STATUS OF THE INJECTION SYSTEM FOR THE AUSTRALIAN SYNCHROTRON PROJECT

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Abstract

DANFYSIK A/S is building the injection system for the Australian Synchrotron Project [1]. It consists of a 100-MeV LINAC, a low energy beam beamline, a full-energy booster synchrotron and a transfer beamline to the storage ring. The current accelerated to the maximum of 3 GeV will be in excess of 0.5 and 5 mA for single- and multi-bunch-mode, respectively. The lattice is designed with many cells consisting of combined-function magnets (dipole, quadrupole and sextupole fields) in order to reach a very small emittance of around 30 nm. In the present contribution, the status of the project and some of the components will be given. Details about some beam dynamics aspects of the booster will be presented in a separate contribution [2].

INJECTION SYSTEM

The main parameters of the booster synchrotron for the Australian Synchrotron Project (ASP) injection system are given in table 1, and the layout of the whole system is shown in fig. 1.

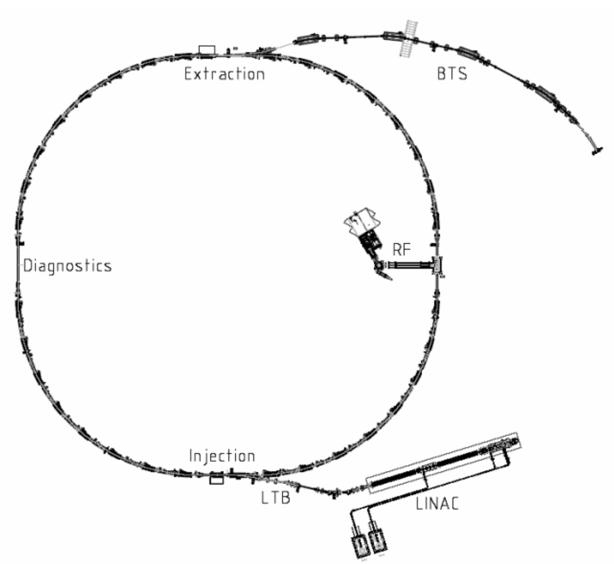

Figure 1: Planar view of the injection system for ASP.

The preinjector is a 100-MeV LINAC delivered as a turn-key system from ACCEL. It can operate in either single bunch mode or multi-bunch mode (150 ns). A beamline (LTB) transports and matches the beam to the injection point of the booster. The beam is injected with a pulsed septum magnet and a kicker placed ¼ of a betatron wavelength downstream of the septum magnet. The 1 Hz synchrotron accelerates the beam to a maximum of 3 GeV. The beam is extracted by means of a slow bump, an extraction kicker and a pulsed septum magnet. A transfer beamline, BTS, transports and matches the beam to the injection point in the storage ring. Independent matching of dispersion and betatron amplitude can be made.

Table 1: Parameters of synchrotron

General Parameters		
Energy	E [GeV]	3.0
Current in single/multi-bunch mode	I [mA]	>0.5/5
Bunch charge in single /multi-bunch mode	[nC]	0.22/0.03
Circumference	L [m]	130.2
Injected emittance	ε [nm]	<250
Injected energy spread	rms	0.5 %
Repetition frequency	[Hz]	1
Lattice parameters		
Horizontal tune	Q_x	9.2
Vertical tune	Q_y	3.25
Horizontal chromaticity	$DQ_x/d(\Delta p/p)$	-8.83
Vertical chromaticity	$DQ_y/d(\Delta p/p)$	-11.50
Synchrotron Radiation parameters		
Energy loss per turn	U_0 [keV]	743
Synchrotron radiation power	P [kW]	3.7
Natural emittance	ε_x [nm]	33
RF parameters		
RF frequency	f_{RF} [MHz]	499.654
Harmonic number	H	217
RF voltage	V [MV]	1.2

The lattice of the booster is a FODO lattice with 4 arcs of each 8 horizontally defocusing and 7 focusing combined-function bending magnets, and with 4 straight sections for injection, extraction, RF cavities and diagnostics, giving a total circumference of 130.2 m, see fig. 1. The lengths of the four straight sections are in excess of 5 m. The horizontal natural emittance at 3 GeV is 33 nm for the nominal horizontal and vertical tunes of 9.2 and 3.25, respectively.

Issues about closed orbit distortions and the dynamical acceptance of the booster will be discussed in [2].

MAGNETS FOR THE ASP BOOSTER

In order to reach a small emittance and with the aim to design the synchrotron with a minimal number of magnetic elements, the ring was designed with combined-function magnets having both a dipole, a quadrupole and a sextupole field in the same magnet. This gives of course

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a less flexible lattice, but in many previous machines a flexible lattice was often not exploited.

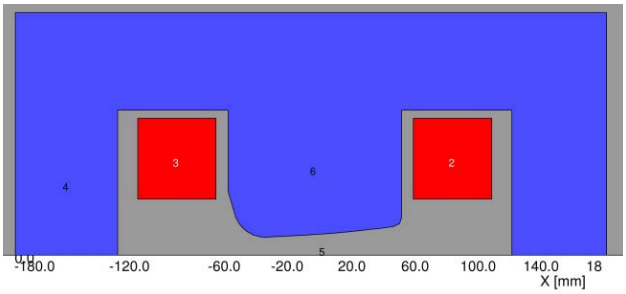

Figure 2: Model of BD magnet showing pole profile

However, proper operation of a combined-function machine is relying on well-designed, well-manufactured and well-characterized magnets as there are only limited tuning possibilities by the trim elements in the machine.

Figure 3: Magnetic measurement with integrating coil of BF magnet

The nominal lattice gives nominal horizontal and vertical tunes of 9.20 and 3.25, respectively, and chromaticity correction to +1 in both planes. Small variations of tunes and chromaticities are expected from the non-linear relationship between fields and excitation current. In addition, a small chromaticity change of up to 0.5 is expected from eddy-currents in the 0.8-mm thick vacuum chambers. For the purpose of adjusting the tunes and the chromaticities, two families of each 8 quadrupoles and two families of each 8 sextupoles are installed in the ring. These are excited by ramped power supplies to keep the variations of the tunes and chromaticities during the ramp at an acceptable level. The quadrupole tuning range is (9.05-9.45) and (3.05-3.45) for the horizontal and vertical planes, respectively. The tuning sextupoles can adjust the chromaticities by ± one unit.

All magnets for the ASP injection system are being field-mapped, but in particular for the combined-function magnets, great care is being taken to characterize the magnetic fields. Hence measurements have been made both with a Hall-probe and with an integrating coil using a ramped power supply. As the integrating coil has a finite width, corrections have been made to extract the quadrupolar and sextupolar fields. The magnetic design values of the combined-function magnets together with the measured quadrupole and sextupole components are given in table 2. These measurements have subsequently been used to calculate the tunes and chromaticities for the different excitations and the results appear from table 3.

Table 2: Magnetic properties of the combined function magnets

Name of magnet	**BD**	**BF**
Number of magnets	32	28
Max. magnetic field [T]	1.2529	0.4436
Bend angle [º]	8.250	3.429
Arc length [m]	1.150	1.350
Radius of curvature [m]	7.9867	22.5602
Magnet gap m]	26	28
Vacuum chamber inner dimension [mm^2]	40×24	
Design gradient [T/m]	6.698	-8.256
Measured gradient at 3 %	6.662	-8.268
10 %	6.680	-8.263
60 %	6.679	-8.266
100 %	6.659	-8.265
Design sextupole [T/m^2]	49.25	-35.41
Measured gradient at 3 %	51.07	-33.86
10 %	50.32	-34.59
60 %	50.20	-35.06
100 %	51.42	-35.10

For the low-field horizontally focusing magnet, BF, there is hardly any change (<0.06 %) in the quadrupole field with excitation, whereas the sextupole component increases monotonically by around 3 % over the full excitation range. Similarly, for the high-field horizontally defocusing magnet, BD, the variation in the quadrupole component is 0.3 % over the full excitation range. The variation in the sextupole component is around 2 % over the full excitation range.

Table 3: Tunes and chromaticities

	Horizontal	**Vertical**
Design tune	**9.200**	**3.250**
Predicted tune		
at 3%	9.210	3.125
10%	9.219	3.168
60%	9.257	3.114
100% excitation	9.264	3.040
Design chromaticity	**1.00**	**1.00**
Predicted chromaticity		
at 3%	0.45	2.75
10%	0.49	2.19
60%	0.91	1.43
100%	0.79	2.29

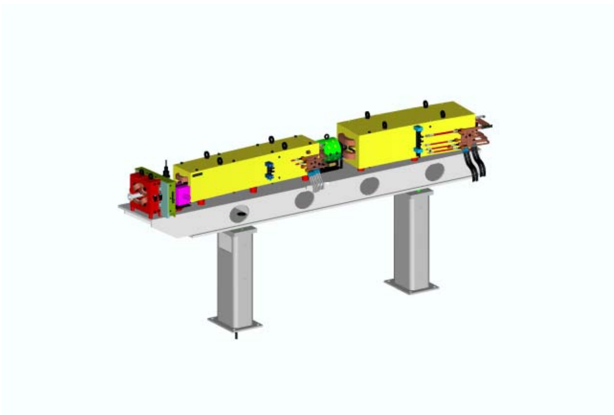

Figure 4: Model of girder with magnets and vacuum chamber. The combined-function BF and BD magnets are yellow, the trim quadrupole red and the trim sextupole green.

As seen from table 3, this corresponds to horizontal and vertical tune changes of 0.05 and 0.13, respectively, over the full excitation range. Similarly, the horizontal and vertical chromaticities changes by 0.5 and 1.3, respectively. These tune and chromaticity changes are small and probably do not need to be corrected. However, the trim quadrupole and sextupole magnets are perfectly capable of compensating these variations.

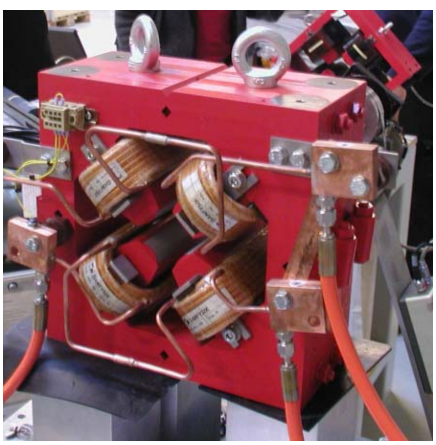

Figure 5: Booster quadrupole magnet.

The vertical tune is found to be slightly too small, but this is being corrected by a small adjustment of the integrated quadrupole field by a small change of the shim angle of 0.25 degrees.

SCHEDULE OF THE INSTALLATION AND COMMISSIONING PLAN

At present, May 2005, most individual components have been manufactured, and they are being assembled into major units like girders etc. before shipment.

The LINAC, manufactured by ACCEL, will be shipped to ASP in June with installation in July and commissioning scheduled for completion in September. Shipment of the transfer beamlines and the booster synchrotron will take place in the period May-August with installation in May-September, followed by commissioning in October-December 2005. Deadline for practical completion of the whole injection system is April 13th 2006.

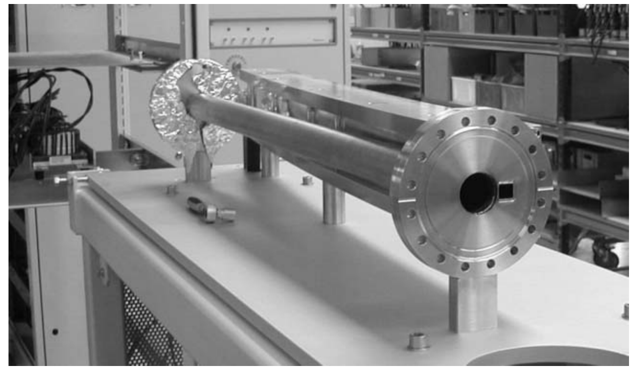

Figure 6: Booster septum magnet with vacuum chamber.

CONCLUSIONS

A relatively compact booster with a very small emittance of around 30 nm has been designed for the Australian Synchrotron Project. The most critical components, namely the combined-function magnets, have been manufactured and the magnetic field has been measured to the required quality. Installation of the injection system has started (May 2005), and will continue over the summer. Commissioning of the LINAC is planned for august 2005, and commissioning of the Booster is foreseen in the period October-December 2005, with final delivery to performance specifications in April 2006.

REFERENCES

[1] A. Jackson, The Australian Synchrotron, this conference.

[2] S. Friis-Nielsen and S.P. Møller, Beam dynamics aspects of the ASP booster, this conference.

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