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Effects of the SSRL Wiggler on the SPEAR Beam

Introduction.

A wiggler for SSRL (Ref. 1) has been built, is now undergoing magnetic testing, and is scheduled to be installed in SPEAR in time for the October turn-on. This wiggler is a 7-pole (5 fulland 2 half-pole), 3-period design, approximately 1 m effective length, and designed to reach 18 kG peak field. It will be placed in the short straight section just counterclockwise from the south symmetry point.

In this note, the effects of this wiggler on the beam are estimated by means of the computer program MAGIC (Ref. 2) and various matching schemes are investigated.

Parameters of the Wiggler.

The optical equivalent and synchrotron radiation integrals of the SSRL wiggler were calculated by a computer program written for this purpose, and are discussed in a previous report (Ref. 3). It was shown that the only significant quantities are the vertical focusing (k_y) , the energy loss integral (Δl_2) , and the excitation integral (Δl_3) . On the basis of computed design fields (Ref. 1) these functions were found to be

 $k_y = 0.05001(B_0/18 \text{ kG})^2(E/1.5 \text{ GeV})^{-2} (m^{-1})$

 $\Delta I_2 = 0.05042(B_0/18 \text{ kG})^2(E/1.5 \text{ GeV})^{-2} (m^{-1})$

 $\Delta l_3 = 0.01424(B_0/18 \text{ kG})^3(E/1.5 \text{ GeV})^{-3} (m^{-2})$

where B_{0} is the peak field and E is the beam energy.

Simulating the Wiggler in MAGIC.

Since MAGIC models only rectangular uniform-field magnets, the problem is to simulate the effects of the actual wiggler with a squared-off field model. Luckily, as may be seen from the results given above, we only need to fit two of the three functions (since k_y and Δl_2 scale in the same way). Consequently only two adjustable parameters are needed in our model. By making a series of runs with the wiggler program (Ref. 3) it was



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found that the effective pole length (L_w) and the effective peak field (B_o) can be adjusted so that the squared-off representation fits the above functions accurately. The effective parameters as compared to the actual peak field and integrated pole length are

 $B_o = 18.0 \text{ kG}$ $B_w = 14.1386 \text{ kG}$ $l_o = 0.094488 \text{ m}$ $l_w = 0.104429 \text{ m}$

where $\ell_{o} = \frac{1}{B_{o}} \int_{pole}^{B} ds$

The wiggle period and number of poles were fixed at the actual values. While the above numbers are based on the design fields, they are not expected to be much different for the measured fields.

MAGIC Results.

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Since there is no longer any symmetry in the ring, it was necessary to use a special version of MAGIC with expanded dimensions to accomodate the complete SPEAR ring.

Five cases were run and compared to the unperturbed reference case:

(1) No special matching for the wiggler.

(2) $\beta_{\rm y}$ matched by varying the pair of QF's nearest the wiggler (designated as QFW).

(3) β_y matched by varying the nearest pair of QD's (designated as QDW).

(4) β_v and n_x matched by varying the nearest pairs of QD's and QF's (designated as QDW and QFW).

(5) β_x^* and β_y^* matched by independent trimming of all the Q3's and Q2's south of the IP's (designated as Q3SE, Q2SE, Q3SW, and Q2SW).

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Table I shows the unperturbed values for the configuration used in the calculations. Table II summarizes results before tune corrections. Additional runs were made to correct the tunes, but the parameters other than the Δv 's changed only marginally.

Conclusions.

Regarding the five cases summarized in Table II:

(1) No matching. The differences in β_y^* of ±3.5 2 at the two IP's may be tolerable.

(2) β_y matched by QFW. This case is a disaster because of the large differences in β_x * and n_x * at the two IP's (1.671 m and 1.280 m for β_x * and +0.203 m, -0.360 m for n_x *). This is especially worrisome because n_x * is believed to be implicated in the "flip-flop" effect (Ref. 4). Moreover, the change of 24 % required for QFW is far out of range of the trim windings.

(3) β_y matched by QDW. Better than Case 2, but the $\eta\star$ mismatch (-0.022 m, +0.040 m at the iP's) is probably still too large.

(4) β_y and n_x matched by QDW and QFW. Quite good optically. The match could be made exact by varying one more set of quadrupoles, but this seems unnecessary. The changes required in QDW and QFW (2.5 \$ and 1.2 \$ respectively) are probably within the range of the trims, at least at low energies.

(5) β_x^* and β_y^* matched by trimming Q3's and Q2's in south arc. Exact match at the JP's. The effect of the +12 \Im β_y mismatch (which occurs only in the south arc) would have to be considered. Quadrupole trim requirements are minimal.

In summary, it appears worthwhile to try running the ring with the wiggler with no special matching (Case 1, above). If the β_y *difference appears unacceptable, either Case (4) or (5) could be tried.

Some other possibly adverse effects are:

(a) Unequal betatron phase advances in the south and north arcs. This could in principle be corrected by making all the quadrupole families independent in the two arcs.

(b) Local energy loss at the wiggler, which might relate to the "filp-flop" effect (Ref.4). This could be partially compensated by dephasing cavities in the north arc.

Acknowledgements:

The author thanks M. J. Lee and J. E. Paterson for helpful discussions, and A. S. King for supplying the special version of MAGIC.

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1. W. Brunk, J. Spencer, and H. Winick: private communications and report to be published.

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2. A. S. King, M. J. Lee, and W. W. Lee, MAGIC, a Computer Code for Design Studies of insertions and Storage Rings, Stanford Linear Accelerator Center Report SLAC-183 (1975).

3. R. H. Helm, Modeling the Effects of a Flat Wiggler on a Storage Ring Beam, Stanford Linear Accelerator Center Report PEP-272 (1978).

4. SPEAR Machine Physics Group, private communication. The "flip-flop" effect is manifested by one of the colliding beams being blown up while the other remains small; slight changes in machine conditions causes the blowup to flip from one beam to the other. The phenomenon lacks satisfactory explanation and is still under investigation.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legil lightlity or response bility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endomement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect thuse of the United States Government or any agency thereof. Table 1. Configuration Specifications. (E = 1.5 GeV). Note: the tunes used here are considerably closer to the integer than tunes which now are commonly used in SPEAR -i.e., $v_x = 5.27$, $v_y = 5.18$. Thus the present example is somewhat of a "worst case" as regards mismatch effects.

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______**____**_________________ _____ <u>Tune:</u> 5.144 ν_x ν_v 5.09872 Machine Functions: β_{*}* 1.20 m β_v* 0.10 m η_×* 0.0 m 0.1229 mm-mrad Emittance εα $3.6 \times 10^{29} \text{ cm}^{-2} \text{ sec}^{-1}$ Luminosity: Lo Damping time: $\tau_{xo} = \tau_{yo} = \tau_{Eo} / 2$ 0.067 sec

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			Case 1	Case 2	Case 3	Case 4	Case S
Matching			None	β _γ	 β _ν	 β _γ ,η _x	β _x *, β _v *
<u>Tunes</u> :		Δv _x	0.0	C.0679	-0.0051	-0.0010	-0.0002
		Δν	0.0119	-0.0108	0.0378	0.0361	0.0171
IP Fund	ctions	;					
<u></u>	β *	(WP) (EP)	1.20 1.20	1.671 1.180	1.194 1.203	1.217 1.193	1.20 1.20
	β _y *	(WP) (EP)	0.101 0.094	0.100 0.100	0.100 0.100	0.1 00 D.100	0.100 0.100
	n _x *	(VP) (EP)	0.0 0.0	0.203 -0.360	-0.022	0.0 0.0	0.0 0.D
<u>Mismato</u>	<u>h in</u>	Arcs:					
	$\Delta \beta_x / \beta_x$		0.0	±0.36	±0.01	±0.02	±0.004
	Δβ _y /β _y		+0.11	0.0	0.0	0.0	±0.12
	Δη _x /η _x		0.0	±0.53	±0.06	0.0	0.0
Energy	Loss:	u∕u _o	1.103	1.103	1.103	1.103	1.103
Emittar	ce	ε/ε _ο	1.31	2.24	1.36	1.34	1.31
Luminos	ilty:	L/Lo	1.31	1.61	1.37	1.32	1.31
<u>Damptne</u>	:: 1	x / ^τ xο	0.907	0.907	0.907	0.907	0.507
<u>Match In</u>	g Qua	drupole	<u>5</u> :				
	ΔQI ΔQ3 ΔQ3 ΔQ2 ΔQ3	DW/QD FW/QF SE/Q3 SE/Q2 SW/Q3		+0.2436	+0.0257	+0.0251 +0.0116 	-0.0027 -0.0008 +0.0043
	4923	5W/42					+0.0010

Table II. Effects of Wiggler with Various Matching Schemes.

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SPEAR - 214 PEP - 273 R. H. Helm July, 1978

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Tune:	V _I	5.144
	ν _y	5.09872
Haching Fun	etims:	
	β _x +	1.20 m
	β _y ≜	0.10 m
	n _x *	0.0 m
Emittance	¢0	0.1229 mm-mrad
Luminosity:	Z.	$3.6 \times 10^{29} \text{ cm}^{-2} \text{ sec}^{-1}$
Damping tim	1 1	
τ _{χο} = τ _{γο}	= T _{Eo} /2	0.067 sec

			Case 1	Case 2	Case 3	Case 4	Case 5
Natching			None	β _y	β _y	β _y ,η _x	β π[*]. βy [*]
Iugas:		۵۷۲	0.0	0.0679	-0.0051	-0.0010	-0.0002
		۵۷	0.0119	-0.010\$	0.0378	0.0361	0.6171
LP .Fund	tion	y 5:					
	g 1	(WP)	1.20	1.671	1.194	1.217	1.20
	Ϋ́Ξ	(EP)	1.20	1.180	1.203	1.193	1.20
	a *	(VP)	0.101	0.100	0.100	0.100	0.100
	Ву	(EP)	0.094	0.100	0.144	0.100	4.100
	n *	(MP)	0.C	0.203	-0.022	0.0	0.0
		(EP)	0.0	-0.360	0.040	0.0	0.0
<u>Hispat</u>	c <u>h In</u>	Arca:					
	LBx/B	x	0.0	±0.3 6	±0.01	±0.02	20.004
	48 ₇ /8	y	+0.11	0.0	0.0	0.0	29.17
	Δŋ _x /ŋ	I	0.0	±0.53	±0.06	0.0	0.0
Engray	1035	1 U/U 0	1.103	1.103	1.103	1.103	1.103
Emitta	nce	e/eg	1.31	2.24	1.36	1.34	1.32
Lumino	<u>sity</u> ;	L/L ₀	1.31	1.61	1.37	1.32	1.31
<u>Damp In</u>	£:	^T x / ^T x0	0.907	0.907	0.907	0.907	0.907
<u>Narch I</u>	n <u>e. Qu</u>	adrupole	<u>is</u> :				
	۵	QDW/QD		da+	+0.0257	+0.0251	
	۵.	QFW/QF		+0.2436		+0.0116	
	60	3SE/03	444				-0.0027
	<u>p</u> ų	ZSE/QZ					-0.0008
	4Q	22M/Q5					+0,0043
	44 	2307 US					*4.4410

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