DYNAMIC APERTURE, COMPARISON OF MEASUREMENTS ON ELETTRA WITH SIMULATIONS

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ABSTRACT

Limitations in dynamic aperture have always been a major concern for third generation light sources. The presence of strong chromaticity correcting sextupoles and the extensive use of insertion devices introduce highly non-linear fields which may effect the maximum stable amplitudes, reducing thus the performances of the storage ring. In this paper, the results of dynamic aperture measurements on ELETTRA are presented and compared with simulations.

1 INTRODUCTION

ELETTRA is the Italian 2.0 GeV third generation synchrotron light source which is fully dedicated to user operation[1] since January '95. The facility is composed of a Linac operating at 1.0 GeV, a Transfer Line and a Storage Ring, ramped to 2.0 GeV after injection. The lattice of the Storage Ring is of the expanded Chasman-Green type[2] composed of twelve double bend achromats, yielding an emittance of 7.1 π nm rad at 2.0 GeV. The horizontal and vertical tunes of the machine are 14.3 and 8.2 respectively and the optical functions are shown in Figure 1 for one achromat.

A characteristic of third generation light sources consists in the presence of strong focussing quadrupoles, giving thus rise to fairly large natural chromaticities, which are for ELETTRA -43.0 horizontally and -14.0 vertically. In order to compensate for these, two strong families of sextupoles were placed in the dispersive arc, introducing thus non-linear effects in the particle dynamics. An additional harmonic sextupole family was introduced in the dispersive-free straight sections in order to minimize the non-linear effects and enlargen the dynamic aperture. Another characteristic of these machines is the extensive use of insertion devices, introducing thus

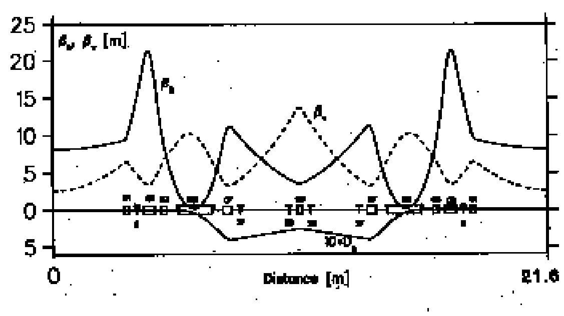

Figure 1. Theoretical Beta Functions in one Achromat

Table 1
Insertion Device Parameters

ID	No. Periods	λ [mm]	Bo [T]
U5.6	81	0.056	0.42
U12.5	36	0.125	0.51
W14.0	30	0.140	1.50
U12.5	36	0.125	0.43
U8.0	19	0.080	0.71

optical symmetry breaking and additional non-linear fields, both of which may have deleterious effects on the dynamic aperture. In ELETTRA, insertion devices may be accomodated in eleven of the straight sections, where additional quadrupole families might be used to compensate the devices' linear distortions on the lattice. At the present day, five insertion devices, whose main parameters are reported in Table 1, are fully operational[3]. All linear distortions measured on the machine are consistent with those predicted by theory and currently only the linear tune shift is being compensated for operations.

One of the major concerns during the design, and which is even more in case of a fourth generation light source, has always been the eventual limitation in dynamic aperture due to the presence of the sextupoles and of the insertion devices. In this respect, many dynamic aperture computations had been made in order to guarantee a sufficiently large dynamic aperture which would not compromise the machine's performances. One of the major unknowns during these simulations was how appropriate was the model used for the insertion devices and to which degree the results would then reflect reality.

In this paper the results of dynamic aperture measurements on the Storage Ring are compared to results coming from simulations. The measurements of the dynamic aperture were done with a scraper situated in a straight section and recording the istantaneous current decay rate $1/\tau$ as a function of its blades' positions. All simulations were done using the code RACETRACK[4] where 100 particles were tracked over 500 turns. In order to ensure a correct rappresentation, the simulations were done reflecting the actual status of the machine when the dynamic aperture measurements were made. In particular, the tunes were matched to the actual values and the vacuum chamber limitations were introduced[5].

2 SEXTUPOLES

Several studies have been done on the effect of the pre-

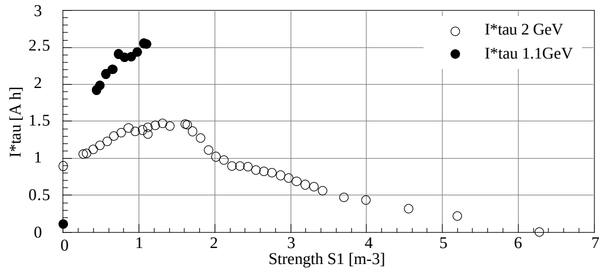

Figure 2. The beam current x lifetime as a function of the harmonic sextupole's strength.

sence of the harmonic sextupole. Simulations have always shown an significant increase in the dynamic aperture, especially in the horizontal plane, when the magnet was included. One of the first concerns was to verify that the theoretically computed strength of -1.1 m^{-3} was effectively the optimal one. Lifetime was recorded as a function of its settings both at injection energy and at 2.0 GeV. The results may be seen in figure 2, where the beam current x lifetime is plotted versus the sextupole's strength in absolute value. It might be without doubt stated that the sextupole is rather well optimized at the theoretical value.

Also horizontal and vertical dynamic aperture measurements have been carried out. Figure 3 shows the results as $\ln(1/\tau)$ versus $\ln(1/A^2)$, with A being the blade position of the scraper, in the horizontal plane. The inclusion or not of the harmonic sextupole makes a difference of 10 mm in the maximum horizontal stable amplitude. A measurement in the vertical plane exhibited a 2 mm reduction, coinciding well with the results of the simulations.

3 INSERTION DEVICES AND SEXTUPOLES

Since insertion devices give rise to linear and non-linear effects which scale inversely with the square of the energy, dynamic aperture measurements were done both at the injection energy of 1.0 GeV and at the operating energy of 2.0 GeV. Since the effects are mainly in the vertical plane, most of the results shown will refer to this plane, unless otherwise stated. All measurements were performed with a beam current of 100 mA and care was taken that both tunes were always kept constant.

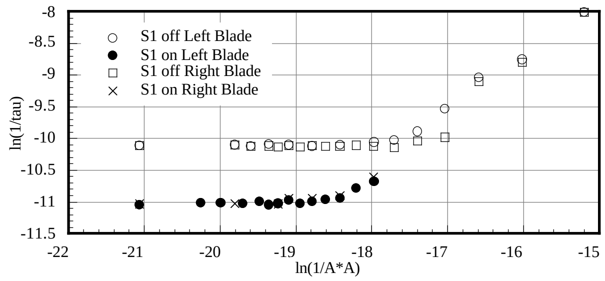

Figure 3. Horizontal dynamic aperture with and without the harmonic sextupole.

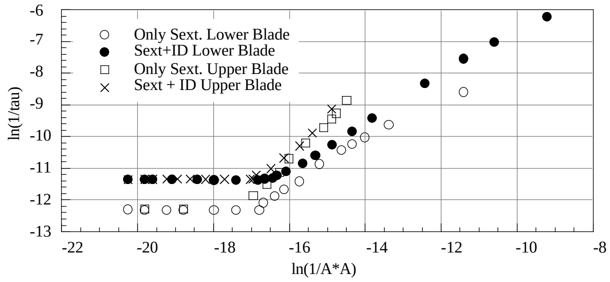

Figure 4. Vertical dynamic aperture measurement at 1.0 GeV with and without the insertion devices.

Figure 4 illustrates the results of the dynamic aperture measurement with and without the insertion devices at 1.0 GeV. A reduction of 1 mm in the maximum stable amplitude has been extracted from the data when the insertion devices are closed to their minimum gaps. In order to understand the cause of the reduction, a second series of measurements were done with first only the wiggler at minimum gap and then only the undulators. The results are reported in figure 5, wich demonstrate that both contribute to the total reduction by roughly 0.5 mm each. Figure 6, instead, illustrates the results of the measurement with and without the insertion devices at 2.0 GeV. At this energy no reduction in the maximum vertical stable amplitude was observed. Also at 2.0 GeV, a horizontal dynamic aperture measurement was performed showing a reduction of 1 mm.

The result of tracking particles in the same machine conditions is shown in figure 7 for the two energies. It can be seen that the simulations reflect quite well the reductions observed on the machine. Furthermore, simula-

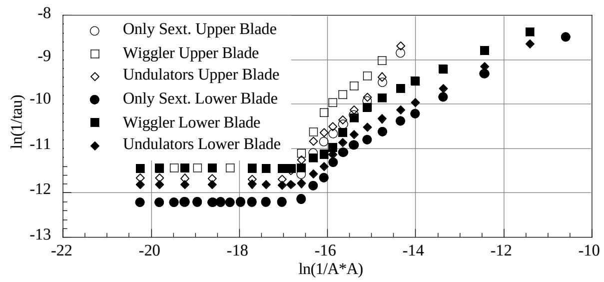

Figure 5. Comparison of dynamic aperture measurements to investigate the relative effects of the insertion devices.

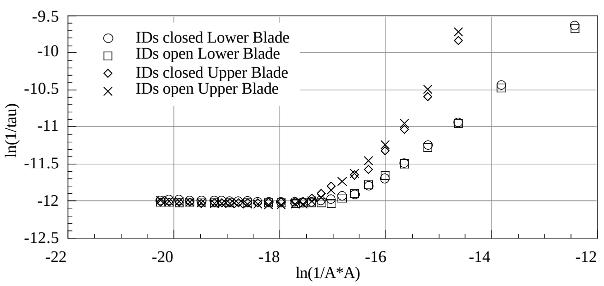

Figure 6. Dynamic aperture measurement with and without the insertion devices at 2.0 GeV.

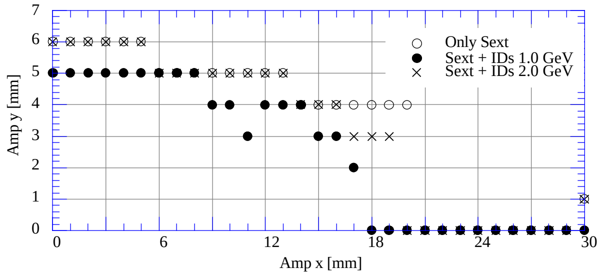

Figure 7. Results of tracking with and without insertion devices at 1.0 and 2.0 GeV.

tions at 1.0 GeV with only the wiggler and with only the undulators also confirmed the 0.5 mm contribution of each.

4 CONCLUSIONS

From comparing the results of the measurements with those from the simulations, it can be concluded that a prediction of the dynamic aperture affected by insertion devices is reliable. Even though the exact maximum amplitude may slightly be different between reality and simulations, the relative reductions in dynamic aperture agree very well.

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