USING MULTI-BEND ACHROMATS IN SYNCHROTRON RADIATION SOURCES

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Abstract

Multi-bend achromats offer small electron beam emittance, large energy acceptance and a good dynamic aperture. Two examples are discussed below, each using 7-bend achromats; a 12 achromat lattice and a 20 achromat one.

Some possible technical solutions associated with the dense lattices are discussed: magnet technology, vacuum system and RF system. Some characteristics of the two rings are also presented; effects of Intra Beam Scattering, Touschek life-time and the electron beam parameter values.

INTRODUCTION

The performance of 3rd generation light sources is steadily increasing. As the technology of IDs is developing, so are the parameters of the storage rings. New, high-performance rings like SLS, Soleil and Diamond are now in operation and new or reconstructed rings of very small emittance like PETRA III (Germany), NSLS II (USA), TPS (Taiwan) and MAX IV (Sweden) are being planned or built.

The 7-bend achromat suggested for the MAX IV storage rings [1] seems to be rather robust regarding dynamic aperture and energy acceptance. An optimised version of this achromat is used here and two rings with different numbers of achromats are studied. The main difference between the achromats of these two rings is the dipole strength of the bending magnets.

The 20 achromat version is now considered for the MAX IV project. A more detailed description of the characteristics of this type of lattice is given in [2].

RING PARAMETERS AND MAGNET LATTICE

The magnet lattice for the 20 achromat lattice is seen in Fig. 1. The 12 achromat lattice looks the same except for some 50% larger dispersion function.

Each achromat consists of 5 central unit cells. Each unit cell houses a vertically focusing dipole magnet and horizontally focusing quadrupoles are interleaved between the dipoles. Two vertically defocusing sextupoles correcting for the vertical chromaticity are flanking each dipole magnet. The horizontally focussing quadrupole magnet contains the sextupole component correcting the horizontal chromaticity.

The unit cells are flanked by matching cells yielding the zero dispersion and suitable beta-functions for the straight sections.

The parameter list for the two lattices is seen below.

Table 1: Ring Parameters

Nr of achromats	12	20
Energy (GeV)	3	3
Circulating current (A)	0.5	0.5
Bunch pattern	Even fill	Even fill
Circumference (m)	318	530
Length of achromat (m)	26.5	26.5
Number of straight sections	12	20
Length of straight sections (m)	5	5
Horizontal emittance (nm rad)	1.25	0.31
Emittance incl. IBS and IDs (nm rad)	0.95	0.24
Vertical emttance (nm rad)	0.009	0.009
Natural energy spread (%)	0.093	0.074
Energy spread incl IDs (%)	0.099	0.085
Q_{hor}/Q_{vert}	26.24/ 9.27	42.24/ 14.27
Corrected chromaticities	1/1	1/1
Mom comp factor	$7.2*10^{-4}$	$2.6*10^{-4}$
Energy loss, no IDs (keV)	605	363
Energy loss, with IDs	946	766
Hor dyn aperture (mm)	-15/+18	-15/+18
Vertical dyn aperture (mm)	-10/+10	-8/+8
Hor physical aperture (mm)	13	13
Smallest ID half-gap (mm)	2.5	2.5
Energy acceptance (%)	6	7

Some features should be noted:

- The small emittances is due to a large number of magnet cells, rather than striving towards Theoretical Minimum Emittance (TME).
- The energy acceptance is large, mainly due to a linear tune dependence on energy deviation and small dispersion functions.
- Combined quadrupole/sextupole magnets are used for an optimal positioning of the sextupoles.
- The long bunches given by a 100 MHz RF system provide transverse coupled bunch stability.

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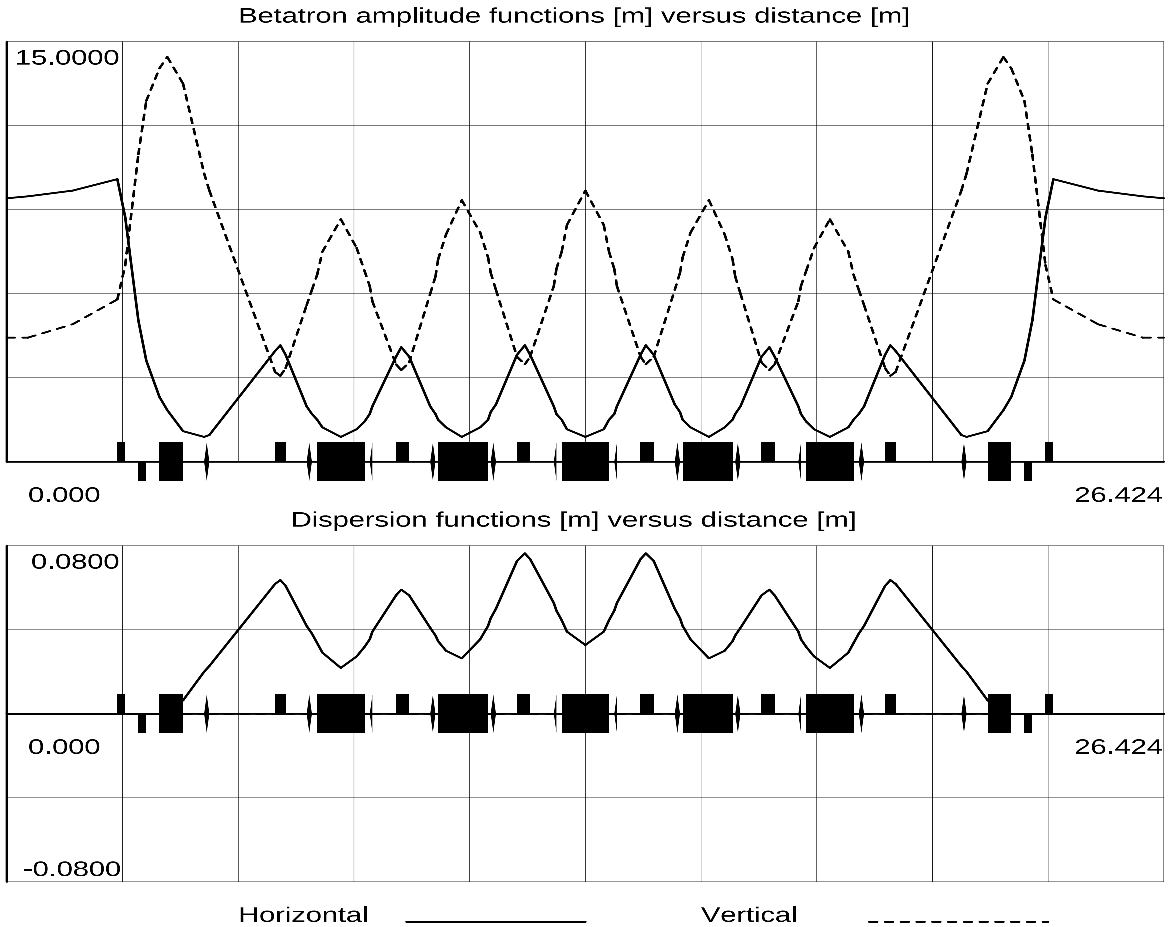

Figure 1: Machine functions for the 20-achromat lattice.

MAGNETS

The small aperture requirement will offer the possibility to use relatively small magnets. The magnet design as given in the MAX IV Conceptual Design Report demonstrates a cross section of the dipole magnets of 0.4*0.3 m^2 and a length of 1.4 m.

Another advantage of the small magnets is that the eigenfrequencies of the magnet support system can be pushed above 100 Hz, which is important regarding the small tolerances for beam vibrations.

The concept of solid steel magnets has been evaluated at the MAX III ring [3] and a MAX IV dipole magnet prototype has been characterized.

VACUUM SYSTEM

The small dimensions of the vacuum system, imposed by the small aperture magnets, yield a poor vacuum conductance. This problem is generally solved in an elegant way for small gap vacuum chambers at the insertion devices in many rings by the introduction of NEG-coated chambers [4]. NEG-coated copper tubes, as installed in one of the MAX II ring dipoles [5], could be used all around the ring. The CH_4 gas, not being pumped by the NEG surface, could be pumped by discrete small ion pumps.

RF SYSTEM

The small aperture of the vacuum system could impose severe resistive wall instability problems if a short-bunch RF system was used. A 100 MHz RF system with bunch-lengthening Landau cavities offers the possibility to restrict the band width of the bunch power spectrum. This will then make it possible to operate the rings at low positive chromaticities, which yields a higher momentum acceptance. The following RF system parameter values are used for the stability analysis and beam life-time calculations.

Table 2: RF parameter values.

Nr of achromats	12	20
RF (MHz)	100	100
RF voltage (MV)	2.0	2.0
RF bucket height (%) (with IDs)	4.35	6.25
Landau cavity harmonic	3	3
Bunch length (cm)	8	8

DISCUSSION

The 7-bend achromat lattice seems to offer quite a small emittance and a sufficiently large dynamic aperture and energy acceptance. The design of the magnets, the vacuum system as well as the RF system should be chosen to comply with the special features of this lattice.

A Conceptual Design Report for the planned MAX IV facility, making use of this type of lattice has been produced and the Technical Design Report is underway.

REFERENCES

[1] MAX IV Conceptual Design Report, http://www.maxlab.lu.se/maxlab/max4/index.html,

[2] M. Eriksson et al., Nucl. Instr. and Meth. A 587 (2008) 221, doi:10.1016/j.nima.2008.01.068

[3] M. Sjöström et al., The MAX III storage ring, to be published.

[4] R. Kersevan, Performance of a Narrow-gap, NEG-coated, Extruded-aluminium Vacuum Chamber at the ESRF, Proceedings of EPAC2000, Vienna, Austria, 2289-2291

[5] A. Hansson et al., Test of a NEG-coated Copper Dipole Vacuum Chamber, this conference, THPP141.