ISA

Institute for
Synchrotron Radiation
University of Aarhus

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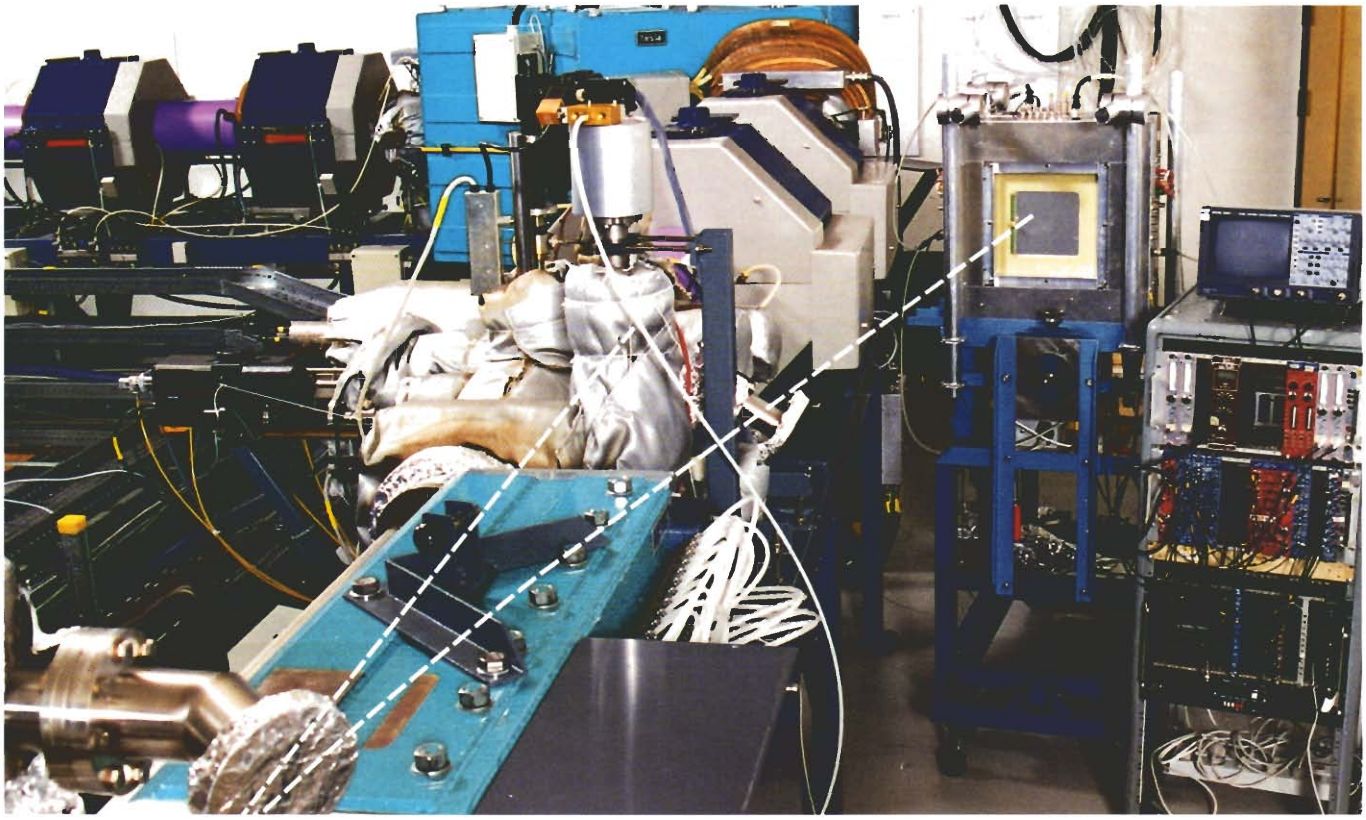


The ASTRID 580 MeV electron extraction facility was made operational and tested during the last electron run. The beam is extracted at the septum in the front. In the back is seen drift chambers set up to characterize the beam. The dashed white line indicates the beam path. More on page 4.

The Second ISA Users' Meeting

About 50 scientists from different European countries were assembled in Aarhus for a two-day meeting on January 23-24 1995 to present ongoing and future scientific programs/plans for both ion storage and synchrotron radiation at the ASTRID facility.

The first day's meeting was opened by S.P. Møller, who presented a status report on ASTRID, which has now reached a maximum accelerated electron current of 250 mA, with beam lifetimes around 10 hrs at 200 mA! Next, the ongoing research programs were presented by group leaders, followed by students' presentations of more detailed results.

The second day was dedicated to future plans/ideas for the Aarhus facility together with reports on research programs from other European facilities, i.e.,
MAX-LAB, Lund (J.N. Andersen)
FELIX, FOM Rijnhuizen (D. Oepts)
TSR, Heidelberg (P. Forck)
CRYRING, Stockholm (H. Danared).
W. Gibson, SUNY, Albany, gave an overview of the possibilities of using glass capillaries in X-ray optics.

The present, tight scheduling has been discussed for some time: How can the running time for ion storage and the number of SR beam lines be increased?

A 2000 m^2 expansion of the existing ASTRID lab is now under construction and will be finished in the summer of 1996. This new laboratory will allow new SR beamlines from bending magnets but will not give more space for insertion devices or more running time. The new lab will allow an upgrade of ASTRID, with more straight sections for insertion devices, or even a new ring: ASTRID II.

Two proposals for the upgrade of the Aarhus facility were presented by V. Lebedev. The first plan suggests to add three more straight sections to ASTRID: one for a superconducting (7.5T) wiggler and two for undulators. This plan is rather complicated concerning beam optics and does not give more running time for ion storage.

Continued on page 4

Negative ions: Structure and dynamics

Neutral atoms or positive ions are well described by the independent electron model which assumes that each electron moves independently of the other electrons around the nucleus, held in a potential originating form the nucleus and the other electrons. This model cannot explain the existence of most negative ions. For these ions it is necessary to accept that the movement of all electrons in the system is correlated. Thus electron-electron interaction plays an important role in the proper description of negative ions.

The potential binding an extra electron to a neutral atom or molecule is usually considered to be a polarization potential which is short ranged in contrast to the Coulomb potential controlling neutral or positively charged systems. Consequently, negative ions are only expected to possess one or a few bound states, and certain ions only exist in a metastable form.

The binding energies of stable negative ions, or the lifetime of metastable ions, contain information about the important electron-electron interactions.

The storage ring ASTRID has been used to measure the lifetimes for the metastable negative ions: He^-, Be^-, and He_2^- and will be used for Li^- and B^- as soon as a new multicharged ion source (EBIS) is ready later this year. The lifetimes measured so far are in the range 45 - 350 μs, a region very difficult to study if storage rings were not available. The experimental data can be compared with theoretical predictions and have already yielded a better understanding of these ions.

Binding energies of weakly bound stable ions such as Ca^-, Sr^-, Ba^- can be obtained by measuring the destruction time for the negative ion due to the temperature dependent blackbody radiation in the storage ring, provided the photodetachment spectrum is known. Binding energies obtained with this technique are in agreement with binding energies obtained from laser-studies in single-pass experiments. For Ba^- the combined experiments have led to the first experimental binding energy values for the ground state, but also to the observation of the existence of a long-lived metastable Ba^- ion.

Laser-excitation of negative ions can lead to population of doubly-excited states, the energies of which can also be used as important testcases for theoretical descriptions.

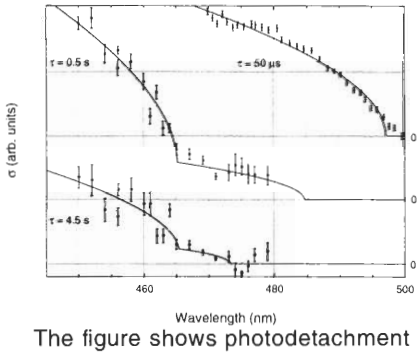
Presently the simplest negative ion system, H^-, with only two electrons and one proton, is being studied with the purpose to determine the position and lifetime of the doubleexcited H^- states located in the vicinity of the n=2 levels of the hydrogen atom.

Torkild Andersen

Photodetachment of C_{60}^-

A well characterized initial state of atomic or molecular particles is of crucial importance for the interpretation of experiments involving interactions of these particles with matter or photons. The ground state of an ion is normally accessed if the ion is left alone for a sufficient period of time.

We have measured the photodetachment threshold, i.e., the minimum photon energy necessary for detaching an electron from C_{60}^- ions as a function of the time elapsed from the creation of the ion in the ion source.



The figure shows photodetachment cross sections versus laser wavelength at three different storage times. A component of the beam, which is essentially "cold", yields a constant photodetachment threshold at 465 nm. This threshold corresponds to an electron affinity of 2.666±0.001 eV for "cold" C_{60}^-.

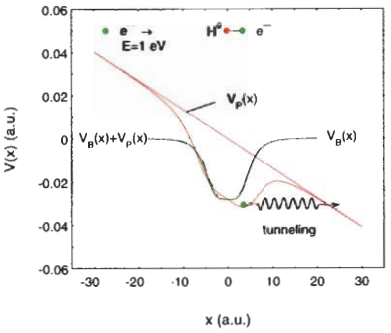
Preben Hvelplund

Knocking electrons off negative ions

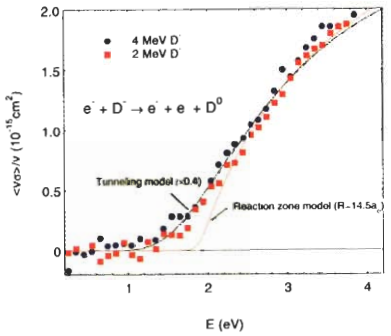
The electron cooler has now been in operation for some years. Different ions have been cooled, and the cooler has served as a free-electron target for different collision experiments involving both positive and negative atomic and molecular ions. Here we report on studies of electron-impact detachment of D^-: Two problems of contemporary interest in atomic physics have been addressed:

1:Threshold behaviour of the detachment cross section

The cross section behaviour near *threshold* is of basic interest from a theoretical point of view and important for all classes of experiments which determine threshold energies. Experimental data for electron-impact detachment have been obtained in the low-energy region from threshold (0.75 eV) to 20 eV. Such data have never been obtained before. Near the threshold, the electron-escape process is controlled by quantum mechanical tunneling through a potential barrier which is created by an atomic-binding potential (V_B) and a potential (V_P) due to the perturbation by the incoming electron. The situation is sketched below in one dimension.



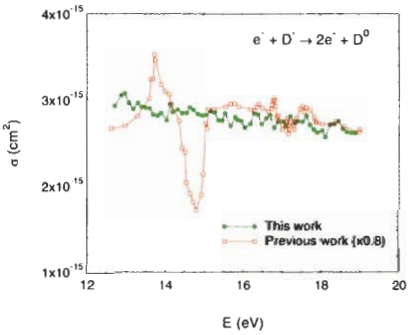
The detachment cross section versus incoming electron energy is shown below.



The data were obtained at two different storage energies. The figure shows results of calculations where the tunneling mechanism is excluded (reaction-zone model) and included (tunneling model). Clearly, tunneling is important in the threshold region.

2: Can a proton hold three electrons?

We have re-investigated an earlier claim of resonances in the detachment cross section that might be associated with triply excited states of D^{2-}. Such resonances would be very spectacular and challenging for theoretical models of atoms with immense electron-electron correlation. Structures in the electron-impact detachment cross section of H^-, attributed to short-lived H^{2-} states have been reported earlier. However, we were not able to confirm the existence of such spectacular states as seen in the last figure.



Lars H. Andersen

Si surfaces with gas and metal adsorbates

Silicon surfaces show strong correlation between their atomic structure and order and their electronic structure, due to the covalent nature of the bonding in the solid phase. Some surface crystalline structures produce varying numbers of unsaturated, localized surface bonds, the so-called *dangling bonds*. Generally, the more ordered the surface, the more dangling bonds! In the present experiments at ASTRID, effects of Cs and H adsorption, and the combination of Cs and H adsorbed, ordered surfaces are studied to detect effects on or of the dangling bonds and changes in surface structure.

The surface atomic structure is indirectly monitored through detection of chemically inequivalent Si atoms in the surface regions. Fig.1 shows how the Si(2p) photoemission core level spectra, recorded with a high surface sensitivity, change with Cs adsorption.

In these spectra, peak a is due to silicon ad-atoms, peak b to bulk and peak c to surface silicon atoms. It is seen that Cs on the Si(111)7×7 surface removes the ad-atoms, and decreases and shifts the Si(2p) spectrum a small amount in energy (upwards), equivalent to lowering the binding energy of silicon atoms. In the case of Si(111):H(1×1) a strong shift downwards of the Si(2p) peaks is

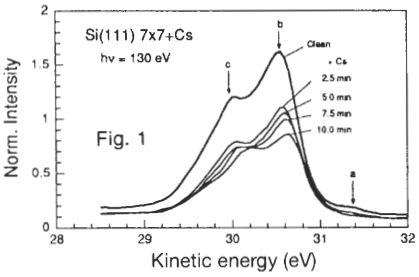


Fig. 1

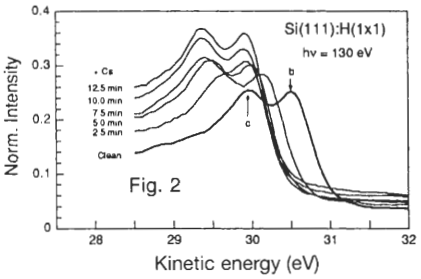


Fig. 2

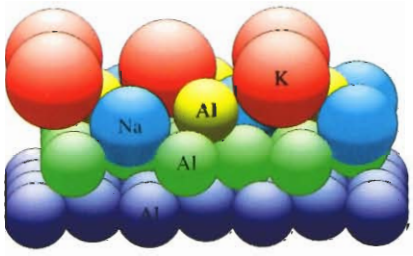
observed (fig.2). This shift, which saturates at the higher coverages, is also observed for the valence band, and is therefore a surface band bending effect.

Such a large shift shows, that for Si(111):H(1×1), the Fermi level is unpinned at the surface, which makes this surface very attractive for testing models for metal-semiconductor contacts (Schottky barriers).

P.Morgen, J.Gordon, H.C.Landmark, A.C.Simonsen, J. van Elp

The discovery of tertiary surface alloys

Measurements of chemical shifts in core electron binding energies, carried out on the surface physics beamline at ASTRID, have led to the discovery of tertiary surface alloys formed by co-adsorption of 1/4 monolayer Na and 1/4 monolayer of K, Rb, or Cs. By comparison with previous results for the Al(111)-(2x2)-Na binary alloy, the observed chemical shifts suggest that the Al(111)-(2x2)-Na/X tertiary alloys consist of an X-Al-Na sandwich on a reconstructed bulk Al layer, where X stands for K, Rb, or Cs (see figure).



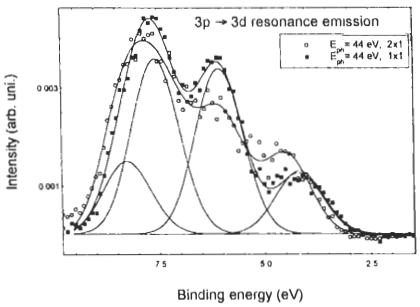
This conclusion has been confirmed by a quantitative LEED analysis for the Al(111)-(2x2)-Na/K structure. Remarkably, as determined both from measurements of chemical shifts and from LEED intensities, the adsorption sequence is immaterial. In all cases Na forms the innermost layer in the alkali-Al-alkali sandwich, even when K, Rb, or Cs is adsorbed first.

S.V.Christensen, J.Nerlov, K.T.Nielsen, J.Burchhardt, M.M. Nielsen, D.L.Adams

TiO_2(110) surfaces

Recent STM results indicate that the 1×2 structure based upon LEED, UPS and EELS may be described by a distorted missing-row model driven by a reduction in surface oxygen.

This was investigated using resonance photoemission (ResPE) with ASTRID-SX700 radiation. ResPE characterizes the surface-related Ti valence-band (VB) states well, and new differences in the electronic structures at the 1×1 and 1×2 surfaces were found.



We studied the 3p→3d and 3p→4s resonance emissions over the 40 eV<E_{ph}<59 eV energy range and found it possible to assign the individual peaks in agreement with the MO diagram. The Ti3d seems to dominate the 3p-3d surface resonance process. Especially, we found that the Ti4s-O2p hybridization is indeed very surface sensitive.

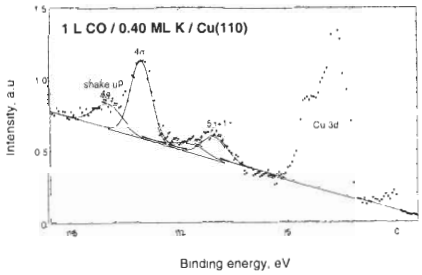
We look forward to fast high-resolution VB and PED studies using the forthcoming SCIENTA analyzer on this and other metal oxide crystal surfaces.

Preben Juul Møller

Adsorption and reactivity of CO on K/Cu(110)

The adsorption and reactivity of CO on a Cu(110) surface modified by K atoms has been studied at the ASTRID SX-700 beamline.

A pronounced chemical shift of the K 3p electrons, 0.6 eV, takes place during K deposition up to one monolayer reflecting the buildup of a strong dipole layer.



The figure shows a photoelectron spectrum of a Cu(110) surface covered with 0.4 monolayer K followed by a 0.4 Langmuir Co exposure. Besides the 3d valence electrons from Cu, the structures in the 5-15 eV binding energy region can be assigned to CO molecular orbitals. The influence of the alkali metal on the binding of CO to Cu can be estimated from the energy separation between the 4σ and the 5σ/1π orbitals. From the work function changes due to the adsorption of CO the K/CO interaction energy is determined to 0.25 eV. This electrostatic interaction energy weakens the internal binding energy of CO considerably, but not enough to dissociate the molecule.

Jens Onsgaard

Beam crystals in ASTRID II?

The construction of a second storage ring in Aarhus will create new opportunities for studying the limits to the quality of a stored ion beam. Recent years have seen a great deal of interest in the prospect of producing a spatially ordered, or so-called "crystalline" beam. Such a state might occur if an ion beam is strongly phase-space cooled by a technique such as laser or electron cooling. Recent theoretical and experimental progress in this field suggests some guidelines for designing a machine that might be more "crystal-friendly".

In particular, Wei, Sessler and Li have proposed a melting criterion for a crystalline beam in a storage ring. They have obtained, in molecular dynamics simulations, crystalline ground states having the periodicity of the storage ring's magnetic lattice. They find that these states are rather stable if the periodicity of the machine is more than twice the betatron tune. Qualitatively, this can be understood as avoiding resonance between the lattice oscillations and the "phonon" bands of the crystalline beam.

In general, one would also prefer a lattice that has small variations in the beam envelope (beta function), so as to minimize intrabeam collisions when the beam is warm.

The ASTRID lattice has been studied by Wei et al. They find no stable crystalline states having transverse extent. Only one-dimensional ordered states, "strings", can be formed. ASTRID has periodicity 4 and tunes about 2.3 (horizontal) and 2.8 (vertical), as well as rather strong variations in the beta function over a period. The 90° bends in ASTRID are also thought to be undesirable from the standpoint of the shearing motion a crystalline beam must undergo in traversing a curved trajectory.

A design for the ion operation mode of the new ring has been found which incorporates the above considerations.

The new lattice has periodicity 4, and horizontal and vertical tunes which are 1.36. The beta functions are very smooth, and the bends are 45° each.

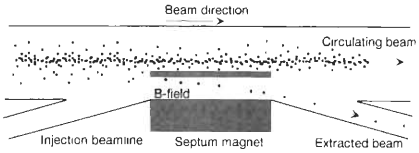
While, with the current state of understanding, we cannot confidently design a ring which allows beam crystallization, we can incorporate what we *do* know in the new design.

Such a machine, coupled with the extensive capability for laser cooling of Mg^+ ions which has recently been developed in Aarhus, should provide an exciting new platform for studies of strongly coupled ion beam plasmas, and perhaps crystals.

J.S. Hangst

Extraction of 580 MeV Electrons

A new extraction scheme has been invented at ASTRID. The lifetime of the electron beam is determined by intrabeam scattering outside the acceptance of the ring. For a 200 mA beam with a lifetime of 10 hours, about $4 \cdot 10^6$ electrons are lost per second. At the position of the septum magnet there is a dispersion of 6 meters, which means that an electron that has gained more than 0.77% in energy in a collision with another electron will jump the septum thickness (11 mm) and be deflected by 9 deg. from the direction of the straight section. In the initial extraction experiments an intensity of around $3 \cdot 10^4$/sec was observed. This extraction is entirely parasitic and delivers a DC beam. The extracted beam has a size of about 0.5×16 mm^2 at the septum.



This beam is interesting for tests of detectors for high-energy physics such as scintillators, wire-chambers and calorimeters, and has already been used in this context. Extraction of ions will also be investigated in the near future.

S. P. Møller and K. Kirsebom

The Second ISA Users'...

Continued from page 1

The second plan concerns a new 1.4 GeV ring (ASTRID II), placed in the new laboratory and using ASTRID I as injector. According to this plan, both rings could operate at the same time, i.e., ASTRID I with ion storage and ASTRID II with electrons for SR. The total running time would be increased by nearly a factor of two, and the Aarhus SR would enter into the X-ray region. Also, new research possibilities would arise, such as using SR from ASTRID II to interact with stored ions in ASTRID I.

Groups investigating laser cooling and ion-electron collisions in the cooler have also brought up interesting ideas for the use of ASTRID II. Laser cooling would benefit from the smooth focusing structure in ASTRID II as compared to ASTRID I. The larger magnetic rigidity in ASTRID II would be appreciated for ion-electron collisions, but ion storage would require a better vacuum system than needed for SR.

The scientific case for the two suggestions will be thoroughly discussed in the near future.

Erik Uggerhøj

Call for Proposals:

International and national groups are invited 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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