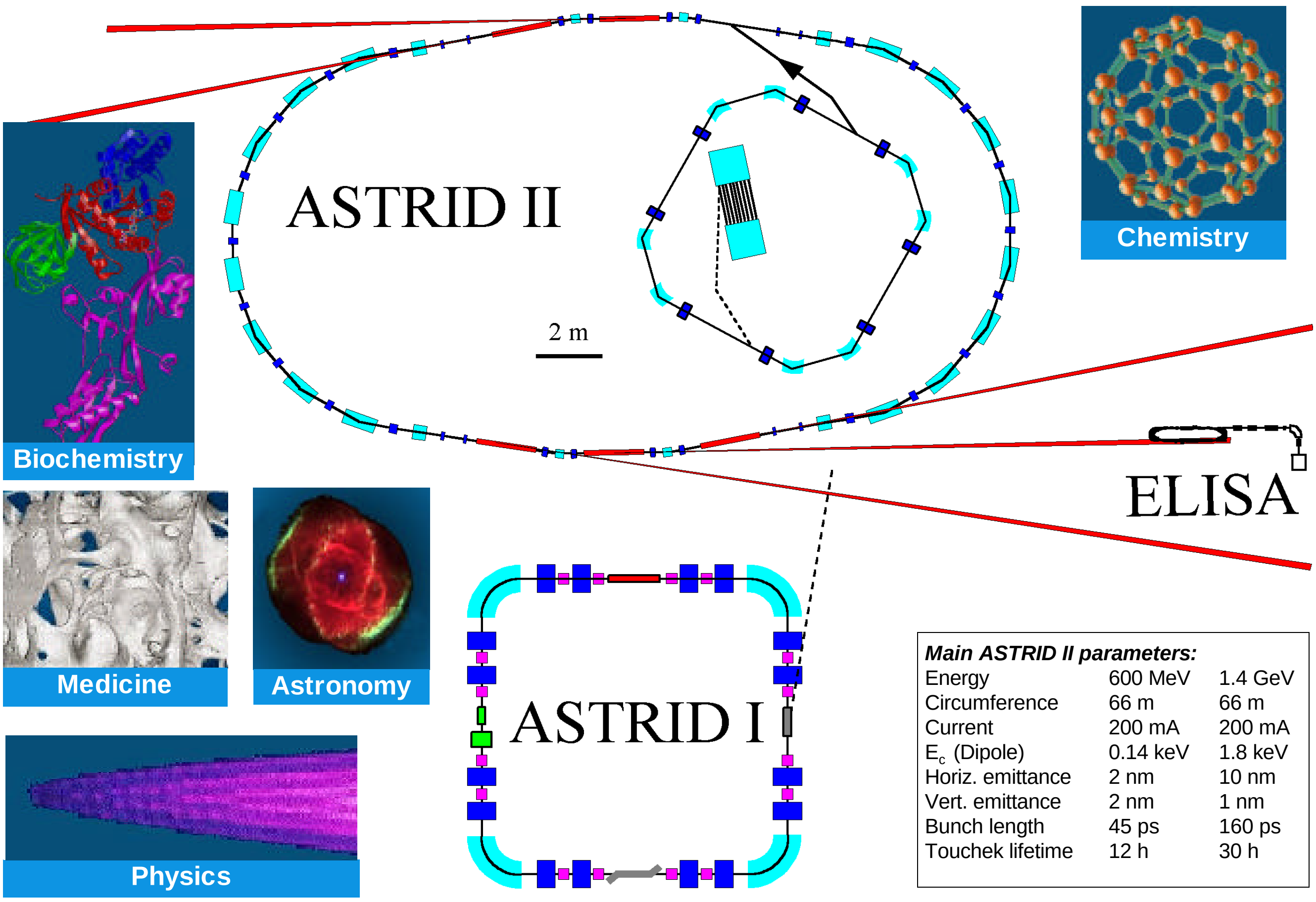
ISA

Institute for Storage Ring Facilities University of Aarhus

Newsletter

No. 7. March 1998



Main ASTRID II parameters:		
Energy	600 MeV	1.4 GeV
Circumference	66 m	66 m
Current	200 mA	200 mA
E_c (Dipole)	0.14 keV	1.8 keV
Horiz. emittance	2 nm	10 nm
Vert. emittance	2 nm	1 nm
Bunch length	45 ps	160 ps
Touchek lifetime	12 h	30 h

The possible future layout of the ISA accelerator complex is shown above, including the proposed electron storage ring, ASTRID II. ASTRID I will be dedicated to ion storage, while ASTRID II will serve a broad spectrum of users in many disciplines, as illustrated in the inserted photos.

ISA Users meet Scientific Advisory Committee

On November 27th 1997 around 70 users and the ISA International Scientific Advisory Committee (ISAC) assembled in Aarhus to discuss ongoing programs and future plans for both ion storage and synchrotron radiation.

In the morning session, Erik Uggerhøj and Søren Pape Møller reviewed the existing facilities including the new electrostatic ring, ELISA, described in more detail on page 4.

An important highlight was the plan for a new dedicated, third generation SR-source, ASTRID II, designed by Y.Senichev at ISA. The parameters of ASTRID II are given in the figure above.

At 600 MeV, ASTRID II is optimized for the UV/VUV spectral region, where there is a distinct lack of modern sources worldwide. ASTRID II will have a performance in the UV/VUV equal to or better than the best sources in Europe, Japan or the USA. ASTRID II can also operate at 1.4 GeV providing in excess of 10^{12} X-ray photons/s (~10 keV) at a target.

The source has been especially designed with cross-disciplinary applications in mind, serving a broad spectrum of users in chemistry, astronomy, physics, medicine and biochemistry. ASTRID II will also be a valuable educational resource.

ASTRID II is versatile, with two long straight sections allowing freedom for insertion devices of differing lengths. The design is also innovative, combining low energy and high brightness (low emittance) with long beam lifetimes.

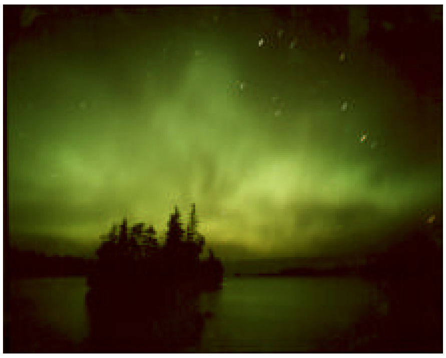
Continued on Page 4

Also in this issue:

ASTRID gets the Green Light

The source of the emission of green light in the upper atmosphere determined from a heavy-ion experiment on ASTRID

During the daytime, the atmosphere is exposed to ultraviolet sunlight that creates ionized molecules like O_2^+. During the night, the molecular ions may recombine with electrons and dissociate into excited atomic fragments. The subsequent relaxation of these atoms in the upper atmosphere gives rise to several characteristic lines in the emission spectrum. The green line at 5577 Å was detected more than 100 years ago, and in 1927 it was suggested, that the origin of this line is the forbidden transition in atomic oxygen $^1S \rightarrow {}^1D$.



In 1947 Bates and Massey pointed out, that dissociative recombination (DR) of O_2^+ was the only process that could explain the observed electron recombination rates in the upper ionosphere of the earth (>100 km altitude).

Dissociative recombination of O_2^+ with low-energy electrons (E~0) may be written as

$$e^- + O_2^+ \rightarrow O + O + \text{kinetic energy}$$

The amount of kinetic energy of the resulting oxygen atoms depends on the electronic state of the atoms.

A number of channels are allowed when O_2^+ recombines with electrons. Of interest here is the channel

$$e^- + O_2^+ \rightarrow O(^1S) + O(^1D)$$

in which $O(^1S)$, which is responsible for the green light, is produced.

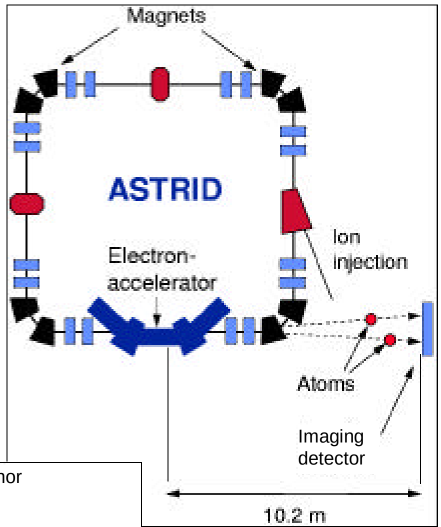
Theory predicts a probability of 0.002 for this process, which does not match the observed intensity of the green light, unless there are other sources of $O(^1S)$ production.

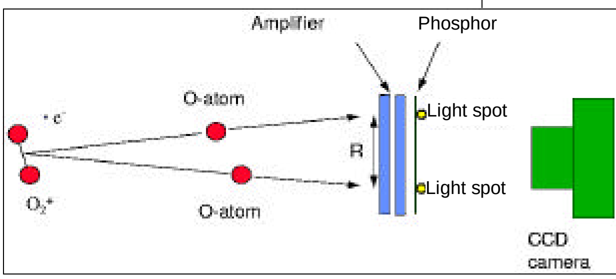
ASTRID is well suited for a determination of the probability for $O(^1S)$ formation. The procedure is to inject and store an O_2^+ beam, and produce an electron beam in an electron accelerator, in which the electrons have almost the same velocity as the circulating O_2^+ molecules, resulting in very low relative energy

When the molecules undergo DR, the resulting neutral O atoms will not be deflected in the bending magnets of the ring, but will continue straight onto an imaging detector as shown in the figures below.

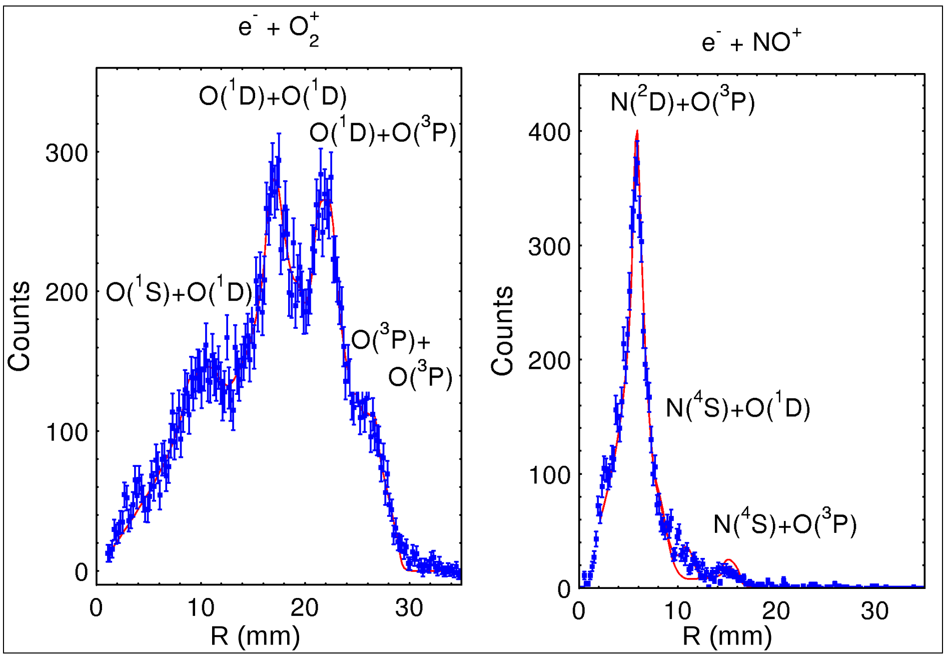
Both atoms resulting from DR give rise to a light flash on the detector, and the spatial separation between the spots on the detector is a measure of the amount of kinetic energy of the atoms. More kinetic energy gives a larger separation.

Since the $O(^1S)+O(^1D)$ channel is the one with the most internal energy, the kinetic energy will be low, and thus the two atoms will hit the detector close to each other.





Above: Sketch of ASTRID showing the position of the electron accelerator and the imaging detector.
To the left: The imaging detector system, indicating the path of two oxygen atoms.



By analyzing the sets of light flashes, the relative probability of the various channels may be determined. It was found, that the channel responsible for the green light had a probability of 5±2 %, significantly more than predicted by theory.

This result from ASTRID is of great importance for models of the chemistry and dynamics of the ionosphere.

The results are shown to the left for DR of O_2^+ and to the right of NO^+. For O_2^+, the $O(^1S)+O(^1D)$ channel has the smallest separation (R). In the case of NO^+ it is not possible to produce $O(^1S)$, so this process does not contribute to the green light.

This experiment was perfomed by a group led by Lars H. Andersen (lha@dfi.aau.dk).
The results were published in Science **276** 1530 (1997)

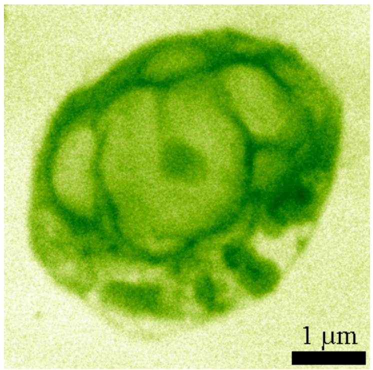
X-ray Microscopy

The X-ray microscope is a busy multi-user facility. It is employed in a diversity of scientific areas: algae, biopolymers, colloidal chemistry, food industry, human sperm, bacteria, pollen and protozoa.

Algae

Together with the School of Biological Sciences, University of Manchester, UK, we are conducting structural studies on a variety of blue-green algae. We are particularly interested in the effects of nutrient conditions, such as phosphorus and nitrogen. The project includes the association of bacteria with the algae and the role of alga mucilage in bacterial adhesion processes.

The blue-green algae play an important role in nutrient recycling in the fresh water environment. Fluctuations in species composition and population densities can have far reaching effects, with sporadic toxic algae blooms causing extensive destruction of eco-systems resulting in the death of many higher organisms such as fish.

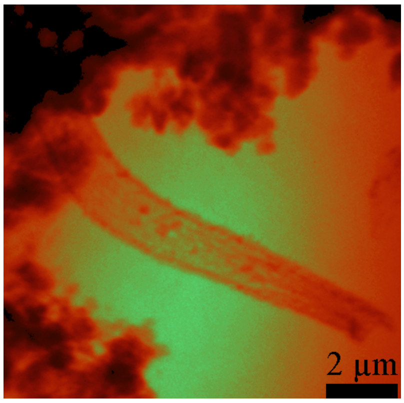


X-ray micrograph of Chlorella

Iron precipitation by bacteria

Around Esbjerg, Denmark, there are high levels of iron in the ground water. The removal of iron before distribution for drinking water has shown to be more efficient, if bacteria are used than by chemical treatment. Bacteria are also responsible for the precipitation of iron deposits in Danish wetlands - in Danish called myremalm.

With the XM, we aim to characterize the bacteria and the different kind of precipitated sludge. These studies are in collaboration with the Department of Earth Sciences, University of Aarhus, and with the Department of Chemistry, Aalborg University, Esbjerg.

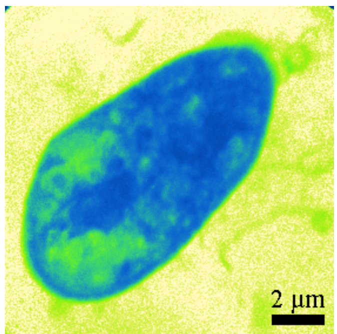


XM-image: Iron precipitating bacteria.

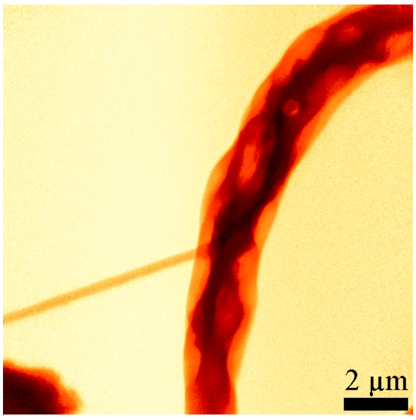
Protozoa

In recent years, research using protozoa has flourished because biologists have recognised that these organisms provide excellent subjects for studying biological phenomena at the cellular level. So far, ultra-structural studies of microorganisms have been limited to the EM. Despite the high resolution obtained with conventional EM, shrinkage is unavoidable during the preparation of many samples.

With XM, the sample can remain free-swimming in solution throughout imaging, thus reducing artefacts caused by dehydration of the sample. Here at ISA, we are studying metal toxicity in the flagellated protozoon, Chilomonas paramecium commonly found in polluted water.



XM image of Chilomonas paramecium



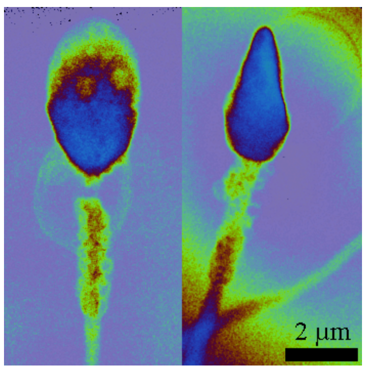
X-ray micrograph of a viscin thread, Clarkia tenella

Pollen-connecting threads

Viscin threads are thin connecting fibres thought to aid dispersal of pollen grains by insect vectors.

With the Department of Botany, Reading University, UK we have applied XM to a study of the structure of viscin threads in the Onagraceae and Ericaceae. It was concluded that by using XM we were able to both complement existing knowledge, and give new information, that had previously been lost during conventional sample preparation. This work is published in Grana 36 (1997).

Human spermatozoa at different stages in the maturing process have been studied with the X-ray microscope in collaboration with the Department of Medical Microbiology & Immunology, University of Aarhus. Furthermore, a collaborative research project with the Department of Obstetrics & Gynaecology, University of Manchester, UK, has been established with special emphasis on clinical evaluation of sperm function. So far, we have evaluated the damage on sperm caused by detergent spermicides and on separated subpopulations of sperm obtained using procedures from assisted reproduction.



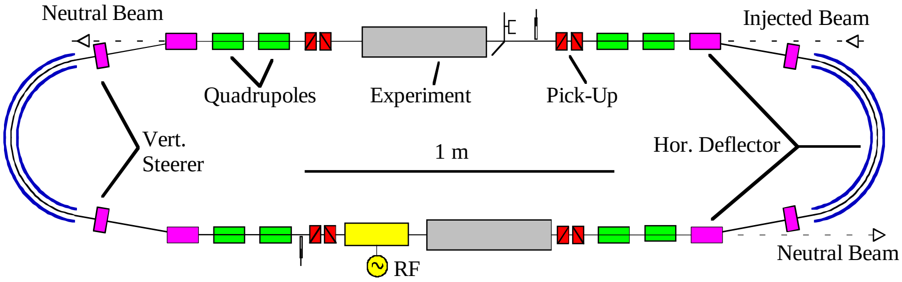
X-ray micrograph of human sperm in seminal plasma.

Measurements were performed by the x-ray microscopy group. For more information, contact Robin Medenwaldt (robin@dfi.aau.dk)

The electrostatic storage ring ELISA

A small electrostatic storage ring, ELISA (ELectrostatic Ion Storage ring, Aarhus), has been designed and constructed. The design involves a new principle of using electrostatic deflection and focusing in a storage ring, as opposed to the magnetic deflection and focusing used in the ASTRID storage ring and, to our knowledge, in all other existing storage rings.

This will have several advantages; in particular 1) the ring can be compact, 2) no hysteresis effects and no need for cooling water, 3) bake-out will be easy, 4) the ring will be able to store particles of a very wide range of masses, since



ELISA. The injector is in the background.

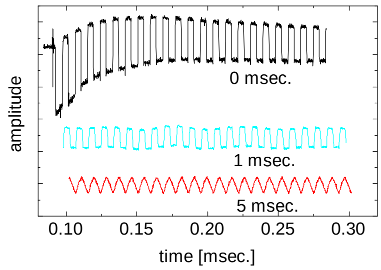
electrostatic deflection depends on the kinetic energy of the particles, and not on their momentum as for magnetic deflection.

The constructed ring has a circumference of 7 m, and consists mainly of two 160° spherical bends forming a race-track shape. The additional bending is made by four 10° bends, and the focusing is provided by four electrostatic quadrupole doublets.

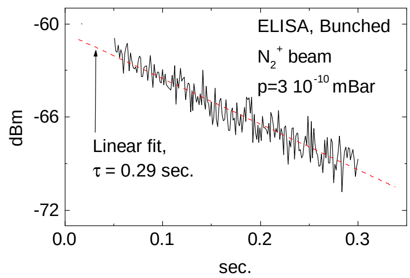
The entrance to one of the spherical bends.

The initial commissioning of the machine has been made using beams of D_2^+ and N_2^+ at 14 keV.

The figure below shows signals from a pick-up electrode for a chopped beam at injection and 1 and 5 milli-seconds later. The beam is seen to de-bunch owing to the velocity spread of the beam.



A measurement of the lifetime as observed with a bunched N_2^+ beam (with a radio-frequency field) is shown below. The lifetime was measured to be around 0.3 seconds at a pressure of 3 10^{-10} mBar.



For more information, contact
Søren Pape Møller (fyssp@dfi.aau.dk).
A description of ELISA is published in NIM A **394** 281 (1997)

ISA Users meet Advisory Committee *(Continued from page 1)*

Following the presentation of ASTRID II, ongoing research programs in ion storage were reviewed, covering the spectroscopy of stored ions, molecular ion dissociation and laser cooling of stored ions. The SR program was then reviewed covering surface physics, atomic and molecular physics and X-ray microscopy.

The afternoon program began with a poster session (65 posters) and visits to the laboratories.

The program continued with presentations of new research horizons for ASTRID II. A variety of qualitatively new experiments were introduced, covering such diverse fields as laboratory astrophysics, x-ray microscopy, medical imaging, protein crystallography and surface science. Powerful industrial connections can also be forged by ASTRID II through applications in surface coating technology.

On the 28th, ISAC had a discussion with ISA-representatives and then retired to formulate an official evaluation of current and future programs.

For more information, contact
Erik Uggerhøj (ugh@dfi.aau.dk)

ELISA Designer wins Accelerator Prize

The leader of the group responsible for the design and construction of ELISA, **Søren Pape Møller, ISA,** has won the EPS-IGA European Accelerator Prize for 1998 for having made a *recent, significant, original contribution to the field*.

In 1996, another Aarhus physicist, Jeff Hangst, won the prize which is awarded bianually.

Members of the ISA International Scientific Advisory Committee :

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Fritz-Haber-Institut der MPG, Berlin, Germany

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McMaster Univ., Hamilton, Canada

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