The IEX Electromagnetic Variably Polarizing Quasi-periodic Undulator

or Just

The IEX Undulator

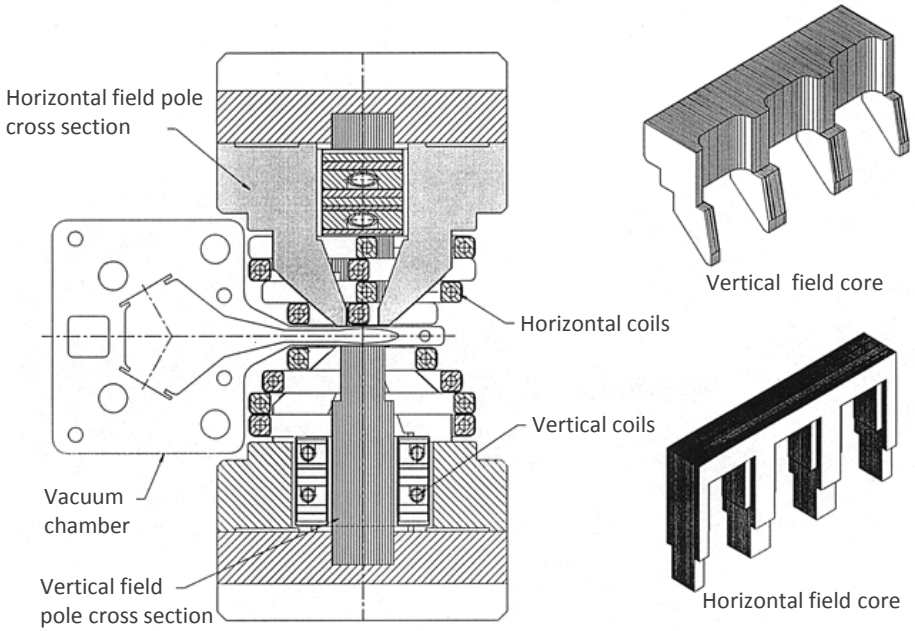
Intermediate **E**nergy **X**-ray

By Mark Jaski

Outline

- History
- Specifications and Parameters
- Prototype
- Quasi-periodicity
- Design and Assembly
- Future Plans

History



The CPU in Sector 4

E. Gluskin et al., AIP Conf. Proc. 521, 344 (2000)

- The project started with a request for a device similar to the circularly polarizing undulator (CPU) installed in Sector 4:
  - low photon energies
  - choice of polarizations (linear horizontal & vertical, left and right-handed circular)
- There were to be differences:
  - An option to minimize higher harmonics in the photon spectrum
  - No need for rapid switching between left- and right-handed circular polarizations
- Several possible undulator designs were discussed
  - Apple II (all permanent magnet)
  - Electromagnetic/Permanent magnet
  - Electromagnetic

Specifications

General	Period	12.5	cm
	Gap	10.5	mm
	Periods per device (including end poles)	38	Periods
Horizontal Linear Polarization	Minimum Photon Energy	250	eV
	Required vertical effective field	4514	Gauss
	Effective K Value	5.27	
Vertical Linear Polarization	Minimum Photon Energy	440	eV
	Required horizontal effective field	3308	Gauss
	Effective K Value	3.86	
Circular Polarization	Minimum Photon Energy	440	eV
	Required horizontal and vertical effective field	2340	Gauss
Maximum Allowed 1st and 2nd Integrals	1st integral Bx	50	Gauss-cm
	2nd integral Bx	100,000	$Gauss\text{-}cm^{2}$
	1st integral By	100	Gauss-cm
	2nd integral By	100,000	$Gauss\text{-}cm^{2}$
Maximum Allowed Integrated Multipoles	Normal Quadrupole	50	Gauss
	Normal Sextupole	200	$Gauss\text{-}cm^{-1}$
	Normal Octupole	300	$Gauss\text{-}cm^{-2}$
	Skew Quadrupole	50	Gauss
	Skew Sextupole	100	$Gauss\text{-}cm^{-1}$
	Skew Octupole	50	$Gauss\text{-}cm^{-2}$

Selected Parameters

General	Period	12.5	cm
	Gap	10.5	mm
	Periods per device (including end poles)	38	Periods
	Length	4.8	m
By Field	Max Achievable Vertical Effective Field	4599	Gauss
	Peak field[1]	5456	Gauss
	Current[1]	47.6	A
	Number of By coils	112	Each
	Number of By Quasi-periodic coils	40	Each
	Total Power of By Coils[1]	4846	Watts
	Total Power of By Quasi-periodic coils[1]	1803	Watts
Bx Field	Max Achievable Horizontal Effective Field	3362	Gauss
	Peak field[1]	3767	Gauss
	Current[1]	50.3	A
	Number of Bx coils	224	Each
	Number of Bx Quasi-periodic coils	80	Each
	Total Power of Bx Coils[1]	8764	Watts
	Total Power of Bx Quasi-periodic coils[1]	3220	Watts

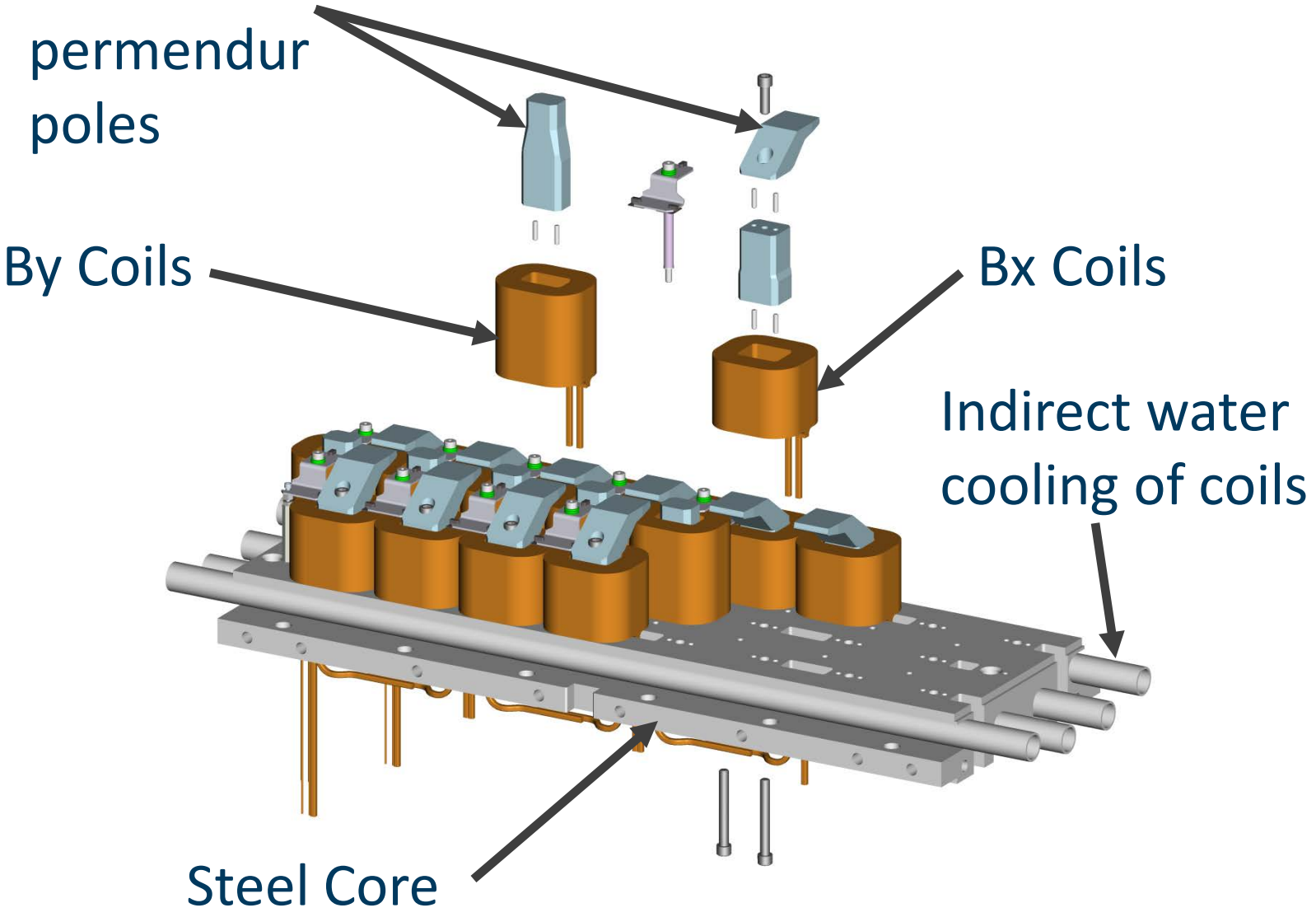
Bx Trim Coils	Peak Current	5.87	A
	Total Power at Peak Current	40	Watts
	Number of Bx trim coils	4 upstream	Each
		4 downstream	Each
By Trim Coils	Peak Current	5.53	A
	Total Power at Peak Current	45	Watts
	Number of By trim coils	2 upstream	Each
		2 downstream	Each
Maximum Achievable Multipole Corrections	DS Skew Dipole	9,021	G-cm
	DS Normal Dipole	13,153	G-cm
	DS Skew Quadrupole	4,251	G
	DS Normal Quadrupole	15,158	G
	DS Normal Sextupole	10,236	G/cm
	DS Skew Octupole	346	G/cm^2
	US Skew Dipole	8,043	G-cm
	US Normal Dipole	13,054	G-cm
	US Skew Quadrupole	4,569	G
	US Normal Quadrupole	15,144	G
	US Normal Sextupole	10,140	G/cm
	US Skew Octupole	375	G/cm^2
Earth Field Corrector	Integrated Field Per Ampere	490	Gauss-cm/A
	Peak Current	8	A
	Total Power at Peak Current	4.5	Watts
	Maximum Temperature of Coils	100	°C

[1]At the Max Achievable Effective Field

All fields listed above are calculated values

17 Power Supplies

Prototype General Assembly Exploded View



OPERA 4 Period Model For Prototype

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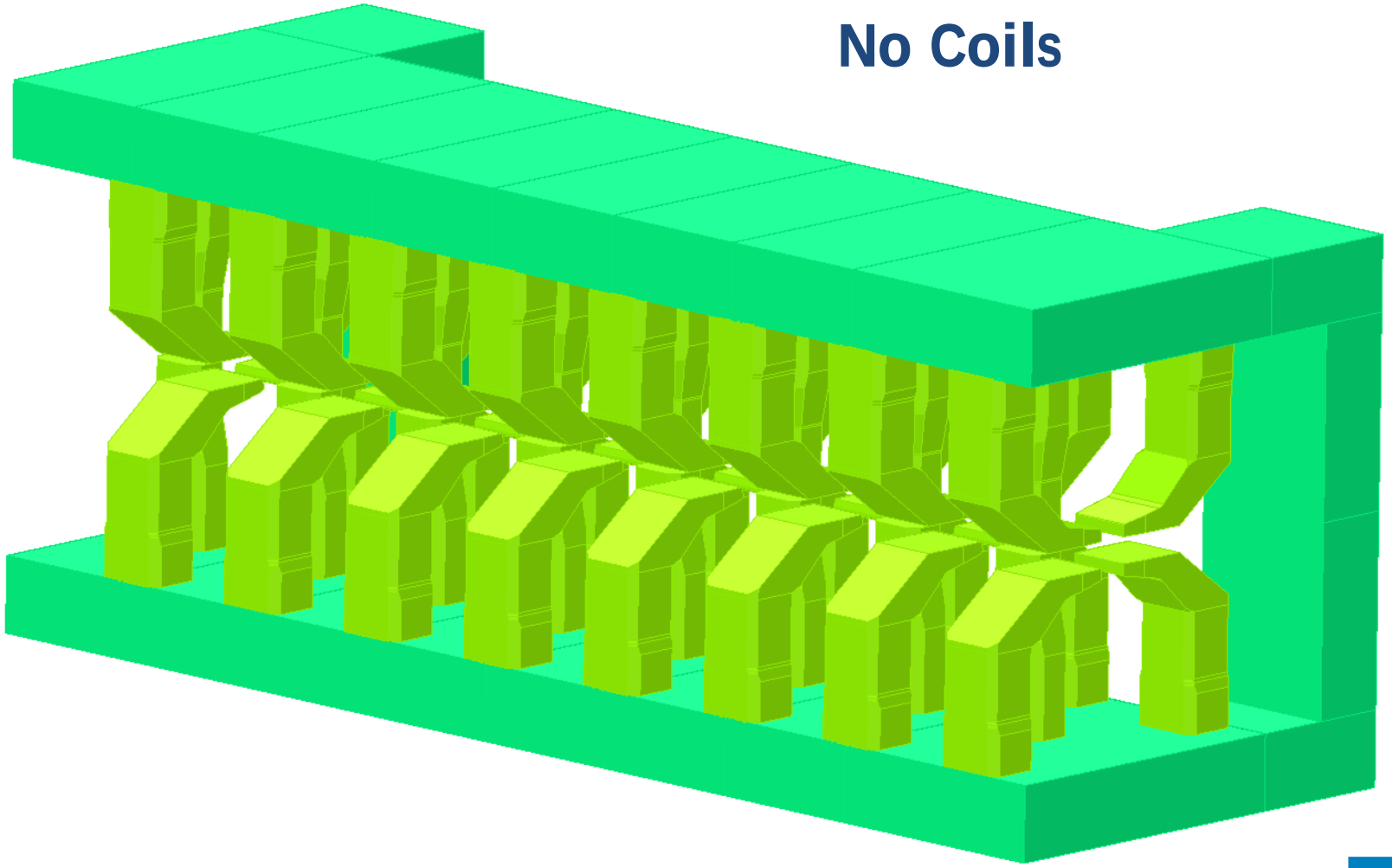
No Coils



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OPERA 4 Period Model For Prototype

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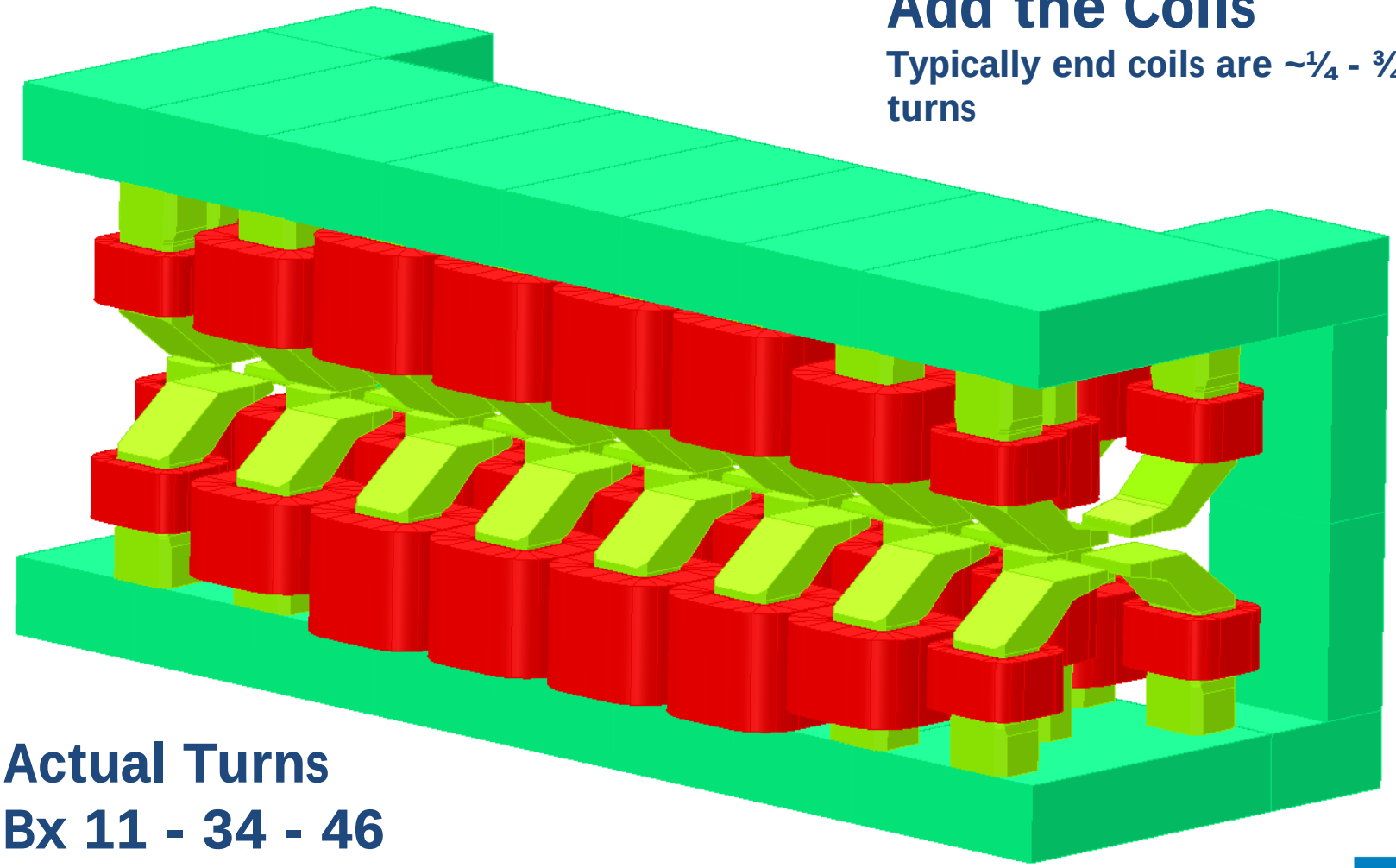
Add the Coils

Typically end coils are ~¼ - ¾ - 1 turns



Actual Turns

Bx 11 - 34 - 46

By 15 - 42 - 62

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OPERA 4 Period Model For Prototype

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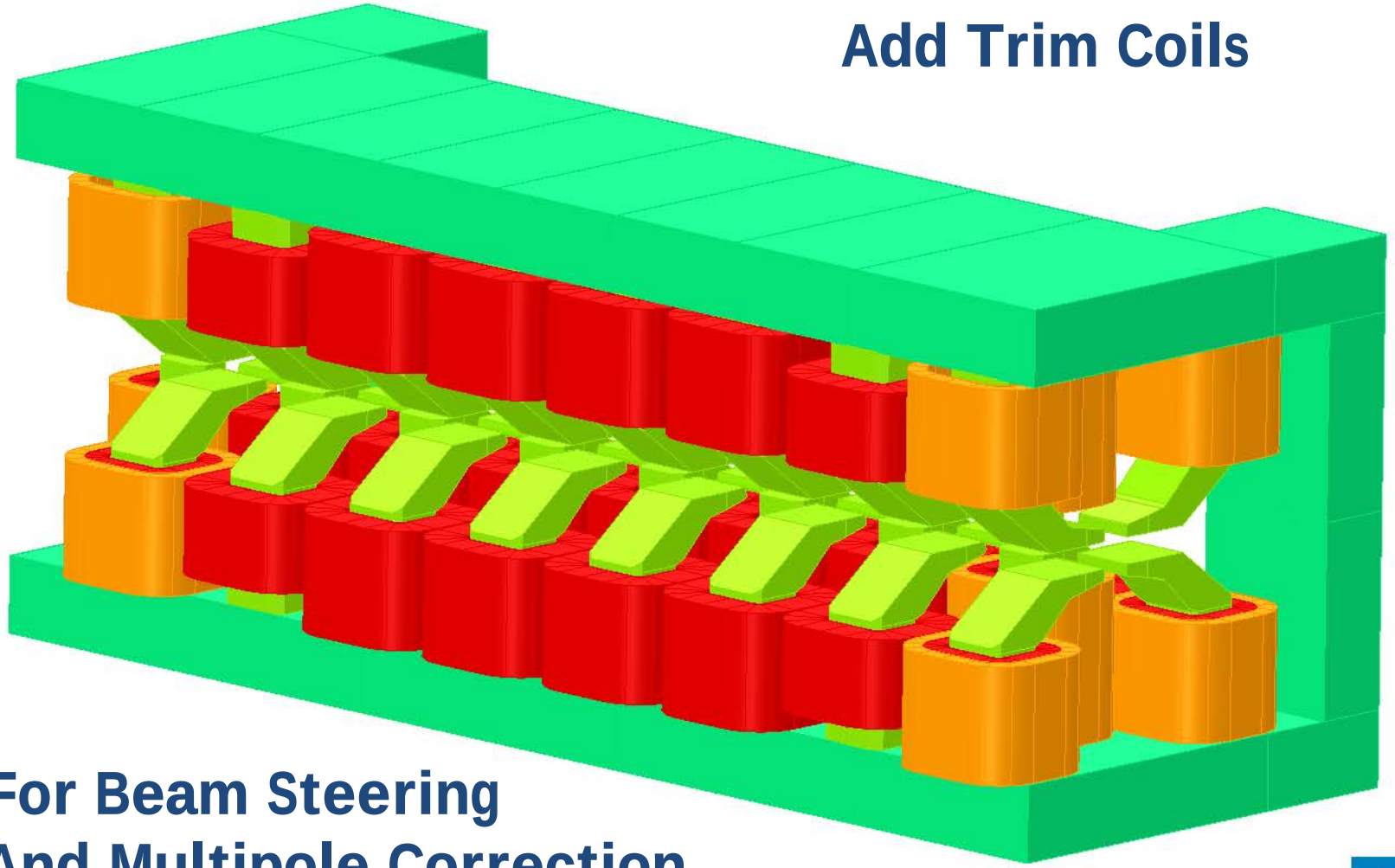

Add Trim Coils

For Beam Steering And Multipole Correction

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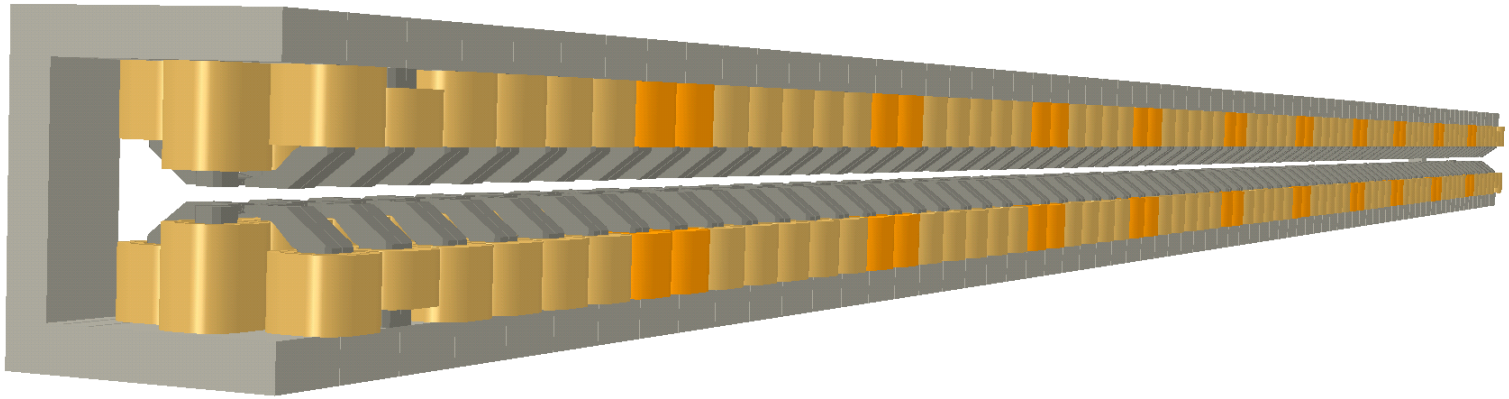
IEX Prototype 2 (4 periods)

Major Findings

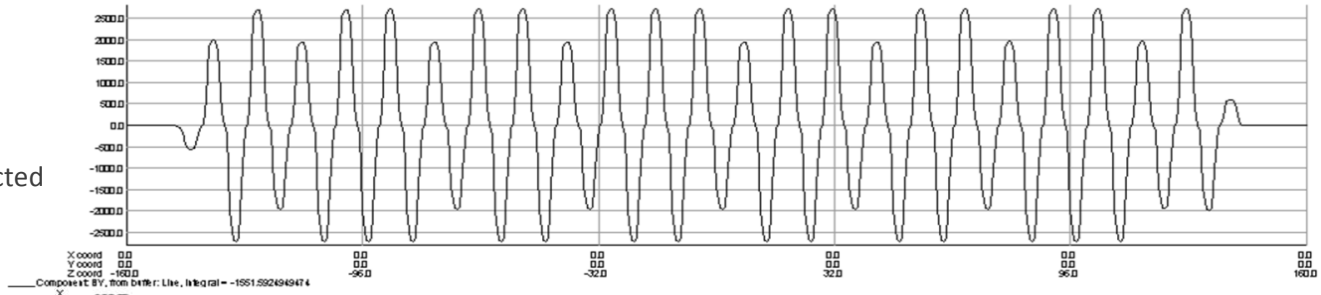
- Two prototypes were built. The first showed that the cooling scheme would work as calculated.
- During the construction of the first prototype, beam simulations showed that the field roll-off was too large for storage ring injection.
- The magnetic design was modified to make the poles wider so as to reduce the roll-off. Prototype 2 was built.
- Magnetic measurements of the prototype agreed with the calculations, after some adjustment of the assumed magnetic properties.
- Separate power supplies for each end coil provides a means to correct several multipoles.

Electromagnet IEX Device Can Be Periodic or Quasiperiodic

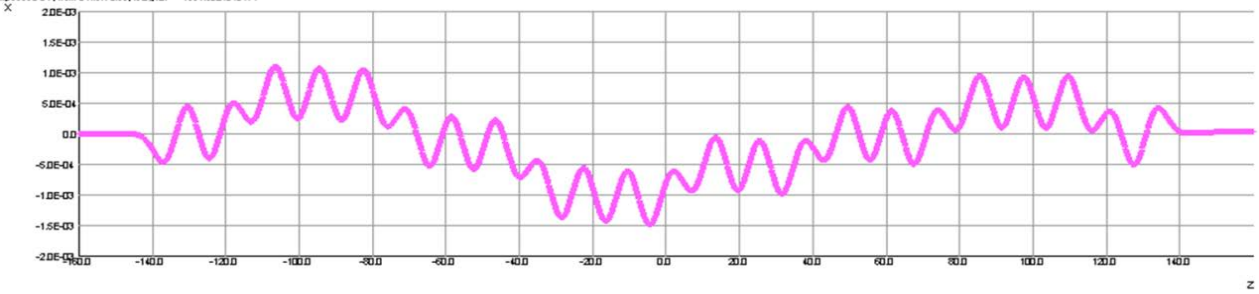


Quasi-periodic Field

The field is reduced at selected poles[1]

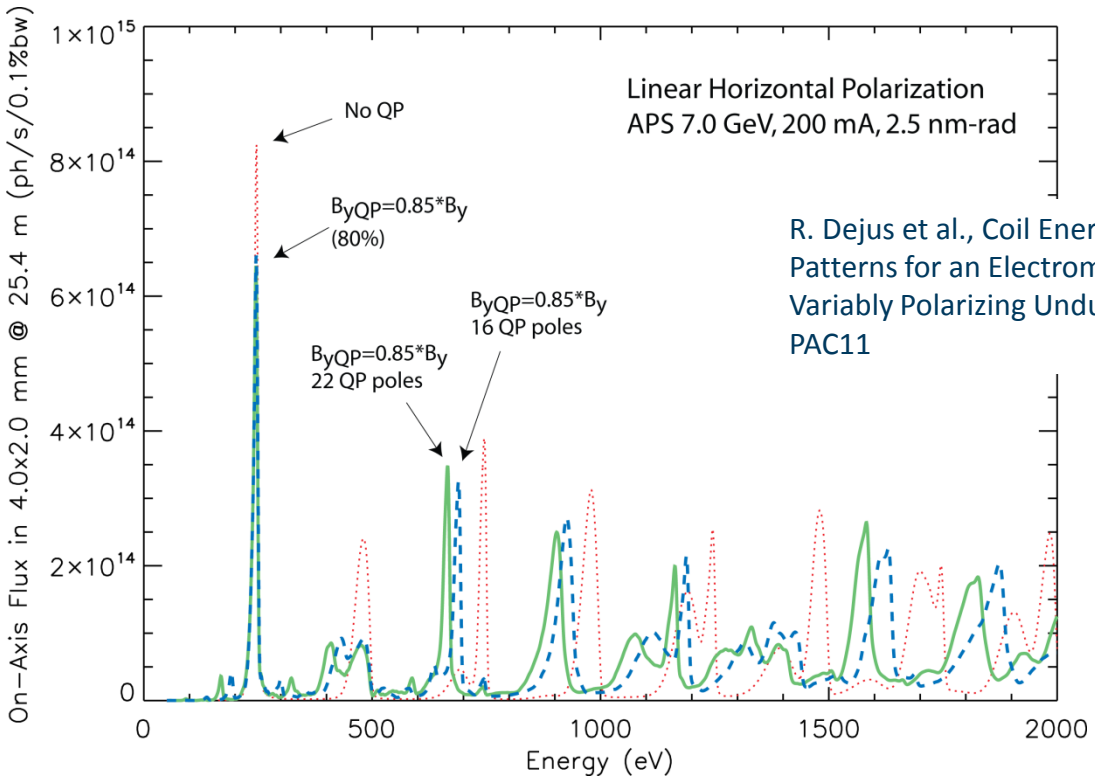


Quasi-periodic Electron Trajectory



[1]S. Sasaki, Overview of Quasi-periodic Undulators, PAC09

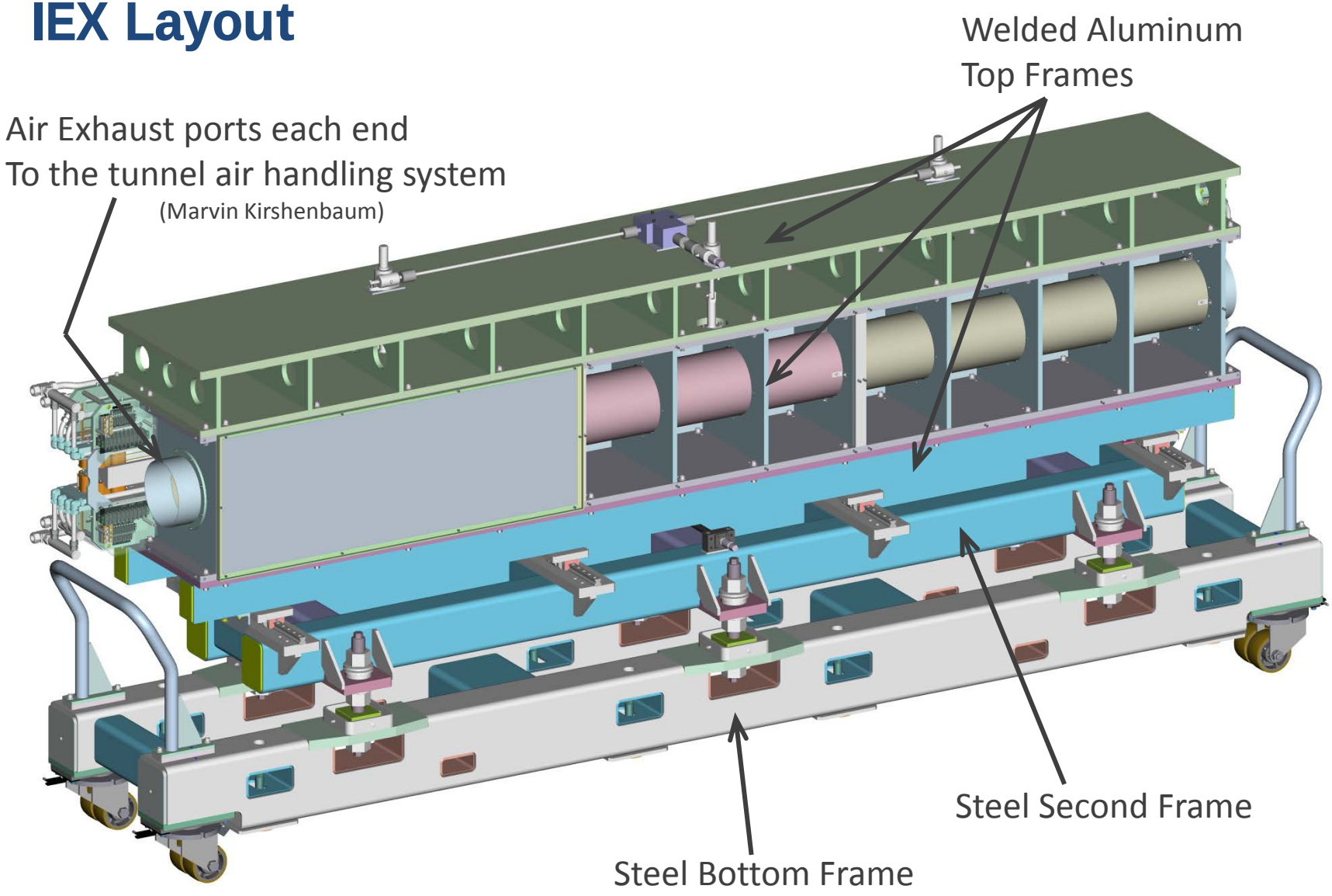
Quasi-periodicity Suppresses the Higher Harmonics



R. Dejus et al., Coil Energizing Patterns for an Electromagnetic Variably Polarizing Undulator, PAC11

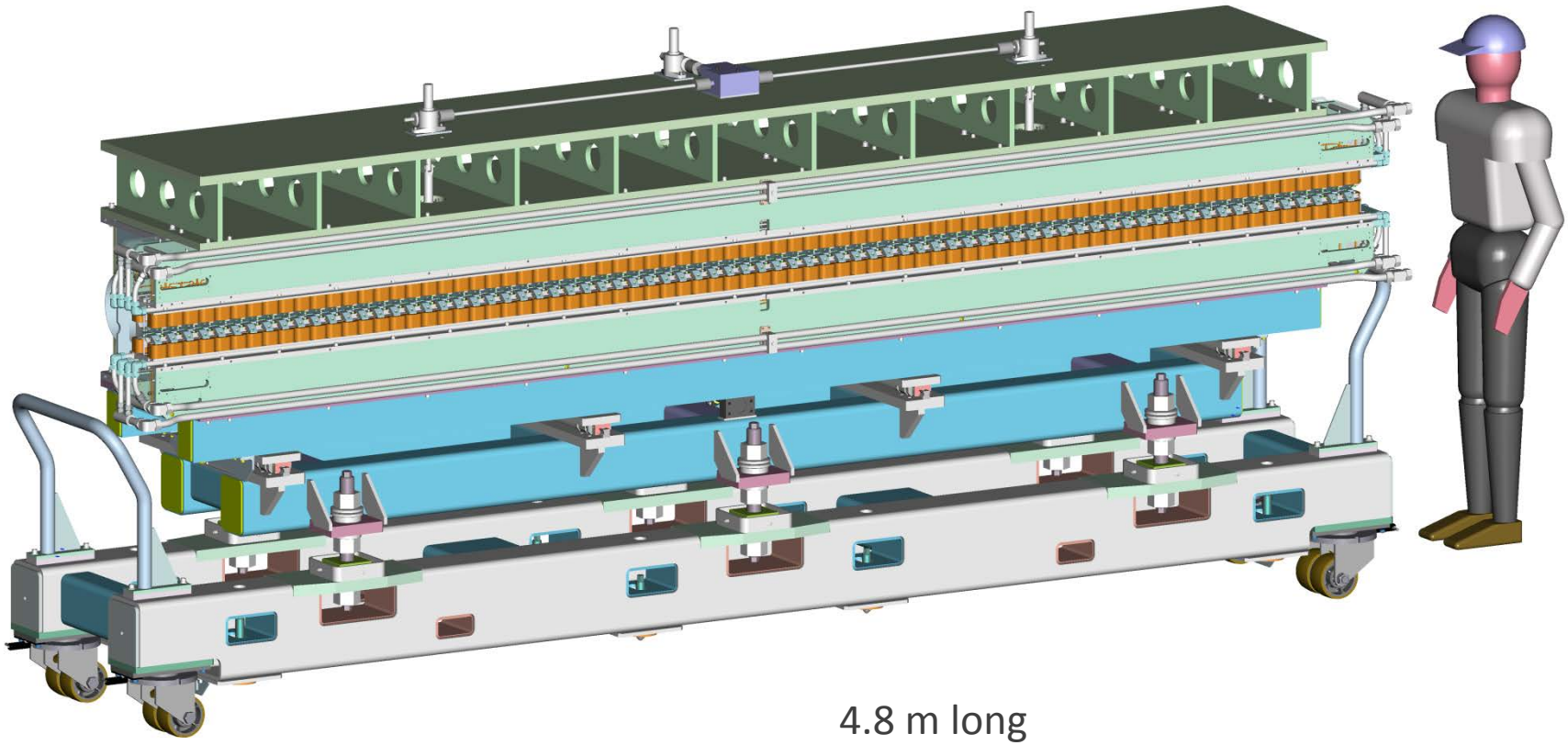
Flux in linear horizontal polarization mode at 250-eV first-harmonic energy for two different QP patterns with reduced magnetic field at the QP poles (85% of regular field). The higher harmonics are shifted to lower energies with the QP turned on. The energy shift is smaller for the 16-pole pattern (blue dashed curve). The flux of the third harmonic is reduced to ~ 8% and the second harmonic is reduced to less than 50% for both patterns. The first harmonic is reduced by ~ 20%.

IEX Layout


Welded Aluminum
Top Frames
Air Exhaust ports each end
To the tunnel air handling system
(Marvin Kirshenbaum)
Steel Second Frame
Steel Bottom Frame

IEX Device

Installation in April 2012



4.8 m long
~14,000 lbs

Assembly

Future Plans

- Complete assembly and begin magnetic measurements in January 2012.
- 3 months for magnetic measurements, testing, and creating look-up tables.
- Installation in sector 29 is currently scheduled for the April/May 2012 shut down.
- Development of a fast switching (10 Hz) electromagnetic device is underway.

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