MEETING REPORTS

SUMMARY OF THE SYMPOSIUM ON THE PRODUCTION AND PHYSICS OF HIGHLY CHARGED IONS, STOCKHOLM, SWEDEN, JUNE 1-5, 1982

Held at the Research Institute of Physics, this meeting attracted 100 participants of 18 nationalities: 37 from the Nordic countries, 38 from the rest of Western Europe, and 17 from the United States. Eastern Europe (including the Soviet Union), Japan, Israel, and Mexico were also represented. The program contained 19 invited overviews, 15 invited oral progress reports, and 36 poster contributions. The scope of the meeting was informally limited to the production of and physics with *slow* multiply charged ions, as motivated by the development of a new generation of ion sources, such as electron beam ion source (EBIS), electron cyclotron resonance ion source (ECRIS), etc., and the low-energy collision experiments that recently attracted much interest (electron capture, transfer ionization, etc.). The sessions were: technical aspects and atomic physics applications (5 overviews, 13 posters), experiments with highly charged ions (15 progress reports, 15 posters), theory related to highly charged ions (5 overviews, 8 posters), speculative outlooks into the future of physics with highly charged ions (5 overviews), and fusion and astrophysical applications (2 overviews). A historical introductory talk was given by B. Edlén (Lund) and a final summary of the meeting was organized by D. H. Crandall [Oak Ridge National Laboratory (ORNL)].

Among the many interesting talks delivered at this meeting were two by the inventors of the EBIS and the ECRIS. E. D. Donets (Dubna) described his work with the EBIS-type ion source KRION-2, which is used for atomic physics and has produced highly charged ions such as Xe^{52+} with an electron beam energy of 20 keV. The cross section for ionization of Xe^{51+} is of the order of 10^{-22} cm^2 at this energy. While the EBIS usually works in a pulsed mode, the ECRIS delivers a continuous beam. R. Geller (Grenoble) presented his compact ECRIS-machine, MINIMAFIOS, which produces a beam of completely stripped light ions with high intensity (in the range of 10^8 to 10^{14} particle/s). The electron temperature is of the order of a few kiloelectron volts and the extraction voltage is tunable from 1 to 20 kV.

As an invited overview, G. Charpak (European Organization for Nuclear Research) described the new generation of gaseous detectors for vacuum ultraviolet, x rays, and charged particles.

Collision experiments with beams of slow EBIS-produced ions were reported by S. Ohtani (Nagoya) and E. Salzborn (Giessen). Using energy-gain and -loss spectroscopy, the Nagoya group has been investigating electron capture into specific excited levels of the projectile, while in Giessen the interest is focused on transfer ionization processes. For a slow Xe^{15+} ion capturing two electrons from a target xenon atom, it has been shown that the target atom may lose as many as five additional electrons.

S. Bliman (Grenoble) reported on x-ray spectroscopic studies of hydrogen-like light ions produced through electron capture by completely stripped ECRIS-produced ions such as N^{7+}, O^{8+}, and Ne^{10+}.

Slow highly charged ions may also be produced by the recoil technique using a fast beam of heavy ions as ionizer. Production of recoil ions was discussed by A. S. Schlachter (University of California-Berkeley) while F. Folkmann (Aarhus) reported on x-ray and electron spectroscopic studies of few-electron recoil ions. C. L. Cocke (Kansas State University) discussed low-energy collision experiments using electrostatically extracted recoil ions as projectiles. With the beam from the Berkeley Superhilac as ionizer, usable amounts of Ne^{10+} and Ar^{15+} could be produced. One way of handling the recoil ions is to catch them in some kind of trap. I. A. Sellin (ORNL) reported on the development of a Penning trap to be used for this purpose while H. A. Schuessler (Texas A&M University) gave an overview on different kinds of ion traps and their use in precision spectroscopy.

A problem tackled by several groups is the identification of excited (n,l) states created in the electron capture process. A theoretical overview was given by R. K. Janev (Belgrade), stressing the need for further experiments. H. Winter (Vienna), D. Dijkkamp (Amsterdam), and H. Knudsen (Aarhus) reported on measurements performed using photon emission spectroscopy while H. B. Gilbody (Belfast) and B. Huber (Bochum) described new powerful setups for high-resolution translational energy spectroscopy. The role of possible selection rules, such as core conservation, was a much discussed issue. D. E. Post (Princeton University) showed the importance of these problems for fusion plasma diagnostics during his overview on the use of neutral beams in fusion plasma heating.

Using intense laser pulses, one can also produce highly charged ions. This field was reviewed by N. J. Peacock (Culham) and results of an electron capture collision experiment performed with unaccelerated laser-produced ions were given by R. A. Phaneuf (ORNL). Phaneuf also reported on the crossed-beam electron-ion collisions being performed at ORNL. One result of these is the realization that excitation-autoionization (as opposed to direct ionization) can dominate the total ionization cross section completely. F. Brouillard (Louvain) described an ingenious method ("animated crossed beams") to circumvent the problem of measuring density profiles of the two beams.

At low relative energies (thermal to a few electron volts), the capture reaction rates for multiply charged ions with neutrals may become very large (of the order of 10^{-9} cm$^3 \cdot$s^{-1}). A theoretical overview of low-energy effects was given by R. McCarroll (Bordeaux) while experimental results using drift tubes were reported by W. Lindinger

(Vienna). Capture preferentially takes place at curve crossings and it has been found that the most effective crossings are those occurring between 5 and 10 a_0. Some aspects of the importance of these processes were given by D. Péquignot (Meudon) in his overview of astrophysical plasmas.

Basic for any understanding of the physics of highly charged ions are the specific effects seen in spectra for high Z. These were discussed in overviews by H. G. Berry (Argonne National Laboratory), R. D. Cowan (Los Alamos National Laboratory), and M. Klapisch (Jerusalem). Berry described tests of relativistic and QED effects while Cowan stressed the importance of taking autoionization into account. Klapisch discussed his recent work with the so-called "unresolved transition arrays" and gave a speculative outlook into the future.

Five invited overviews of a speculative nature were also given: M. Barat (Orsay) speculated on the high-resolution energy-loss (gain) experiments to be performed in the future and what they might unravel. S. Bliman (Grenoble) described future problems connected with photon spectroscopic studies while C. Bunge (Mexico City) discussed computational methods to be used in studying core-excited few-particle systems. S. Datz (ORNL) speculated on future experiments with highly charged ions and solids while, finally, M. L. Gaillard (Lyon) gave a personal view of what will happen when the techniques of laser spectroscopy are combined with those of highly charged ion spectroscopy.

It is the private opinion of the author of this summary that all overviews, progress reports, and poster contributions (not summarized here) were carefully prepared, skillfully delivered, and of high scientific quality. I hope this will be reflected in the proceedings of the symposium, which will be published as a topical issue of *Physica Scripta* in late 1982 or early 1983. The estimated price (for those not subscribing to *Physica Scripta*) is $30 to $50. For information, write to The Royal Swedish Academy of Sciences, Publications Department, Box 50005, S-104 05 Stockholm, Sweden.

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REPORT ON THE 5TH INTERNATIONAL CONFERENCE ON PLASMA/SURFACE INTERACTIONS IN CONTROLLED FUSION DEVICES, GATLINBURG, TENNESSEE, MAY 3-7, 1982

This international conference, sponsored jointly by Oak Ridge National Laboratory (ORNL) and the Office of Fusion Energy, U.S. Department of Energy (OFE, DOE), heard 14 invited and 149 contributed papers on plasma edge physics, recycling, fueling, impurity control, divertors, pumped limiters, thermal processes (disruptions), hydrogen trapping, detrapping and diffusion, helium implantation, retention and re-emission, coatings, diagnostics, and other ion/solid interactions.

Major plasma physics laboratories in America, Western Europe, Japan, and the Peoples' Republic of China were represented at the meeting. Due to a decision of the Soviet Union's government, there was unfortunately no Soviet participation. There were 197 participants; 84 were from foreign laboratories.

Eight invited talks dealt with important current areas in plasma/surface interactions in fusion devices. The presentation of D. H. Goodall (Culham Laboratory) showed the results of using high-speed cine cameras as a diagnostic aid in the investigation of plasma phenomena. Results were shown for many tokamaks, i.e., Axially Symmetric Divertor EXperiment (ASDEX), Divertor and Injection Tokamak Experiment (DITE), Divertor Assembly, Impurity Studies Experiment, JAERI Fusion Torus-2, and Tokamak Fontenay-aux-Roses. Plasma behavior including disruptions, formation of magnetic islands, limiter shadow, and transient phenomena, was shown. This technique gives a spectacular illustration of some of the more dramatic forms of plasma/wall interactions and its use in detailed analysis of plasma behavior was the subject of lively discussion. F. Waelbroeck (Kernforschungsanlage-Jülich) reviewed thermally activated processes in hydrogen recycling and P. Mioduszewski (ORNL) described the new and important area of pumped limiters. Models for determining the performance of poloidal gas target divertors were summarized by D. E. Post [Princeton Plasma Physics Laboratory (PPPL)]. Comparison of pumped and gaseous divertors is a key topic in near-term experiments and has serious consequences for the feasibility of International Tokamak Reactor-scale reactor designs. A Miyahara [Institute for Plasma Physics (IPP), Nagoya University] discussed plasma material problems in burning plasma experiments and concentrated on the proposed Japanese R-tokamak. The area of thermal processes including disruptions was addressed by H. Vernickel (Max-Planck Institute for Plasma Physics, Garching). P. Staib (Max-Planck Institute for Plasma Physics, Garching) described various probe systems that have been developed and utilized in studying the outermost plasma layer. He showed that there now exists convergence in the data taken with different types of probes in different machines although there are still some areas of inconsistency. D. Mattox (Sandia National Laboratories) discussed the requirements of coatings for in-vessel components in advance fusion reactors.

D. Meade (PPPL) moderated a special invited symposium on recent divertor experiments. Recent results for the major divertor experiments were described; DITE, P. C. Johnson (Culham Laboratory); ASDEX, W. Engelhardt (Max-Planck Institute for Plasma Physics, Garching); Poloidal Divertor Experiment (PDX), R. J. Fonck (PPPL); Doublet III, M. Ali Mahdavi (General Atomic), and M. Shimada [Japan Atomic Energy Research Institute (JAERI)].

First results comparing operation with a poloidal divertor and operation with a toroidally closed limiter (both stainless steel and graphite were used) were given for ASDEX. Initial results showed that diverted discharges were considerably cleaner and easier to create. Experimenters on PDX found that poloidal divertor discharges with up to 5 MW of injected power were cleaner than similar limiter discharges. They also announced that the average beta had been raised to 3.2% for low magnetic field circular discharges with high-power neutral beam injection using a graphite limiter. Comparison with divertor discharges under the same conditions will be made in the near