ISA

Institute for
Synchrotron Radiation
Aarhus University

Newsletter No.5. January 1994

The ASTRID storage ring is situated under the parking lot in the center of the photo. The laboratory is shown with solid lines, while the extension is shown with dotted lines. The building complex to the left is the Institute of Physics and Astronomy.

ASTRID surpasses expectations

The idea behind the Aarhus storage ring was to design a facility which could function both as a Synchrotron Radiation (SR) source and as a ring for ion storage, including laser and electron cooling equipment.

For SR, a current of more than 200 mA (design value) is routinely stored at the maximum energy of 580 MeV, and with lifetimes in excess of 6 hours (see figure on page 3).

In the ion mode, species which were unheard of at the time of the design have been stored. More than 30 ions and clusters of both polarities and with masses from 1 to 840 amu have been stored at energies ranging from 6 keV to 6 MeV (see table on page 4).

So, today ASTRID is the scene of a wide range of research using SR from infrared to X-rays, and ions of many types. The SR/ion periods of operation alternate every ten weeks, with change-over periods of 2-3 days. The first SR-run in 1994 starts in February. The dual purpose ring has thus met its design values and even surpassed expectations.

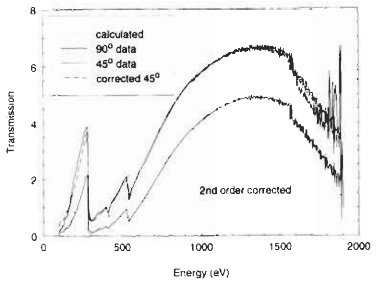
The three SR-beamlines funded to date (stage 1) are now practically completed. The three beamlines are for: imaging X-Ray microscopy using zone plates, surface physics using a SX-700 monochromator, and last a beamline with a Spherical Grating Monochromator (SGM) mostly for atomic physics.

Continued on page 4

ASTRID in space

The graph shows transmission measurements of a thin film composite material supplied by the Danish Space Research Institute which is to be used as a X-ray window in the LEPC detector of the joint Russian-Danish SODART telescope scheduled for launch in 1995.

Measurements were taken at normal and forty five degrees incidence with the SX700 monochromator using gold as a reference material, and corrected for the second order contribution of the monochromator which is significant in the low energy region. Both measurements are in good agreement after correction for the angle difference.

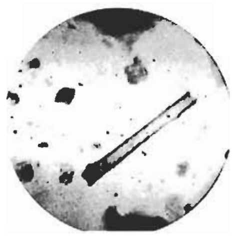


The calculated window transmission agrees well with experiment except at energies above 1000 eV which is due to the low flux and the scattered light contribution from the monochromator. Further measurements are planned.

D. Batchelor and S.V. Christensen

The X-Ray Microscope

Measurements with the XRM have been aimed at gaining experience with the handling of wet samples. All samples are kept at atmospheric pressure (He) during measurement, which drastically reduces handling and cooling problems and enables fast sample changing. An image of a wet sample from the ASTRID microscope is shown. The image shows iron structures made by the bacteria Leptotrix. The imaged area is 20 µm in diameter.

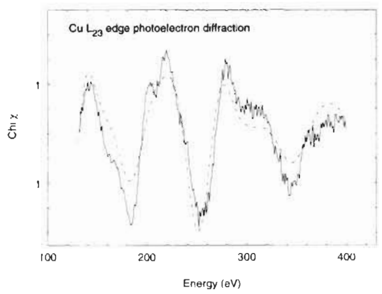


Several other specimens have been investigated, and a plan for the coming run has been made in collaboration with colleagues from the institutes of biology and medicine. The projects have been chosen for their ability to exploit the unique properties of the X-ray microscope. The collaboration with the Göttingen group also continues, aiming at developing better optics and foils.

N. Hertel and R. Medenwaldt

Surface structure determination

In recent years Photoelelectron Diffraction (PhD) has been established as a useful technique in determining surface structures complementary to Surface Extended X-ray Absorbtion Spectroscopy (SEXAFS). In PhD experiments the intensity of a photoelectron peak is measured as a function of emission angle or photon energy. With SEXAFS the intensity oscillations with photon energy give primarily information about the bond length, the site is determined through non-nearest neighbour distances and/or variations in the amplitude of the oscillations as a function of polarisation angle, whereas in PhD information about the site is more directly ob-



tained. The figure shows a Cu $L_{2,3}$ PhD spectrum taken at the ASTRID SX-700 monochromator compared with a theoretical calculation. An experimental program to utilise these techniques in structure determination is underway.

D. Adams and D. Batchelor

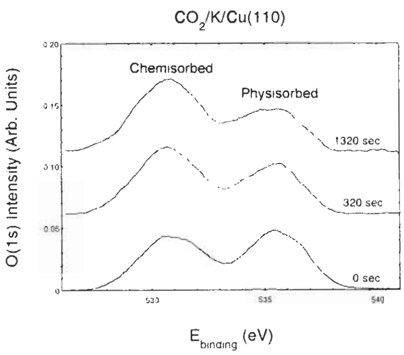
Growth and structure of ultra-thin films

In continuation of previous work in Copenhagen and on the Danish beamline at BESSY, valence-band photoemission and photoelectron diffraction measurements have started on the SX-700 beamline at ASTRID for the catalytically active Cu/ZnO(11$\bar{2}$0) system. It is already evident, that the photoelectron diffraction method will provide new structural information for this system.

P. Juul Møller

Reactions on copper surfaces

In a joint project with Odense University and the synchrotron surface group at Aarhus University, we have studied the adsorption and reactivity of CO_2 on the K/Cu(110) interface and the effect of photon irradiation. The measurements were performed at the SX-700 monochromator with a hemispherical electron energy analyzer. An overall resolution of 0.25 eV was obtained with photon energies in the 120-700 eV range. The applicability of synchrotron radiation for this study is demonstrated by the photoelectron spectra of core and valence electrons at the interface.



Core electron spectra: The figure shows the oxygen 1s electrons originating from CO_2 adsorbed on an interface formed by deposition of half a monolayer of K on a Cu(110) surface. There are two oxygen states, at 535.5 and 531.2 eV binding energy, reflecting physisorbed and chemisorbed CO_2, respectively. The effect of photon irradiation is demonstrated by the development of the spectra with photon irradiation. A conversion from the physisorbed to the chemisorbed state is induced by irradiation with 120 eV photons. The decay of the physisorbed state is compensated by the growth of the chemisorbed state. *A photochemical process takes place.*

Valence electron spectra: Useful information on the bonding and reaction of CO_2 at the K/Cu(110) interface can be obtained from the valence electron energy distribution and states with low binding energies, 0-25 eV, relative to the Fermi level. The effects of admitting CO_2 to the K/Cu interface are a "chemical shift" of the K-2p electrons and the appearance of new peaks of pronounced intensity which is correlated with the CO_2 bonding.

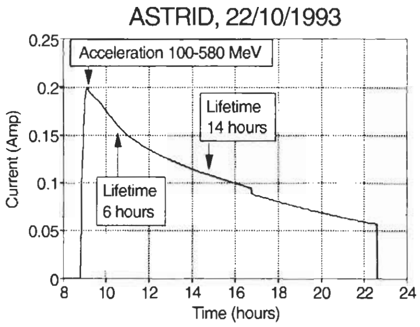
J. Onsgaard

Injection and storage of electrons

The goal for electron operation was reached during the second run of 1993. The highest current accumulated to date is 225 mA, of which 215 mA was brought to full energy (580 MeV).

Mainly fine-tuning of the electron injector (a 100 MeV Race-Track Microtron) and the ring RF system were responsible for reaching the designed 200 mA at full energy. As seen in the figure, the lifetime is around 6 hours at 200 mA, and 14 hours at 120 mA.

This lifetime was obtained at the cost of an increase in the vertical beamsize



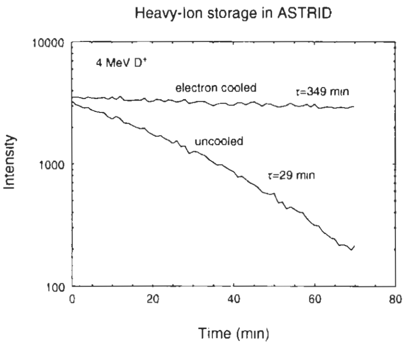
caused by exciting the beam vertically at the vertical betatron oscillation frequency. During the next electron run, beginning in February of 1994, this is to be studied further. The increase in lifetime is about a factor of five, while the reduction in throughput in e.g. the SX-700 is about 25%. The X-Ray microscope in fact benefits from an increased vertical beamsize.

S.P.Møller and N.Hertel

Ion storage

Electron cooling of D^+

It has been demonstrated that bare heavy ions can be stored in ASTRID for a very long time when they are cooled by electron cooling. In a recent experiment, we injected the hydrogen isotope D^+ into the ring at an energy of 150 keV. The beam was then accelerated to an energy of 4 MeV by the RF-acceleration system in the ring. By recording the circulating beam intensity as a function of time, we measured a lifetime of about 30 minutes as seen in the figure.



By merging the ions with a beam of 'cold' electrons over a section of 1 meter in length, the storage lifetime became almost 6 hours, corresponding to an improvement by a factor of 12 !

During the time of storage, the ions will pick up 'excess' momentum from collisions with the background gas and via collisions within the stored beam. The ions can deliver this excess momentum to the cold electrons and thereby remain stored.

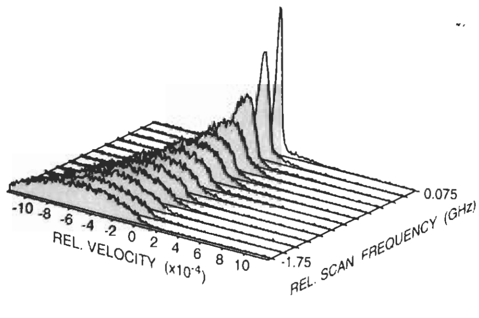
Lars H. Andersen

Laser cooling at ASTRID

A new ion has been chosen for laser cooling studies in ASTRID. This ion, $^{24}Mg^+$, has a closed transition operating directly from the groundstate, so that it now is possible to cool all of the ions instead of just a small fraction of them, which was the case with $^7Li^+$ (see newsletter 2 and 3). As the wavelength of the $^{24}Mg^+$ transition is in the UV at 280 nm, it has been necessary to build a frequency doubling system for our ring dye lasers. This system uses an external resonator and a KDP crystal, and is capable of producing up to 80mW CW.

In the summer of 1993, only one UV laser system was available, so standard laser cooling, which requires two lasers, could not be performed. However by scanning the frequency of the one available laser, a quasisteady state, where the longitudinal temperature of the beam was only 1 K, could be created. The 1 K should be compared with several thousand Kelvin without laser cooling.

Another interesting new thing that was studied was laser cooling of an RF-bunched beam. When the beam is RF-bunched the energy of the ions will oscillate around the synchronous energy. The amplitude of this oscillation can be damped by the laser, and cooling thereby achieved. This technique allows attainment of a steadystate cold beam using only one laser. In this way a longitudinal temperature of ~1 K was also achieved. The figure shows the time



development of the velocity distribution of a bunched beam undergoing laser cooling. The width of the velocity distribution is decreased by a factor of 10 in 0.6 s.

A second frequency-doubled laser has been readied and will be employed in measurements starting December 1993.

J.S. Nielsen and J.S. Hangst

Cluster storage in ASTRID

The storage times of negative carbon and aluminum cluster ions have been investigated at an energy of 100 keV. Negative cluster ions were produced in a sputter ion source (ANIS), and beams of C_n and Al_n (n=1..14) were obtained with sufficient intensities. Lifetime spectra of stored cluster ions were obtained by recording the count rate of neutral particles as a function of elapsed time following injection of a 10 μs long pulse. The lifetime exhibited two components. The long lifetime is believed to be connected with collisional destruction of ground-state ions, while the short stems from either metastable or highly excited ions. The two lifetimes were found to depend strongly on the cluster size.

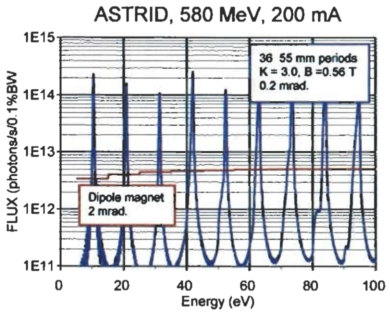
P. Hvelplund

ASTRID surpasses...

Continued from front page:

The many different ions and clusters have been stored to investigate 1: laser cooling, 2: ion-electron collisions using the electron-cooler beam as target, 3: lifetime of metastable ions and effects influencing this, such as vacuum, intra-beam scattering and field stripping. A special stripping mechanism was identified for loosely bound electrons, namely ionization by blackbody radiation emitted from the surrounding vacuum chambers (Newsletter No.4).

In 1993 a new Aarhus Center for Advanced Physics (ACAP) was funded. ACAP will be a major user of ASTRID. To fulfill some of the ACAP programs, a new detector facility for experiments around ion storage will be installed. Here it is possible to investigate charge and mass of fragments/ions/clusters from collisions and laser interaction. Also, an EBIS ion source for multiply charged ions will be installed. Furthermore, a VUV undulator (see Newsletter no.4) for use mainly in atomic physics will be constructed. The undulator radiation will merge with keV-ions stored in a small ring.



New capillary lenses of the 'Kumakhov-type' are being tested for focusing SR, and for use in X-ray lithography.

To accomodate all these new activities, an extension of the existing lab space has been planned, as indicated with a dotted line in the photo on the front page of this newsletter. The extension will allow for new SR-beamlines as well as for a laboratory for experiments with extracted 580 MeV electrons. From a 200 mA stored electron beam there is a continous loss of about 10^6 e^-/s. This by-product can be extracted and used for collision physics, test beamlines for high energy physics, space research and a home laboratory for experimental physics at international facilities.

E. Uggerhøj

Positive ions:
H_2^+, D^+, $^4He^+$, $^6Li^+$, $^7Li^+$, $^9Be^+$, $^{16}O^+$, $^{20}Ne^+$, $^{24}Mg^+$, $^{40}Ar^{++}$, $^{151}Eu^+$, $^{166}Er^+$, $^{13}CO^+$, $^{13}CO^{++}$

Positive cluster ions:
$^{12}C_{60}^+$, $^{12}C_{70}^+$

Negative ions:
D^-, $^3He^-$, $^4He^-$, $^4He_2^-$, $^9Be^-$, $^{12}C^-$, $^{16}O^-$, $^{19}F^-$, $^{40}Ca^-$, $^{56}Fe^-$, OH^-

Negative cluster ions:
$^{12}C_{60}^-$, $^{12}C_{70}^-$, $^{12}C_n^-$ (n=1..14), $^{27}Al_n^-$(n=1..14), $^{27}Al_{12}B^-$

Table 1: Ions stored in ASTRID.

Testing the SGM

In the summer 1993, the commissioning of the ISA spherical grating monochromator (SGM) has been started. The performance of the low (30-80 eV) and the medium energy (80-250 eV) grating was tested and photocurrent spectra taken on various samples.

The PC-based control and data taking software was successfully tested and enables a safe and user-friendly operation of the SGM in any mode.

The commissioning will be continued in the spring electron run of 1994.

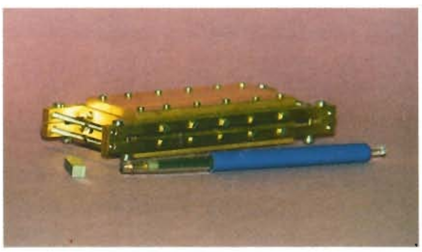
A. Baurichter, C.S.Mythen and T. Worm

The Micropole Undulator

A micropole undulator (minimum gap: 1 mm), serving as an enhanced flux source for e.g. the X-ray microscope has been designed. A Halbach-type pole structure (permanent magnet configuration) with 15 periods of 6 mm length will yield a flux gain in the energy range from 0.28 to 0.54 keV ('water window') by an order of magnitude over the radiation from a dipole magnet.

Computer simulations show that beam properties should not be seriously affected by insertion of the device.

The properties of the high remanent magnet material $SmCo_x$ were analysed at ISA under ring vacuum conditions (baking at 300°C for 36 h, pressure $<3\times10^{-11}$ mbar). The material was proved to be fully vacuum compatible.



The Micropole Undulator prototype with 4 stacked magnets to the left.

The remanent magnetic field was totally preserved after baking.

The undulator radiation will be analysed by a zone plate monochromator (ZPM), which has been designed in parallel to the undulator. It consists of a zone plate (same type as the X-ray microscope condenser lens), a moveable 50 µm pinhole, and a GaAsP-diode as photon detector.

A. Baurichter and S.P. Møller

Call for Proposals:

International and national groups are welcome to submit proposals for both the heavy ion and the synchrotron radiation program.

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Interest in ASTRID-programs should be expressed to

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