Symposium Fast Ion Beams in Nuclear, Atomic and Molecular Physics Research (SYIB)

jointly organized by
the Atomic Physics Division (A)
the Mass Spectrometry Division (MS), and
the Molecular Physics Division (MO)

Thomas Stöhlker
GSI
Planckstrasse 1
64291 Darmstadt
t.stoehlker@gsi.de

Andreas Wolf
Max-Planck-Institut für Kernphysik
Postfach 103980
69029 Heidelberg
A.Wolf@mpi-hd.mpg.de

Overview of Invited Talks and Sessions

(lecture room V55.22)

Invited Talks

SYIB 1.1	Tue	10:30–11:00	V55.22	**Nuclear physics with stored highly-charged radioactive ions** — •Yuri Litvinov
SYIB 1.2	Tue	11:00–11:30	V55.22	**High Precision Laser Spectroscopy at the Storage Ring ESR** — •Wilfried Nörtershäuser
SYIB 1.3	Tue	11:30–12:00	V55.22	**Storage-ring measurements of hyperfine-induced one-photon transitions in highly charged ions** — •Stefan Schippers
SYIB 1.4	Tue	12:00–12:30	V55.22	**Low-Temperature Molecular Recombination from fast Electron and Ion Beams** — •Oldrich Novotny
SYIB 2.1	Tue	14:00–14:30	V55.22	**Ion induced fragmentation of large (bio)molecules** — •Thomas Schlathölter
SYIB 2.2	Tue	14:30–15:00	V55.22	**Using femtosecond lasers for determining the structure and dynamics of complex molecules** — •Jason Greenwood
SYIB 2.3	Tue	15:00–15:30	V55.22	**Fast beam momentum spectroscopy on XUV excited molecular ions** — •Henrik Pedersen
SYIB 2.4	Tue	15:30–16:00	V55.22	**Electron Emission from Hot Stored Molecular and Cluster Anions** — •Michael Lange, Klaus Blaum, Christian Breitenfeldt, Michael Froese, Sebastian Menk, Andreas Wolf, Swarup Das, Manas Mukherjee

Sessions

SYIB 1.1–1.4	Tue	10:30–12:30	V55.22	**Fast Ion Beams in Nuclear, Atomic and Molecular Physics Research I**
SYIB 2.1–2.4	Tue	14:00–16:00	V55.22	**Fast Ion Beams in Nuclear, Atomic and Molecular Physics Research II**

SYIB 1: Fast Ion Beams in Nuclear, Atomic and Molecular Physics Research I

Time: Tuesday 10:30–12:30 Location: V55.22

Invited Talk SYIB 1.1 Tue 10:30 V55.22

Nuclear physics with stored highly-charged radioactive ions — •Yuri Litvinov — GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — Max-Planck Institut für Kernphysik, Heidelberg

Investigations with stored highly-charged radionuclides are presently possible at two storage ring facilities. These facilities are the experimental storage ring ESR at GSI in Germany and the cooler-storage ring CSRe at IMP in China.

Storage ring mass spectrometry is a powerful tool to address rare nuclear species with tiny production rates. Large-scale explorations of the nuclear mass-surface have been done in the last years providing a vast information for nuclear structure investigations.

Beta-decay of highly-charged ions can presently be only studied with storage rings. Such measurements are of direct importance in nuclear astrophysics, since in hot stellar environments the atoms are highly-ionized. Another important reason is that the decays of well-defined quantum systems, such as one-electron ions, where the interactions with other bound electrons are excluded, can be investigated.

New experiments are inevitably connected with new technical developments. For instance, a novel highly-sensitive resonant Schottky pick-up detector has been commissioned in the ESR and CSRe.

The physics motivation, the techniques, recent experiments, and the main results will be discussed. Plans for future experiments at the ESR, CSRe as well as at the future FAIR facility will be outlined.

Invited Talk SYIB 1.2 Tue 11:00 V55.22

High Precision Laser Spectroscopy at the Storage Ring ESR — •Wilfried Nörtershäuser — Institut für Kernchemie, Johannes Gutenberg-Universität Mainz, 55099 Mainz — GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt

The Experimental Storage Ring (ESR) at GSI Darmstadt has proven to be a versatile tool for laser spectroscopy of highly charged ions and relativistic ion beams. During the last years, laser spectroscopy concentrated on experiments with relativistic lithium ions and the search for the hyperfine transition in lithium-like bismuth $^{209}Bi^{80+}$. The former aimed at an improved test for time dilation in Special Relativity, whereas the hyperfine transition will allow for a test of QED in highly charged ions. Both experiments have recently been successful and the latest results will be presented.

Invited Talk SYIB 1.3 Tue 11:30 V55.22

Storage-ring measurements of hyperfine-induced one-photon transitions in highly charged ions — •Stefan Schippers — Instiut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen

Hyperfine quenching in atoms and ions is the shortening of excited-state lifetimes by the interaction of the electron shell with the magnetic moment of the atomic nucleus. A particularly drastic hyperfine quenching effect is observed in alkaline-earth-like and, in general, divalent atoms and ions (with valence shell n) where the first excited level above the ground state is the $ns\,np\,^3P_0$ state. A total electronic angular momentum of $J = 0$ for this level makes a single-photon decay to the $(ns)^2\ ^1S_0$ ground state impossible. However, a nucleus with nonzero spin induces a mixing of the $ns\,np\ ^3P_0$ level with its neighboring $ns\,np\ ^3P_1$ state via the hyperfine interaction. In Be-like ions, calculated hyperfine induced (HFI) lifetimes of the $2s\,2p\ ^3P_0$ level decrease from about 3000 s to a few μs with increasing nuclear charge.

Accurate measurements of such long lifetimes require an experimental environment where the ions can be stored for sufficiently long times without external perturbations. The only laboratory measurements of HFI lifetimes in multiply charged ions were carried out at the heavy-ion storage ring TSR of the Max-Planck-Institute for Nuclear Physics in Heidelberg. In the talk, I will describe the experimental method which makes use of fast ion beams and state-selective, resonant electron-ion recombination. The experimental results will be compared with theoretical calculations, which — in particular for Be-like ions – are extremely sensitive to electron-correlation effects.

Invited Talk SYIB 1.4 Tue 12:00 V55.22

Low-Temperature Molecular Recombination from fast Electron and Ion Beams — •Oldrich Novotny — Columbia Astrophysics Laboratory, New York, USA — Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany

Dissociative recombination (DR) of molecular ions plays a key role in controlling the composition and charge density of cold interstellar clouds. Experimental DR data are required in order to understand the chemical network in clouds and related processes such as star formation in the clouds. Needed data include reaction cross sections and also the chemical composition and excitation states of the neutral products. With the TSR storage ring in Heidelberg, Germany, we are measuring DR for astrophysically important molecular ions. We use a merged electron-ion beams technique to generate high-quality phase-space cooled, stored ion beams. This is combined with event-by-event fragment counting and fragment imaging. The neutral product count rate yields the absolute DR rate coefficient. Imaging the distribution of fragment separations provides information on the kinetic energy released and the states of both the initial molecule and the final products. Fragmentation channels are identified from the fragment-mass combination within each dissociation event. Such information is essential for studies on DR of polyatomic ions with multi-channel multi-fragment breakup. In this talk we will demonstrate these experimental capabilities on the recent DR results. Future experiments on the new cryogenic electrostatic storage ring CSR will be discussed.

SYIB 2: Fast Ion Beams in Nuclear, Atomic and Molecular Physics Research II

Time: Tuesday 14:00–16:00 Location: V55.22

Invited Talk SYIB 2.1 Tue 14:00 V55.22

Ion induced fragmentation of large (bio)molecules — •Thomas Schlathölter — KVI Atomic and Molecular Physics, University of Groningen , Zernikelaan 25, 9747AA Groningen, The Netherlands

The advantage of fast ions for cancer therapy lies in their unique dose-distribution in human tissue. At a well-defined depth ions are slowed down to MeV energies and cell killing is most effective due to maximum linear energy transfer and radiobiological effectiveness. Such volume sensitivity renders ion-therapy a superior tool for a number of localized tumors, in some cases decreasing the yearly risk of radiation induced development of lethal secondary tumors by up to one order of magnitude! To date, many molecular mechanisms underlying biological radiation action remain unclear and particularly the exceptional cell killing efficiency of heavy ions and protons is largely unexplored on the molecular level. In this talk I will show that ion collisions with gas phase DNA, proteins and their building blocks are an excellent approach to study molecular mechanisms underlying ion-therapy. Controlled attachment of water molecules even allows to study solvation effects on ion induced fragmentation in the gas-phase.

Invited Talk SYIB 2.2 Tue 14:30 V55.22

Using femtosecond lasers for determining the structure and dynamics of complex molecules — •Jason Greenwood — Centre for Plasma Physics, Queen's University Belfast, Belfast, UK

Ultrashort laser pulses are powerful tools with which to probe matter since their spectral, phase and polarisation parameters can to a degree be controlled. This has led to the field of attoscience where we now are on the cusp of observing electronic motion in matter. Biomolecules are one area where ultrafast phenomena are increasingly being recognised as central to biological processes such as photosynthesis, vision, and DNA damage and repair. To probe the fundamental of such dynamics and compare with theoretical models, it is necessary to study these molecules in the gas phase and to be able to mass analyse these systems which may have very high masses. In this talk I will describe an instrument which uses a laser induced acoustic desorption process to volatilise some simple biomolecular building blocks, ionise and frag-

ment them with a femtosecond laser, and mass analyse the resulting ions. Our instrument can use either conventional time of flight or for very heavy masses a novel, very high resolution electrostatic ion trap mass spectrometer. The potential for using femtosecond lasers as ion sources for sensitive gas analysis and in determining the structural and dynamic properties of biomolecules will be discussed.

Invited Talk SYIB 2.3 Tue 15:00 V55.22

Fast beam momentum spectroscopy on XUV excited molecular ions — •Henrik Pedersen — Department of Physics and Astronomy, Aarhus University, Denmark

Dynamics of highly excited molecular ions reached by XUV-photoabsorption has been a main field of research at the Free-electron LASer in Hamburg FLASH. XUV photoinduced processes in molecular ions are relevant both for understanding molecular dynamics in simple model systems, for characterizing processes in ionized gas-phase media, e.g. in astrophysical plasmas and outer planetary atmospheres, as well as for describing ionic states in liquid media. In the presentation, we will exemplify the new possibilities for studies of molecular ions using FELs by recent results from the TIFF (Trapped Ion Fragmentation with an FEL) experiment at FLASH. For the simplest water cluster cations, $H^+(H_2O)_{n=1-4}$, the dominating photoionization and -dissociation channels have been clarified among numerous possibilities and revealed interesting trends in the product branching ratios for dissociative photoionization with cluster size. Finally, we will give some perspectives for further developments when FELs and synchrotron radiation facilities are combined with methods based on accelerated, stored, and cooled ion beams.

Invited Talk SYIB 2.4 Tue 15:30 V55.22

Electron Emission from Hot Stored Molecular and Cluster Anions — •Michael Lange[1], Klaus Blaum[1], Christian Breitenfeldt[1,2], Michael Froese[1], Sebastian Menk[1], Andreas Wolf[1], Swarup Das[3], and Manas Mukherjee[3] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisches Institut, Ernst-Moritz-Arndt-Universität Greifswald — [3]Raman Center for Atomic Molecular & Optical Science, Kolkata

Electron emission from excited molecular or cluster anions has been extensively studied in both ion storage rings and traps, which because of the long observation times are ideal tools for such investigations. For a variety of molecular and cluster anions a power law decay was found over a long time interval, followed by a reduction in rate often attributed to radiative quenching. However, evidence for this interpretation has remained circumstantial.

Our cryogenic electrostatic ion beam trap affords a very low residual gas density and, hence, a significant reduction of residual gas-related background in the measured decay rates. This has enabled us to observe the expected deviation from the power law in the decay of SF_6^- for the first time. Using a statistical rate model we found that this feature can be well reproduced by assuming a sizeable rotational excitation of the anions, which so far has not been fully considered in experiments. Further evidence was found in an experiment on aluminum clusters with $3\ldots7$ atoms where after the initial power-law decay and steep decline in rate a second, weaker power-law phase was found that is not readily explained from decay models including radiative relaxation.