A FULL-ENERGY-INJECTOR FOR THE ANKA STORAGE RING

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Abstract

The design of a full energy injector for the ANKA storage ring is presented. The injector will be housed inside the storage-ring in the same tunnel, comparable to the SLS and ALBA lay-out. The optics is based on vertical focussing gradient magnets and horizontal focussing quadrupole. The emittance is 40 nmrad and the circumference is 96 m. In addition a modification of the storage ring is foreseen to house the more powerful injection elements.

INTRODUCTION

At present the ANKA storage ring is filled at 0.5 GeV and then ramped to 2.5 GeV for regular user operation. A full-energy injection of the ANKA storage ring would have several advantages. The damping at a beam energy of 2.5 GeV is stronger, therefore reducing instabilities during the injection and thus allowing higher beam currents. The injection time would be reduced and topping-up operation possible. With constant settings of the storage-ring magnet, the orbit stability would improve significantly. The optical elements of the user beamlines would also see a constant power versus time, which further enhances the overall stability.

The type and location of the preamplifier is in discussion. It could be a stand alone linac or a microtron or by using the SC linac of the TBONE project [1]).

LOCATION

The presented proposal foresees to install the booster inside the storage ring. This has the advantage that no separate building is needed and no beamlines are affected by a tunnelled transfer line from the outside. The disadvantage might be a longer shut down of the storage ring. However a longer shut down period is needed for several reasons:

For an injection at 2.5 GeV the radiation level will be considerable higher, which will make the present shielding with only an outer wall no longer tolerable and a tunnel has to be installed.

Due to the tunnelled transfer line from an external booster, some beamlines would have to be modified.

Because of the more powerful and thus larger injection elements the location of the injection has to be moved to a longer straight section, foreseen for an insertion device. Alternatively, the magnetic structure has to be changed to get more space in the present small straight section. This is studied and proposed and in addition. The modified optics is also more convenient for insertion devices, having smaller betas both in horizontal and vertical direction in all straight sections.

BOOSTER OPTICS

Different optics have been studied: Two fold symmetric and four fold symmetric. The four fold structure is better matched to the four fold storage ring symmetry and also gives better results concerning the performance of the optics. Further studies have been a classical FODO structure as in ELETTRA [2]), a structure with gradient dipoles for both vertical and horizontal focussing as in SLS [3]) and ASP [4]) and gradient dipoles for vertical focussing only, as at ALBA [5]). The classical FODO structure gave a rather large emittance of 150 nmrad. When gradient magnets are used, the emittance is in the order of 40 nmrad. The structure with gradient dipoles for the vertical focussing gives a better performance for the extraction. The beta functions for this optics are shown in Figure 1, the main parameters are given in Table 1.

Calculation show that a gradient error of 5% can be compensated by adjusting the three quadrupole families while keeping the same tune and having minor effects to the beta function. Also a variation of the tunes within +/- 0.25 is feasible.

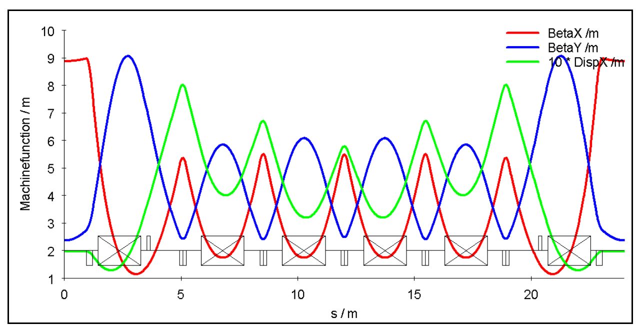

Figure 1: Beta functions for one quart of the ANKA full energy booster with vertical focussing gradient dipole.

Table 1: Parameters of the full energy booster

Energy	2.5	GeV
Emittance	40	nmrad
Circumference	96	m
Period	4	
Repetition rate	1	Hz
Energy loss per turn	494	keV
Mom. compaction	.028	
Tune (h/v)	5.8 / 3.7	
Nat. chromaticity	-7 / -4	
Damping Times ((h,v,l)	1 / 3 / 12	ms

CHROMATICITY CORRECTION

The natural chromaticities of -7/-4 can be compensated by introducing additional sextupole components into the dipoles and focussing quadrupoles. The changing field in the dipole during the ramp induces eddy currents into the vacuum chamber [6]), corresponding to a sextupole component of m = 0.2 m^{-3}, compared to the m = -0.9 m^{-3} strength for compensating the natural chromaticity. Having the chromaticity compensated every time during the ramp will afford at least additional separate vertical focusing sextupoles. Calculations of the dynamic aperture were done with and without the separate sextupoles and are shown in Figure 2. It turned out that the dynamic aperture is larger then the physical aperture in all cases. Thus these additional sextupoles might not be needed.

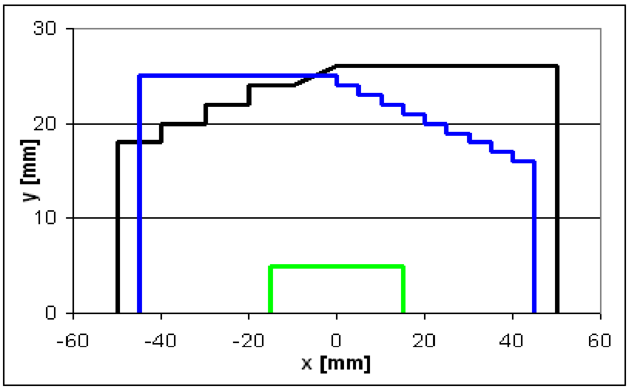

Figure 2: Dynamic aperture for 'eddy-current-sextupoles' only (black) chromaticity -5/-10. Chromaticity corrected to 1/1 (blue), and acceptance (green).

VACUUM SYSTEM

The vacuum system will be made with a round profile in the straight sections (diameter 35 mm), and an elliptical profile in the bend section (external width 40 mm, height 22 mm). The thickness will be 1 mm or less. Pumping will be done by small 20 l/s diode pumps, two at each end of the 24 dipoles plus additional pumps in the longer straight section.

MAGNETS

24 Dipole magnets with gradient are used for deflection and vertical focussing. The magnets will be produced using laminated 0.5 mm low carbon steel. Table 2 gives the main parameter of the gradient dipole. Figure 3 shows the cross section and calculated field distribution.

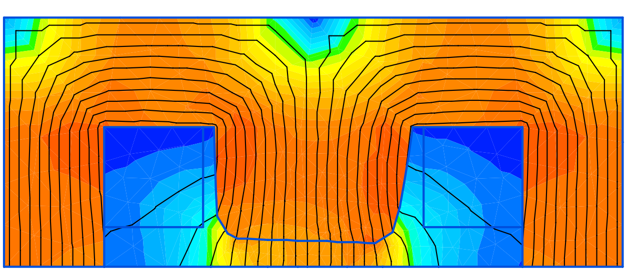
Figure 3: Magnetic field plot of the gradient magnet.

Three families of quadrupoles will be used for the main horizontal focussing, the horizontal and the vertical matching to the long straight sections and tune adjustment. The families have different length but the same profile. Table 3 gives the main parameters.

Table 2: Main Parameter of the gradient dipole

Number of Magnets	24	
Deflection radius	7	m
Deflection angle	15	°
Arc Length	1.833	m
Gap	26	mm
Maximum field	1.19	T
Gradient	3	T/m

Table 3: Main Parameter of the quadrupoles

Number per family	20 / 8 / 8	
Length	0.3 / 0.3 / 0.15	m
Bore-diameter	40	mm
Maximum Gradient	20 / 14 / 9	T/m

RF SYSTEM

The energy loss due to SR radiation losses at extraction is 490 kV. With an over-voltage factor of 1.5 about 750 kV should be provided. This can easily be achieved with a PETRA 5 cell cavity. With a shunt impedance of 15 MΩ ($R = U^2/(2P)$) the required power is 19 kW for the cavity plus 5 kW for the beam, which can be provided by an IOT or a semiconductor amplifier system.

BOOSTER TO STORAGE RING TRANSFER LINE

For extraction out of the Booster a kicker will be positioned between the last dipoles before the extraction septum. A 4 mrad kick allows an extraction without the need for bumper magnets. The extraction orbit is shown in Figure 4. The transfer of the e-beam from the Booster to the storage ring shall be achieved by three 14° bends, one 11° septa for extraction and two 7.5 ° septa for injection into the storage ring plus corresponding quadrupole doublets. Due to the limiting space in the injection section of the storage ring a larger deflection by septa is needed. The separation into two septas has been done to limit the necessary pulsed voltage. Figure 5 shows the beta functions for the transfer line.

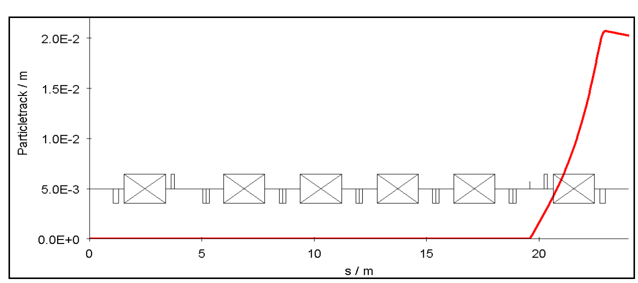

Figure 4: Extraction orbit followed by a 4 mrad kick.

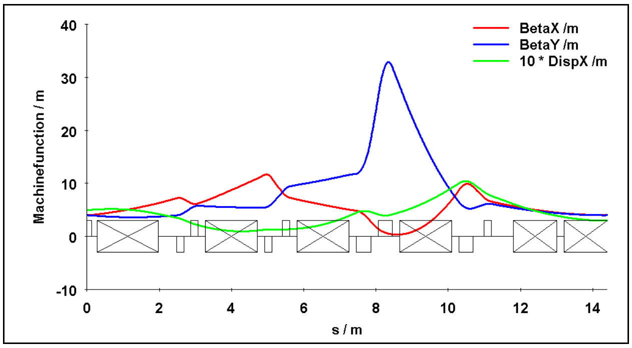

Figure 5: Beta functions for the booster to storage-ring transfer-line.

MODIFICATION OF THE STORAGE RING OPTICS

Main motivation for a different storage ring optics is to provide more space for the larger injection elements of the full energy injection system. As a constraint the position of the dipole and thus the location of the beamline ports have been kept as they are now. The additional space can be achieved by replacing the present dipoles by combined function dipoles. This allows having only focussing quadrupoles in the injection sections (the defocusing quadrupoles have been moved into the bends). Additional smaller vertical focussing quadrupoles are needed for tune correction within the cells. Besides these additional new small quadrupoles all present quadrupoles will be used but moved to different locations. Figure 6 shows the beta functions for the modified storage ring optics, Table 4 shows the main parameters. The modified optics has the additional advantage of having smaller beta functions for the long sections in both vertical and horizontal plane and is thus better adopted for insertion devices. The dynamic aperture is shown in Figure 7 as a frequency map together with the tune points. The dynamic aperture is horizontally smaller compared to the present optics, but still acceptable and could be improved by further optimization. A layout of one quart of the modified ANKA storagering and full energy injector is shown in Figure 8.

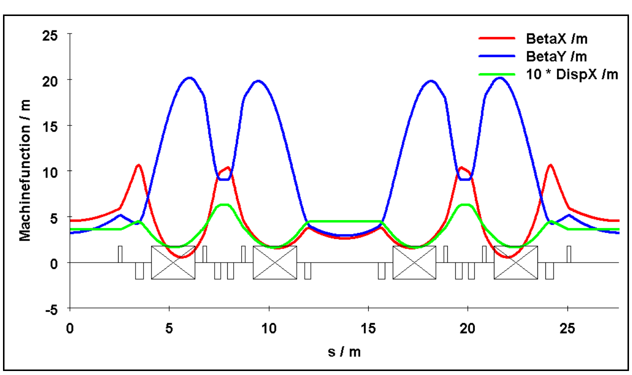

Figure 6: Beta functions for the modified ANKA storage ring optics.

Table 4:Parameter of the modified ANKA optics

Energy	2.5	GeV
Emittance	40	nmrad
Circumference	110.4	m
Energy loss	622	keV
Mom. compaction	.012	
Tune (h/v)	6.8 / 2.7	
Nat. chromaticity	-10.2 / -6.7	

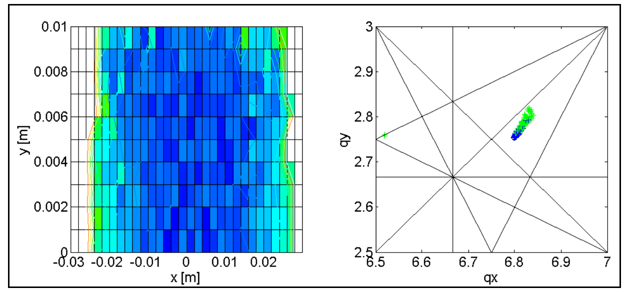

Figure 7: Dynamic Aperture of the modified ANKA storage ring optics and frequency map. Colour code for diffusion: red: > 10^{-3}, green: 10^{-3} – 10^{-6}, blue: < 10^{-6}.

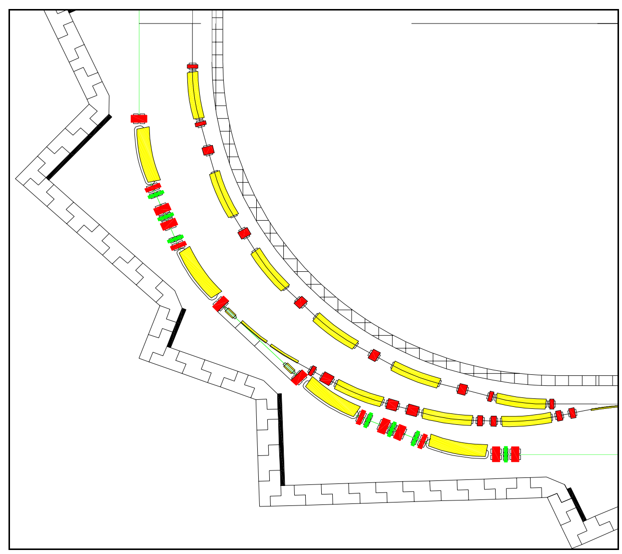

Figure 8: Layout of one quart of the modified ANKA storage ring and full energy injector.

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