# STATUS AND VERY FIRST COMMISSIONING OF THE ASTRID2 SYNCHROTRON LIGHT SOURCE

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*Abstract*

The new Danish light source, ASTRID2, to provide brilliant UV and soft x-rays from a 10-nm electron beam at 580 MeV, was completed in 2012. Commissioning is in progress and planned to continue through 2013 with interleaved user operation of ASTRID, until all beamlines are fully operational on ASTRID2 at the end of 2013. The status of the project will be given together with comments on some identified issues.

## INTRODUCTION

ASTRID is the 140 nm emittance UV/VUV/soft x-ray light source at Aarhus University now in operation for almost 20 years. Electrons are injected and accumulated at 100 MeV from a race-track microtron to more than 150 mA before being accelerated and stored with lifetimes in excess of 100 hours [1].

The new machine, ASTRID2 [2, 3, 4], is designed to produce close-to diffraction-limited synchrotron radiation in the same energy range. With an emittance of 10 nm, a relatively low lifetime of a few hours is expected. Hence, the new facility will employ full-energy top-up operation converting ASTRID to become a 580 MeV booster.

The project started in august 2009 with an expected completion date in December 2013 with all 5 beamlines operational. The total project cost is around 5 M€ including upgrades of existing monochromators and beamlines. Since the start of the project, an additional beamline was funded and is being built.

## DESCRIPTION AND INSTALLATION

Table 1 outlines some parameters of the ASTRID2 accelerator.

Table 1: ASTRID2 specifications

| Quantity | Value |
|---|---|
| Energy | 580 MeV |
| Betatron tunes | 5.185; 2.14 |
| Horizontal emittance | ~10 nm |
| Natural chromaticity | -6; -11 |
| Design current | 200 mA |
| RF frequency | 105 MHz |
| Circumference | 45.7 m |
| Dynamical aperture | 25-30 mm |
| Beam power | 1.1 kW |

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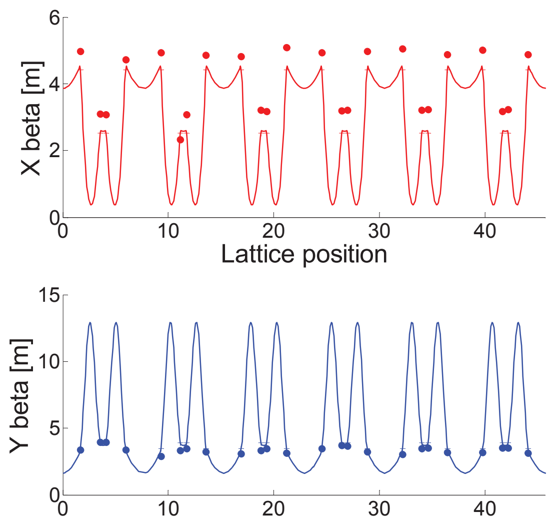


Figure 1: Horizontal (X) and vertical (Y) betafunctions in ASTRID2.

### General Layout and Lattice

The lattice of ASTRID2 is a double bend achromat with six periods. The nominal beta-functions are shown in Fig. 1 with the full-drawn curves. The lattice includes in addition to the two quadrupole families pole-face windings installed in all the vertically-focusing gradient dipoles mainly for adjusting the vertical tune. Four families of sextupoles are installed in the machine for chromaticity correction. Two beam-position monitors and four corrector magnets are available in each sextant of the machine for orbit correction.

### Installation and Mechanical Alignment

All magnets and most other systems are mounted on the 6 heavy girders, see Fig. 2. The girders were delivered with aligned magnets before being transported to the accelerator hall. Subsequently the girders were aligned, but at the same time an independent control of the magnets on the girders was performed. Next, all vacuum systems with bake-out systems were mounted by opening up the magnet yokes. After installation of all equipment, the concrete shielding wall was installed. Although the reinforced concrete floor was poured a long time ago, subsidence's after the installation of the heavy concrete shielding has been seen, and a realignment of girders is planned. Hence the commissioning of the machine has up to now been made with a somewhat mis-aligned machine possibly up to a few mm.

### *Vacuum System*

The vacuum system is a stainless steel system making extensive use of NEG coating in all straight vacuum chambers. Additionally, the extruded aluminium vacuum chambers in the insertion devices are NEG coated. The bake-out system is mounted in situ, and in magnets the use of thin insulating "ceramic paper" and flexible print foils is used.

After the initial heavy outgassing of the vacuum chambers, an average pressure of a few $10^{-9}$ mBar with 50 mA of circulating current is obtained. One particular insertion device chamber is causing a pressure increase, but still not affecting the lifetime too much.

Figure 2: The square ASTRID ring is seen at the lower left with the ASTRID2 storage ring at the right. Most of the concrete shielding in place around ASTRID2 with some beamline components installed too. The upper left shows a magnet girder with the red dipoles, the blue quadrupoles and the yellow sextupoles.

### *Radio Frequency System*

The cavity for ASTRID2 is an electron-beam welded capacitively-loaded copper cavity designed for the MAX IV project, but adjusted to the ASTRID and ASTRID2 frequencies of 105 MHz. A solid-state amplifier can deliver up to 8 kW of RF power. At present only ~1 kW has been supplied to the cavity as the final cooling system has just being finished. A Landau cavity will be installed later in 2013.

## OPERATIONAL STATUS

ASTRID booster operation including extraction has been operational since almost 2 years. Up to 4 mA has been accelerated and extracted into ASTRID2 with efficiencies up to 75 %. An additional loss originates from the extraction kicker rise-time in ASTRID. Although not used yet, ASTRID operation also allows transfer of high accumulated currents into ASTRID2.

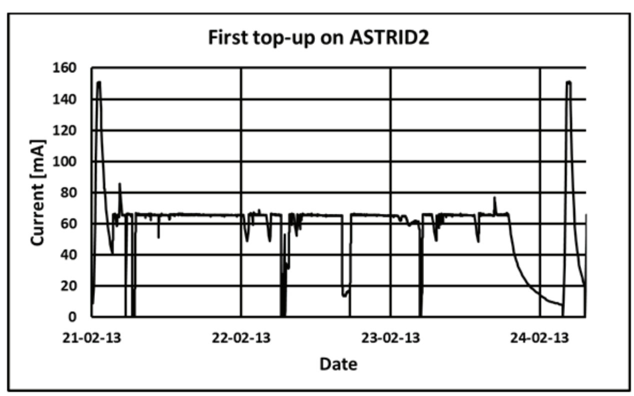


Figure 3: First top-up tests at 65 mA during 3 days. Two short accumulations to 150 mA are also seen.

With the short Touschek-dominated lifetime of the ASTRID2 beam, top-up is mandatory. This operation has been implemented as demonstrated during several days in Fig. 3. Several periods with 65 mA current are clearly




ISBN 978-3-95450-122-9

visible. The drops in current are partly due to adjustments and machine experiments taking place in the daytime of this period

Although ASTRID is a relatively slow ramping machine (25 s), Fig. 3 and 4 demonstrated early on a sufficiently fast accumulation to achieve 150 mA circulating beam. At the shown early test, the beam accumulation was stopped and the beam only kept for a short period due to heating of the injection bumpers, see next section.

Several functionalities and checks of the machine have been performed. For example, orbit correction has been demonstrated using the installed quadrupole shunts resulting in a correction of the orbit to better than 0.2 mm.

Next, measurements of the beta-functions in the quadrupoles have been made using quadrupole shunting; see dots on Fig. 1. Variance with the nominal lattice is less than 20%.

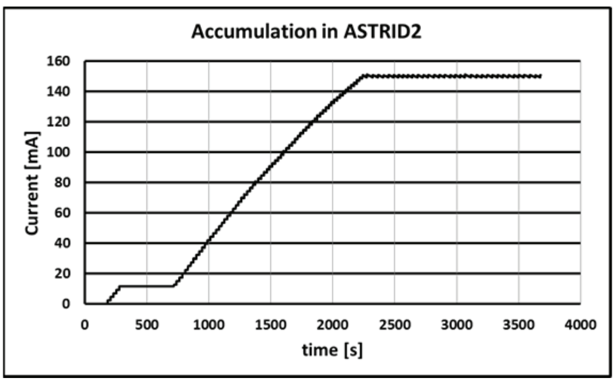


Figure 4: First high-intensity accumulated beam in ASTRID2. Top-up at 150 mA was subsequently used.

## LIMITATIONS AND IMPROVEMENTS

During the course of ASTRID2 commissioning, a couple of restrictions to the machine were detected and improvements to the machine are currently being made in order to reach the design performance of the machine.

During the first few months of **ASTRID booster** operation, it was realized that the rubber plates mounted between the magnet coils and magnet yokes had to be replaced. Otherwise, it was feared that the large forces between coils and yokes would impact the epoxy insulation. This major operation of opening all 8 magnet yokes is presently on-going.

**The injection bumpers**, and also the ASTRID extraction kicker, were designed with the use of ferrite yokes inside the vacuum system and without any thin metal coating on the ferrite. It was realised during steady-state operation of the bumpers, that the bumpers stopped working above 70 mA circulating current. Heating of the ferrites in the bumpers above the Curie temperature is expected to be the cause of the problem, and the bumpers are now being modified by two initiatives. The first is installation of an RF shield, as seen in Fig. 5, at the entrance and exit of the bumper chambers. Such rf shields has been installed in almost all other vacuum chambers in ASTRID2. The second initiative is the installation of cooling of the ferrites by copper bars in thermal contact with the ferrite plates. The three bumpers are located in three consecutive sextants with vacuum valves between. The first bumper has recently been modified with a strong reduction in the temperature, and the next two bumpers are presently being modified!

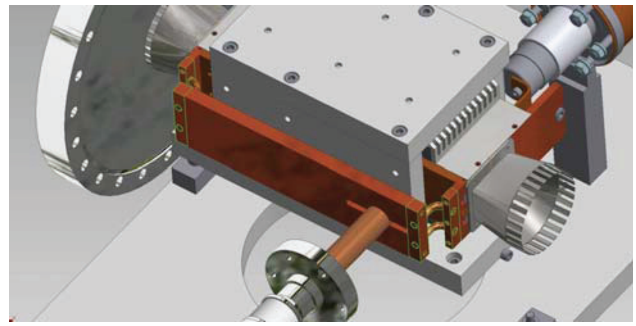

Figure 5: CAD model of the bumper magnet. The two improvements consisting of installation of the rf-screens and the copper cooling bars are clearly visible.

## CONCLUSIONS

The replacement of the old ASTRID light source with the new ASTRID2 machine is in progress. In 2012 and 2013, interleaved operation of ASTRID and ASTRID2 allows operation for users without any long dark periods. After minor modifications of some ASTRID2 components, ASTRID2 is well on the way to reach the design current at the end of 2013 using 5 beamlines. An additional beamline with a new undulator for atomic and molecular physics has been funded and is being built.

## ACKNOWLEDGMENT

Being a small acceleratory, the ASTRID2 project has only been possible by extensive use of assistance from many light-source laboratories in Europe. We deeply acknowledge the involved colleagues.

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