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(A)

OPTICAL DISTORTIONS IN ELECTRON/POSITRON STORAGE RINGS*

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SUMMARY We have studied the optical distortions in the PEP electron/ positron storage ring for various optical configurations using the computer programs DIMAT, HARMON, PATRICIA, AND TURTLE. The results are shown graphically by tracing several thousand trajectories from one interaction region to the next using TURTLE and by tracing a few selected rays several hundred turns using the programs DIMAT and PATRICIA. The results show an interesting correlation between the calculated optical cleanliness of a particular lattice configuration and the observed operating characteristics of the machine.

DISCUSSION Prior to January 1983 the operational characteristics of PEP were not good. The machine was unable to operate at the original design parameters and did not reach the intended luminosity. By the fall of 1982 both insertion quadrupoles Q1 and Q2 had been moved closer to the interaction point. This had the advantage that we could now use our design values of $\beta_x = 3$ metres, $\beta_y = 0.11$ metres without introducing severe chromatic correction problems (Fig. 1).

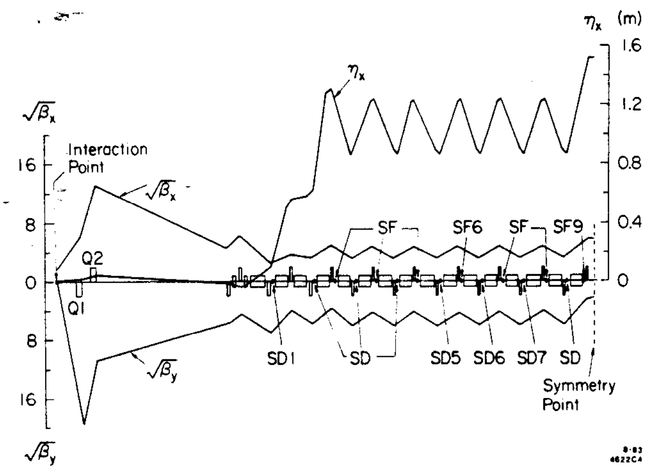

Fig. 1. PEP magnet lattice during 1983.

We started running in the fall of 1982 with the spring 1982 tunes of $\nu_x = 25.27$ and $\nu_y = 20.19$ but without a significant improvement in the machine performance. Then in January 1983 we returned to the more favorable 'design' tunes of $\nu_x = 21.24$ and $\nu_y = 18.19$. Under these conditions the performance of the machine was dramatically improved and the operators improved it even further. At high values of the beam-beam tune shift parameter ($\xi_x \approx 0.4, \xi_y \approx 0.5$) it was possible to adjust the strengths of the sextupole families to reduce the 'noise' in the experiments. The largest improvements were made early in January but the machine performance improved gradually into March. The detailed history of this has been clearly discussed by R. Helm et al.[1]

At that time the strengths of the sextupoles were recorded in order to simulate the operation by the tracking programs DIMAT[2] and PATRICIA.[3]

The results were unexpected, the final operating configuration seemed to have reduced the stable six-dimensional phase space acceptance (Figs. 2b-8b) compared to the starting configuration using the theoretically derived sextupole distribution (Figs. 2a-8a). The 'fuzziness in y, y' phase space had been slightly improved, but the chromatic properties seemed very much worse. Even more unexpected were the findings when these configurations were simulated using the program TURTLE.[4] DIMAT and PATRICIA track a few particles for a large number of turns and include simulation of synchrotron oscillations, TURTLE tracks a large number of particles, chosen randomly, for a short distance (here $1/6^{th}$ turn). The TURTLE tracking clearly shows, that for very large amplitude particles, there is less distortion of the phase space after the operators completed their sextupole tuning.

DIMAT and TURTLE simulations (not shown) of running conditions prior to January 1983 were also done. They showed very poor tracking, particularly TURTLE runs, compared to the cases presented here. It was considered more instructive to present here the more subtle differences between good and better conditions.

The apparent degradation of the multiturn optical properties of PEP could be misleading for several reasons:

1. There are probably small differences between the model and the actual machine, particularly in the match between insertions and arcs.
2. The linear part of the beam-beam force causes a perturbation of the focussing properties.
3. The nonlinear part of the beam-beam force causes amplitude dependent tune shifts which we do not simulate.
4. The tracking ignores quantum excitation and radiation damping.

The TURTLE tracking for one superperiod shows only the nonlinearity of the arc section where the sextupoles are located and is insensitive to linear beam-beam tune shift and mismatch between arcs and insertions.

We conclude from these simulations that it is important for the very large amplitude particles to have sufficiently linear motion between the interaction points. The beam-beam interaction apparently causes a large number of particles to have very large transverse amplitudes but the longitudinal (momentum) distribution remains gaussian and falls off very rapidly.

FUTURE PLANS In the fall of 1983 we shall have more power supplies and buses available for the sextupoles, and by using one more sextupole family it is possible to achieve a significantly better compromise between geometric and chromatic aberrations. A new lattice configuration for the fall of 1983 (pepmin3) has been formulated using HARMON.[5] The tracking simulations for pepmin3 are shown below in Figs. 2c-8c.

Operation this fall (1983) should show how successful this new configuration is. It should also provide extremely useful information about the relative importance of geometric versus chromatic distortions in an operating machine.

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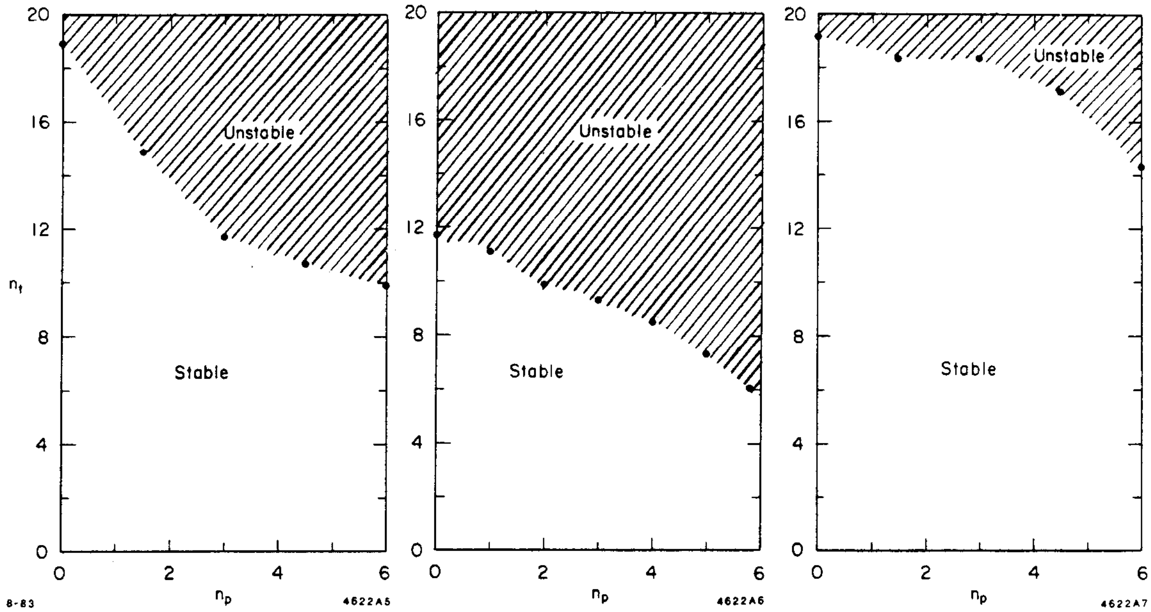
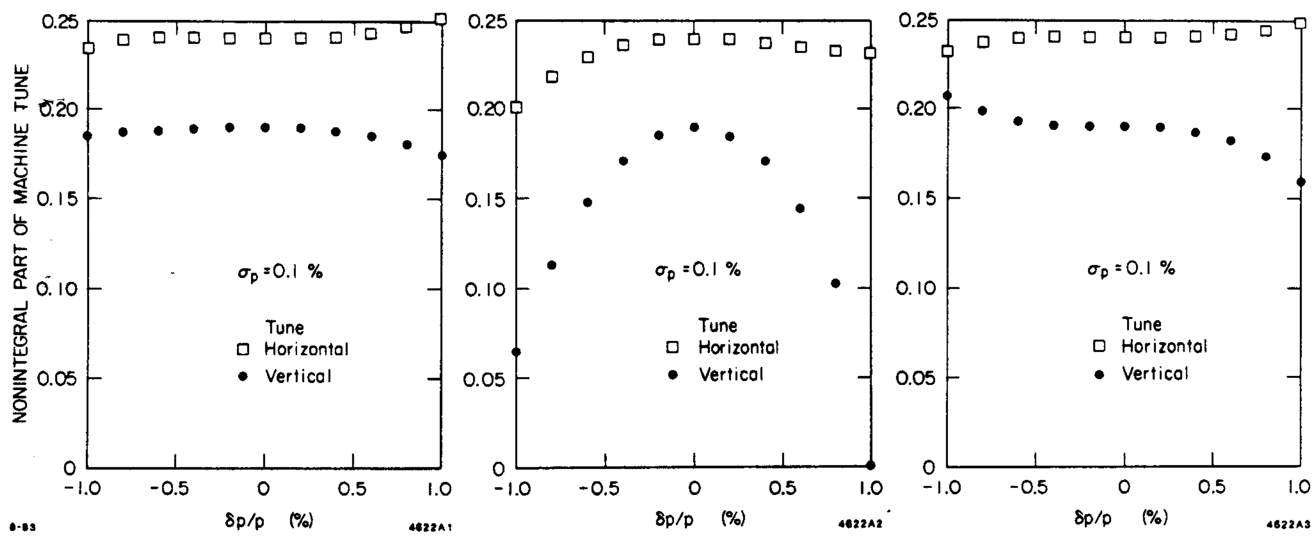
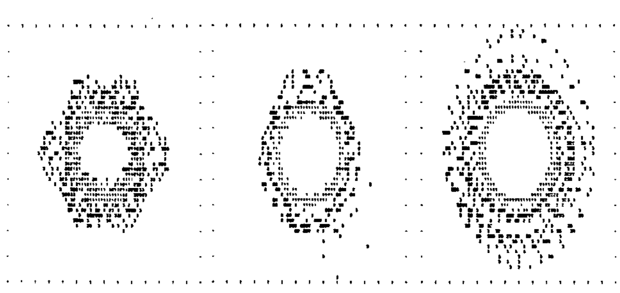


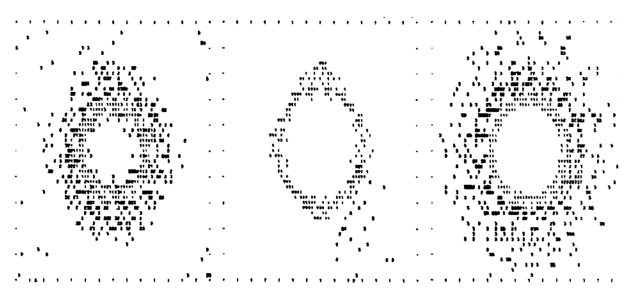
Figs. 2a-2c. Stability regions found by tracking for 1024 turns using the program PATRICIA. (n_t = number of standard deviations of transverse amplitude. n_p = number of standard deviations of momentum deviation during synchrotron oscillation).



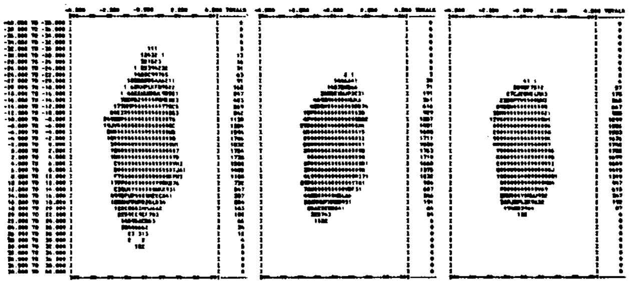
Figs. 3a-3c. Variation of tune with momentum obtained using the program PATRICIA.



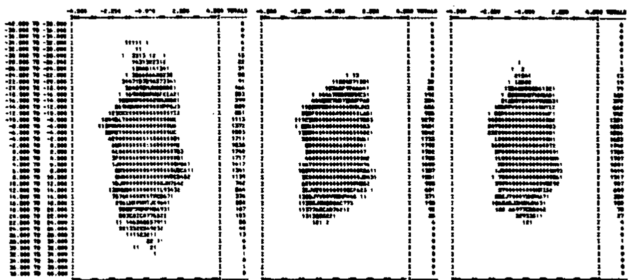
Figures 4a-4c. Vertical phase space when tracking with the program DIMAT. Particles are shown with 9, 12 and 15 standard deviations of transverse amplitude and zero momentum deviation.



Figs. 5a-5c. Vertical phase space when tracking with the program DIMAT. Particles are shown with 9, 12 and 15 standard deviations of transverse amplitude and three standard deviations of momentum deviation.



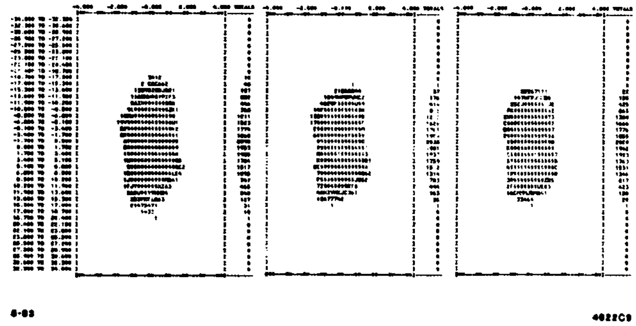
Figs. 6a-6c. Vertical phase space when tracking 20,000 particles for $1/6^{th}$ turn using the program TURTLE. The maxima of the distibution are 20 standard deviations of transverse amplitude and zero momentum deviation.



Figs. 7a-7c. Vertical phase space when tracking 20,000 particles for $1/6^{th}$ turn using the program TURTLE. The maxima of the distibution are 20 standard deviations of transverse amplitude and 10 standard deviations of momentum deviation.

ACKNOWLEDGEMENTS

We wish to thank particularly the PEP operators for tuning up PEP so that we were able to make this before/after comparison. The sextupole tuning was only a small part of the tuning that they did, their work with the orbit correctors led to making the linear machine more symmetric and achieved higher beam-beam tune shifts. We also thank all those who developed the instrumentation and control so that the operators had the necessary tools to work with.



Figs. 8a-8c. Vertical phase space when tracking 20,000 particles for $1/6^{th}$ turn using the program TURTLE. The maxima of the distibution are 15 standard deviations of transverse amplitude and 6 standard deviations of momentum deviation.

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