THE TRIESTE SYNCHROTRON LIGHT SOURCE ELETTRA

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Introduction

The goal of the SINCROTRONE TRIESTE is to design and to construct a light source optimized for photon energies from undulators in the ultraviolet to soft X-ray region with good tunability over this range and with the capability to accomodate a large number of insertion devices. High spectral brilliance from undulators and high spectral flux from wigglers is required.

These design goals can be achieved by a storage ring for electrons or positrons in the energy range from 1.5 to 2 GeV and an emittance $\varepsilon < 10^{-8}\ \pi$ m-rad. As a compromise between costs and user demands a twelve fold achromat structure with 12 straight sections of 6 meter length has been adopted for ELETTRA. Due to the high requirements on orbit stability and reproducibility, a full energy injection scheme with a 100 MeV linear preaccelerator and a full energy booster synchrotron has been chosen as the injection system [1,2]. A general layout of the accelerator is shown in figure 1.

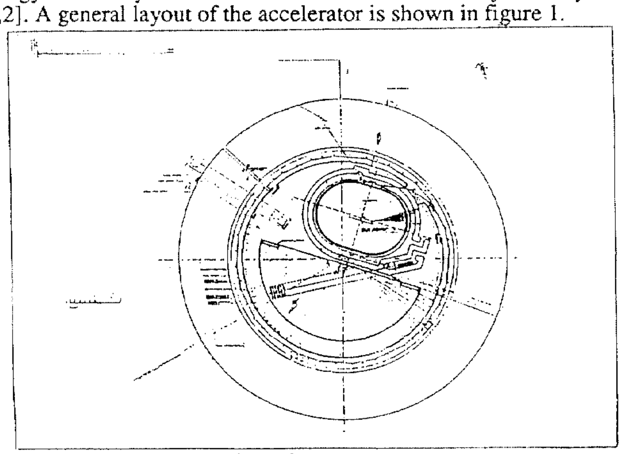

Figure 1. General layout of accelerator.

Radiation Source Performance

Synchrotron light will be used in ELETTRA coming from bending magnets, wigglers and undulators. For a storage ring energy of 2 GeV, the critical energy of the bending magnet light is 3.2 keV, with a peak flux around 0.9 keV and a useful flux up to about 20 keV, as shown in figure 2.

The flux can be increased by about two orders of magnitude by using a wiggler and may be extended to higher photon energies if the wiggler field is increased as compared to the magnetic field of the bending magnet. Figure 2 also shows the spectral flux of a wiggler with 4.4 meter length, 1.5 Tesla field and 35 periods.

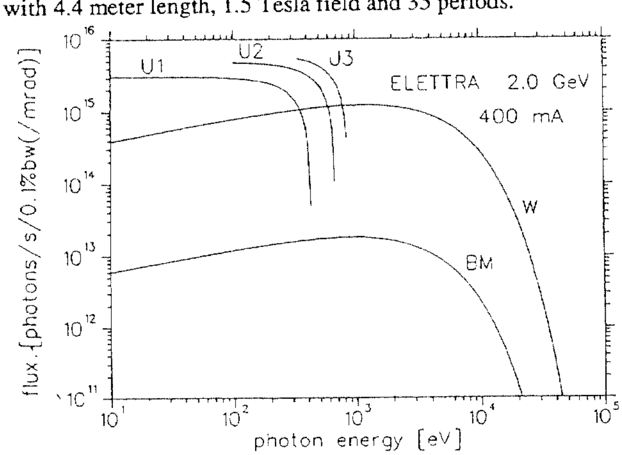

Figure 2. Spectral flux for bending magnet and wiggler.

Figure 3 shows the spectral brilliance of 3 representative undulators with 5 meter length (U1 with B=1.12 T and λ_0=8.8 cm, U2 with B=0.65 T and λ_0=5.6 cm, U3 with B=0.44 T and λ_0=4.4 cm) [3]. If the third harmonic is taken into account, high spectral brilliance and good tunability is achieved in the range from 100 eV to 2 keV.

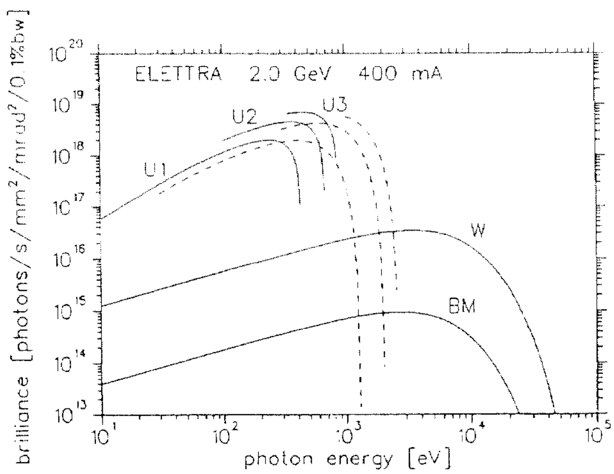

Figure 3. Spectral brilliance for undulators.

Lattice and Lattice Performance

A lattice comparison between the Triplet-Bend-Achromat (TBA) structure and the Double-Bend-Achromat (DBA) structure (or Chasman-Green type structure) has been performed [4,5]. Since there is no constraint on the circumference of the ring, the DBA could be expanded to a total length of 259.2 meters in order to approach the Chasman-Green minimum in emittance and has been found to be the superior lattice. Magnet structure and lattice functions are shown in figure 4. A list of the general lattice parameters is given in table 1.

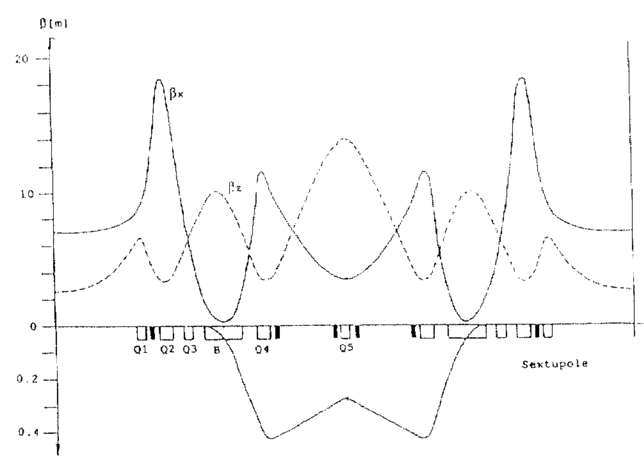

Figure 4. Magnet structure and lattice functions.

As a novel feature for the DBA, a vertical focusing gradient has been introduced in the bending magnet to avoid excessive growth of the vertical beta function and to increase the horizontal damping partition number in order to further reduce the emittance. Beside the characteristics of the linear optics, the performance of the machine is determined strongly by the non-linear dynamic behaviour, collective beam effects and scattering effects.

Table 1. Lattice parameters.

Betatron tunes			
Horizontal		14.3	
Vertical		8.2	
Natural chromaticities			
Horizontal		- 39.6	
Vertical		- 12.3	
Beta functions at the ID symmetry point			
Horizontal		7.0	m
Vertical		2.6	m
Natural energy spread		$7.9\ 10^{-4}$	
Momentum compaction		$1.6\ 10^{-3}$	
Emittance	1.5 GeV	$4.2\ 10^{-9}$	m-rad
	2.0 GeV	$7.4\ 10^{-9}$	m-rad

Since usually there is not much space to place sextupoles in low emittance achromat structures, in the design of the linear lattice the optimization of the nonlinear behaviour must already be incorporated. The dynamic aperture achieved in that way for ELETTRA is shown in figure 5 for on momentum particles and particles with ± 4% momentum deviations. A large dynamic aperture and a large momentum acceptance is necessary to accomodate gas scattered and Touschek scattered particles which are the most relevant scattering effects for ELETTRA. They have been calculated with the computer code ZAP [6] and are displayed as a function of energy in figures 6 and 7. The Touschek half lifetime is drawn there for the peak threshold currents limited by the fast transverse blow up, taking also bunch lengthening into account. The effective beam pipe radius has been derived assuming a 1.5 cm undulator gap in the insertion regions. A lifetime of 10 hours has been calculated under the assumption that the effective longitudinal broadband impedance decreases for bunch lengths smaller than the pipe diameter (Spear Scaling), in that case the bunch is less lengthened, i.e. the bunch density is higher which leads to lower lifetimes for Touschek scattering. The dominant beam gas effect is single Coulomb scattering. Even under the assumption of 5 nTorr average gas pressure (design pressure 1-2 nTorr) the lifetime is still 10 hours at the more critical lower energy boundary of 1.5 GeV.

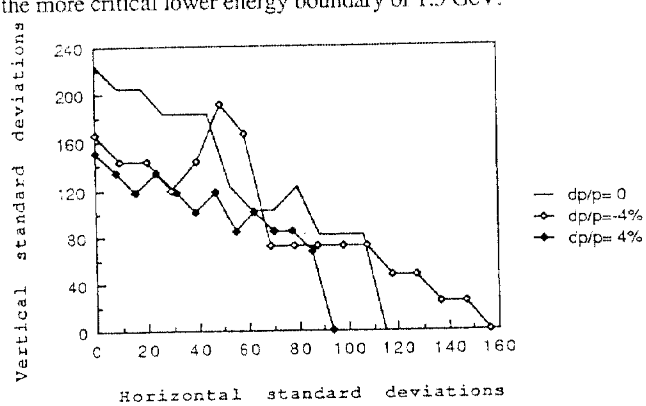

Figure 5. Dynamic aperture.

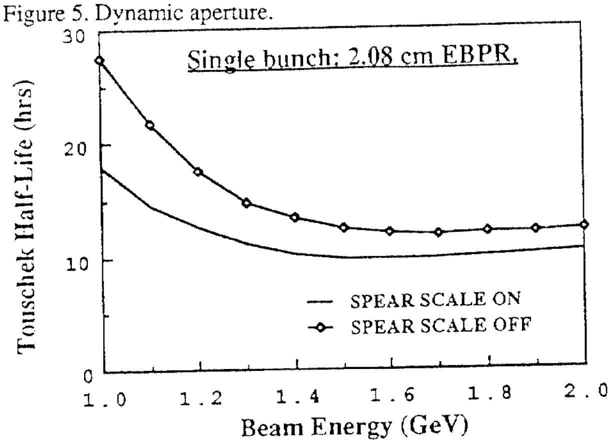

Figure 6. Touschek scattering lifetime.

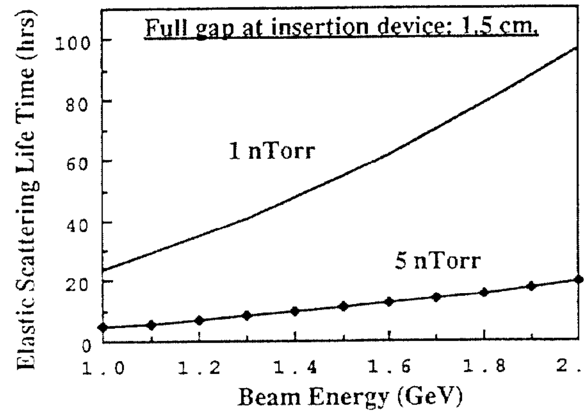

Figure 7. Beam gas lifetime for single Coulomb scattering.

The single bunch current threshold has been calculated to be 8 mA at 1.5 GeV, under the assumption of a conservative value of 3 Ohms longitudinal broadband impedance.

Radio Frequency System

The main parameters for the RF design are listed in table 2. The total losses have been evaluated including two undulators with 1.1 T field, 3 undulators with 0.6 T field, one undulator with 0.4 T field (each 5 meters long) and one 4.4 meter long wiggler with 1.5 T field.

Table 2. Main parameters for the RF design.

Energy	2.0		1.5	GeV
Revolution frequency		1.157		MHz
Harmonic number		432		
RF frequency		499.654		MHz
Total losses	320		127.6	keV/turn
Bending magnets	257.5		81.5	keV/turn
Insertion devices	62.5		46.1	keV/turn
Peak effective RF voltage	1.8		1.7	MV

The peak RF-voltage is essentially determined by the large momentum acceptance needed for good Touschek scattering lifetime.

Figure 8 shows a preliminary cavity design. The shape has been optimized to minimize multipacting in the gap region, and to reduce the higher order mode content.

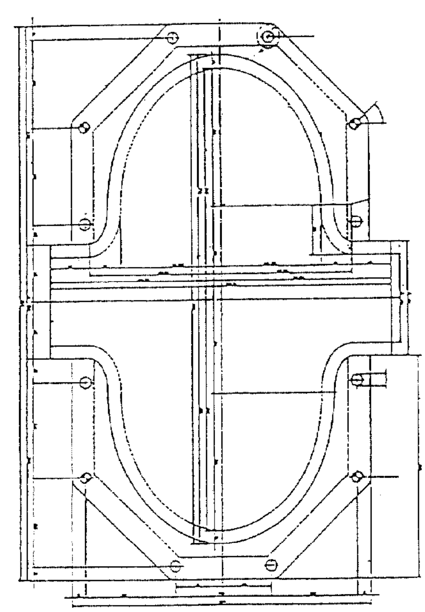

Figure 8. Preliminary cavity design.

Vacuum System

For the vacuum system the possibility of using an antechamber has been investigated. A preliminary design is shown in figure 9, where the bending magnet upstream of an achromat is shown with the insertion device beam line and one bending magnet beam line.

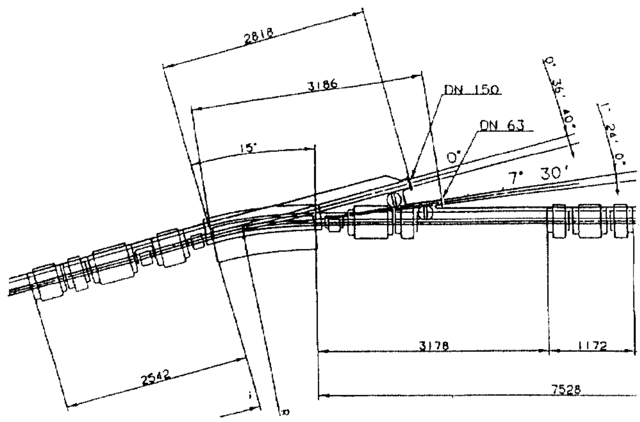

Figure 9. Preliminary vacuum chamber design.

In addtition a conventional vacuum chamber without antechamber has been investigated. It was found that for a chamber cross section of 80x40 mm^2 and 4 localized vacuum pumps of 300 l/s pumping speed per half achromat, the average pressure can be reduced below 2 10^{-9} Torr, even under the assumption that 100 % of the radiation produced by 400 mA beam current is hitting the vacuum chamber walls.

Storage Ring Magnets

In total the basic lattice has 24 bending magnets, 108 quadrupoles and 72 sextupoles. To avoid interference with the extracted synchrotron light it has been decided to open all magnets to the outer side. This also leaves the possibility open to add additional bending magnet beam lines in the future if the need should arise. As an example for the preliminary magnet design the sextupole is shown in figure 10. For the sextupole with the small azimuthal pole distance it is most difficult to achieve the required opening.
Correction elements for closed orbit adjustment are designed as lumped elements or integrated in the sextupole, as can also be seen in figure 10.

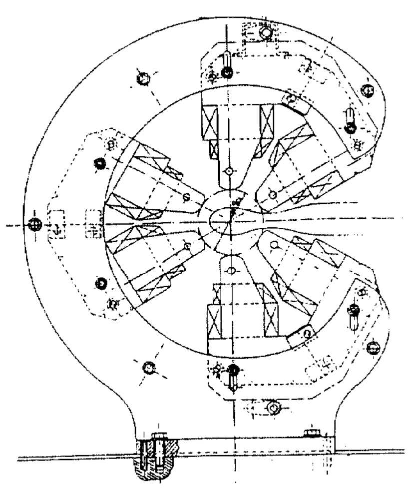

Figure 10. Preliminary sextupole magnet design.

References

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[6] M. Zisman, S. Chattopadhyay and J. Bisognano, "ZAP User's Manual", Lawrence Berkeley Laboratory Report LBL-21270, UC-26, 1986