NEW DEVELOPMENTS AT THE ASTRID STORAGE RING

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Abstract

The ASTRID storage ring [1] has now been in operation for more than 8 years, running as a dual-purpose storage ring. Electrons are stored at an energy of 580 MeV for synchrotron radiation production, and ions/molecules are stored primarily for atomic physics studies. In this article a short description of the ASTRID storage ring will be given, together with some of the new developments which has taken place during the last years. The new developments include installation of a 1.7 m long undulator, change of the old ferrite-loaded RF cavity for ion acceleration to a drifttube setup, and installation of quadrupole shunts for better orbit control. Furthermore the lifetime has been increased from about 10-15 h to more than 30 h for electron operation.

1 THE ASTRID STORAGE RING

ASTRID consists of four pairs of dipoles and four straight sections, see Fig 1. For focusing are four families of quadrupoles, two for horizontal focusing and two for vertical focusing. To correct the chromaticity there is two families of sextupoles. For orbit correction there is 16 corrections dipoles (8 in each plane).

As injector for ions, a small 150 keV electrostatic separator is used, which can be equipped with a variety of ionsources. In this way we can produce almost any singly charged positive ion, many negative ions, and many (positive or negative) molecules. For production of moderately highly charged ions an EBIS (Electron Beam Ion Source) is presently being commissioned, see section 6. The electron injector is a 100 MeV racetrack microtron, which can produce up to 10 mA in a one microsecond long pulse.

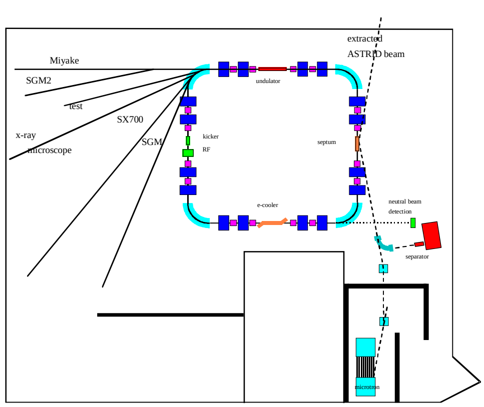

Figure 1: The ASTRID storage ring.

Table 1: Main parameters of the ASTRID storage ring

Circumference:	40 m
Max. rigidity:	1.9 Tm
Storage Energy:	580 MeV (electrons)
	6 keV – 80 MeV (ions)
Stored current:	150 – 200 mA (electrons)
	up to ~1 μA (ions)
Tunes:	
Horizontal:	2.208 (electrons)
	2.27 (ions)
Vertical:	2.64 (electrons)
	2.6-2.8 (ions)
Pressure:	$<10^{-9}$ mB (electrons)
	$2\text{-}4 \cdot 10^{-11}$ mB (ions)

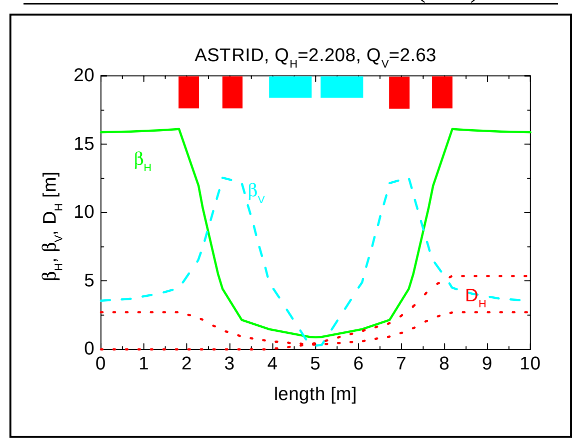

Figure 2: The ASTRID lattice.

2 THE NEW UNDULATOR FOR ASTRID

For increased SR flux in the energy range 10-200 eV a 1.7 m long undulator has been installed in one of the straight sections. As the same section in ion-mode is used for diagnostics for the laser cooling experiments, the undulator is mounted on a rail so that it easily can be rolled back. The vacuum chamber can then be changed between operation modes the same way as with the RF cavity. The undulator has been built by Danfysik, and is a standard ESRF Hybrid type. The main parameters are given in table 2.

Table 2: Main parameters of the ASTRID undulator

Period length	55 mm
Undulator gap	22-240 mm
Number of periods	30
Peak field at 22 mm gap	0.558 T

3 DRIFTTUBE FOR ACCELERATION (ION-MODE)

For acceleration of the ionbeam the old ferrite-loaded cavity has now been changed to a drifttube acceleration setup [2]. All the old low-level electronics has been retained, and only the final-stage amplifier has been changed. The amplifier presently used is a standard 10 W broadband amplifier, which limits the maximum energy gain to ~70 V per turn. A new, matched amplifier extending the maximum energy gain to ~200 V per turn is being designed. This amplifier will also have a better amplitude characteristic (especially at lower frequencies). At present the available frequency range is 0.5 – 5 MHz limited by the low-level electronics. It is being considered to change the low-level electronics with a new direct digital synthesiser (DDS) extending the frequency range. This may also include a stage with an arbitrary waveform generator, so other curve forms than sinusoidal can be exploited.

4 BETTER ORBIT CONTROL/ QUADRUPOLE SHUNTS

4.1 History

The ring has from the start been equipped with 16 pickups (8 in each dimension), that mechanically were aligned together with the rest of ring. Vertically it has always been quite easy to achieve good positions (overlap with lasers, etc.), but horizontally, good positions were always difficult to achieve. The position of one pickup was then remeasured, and found to be displaced 2.5 mm inwards. For long it was then believed that this was true for all of pickups. Good horizontal orbit control was however still difficult to achieve. It was therefore decided to install a quadrupole shunt on each quadrupole, which would enable measurements of the beam positions in the quadrupoles. By aligning the beam to the centers of the quadrupoles it has now been possible to calibrate the offsets in the pickups, which for unknown reasons have been found to vary quite a lot (from -2.0 mm to +2.5 mm).

4.2 Principle of measurement

The 16 pickups located close to dipole magnets allows measurement of beam position to within ~½ mm. Using a least-square closed-orbit correction method this allows the beam to be positioned within a few mm in all of the machine, if the pickup offsets are known. See table 3 for some of the parameters of the pickups.

For more accurate beam positioning, and calibration of offsets in the pickups, the beam positions can be measured in the quadrupoles by shunting their current. If the beam is not in the center of a quadrupole, changing the strength of the quadrupole will cause a change in the deflection of the beam. This will in turn cause a change of positions around the machine, which can be measured by the pickups. The quadrupole shunt based beam-position measurements allows the beam to be positioned to within one mm in the entire machine.

Table 3: Some parameters of the ASTRID beam positioning system

Pickups:	
Electrostatic type (diagonal cut “shoe-box”) with Σ- and Δ-signals	
Nr of pickups (horz, vert):	8, 8
Short term precision:	~30 μm
Long term accuracy:	~0.5 mm
Quadrupole shunts:	
Installed autumn 1996	
Shunts one Q-pole at the time	
Shunt current:	0 – 30 A
Precision (of resulting beam position measurement):	0.2 – 0.5 mm

5 LIFETIME (ELECTRON MODE)

5.1 Vertical excitation (t = 10-15 h) (before Autumn 1997)

Being a small ring the “natural” (Touchek limited) lifetime is quite low (only a 1-2 hours at 100-200 mA). As the users mostly have been interested in flux, and not so much brilliance, the vertical emitance has been increased by a factor of ~10, with corresponding lifetime increase, by excitation at the first vertical betatron sideband.

5.2 Phase modulation (t = 15-20 h) (Autumn 1997)

At the 5th ESLS in Lund 1997 it was reported by Peter Kuske, Bessy that phase modulation of the acceleration RF field at appr. three times the synchrotron frequency had lead to an increase in lifetime at Bessy I.

Phase modulation was subsequently tried at ASTRID, where we have found that the lifetime of the “natural” beam increases by a factor of 2-3 by applying a (small) phase modulation at any harmonic (up to the fourth) of the synchrotron frequency. The gain in lifetime increases as current is increased. The gain is however reduced to approx. 50% when the vertical excitation is applied. Phase modulation together with the vertical excitation, however still led to a lifetime of 15-20 h, which was a significant increase, and phase modulation was then applied routinely, with a frequency of 57 kHz (third harmonic).

To our knowledge there is no theory which completely explains what happens to the bunches when phase modulation is applied, but a model which describes some of the features has been suggested (in the spring of 1997) by Yu. Senichev [3]. The keypoint in this theory is that particles with small synchrotron amplitude are made to oscillate in longitudinal phase space, whereas the motions of large amplitude particles are not affected. The overall effect is that the particle density is reduced in the bunch center, which reduces the Touchek scattering, but as the large amplitude particles are not affected the overall bunch length is not increased very much.

5.3 Better orbit (t = 30-35 h) (spring 1998)

Following an orbit change associated with commissioning of the undulator, the lifetime jumped to 30-35 h (vertically excited and with phase modulation on). Without phase modulation the lifetime is now normally 15-20 h, but sometimes we get the long lifetime even without phase modulation. The reason for this is not fully understood, but it has been correlated with an uneven fill of the machine (different bunches have different currents), and it may therefore be a microwave instability, which causes bunch lengthening. This is also consistent with the fact, that the bunch lengths have been seen to increase in the first minutes after acceleration.

Phase modulation is still routinely applied, as we newer have seen any disadvantages from it. (We do not presently have users, which performs time-resolved experiments.)

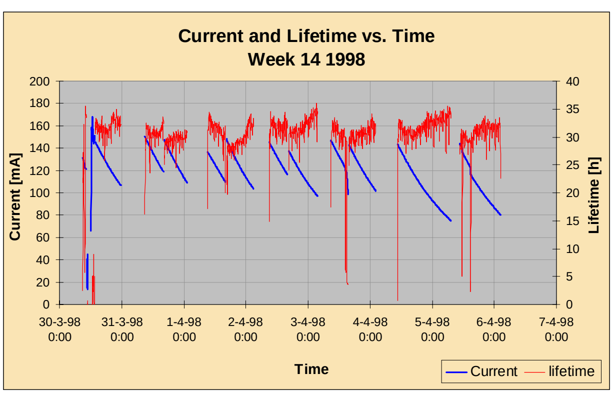

Figure 3. Current and lifetime as function of time during week 14, 1998.

6 EBIS

An EBIS (Electron Beam Ion Source) is presently being commisioned, and is planned to be connected to ring in the autumn of 1998 (see Fig. 4 for the new injection layout). The ASTRID EBIS [4] is a "warm" source, i.e. not using a superconducting solenoid, and will be able to produce moderately charged ions. For elements lighter than oxygen all charge states can be produced, and for heavier elements charge states up to ~10 can be produced. See table 4 for the main parameters of the ASTRID EBIS.

Table 4: The main parameters of the ASTRID EBIS

Maximum axial magnetic field:	0.1 Tesla
Length of solenoid:	0.6 m
Electron current:	0.05–0.25 A
Electron beam energy:	2-7 keV
Confinement time:	<1 s
Number of ions:	$<10^{10}$ charges/ pulse

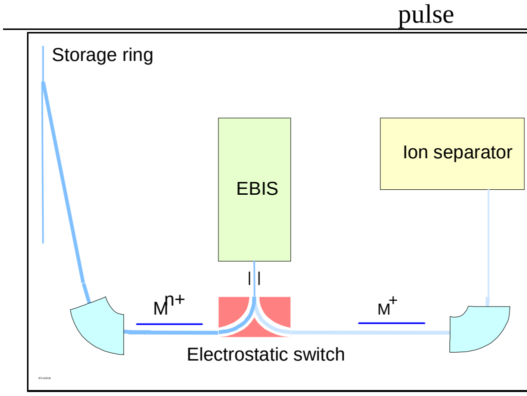

Figure 4. The ASTRID EBIS.

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[1] S.P. Møller, "ASTRID – A Small Multi-purpose Storage Ring", Proc. 3rd EPAC, Berlin 92, p 158.
[2] See for instance K. Abrahamsson *et.al.*: "A Drift Tube Accelerating Structure for CRYRING", NIM **B31**, (1988), p 475
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