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A 75% Solution for the FEL Upgrade

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Abstract

I give a rough description of the accelerator design for the 10 kW IR FEL upgrade. This "75% solution" can be used as a basis for initial project cost and schedule evaluation. The reader is, however, reminded that "the devil is in the details", and "the last 10% of the work takes 90% of the time".

Assumptions/Remarks

In this note, I make the assumption that we will build a machine such as that described in JLAB-TN-99-019, "A Driver Accelerator for an FEL Upgrade" [1]. Working from this initial concept, I provide in the following a configuration and an approximate component count for the upgrade driver. This layout is based on results in the aforementioned JLAB technical note and from ongoing design work, and may be considered a statement on the status of the machine design. The following remarks may be of use:

1. The injection/reinjection and extraction lines must be modified to accommodate the use of rectangular dipoles. These are needed to provide an increase in bandwidth for the injected-to-final energy ratio required for the upgrade (10 MeV:100-200 MeV, ultimately, vs. 9.5 MeV:35-48 MeV in the IR Demo). This, coupled with changes in layout of the energy recovery arc, may in turn require some movement of the injector itself.
2. Minor changes in injector layout driven by the above beam transport requirement could profitably be used to implement additional diagnostics. The following layout assumes this has been done.
3. A preliminary solution for uncoupled linac linear optics has been developed [2]; the following layout is based on this solution.
4. Quadrupole/multipole counts are approximate and based on previous experience, present expectations of wiggler layout (vertically bending, horizontally focussing [3]), and a preliminary study of longitudinal dynamics during energy recovery [4].
5. Very preliminary results suggest that Bates-type transport arcs will provide adequate performance and operability (see Figure 1 for a momentum scan of position and path length), though a detailed design solution is several months off.
6. The diagnostic configuration is based on operational experience with the IR FEL Demo driver rather than a detailed design and operational

simulation. They must therefore be regarded as preliminary, but are, as are all component counts, probably correct to the ~25% level.

7. As the beam energy is higher than in the IR Demo (100 MeV, as opposed to 48 MeV), more extensive use of synchrotron light monitors (slm's) is made than was done in the present system.
8. Because of the higher beam currents, larger momentum spreads, higher peak current requirements, and larger optical modes, 3 inch (7.5 cm) vacuum chamber will be used in straight sections, and horizontal acceptances in dispersed regions will have to approach 1 foot (30 cm).

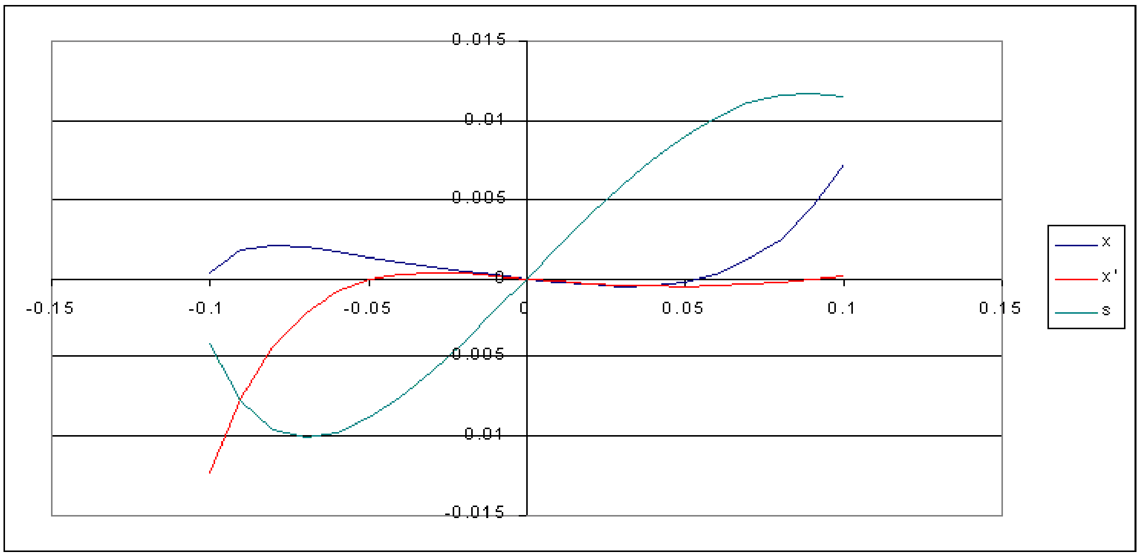


Figure 1: Momentum scan of position and path length after wiggler-to-linac return arc.

The reader is encouraged to visit

http://www.jlab.org/~douglas/FELupgrade/masterindex.html

for further and ongoing updates to this information. We note that accelerator physics studies on the upgrade design [5] may dictate additional functionality be provided in the driver accelerator system. This discussion is therefore to be considered only a preliminary working document.

Layout

Figure 2 provides a conceptual layout of the IR FEL Upgrade Driver. At the top level, the machine comprises an injector (a gun, a 10 MeV cryounit, and achromatic transport to the linac injection point), a 3 module linac with triplet focussing, and a recirculator. The recirculator is based on Bates-style end loops; matching into and out of each end loop is provided. A single chicane is used to provide clearance for the upstream end of the optical cavity; the downstream end is assumed to lie beyond the first dipole of the energy-recovery end loop.

This chicane can also be used assist in compaction management. At present, we intend to perform longitudinal manipulations as in the IR Demo. Thus, acceleration will occur off-crest (and energy recovery off-trough); the linac to wiggler transport will have an overall M_{56} of ~-0.3 m, and the wiggler to linac transport will have an overall M_{56} of ~+0.2 m [6]. This is easily provided with "identical" end loops if an upstream arc with a natural M_{56} of +0.2 m (as implied by Figure 1) is followed by a chicane with M_{56} of –0.5 m. The downstream arc can then be essentially the same as the upstream. We expect [7] that the upstream end loop will require compaction control through second order while the downstream will require third order compaction control. Hence, trim quads and sextupoles will be provided in both arcs; octupoles will be provided in the downstream arc only. Happek-device longitudinal diagnostics will be required in the vicinity of the wiggler, and a BCM-based transfer function measurement system should be provided for longitudinal characterization at appropriate points of the system.

Component Count

Table 1 provides a ~25% accurate (this is, after all, a 75% solution!) count of beam transport components.

Notes and References

[1] D. Douglas, "A Driver Accelerator for an FEL Upgrade", JLAB-TN-99-019, 21 July 1999.

[2] *ibid.*

[3] S. Benson and G. Neil, private communication.

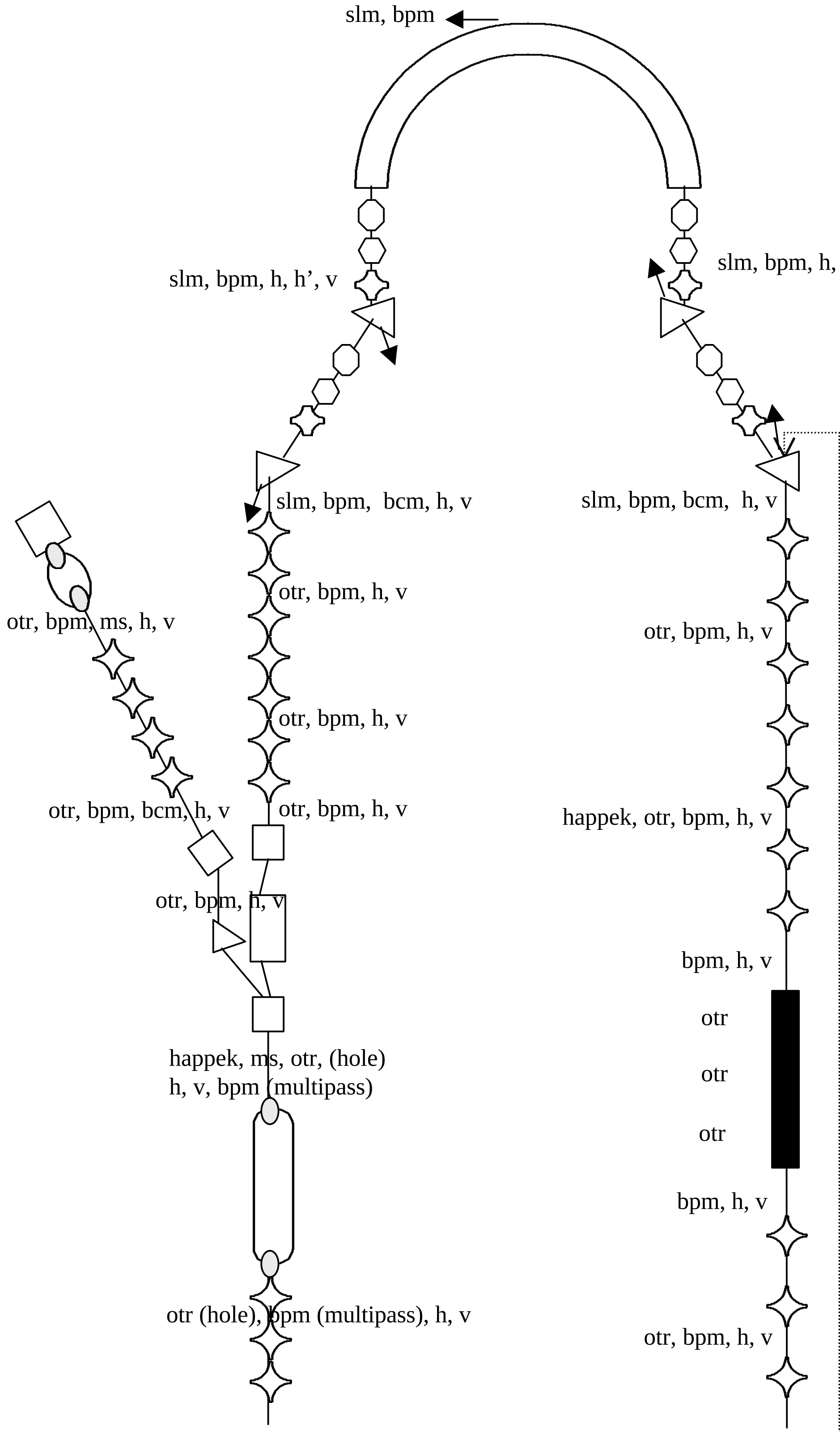
[4] D. Douglas, "Modeling of Longitudinal Phase Space Dynamics in Energy-Recovering FEL Drivers", JLAB-TN-99-002, 14 January 1999.

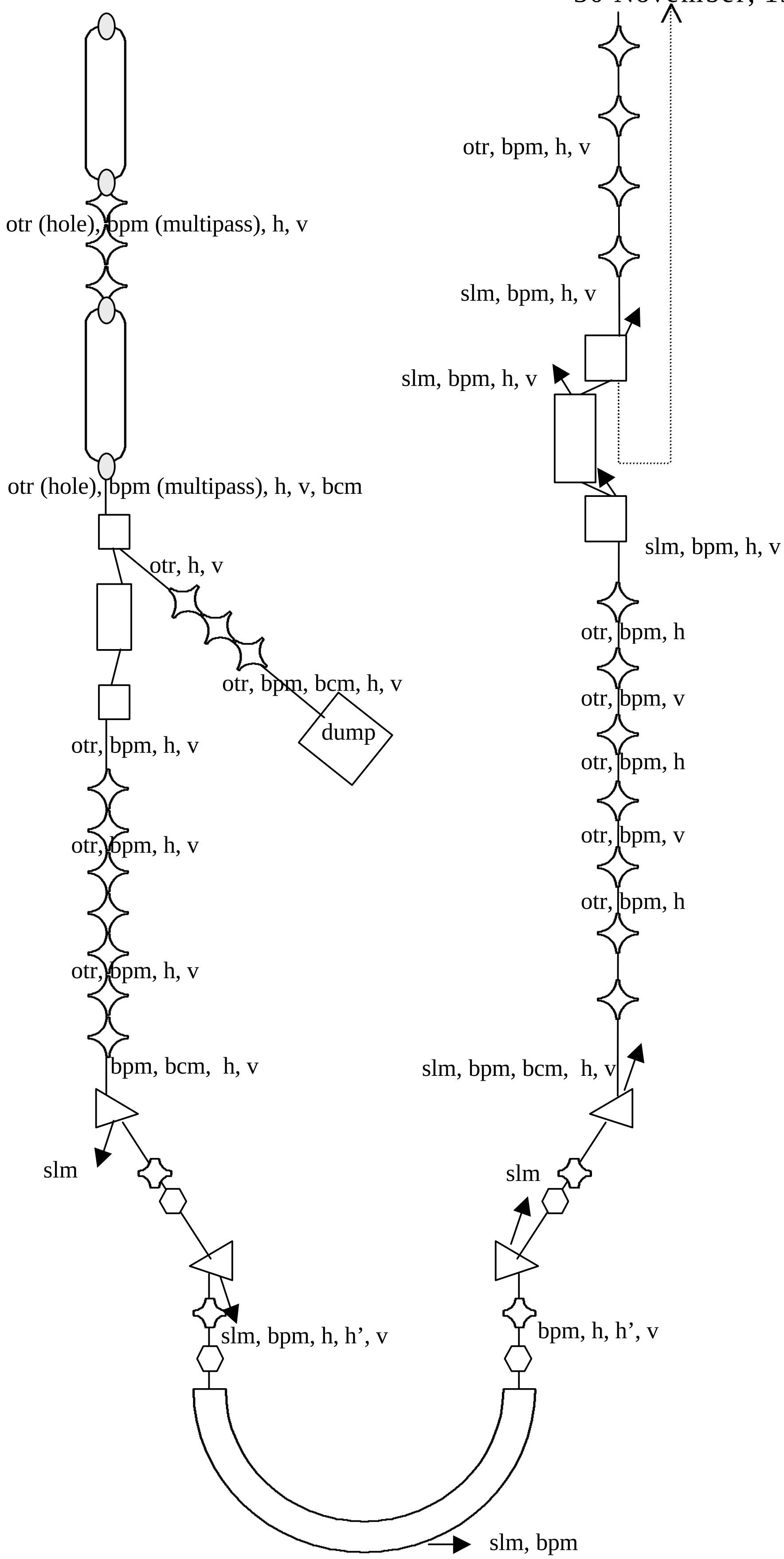
[5] D. Douglas, "IR/UV FEL Upgrade Project Accelerator Physics Plan", JLAB-TN in preparation.

[6] D. Douglas, "Modeling of Longitudinal Phase Space Dynamics in Energy-Recovering FEL Drivers", *op. cit.*

[7] *ibid.*

Figure 2: System Configuration




otr, bpm, h, v
otr (hole), bpm (multipass), h, v
slm, bpm, h, v
slm, bpm, h, v
otr (hole), bpm (multipass), h, v, bcm
slm, bpm, h, v
otr, h, v
otr, bpm, h
otr, bpm, bcm, h, v
otr, bpm, v
dump
otr, bpm, h, v
otr, bpm, h
otr, bpm, h, v
otr, bpm, v
otr, bpm, h
otr, bpm, h, v
bpm, bcm, h, v
slm, bpm, bcm, h, v
slm
slm
slm, bpm, h, h’, v
bpm, h, h’, v
slm, bpm

Key

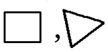
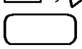
otr:	optical transition radiation foil
bpm:	beam position monitor
slm:	synchrotron light monitor
bcm:	beam current monitor cavity
happek:	Happek device
h:	horizontal corrector
h':	ganged horizontal (pathlength) corrector)
v:	vertical corrector
 :	skew quad
 :	normal quad
 :	sextupole
 :	octupole
 :	synchrotron light monitor
ms:	multislit monitor
 :	dipole
 :	cryounit or cryomodule

Table 1: Beam Transport System Component Count

Region	bends	quads	skew quads	sext.	oct.	corr.	otr	slm	bpm	special	comments
injector	3	4	2	0	0	6	3	0	3	2	ms, bcm
linac	0	6	6	0	0	8	4	0	4	3	h, ms, bcm, otr with holes, multipass bpm
extract/match	3	7	0	0	0	8	3	0	4	1	bcm
1st endloop	5	4	0	4	0	6	0	5	3	0	1 corrector pair in "gang" for pathlength
backleg	3	7	0	0	0	11	5	3	8	1	bcm
wiggler match	0	7	0	0	0	8	2	0	4	0	
wiggler	0	0	0	0	0	0	3	0	0	1	h
match to arc	0	7	0	0	0	8	2	0	4	1	bcm
2nd endloop	5	4	0	4	4	6	0	5	3	0	1 corrector pair in "gang" for pathlength
reinj. match	2	7	0	0	0	8	3	0	4	1	bcm
dump line	0	3	0	0	0	4	2	0	1	1	bcm
total	21	56	8	8	4	73	27	13	38	11	

comments:

otrs	23 "conventional", 4 with ~5 mm hole
bpm	34 "conventional", 4 multipass
happek dev.	2
bcm	7
multislits	2

3" tube in straig ~60 m total
12" horizontal acceptance in dipoles