Design of the 800 MeV Booster Synchrotron for the Synchrotron Light Source ROSY

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Abstract

The injection system of the proposed 3 GeV Rossendorf Synchrotron Light Source ROSY consists of an 800 MeV booster synchrotron and a 22 MeV microtron as preaccelerator. As lattice for the booster synchrotron different DBA and FODO structures have been studied. The DBA lattice has been chosen over the sixfold FODO structure on account of the lower emittance and better results for the injection process characterized by a large energy acceptance, small synchrotron tune and a small transversal beam size.

1. INTRODUCTION

As injector for synchrotron light sources booster synchrotrons, linacs or microtrons are used. The injection energy for most of the 3rd generation light sources equates to the nominal energy. For 2nd generation light sources, in most cases the injection energy is smaller than the nominal energy ($0.08 \leq E_{inj}/E_0 \leq 1.0$). Table 1 represents injection energies and also the types of injectors for different light sources.

Table 1. Parameters of different booster synchrotrons [1]

Ring	E_0 [GeV]	E_{inj} [GeV]	Injector	E_{inj}/E_0
BESSY I	0.8	0.8	Booster syn.	1
SUPERACO	0.8	0.8	Linac	1
SRC	1.0	0.1	Microtron	0.1
LNLS	1.15	0.1	Linac	0.087
CAMD	1.2	0.2	Linac	0.17
SRRC	1.3	1.3	Linac	1
ALS	1.5	1.5	Booster syn.	1
DELTA	1.5	1.5	Booster syn.	1
MAX II	1.5	0.5	Storage ring	0.33
SOR	1.5	1.5	Booster syn.	1
ELETTRA	2.0	1.5	Linac	0.75
PLS	2.0	2.0	Linac	1
SRS	2.0	0.6	Booster syn.	0.3
SOLEIL	2.15	2.15	Booster syn.	1
NSLS	2.5	0.7	Booster syn.	0.28
ESRF	6.0	6.0	Booster syn.	1
SPring-8	8.0	8.0	Booster syn.	1

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The experience at ALADIN, NSLS and SRS has shown that a ratio E_{inj}/E_0 between 0.1 and 0.3 keeps the particle loss during ramping in the range of 5% [2, 3]. To follow this intention, the injection energy for ROSY [4] (as a 3rd generation light source) was determined to 800 MeV (E_{inj}/E_0 = 0.27). The booster synchrotron is proposed because of lower costs.

2. LATTICE OF THE BOOSTER SYNCHROTRON

Different lattices have been developed for booster synchrotrons. The 700 MeV SRS injector consists of only combined function bending-magnets, while the NSLS injector has combined function magnets for vertical focusing and quadrupoles for focusing in the horizontal direction. The 800 MeV booster synchrotrons of BESSY I and SRRC use homogeneous deflection bending magnets and perform focusing with quadrupoles.

Any frozen focusing within the bending magnets reduces the flexibility of the lattice. Therefore it was decided to use homogeneous dipole magnets and perform the focusing only with quadrupoles. This means furthermore some benefits with respect to the alignment. As lattices we investigated FODO structures as well as a DBA structures which so far have not been used yet as lattice for a booster synchrotron. The calculations have been performed with the code BETA [5]. As optimal configurations the fourfold DBA and the sixfold FODO structures have been derived. The lattice functions and schemes of both configurations are displayed in fig. 1. Their parameters are summarized in table 2.

3. COMPARISON OF FODO AND DBA STRUCTURES

The efficiency of the injection process is an essential criterion for choosing the lattice structure. The efficiency depends on the energy acceptance, the synchrotron tune and the beam dimension at the injection energy.

The energy acceptance ($\Delta E/E$) is related to the momentum compaction α and the the rf amplitude containing in the overvoltage factor q [6] (for notation see also [7]):

$$\left(\frac{\Delta E}{E}\right)_{rf} = \sqrt{\frac{2U_0}{\pi\alpha k E_0}\left[\sqrt{q^2-1} - arc\cos\left(\frac{1}{q}\right)\right]} \quad (1)$$

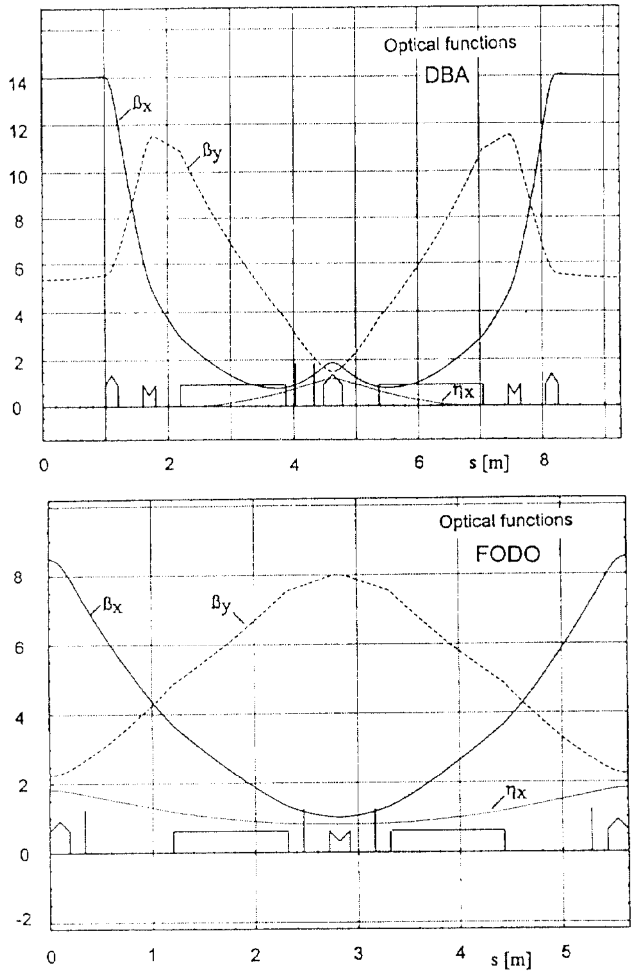

Figure 1. Lattice functions β_x, β_y, η_x and indication of the optical elements for the DBA (upper part) and FODO structure (lower part).

The smaller momentum compaction α of DBA leeds to higher energy acceptance at the same accelerating voltage. Plots for the energy acceptance are displayed in fig. 2. Obtaining equal energy acceptance at the 22 MeV injection energy the FODO structure requires a five times higher cavity voltage than DBA.

The synchrotron tune [6]

$$\upsilon_s = \frac{\Omega_s}{\omega_0} = \sqrt{\frac{\alpha h V_{CAV} \sqrt{1-1/q^2}}{2\pi E/e}} \tag{2}$$

contains the momentum compaction factor in the numerator of the root-term. That is why the DBA structure generates the lower synchrotron tune $\upsilon_s = 7.9*10^{-3}$ for 22 MeV than the FODO structure with $\upsilon_s = 3.6*10^{-2}$. Due to possible coupling between synchrotron and betatron oscillations the synchrotron tune should be $\upsilon_s < 10^{-2}$. This requirement can be fulfilled only with the DBA structure.

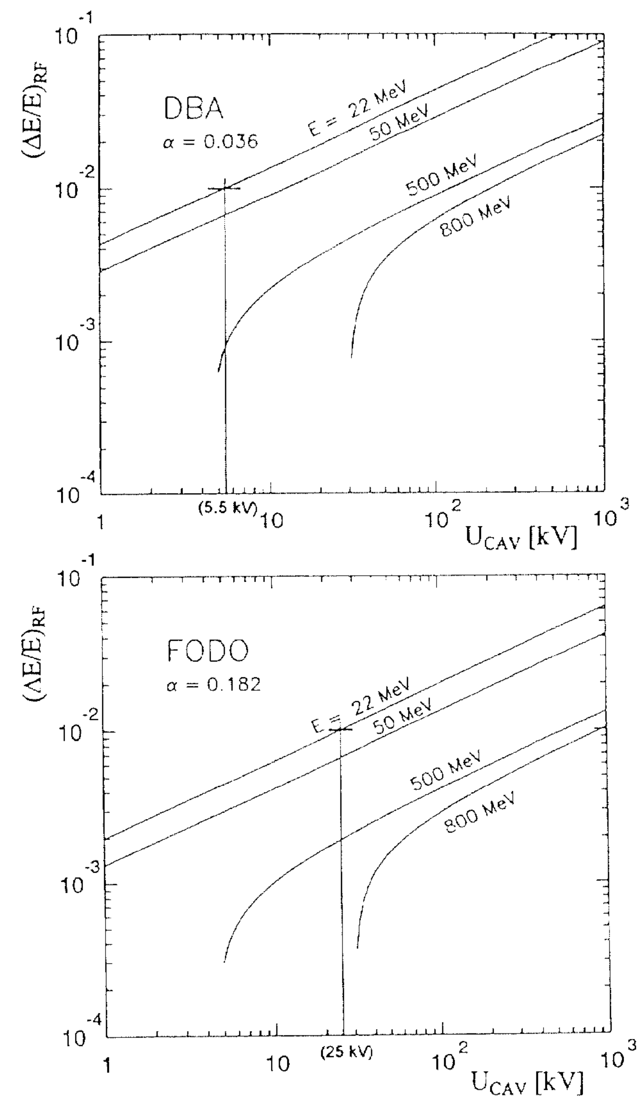

Figure 2. Energy acceptance of the booster synchrotron at 352.2 MHz for the DBA (upper part) and FODO structure (lower part).

Furthermore the dispersion function for FODO is always nonzero. Its maximum is larger than that obtained for DBA (fig. 1). For DBA the beam extension is x = ± 12 mm at 1% energy spread and for the FODO lattice in the range from ± 12 to ± 24 mm. For the DBA structure the beam extension caused by the energy spread is zero at the injection point (long straight section). The damping time is around 600 seconds at the injection energy of 22 MeV. Hence the betatron oscillation cannot be damped during the time of injection. Therefore, the beam size should be made as small as possible for the injection process. This is the mean reason for choosing the DBA structure as lattice for the ROSY booster synchrotron. The comparison of the dynamic aperture for both configuration shows fig. 3 at the nominal energy of 800 MeV. Fig. 4 represents the lay-out of the DBA booster synchrotron.

Table 2. Parameters of the booster synchrotron

Structure	DBA	FODO
Final energy [MeV]	800	800
Injection energy [MeV]	22	22
Circumference [m]	37.453	34.648
Superperiod	4	6
RF frequency	352	352
Harmonic number	44	40
Current (multi bunch) [mA]	20	20
Current (single bunch) [mA]	5	5
Nat. emittance [π mm mrad]	0.161	0.375
Betatron tunes Q_x / Q_y	2.902 / 1.178	2.221 / 1.208
Nat. chromaticities ξ_x / ξ_y	-5.528 / -0.874	-4.380 / -0.639
Momentum compaction α	0.036	0.182
Energy spread $\Delta E/E$	$0.463*10^{-3}$	$0.420*10^{-3}$
$\beta_x(max)$ / $\beta_x(min)$ [m/rad]	14.06 / 0.79	8.50 / 1.01
$\beta_y(max)$ / $\beta_y(min)$ [m/rad]	11.5 / 1.50	8.00 / 2.25
Max dispersion η_x [m]	1.19	1.83
Dispersion of straight lines	0	1.40
Bending radius [m]	2.135	2.135
Magnetic dipol field [T]	1.25	1.25
Number of quadrupols	20	12
Quadrupol gradient [T/m]	12.8	4.5
Number of sextupols	8	24
Sextupol strength S*l [m^{-2}]	20	1
Damping constants J_x / J_ε	1.1 / 0.9	0.54/1.46

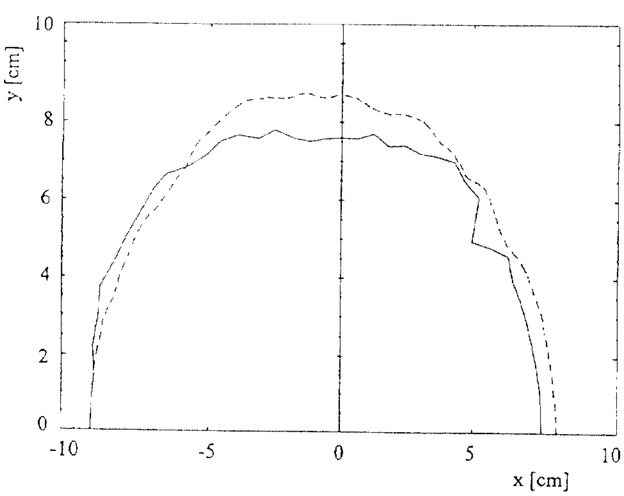

Figure 3. Dynamic aperture for DBA (full line) and FODO lattice (dashed line) at the nominal energy of 800 MeV.

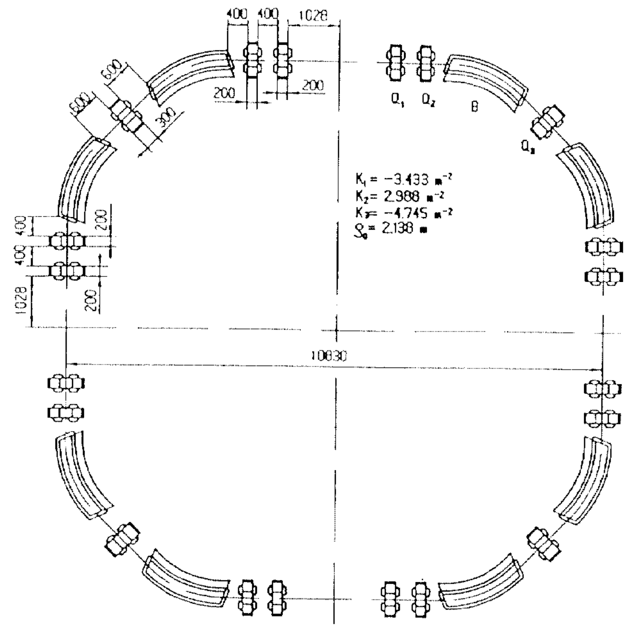

Figure 4. Lay-out of the DBA booster synchrotron (measures in mm).

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