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OPTICS CALIBRATION AND MEASUREMENT FOR LOW ALPHA LATTICES IN TPS STORAGE RING

F. H. Tseng†, C. C. Kuo, C. H. Chen, J. Y. Chen, Y. C. Liu, H. J. Tsai, C. C. Liang, C. H. Huang, P. C. Chiu and C. Y. Liao
NSRRC, 101 Hsin-Ann Road, Hsinchu Science Park, Hsinchu 30076, Taiwan, R.O.C.

Abstract

In order to provide short-pulse radiation for pump-probe experiments and coherent radiation for IR/THz measurements, we developed low alpha lattices to reduce the momentum compaction factor from nominal operation values 2.4×10^{-4} to 2.6×10^{-5} or lower. The corresponding bunch length at 2.8 MV RF voltage and zero current are from 10.78 ps to 3.55 ps or less. In the low alpha operations, the bunch lengthening as a function of bunch current, the orbit drift and noise enhancements as well as RF stability effect are observed. In this report we will present our studies on the lattice design, optics correction, beam parameters measurements and alpha measurements.

INTRODUCTION

By using short pulse beam in an electron storage ring, one can generate coherent IR/THz sources and provide time-resolved experiments. There are several approaches to generate short pulse beam in a storage ring, e.g. lower beam energy, low alpha lattice configurations, laser sliced beam, crab-cavity defected beam, high RF frequency and potential, and different RF frequency and potential combinations, etc. [1].

An economical way to generate short pulse beam is by using low alpha mode operation. Until now, there are several light sources in routine operations. However, bunch current is limited due to low current threshold of bunch lengthening, hence resulting in significant reduced photon flux and brightness. Nevertheless, such an operation mode is still of much interest for a number of potential users [1].

We have commissioned several low alpha lattices recently. In this paper, we will present two kinds of lattices. One is high emittance, low alpha lattice. The other is low emittance, low alpha lattice.

LOW ALPHA LATTICE FUNCTION

High Emittance, Low Alpha Lattice

We can obtain low alpha lattices with high emittance by changing the dispersions to negative values in the straight sections and crossing zero in dipoles. The lattice design code MAD [2] is used to match the optical functions, tunes and alphas. But two family of sextupoles need to be reversed in polarity. A number of lattices with very small positive and negative alphas down to 1×10^{-5} or less can be matched. Figure 1 shows optical functions of one high emittance, low alpha lattice. The emittance is 37.2 nm-rad and the bunch length is 4.5 ps at 2.8 MV RF voltage (shown in Table 1) [1].

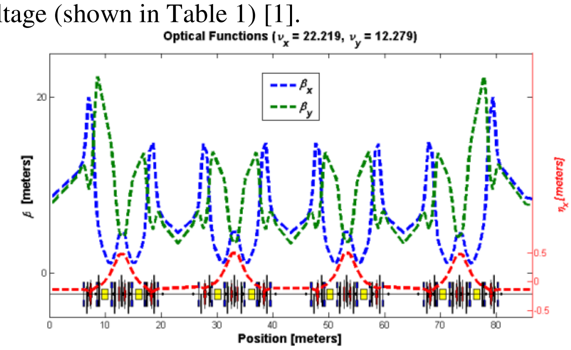

Figure 1: Optical functions for high emittance, low alpha lattice.

Low Emittance, Low Alpha Lattice

We can get low alphas with low emittance lattices by keeping dispersion positive in the straights and getting both positive and negative dispersions inside dipoles. The working tunes are higher than the high emittance lattice in the horizontal plan but smaller in vertical. Figure 2 shows the optical functions of one low emittance, low alpha lattice. The emittance is 2.9 nm-rad and the bunch length is 3.5 ps at 2.8 MV RF voltage (shown in Table 1) [1].

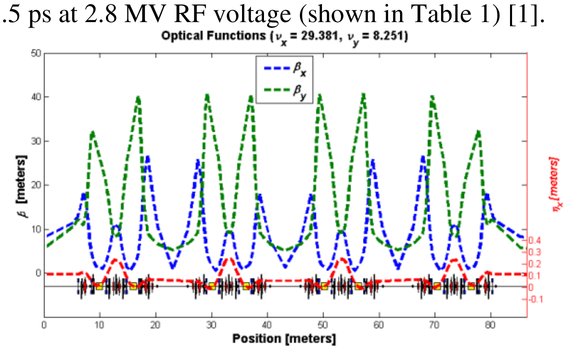

Figure 2: Optical functions for low emittance, low alpha lattice.

Table 1: Beam Parameters of the Low Alpha Lattices

Parameter	High Emittance	Low Emittance
Emittance (nm-rad)	37.2	2.9
α_1	4.2×10^{-5}	2.6×10^{-5}
α_2	-1.9×10^{-3}	7.2×10^{-4}
ν_x / ν_y	22.219 / 12.279	29.381 / 8.251
σ (ps), RF = 2.8MV	4.5	3.5
Natural Chrom. ξ_x /ξ_y	-35.6 / -21.6	-65.2 / -46.0

† tseng.fanhsin@nsrrc.org.tw

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OPTICS CORRECTION RESULTS

High Emittance, Low Alpha Lattice

After beam was stored during commissioning, we conducted optics correction by LOCO [3-4]. Before the optics correction, the beta beating was 8.157% rms in horizontal and 18.985% rms in vertical respectively, as shown in Fig. 3 and 4. The beta beating was reduced to 1.958% rms in horizontal and 0.519% rms in vertical after two iterations. More iterations in LOCO procedure can further reduce the optics errors.

Table 2 shows the comparison of optics correction results. Before optics correction, the tunes in both planes are far away from the design values, especially the horizontal tune. The horizontal and vertical tunes are close to the design value after optics correction.

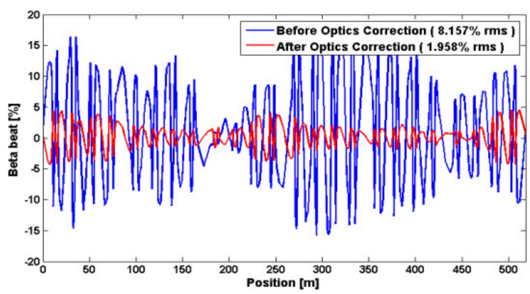

Figure 3: Beta beating of the high emittance, low alpha lattice in the horizontal plane.

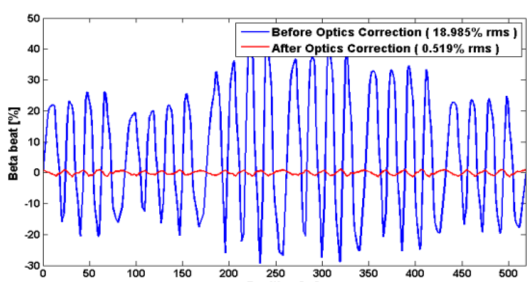

Figure 4: Beta beating of the high emittance, low alpha lattice in the vertical plane.

Table 2: Optics Correction Results of High Emittance, Low Alpha Lattice

	Tune X	Tune Y
Design Value	22.219	12.279
Before Correction	22.251	12.286
After Correction	22.224	12.281

We also measured the dispersion functions after optics correction as shown in Fig. 5. The vertical dispersion in the real machine is mainly due to coupling. In order to correct the horizontal and vertical dispersion simultaneously, we need to use skew quadrupoles in LOCO correction. After correction, the dispersion symmetry was restored and the vertical dispersion was smaller. As shown in Fig. 6, the vertical beam size was reduced from 35.9 um to 30.8 um after coupling correction. In the same way, the horizontal beam size was reduced from 241.8 um to 235.8 um.

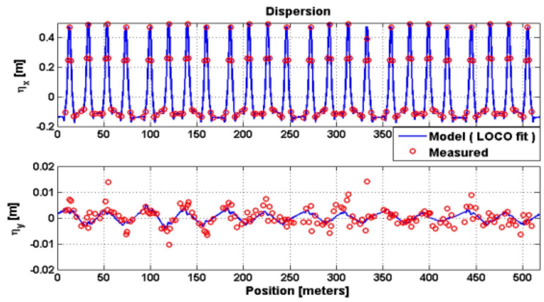

Figure 5: Dispersion function measurement after optics correction in the high emittance, low alpha lattice.

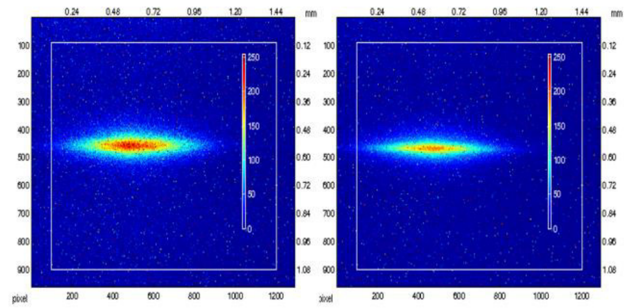

Figure 6: Beam profile before coupling correction (left) and after correction (right) in the high emittance, low alpha lattice.

Low Emittance, Low Alpha Lattice

Before optics correction in this case, the perturbation of the beta beating in the vertical plane was larger than in the horizontal plane. The beta beating was reduced to 1.32% rms in horizontal and 1.24% rms in vertical after optics correction (shown in Fig. 7-8).

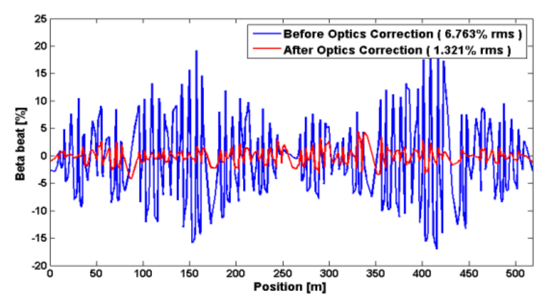

Figure 7: Beta beating of the low emittance, low alpha lattice in the horizontal plane.

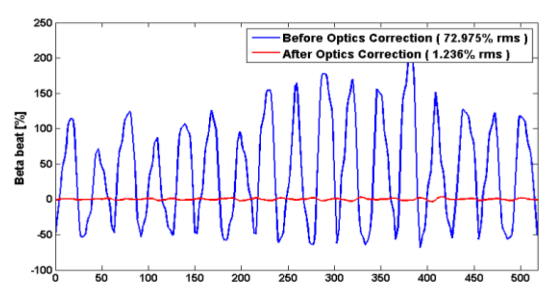

Figure 8: Beta beating of the low emittance, low alpha lattice in the vertical plane.

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Due to the large vertical beta beating, the tune shift in the vertical plane is also very large and the vertical tune is very close to the half-integer tune (shown in Table 3). The tune shift in both planes are reduced after optics correction.

Table 3: Optics Correction Results of Low Emittance, Low Alpha Lattice

	Tune X	Tune Y
Design Value	29.381	8.251
Before Correction	29.248	8.483
After Correction	29.385	8.264

Due to the perturbed dispersion, we also use skew quadrupoles to reduce the vertical dispersion and the coupling in LOCO correction (shown in Fig 9.). After optics correction and coupling correction, the dispersion is symmetric and the vertical dispersion is smaller.

The emittance of this lattice is smaller, so we can see the horizontal beam size (shown in Fig. 10) is smaller than the high emittance, low alpha lattice. The vertical beam size was reduced from 60.7 um to 34.9 um after coupling correction. The horizontal beam size was increased from 69.1 um to 70.5 um.

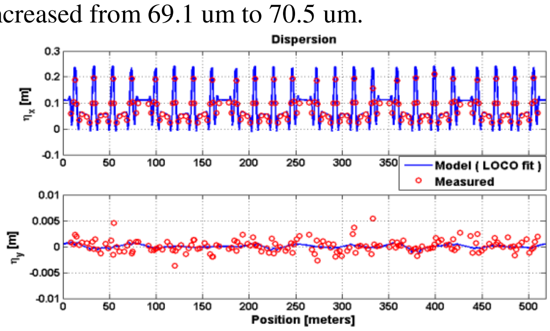

Figure 9: Dispersion function measurement after optics correction in the low emittance, low alpha lattice.

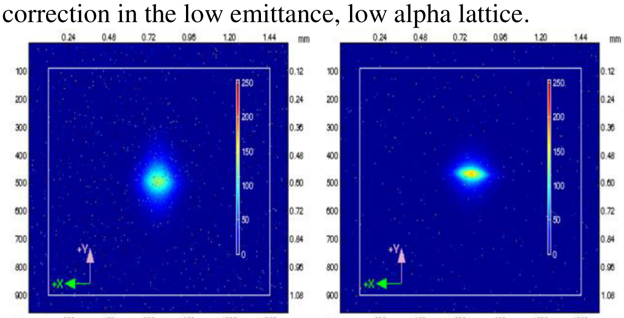

Figure 10: Beam profile before coupling correction (left) and after correction (right) in the low emittance, low alpha lattice.

ALPHA MEASUREMENT

The method of alpha measurement is by changing RF frequency for obtaining the orbit variation, and then we can calculate the alphas of the lattice [5].

As shown in Table 4-5, the measured data are well matched to the model. But sometimes due to the orbit stability, we need to repeat the measurement to obtain the accurate results, especially the second-order alpha.

If we want to reduce the first-order alpha effectively, we can adjust the quadrupoles in the high dispersion regions. In order to change the second-order alpha, we can use the sextupoles in the high dispersion regions.

Table 4: Alphas of High Emittance, Low Alpha Lattice

	α_1	α_2
Model	4.2×10^{-5}	-1.9×10^{-3}
Measured	4.4×10^{-5}	-1.7×10^{-3}

Table 5: Alphas of Low Emittance, Low Alpha Lattice

	α_1	α_2
Model	2.6×10^{-5}	7.2×10^{-4}
Measured	3.0×10^{-5}	1.2×10^{-3}

ORBIT STABILITY ISSUE

The orbit stability issue in the low alpha lattices is very important. If the RF frequency is perturbed or path length is changed due to noises, it will produce the energy variation. We can see the dispersion orbit in the horizontal plane. Along with the smaller alpha, the phenomenon is more obvious [6].

If we want to operate low alpha lattices to the users, we need a fast orbit feedback system to suppress the orbit noises to keep orbit stability at sub-micron level.

SUMMARY

We have commissioned two kinds of low alpha lattices recently. A low emittance lattice of 2.9 nm-rad could be provided for user mode to deliver a picosecond short bunch length source. In the commissioning, we encountered many difficulties (such as orbit stability issue, beam dynamics issue). These issues need to be studied in the future [6].

ACKNOWLEDGMENT

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