A Low Vertical β Mode for the LNLS UVX Electron Storage Ring

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Abstract

An operation mode with low vertical betatron function in one of the long dispersion free straight sections of the LNLS UVX Electron Storage Ring is studied for applications with small gap insertions. The flexibility of this lattice is analyzed regarding two aspects: the range of variation of the vertical betatron tune and the ability to set the betatron functions to high/low values in the insertion straights.

1. INTRODUCTION

The LNLS UVX electron storage ring is a 1.15 GeV six fold symmetric double bend achromat lattice[1]. Some of its parameters for the nominal operation mode are given in table 1. To meet the need of different kinds of experiments, other operation modes are foreseen, including a low vertical beta mode envisaging the use of micro-undulators or other devices with very small gaps.

Table 1: Main Parameters of the UVX storage ring for nominal operation mode.

Energy	1.15	GeV
Current	100	mA
Circumference	77.3977	m
Magnetic Structure	CG-6-fold	
Revolution Frequency	3873.17	kHz
Harmonic Number	129	
RF-Frequency	500	MHz
Natural Emittance	63.4	nm.rad
Horizontal betatron tune	5.23	
Vertical betatron tune	2.12	
Synchrotron tune	4.054	1/1000 (@108 kV)
Momentum Compaction	0.010	
Natural energy spread	0.059	%
Nat. hor. chromaticity	-8.3	
Nat. vert. chromaticity	-6.2	
Hor. betatron damping time	11.0	ms
Ver. betatron damping time	10.5	ms
Synchrotron damping time	5.1	ms
Dipoles		
Bending radius	2.735	m
Bending field	1.4	Tesla
Number	12	
Quadrupoles		
Number of families	4	
Number	42	
Sextupoles		
Number of families	4	
Number of sextupoles	42	

2. LOW VERTICAL β MODE

We have investigated an operation mode with low vertical beta function in one of the long dispersion-free straight sections that could be achieved by continuously transfering the configuration of the lattice from the normal operation mode. This requires that no resonance lines are crossed during the process. This scheme has the advantage of circumventing the need to establish new injection conditions in this mode.

The proposed mode can be accomplished in this lattice by independently powering the quadrupole doublets adjacent to the low β straight. The lattice functions for 3 superperiods of the ring are shown in figure 1. The vertical beta is matched to 0.69 m in the small gap insertion straight, a factor of 10 smaller than the value for the normal operation mode. Both the vertical and the radial tunes, as well as the emittance are kept the same as in the normal operation mode. The reduction in the vertical beta in the insertion straight causes the vertical phase advance to increase across this region. To keep the same tune, the vertical phase advance over the achromat must be reduced. This is not the case in the horizontal plane: the change in horizontal beta is very small, not significantly affecting the horizontal phase advance in the achromat, and this is the reason why the emittance of the lattice in this mode (ε_0=6.4 x 10^{-8} rad.m.) does not change.

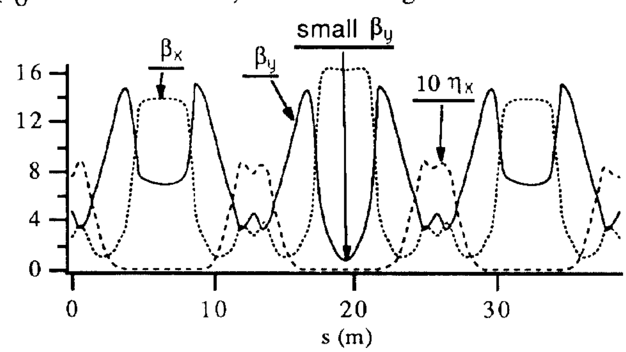

Figure 1: Lattice functions for three superperiods of UVX in the low vertical β mode.

We look now at the various dimensions at the point where β=0.69 m. The residual vertical emittance after closed orbit correction in ten simulations for the normal operation mode [1] is ε_y=(0.10±0.11) x 10^{-9} rad.m. and the maximum residual vertical orbit distortion y_{max}=0.19±0.06 mm. We assume the mean values plus 3 standard deviations, i.e, ε_y=0.43 nm.rad and y_{max}=0.37 mm. With these values the vertical beam size is σ_y=0.017 mm giving for a very small gap insertion, say, 2 mm, a distance of 95 σ from the center of the displaced closed orbit to the insertion wall. At 69 cm

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from this point of minimum, the vertical betatron function doubles its value and the beam size increases by a factor of 1.4. It is also interesting to note that the β scaled physical aperture at the small β symmetry point is 1.3 mm; thus any gap greater than this value will not limit the vertical acceptance of the ring.

Dynamic aperture studies are performed with the code PATPET[2]. The two families of sextupoles placed in the dispersion-free region are used to improve the dynamic aperture, which can be made as large as the dynamic aperture of the normal mode. Particles are tracked for 500 turns. The effect of systematic and random multipole errors and random strength and alignment errors are simulated. The tolerances and error distributions are the same as the ones used in the normal operation mode. Figure 2 shows the dynamic aperture at the midpoint of the long dispersion-free, high beta straight section. The hatched regions correspond to the uncertainty area of dynamic aperture for 5 different sequences of random errors.

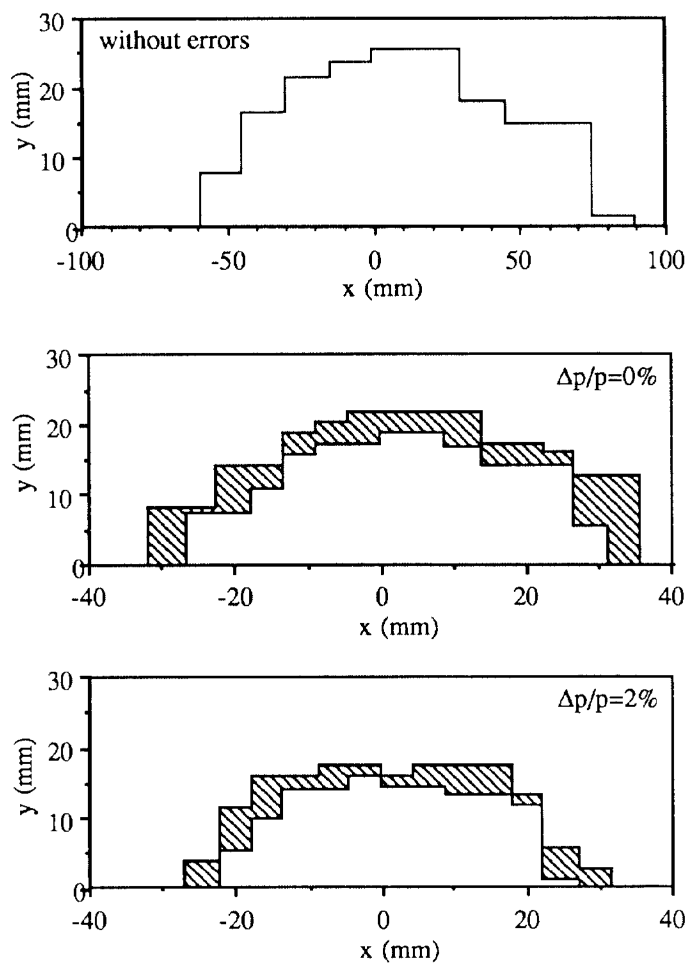

Figure 2. Dynamic aperture at the midpoint of the dispersion-free, high beta straight section for the low vertical beta mode. The upper graphic shows the dynamic aperture for the machine without errors and the other two show the dynamic aperture including the errors described in the text. The last figure also includes 2 % momentum deviation.

Since a large dynamic aperture is not required for injection in this mode, we analyse it from the viewpoint of the beam lifetime.

2.1 Beam Lifetime

A thorough analysis of collective effects and lifetime limitations for the low-ß operation mode has not been carried out yet. Nevertheless, we do not expect to observe significant deviations from the characteristics of the normal operation mode, since all lattice parameters (momentum compaction, damping times, natural emittance, average beta functions) for both modes are quite similar, so that instability thresholds and equilibrium bunch dimensions should not vary much. The main difference lies in a slightly reduced dynamic aperture and a slightly smaller physical vertical acceptance(essentially due to the higher values of the vertical ß function in the bending magnets). The former can significantly alter the Touschek contribution to the overall lifetime, whereas the latter only influences the lifetime due to elastic scattering of residual gas molecules. Since the cross-section for this process decreases sharply with energy, it should not be very important at full energy. In order to check these assertions, a calculation that consistently takes into account bunch lengthening due to microwave instability and potential-well distortion for an assumed 13 Ω ring broadband impedance and emittance growth due to intrabeam scattering was carried out with the computer code ZAP[3] to determine the expected overall lifetime for one single set of operating parameters (RF voltage = 600 kV, bunch current = 3 mA, emittance coupling = 10%). The Touschek lifetime is reduced from 80 hours (normal mode) to 59 hours, whereas the gas scattering contribution remains essentially constant, the overall lifetime being in both cases ~ 18 hours.

3. FLEXIBILITY OF THE UVX LATTICE

The flexibility of the UVX lattice is analyzed regarding two aspects: the range of variation of the vertical betatron tune and the ability to set the betatron functions to high/low values in the insertion straights.

The inclusion of insertion devices in the ring affects the beam in various aspects. In the case of wigglers and undulators with plane poles, the edge-focussing of these poles produces a vertical betatron tune shift which must be compensated to ensure operation far from resonances. A plane pole insertion device with length L and bending radius ρ produces a vertical tune shift

$$\Delta\nu_y = \frac{1}{4\pi}\beta_y\frac{L}{\rho^2}$$

where β_y is the betatron function at the wiggler position, assumed to be constant over the length of the magnet. A 1 m, 2 Tesla wiggler increases the vertical tune by 0.14; and a 25 cm, 5 Tesla one by 0.22. Let us take a worst case estimate of $\Delta\nu_y$=0.4. The UVX lattice can be tuned to compensate this vertical tune-shift without changing the horizontal tune. Larger tune shifts were not investigated up to now.

It is always desirable to set the betatron values in the insertion straights to values suitable for particular applications. Compared to a previous design (VUV-III) [4], UVX has an extra quadrupole family in the dispersive region. This allows for the changing of the betatron function in the insertions while keeping the same tune. An example is the low vertical beta mode described above. Lowering the horizontal beta while keeping the tune has the price of increasing the emittance. Further flexibility to tailor the beta values can be achieved using quadrupole triplets to match the betatron functions in the insertion regions.

4. REFERENCES

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