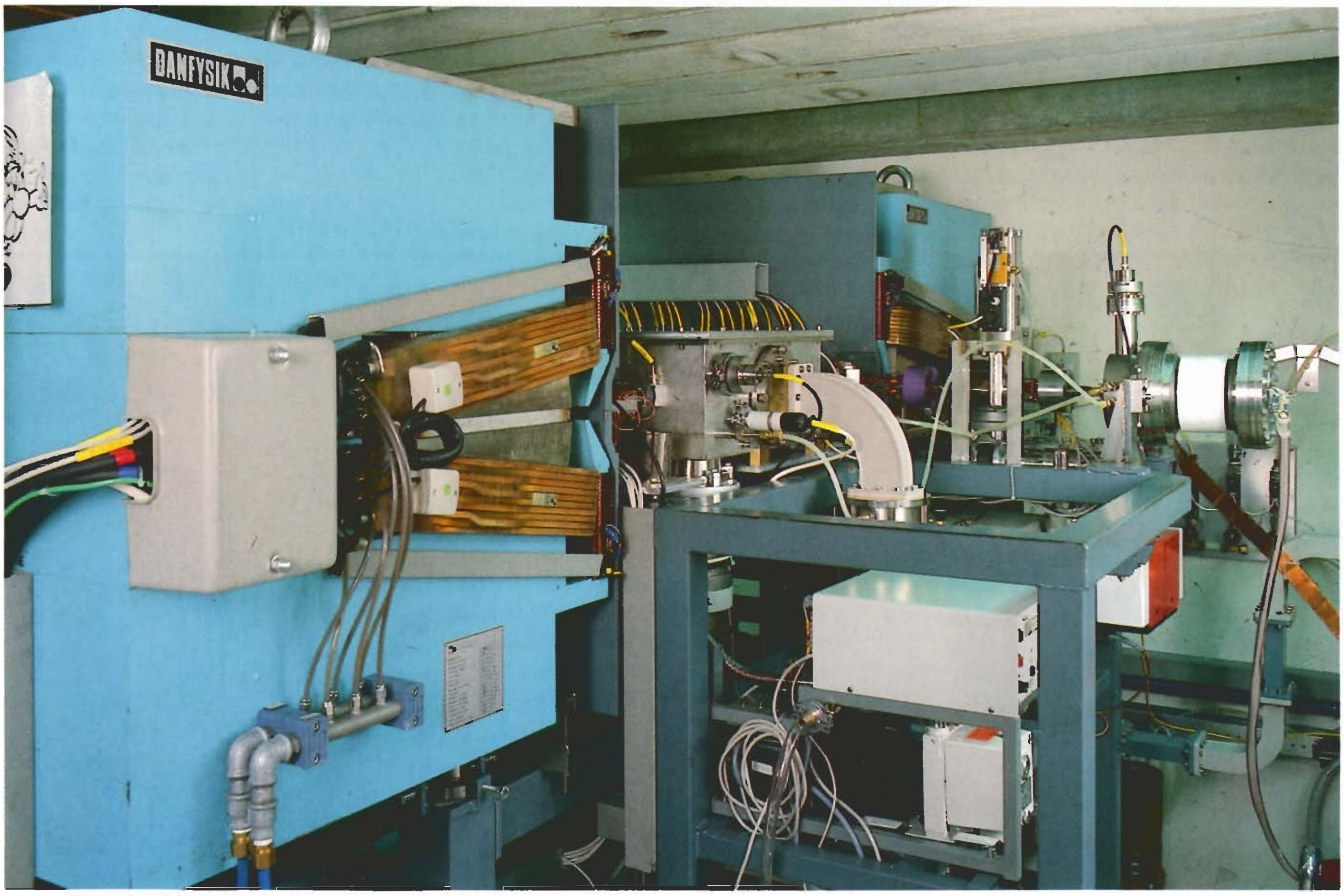
ISA

Institute for Synchrotron Radiation Aarhus University

Newsletter — **No.2. November 1990**



The ASTRID microtron which injects electrons into the storage ring.

Status of Aarhus Storage Ring Facility

The Aarhus Storage Ring (ASTRID) was completed for heavy ion injection at the end of 1989. Setting up and running in of the heavy ion injector and ASTRID took less than two months. Beams of Li^+, Ar^+ and Ne^+ with an energy of 100 keV were stored in March. After a celebration of this milestone the physics program was started. Laser cooling of Li^+ was investigated until the middle of June. Modifications of the ring for electron storage was then started.

The Aarhus Synchrotron radiation program commenced with setting up a Danish beamline at BESSY in Berlin. This beamline with monochromator and ultrahigh vacuum equipment has now been running for nearly a year. The electron injector (the microtron) and ASTRID modifications have been completed and electron storage is under preparation. The X-ray microscope is under construction and will be completed early in 1991. A new monochromator is being designed. In the following a more detailed status report of the whole facility is given together with some experimental results from the heavy ion and synchrotron radiation programs.

Erik Uggerhøj

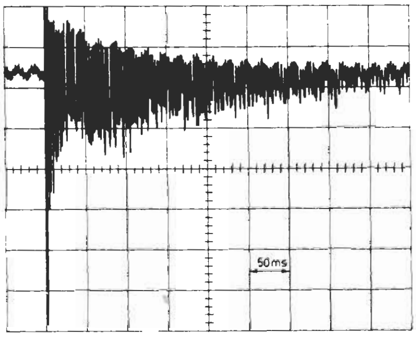
National and international groups are invited to submit proposals and letters of intent to the heavy ion and synchrotron radiation programs.

The heavy ion program

Storage of heavy ions

The commissioning of ASTRID with heavy ions started in late 1989 (for details about the facility, see Newsletter No.1). After debugging the isotope separator and the injection-beamline, the first beam was injected into the ring january 31th 1990. After a few days the first turn was completed by the beam as observed on the pick-up plates and the scintillator screens. Within another few days, three turns were observed, and after proper adjustment of the chopper in the injection-beamline and the kicker in the ring, a stored beam could be observed for 0.3 sec.

The next step was to tune the quadrupoles to the correct betatron tunes, $Q_H = 2.29$ and $Q_V = 2.73$, using FFT analysis on a digital oscilloscope of the pick-up signals. Furthermore, the closed orbit was measured, and the closed-orbit deviations were found to be less than 10 mm, reflecting the good alignment and the good field quality of the magnetic elements. The closed orbit was later corrected with the correction dipoles.



Pickup-signal of beam, showing a storage time around 1 sec.

The separator and the ring has mainly been running at 100 kev, although it has been tested to 150 kev. The first ions used were Ar^+, but soon after the first tuning of the ring, we changed to Li^+ ions as required for the laser-cooling experiments (see below). These experiments started in March, and ran until the machine was closed down in mid June for upgrading to electron operation (see later). Other ions have also been used, e.g. simultaneous storage of $^{20}Ne^+$ and $^{40}Ar^{++}$ ions. The stored currents were in the 1-10 μA range.

The RF system has only been tested at a fixed frequency, and the beam lifetime observed with a bunched beam was a few seconds at a average pressure below 10^{-10} torr obtained after bakeout to 150°C. A similar lifetime was observed using the longitudinal Schottky pickup.

Søren Pape Møller

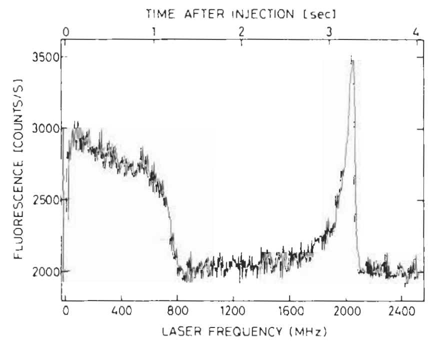
Laser physics at ASTRID

Lithium ions were injected into the storage ring. A fraction (about 10^{-4}) of the ions is produced in the metastable $1s2s^3S_1$ state. This state is connected with the $1s2p^3P_2$ state through allowed optical transitions. One of the hyperfine lines, the F"=5/2↔F'=7/2 is practically closed with a branching ratio of less than 10^{-5} from the upper level to the ground state. This line allows studies of the evolution of the beam dynamics using laser induced fluorescence (LIF).

The characteristic beam parameters, as measured by LIF, are given in the Table.

Beam radius,R	2.5 mm
E_{trans}	90 meV
$T_\perp$	1000 K
$T_\parallel$(@ injection)	15 mK
heating rate	4000 K/s

Laser cooling is the result of the velocity-selective transfer of momentum from photons absorbed from one direction followed by spontaneous reemission in nearly random directions. The results of laser cooling, shown in the figure, first exhibit a high fluorescence established within 20 ms after injection, terminated by a sharp "edge" or drop, and then a laser-cooled peak. The rapid turn-on of LIF indicates a strong plasma coupling. The nature of the edge is not yet well understood; its position is independent of intensity,



Laser cooling of a 100 keV stored $^7Li^+$ beam with the circumference of the ring filled. An edge structure is observed followed by a sharp fluorescence peak, as a function of time after injection. The position of this peak is determined solely by the initial frequencies of the lasers. The temperature of the laser cooled ions is ~1 mK.

scanning rate and detunings of the lasers, but it depends on the time after injection and on the length and shape of the injected bunch of ions. The drop is interpreted as a sudden decoupling of the metastable ions from the ground state ions: the velocity of the metastable ions is no longer changed into resonance with the lasers by their interaction with the ground state population. The sharp peak indicating a cold state can only be achieved in the laser cooling process after the edge. From a theoretical calculation, using only the light induced force and momentum diffusion, a minimum temperature of 1 mK is obtained, consistent with the observed LIF.

The lifetime of the cold distribution was also studied. With both lasers on, the lifetime was 2.8(3) s, with one laser turned off 2.1(2) s and with both lasers turned off 1.6(2) s, to be compared with a lifetime for the ground state ions of 1.4(1) s, measured with the Schottky and position pick-ups. The cooled distribution, unlike the initial beam, does *not* heat up longitudinally; it does not seem to be coupled to the much larger number of ground state ions that are still present. This anomalous behaviour is not understood.

It is rewarding that ASTRID allows ultra low temperatures to be realized. The anomalous long lifetimes of the laser cooled distribution directly set limits on the heating due to technical imperfections. They are very small and indeed make ASTRID a very interesting tool for the ongoing quest for crystalline beams. A one-dimensional string, which will not shear, will be easier to form and should be within immediate reach with our ring.

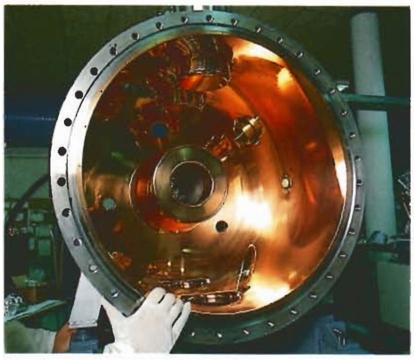
Ove Poulsen

The Synchrotron radiation program

Upgrade of ISA to electrons

In the first stage ASTRID was only built for storage of ions, and we shall here describe the modifications, that have been made during the summer of 1990 to allow injection, accumulation, acceleration and storage of 600 MeV electrons.

A new septum magnet and vacuum chamber has been acquired to allow injection of the 100 MeV electrons into the ring. The same septum can also be used for the ions. Furthermore the septum can extract 600 MeV electrons. A new magnetic kicker powered by a thyratron has also been built. This kicker is mounted together with the RF cavity on a cart which can be rolled into the ring to replace the heavy-ion kicker, RF system and transverse Schottky pickups. The kicker can also be connected to the electrostatic heavy-ion kicker supply for a fast change between electron and heavy-ion storage without change of the RF-system.



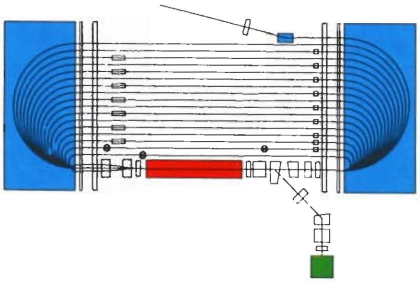
The interior of the RF-cavity

The 105 MHz RF cavity has been constructed and copper plated at GSI. The resonance frequency and the Q were measured before the copper plating with satisfactory results. The RF window has been brazed at CERN, and the system is awaiting a full-power test.

Finally, synchrotron-radiation beam ports have been installed and new preamplifiers for the pickups have been constructed. A new beam-current transformer has been installed and preparations for the synchrotron-radiation diagnostics have been made.

Electrons for injection in ASTRID are to be delivered from a 100 MeV Racetrack Microtron (RTM). This accelerator is designed to deliver 1 microsecond pulses of 100 MeV electrons with a 10-20 Hz repetition rate.

Construction of the RTM is now finished, and running-in has begun. A picture of the microtron is reproduced on the front cover of this newsletter, and a drawing is shown in the figure.



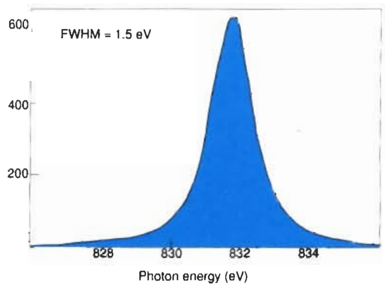
Schematic drawing of microtron

After 19 passes through the linac, the 100 MeV electron beam is deflected 14 degrees away from the machine, and via 2 additional 14 degree dipoles and two sets of quadropole triplets it enters the 14 degree magnetic septum of the ring. Additional data on the microtron may be found in ISA Newsletter No.1. Routine operation of the microtron is expected to start by the end of the year.

Niels Hertel and Søren Pape Møller

The BESSY beamline

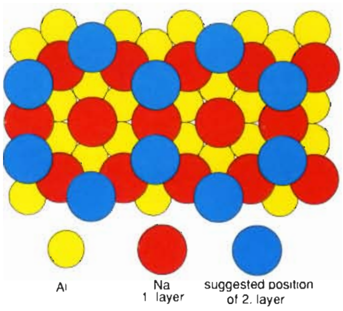
The SX-700 monochromator on the Danish beam-line at BESSY has been tuned and characterized. The beamline was incorporated in BESSY's scheduling of beam time on April 2, 1990 and it has since been used by groups from The Free University, Fritz Haber Institute and Sietec Corp., Berlin and by groups from Denmark in various studies of surface phenomena. The performance of the monochromator is regarded as being most satisfactory.



Energy resolution of monochromator illustrated by the linewidth of an atomic transition.

The Aarhus group is assembling a versatile experimental station which will be installed at BESSY at the beginning of November, 1990. The system is built around a rotatable analyzer for angular- and energy-resolved measurements of the intensity of photoemitted valence electrons. These measurements will be used in studies of surface electronic structure. The system will also contain facilities for measurements of surface geometrical structure using low-energy electron diffraction and for surface chemical characterization using Auger electron spectroscopy, together with the usual facilities for surface preparation and residual-gas analysis. The system will also include a large electron energy analyzer for high energy-resolution measurements of photoemitted core electrons to be used in investigations of the local chemical environment of surface atoms. This analyzer, together with X-ray and ultra-violet photon sources for off-beamline use, will be installed later in 1991.

The work of the Aarhus group is aimed at correlated investigations of the geometrical and electronic properties of clean and adsorbate-covered surfaces, involving in particular studies of alkali metal adsorption on simple and transition metal surfaces. The first studies in this program, carried out in collaboration with Joachen Haase, Fritz Haber Institute, have involved measurements of the X-ray-absorption-fine-structure associated with Na adsorption on Al surfaces. A Fourier transform of the fine-structure as a function of photon energy for Na adsorbed on Al(111) leads to a determination of the Na-Al bond length of 3.32Å.



Structure of the Na-Al surface, concluded from the experiment.

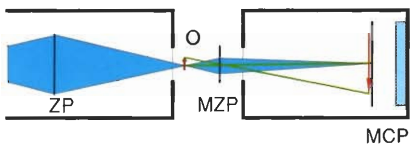
A detailed analysis of the results leads to the surprising conclusion that Na atoms are substitutionally adsorbed in sites of 6-fold symmetry, replacing every third Al atom in the close-packed (111) surface, as shown on the figure. This conclusion can be expected to have a major impact on current theories of alkali metal adsorption, since these are based on geometrical models in which the adsorbed alkali atoms are adsorbed on an unreconstructed substrate.

D.L. Adams, D.H. Batchelor and E. Bøgh

New equipment

X-ray microscope

The design of the microscope is completed and the hardware parts will soon be finished and installed. Briefly, the Aarhus X-ray microscope consists of two vacuum chambers with the object kept in air. A sketch is shown below. The synchrotron radiation is focused onto the object O by a condenser zone plate (ZP). A pinhole in front of the object gives the possibility of illuminating the object with a certain prechosen wavelength (monochromaticity around 250). The micro zone plate MZP images the object with a magnification of 300-1000 onto a photographic film or a microchannel plate positioned in the second vacuum chamber. A resolution of less than 100 nm is achievable.



Schematic drawing of X-ray microscope

Having the object chamber in air allows fast adjustments and exchange of the object, and simplifies the study of living cells in a wet environment.

Studies are in progress on the use of thin silicon crystals (some thousand Å thick and several mm in diameter) as walls for the object chamber and vacuum windows. New zone plates are being developed in a Aarhus-Göttingen collaboration. Here thin Si crystals are used as carriers instead of mylar foils to reduce absorption of C-X-rays. Moreover, the damage due to large radiation doses is strongly reduced.

Robin Medenwaldt

Spherical Grating Monochromator (SGM)

A SGM for atomic physics is under design. The energy region is 70-500 eV with a resolution, E/ΔE, between 1500 and 3000. The beamline can also be used for X-ray litography.

Interest in ASTRID should be expressed to

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Call for proposals and letters of intent.
Research groups and industrial teams are invited to use ISA.
Contact ISA for further details.

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