The QBA Optics for the 3.2 GeV Synchrotron Light Source ROSY II

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Abstract

ROSY, a synchrotron light source dedicated to material research has been proposed to be built at the reseach Center Rossendorf in the Dresden region of Germany. At a early stage of the project the idea was to built ROSY in two steps: ROSY I as an compact light source and as an injector for ROSY II. ROSY II shall be a high brillance light source (3rd generation) serving photons with energies up to 30 keV. For the design of ROSY II a modified QBA-lattice was taken. With an energy of 3.2 GeV and a magnetic field of 1.33 T in the bendings magnets the critical photon energy is 9.0 keV. With 12 achromats and a circumference of 310 m, the emittance yields 3 nm rad. The dynamic aperture is +/- 10 mm in both directions .

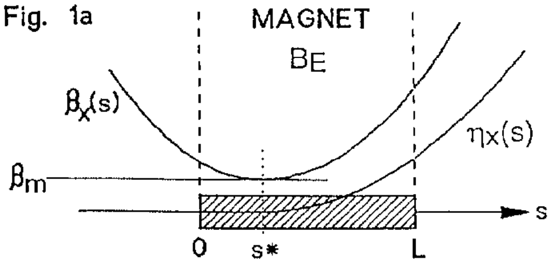
I. INTRODUCTION

Synchrotron light sources of the 3rd generation have been built for an energy range between 1.5 - 2.0 GeV and 6.0 - 8.0 GeV [1]. A gap exist around the energy region 3 to 4 GeV. In this region there are at present only the sources DORIS, IHEP and SPEAR [1] which are running mostly as dedicated light sources, but from the machine point of view they are first generation machines. Therefore ROSY II should be a 3rd generation light source with an energy of at least 3 GeV. As a lattice the modofied QBA-Optic, which showed very promising results for LISA [2], has been choosen. At the "Workshop on Fourth Generation Light Sources" [3] the QBA - lattice has been recognized as one structure which could meet the requirements of the next generation of light sources.

II. MINIMIZING THE EMITTANCE

The most important factor for synchrotron radiation users is the brilliance which is mainly determined by the cross-section of the beam and given by the square root of the emittance multiplied with the betatron function. The emittance scales in general with the square of the energy and the third power of the bending magnet's deflection angle. The optics influence the emittance via the H-function, which is determined by the shape of the horizontal betatron (β) and dispersion (η) functions within the dipole magnets only. Low emittances can be reached if the β(s) and η(s) have a minimum there. Two extrem cases are shown in Figure 1. Figure 1a represents the two dipoles of the double bend achromat (DBA) structure [4] and Figure 1b represents the central dipole of the triple bend achromat (TBA) structure[4]. In both cases the formula

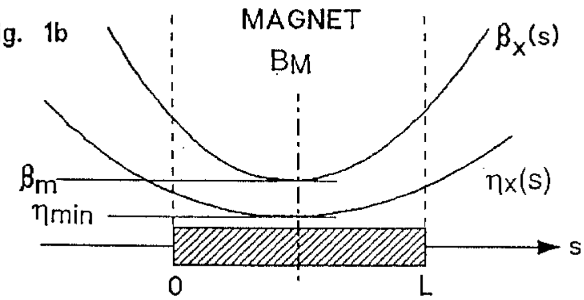
Fig. 1a



$$S^* = 3\,L/8, \qquad \beta_m = \sqrt{\frac{3}{320}}\cdot L$$

$$\varepsilon_{xo} = C_q \cdot \gamma_o^2 \cdot \frac{1}{J_x} \cdot \varphi^3 \cdot \frac{1}{4\sqrt{12}}$$

Fig. 1b



$$\beta_m = \frac{1}{2\sqrt{15}}\cdot L, \qquad \eta_m = \frac{1}{24\,\rho}\cdot L^2$$

$$\varepsilon_{xo} = C_q \cdot \gamma_o^2 \cdot \frac{1}{J_x}\,\varphi^3 \cdot \frac{1}{3\cdot 4\sqrt{12}}$$

Figure 1. Twiss functions in a bending magnet which ninimize the H - function for a nondispersive entrance (a) and in the general case (b). The expressions for the optimal values of the Twiss function and the minimal emittances are shown.

for the smallest emittance and also the conditions to reach this are given. ε(Fig. 1b) is roughly one third of ε (Fig. 1a) The smallest emittance can be reached with the case represented in Figure 1b. Hence to get the smallest emittance, a storage ring should have a lattice which provides a shape of the horizontal betatron and dispersion functions as represented in Fig. 1b in all dipole magnets, However, other design considerations forbid this. A light source includes undulators and wigglers and at the position of these insertion devices, in the long straight sections, the dispersion has to be zero. This requires a matching of the twiss functions to the desired values within the straight sections.

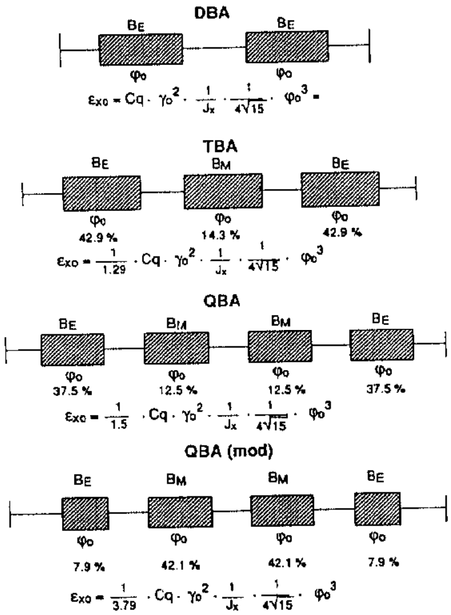


Figure 2. A comparison of theoretical minimal emittances obtained by different bending magnet structures. The persentages under the magnets indicate their relative contributions to the H - function average.

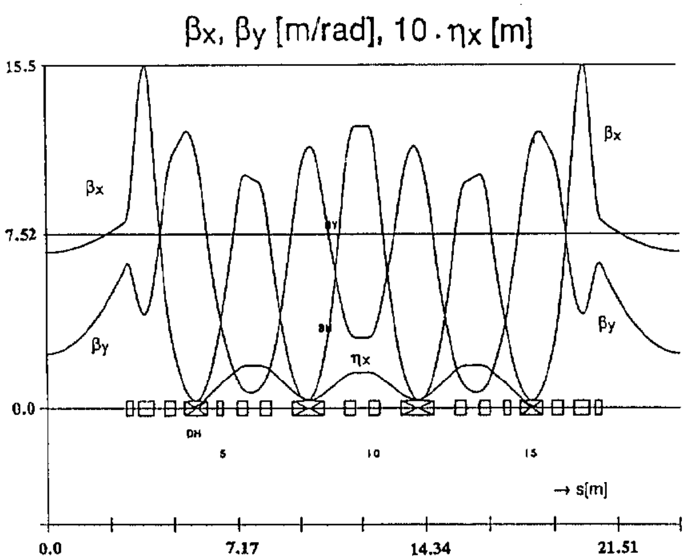


Figure 3. The lattice of a 3 GeV, 3 pi nm rad emittance light source ROSY II. The positions of the chromatic sextupoles are indicated with vertical bars.

The zero dispersion can be matched only in the case the straight section is on the left side of the dipole in Fig. 1a. Two of these dipoles with one quadrupole in between form the well known DBA structure [6]. Implicit to the DBA structure is the requirement that the phase advance from the beginning of the first to end of the second dipole has to be π. This is only possible if the distance between both dipoles is very large [7] or there are at least two more quadrupoles in between the dipoles, as for the ELETTRA design [8]. In most DBA designs the minimal emittance has not been attained.

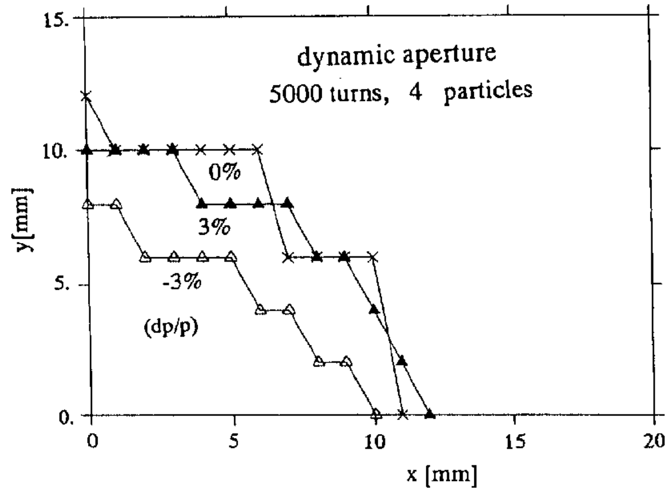


Figure 4. The dynamic aperture of ROSY II with optimized chromatic sextupoles.

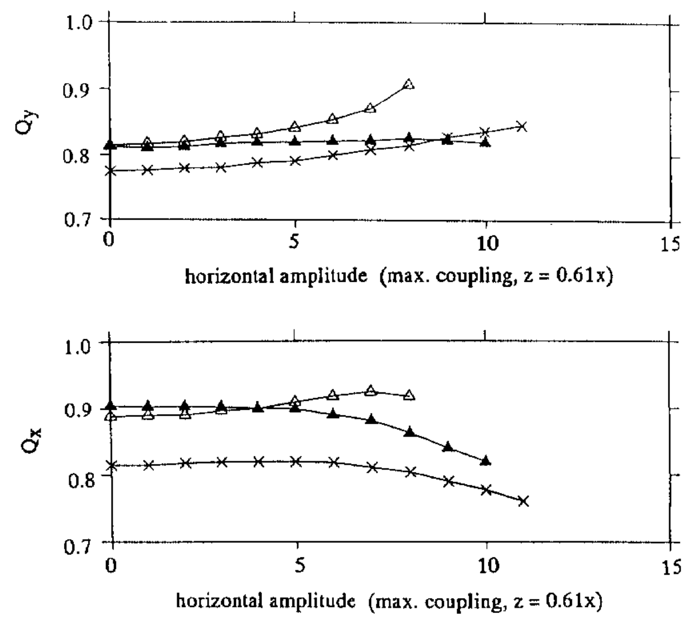


Figure 5. The fractional tune of ROSY II as a function of the initial particle amplitude for on energy particles (crosses), and dp/p = -3% (open triangles), and + 3 % (full triangles), respectively.

Inserting a further dipole between the two DBA dipoles and providing there a shape of the Twiss functions as given in Fig. 1b represents a TBA structure. Such an arrangement would have a lower emittance if the Twiss functions reached the optimal values both in the central and in the outer dipoles. However, it has been proved that this is not possible [9]. Even if it was possible, the ideal emittance of the TBA lattice would be smaller than the ideal DBA emittance by only a factor 1.3 because of the relatively high contributionof the outer magnets to the total emittance (85.5%, see Fig. 2). In conclusion, it can be said that the TBA - structure is DBA dominated.

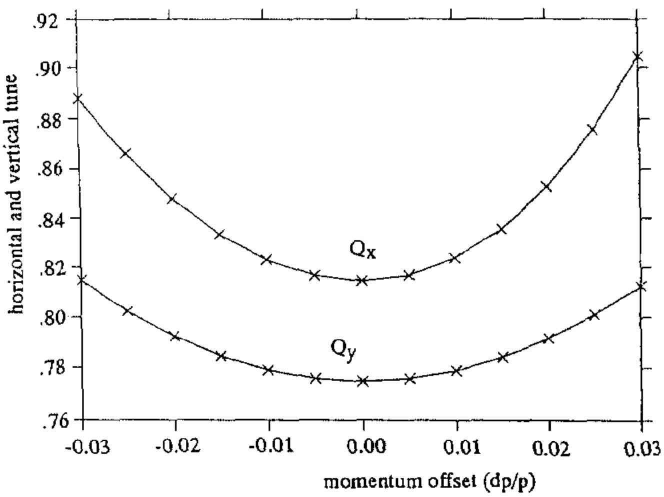


Figure 6. The fractional tune of ROSY II as a function of particle energy deviation

STORAGE RING PARAMETERS

Achromatic structure	QBA
Normal energy (GeV)	3
Superperiod	12
Circumference (m)	292.8
Mean radius (m)	46.6
Max. current (mA)	300
R.F. Frequency (MHz)	500
Harmonic number	488
Quantum lifetime (h)	10
Natural emittance (π nm rad)	3
Natural energy spread (%)	0.1
Betatron tunes Q_x/Q_y	21.90/14.80
Natural chromaticities ξ_x/ξ_y	-51/-30
Momentum compaction factor	$0.75 \cdot 10^{-3}$
Beta functions	
Horizontal (max/min)	13.3/0.3
Vertical (max/min)	12.1/0.6
Straight section (max/min)	7.18/2.29
Maximum dispersion (m)	0.18
Number of dipole magnets (5/10)	24/24
Dipole length (m) (5/10)	0.84/1.62
Bending radius (m)	8.00
Bending field (T)	1.25
Gradient (T/m) / field index	7.5/48.00
Number of quadrupoles	18/96/24=168
Length of quadrupoles (m)	0.25/0.40/0.6
Quadrupole families	6
Gradient (T/m) / strength (m^{-2})	17
Number of sextupoles	132
Length of sextupoles (m)	0.2
Sextupole families	3
Sextupol parameter, S=B/R2 (T/m^2)	750

Table 1. Parameters of the storage ring ROSY II designed with a modified QBA - optic

[1] J.Murphy,"Synchrotron Light Source Data Book",BNL 4233, Brookhaven National Laboratory

[2] D.Einfeld, D.Husmann, M.Plesko,"Dynamic Aperture of the 2.5 GeV Synchrotron Radiation Source Lisa", This Proceeedings

[3] M.Cornacchia and H. Winick,"Workshop on Fourth Generation Light Sources",SSRL 92/02, Stanford, February 1992

[4] R.Chasmann and K. Green,"Preliminary Design of a Dedicated Synchrotron Radiation Facility",IEEE Trans. Nucl. sci.,NS - 22, 1765 (1975)

III THE MODIFIED QBA - LATTICE

The QBA structure is obtained by inserting two dipoles between the two DBA bending magnets. Also in this arrangement the highest contribution to the emittance is given by the outer magnets (Fig. 2, 37.5 %). The investigation of a QBA structure for the 6 GeV Riken storage ring [10] has shown that this structure has no merits with respect to the DBA or TBA structures.

Quite different is the behavior of a modified QBA structure which we firstly proposed for a planned synchrotron light source LISA [2]. As mentioned above, the emittance of the TBA structure is not ideal because of the unsatisfactory matching of the twiss functions from the straight sections to the central dipole. Matching the twiss functions to an outer dipole with a deflection angle $\varphi/2$ should force a smaller increase in the emittance with respect to the ideal one, because the differences between the existing and the matching conditions are not so large. The second advantage of the halved deflection angle in the outer dipole is that its contribution to the emittance is small. According to Figure 2 the contribution of the outer magnets to the emittance in the ideal case is reduced to 15 %. Consequently, this structure is really determined by the dipole of Figure 1b, which gives the smallest emittance.

IV THE SYNCHROTRON LIGHT SOURCE ROSY II

The lattice of ROSY II is shown in Figure 3. The bending magnets in the middle of the achromat perform a deflection of 6 degree and the magnets in the matching section of 3degree. With this ratio one gets the smallest emittance. The space for the insertion devices is 6 m. The main parameters of the storage ring ROSY II are summarized in Table 1. The dynamical aperture is given in Figure 4 and the tuneshifts with amplitude as well as momentum are presented in the Figures 5 and 6

All dynamic properties of the lattice behave sufficiently well. The low emittance of 3 nm rad indicates that with such kind of lattices performances in the direction of fourth generation light sources are feasible indeed.

[5] D.Einfeld and G. Mülhaupt,"Choice of the Principle Parameters and Lattice of BESSY",Nucl. Instr. Meth. 172 (1980)

[6] see [4]

[7] A.Jackson,"A Comparison of Chasmann - Green and Triple Bend Achromat",Particle Accelerators, Vol 22,111 (1987)

[8] "ELETTRA Conceptional Design Report",Sincrotrone Trieste, April 1989

[9] G. Wüstefeld," The Minimization of the Natural Emittance in the Triple Bend Achromat", BESSY TB 108/87, March 1987

[10]K.Tsumaki, R. Nagaoka, H. Tanaka, K. Yoshida, M. Hara, "Lattice Comparison for the 8 GeV Synchrotron Radiation Source", 1989 Particle Acc. Conf., Chicago

[11] see [2]