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IR Upgrade Driver Design Revision 113a: Recirculator Matching With Use of a Permanent Magnet Wiggler

D. Douglas

Abstract

We present a recirculator design solution for use with a permanent magnet wiggler.

Introduction

Use of a permanent magnet wiggler in the IR Upgrade has been suggested in order to produce 1 μm light [1]. Parameters specified for this wiggler are given in Table 1 [2]. We have modeled the wiggler in our usual slipshod fashion – specifically, as a sequence of achromatic dipole chicanes, each of length equal to the wiggler period and bending in the vertical plane at radius equal to the specified wiggler matched beam envelope.

With this modeling we have derived a solution, designated Revision 113a, for the IR Upgrade recirculator optics. A description of this solution follows.

Table 1: 1 μm Permanent Magnet Wiggler Parameters

Period length L_{period}, (cm)	5.5
Number of Periods N_{per}	30
Bending plane	vertical
Horizontal matched envelope $\beta_{wiggler}$ (cm)	40
Vertical envelope at waist, wiggler center (cm)	60

Details of Solution

From linac to wiggler: We chose to maintain the linac-to-arc match at rev113 values (matched to upright ellipse in center of pi bend with betax=0.25m, by=2.671 m), and chose to vary the FODO backleg phase advance (through minor ganged changes of quad strength) to optimize chromatic behavior at wiggler. The telescope downstream of the chicane and upstream of the wiggler was used to rematch to beam envelope values specified in Table 1.

Due to the small matched envelope values and much shorter wiggler (yielding increased wiggler-to triplet spacing), very large envelopes were unavoidable in the matching telescope unless final triplet was moved in. This was done (by 2 m, toward wiggler); when an on-momentum match was evaluated, the results were satisfactory when an appropriate FODO phase advance was selected to optimize chromatics. These results are characterized by Figures 1 through 3.

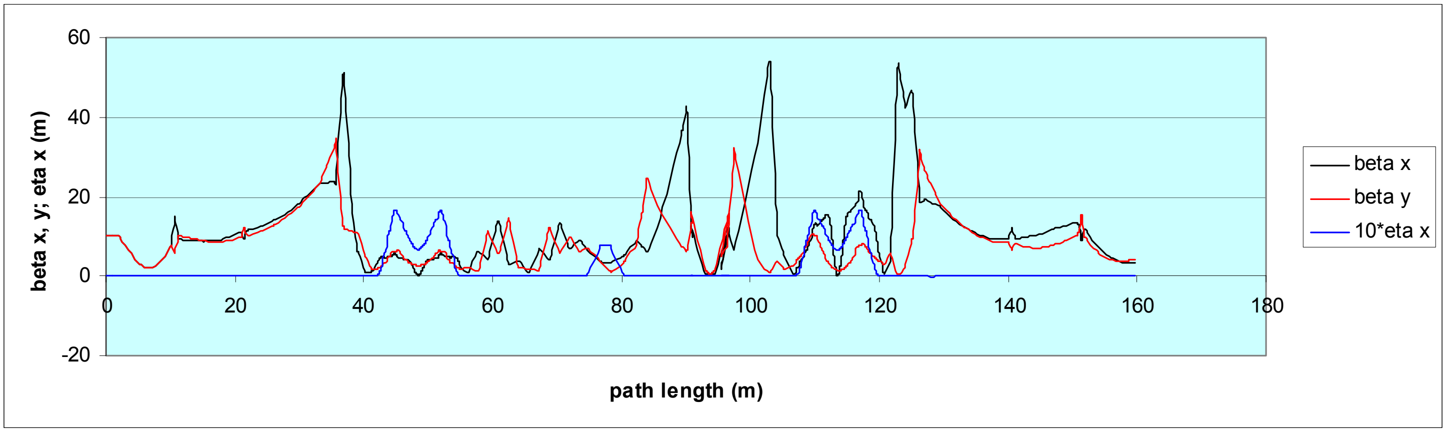


Figure 1: Beam envelopes through system with 1 µm wiggler and relocated adjacent triplets.

Figure 2: Results of momentum scan from linac to wiggler

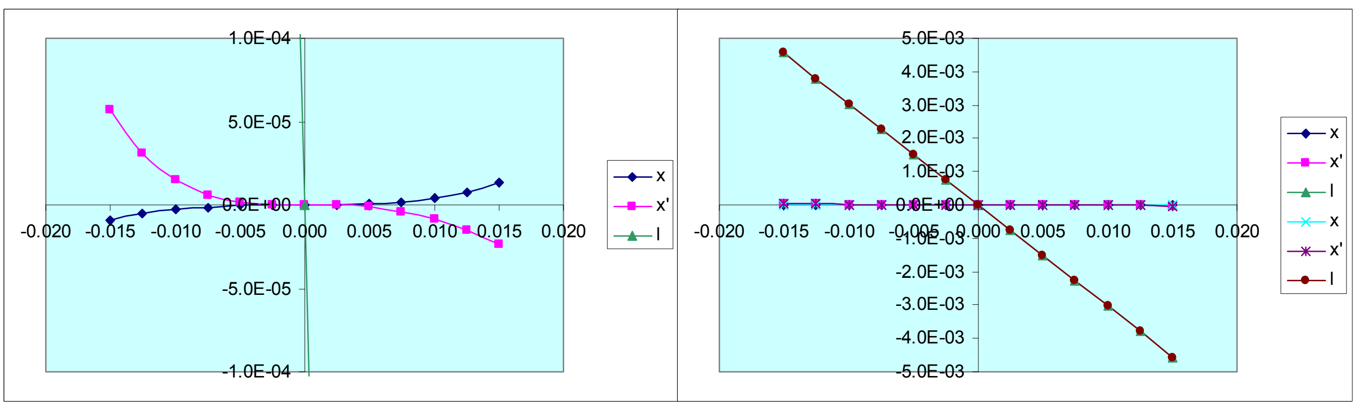


Figure 2a: Orbit variation at wiggler center

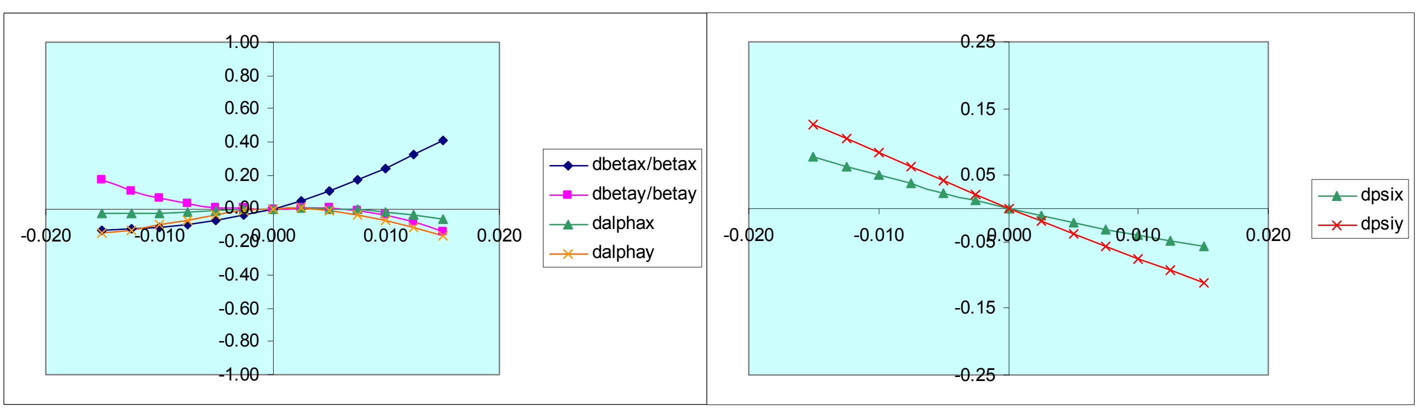


Figure 2b: Beam envelope and phase advance variation at wiggler center.

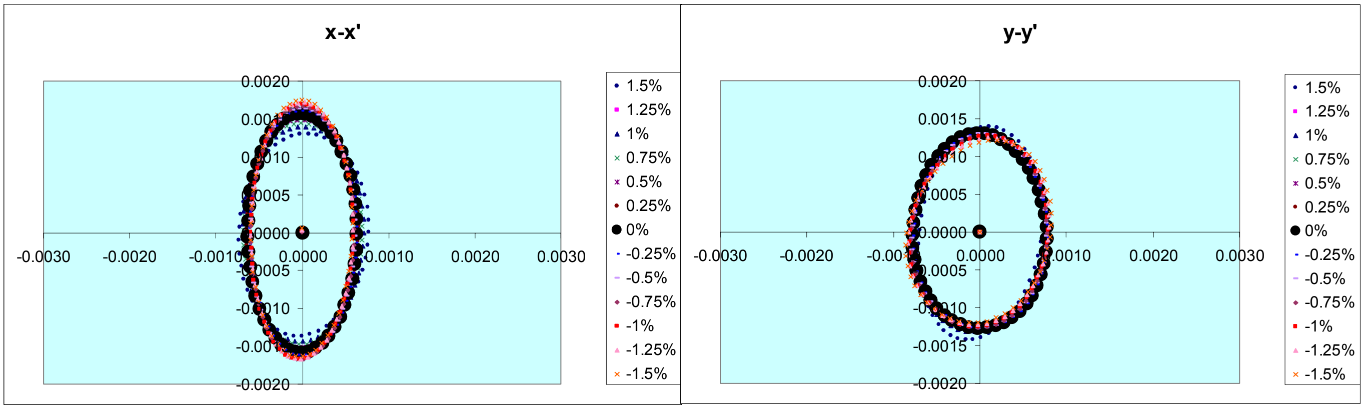


Figure 3: Geometric aberration analysis: ellipses with nominal beam envelopes at 1 mm-mrad geometric emittance (ten times the nominal value of 30 mm-mrad normalized emittance at 145 MeV) transported from linac to wiggler center at each of several momentum offsets between -1.5% and +1.5%. Left chart, horizontal plane; right chart, vertical plane. Phase space is regular, little geometric distortion is observed.

From wiggler to linac: As with the linac-to-wiggler transport, envelopes get quite large unless the first triplet is moved in. This was done as above (a 2 m move toward the wiggler). Given large required momentum aperture, some guidance was needed to produce a chromatically benign match. This was provided, as in the rev113 solution, through use of a simple Excel model. Thin lens quads and drifts were used to describe each telescope, the arc transfer matrix was evaluated with "rmatrix" operation and entered numerically into the spreadsheet. Each object was characterized for several momenta (-6% to +6% in 1% steps) and used to compute the global transfer matrix from the linac to the wiggler at each momentum over the full momentum range and to propagate the wiggler matched beam envelopes to the reinjection chicane. "Solver" was used to vary the quads in an effort to simultaneously match, at all momenta, the propagated values to nominal design parameters at the start of the reinjection chicane

These values were then entered into DIMAD, and a least squares fit of the reinjection telescope quad excitations used to fine-tune the on-momentum match to design reinjection beam envelope values. With the aforementioned move of the first triplet, acceptable performance was obtained. Beam envelopes are as in Figure 1; other results are documented in Figures 4 through 6.

Conclusions

A beam optics solution for use with a specified permanent magnet wiggler has been derived. Performance appears adequate provided the quad triplets adjacent to the wiggler are moved inward by 2 m (each) from their nominal (Rev113) locations.

Acknowledgments

I would like to thank Steve Benson for requesting this investigation and for supplying the FEL design information required for its execution.

Figure 4: Results of momentum scan from wiggler to linac

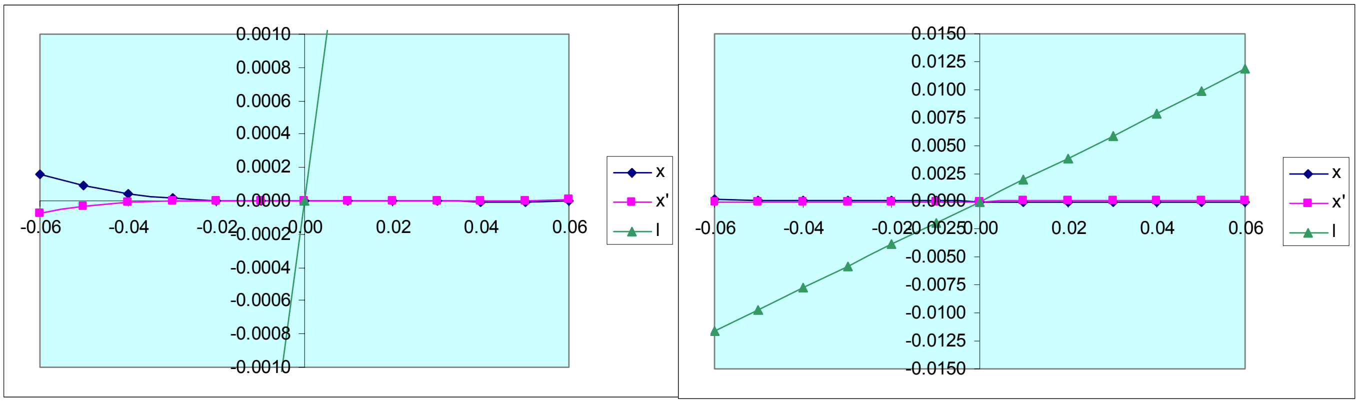


Figure 4a: Orbit variation at reinjection

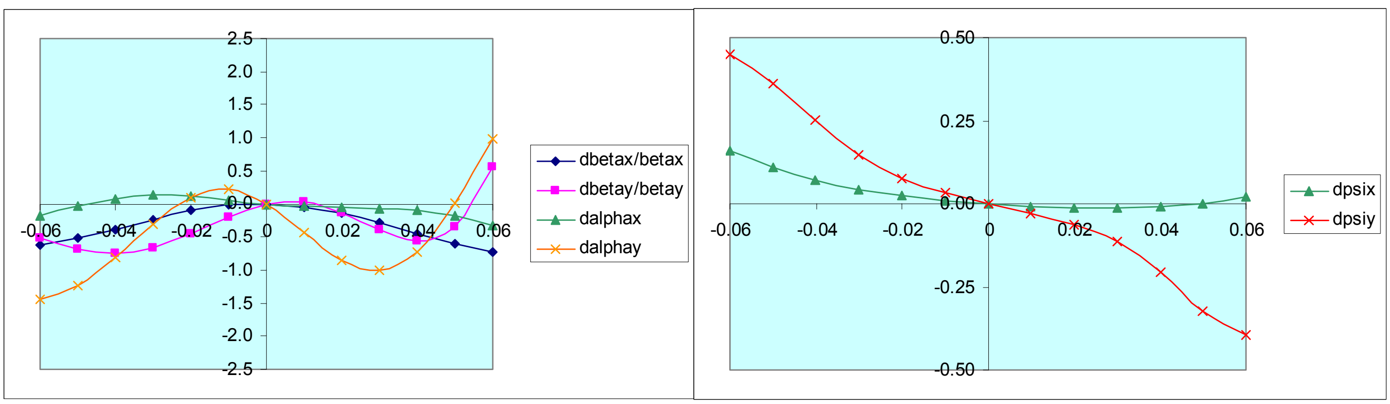


Figure 4b: Beam envelope and phase advance variation at reinjection.

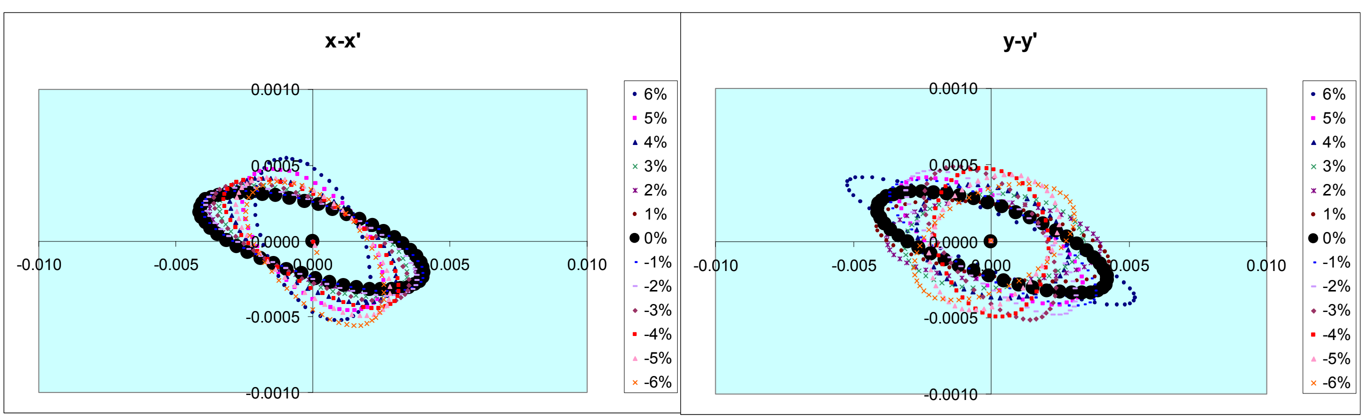
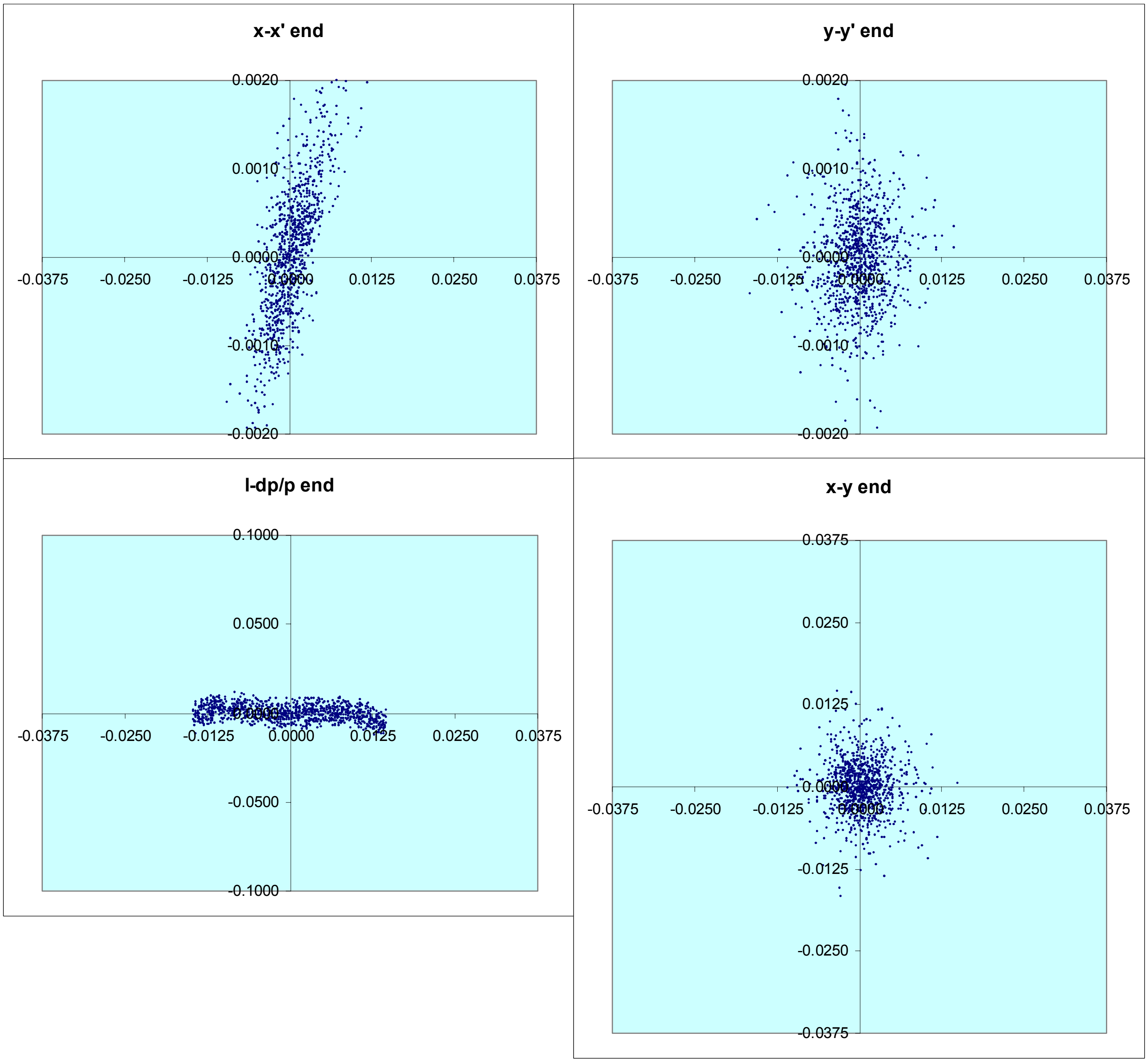


Figure 5: Geometric aberration analysis: ellipses with nominal beam envelopes at 1 mm-mrad geometric emittance (ten times the nominal value of 30 mm-mrad normalized emittance at 145 MeV) transported from wiggler center to linac at each of several momentum offsets between -6% and +6%. Left chart, horizontal plane; right chart, vertical plane. Phase space is regular, little geometric distortion is observed.

Figure 6: Results of tracking simulation of energy recovery. Initial distribution generated with 6σ transverse full width of 30 mm-mrad rms emittance and 15% quasi-uniform momentum relative full momentum spread over 4σ of 60 μm (200 fsec) rms bunch length at wiggler recovered from 145 MeV to 10 MeV. Various cuts of final phase space shown.



References

[1] S. Benson, private communication.
[2] *ibid*.