ISA

Institute for
Synchrotron Radiation
Aarhus University

Newsletter

No.4. December 1992

Synchrotron radiation beamlines at ASTRID

The First ISA Users' Meeting

On May 11th more than 50 scientists and students from European countries were assembled in Aarhus for at two-day meeting to discuss the existing and future scientific programs around ASTRID, both for ion storage and synchrotron radiation (SR).

In the morning of the first day, S.P.Møller presented a status report of ASTRID. Next, the three approved beamlines were presented. N.Hertel showed the details of the X-ray microscope and the future scientific program in biology (see page 2). D. Adams discussed the ZEISS SX-700 monochromator, which is installed in Aarhus. The experimental setup consists of a UHV system for surface physics, including equipment for SEXAFS, XPS, ARUPS, LEED, HREELS, gas adsorption and metal deposition. C.Mythen presented the new high-resolution (E/ΔE=5-10000) spherical grating monochromator, which has been designed in collaboration with Daresbury (H.Padmore).

In the afternoon session, J.Haase (Berlin), J.Onsgaard (Odense) and P.Juul Møller (Copenhagen) presented results on adsorption on surfaces. These results were obtained at BESSY on the ISA SX-700 beamline. (page 4)

In the second session, O.Poulsen presented results on laser cooling of stored ions (Newsletters # 1 and 2). T.Andersen discussed lifetime measurements of stored, metastable ions with lifetimes in the 10 μs to 100 ms region. This region is very difficult to study with traditional techniques, but it turns out, that ASTRID is well suited for such studies. Negative ions present a very interesting class of atomic and molecular systems, where the electron-electron correlations play a significant role.

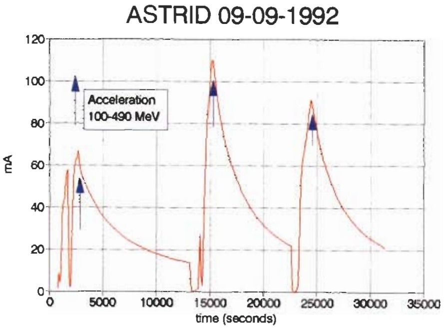
L.H.Andersen presented results from the electron cooler, installed at the Aarhus Tandem accelerator. It is now installed at ASTRID. Here the 'merged beams' geometry offers an ideal tool for the study of low energy charge changing collisions between electrons and positive/negative ions.

On the second day, E.Uggerhøj sketched the future plans for insertion devices and extensions of the laboratory. A VUV undulator is designed with an optimum energy range of 10 to 40 eV and a brilliance as shown in the figure below which is competitive with the

(continued on page 4)

Machine status

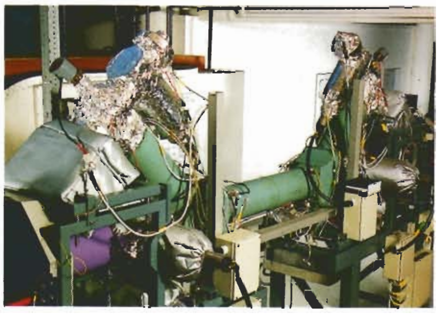
In the spring and summer of 1992, work continued on electron storage in ASTRID. The goal was to reach the design current of 200 mA at full energy (550 MeV). During the months which were allocated for this purpose, an injected current (100 MeV) of 135 mA was reached, and about 120 mA was accelerated, not far from the design value. The closed orbit of the accelerated beam was positioned correctly in the ring, and this position was reproduced from one injection to the next, so the facility is ready to serve experiments.



Lifetime of stored electrons

The factor limiting the accumulated current was mainly beam loading in the RF system. It was found necessary to improve the diagnostic tools and introduce new ones, so that the size of the stored beam can be monitored accurately together with the bunch length. After consulting experts in these fields, the beam loading problems should be cured for the next SR period (January to March 1993).

The operational current of more than 100 mA was sufficient for much of the initial work to be done on the ASTRID beamlines. The SX-700 monochromator was aligned, and very successful work was done with the X-ray microscope, as shown at the bottom of this page.


The ASTRID electron cooler

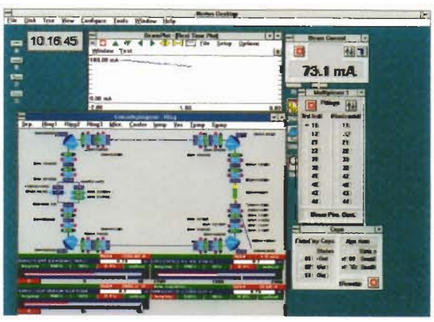
Concerning heavy ions in ASTRID, the electroncooler was installed in the spring of '92, and commissioning of the heavy-ion RF system started in the fall with the aim to provide singly-charged ions at 2 MeV/amu for e.g. recombination studies.

Niels Hertel and Søren Pape Møller

The ASTRID control system

There are some 220 variable parameters in ASTRID (dipoles, electrostatic and magnetic quadropoles, steerers etc.). The value of each of these parameters is held in a database in the control computer, which is a 16-bit minicomputer.

During machine setup, values in the database may be changed from one of the control consoles, which are standard PCs, linked to the control computer as terminals via a 9600 baud serial link. The control terminals run a local control program, which makes selection, display and precise control of any of the parameters easy. Four parameters may be selected for simultaneous control from each terminal, either by selecting it from one of the parameter lists, or by pointing to the desired element on a graphical representation of the ring.



Screendump of operator console

When selected, parameters may be changed either by typing the desired value or by turning one of the two control knobs, which are linked to each terminal.

The value of all ring parameters may be saved or retrieved at any time.


ASTRID main control room

A PC is running the diagnostic system consisting of position pickups, current transformers, Faraday cups, scintillation screens etc. This PC may also read and write in the central database, thereby making e.g. position and tune changes easy.

When the beam is accelerated, the values of many parameters must be changed very precisely, both in time and amplitude. To achieve this, each of these 'dynamical' parameters may be controlled from an autonomous function generator, into which a table with 'amplitude versus time' values may be loaded prior to acceleration. When acceleration takes place, the various function generators are controlled by a common clock, which makes all the connected function generators step synchronized through the preloaded values. This system is similar to e.g. the one found at LEAR, CERN.

Torben Worm

The ASTRID X-

In the summer of 1992 the Aarhus X-Ra imaging microscope was installed, ar the first pictures were taken.

Below is shown a picture of a te object taken with the microscope at wavelength of 2.4 nm. The object is mad by electron beam lithography. In the IS target the height of the smallest letters 800 nm.

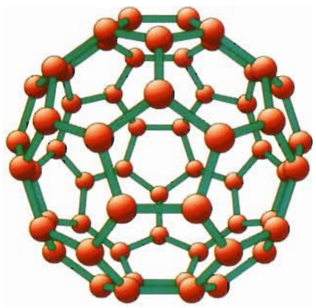
The imaging system proved its valu during these first measurements. Th object is focused on a microchannel plate which is imaged by a TV camera. Man frames from this camera are averaged b a commercial frame-grabber system. Wit this technique, finding the object an focusing can be performed on-line at low SR-intensity. Photographic films, ar used for the final high resolution pictures

New-developed phase zone plate (see below) with germanium zones o Silicon backings are used for the micro scope, together with pure Si foils as vacu um windows. Typical foil-thicknesse

Playing soccer in a roundabout:

Storage of carbon clusters.

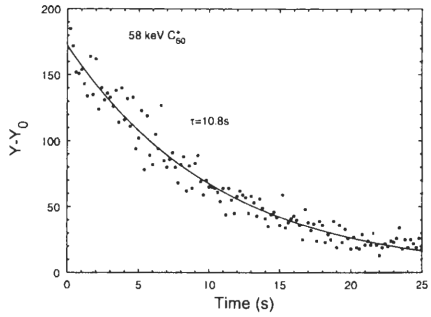
The discovery of the exceptional stability of C_{60} (Buckminsterfullerene) and techniques of making ion beams of the large molecules has made 'molecular soccer playing' a popular sport.



Recently, both C_{60}^{+} and C_{60}^{-} have been stored in ASTRID at energies between 25 and 60 keV with the purpose of determining the storage lifetime. These ions, with a mass of 720 amu, are by far the heaviest ions ever held in a storage ring. The velocity of a C_{60} ion with this energy is 10^5 m/s, giving a revolution time of about 350 µs. The ion lifetime was determined by recording the rate of neutral particles formed in one of the straight sections of the storage ring as a function of time.

So far the C_{60} ions injected in ASTRID were formed in a conventional ion source of the Penning type, therefore the temperature of the molecules was not under direct control. We observed a long-lived component in the beam with a lifetime of around 10 s, corresponding to a flight length of 1000 km. This is due to restgas collisions. The average pressure in the ring was about $5 \cdot 10^{-11}$ Torr.

For both the negative, and even the doubly negative as well as positive C_{60} ions it would be of interest to determine lifetimes influenced by other mechanisms, i.e. metastable molecular dissociation and thermionic emission.



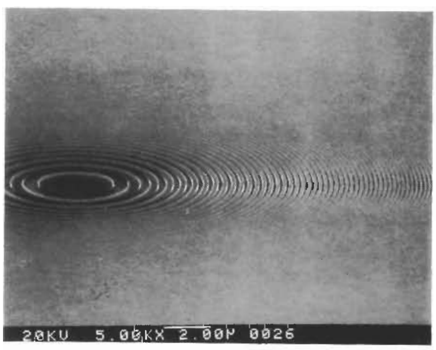
Lifetime of stored C_{60}

Measurements in which the temperature of the molecule is under control are presently being considered, as are experiments utilizing the long storage time, and the possibility for further cooling of the C_{60} molecules.

Preben Hvelplund

Ray microscope

are 80-150 nm. The silicon backings are made by etching boron-doped Silicon-wafers with windowdiameters up to 10 mm. Compared to previously used foils this greatly improves transmission in the water window (2.4-4.4 nm). The new zone plates have been developed in a collaboration between ISA and the Institute for X-Ray Physics in Göttingen. Besides good transmission (83% for 100 nm thickness at 2.4 nm), they also are resistant to X-radiation. Zone plate efficiencies of more than 6% have been measured.



Samples are measured at atmospheric pressure. During the next run, live and wet biological specimens will be imaged. An Aarhus collaboration between biologists and physicists have proposed an extended scientific program.

Robin Medenwaldt

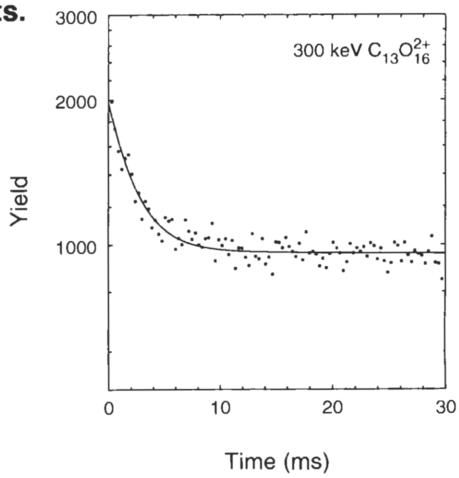
Atomic and Molecular Physics:

New exiting lifetime measurements.

In a series of measurements at ASTRID, the lifetime of metastable electronic states of negative ions as well as metastable states of molecular ions was studied. Measurements of lifetimes in the range 10 µs to fractions of seconds are possible at the ring. The lower limit is set by the revolution time in the ring, and the upper limit is dictated by the destruction time due to collisions with the restgas, typically some seconds.

Several negative ions have been studied: He^-, Be^- and Ca^-. The lifetimes obtained with these ions were in most cases determined by the intrinsic electronic structure of the negative ions. However, the influence from blackbody radiation was observed for the first time, for the most loosely bound systems. In the particular case of Ca^-, with a detachment energy of only 18 meV, the observed lifetime of 490 µs was attributed solely to blackbody-radiation induced photodetachment of the stable ground state.

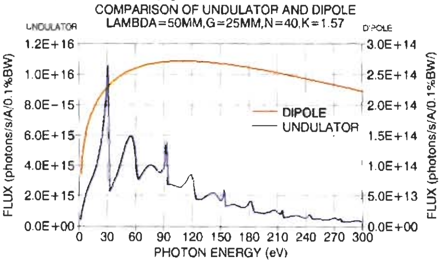
In the fall of 1992, some molecular ions were studied, in particular the negative He_2^- molecule and the doubly charged CO^{++} molecular ion. In contrast to the atomic ions, these ions may be excited electronically, vibrationally and rotationally.



The available experimental information related to doubly charged molecules is very limited. In particular, information on the lifetime of excited states is sparse. Above is shown the yield of neutral atoms leaving the ring at one of the dipole magnets as a function of time after injection of $^{13}C^{16}O^{++}$ (preliminary data). The long component, which on the 30 ms range is almost constant, is due to collisional neutralization of the molecule by the rest gas. The short component, which is about 2 ms, is due to the decay of the metastable state in the molecule.

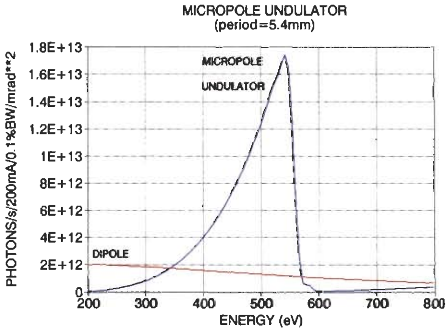
Lars H. Andersen

(continued from front page)
advanced third generation sources under construction - an excellent source for spectroscopy.

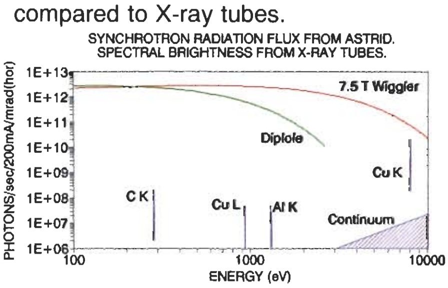


UNDULATOR FLUX INTEGRATED OVER ALL ANGLES
DIPOLE FLUX INTERGRATED OVER 20 MRAD HORIZONTALLY AND FULLY VERTICALLY

A micropole undulator with a gap of about 1 mm is planned. The very pronounced first harmonic as shown below can be placed at an energy from 500 eV to 2 keV - an ideal source for X-ray microscopy and ESCA.



Also a 7.5 Tesla Wiggler is proposed, which will extend the useful range of X-Rays to about 10 keV. This device, which is of great interest for crystallography, LIGA etc, will require an extension of the laboratory. The intensity of the emitted radiation is shown below, compared to X-ray tubes.



The two orders of magnitude ranges for the x-ray tubes show the output from stationary-anode tubes (lower end of range), rotating-anode tubes (middle), and rotating-anode tubes with microfocusing (top end of range).

J.West (Daresbury) discussed the use of the undulator beamline for measurements of photoionization of atomic ions by merging SR and 10 keV ion beams. P.Hvelplund showed the first data on lifetimes of clusters such as C_{60} and other molecules. E. Källne (Stockholm) expressed great interest in using the new SGM beamline for measurements of photoionization and dissociation of ions and molecules in the gas phase, together with resonance structures at outer and inner shell energies.

After a summary of the two days' program, the participants had private discussions with members of the Institute of Physics and Astronomy and ISA. Concluding, it was a meeting that showed great interest in our facility.

Erik Uggerhøj

The ISA beamline at BESSY:

SEXAFS and LEED studies of the adsorption of alkali metals.

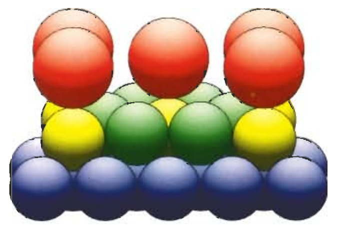
The work described here is the result of a collaboration with the groups led by Jochen Haase and Matthias Scheffler at the Fritz Haber Institute, Berlin.

The surface structures formed by adsorption of alkali metals on close-packed surfaces of aluminum have revealed a wealth of unexpected phenomena. SEXAFS studies of Na adsorption on Al(111) and Al(100) and a LEED study of K adsorption on Al(111) have shown that simple chemisorption structures are formed only at low temperature (100 K). Adsorption at 300 K, or annealing to 300 K after adsorption at 100 K, leads to structures involving a reconstruction of the substrate. For two of these systems, the irreversible phase transition which occurs on heating from 100 K to 300 K preserves the two-dimensional periodicity of the surface structure.

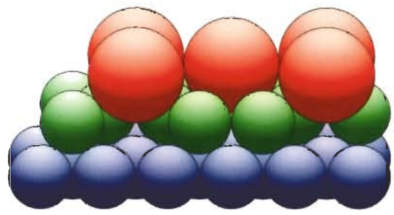
Adsorption of ⅓ monolayer Na on Al(111) at 300 K leads to the formation of a $(\sqrt{3}\times\sqrt{3})R30°$ structure, in which Na atoms occupy 6-fold coordinated substitutional sites formed by removal of ⅓ monolayer Al atoms from the first layer of the substrate. This conclusion is supported by the results of *ab initio* density functional calculations. Adsorption of Na at 100K leads to the formation of a close-packed hexagonal layer of Na atoms with an epitaxial relationship to the reconstructed substrate.

Adsorption of ⅓ monolayer K on Al(111) at 300 K leads to the formation of a $(\sqrt{3}\times\sqrt{3})R30°$ structure, in which K atoms occupy 6-fold coordinated substitutional sites as in the case of Na adsorption. Adsorption at 100 K leads also to the formation of a $(\sqrt{3}\times\sqrt{3})R30°$ structure, but with K atoms in on-top sites on an unreconstructed substrate. For this system an orderpreserving phase transition occurs on heating from 100 K to 300 K. Sketches of the surface structures determined for this system are shown in the accompanying figure.

Al(111)-($\sqrt{3}$x$\sqrt{3}$)R30°-K



100K K in on-top site on rumpled Al layer



300K K in 6-fold substitutional site

Adsorption of ½ monolayer Na on Al(100) leads to the formation of a c(2×2) structure both at 100 K and at 300 K. The structure formed at 100 K contains Na atoms in 4-fold hollow sites on an unreconstructed substrate, whereas the structure formed at room temperature is believed to consist of a subsurface c(2×2) layer of Na atoms occupying on-top sites, beneath a c(2×2) layer of Al atoms adsorbed in 4-fold hollow sites in the Na layer.

Dave Adams

Interest in ASTRID-programs should be expressed to

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