Atomic Physics With Heavy Ions Springer Series On Atomic Optical And Plasma Physics

The physics of highly charged ions has become an essential ingredient of many modern research fields, such as x-ray astronomy and astrophysics, con- trolled thermonuclear fusion, heavy ion nuclear physics, charged particle ac- celerator physics, beam-foil spectroscopy, creation of xuv and x-ray lasers, etc. A broad spectrum of phenomena in high-temperature laboratory and astrophysical plasmas, as well as many aspects of their global physical state and behaviour, are directly influenced, and often fully determined, by the structure and collision properties of multiply charged ions. The growth of in- terest in the physics of highly charged ions, experienced especially in the last ten to fifteen years, has stimulated a dramatic increase in research activity in this field and resulted in numerous significant achievements of both fun- damental and practical importance. This book is devoted to the basic aspects of the physics of highly charged ions. Its principal aim is to provide a basis for understanding the structure and spectra of these ions, as well as their interactions with other atomic par- ticles (electrons, ions, atoms and molecules). Particular attention is paid to the presentation of theoretical methods for the description of different radi- ative and collision phenomena involving multiply charged ions. The exper- imental material is included only to illustrate the validity of theoretical methods or to demonstrate those physical phenomena for which adequate theoretical descriptions are still absent. The general principles of atomic spectroscopy are included to the extent to which they are pertinent to the subject matter.

This book provides an overview of the recent experimental and theoretical results on interactions of heavy ions with gaseous, solid and plasma targets from the perspective of atomic physics. The topics discussed comprise stopping power, multiple-electron loss and capture processes, equilibrium and non-equilibrium charge-state fractions in penetration of fast ion beams through matter including relativistic domain. It also addresses mean charge-states and equilibrium target thickness in ion-beam penetrations, isotope effects in low-energy electron capture, lifetimes of heavy ion beams, semi-empirical formulae for effective cross sections. The book is intended for researchers and graduate students working in atomic, plasma and accelerator physics.

The principal goal of this book is to provide state-of-the-art coverage of the non-relativistic three- and four-body theories at intermediate and high energy ion-atom and ion-molecule collisions. The focus is on the most frequently studied processes: electron capture, ionization, transfer excitation and transfer ionization. The content is suitable both for graduate students and experienced researchers. For these collisions, the literature has seen enormous renewal of activity in the development and applications of quantum-mechanical theories. This subject is of relevance in several branches of science and technology, like accelerator-based physics, the search for new sources of energy and high temperature fusion of light ions. Other important applications are in life sciences via medicine, where high-energy ion beams are used in radiotherapy for which a number of storage ring accelerators are in full operation, under construction or planned to be built worldwide. Therefore, it is necessary to review this field for its most recent advances with an emphasis on the prospects for multidisciplinary applications.This book is accompanied by Interdisciplinary Research on Particle Collisions and Quantitative Spectroscopy Volume 2 - Fast Collisions of Light Ions with Matter: Charge Exchange and Ionization.

This book is devoted to one of the most active domains of atomic physic- atomic physics of heavy positive ions. During the last 30 years, this terrain has attracted enormous attention from both experimentalists and theoreti cians. On the one hand, this interest is stimulated by rapid progress in the development of laboratory ion sources, storage rings, ion traps and methods for ion cooling. In many laboratories, a considerable number of complex and accurate experiments have been initiated, challenging new frontiers. Highly charged ions are used for investigations related to fundamental research and to more applied fields such as controlled nuclear fusion driven by heavy ions and its diagnostics, ion-surface interaction, physics of hollow atoms, x-ray lasers, x-ray spectroscopy, spectrometry of ions in storage rings and ion traps, biology, and medical therapy. On the other hand, the new technologies have stimulated elaborate theo retical investigations, especially in developing QED theory, relativistic many body techniques, plasma-kinetic modeling based on the Coulomb interactions of highly charged ions with photons and various atomic particles - electrons, atoms, molecules and ions. The idea of assembling this book matured while the editors were writ ing another book, X-Ray Radiation of Highly Charged Ions by H. F. Beyer, H. -J. Kluge and V. P. Shevelko (Springer, Berlin, Heidelberg 1997) covering a broad range of x-ray and other radiative phenomena central to atomic physics with heavy ions.

This book contains the invited lectures and contributed papers presented at the V International Conference on the Physics of Highly Charged Ions, which was held at the lustus-Liebig-Universi tat Giessen, 10-14 September 1990. This conference was the ftfth in a series -after Stockholm (1982), Oxford (1984), Groningen (1986) and Grenoble (1988) -to deal with a rapidly growing fteld, which comprises the spectroscopy of highly charged ions and their interactions with photons, electrons, atoms, ions, and solids. Most of the matter of the universe is in the ionized state. Investigations dealing with hot plasmas on earth have been greatly furthered by thermonuclear-fusion research. The increasing maturity of this programme has revealed the fundamental role of highly charged ions in fusion plasmas. Today, it is clear that a detailed knowledge of the production mechanisms of highly charged ions and their interactions with other plasma constituents is an important prerequisite for a better understanding of the microscopic and macroscopic plasma properties. The study of highly charged ions involves various branches of physics. It was the aim of the conference to bring together physicists working in atomic collisions and spectroscopy, in plasma physics and astrophysics, as well as in solid-state and ion-source physics. About 220 scientists from 20 nations attended the conference, indicating the strong worldwide interest and the vital ity of research in this fteld.

Atomic Physics 10 presents the manuscripts of the invited talks delivered at the ICAP-X. The conference continued the tradition of the earlier conferences by reviewing broad areas of fundamental atomic physics and related subjects. In addition to the invited talks two hundred and fifty four contributed papers were presented in two poster sessions. The conference was attended by three hundred and thirty participants from twenty countries and the topics covered include: - fundamental atomic physics including QED; - parity violation and quark physics; - exotic atoms; - electronic structure of atoms and the dynamics associated with advanced laser spectroscopy; - applied and interdisciplinary fields using synchrotron radiation spectroscopy; - atomic processes in hot plasmas and interstellar space; - the quantum Hall effect in solids.

This volume presents the state-of-the-art in selected topics across modern nuclear physics, covering fields of central importance to research and illustrating their connection to many different areas of physics. It describes recent progress in the study of superheavy and exotic nuclei, which is pushing our knowledge to ever heavier elements and neutron-richer isotopes. Extending

nuclear physics to systems that are many times denser than even the core of an atomic nucleus, one enters the realm of the physics of neutron stars and possibly quark stars, a topic that is intensively investigated with many ground-based and outer-space research missions as well as numerous theoretical works. By colliding two nuclei at very high ultra-relativistic energies one can create a fireball of extremely hot matter, reminiscent of the universe very shortly after the big bang, leading to a phase of melted hadrons and free quarks and gluons, the so-called quark-gluon plasma. These studies tie up with effects of crucial importance in other fields. During the collision of heavy ions, electric fields of extreme strength are produced, potentially destabilizing the vacuum of the atomic physics system, subsequently leading to the decay of the vacuum state and the emission of positrons. In neutron stars the ultra-dense matter might support extremely high magnetic fields, far beyond anything that can be produced in the laboratory, significantly affecting the stellar properties. At very high densities general relativity predicts the stellar collapse to a black hole. However, a number of current theoretical activities, modifying Einstein’s theory, point to possible alternative scenarios, where this collapse might be avoided. These and related topics are addressed in this book in a series of highly readable chapters. In addition, the book includes fundamental analyses of the practicalities involved in transiting to an electricity supply mainly based on renewable energies, investigating this scenario less from an engineering and more from a physics point of view. While the topics comprise a large scope of activities, the contributions also show an extensive overlap in the methodology and in the analytical and numerical tools involved in tackling these diverse research fields that are the forefront of modern science.

This book offers a concise presentation of theoretical concepts characterizing and quantifying the slowing down of swift heavy ions in matter. Although the penetration of charged particles through matter has been studied for almost a hundred years, the quantitative theory for swift penetrating ions heavier than helium has been developed mainly during the past decade and is still progressing rapidly. The book addresses scientists and engineers working at accelerators with an interest in materials analysis and modification, medical diagnostics and therapy, mass spectrometry and radiation damage, as well as atomic and nuclear physicists. Although not a textbook, this monograph represents a unique source of state-of-the-art information that is useful to a university teacher in any course involving the interaction of charged particles with matter.

This paper outlines the discussion which took place at the "round table" on experimental atomic physics in heavy-ion storage rings. Areas of discussion are: electron-ion interactions, ion-ion collisions, precision spectroscopy of highly charged ions, beta decay into bound final states, and atomic binding energies from spectroscopy of conversion elections. 18 refs., 1 tab. (LSP).

An Atomic Physics Facility (APF) based on the combination of photons produced by a synchrotron light source with heavy ions in a storage ring will open the way to the study of ionic states of almost all elements. The design considerations for such a facility are discussed in terms of the use of synchrotron radiation for photoexcitation and ionization experiments. Design considerations for an APF are given in terms of the accelerator facilities presently available at BNL which include the National Synchrotron Light Source and Tandem Van de Graaff Laboratory. The results show that the concept is valid and therefore that implementation would result in entirely new capabilities for the study of multiply-ionized atoms.

Intended for advanced students of physics, chemistry and related disciplines, this text treats the quantum theory of atoms and ions within the framework of self-consistent fields. Data needed for the analysis of collisions and other atomic processes are also included.

This book is based on Valery Zagrebaev's original papers and lecture materials on nuclear physics with heavy ions, which he prepared and extended through many years for the students of nuclear physics specialties. Th? book outlines the main experimental facts on nuclear reactions involving heavy ions at low energies. It focuses on discussions of nuclear physics processes that are a subject of active, modern research and it gives illustrative explanations of these phenomena in the framework of up-to-date theoretical concepts. This textbook is intended for students in physics who have completed a standard course of quantum mechanics and have basic ideas of nuclear physics processes. It is designed as a kind of lifeboat that, at the end of the course, will allow students to navigate the modern scientific literature and to understand the goals and objectives of current, on-going research.

CD-ROM contains: articles in PDF format and "charge cloud movies" in Quick Time format.

"Bringing together the contributions of many prominent researchers, this collection of original papers unifies the main areas of modern experimental atomic physics. The unusually broad coverage includes discussion of heavy-ion storage rings and fast neutral beams, topics not well represented in the literature. Also revealed are innovative techniques for resolving zero-degree Auger electrons, performing molecular ion imaging, and characterizing ion_atom collisions by means of the new coltrims method. Emphasizing state-of-the-art accelerator-based techniques, this book is a practical introduction to the working methods of the world's leading accelerator facilities." Contents

The last decade has seen dramatic progress in the development of devices for producing mu1ticharged ions. Indeed it is now pos sible to produce any charge state of any ion right up through 92 fully-stripped uranium (U +). Equally dramatic progress has been achieved in the energy range of the available ions. As an example, fully-stripped neon ions have been produced in useable quantities with kinetic energies ranging from a few ev to more than 20 Gev. Interest in the atomic physics of multicharged ions has grown apace. In the fusion program, the spectra of these ions is an im portant diagnostic tool. Moreover the presence of mu1ticharged ions presents a serious energy loss mechanism in fusion devices. This fact has motivated a program to study the collision mech anisms involved. In another area, mu1ticharged ions are present in the solar corona and the interstellar medium and knowledge of their collision properties and spectra is essential to understand ing the astrophysics. Other possible applications are to x-ray lasers and heavy ion inertial fusion. On a more fundamental level, new possibilities for testing quantum electrodynamics with mu1ti charged ions have emerged.

This symposium on Reflections and Directions in Low Energy Heavy-Ion Physics celebrates twenty years of the University Isotope Separator at Oak Ridge (UNISOR) and ten years of the Joint Institute for Heavy Ion Research (JIHIR). It reflects on the accomplishments in low energy heavy-ion science and emphasizes the new directions and opportunities to be explored with low energy heavy-ion facilities. It includes a special section devoted to structure theory and another emphasizing new research to result from facilities exhibiting radioactive ion beam capabilities, new generation recoil mass spectrometers and sophisticated gamma-ray detector arrays. With the participation of leading researchers in the field, the proceedings of this conference is a major reference work for graduate students and research workers in nuclear physics.

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Jaeschke)Storage and Cooling of Heavy Ions in the ESR up to 200 MeV/u (H Eickhoff et al)Present Status of CELSIUS (A Johansson & D Reistad); Cooler Synchrotron TARN II, Present and Future (T Katayama)Beam Cooling: Electron Cooling at TARN II (T Tanabe et al)Ion Trap: Penning Trap Experiments at the University of Washington and at NIST in Boulder (F L Moore) Electron Cooling and Trapped Antiprotons (H Kalinowsky)Nuclear and Particle Physics: High-Resolution Spectroscopy of Deeply-Bound Pionic Atoms in Heavy Nuclei by Pion-Transfer Reactions of Inverse Kinematics Using the GSI Cooler Ring ESR (T Yamazaki)Nuclear Physics with the Indiana Cooler (H O Meyer)The Anomalous Magnetic Moment of the Muon (V W Hughes)Particle Physics at CELSIUS (S Kullander et al)Accelerator: Advanced Stacking Methods Using Electron Cooling at the TSR Heidelberg (M Grieser et al)Accumulation of Radioactive Beam and Collision with Electron Beam in TARN II (A Ando & T Katayama)Internal Target: Internal Targets at the CELSIUS Storage Ring (C Ekström)A Thin Foil as an Internal Target for a Cooler Ring Experiment (K Noda et al)Atomic Physics: Radiative and Dielectronic Recombination: Measurements at UNILAC and ESR (A Müller et al)Electron-Ion Recombination Measurements with an Electron Cooler (L H Andersen)and other papers Readership: Atomic, nuclear and high energy physicists. keywords:

ATOMIC PHYSICS 4 extends the series of books containing the invited papers presented at each "International Conference on Atomic Physics." FICAP, the fourth conference of this type since its foun dation in 1968, was held at the University of Heidelberg. The goal of these conferences, to cover the field of atomic physics with all its different branches, to review the present status of research, to revive the fundamental basis of atomic physics and to emphasize future developments of this field as well as its applications was met by more than thirty invited speakers, leaders in the field of atomic physics. Their talks were supplemented by more than two hundred contributed papers contained in the FICAP Book of Abstracts. This volume begins with papers given in honour and memory of E. U. Condon, to whom this conference was dedicated. It continues with articles on fundamental interactions in atoms and Quantum electrodynamics, on the fast progressing field of high energy heavy ion collisions and Quasi-molecules, on electronic and atomic collisions and the structure of electronic and ~-mesic atoms. The volume closes with contributions concerning the application of la sers in atomic physics, a new field of vastly increasing importance to fundamental experiments as well as applications. We feel that this book contains a very stimulating account of the present main streams of research in atomic physics and its possible future di rections.

Some recent experiments at the Bevalac are discussed which demonstrate the usefulness of relativistic heavy ion beams for study of the nuclear structure of radioactive isotopes.

The progress in the physics of highly-ionized atoms since the last NATO sponsored ASI on this subject in 1982 has been enormous. New accelerator facilities capable of extending the range of highly-ionized ions to very high-Z have come on line or are about to be completed. We note particularly the GANIL accelerator in Caen, France, the Michigan State Superconducting Cyclotrons in East Lansing both of which are currently operating and the SIS Accelerator in Darmstadt, FRG which is scheduled to accelerate beam in late 1989. Progress i~ low-energy ion production has been equally dramatic. The Lawrence Livermore Lab EBIT device has produced neon-like gold and there has been continued improvement in ECR and EBIS sources. The scientific developments in this field have kept pace with the technical developments. New theoretical methods for evaluating relativistic and QED effects have made possible highly-precise calcula tions of energy levels in one- and two-electron ions at high-Z. The calculations are based on the MCDF method and the variational method and will be subject to rigorous experimental tests. On the experimental side, precision x-ray and UV measurements have probed the Lamb shift in the one and two electron ions up to Z=36 with increasing precision.

Proceedings of a workshop held at Oak Ridge, Tennessee, April 1988, deal with problems in atomic and nuclear physics that require access to supercomputing at effective rates of one gigaflop or more. Topics include strong fields, quarks, the few body problem, heavy-ion collisions, nuclear hydrodynamics, Monte Carlo techniques, and more. No subject index. Acidic paper. Annotation copyrighted by Book News, Inc., Portland, OR

The book is a comprehensive edition which considers the interactions of atoms, ions and molecules with charged particles, photons and laser fields and reflects the present understanding of atomic processes such as electron capture, target and projectile ionisation, photoabsorption and others occurring in most of laboratory and astrophysical plasma sources including many-photon and many-electron processes. The material consists of selected papers written by leading scientists in various fields.

Heavy Ions in Nuclear and Atomic Physics, an area of growing interest, aims to familiarise graduate students with new concepts and results in both the theoretical and experimental aspects of this sphere of physics. Based on the 1988 annual International Summer School in Nuclear Physics, organized by Warsaw University, Heavy Ions in Nuclear and Atomic Physics brings together invited papers on a diversity of topics. These include mechanisms of heavy-ion reactions, high-energy gamma-ray production in heavy-ion collisions, the influence of nuclear spin on reaction mechanisms and nuclear structure investigated by means of heavy-ion reactions. Nuclear scientists from some 14 countries, including USA and Japan, have contributed to this volume, which should be of considerable value to nuclear, atomic and high-energy physicists and astrophysicists at graduate level and above.

The activities of this Division continue to be concentrated in the areas of experimental nuclear physics, experimental atomic physics, and theoretical nuclear and atomic physics. The Holifield Heavy Ion Research Facility and its operation as a national user facility continued as the single largest activity within the Division. The experimental nuclear physics program continues to emphasize heavy ion studies, with much of the activity centered at the Holifield Facility. The work with heavy ions at ultrarelativistic energies continues at the CERN SPS. Studies at the Brookhaven AGS, particularly in preparation of future experiments at RHIC, have seen an increased emphasis. A major consortium has been formed to propose the design and construction of a dimuon detector as the basis for one the principal experiments for RHIC. Also included are results from the increasing effort in particle physics, including participation in the L* proposal for the SSC. The UNISOR program, since its inception, has been associated intimately with the Division and, most particularly, with the Holifield Facility. A major area of experimental research for the Division is atomic physics. This activity comprises two groups: one on accelerator-based atomic physics, centered primarily at the EN-tandem and the Holifield Facility, but extending this year to an experiment at ultrarelativistic energies at the CERN SPS; and one on atomic physics in support of fusion energy, based primarily at the ECR ion source facility. Included in this section is also a description of a new effort in multicharged ion-surface interactions, and details of a planned upgrade of the ECR source.

Case Studies in Atomic Physics III focuses on case studies on atomic and molecular physics, including atomic collisions, transport properties of electrons, ions, molecules, and photons, interaction potentials, spectroscopy, and surface phenomena. The selection first discusses detailed balancing in the time-dependent impact parameter method, as well as time-reversal in the impact parameter method and coupled state approximation. The text also examines the mechanisms of electron production in ion. Topics include measurement of doubly differential cross sections and electron spectra, direct Coulomb ionization, autoionization and Auger effect, charge transfer to continuum states, and electron promotion. The book takes a look at the production of inner-shell vacancies in heavy ion-atom collisions and hyperfine and Zeeman studies of metastable atomic states by atomic-beam magnetic-

resonance. Topics include molecular orbital model, experimental considerations, and theoretical considerations and interpretation of experimental results. The manuscript also evaluates the coupled integral-equation approach to nonrelativistic three-body systems with applications to atomic problems, including kinematic theory of three-body system, reduction of the coupled equations, and application to atomic problems. The selection is a dependable reference for readers interested in atomic and molecular physics.

Electron EM reviews the theoretical and experimental work of the last 30 years on continuous electron emission in energetic ion-atom collisions. High incident energies for which the projectile is faster than the mean orbital velocity of the active electron are considered. Emphasis is placed on the interpretation of ionization mechanisms. They are interpreted in terms of Coulomb centers associated with the projectile and target nuclear fields which strongly interact with the outgoing electron. General properties of the two-center electron emission are analyzed. Particular attention is given to screening effects. A brief overview of multiple ionization processes is also presented. The survey concludes with a complete compilation of experimental studies of ionization cross sections.

Dramatic progress has been made in all branches of physics since the National Research Council's 1986 decadal survey of the field. The Physics in a New Era series explores these advances and looks ahead to future goals. The series includes assessments of the major subfields and reports on several smaller subfields, and preparation has begun on an overview volume on the unity of physics, its relationships to other fields, and its contributions to national needs. Nuclear Physics is the latest volume of the series. The book describes current activity in understanding nuclear structure and symmetries, the behavior of matter at extreme densities, the role of nuclear physics in astrophysics and cosmology, and the instrumentation and facilities used by the field. It makes recommendations on the resources needed for experimental and theoretical advances in the coming decade.