ASTRID - a storage ring for ions and electrons

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Abstract

A small storage ring, ASTRID, for ions and electrons has been constructed in Aarhus. It is a dual-purpose machine, serving as a storage ring for either ions or electrons for synchrotron-radiation production. The ring has for more than one year been operational with ions and is presently being commissioned for electron storage. In the following both running modes will be described.

I. INTRODUCTION

The motivation for the storage ring ASTRID first came from the wish to store low-energy ions for laser and recombination experiments. Later it was realized that the requirements for ion operation could be fulfilled by a storage ring which also could serve as a competitive VUV/XUV synchrotron-radiation source [1]. Hence a relatively expensive piece of equipment could serve a wider user community.

II. THE FACILITY

The storage ring with injectors and associated lab space is situated in a recently constructed laboratory in connection to the Institute of Physics, see fig. 1. The electron injector is placed in a separate well-shielded cave. There is no radiation shielding around the storage ring, and during filling of the ring with electrons, the ring hall is evacuated. When a beam is stored at high energy, researchers are allowed to reenter. Scrapers in the ring are left close to the beam to give a well-defined beam dump.

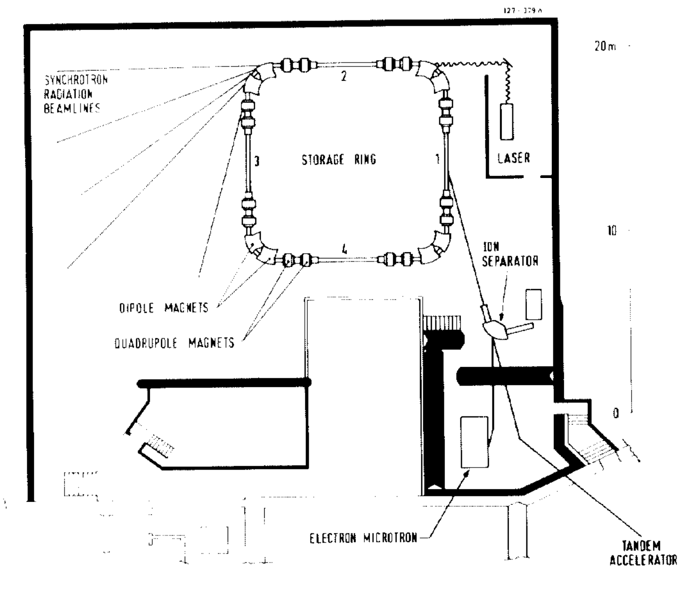

Figure 1. Layout of the ASTRID laboratory.

A. The ion injector

Ions are preaccelerated in an isotope separator using a very stable (RMS < 1 V) 200 kV high-voltage supply. A variety of ion sources can be used with the separator to produce singly-charged ions of almost any type. A sputter ion source has also been used to produce negative ions. A charge exchange cell is presently being installed after the separator magnet to increase the current of negative ions. Differential pumping is made in the injection beamline in order to separate the high-pressure ion source (10^{-2} torr) from the storage ring vacuum (10^{-12} torr).

B. The electron injector

A pulsed (10 Hz) race-track microtron [2] has been built to produce the 100 MeV electrons for the storage ring. The RF system is operating at 2998.6 MHz. The resonant energy gain is 5.3 MeV corresponding to 19 turns. Horizontal and vertical correctors are installed on every turn.

C. The storage ring

The "ring" is a square as formed by the two 45° bending magnets, excited by a common coil, in each corner. The lattice functions for ASTRID is shown in fig. 2. The quadrupoles are grouped in four families,

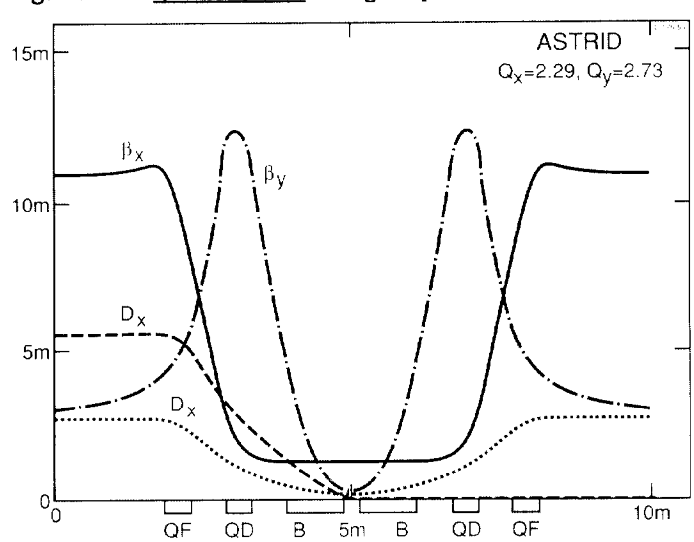

Figure 2. Lattice functions of ASTRID.

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so that the dispersion in two opposite straight sections can be varied continously between 0 and 6 m without change of the tunes. In fig. 2 is shown the dispersion in ASTRID with four superperiods, and with two superperiods giving two dispersion-free straight sections.

Two families of 8 sextupoles are available for chromaticity corrections. Superimposed on the air-cored sextupoles are 8 horizontal and 8 vertical

Table 1
Parameters of ASTRID

general	
Magnetic rigidity	1.87 Tm
Circumference	40 m
Hor., vert. tune	2.29, 2.73
Hor., vert. chromaticity	-3.4, -7.5
Momentum compaction	0.053
electrons	
Nominal current	200 mA
Electron energy	560 MeV
Horizontal emittance	0.17 mm mrad
Critical energy, wavelength	0.33 keV, 37 Å
Energy loss/turn	7.1 keV
Beam lifetime (Touschek)	24 hours
Number of bunches	14
RF system	105 MHz, 25 kV

correction dipoles. Furthermore 4 horizontal correctors are available as back-leg windings on the main dipoles.

The vacuum system is designed for the 10^{-12} torr region, as required for long storage times of the ions. Hence the system has been vacuum fired and is prepared for a 300° C in-situ bake-out. There is installed a total of 20 ion pumps and 24 sublimation pumps in the ring. Presently the system has only been baked to 150° C, resulting in an average pressure around 10^{-10} torr. A small leak is responsible for this pressure, and the minimum pressure in the ring is around 10^{-11} torr.

Two different RF systems are used. For the ions, a ferrite-loaded cavity operating in the 0.4-5 MHz region is available, giving a maximum voltage of 2 kV. For the electrons, a capacitively loaded coaxial TEM cavity operating at 104.9 MHz is used. This cavity was fabricated in steel, which was then copper plated. The obtained Q was around 8000.

Ions and electrons are injected with a magnetic septum (dc) and a kicker placed diametrically opposite. For the ions an electrostatic kicker excited by a square pulse injects one turn. For the electrons, a magnetic kicker excited by a half-sine pulse is used to accumulate electrons. The septum is also designed for extraction of a high-energy electron beam.

Clearing electrodes covering around half the circumference are installed in the ring to reduce ion-trapping effects.

The kicker and RF-system are the only hardware being exchanged when swapping between electron and ion operation.

A variety of diagnostics is installed, including 8 horizontal and vertical position pick-ups, scintillation screens, transverse and longitudinal Schottky pick-ups, beam-current transformer, beam scrapers and synchrotron-radiation detectors.

A control system based on a NORD main computer with PC's as consoles is used. Function generators are used for all dynamical parameters for acceleration and similar operations.

III. THE FIRST ION RUNS

Since the start up of the facility many different ions have been stored in the ring. The long physics runs

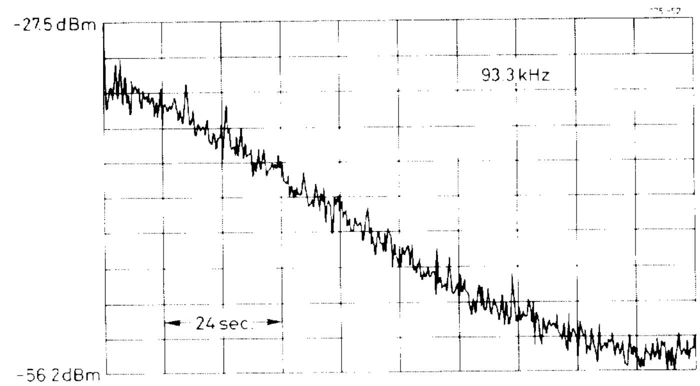

Figure 3. Decay of an $^{166}Er^{+}$ beam; the lifetime is 9 seconds.

have been with $^{7}Li^{+}$ and $^{166}Er^{+}$ for Laser-cooling experiments [3]. These ions were injected at an energy of 100 keV. The lifetime of the stored beam was limited by the vacuum, typically in the 10^{-10} torr region, giving lifetimes of some seconds. In fig. 3 is shown the decay of an Erbium beam as observed with a longitudinal Schottky pick-up electrode. Other runs included simultaneous storage of $^{20}Ne^{+}$ and $^{40}Ar^{+}$ ions. A test run with negative ions, $^{12}C^{-}$, has also been performed. The lifetime of the negative carbon beam was only around 20 msecs. owing to rest-gas stripping of the loosely bound outer electron. Stored currents were in the 1-10 μA range.

The observed closed-orbit deviations were less than 10 mm and could be corrected to less than 1 mm, limited by the position resolution, both horizontally and vertically by the correction magnets.

The ion cavity has only been used at a fixed frequency to bunch the beam for life-time measurements.

IV. THE FIRST ELECTRON RUN

The 100-MeV race-track microtron has been commissioned and routinely delivers 5-10 mA pulses of 1 μsec width. An example of an electron pulse from the microtron is shown in fig. 4. A few turns are injected into the ring and captured by the 105 MHz RF system. Around 0.3 mA has been captured in one shot, and several pulses has been accumulated to reach 1 mA. The electron beam has been accelerated to 500 MeV without significant losses. The decay of a stored electron beam at 500 MeV is shown in fig. 5. The lifetime is around 15 hours at a pressure of 8 10^{-10} torr. Only a modest RF power (1.5 kW) was fed into the cavity during these runs. No detectable outgassing of the vacuum system was observed under these conditions.

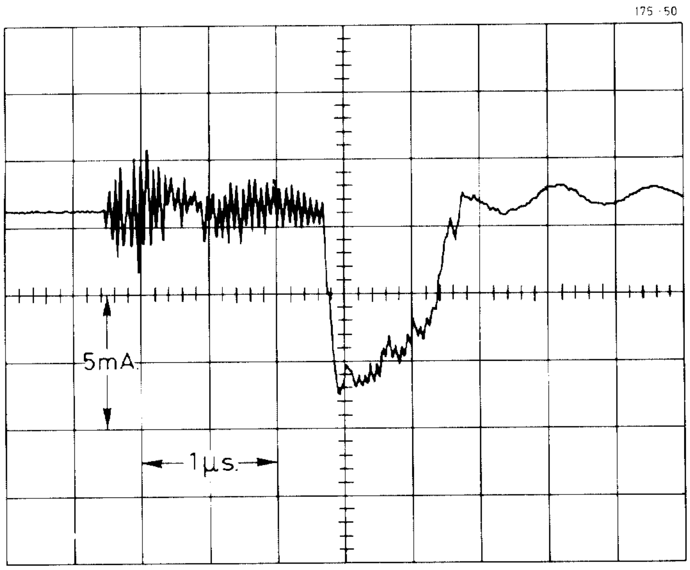

Figure 4. The microtron pulse.

V. FUTURE PLANS

The final step in the commissioning of the ion facility, namely acceleration, will be completed.

The future runs will include further $^7Li^+$ runs for laser cooling and also $^6Li^+$ for RF spectroscopy with laser detection.

Following the succesfull test run with negative ions, a sodium vapour cell is being installed after the isotope separator to produce a variety of negative ions. The first experiments with negative ions will simply consist of measuring the lifetimes of the metastable ions, which are completely unknown in most cases. A program for laser spectroscopy of H^- is also under development.

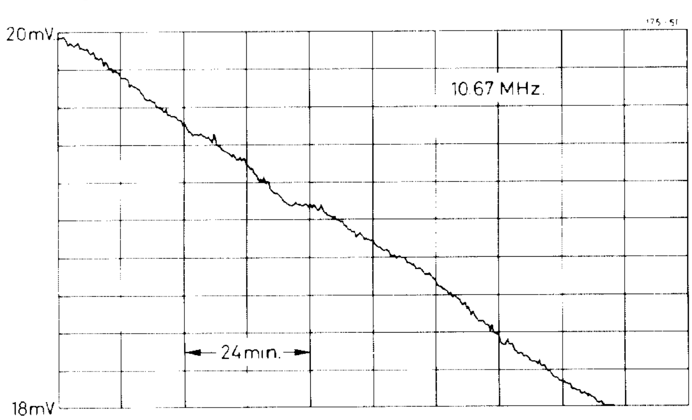

Figure 5. Decay of a stored electron beam; the lifetime is 17 hours.

Based on the first electron cooler, which has been operational at the Tandem accelerator at the Institute of Physics for several years [4] a new electron target (cooler) is being designed for the ring. The physics aim is electron recombination/detachment studies using positive/negative ions and molecules.

It is planned that the electron/ion operation will alternate approximately every six months. The next electron run will comprise commissioning of the synchrotron-radiation facility to full specifications, i.e. 200 mA electron beam at 560 MeV. Several improvements will be added to the electron facility, including full power (20kW) operation of the electron cavity and better focusing in the injection beamline. Three beamlines will then be ready, i.e. 1) an x-ray microscope, 2) an SGM monochromator operational in the 30-600 eV region for atomic physics and 3) an PGM monochromator (SX-700) for the 11-2300 eV range for surface physics.

VI. REFERENCES

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