STATUS OF ELETTRA

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Introduction

Sincrotrone Trieste has been founded to design and construct a radiation source in the ultraviolet to soft X-ray range. It will be an insertion device dominated facility with a large number of straight sections for wigglers and undulators, with high flux of radiation from wigglers and high brilliance from undulators in the photon energy range from 10 eV to 1-2 keV.

These design goals will be achieved by a low emittance storage ring with beam energies between 1.5 and 2 GeV. The general layout of the accelerator facility is shown in figure 1. To minimize costs and to have a high injection rate available during machine operation electrons have been chosen as the accelerated particles. The injection system made out of a linear accelerator and a full energy booster synchrotron has been placed inside the storage ring to avoid interference with outgoing beamlines.

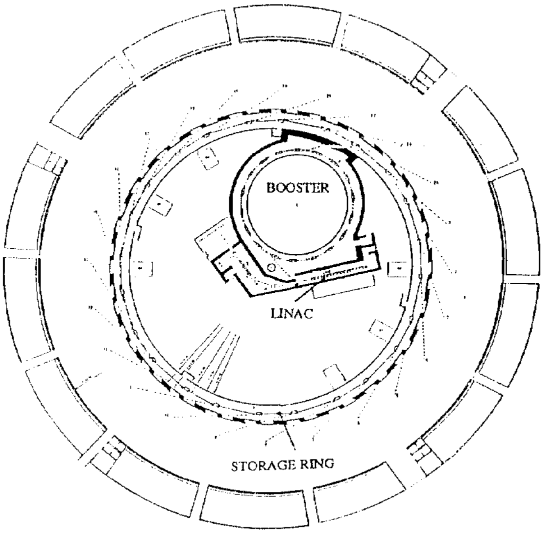

Fig.1 Layout of storage ring and injection system

The Lattice and its Performance

A double bend achromat structure has been chosen for ELETTRA. This choice has been made after a lattice comparison between different types of achromat lattices. Since there is no constraint in the circumference for ELETTRA, the magnet structure could be expanded inside the dispersive region to approach the minimum emittance of the Chasman-Green structure. A summary of relevant machine parameters is given in table 1.

Table 1 : Storage ring parameters

Achromat structure	Double Bend	
Number of achromats	12	
Insertion straight length	6	m
Circumference	259.2	m
Maximum beam energy	2	GeV
Natural emittance	$7.1\ 10^{-9}$	π m-rad
Natural energy spread, rms	$7.3\ 10^{-4}$	
Momentum compaction	$1.6\ 10^{-3}$	
Betatron tunes:		
Horizontal	14.3	
Vertical	8.2	
Natural chromaticities:		
Horizontal	-43.0	
Vertical	-13.9	
Beta functions at insertion symmetry point:		
Horizontal	8.0	m
Vertical	2.6	m

The performance of the linear lattice is deteriorated by various effects. Large strengths of sextupoles which are necessary to compensate the natural chromaticity, cause a reduction in dynamic aperture. It has been shown for ELETTRA[1] that the residual acceptance is more than sufficient to accommodate large amplitudes of Touschek scattered particles and beam-gas scattered particles respectively. The high flux of radiation requested from the users needs large beam currents which in turn enhances all adverse effects caused by large particle densities, such as Touschek scattering, collective single bunch and multibunch instabilities[2] (multiple intrabeam scattering is not a problem in the energy range from 1.5 to 2 GeV). Due to the small undulator gaps envisaged for ELETTRA elastic beam gas scattering becomes pronounced and to alleviate it an extremely low gas pressure in the range 1 to 2 nTorr must be achieved in the presence of the stored beam.

The choice of electrons has the adverse effect that under certain circumstances ions can be trapped inside the circulating beam which could enhance the local gas pressure and in turn decrease the lifetime and blow up the emittance. Extensive studies on this field have shown that for ELETTRA beam currents and beam emittances the beam forces are large enough to overfocus most of the ions and to release them from the potential of the beam, if a gap of 10 to 20 percent is introduced in the multibunch filling of the beam[3]. For the remaining stabilized ion masses, clearing systems have been investigated. Most promising is a system where the ions are excited at their resonance frequency. Whereas a constant field with 10 kV per meter is hardly capable of moving the ions some tens of microns, a resonant excitation in an electrical field of 1kV/m is sufficient to kick out the ions after 80 revolutions of the multibunch filling.

The enhancement of ion trapping in undulators has been investigated and it was found that depending on the longitudinal position of ion production within an undulator, an enhancement in trapping efficiency could be found[3]. Figure 2 shows the trapping efficiency inside an undulator for a highly unstable ion mass. The number of bunch train revolutions for which the ion survives, is drawn as a function of its initial coordinates. Without undulator the ion is immediately lost whereas with undulator the surviving time is greater than 300 revolutions (the maximum density in the figure corresponds to the computation limit of 300 revolutions). The nonlinear space charge force of the beam has been taken into account.

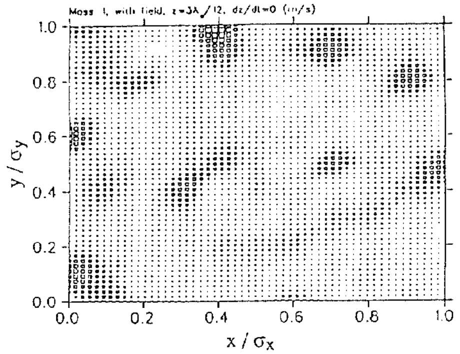

Fig.2 Ion trapping enhancement in undulators (the maximum density corresponds to 300 revolutions of the bunch train)

The effects of insertion devices on beam dynamics have been investigated for ELETTRA[4]. Insertion devices have intrinsic nonlinearities which deteriorate the dynamic aperture. Due to the vertical focusing generated by a plane undulator, the linear optics is vertically distorted and must be locally compensated if the distortions becomes too large.

Figure 3 shows the reduction in dynamic aperture if six insertion devices (1xW,2xU1,2xU2,1xU3), a possible scenario of the initial operation phase, are incorporated in the lattice. The stable amplitude areas for on momentum particles and off momentum particles with

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±4 % momentum deviation respectively are compared with the dynamic aperture for chromaticity correcting sextupoles only. For good Touschek lifetime a momentum acceptance of ±3% is more than sufficient.

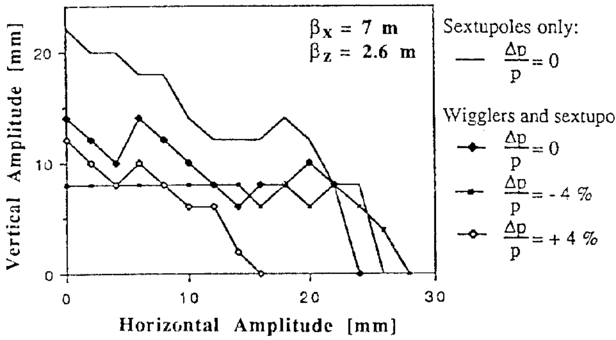

Fig.3 Dynamic aperture with chromaticity correcting sextupoles and insertion devices

Radiation Sources

For the initial operation phase up to seven beamlines, from bending magnets, different types of undulators and a 1.5 T wiggler, are foreseen. All insertion devices will be segmented, i.e. each device is made out of three sections with 1.5 to 1.6 m maximum lengths. Undulators will be of the pure permanent magnet type in order to avoid phase errors between the sections, whereas the wiggler will be of the hybrid type[5]. The wiggler has been designed with the constraint that the total power does not exceed 10 kW and the opening angle fits within the normal vacuum chamber. The detailed design of the undulators will be carried out after the beamlines have been defined. Table 2 gives a collection of parameters for representative undulators and the wiggler.

Table 2: Parameters of multipole wiggler and three representative undulators of the initial operation phase (at 2 GeV)

Type	B_0 [T]	λ_0 [cm]	K	N_{per}	P [kW]	P'' [kW/mrad^2]
W	1.5	12.5	17.5	38	9.9	3.6
U1	1.12	8.8	9.2	56	6.2	4.3
U2	0.65	5.6	3.4	89	2.1	4.0
U3	0.44	4.4	1.8	114	0.98	3.4

The bending magnet radiation has a critical energy of 3.2 keV and peaks around 0.9 keV. For the Wiggler an increase in flux by two orders of magnitude is achieved and it can supply 30 keV photons to X-ray users. The first, and third undulator harmonics cover a photon energy range from 10 eV to about 2 keV.

Storage Ring Magnets

The design of the storage ring magnets has been completed. The construction of a prototype quadrupole is currently under way and will be finished towards the end of March. There are 24 bending magnets with 1.44 m magnetic lengths, 108 quadrupoles with magnetic lengths of 0.25 to 0.5 m and 72 sextupoles with 0.14 or 0.27 m magnetic lengths. In addition 82 steering elements will be provided for orbit correction and local adjustment of beam position and angle for the radiation produced by insertion devices and bending magnets. The steering elements are designed to perform horizontal and vertical orbit correction at the same time. They are C-shaped and open on the lower side to allow the installation of a vacuum pump at the same position. Figures 4 and 5 show the bending magnet and a 0.5 m long quadrupole. All magnets will be mounted on two different types of girders, a long one for the bending magnet and the adjacent quadrupoles and sextupoles, and a short one for the elements around the achromat center.

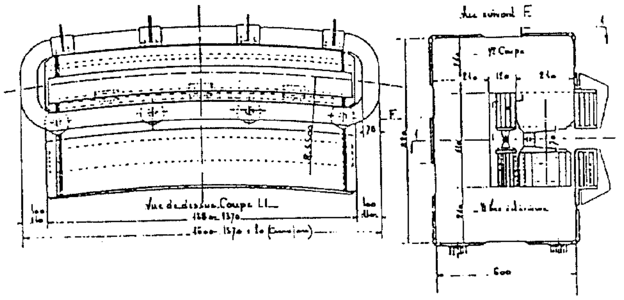

Fig.4 Storage ring bending magnet

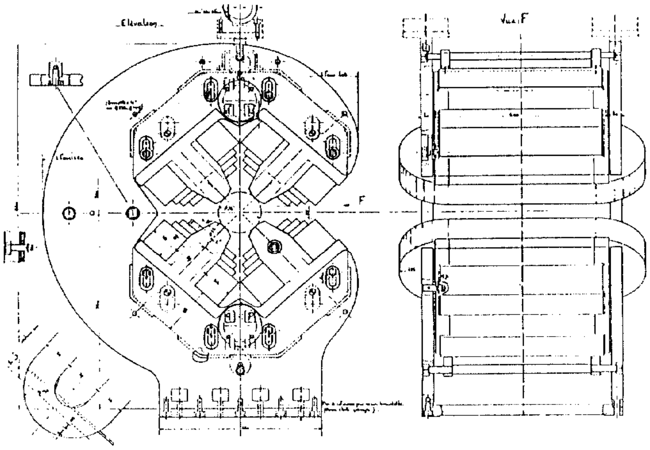

Fig.5 Storage ring quadrupole

Vacuum

A conventional solution for the vacuum chamber made out of stainless steel without antechamber has been chosen.The major part of the radiation will be absorbed by special photon absorbers and photon stoppers located at the end of each bending magnet. Top and side views of the chamber for the bending magnet beam line are shown in figure 6.

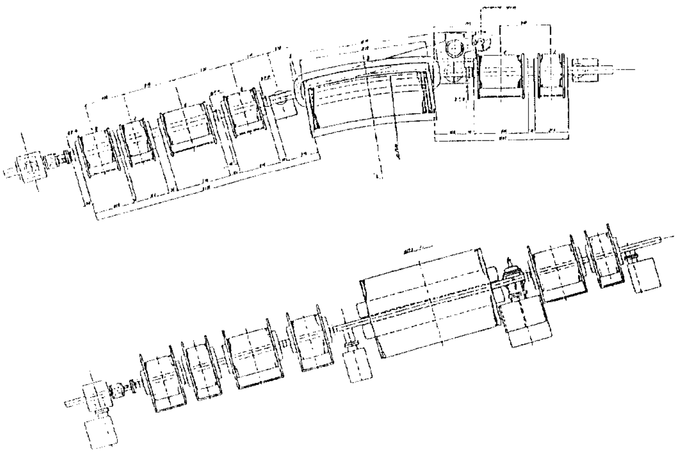

Fig.6 Vacuum chamber for the bending magnet beamline

The target pressure is less than 2×10^{-9} Torr for 400 mA beam current. This will be achieved by a pumping system made up of 84 (120 l/s) and 24 (240 l/s) sputter ion pumps distributed around the ring. In addition 24 high power (400 l/s) sputter ion pumps close to the absorbers and 24 NEG ribs of 1.5 m length inside the bending magnets assure efficient removal of the locally desorbed gases due to synchrotron radiation.

Radio Frequency

A frequency of 500 MHz has been chosen for the RF-system[6]. For radiation losses of 320 keV/turn a peak effective rf-voltage of 1.8 MV is necessary to provide enough momentum acceptance for Touschek scattered particles. Four cavities are foreseen, symmetrically arranged around the ring with a separate power system for each. The cavity has been designed to minimize multipactoring and to reduce the excitation of higher order modes in order to alleviate multibunch instabilities[7]. Its cross section is shown in figure 7. It is stamped out of 12 mm copper and then machined to a 4 mm thickness. The fabrication of the cavity body has been contracted to local Italian firms and the first prototype has just been delivered recently.

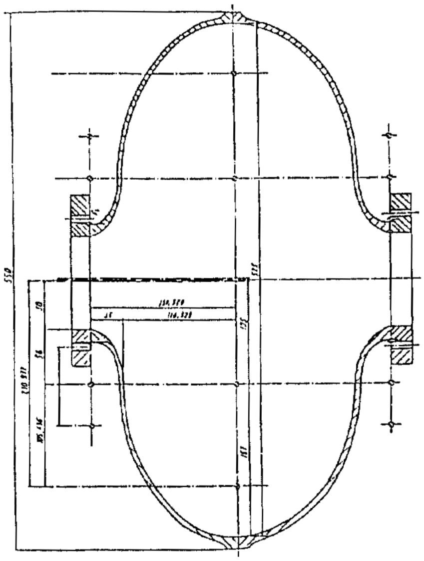

Fig.7 RF-cavity

Injection System

A full energy injection system has been provided for the storage ring. The first part is made out of a 100 MeV Linac which has been contracted outside to CGR-MeV [8]. The Linac has a 1 A thermionic gun, a 500 MHz chopper, a 500 MHz subharmonic buncher, a S-band prebuncher, a S-band buncher and two 3 GHz accelerating sections. The specifications of the Linac have also been selected with the intention of driving an infrared FEL.

The Linac is followed by a booster synchrotron working at 10 Hz. The magnet powering is performed by a classical White circuit resonant system for each magnet family. In table 4 the booster parameters are collected. The lattice follows the design of the SRS (Daresbury) storage ring. To reduce eddy current effects, the vacuum chamber is made out of 0.3 mm stainless steel, reinforced by ribs brazed onto the chamber.

Table 3 : Booster main parameters

Circumference	100.8	m
Nominal energy	2	GeV
Natural emittance, rms	1.1 10^{-7}	π m-rad
Natural energy spread, rms	6.6 10^{-4}	
Momentum compaction	0.015	
Betatron tunes		
Horizontal	5.18	
Vertical	3.22	
Natural chromaticities		
Horizontal	-5.9	
Vertical	-4.9	
Maximum beta functions		
Horizontal	8.2	m
Vertical	10.2	m
Maximum horizontal dispersion	1.0	m

Instrumentation

The beam instrumentation which will be ready for the commissioning of ELETTRA is composed of one current monitor, a synchrotron radiation beam profile monitor, 6 destructive monitors, two horizontal and vertical scrapers, a betatron tune measurement system and 96 beam position monitors. Special attention has been given to the beam position monitors, since orbit stability and reproducibility is of paramount importance for the optimum functioning of the radiation source. A beam position monitor is attached to eight out of the nine quadrupoles of each achromat. The design of the monitor with its support system is shown in figure 8.

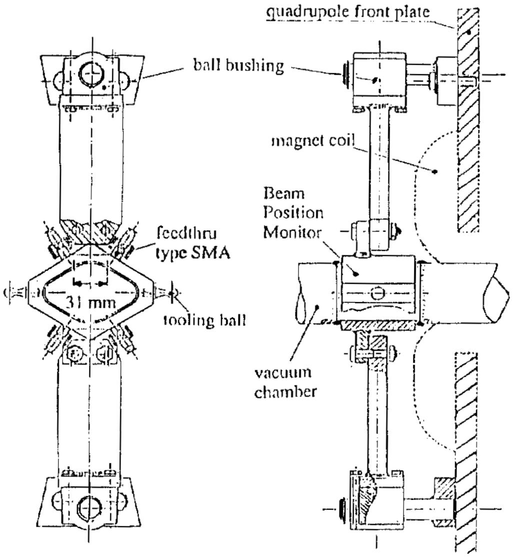

Fig.8 BPM and its support attached to a quadrupole.
Two ball bushings hold strongly the BPM position transversally and leave it free longitudinally.

Control System

A fully distributed control system has been chosen for ELETTRA. Extensive use of standards and commercial products will be made. The hierarchical system is made out of two network layers, Ethernet running the DARPA TCP/IP protocols[9] and a multidrop highway running a data acquisition oriented protocol. The computer system may be split into three layers, the operator console made up of UNIX workstations, the local process computer and the equipment interface unit both composed of VME [10] and Motorola 680xx based assemblies running a real time operating system.

Acknowledgement

The present work is a result of the Machine Division of Sincrotrone Trieste, which has reached 51 persons now. We would like to thank Prof. C.Rubbia, the president of Sincrotrone Trieste.

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