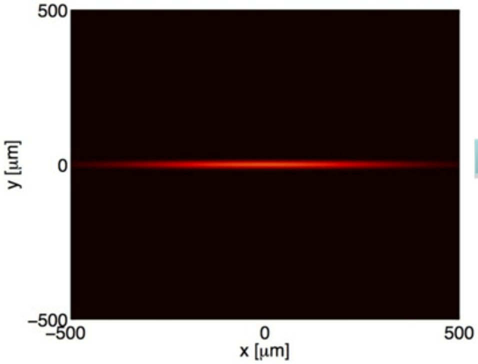
Power Supplies for ALS-U

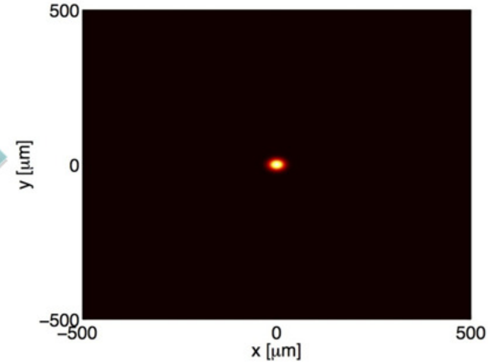
POCPA 2016
Barcelona, Spain

Chris Pappas

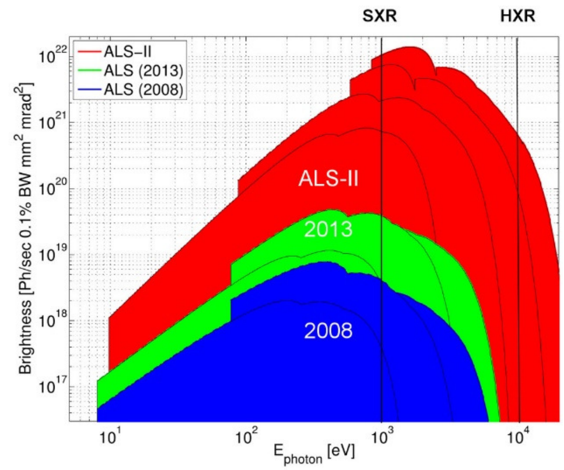
ALS-U Motivation & Concept



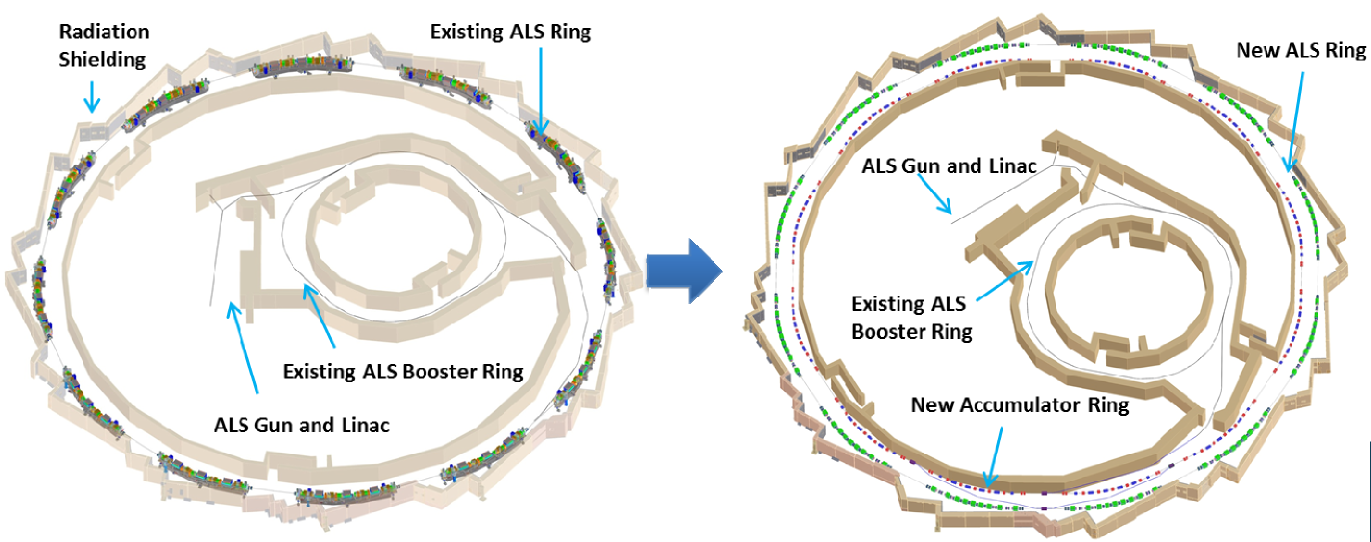
ALS Beam



ALS-U Beam



ALS has good vertical emittance but the horizontal emittance (ε_x=2000 pm) is limited by magnet dispersion. By using more, smaller angle bend magnets, and refocusing after each bend, the emittance for ALS-U can be reduced to 50 pm, and the brightness increases by a factor of > 100.



Christoph Steier, et al., *Proposal for a Soft X-Ray Diffraction Limited Upgrade of the ALS*, IPAC14.

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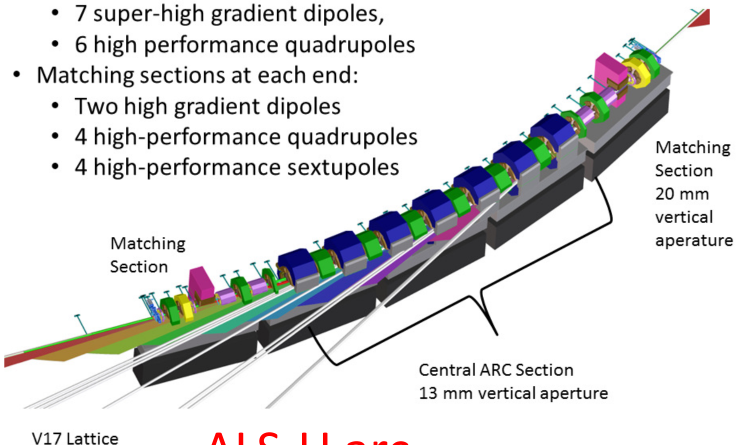
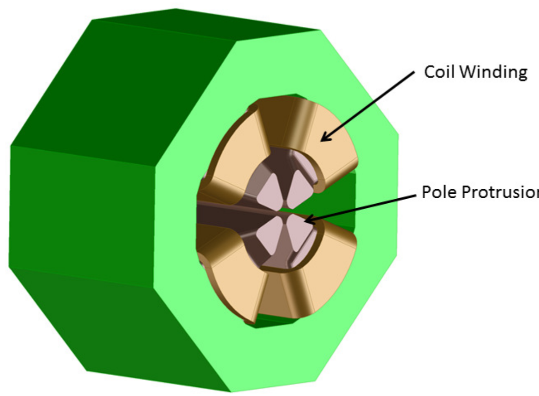
ALS-U Magnets

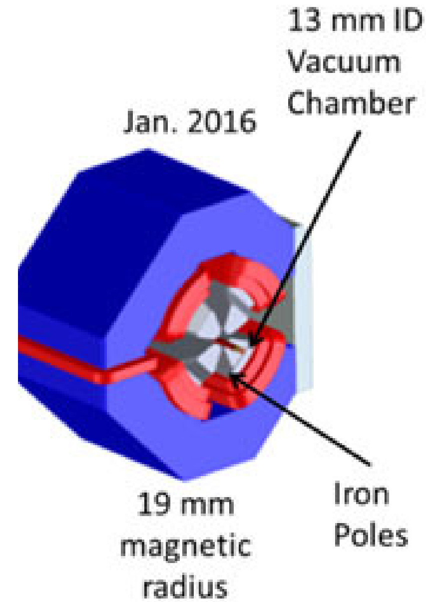
- Central arc section:
  - 7 super-high gradient dipoles,
  - 6 high performance quadrupoles
- Matching sections at each end:
  - Two high gradient dipoles
  - 4 high-performance quadrupoles
  - 4 high-performance sextupoles



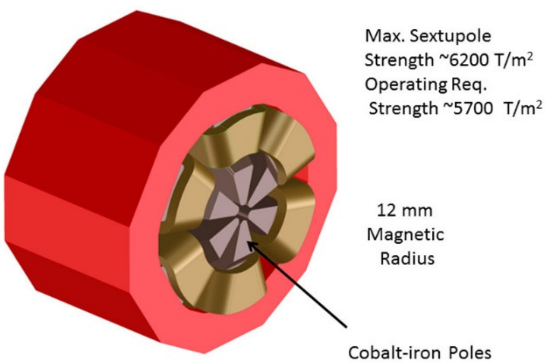
ALS-U arc



Quadrupole

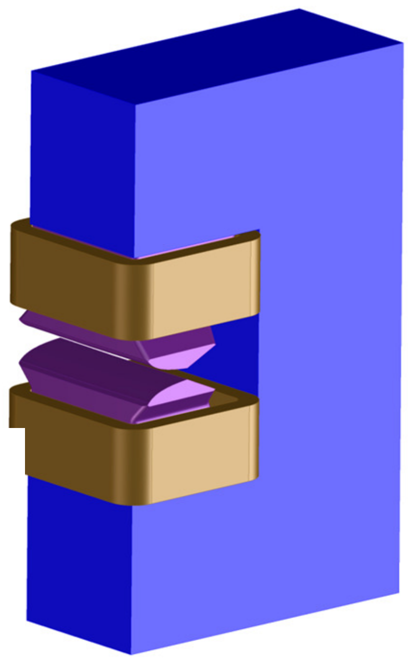


Offset Quadrupole

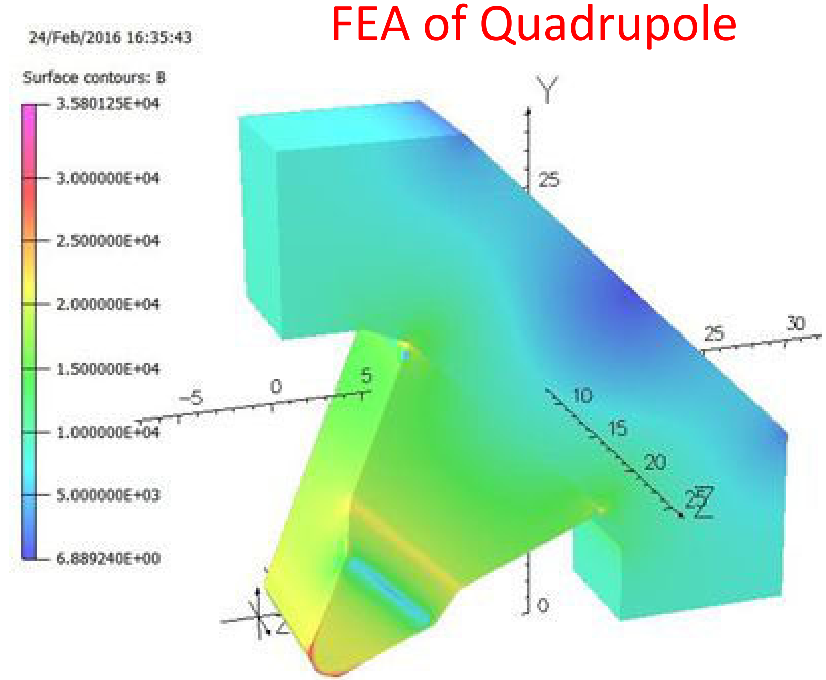


Sextupole

Gradient Dipole



FEA of Quadrupole



Charles Allen Swenson, et al., *Conceptual Design of Storage Ring Magnets for a Diffraction Limited Light Source Upgrade of ALS, ALS-U*, IPAC16.

Power Supply Requirements

Magnet	Material	Total current (Amp-turns)	# of coil turns	Current (A)	Energy (J)	Inductance (H)
Quad bend	pure iron pole and yoke	7420	34	218.2	1282.1	5.4E-02
Gradient dipole	pure iron pole and yoke	11465	64	179.1	843.2	5.3E-02
Quadrupole (L=90mm)	Vacoflux 50 pole, 1010 steel yoke	3300	22	150.0	59.6	5.3E-03
Quadrupole (L=180mm)	pure iron pole and yoke	4400	22	200.0	182.5	9.1E-03
Quadrupole (L=190mm)	pure iron pole and yoke	4200	22	190.9	177.2	9.7E-03
Quadrupole (L=190mm)	Vacoflux 50 pole, 1010 steel yoke	5100	22	231.8	262.9	9.8E-03
Quadrupole (L=305mm)	pure iron pole and yoke	4100	22	186.4	267.4	1.5E-02
Sextupole	Vacoflux 50 pole, 1010 steel yoke	2630	14	187.9	188.5	1.1E-02
H Sextupole						
Quad bend, no quad coil, dipole coil only	pure iron pole and yoke	970	6	161.7	4.8	3.7E-04
Totals			228			

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Requirements Continued

Magnet	Power (kW)	Voltage (V)	Magnet Current	Magnet Voltage	Winding Resistance	Time constant	Power Supply Bandwidth
Quad bend	4.8	22.0	218.2	22.0	1.0E-01	5.3E-01	DC + 5 A/s
Gradient dipole	2.6	14.5	179.1	14.5	8.1E-02	6.5E-01	DC + 5 A/s
Quadrupole (L=90mm)	0.5	3.2	150.0	3.2	2.1E-02	2.5E-01	DC + 5 A/s
Quadrupole (L=180mm)	1.2	6.0	200.0	6.0	3.0E-02	3.0E-01	DC + 5 A/s
Quadrupole (L=190mm)	1.1	6.0	190.9	6.0	3.1E-02	3.1E-01	DC + 5 A/s
Quadrupole (L=190mm)	1.7	7.2	231.8	7.2	3.1E-02	3.1E-01	DC + 5 A/s
Quadrupole (L=305mm)	1.5	7.9	186.4	7.9	4.3E-02	3.6E-01	DC + 5 A/s
Sextupole	1.2	6.4	187.9	6.4	3.4E-02	3.1E-01	DC + 5 A/s
H Sextupole							kHz range
Quad bend, no quad coil, dipole coil only	0.1	0.7	161.7	0.7	4.4E-03	8.4E-02	DC + 5 A/s

Requirements Continued

Magnet	Number of Trim Circuits	# of Magnets	# of Supplies	Chamber Bandwidth	Ripple @ Frequency	Stability 8 Hrs	MTBF , 500 hr for power supply failures	Polarity
quad bend	1	84	84	3 kHz	10 ppm	10 ppm	4.44E+05	Unipolar
gradient dipole	0	24	24	3 kHz	10 ppm	10 ppm	4.44E+05	Unipolar
quadrupole (L=90mm)	TBD	24	24	3 kHz	10 ppm	10 ppm	4.44E+05	Unipolar
quadrupole (L=180mm)	TBD	24	24	3 kHz	10 ppm	10 ppm	4.44E+05	Unipolar
quadrupole (L=190mm)	TBD	24	24	3 kHz	10 ppm	10 ppm	4.44E+05	Unipolar
quadrupole (L=190mm)	TBD	24	24	3 kHz	10 ppm	10 ppm	4.44E+05	Unipolar
quadrupole (L=305mm)	2	72	216	3 kHz	10 ppm	10 ppm	4.44E+05	Unipolar with bipolar trims
sextupole	3	48	192	TBD	100 ppm	100 ppm	4.44E+05	Unipolar
H Sextupole	3	48	192				4.44E+05	
quad bend, no quad coil, dipole coil only	Trim coil for line 3	84	84		3 ppm	20 ppm	4.44E+05	Bipolar
Totals			888					

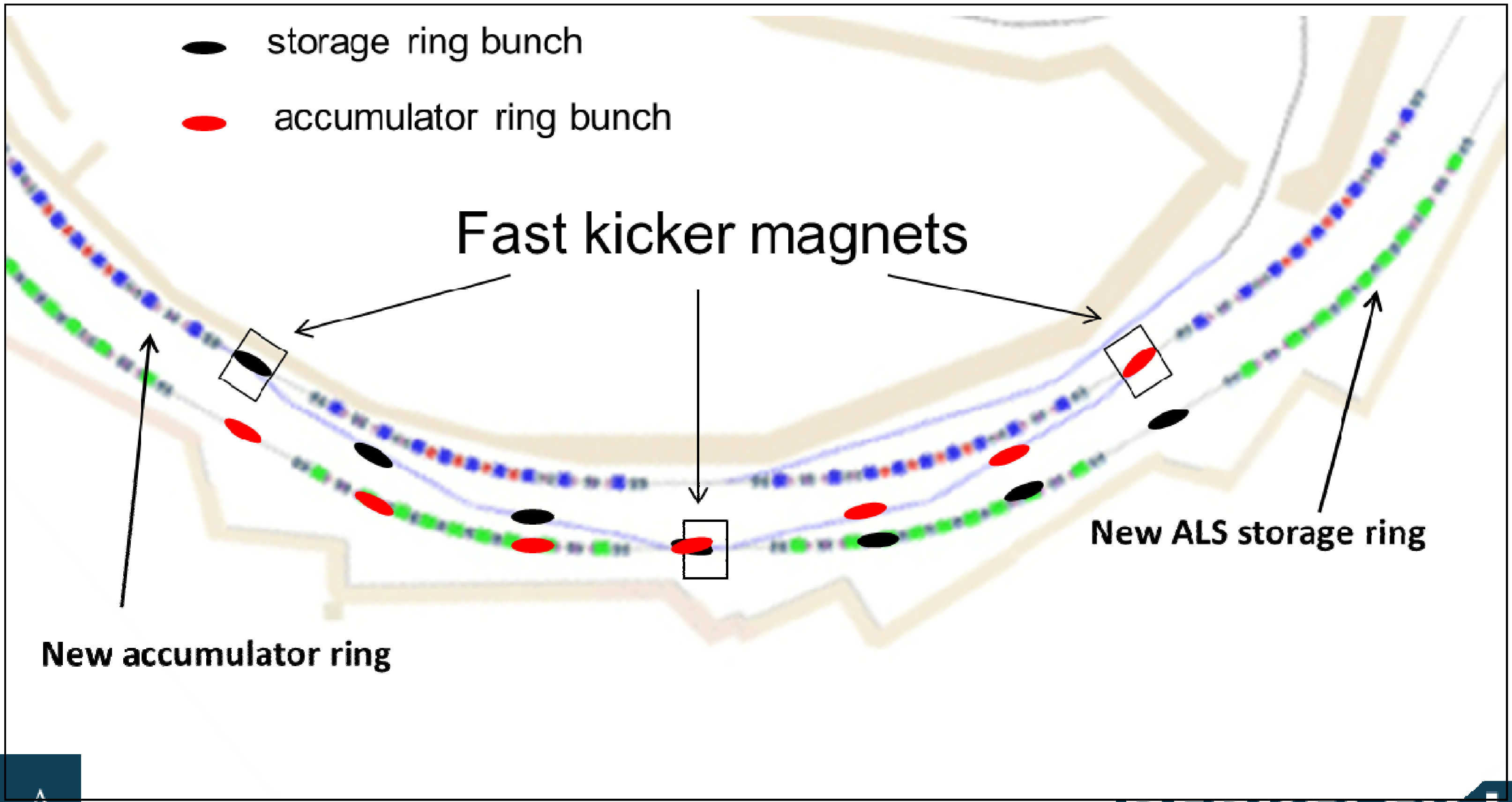
Loss of any of these supplies will result in beam loss.

Power Supply Options

- ALS Physics Group would like to power each magnet with a dedicated supply.
- I question if this is the best option; reliability, cable installation could be compromised….
- One option would be to use redundant, high bandwidth power supplies for critical magnets, that could switch from a partial load to full load quickly.
- Would transients be tolerable?
- What about cost, and an even more complicated cable plan?
- Hoping for expert feedback on options.

ALS-U Swap-Out Injection

Beam lifetime in ALS-U is limited due to inter-bunch scattering. One solution is to use an accumulator ring at the same energy as the ALS-U with less scattering, and swap bunches between the accumulator and storage rings.



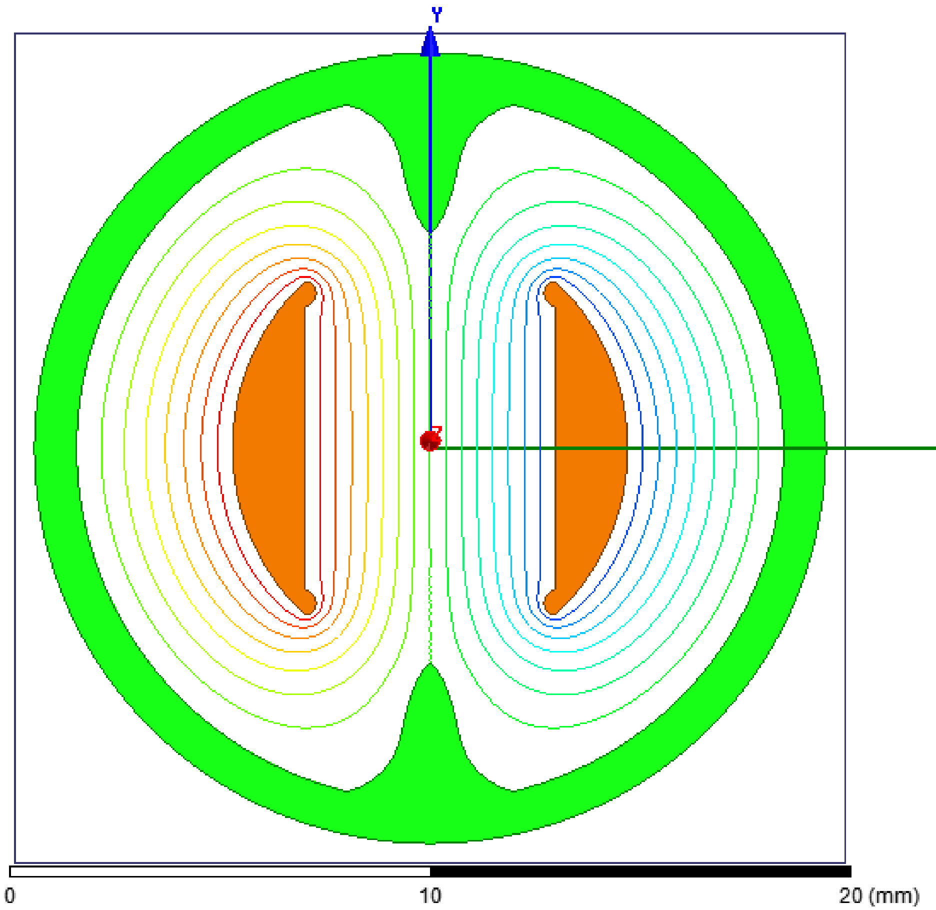
Kicker Requirements

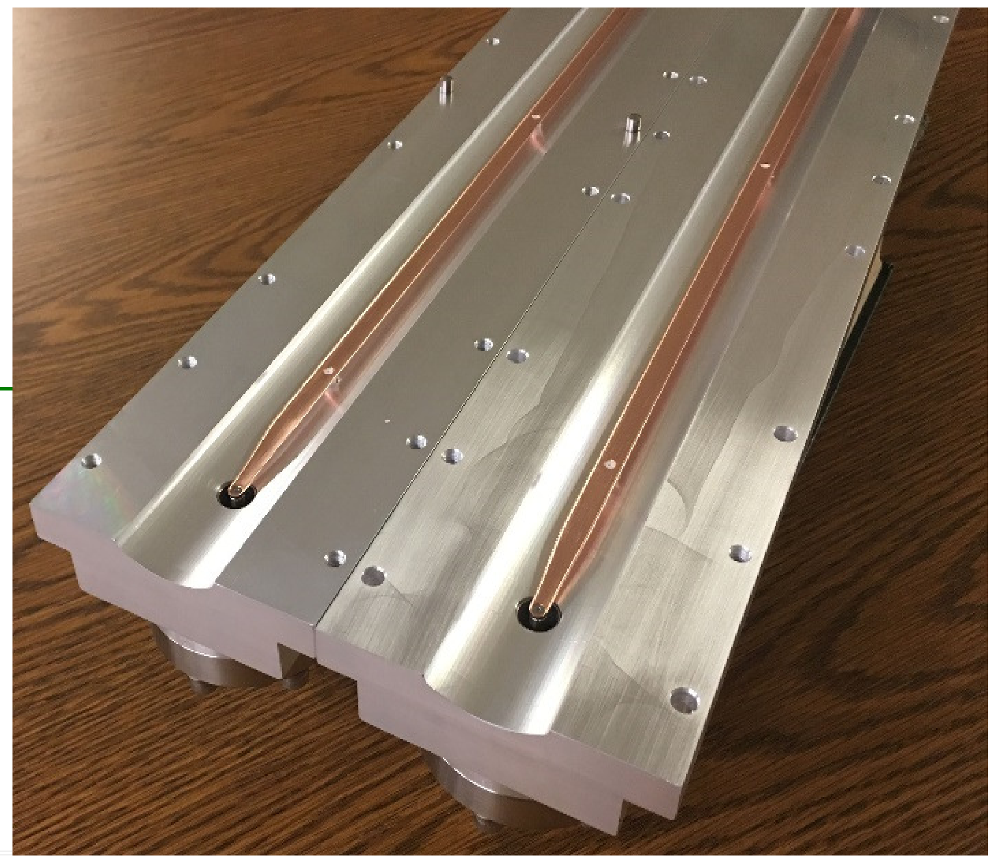
Parameter	Value
Beam Energy	2 GeV
Bend Angle	3.5 mrad
Magnetic Length	2 m
Aperture	10×6 mm (H×V)
B Field	5.83 mT
E Field	1.75 MV/m
Rise/Fall Time	<10 ns
Pulse Width	50 ns
PRF	1 Hz
Inter/Intra Pulse Ripple	<10/1 % FS

Kicker Magnet Design

Magnet is a tapered stripline designed for 50 Ω even mode (2D field simulation shown of left).

A magnet has also been designed to install in the ALS. This will be used to validate our design, and could be used as a vertical pinger. A non-vacuum "cold model" is shown on the right.



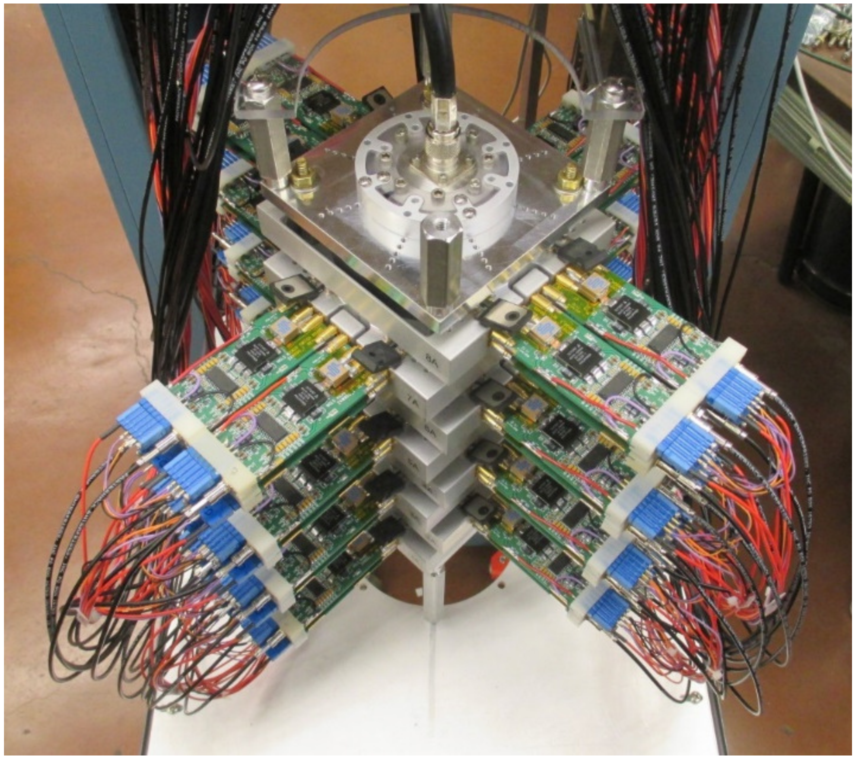


Modulator Requirements

Parameter	Value
System Impedance	50 Ω
Magnet Current	± 106 A
Magnet Voltage	± 5300 V
# of Adder Cells	8
# of MOSFETs/ Cell	8

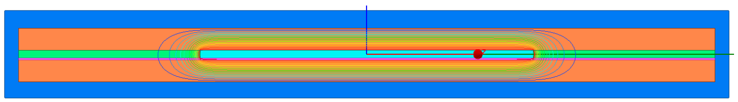
We are investigating three options for the power modulators – a commercial unit from FID Technologies, a conventional inductive adder topology, and a transmission line adder, both adders designed and built at LBNL.

Power Modulators

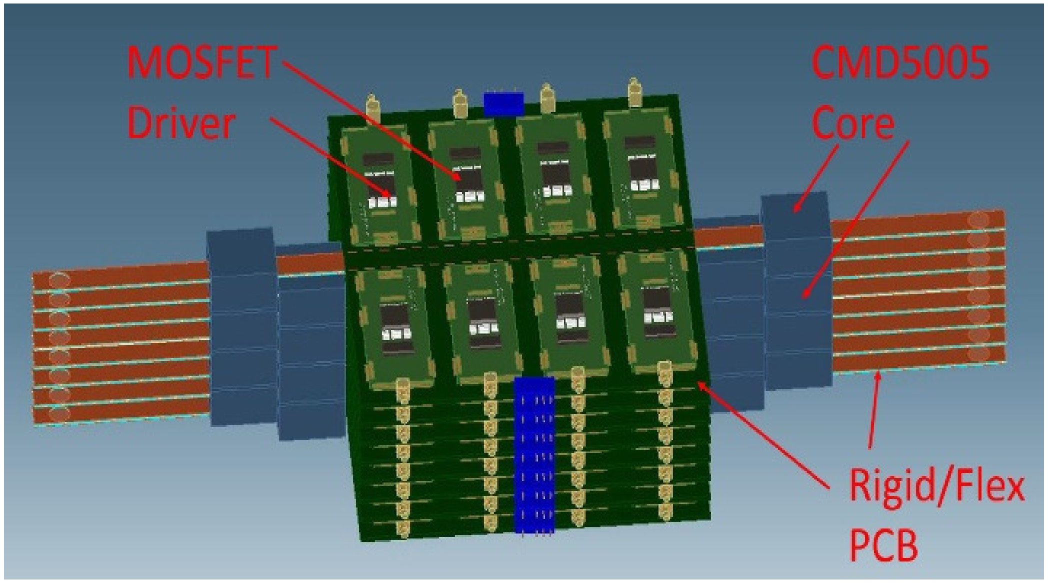


8 Cell Inductive Adder

FID Pulser



6.25 Ω, 3 Layer Flexible Stripline



Rigid/Flex Transmission Line Adder

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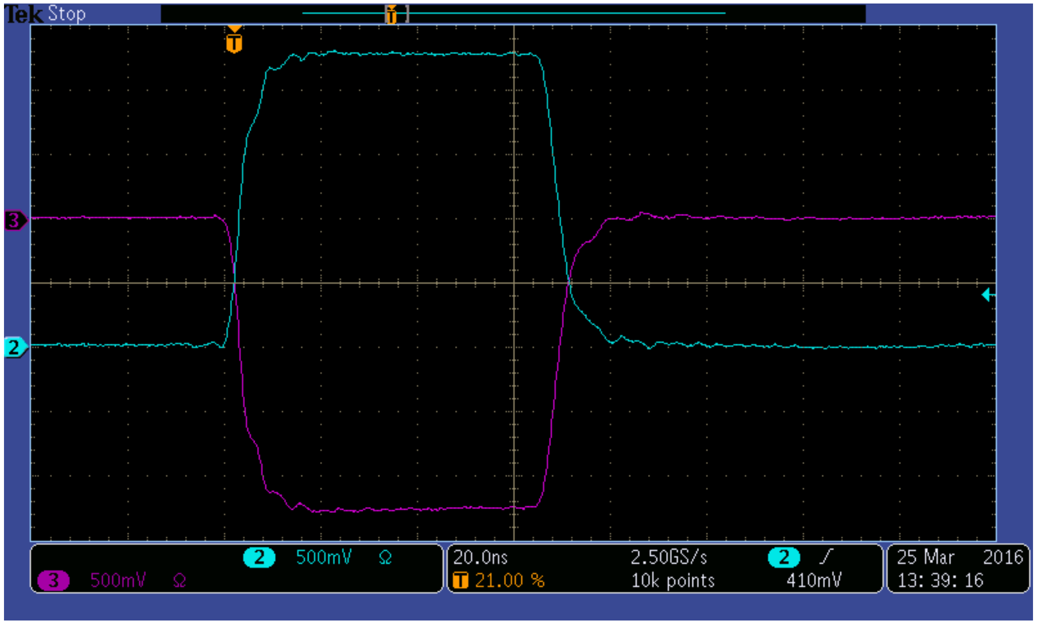
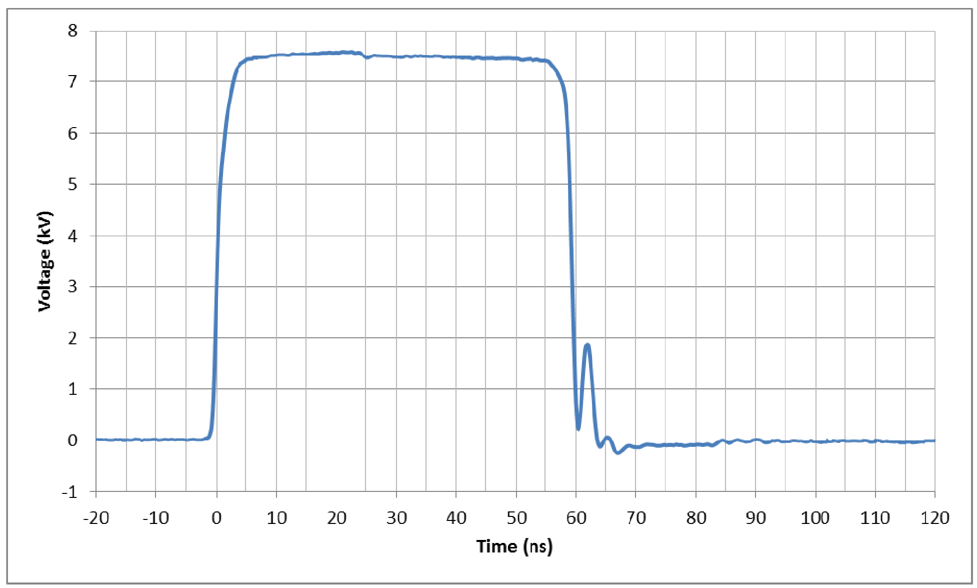
Modulator Testing



Bi-polar output from inductive adder
1000 V/div into 50 Ω.

Unipolar FID output into 50 Ω.



Conclusion

- Discussion of power supplies is just beginning.
- Physics group would like control over every magnet. How to manage availability with such a large number of supplies that could abort beam?
- Plan to test commercial high bandwidth supplies for transients when switching from partial load to full load (redundant supplies). What is the added cost of this plan?
- Swap out kicker work is progressing and we hope to install a prototype system in ALS in Jan. 2017.

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