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AN OVERVIEW OF THE PROPOSED BEAM DIAGNOSTIC FOR ASTRID2

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Abstract

This paper presents an overview of the proposed beam diagnostics for ASTRID2, the new 580 MeV 3rd generation low-emittance synchrotron light source to be built in Aarhus, Denmark. ASTRID2 will use the present ASTRID1 as booster, permitting full energy injection and thereby top-up-operation. The diagnostics will include viewing screens, beam current monitors, electronic beam position monitors, striplines, etc. The description includes both the storage ring and the transfer beam line.

INTRODUCTION

There has been a tremendous development of synchrotron radiation sources over the last two decades since ASTRID1 [1-3] was built. The biggest quantum leap possible came with the introduction of undulators, whereby the photon rate on a target increased by many orders of magnitude. ASTRID1 was not original equipped with insertion devices, although one undulator has been retrofitted. Therefore we have wanted to build a modern machine in Aarhus for several years. This has now become possible through a grant from the Danish government.

Table 1: Main parameters of the ASTRID2 storage ring compared to ASTRID1

	ASTRID2	ASTRID1
Energy [MeV]	580	580
Circumference [m]	45.704	40.00
Current [mA]	200	200
Revolution time [ns]	152.45	133.40
Length of straight sections [m]	2.7	
Number of straight sections	4	1
Horizontal tune	5.23	2.22
Vertical tune	2.23	2.63
Natural emittance [nm]	13	140

The main parameters of the ASTRID2 storage ring are shown in Table 1, together with the corresponding parameters for ASTRID1 as comparison. The major differences are the emittance, which is about ten times smaller for ASTRID2, and the number and length of straight sections. ASTRID2 will allow for 4 insertion devices, as opposed to ASTRID1's single.

The other marked difference is that ASTRID2 will have full-energy injection, and hence top-up operation will be employed. This will in many ways make the machine much more stable. The current will be stable, which means that the Synchrotron Radiation (SR) intensity will be constant. And since the heat load will also be constant, it will be much easier to keep the beam parameters stable, such as the beam positions.

TRANSFER BEAM LINE

The primary purpose of the beam diagnostic in the transfer beam line is to facilitate easy steering of the beam through the beam line, with good transfer efficiency. Since ASTRID1 has not been designed as a rapid cycling booster, the injection rate will be slow (≤0.1 Hz). It is therefore even more essential to have the proper diagnostic and tools to help steering the beam from ASTRID1 to ASTRID2.

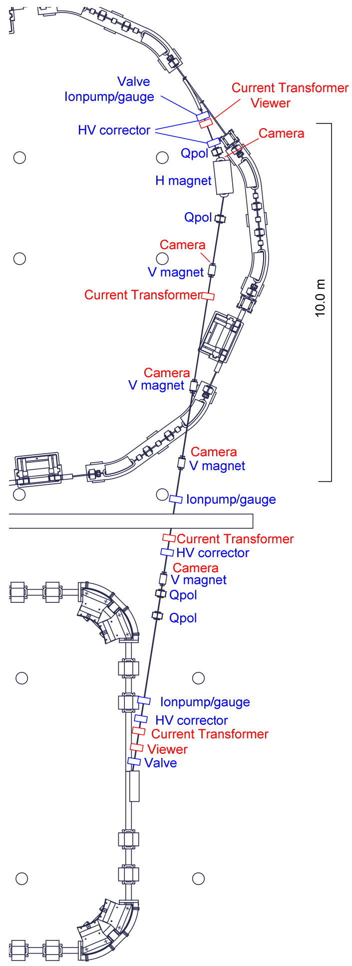

Figure 1: Layout of the transfer beam line from ASTRID1 to ASTRID2.

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To verify proper extraction from ASTRID1 we will soon after the Astrid extraction septum install a **viewing screen**. This will either be of the optical transition radiation type, or a fluorescent screen. The fluorescent screens have a higher sensitivity, but can have problems with saturation (and thereby problems with proper representation of the beam) at higher intensities. At the end of the beam line another viewing screen will be used to centre the beam at the ASTRID2 injection septum channel, and to verify that be beam has not been cut. Using quadrupole scans this viewing screen can also be used to measure the emittance of the extracted beam, and to verify the optical properties of the beam and the transfer beam line.

Since the transfer beam line has to cross the ASTRID2 storage ring, there will be 4 vertical magnets to bring the beam above the ASTRID2 ring. After each of these magnets and after the 30° horizontal magnet we will install cameras to monitor the emitted **Synchrotron Radiation**. This SR light can be used to monitor the beam properties (primarily the position).

To quantity the transfer efficiency a number of **current transformers** will be installed along the beam line. To keep cost down, these will probably be homemade, consisting of a ferrite ring with a small coil mounted in a flange.

Automatic Beam Steering

With the low injection rate, the initial commissioning of the transfer beam line will be somewhat time consuming if done manually. We therefore plan to implement an Automatic Beam Steering (ABS) system to assist commissioning and the daily operation of the transfer beam line. The ABS will take beam positions from the two viewers (beam destructive) and the 5 SR cameras located after the 5 bending magnets (4 vertical and 1 horizontal), and use these positions to calculate new corrector settings.

In the initial phase the system will just sequentially centre the beam on each camera/viewer using the nearest upstream corrector. In phase 2, when the beam has been threaded to the end, the system should measure the response matrix. This will allow position correction to be performed in all of the transfer line in one go. In the third phase the beam will be centred in the quadrupoles, using the quadrupole variation method.

STORAGE RING

The beam diagnostic in the storage ring should not only facilitate the initial storage of the beam, but should more importantly allow for sufficient characterisation of the stored beam (current, positions, emittance, stability, etc.).

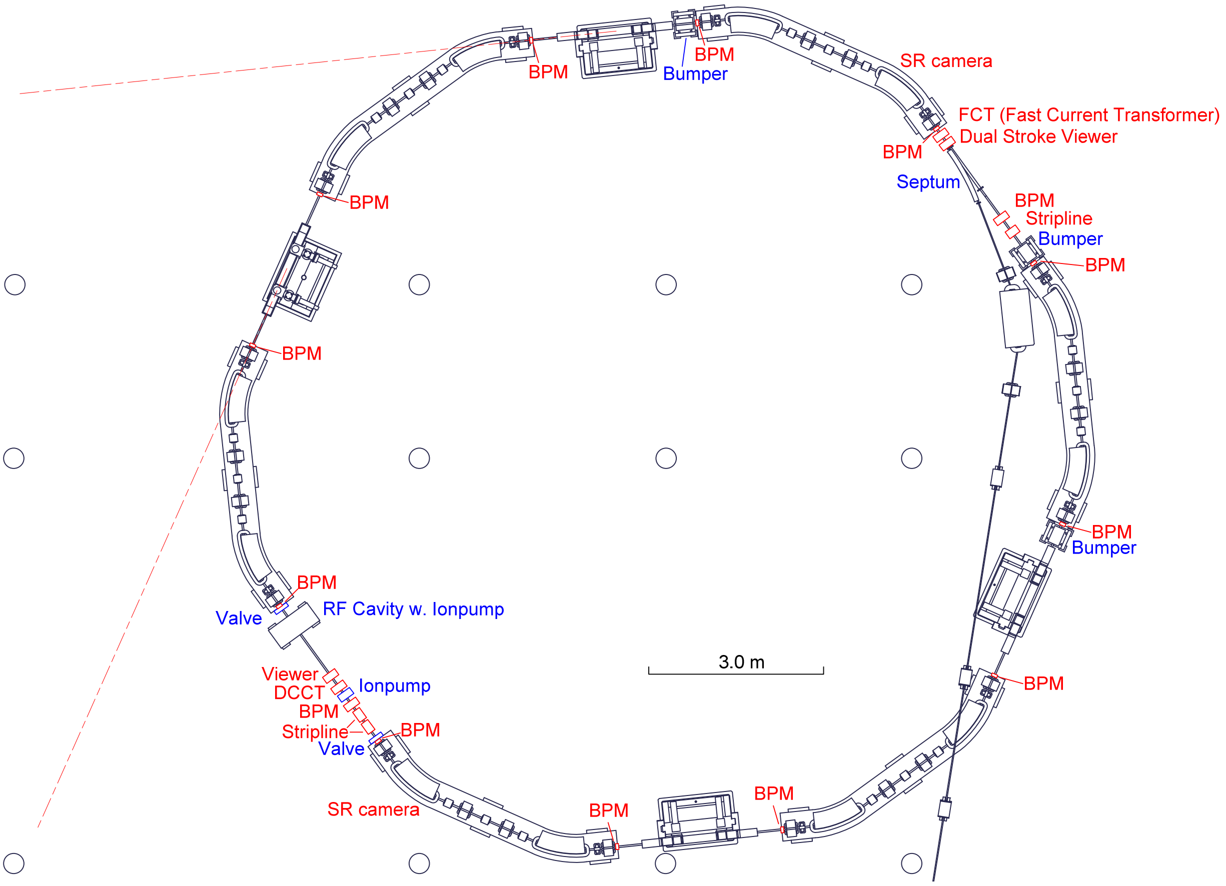

Figure 2: An overview of the ASTRID2 storage ring showing the locations of diagnostic elements. The small circles are pillars in the building.

Initial storage

To facilitate the initial storage, two **viewing screens** will be installed. One dual-stroke viewing screen will be installed just after the injection septum. Fully inserted this will allow monitoring the beam coming out of the septum. Partly inserted it will permit monitoring the beam after one turn. Opposite the injection straight in the RF and diagnostic straight, another viewing screen will allow monitoring the beam after half a turn.

To quantify the injection efficiency a **Fast Current Transformer** (FCT) will be installed just after the injection septum. This will allow determining the injected current, and the turn-by-turn loss. Since we here have much higher requirements for bandwidth, accuracy, and vacuum compatibility, this will most likely be a high quality commercial product.

Current

One of the most important parameter of the stored beam is the current. We plan to install a commercial **DC Current Transformer** (**DCCT**) in the diagnostic straight.

Beam Positions

Absolute control of the beam position is of course essential to the Synchrotron Radiation user. In order to facilitate this, we will install Beam Position Monitors (BPMs) of the button type at the end of each arc. With 6 arcs, we will have a total of 12 BPMs.

The read-out electronics will be of the multiplexed analog type. We are presently testing a card developed at MAX-lab [4]. The MAX-lab card is designed for 300 MHz, which is their 3rd harmonic. At 315 MHz, which is our 3rd harmonic there is 3 dB attenuation in the input filters. It is possible to change the input filters and make the card operate at other frequencies (say 105 MHz or 210 MHz).

Quadrupole Shunts

In order to perform offset calibration of the BPMs and for betafunction measurement, all of the quadrupoles will be equipped with quadrupole shunts. Copying the MaxLab solution, we plan the shunts to be power resistors in series with solid state relays. For each magnet we will have a few circuits, say at 1% and 2%. By having individual control of each shunt, we will with two shunts have the possibility of 3 shunt currents (say for instance 1%, 2%, and 3%).

Tunes

We will install two sets of **striplines** at 45° for tune measurement. One set will be installed in the injection straight and another set will be installed in the RF and diagnostic straight. Tunes will be measured using a swept spectrum analyser. The output from the tracking generator will be connected to one stripline through an amplifier, and input of the spectrum analyser will be connected to another stripline.

Initially we will not install any transverse feedback systems, but we will install a set of striplines at 90°, for future use. For use as a longitudinal pickup we will install a short circular tube in the diagnostic straight. Two extra BPM's will be installed, one in the injection straight, and one in the RF and diagnostic straight, for various diagnostic purposes.

Emittance

At two places (at the first bending magnet after injection, and at a bending magnet opposite injection) we plan to install **Synchrotron Radiation (SR) cameras** to monitor the beam properties. Besides giving an easy visual inspection, the pictures can also be analysed in real time (up to some tens of Hz), and a number of electron beam properties can be extracted. By measuring the beam size we will have a measure of the emittance of the stored electron beam, and the position of the SR-light on the camera will directly be a measure of the position of the electron beam. The visual representation of the beam, can often be very useful, for example in diagnosing instabilities.

TIMELINE

The project has been approved, and we are presently preparing for contract negotiation. The timeline of the project is given in table 2.

Table 2: Timeline of the project

Year	
2009	Design and order
2010	Delivery and installation
2011	Commissioning of the ring and installation (transfer) of the first beam lines
2012	Transfer of the remaining beam lines
2013	Full operation

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