics Institute Portsmouth, RI 02871			10. SPONSORING / MONITORING AGENCY REPORT NUMBER AFOSR-87-0026	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) AFOSR/NP Bolling AFB DC 20332-6448			11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Properties of highly stripped ions have been computed relativistically in intermediate coupling with configuration interaction, including quantum electrodynamic effects. Charged-particle ionization cross sections have been calculated, including effect of autoionizing resonances on electron-impact excitation rates. Dielectronic recombination rates have been calculated. An extensive computation of relativistic Auger radial matrix elements has been performed; the results can be used to calculate radiationless transition rates in multiply ionized atoms and are expected to be very useful for the computation of Auger rates in molecules. <i>W. M. St.</i>				
14. SUBJECT TERMS atomic physics, atomic inner shell processes			15. NUMBER OF PAGES	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL SAR	

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UNIVERSITY OF OREGON

Department of Physics and Chemical Physics Institute

FINAL TECHNICAL REPORT

Energetic X-Ray Processes in Atoms

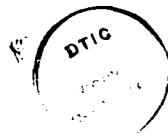
U. S. Air Force Office of Scientific Research

Grant AFOSR-87-0026

15 January 1987 - 30 June 1990

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July 10, 1990

## 1. Research Summary

With partial support from AFOSR, a broad experimental and theoretical program in research on atomic inner-shell processes has been carried out.

Dynamic correlation phenomena in atoms have been explored experimentally with synchrotron radiation as well as theoretically in terms of resonant scattering theory; special attention has been given to the elucidation of fundamental aspects of rearrangement following ionization in deep inner shells. The relativistic quantum theory of post-collision interaction has been formulated and perfected by inclusion of final-state interactions; critical predictions have been tested through experiments.

Properties of highly stripped ions have been computed relativistically in intermediate coupling with configuration interaction, including quantum electrodynamic effects. Charged-particle ionization cross sections have been calculated, including the effect of autoionizing resonances on electron-impact excitation rates. Dielectronic recombination rates have been calculated. An extensive computation of relativistic Auger radial matrix elements has been performed; the results can be used to calculate radiationless transition rates in multiply ionized atoms and are expected to be very useful for the computation of Auger rates in molecules.

The theory of multiphoton ionization in strong laser fields has been reexamined and tied to basic quantum electrodynamics. By quantizing the field and introducing suitable boundary conditions, a time-independent approach has been developed on the basis of formal scattering theory. The approach has been applied to photodetachment of the negative hydrogen ion, recently explored at LAMF; the theory agrees well with the new data.

## 2. Publications

### Journal Articles

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B. Crasemann, "Relativistic Phenomena in Atomic and Chemical Physics: Opportunities for Studies with Synchrotron Radiation." *Acta Physica Hungarica* 65, 171 (1989).

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- S. L. Sorensen, R. Carr, S. J. Schaphorst, S. B. Whitfield, and B. Crasemann: "Coster-Kronig Yields in Silver Measured with Synchrotron Radiation." Phys. Rev. A 39, 6241 (1989).
- D.-S. Guo, T. Åberg, and B. Crasemann: "Scattering Theory of Multiphoton Ionization in Strong Fields." Phys. Rev. A 40, 4997 (1989).
- M. H. Chen and B. Crasemann: "Systematic Trends of the Oscillator Strengths for n=3-2 Electric Dipole Transitions in Oxygenlike Ions." Phys. Rev. A 40, 4330 (1989).
- J. Tulkki, T. Åberg, S. B. Whitfield, and B. Crasemann: "Quantum Approach to Photoelectron Recapture in Post-Collision Interaction." Phys. Rev. A 41, 181 (1990).
- X. Mu: "Multiphoton Absorption Probabilities in Strong Laser Fields with Application to H<sup>-</sup>." Phys. Rev. A (in press).
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T. Åberg, "Theory of Post-Collision Interaction." Invited Lecture. Proceedings, Workshop on New Directions in Soft X-Ray Near-Threshold Phenomena, Asilomar, California, 1-4 March 1987.

X. Mu, B. Crasemann, K. Ilakovic, B. Busic, and V. Horvat, "Two-Photon Transitions in Atomic Inner Shells of Ag: Theory and Experiment." Contributed Paper, Eleventh International Conference on Atomic Physics (ICAP XI), Paris, 4-8 July 1988.

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M. H. Chen and B. Crasemann, "Dielectronic Recombination and Resonance Excitation Rate Coefficients for Li-Like Ions." Contributed Paper, Sixteenth International Conference on the Physics of Electronic and Atomic Collisions, New York, 26 July - 1 August 1989.

D.-S. Guo and B. Crasemann, "Multimode QED Approach to Multiphoton Ionization in a Single-Mode Laser Field." Contributed Paper, Annual Meeting of the Division of Atomic, Molecular, and Optical Physics, Windsor, Ontario, 17-19 May 1989.

M. H. Chen and B. Crasemann, "Trends of the Energy Levels and Oscillator Strengths for  $n=3-2$  Electric Dipole Transitions of the Oxygen Isoelectronic Sequence." Contributed Paper, Annual Meeting of the Division of Atomic, Molecular, and Optical Physics, Windsor, Ontario, 17-19 May 1989.

X. Mu and B. Crasemann, "Gauge Transformation in Nonrelativistic Quantum Mechanics and Different Forms of the Photon-Electron Interaction." Contributed Paper, Annual Meeting of the Division of Atomic, Molecular, and Optical Physics, Windsor, Ontario, 17-19 May 1989.

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X. Mu, "Multiphoton Absorption Rates in Strong Laser Fields with Application to  $H^-$ ." Abstract of invited paper presented at the Second International Meeting on the Physics of  $H^-$ , Albuquerque, New Mexico, November 1989 (unpublished).

M. H. Chen and B. Crasemann, "Autoionizing Resonances in Electron-Impact Excitation of Argonlike Ions." Contributed Paper, Annual Meeting, APS Division of Atomic, Molecular, and Optical Physics, Monterey, 21-23 May 1990. Bull. Am. Phys. Soc. 35, 1172 (1990).

A. Mäntykenttä, H. Aksela, and S. Aksela, "Electron Correlation in the 4d Hole State of Ba Studied by Using Auger Spectroscopy." Contributed Paper, Annual Meeting, APS Division of Atomic, Molecular, and Optical Physics, Monterey, 21-23 May 1990. Bull. Am. Phys. Soc. 35, 1192 (1990).

A. Kodre, S. J. Schaphorst, J. Ruscheinski, Y. Azuma, G. S. Brown, and M. H. Chen, "Double Inner-Shell Photoexcitation of Krypton and Xenon: Observation of Breit-Coulomb Splitting." Abstracts of Contributed Papers, X-90 Fifteenth International Conference on X-Ray and Inner-Shell Processes, Knoxville, Tennessee, 9-13 July 1990 (in press).

A. Mäntykenttä, B. Crasemann, S. L. Sorensen, and M. H. Chen, "Width of the Xe [3s] Level." Abstracts of Contributed Papers, X-90 Fifteenth International Conference on X-Ray and Inner-Shell Processes, Knoxville, Tennessee, 9-13 July 1990 (in press).

D. L. Wark, R. Bartlett, T. J. Bowles, R. G. H. Robertson, D. Sivia, W. Trela, J. F. Wilkerson, G. S. Brown, S. L. Sorensen, S. Schaphorst, B. Crasemann, D. A. Knapp, J. Henderson, J. Tulkki, and T. Åberg, "Electron Satellite Spectrum in Photoionization and in Internal Conversion of the Krypton K-Shell." Abstracts of Contributed Papers, X-90 Fifteenth International Conference on X-Ray and Inner-Shell Processes, Knoxville, Tennessee, 9-13 July 1990 (in press).

X. Mu, "Multiphoton Absorption Rates in Strong Radiation Fields with Application to  $H^-$ ." Contributed Paper, ICOMP V Fifth International Conference on Multiphoton Processes, Paris, 1990.

J. Tulkki, T. Åberg, S. Schaphorst, and B. Crasemann, "Shake Theory Revised." Abstracts of Contributed Papers, X-90 Fifteenth International Conference on X-Ray and Inner-Shell Processes, Knoxville, Tennessee, 9-13 July 1990 (in press).

### 3. Professional Personnel

Bernd Crasemann, Professor of Physics, Principal Investigator

G. Bradley Armen, Research Associate to May 30, 1987

Dong-Sheng Guo, Research Associate to December 31, 1989

Xingdong Mu, Research Associate

Johannes Ruscheinski, Research Assistant

Stephen J. Schaphorst, Research Assistant

Stacey L. Sorensen, Research Assistant to March 15, 1989

Scott B. Whitfield, Research Assistant to June 30, 1989

Mei Chi Chen, Computer Programmer at NASA-ARC (half-time, to  
December 31, 1989).

Off-campus collaborators:

Teijo Aberg, Helsinki University of Technology

George S. Brown, Stanford Synchrotron Radiation Laboratory

Mau Hsiung Chen, Lawrence Livermore National Labortory

4. Advanced Degrees Awarded

Stacey L. Sorensen, Ph.D., 1989. Thesis: "Atomic Electron  
Spectrometry with Synchrotron Radiation."

Scott B. Whitfield, Ph.D., 1989. Thesis: "Dynamics of Atomic  
Photoionization: Studies with Synchrotron Radiation."