An Overview of the Proposed Beam Diagnostics for ASTRID2

Jørgen S. Nielsen, Niels Hertel, Søren Pape Møller

Institute for Storage Ring Facilities, University of Aarhus, Denmark

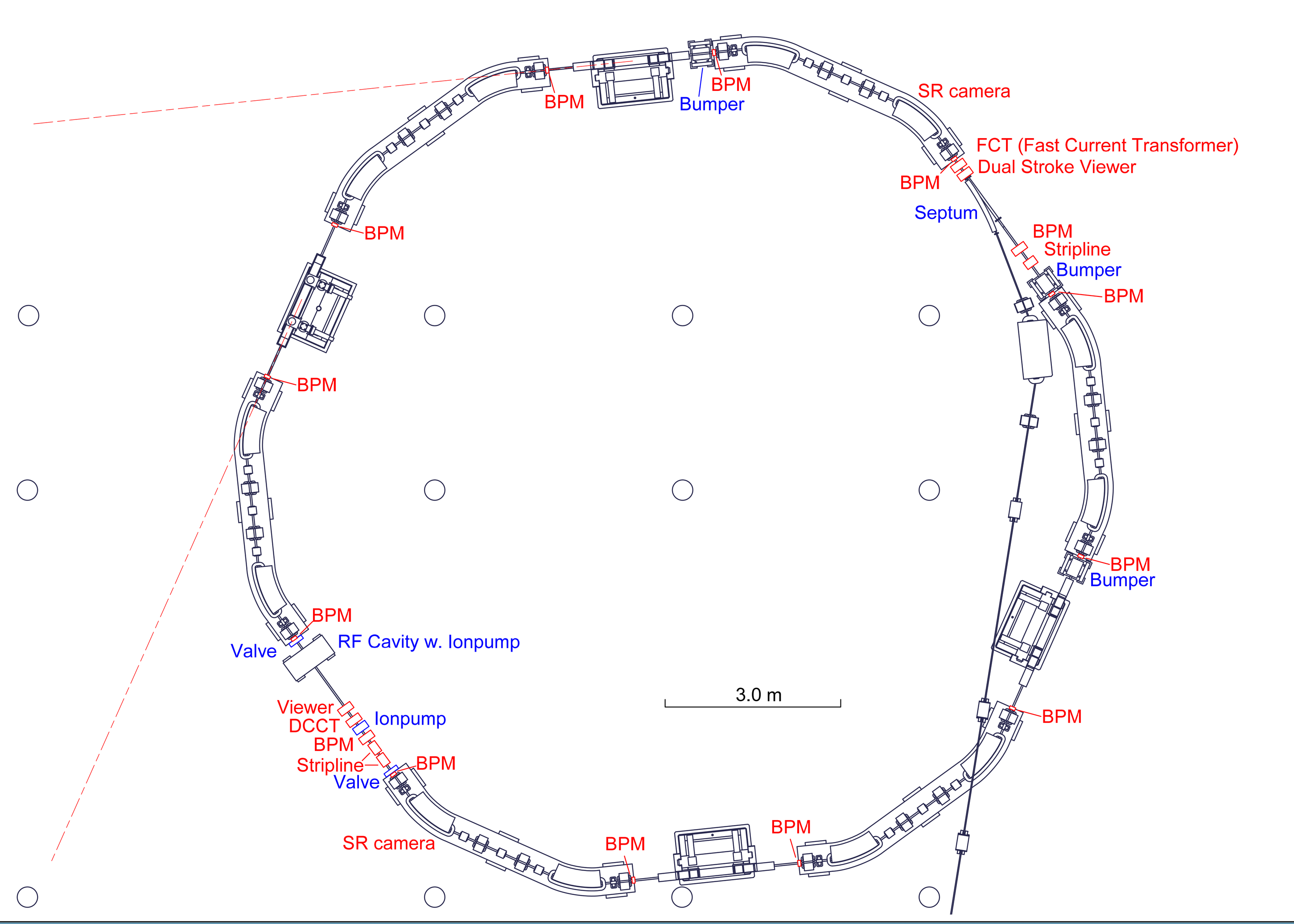
This paper presents the proposed beam diagnostics for ASTRID2, the new 580 MeV 3rd generation low-emittance synchrotron light source to be built in Aarhus, Denmark. ASTRID2 will use the present ASTRID1 as booster, permitting full energy injection and thereby top-up-operation.

To minimize the dark period, the beam lines will only be transferred after ASTRID2 has been commissioned, and the individual beam lines will be transferred sequentially. We will therefore need to operate ASTRID1 and ASTRID2 simultaneously for a period of time.

Overview of the diagnostic for the ASTRID2 storage ring

Type	Purpose
DCCT	Current measurement
FCT (Fast Current Transformer)	Injection (optimizations, loss, …)
Viewer, OTR (or fluorescence) One after septum (dual stroke), and one in RF straight	Commissioning (Injection detection) (injection) Emittance measurement (Check of transport line lattice, (Qpole scans))
BPM (Beam Position Monitor), 12 BPMs of the button type)	Orbit Monitoring and orbit correction Slow orbit correction (1 Hz)
Q-pole shunts (shunt resistors at 1% and 2%)	BPM offset calibration Additional beam position monitors Lattice measurements (beta functions, LOCO)
SR cameras, two sets	Emittance measurement Visual check (instabilities, drifts, …) Injection optimization (feedback on SR light position)
Striplines, 45°, two sets (measure and excitation) Injection straight and RF straight	Tune measurement Commissioning (Injection detection)
Striplines, 90°, RF straight	Excitation (vertical betatron excitation for lifetime improvement) Excitation for feedbacks (TMBF)
2 BPM for diagnostic, RF straight and injection straight	Detector for feedback General pickup
A ring formed pickup (short tube), RF straight	Longitudinal pickup for (RF) diagnostic.

Layout of ASTRID2, showing the diagnostic elements



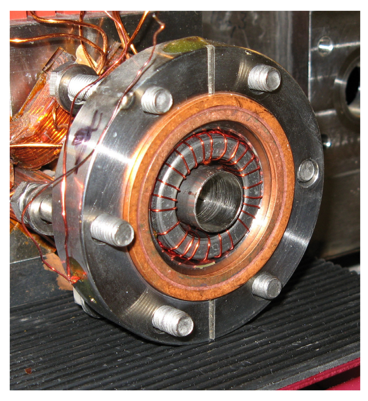
Instrumentation:

The general philosophy is, like most other modern SR sources, to have the instruments close to the ring, and access them via the network. In this way cabling is reduced. The idea is to have one fast oscilloscope connected to a multiplexer. By having sufficient inputs in the multiplexer we will be able to select and view any relevant signal.

Type	Purpose
Fast Scope (BW: ≥1GHz, Sample rate: ≥4GS/s, 4 ch.)	Monitor fast signals (injection (strip lines, BPMs), monitor signals from fast elements (septum, bumpers, …), RF, triggers, etc.)
Multiplexer for fast scope	To allow for remote selection of inputs for the fast scope
Spectrum Analyzer	Tune measurement, sensitive injection detection

Current Transformers:

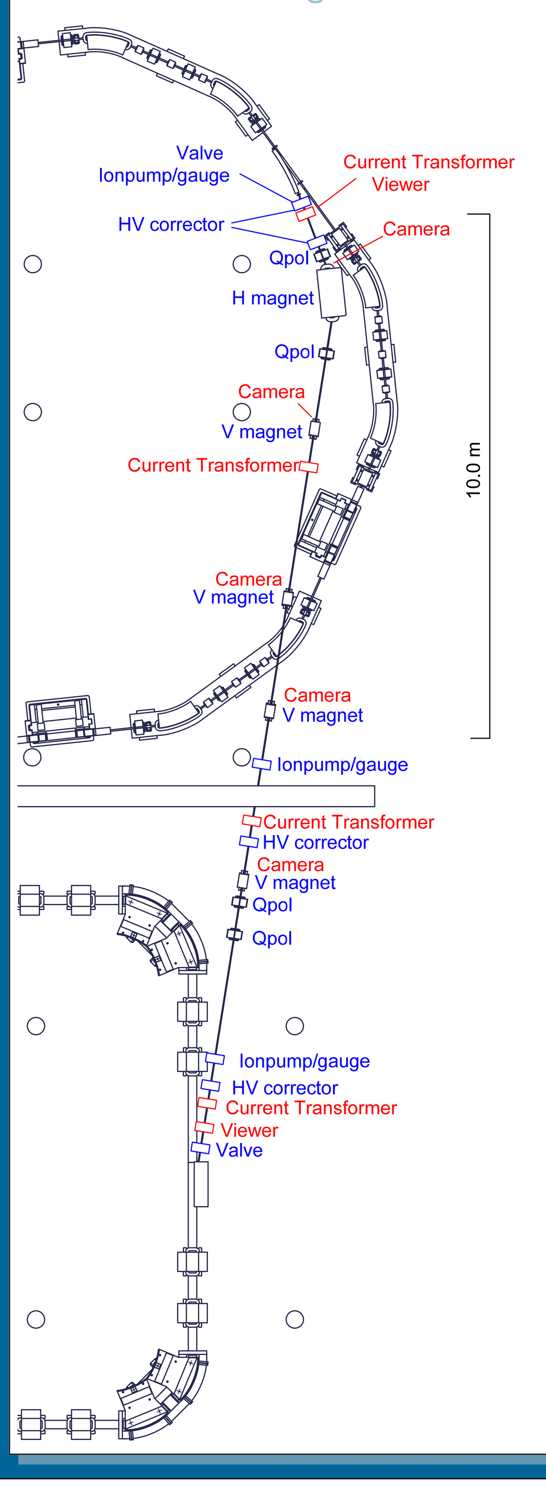
To save cost we will in the transfer beam line do with homemade current transformers. The picture shows an example which we are using in our 100 MeV microtron.



Beam Position Monitors:

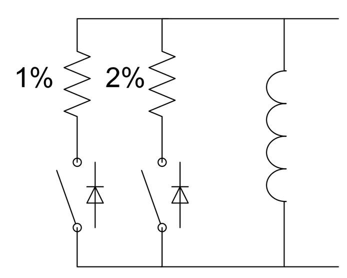
ASTRID2 will be equipped with 12 BPM blocks of the button type at the end of each arc. Having the BPMs at the end of the arcs will allow good control of the orbit in the straights. The BPM electronics will be of the multiplexed analogue type. We are presently testing a card developed at MAX-lab. The 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).

Layout of the ASTRID2 transfer beam line with diagnostic



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 MAX-lab 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%).



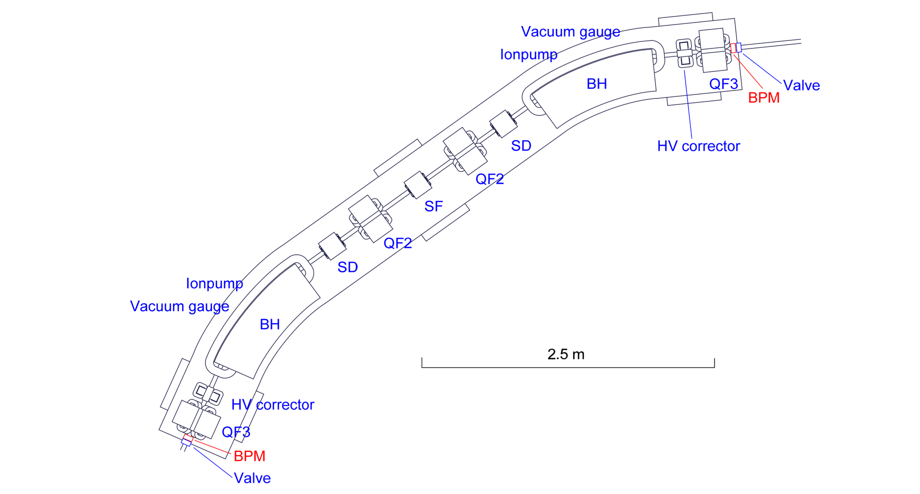
Transfer beam line steering:

Since ASTRID1 was not designed to be a fast cycling booster, the injection rate will only be ≤0.1 Hz. Such a low rate will make the initial commissioning time consuming if done manually. We therefore plan to implement an Automatic Beam Steering system in software. 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, which will permit position correction in all of the transfer line in one go. In the third phase the beam will be centred in the quadrupoles, by using the quadrupole variation method.

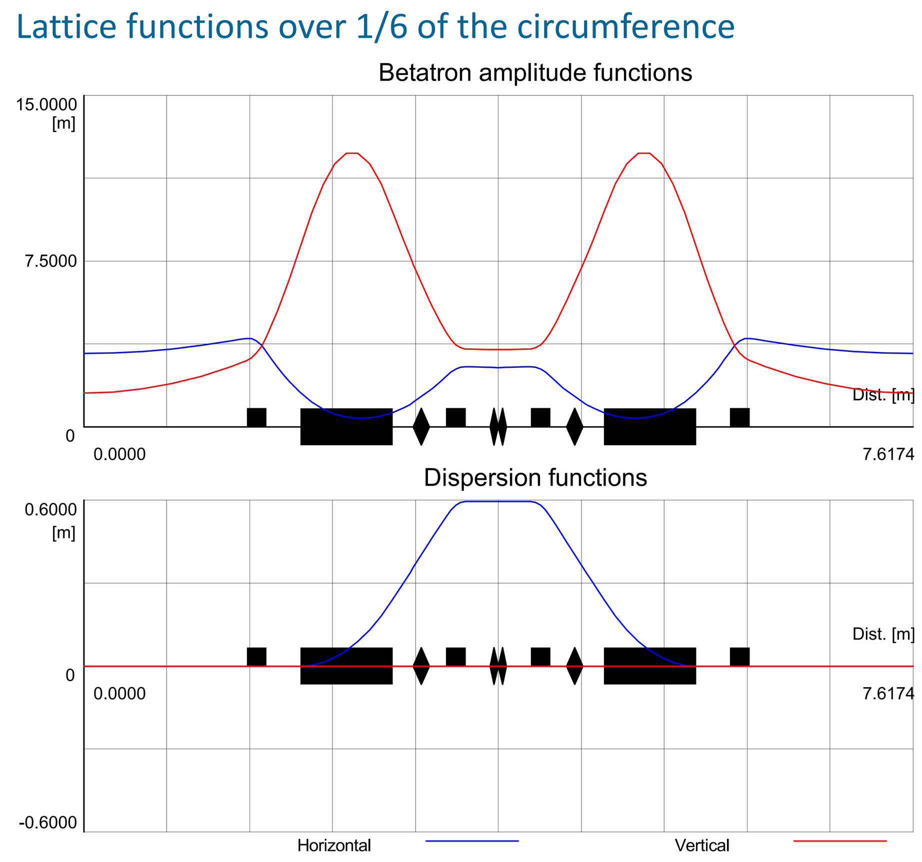
Main parameters of the ASTRID2 storage ring

General parameters		**ASTRID2**	**ASTRID**
Energy	E [GeV]	0.58	0.58
Dipole field	B [T]	1.192	1.6
Circumference	L [m]	45.704	40.00
Current	I [mA]	200	200
Revolution time	T [ns]	152.45	133.40
Length straight sections	[m]	2.7	
Number of insertion devices		4	1
Lattice parameters			
Straight section dispersion	[m]	0	2.7
Horizontal tune	Q_x	5.23	2.22
Vertical tune	Q_y	2.23	2.63
Horizontal chromaticity	$dQ_x/d(\Delta p/p)$	-6.0	-4.0
Vertical chromaticity	$dQ_y/d(\Delta p/p)$	-10.8	-7.1
Momentum compaction	α_p	0.0107	0.068
Coupling factor		5 %	5 %
Synchrotron Radiation parameters			
Synchrotron radiation integrals	I_1 [m]	0.489197	2.7164
	I_2 [m^{-1}]	3.870433	5.2016
	I_3 [m^{-2}]	2.384181	4.3060
	I_4 [m^{-2}]	-1.499123	1.8615
	I_5 [m^{-1}]	0.138303	0.9363
Energy loss per turn	U_0 [keV/turn]	6.2	8.3
Synchrotron radiation power	P_0 [kW]	1.2	1.6
Natural emittance	ε_H [nm]	13	140
Diffraction limit	λ [nm]	38-101	1759
Characteristic wavelength	λ_c [nm]	4.6	3.5
Characteristic energy	ε_c [eV]	267	358
Horizontal damping time	τ_h [ms]	20.6	29.1
Vertical damping time	τ_v [ms]	28.6	18.7
Longitudinal damping time	τ_s [ms]	17.7	7.9
RF parameters			
Damped energy spread	σ_E/E [0/00]	0.434	0.416
Damped bunch length	[cm]	2.2	6.5
RF frequency	[MHz]	105	105
Revolution frequency	[MHz]	6.56	7.5
Harmonic number	h	16	14
RF voltage	[kV]	50	30
Overvoltage factor	q	8.1	4
Quantum lifetime		∞	∞
Synchrotron frequency	$\upsilon=\Omega/2\pi$ [kHz]	10	20.6

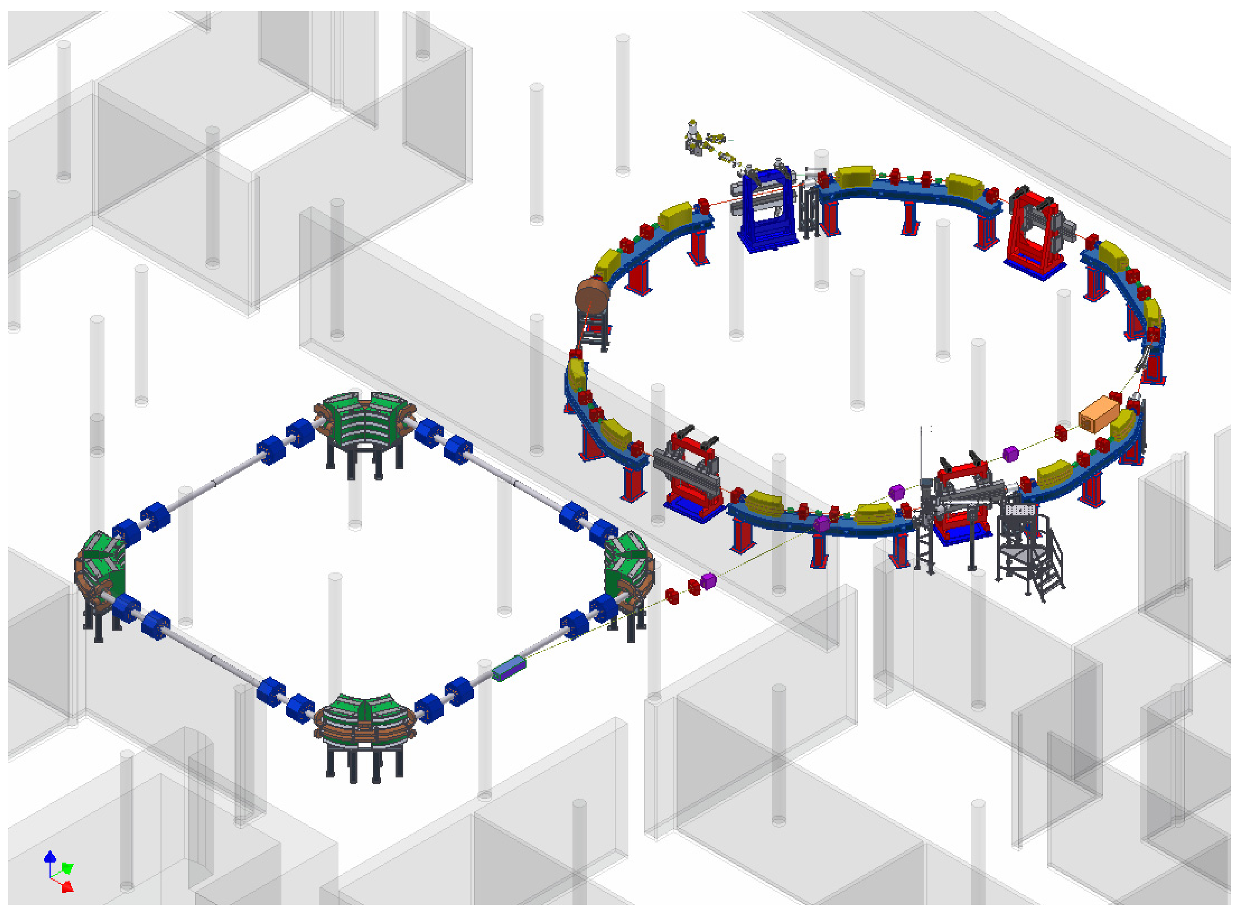
One arc (1/6) of ASTRID2, showing the magnetic elements



Lattice functions over 1/6 of the circumference



ASTRID1 and ASTRID2 as they will be located in the building



Lattice:

- The lattice is a DBA, with integrated quadrupoles in the bending magnets. No integrated sextupole since this reduces the dynamic aperture quite strongly.
- Due to the low beam energy, the Insertions Devices perturb the lattice quite strongly (in particular the 2 T MultiPoleWiggler)
- We are still doing calculations to optimize the lattice (lattice stability for all combination of insertion devices, dynamic aperture, emittance, lifetime)

Timeline:

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