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STATUS OF THE ASTRID2 SYNCHROTRON LIGHT SOURCE

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Abstract

With regular user beam delivered to experiments, the commissioning of the ASTRID2 synchrotron light source is now mostly completed. The ring is running stable in top-up mode for beam currents up to 90 mA, with a lifetime of ~0.8 h at 90 mA. The orbit is controlled by a 10 Hz feedback loop, which includes feed forward loops when the insertion devices change gap. A similar 10 Hz loop compensates tune and beta function changes from the insertion devices.

Some issues are still remaining. These include installation of a Landau cavity for lifetime improvements, a reduction in the heating of the in-vacuum ferrites of the injection bumpers, and a shielding of the stray magnetic field from the booster dipoles.

INTRODUCTION

ASTRID2 [1-4], the new 580 MeV, low emittance synchrotron light source in Aarhus, Denmark, has now been in regular user operation for ~½ year. ASTRID2 is presently operating approximately half the time with user beam. The remaining time is used for machine upgrades, machine studies, and beam line commissioning.

The first user beam on ASTRID2 was in September 2013 allowing the commissioning of the AU-UV beam line, which 10 weeks later, hosted the first external users. Three beam lines transferred from ASTRID [5] (AU-UV, AU-Matline and AU-SGM3/ARPES), are now in operation on ASTRID2 and have all experienced vast improvements in performance compared to operation on ASTRID. A further three beam lines are in various stages of installation (AU-CD, AU-IR and AU-AMO). The final beam line was removed from ASTRID in April 2014.

OPERATIONAL STATUS

In user mode the machine is normally operating fully automatically in top-up mode without operator attendance. In case injections into ASTRID2 fail, top-up is disabled, and operators are alerted via SMS. The mean time between serious failures (longer periods without injections into ASTRID2 or beam loss in ASTRID2) is about a week.

Beam Current

Presently the maximum current for continuous operation is ~90 mA, limited by the bumper problem (see below). However most frequently the top-up current is set to 50 mA, partly to limit outgassing in (one of) the beam lines, partly to have fewer injections, which presently cause an orbit disturbance (see below). The design current of 200 mA has been achieved for shorter time spans (~0.5 h).

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Lifetime / Filling Mode

The lifetime at 50 mA with an even bunch filling is ~1.2 h, dominated by Touschek scattering. With poorer vacuum (during the first months of commissioning and presently the first days after a vacuum interventions), we see vertical blow-up of the beam, probably due to capture of ions. Here better performance is obtained with a gap of ~5 empty bunches.

Presently the only acceleration mode from ASTRID is multi-bunch (~10 extracted consecutive bunches). This bunch train can then either be injection into the same buckets in ASTRID2 (with a jitter of one bucket), leaving a gap of ~5 bunches, or the injection of the bunch train can be shifted in time, so a more or less uniform bunch filling can be achieved.

In the near future we expect to implement the option of single bunch operation of ASTRID2. The plan is to do bunch cleaning in ASTRID, leaving only one bucket with current. In order to have this single bunch transferred to a specific bunch in ASTRID2 a new and more advanced timing system is planned.

RF

The RF cavity has now been fully commissioned to the maximum available RF power (8 kW). However, operating at high cavity voltage is not advantageous, since at higher cavity temperature we see an instability believed to be a coupled bunch instability. The instability clearly gets worse at higher cavity temperature (reduced water flow).

At the moment it is being considered whether we need an improved cooling system for the RF cavity. However the planned Landau cavity may provide enough damping to suppress the instability sufficiently. The Landau cavity is expected to be installed during this autumn. The Landau cavity is of course also believed to increase the beam lifetime.

Orbit Correction

The BPM system consists of 24 button pickups, four in each of the six double-bend achromatic arcs (see ref [1] for a description of the ASTRID2 lattice). There is one pickup at each end of the arcs, and two in the middle of the arcs. Each of the button pickups is connected to a Libera Electron beam position processor. The Libera 10 Hz (SA) output is used for continuous orbit correction. Presently only the 12 vertical and horizontal window frame correctors close to the girder ends are used in the orbit correction scheme. The 12 horizontal correctors built into the horizontal sextupoles in the middle of the girders are not yet used. The short term (1 h) stability of the orbit (as measured by the Liberas) is 1-2 µm, whereas the

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longer term (1 week) stability (again measured by the Liberas) is about 10 µm.

To calibrate the offsets in the button pickups and cables, current shunts have been installed at all 24 (horizontal) quadrupoles. At each magnet there are two resistors each of which can be shunted across the magnet coil using a solid state relay. The two resistors shunt ~1% and ~2% of the current. Usually both shunts are used, resulting in a shunt current of ~3%. Measuring the position change in all of the regular BPMs when shunting one quadrupole, it is possible to determine the position in the quadrupole. This way the orbit can be measured and corrected in all 24 quadrupoles. The residual BPM positions after corrections are ~0.1 mm in both planes. Vertically it is believed that the residual may be due to (vertical) alignment errors of some of the combined function dipole magnets. Horizontally the residual could also be due to an insufficient number of correctors (i.e. the neglect of some of the horizontal correctors).

ID compensation: For all the insertion devices (ID's) a feed forward correction based on the ID gap is running at 10 Hz. These feed forwards covers a control of local ID orbit correctors, a change of global orbit correctors, a control of (local) beta correction (see below), and a change of global tune control.

ID BETA COMPENSATION

Since ASTRID2 is a low energy ring, the influences of the (strong) insertions devices are quite significant. It was already during the design [1] realised that the 0.70 m long 2.0 T wiggler and the 2.3 m long undulator for the AU-AMO beam line would reduce the vertical dynamical aperture from a comfortable 25 mm to a less comfortable 10 mm. During the design it was also found that the dynamic aperture could be restored by a compensation of the beta function and of the global tune using pole face windings (PFW's) in the dipole magnets [2]. Since the vertical beta function here is very large, a quadrupole correction here mainly affects the vertical plane. The beta correction is done using the PFW's in the dipole magnets just before and after the straight section housing the insertion device. If the ID is centered the two corrections are equal, whereas if the ID is not centered (as for the wiggler) the two corrections are different. The values for each PFW are then a sum of the global tune setting and a local beta compensation value.

Experimentally we find that neglect of the beta compensation of the Wiggler at its minimum gap of 12 mm reduces the lifetime by 5-10%. The relative reduction is expected to increase with the better lifetime anticipated when the Landau cavity is installed.

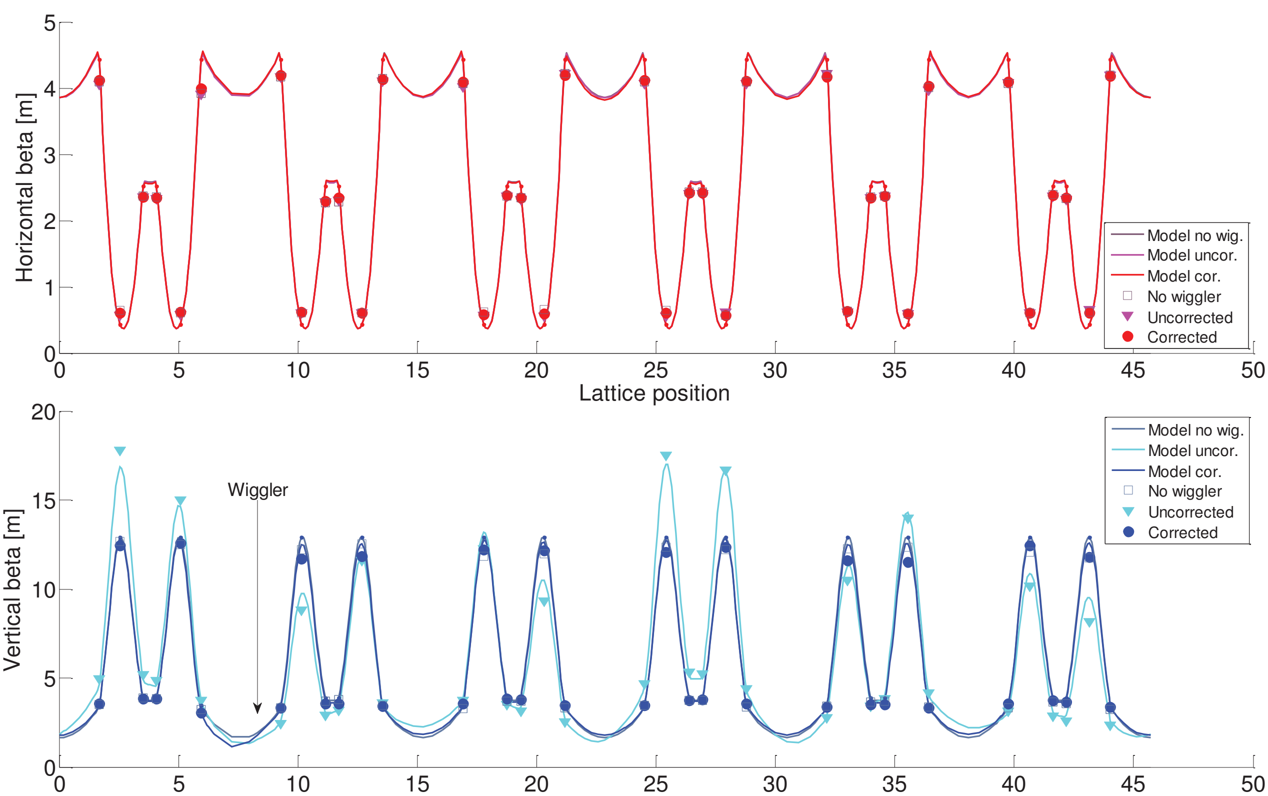

Figure 1: Measurements of the beta functions with the wiggler gap fully opened, and with the wiggler gap fully closed in the beta uncorrected and corrected case. The tunes are always corrected to the nominal (5.185/2.140). The measurements have been done using both the regular quadrupole shunts and the pole face windings.

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Figure 1 shows measurements of the beta functions with the wiggler gap fully opened, and with the wiggler gap fully closed (12 mm) in the beta uncorrected case and in the beta corrected case. As can be seen in the figure the correction is very good, although some improvement could perhaps be done in arc 2 and 5 (lattice positions ~12 m and ~34 m). The wiggler position is offset 0.70 m from the center of the straight section, and the non-symmetrical response is clearly seen. Generally the agreement between the model and the measurements is quite good.

UNRESOLVED ISSUES

Even though ASTRID2 is operating routinely in user mode, there are still some unresolved issues, which are expected to be solved during the next 6-12 months.

Stray Magnetic Field from the ASTRID Dipole Magnets

During the ASTRID2 commissioning it was realized that the ramping of the ASTRID dipole magnets caused the beam in ASTRID2 to move. By shorting ASTRID dipole 11 (the magnet closest to ASTRID2, see ref [2] for the layout of the two rings), it has been verified that most (~65%) of the effect is from ASTRID dipole 11, but there is also a strong (~35%) effect from dipole 21 (the magnet second closest).

Presently (with all the insertion devices installed in ASTRID2) the horizontal/vertical orbit change in ASTRID2 is up to ~130/~20 µm, of course varying around the ring. Since ASTRID is ramping slowly the disturbance last from ~5 s before to ~5 s after injection. Using a 10 Hz feed forward loop in the orbit control program, the disturbance can be brought down to ~20 µm horizontally, and a few µm vertically. However the disturbance is clearly visible in some of the beam lines, especially AU-UV.

To solve the problem (or at least reduce it so much that it (with the help of the feed forward loop) no longer disturbs the beam lines), 5 mm thick iron plates with high permeability (ARMCO® Pure Iron) will be mounted in the ASTRID hall on the wall facing ASTRID2, and on the floor (extending 1.3 m from the wall). These plates will be installed during one of the shutdowns this summer.

Should one layer of iron plates not be enough, another layer can be installed in the ASTRID2 hall on the wall facing the ASTRID hall. Simulations show this is the most effective way of achieving the desired reduction.

Injection Bumpers

It has previously [4] been reported that the injection bumpers stopped working in continuous operation for currents above ~65 mA. The reason is believed to be heating of the in-vacuum ferrites above their Curie temperature of ~130°C by RF fields from the beam. As reported in [4] the bumpers were modified by installation of RF shields at the ends of the bumpers to make a more smooth transition of the vacuum chamber, and by installation of a thermal feed-through in thermal contact with the in-vacuum ferrites, and water cooled on the outside.

With all three bumpers modified, but no cooling applied (no cooling water), the limit for stable long-term operation was ~90 mA, i.e. the more smooth vacuum chamber has increased the limit by ~25 mA. Applying cooling did, however, not increase the limit very much (only a few mA). The reason for the poor efficiency of the cooling is not completely understood. Temperature simulations do not reveal any particular cause, but suggest the reason simply is too poor thermal conductance – the thermal path is too long. It will not be easy to improve cooling further without a complete redesign of the bumpers, a task which is not feasible.

Another (more simple) solution is therefore suggested, see Fig. 2. Inside the C-shaped ferrite block will be placed two curved ceramic shells (upper and lower cuts from a round tube Ø55 mm). These two ceramic shells will be coated on the side, which face the beam with a 2 µm layer of titanium to carry the image charges of beam. To insure good contact with the copper endplates the outermost 10 mm of the shells will be completely metallized. The RF shields will be modified to match the shape of the ceramic shells.

We believe that with this modification we will have the advantages of an out-of-vacuum ferrite type fast magnet, but at a much reduced cost.

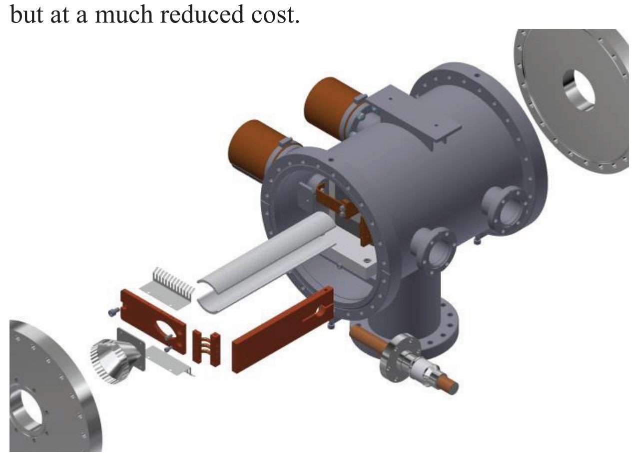

Figure 2: Exploded CAD model of the proposed change of the bumpers.

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