ASTRID2 - THE NEW LOW-EMITTANCE LIGHT SOURCE IN DENMARK

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Abstract

A new low-energy synchrotron radiation light source is presently being built at Aarhus University. The storage ring will circulate a 580 MeV electron beam with an emittance of 10 nm. Due to the moderate lifetime of a few hours, the machine will be operated in top-up mode at 200 mA with injection from the present ASTRID storage ring. In the present contribution, we will describe aspects of the lattice, the injection and the expected performance of the machine.

INTRODUCTION

The ASTRID storage ring [1] has now been in operation for 20 years, and although the machine at 580 MeV has a very good lifetime in excess of 100 hours at 150 mA, the relatively large emittance (140 nm), the limited stability and lack of straight sections for insertion devices has since long called for an upgrade. At the end of 2008, we obtained a grant from the National Research Infrastructure Fund in Denmark to build a new low-emittance UV and soft x-ray light source named ASTRID2. At present, most major components are ordered for installation in the beginning of 2011, with first operation of the storage ring in late 2011 and most beamlines operational in 2012. Initially an undulator and a multi-pole wiggler will be installed.

THE ASTRID2 STORAGE RING

A new accelerator hall including infrastructure like air-conditioning, water cooling for magnets and power supplies, electricity, and a stable thick single reinforced concrete plate was built several years ago in our under-ground accelerator hall. Some of these boundary conditions have influenced the design parameters described below.

Lattice

The ASTRID2 lattice was designed to provide several straight sections, a limited circumference and at the same time minimize the emittance. The energy was dictated by the available ASTRID storage ring to be converted into a booster synchrotron. Furthermore, ASTRID2 was designed to produce brilliant UV, VUV and soft x-rays extending to around 1 keV.

Several lattices have been studied, and a double-bend achromat lattice was finally chosen, with zero dispersion in the straight sections. The dipoles are combined-function magnets providing vertical focusing. Hence the two quadrupole families are both horizontally focusing. Small adjustments of both horizontal and vertical tunes around 0.1 are obtained with additional pole-face windings in all dipoles.

Two families of sextupoles are installed to compensate and vary chromaticity. Initially, strong sextupole components in the combined-function dipoles were proposed, but it turned out that such extended strong sextupoles reduced the dynamical aperture drastically [2]. After introduction of short sextupoles, the dynamical aperture could be enlarged to a value in excess of the physical aperture. However, a small negative sextupole component was introduced in the dipoles as this increased the vertical dynamical aperture even further by ~50 %.

The main data for ASTRID2 are given in Table 1.

The lattice will include 24 button pickup systems, 24 horizontal and 12 vertical correction dipoles.

Table 1: ASTRID2 Specifications

Quantity	Value
Energy	580 MeV
Circumference	45.704 m
Current	200 mA
Betatron tunes	5.185, 2.140
Horizontal emittance	~10 nm
Natural chromaticity	-6, -11
Current	200 mA
RF frequency	105 MHz
Circumference	45.7 m
Dynamical aperture	25-30 mm

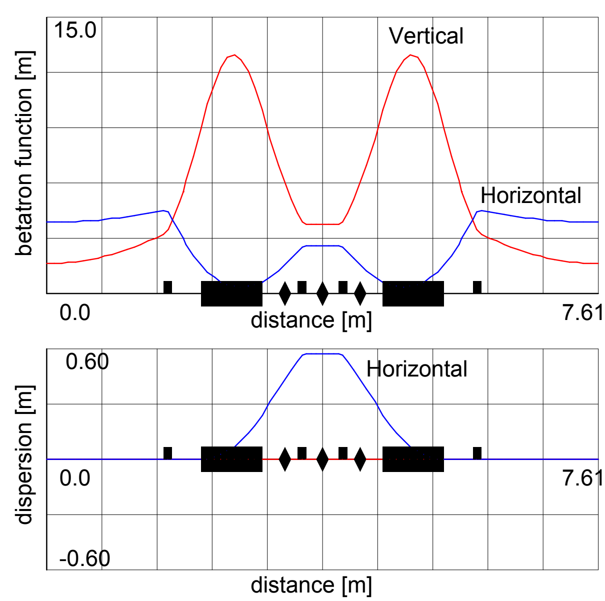

Figure 1: Lattice functions of ASTRID2.

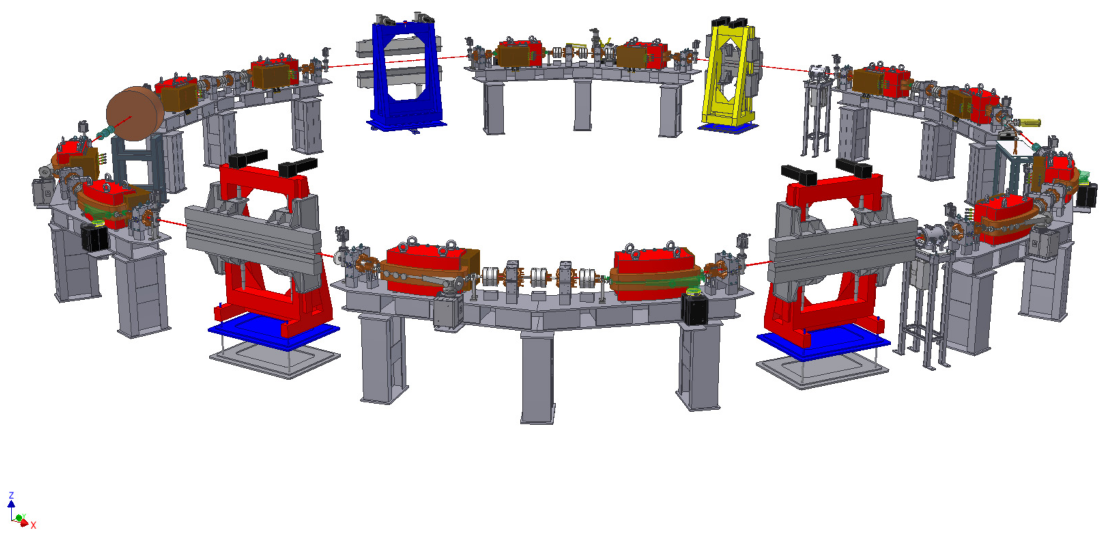

Figure 2: The ASTRID2 storage ring with six magnet girders and four insertion devices.

The betatron functions with particularly small horizontal values are displayed in Fig. 1.

Table 2: ASTRID2 Magnets

Combined function dipoles	632 solid sector
Nominal (max.) dipole field	1.1975 (1.25) T
Bending radius	1.62 m
Nominal quadrupole field	-3.219 T/m
Nominal sextupole field	-8.0 T/m^2
Quadrupoles	63(2+2)
Magnetic length	0.132 m
Max. gradient	20 T/m
Sextupoles	63(2+1)
Magnetic length	0.170 m
Max. sextupole field	300 / 180 T/m^2
Nominal sextupole field	249 / 161 T/m^2
Dipole corrector angle	0 / 1.5 mrad
Correctors	63(1+1)
Corrector angle	3 mrad

The ASTRID storage ring has for many years provided stable operation of the beam by using our 105 MHz RF cavity. This cavity was constructed by copper-plated soft iron. For ASTRID2, we are planning to use a solid electron-beam welded copper cavity also at 105 MHz. This cavity, together with a Landau cavity, is being designed and built together with MAXLAB [3].

Magnets

All magnets will be mounted on 6 girders as shown in Fig. 2, with main parameters given in Table 2. Notice that the combined-function dipoles will have dipole as well as quadrupole and sextupole components. A total of 12 combined horizontal and vertical corrector magnets will be installed at the end of each girder. Additionally, the pairs of sextupoles close to the two dipoles on each girder will have horizontal correction dipole windings.

Vacuum System

The vacuum system will be an in-situ bakeable system. In the arcs, the round tubes passing through the quadrupoles, sextupoles and steerer magnets will be made from stainless steel with a NEG coating. In the dipole chambers with exit ports, absorbers etc. a discretely pumped system is designed. Finally, in the long straight sections for insertion devices, an extruded aluminum vacuum system with NEG coating will be used.

Diagnostics

ASTRID2 will be equipped with the standard list of diagnostics such as viewing screens, beam current transformers, button beam position monitors, strip-lines etc. For an overview, see [4].

Injection System

The present ASTRID storage ring will be used as a full-energy booster for the new ASTRID2 storage ring. The cycle time will be around 10 s, and the accelerated beam, bumped towards the septum magnet, will be extracted by a fast kicker. Due to the rather small revolution time of 133 ns, and our rather thick DC septum magnet, a demanding extraction kicker with a kick angle of 1.75 mrad and a rise-time < 50 ns will be required. The kick angle is reduced by extracting the beam through the septum after 1¼ turn. Injection in ASTRID2 will be made with a pulsed septum magnet and 3 fast bumper magnets providing a closed orbit bump. The septum magnet will be placed 11-14 mm from the stored beam.

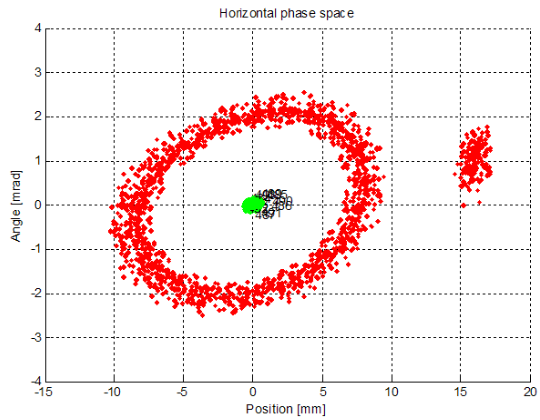

Figure 3: Injection simulations of injected beam.

In Figure 3 we observe the beam at the right on its first turn, and turns number 490-500 circulating around the stored beam.

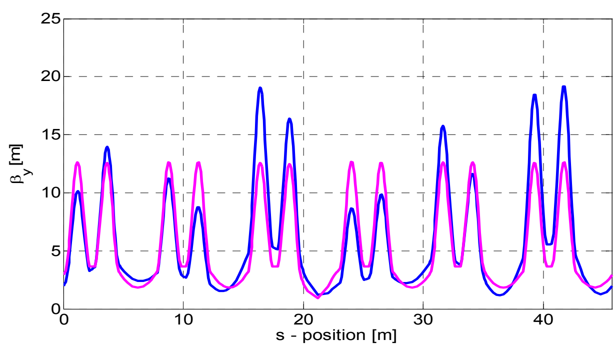

Figure 4: Vertical betatron beat originating from multi-pole wiggler (blue) and in magenta corrected by the pole-face winding quadrupoles.

Tune and Beta Beat Correction

Insertion devices will have a rather strong effect on a low-energy beam as that stored in ASTRID2, and a carefully developed correction scheme is necessary to provide a well-controlled beam independent of insertion-device gap variations. Figure 4 shows the vertical betatron beat (blue curve) after insertion of the 12-pole 2 T multi-pole wiggler. The magenta curve is obtained after compensation of the wiggler fields with the pole-face winding quadrupoles. The influence of the wiggler, or any other insertion device, is compensated using the two nearest pole-face winding quadrupoles and a global tune correction using all pole-face winding quadrupoles. Note that the pole-face winding quadrupoles almost only change the vertical tune due to the large difference of the two beta functions in the dipoles.

Dynamical Aperture

Dynamical aperture studies have been performed to secure a sufficient dynamical aperture, in particular also with insertion devices included.

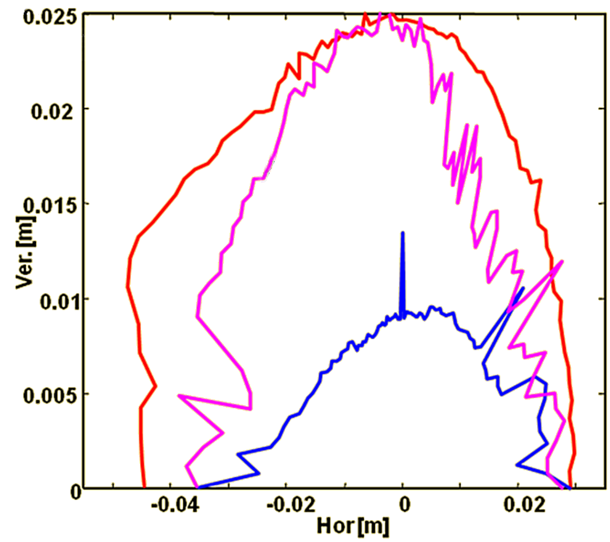

Figure 5: Dynamical aperture without (red), with MPW (blue) and with MPW and tune-corrected lattice (magenta).

The red curve in Figure 5 shows the dynamical aperture in excess of 25 mm in both planes, i.e. larger than the physical aperture. The weak sextupole component in the combined-function magnets is here included. The blue curve displays the considerable reduction in the dynamical aperture after insertion of the 12-pole 2 T wiggler. The magenta curve displays the recovered dynamical aperture after compensating the betatron functions with the nearby pole-face winding quadrupoles and global adjustment of the betatron tunes with all pole-face windings.

ACKNOWLEDGEMENT

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REFERENCES

[1] J.S. Nielsen and S.P. Møller, EPAC'98, p. 406.
[2] L.J. Lindgren is acknowledged for pointing this out.
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