Delta undulator magnet beam test at ATF (BNL)

M. Babzien, D. Davis, M. Fedurin, K. Kusche, J.Park, V. Yakimenko,
Brookhaven National Laboratory, Upton, USA

Alexander Temnykh, CLASSE, Cornell University, Ithaca, New York, USA

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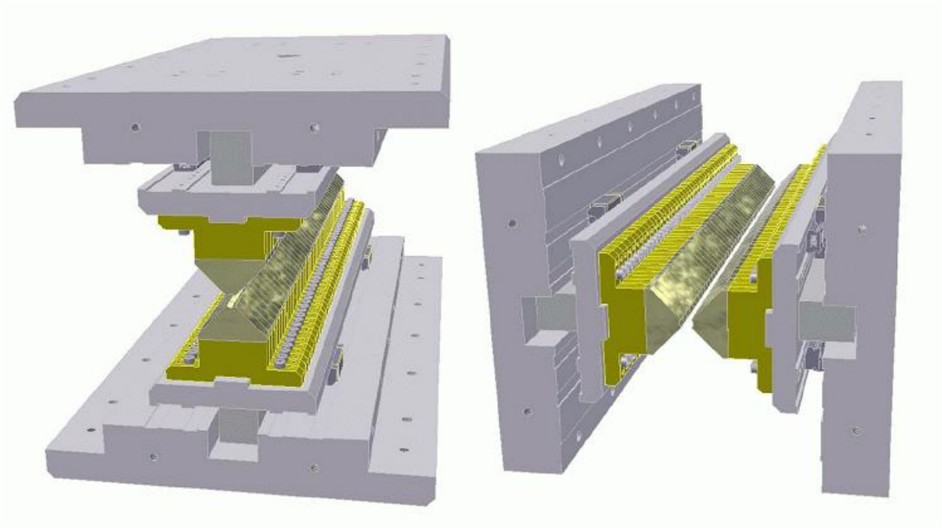
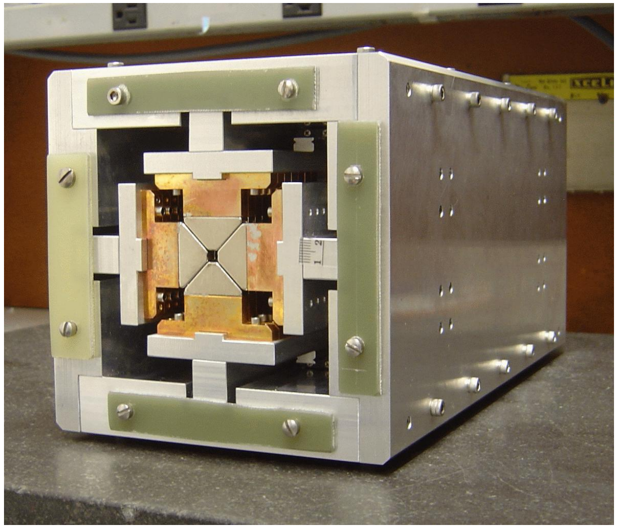
Outline

- Introduction
  - Delta undulator magnet concept and characteristics
- Beam test setup
- Beam test procedure and results
  - Planar mode / linear polarized radiation
  - Helical mode / circular polarized radiation
  - Measurement of spatial distribution of 4520nm undulator circular polarized radiation
- Conclusion

Delta undulator magnet concept*

Two AP (adjustable phase**) undulators assembled in one device.



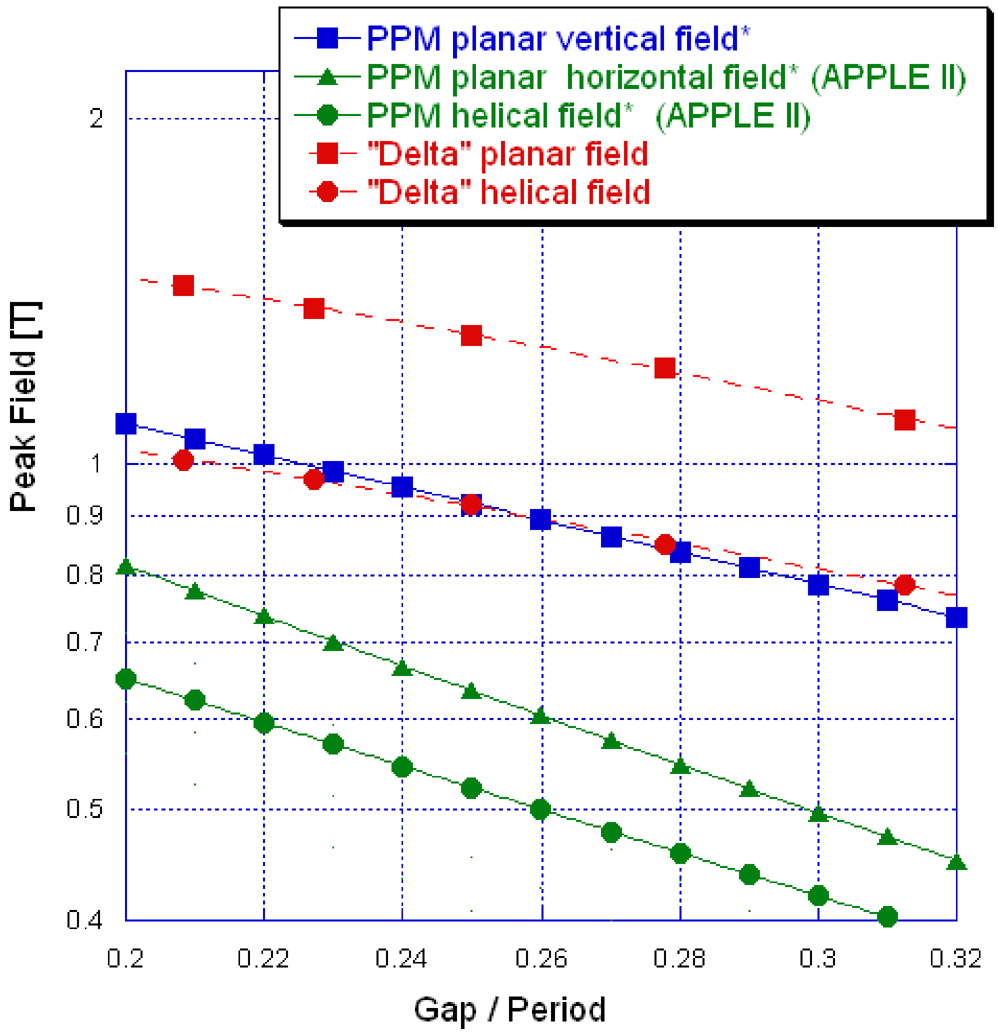


1. Compact box-like frame: (prototype dimension ~150mmx150mm)
2. Full polarization control
3. Sqrt(2) stronger field in planar mode and ~2X stronger in helical mode in compare with conventional / Apple II type undulators.

Potential applications: ERLs, XFELs , (storage rings?)

*A. Temnykh, Phys. Rev. ST Accel. Beams 11, 120702 (2008).
**Basic theory: Roger Carr, Nucl. Instr. And Meth. A 306(1991) 391-396

Delta undulator magnet concept*

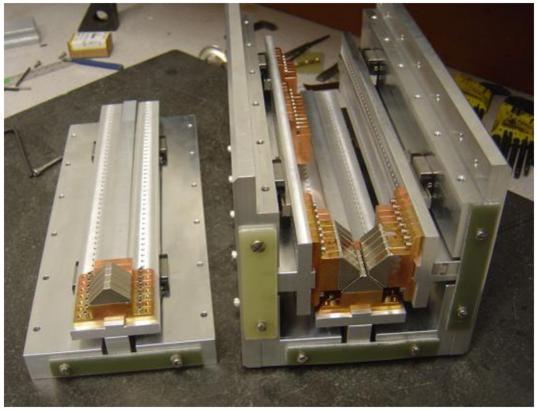


*P. Elleaume, et al., Design considerations for a 1 A SASE undulator, NIMA, 455(2000) 503-523

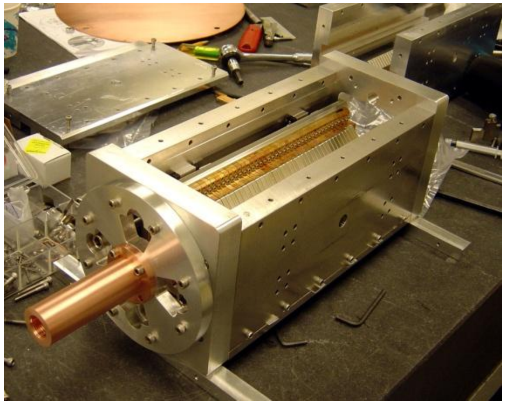
Model construction at Cornell

Model parameters

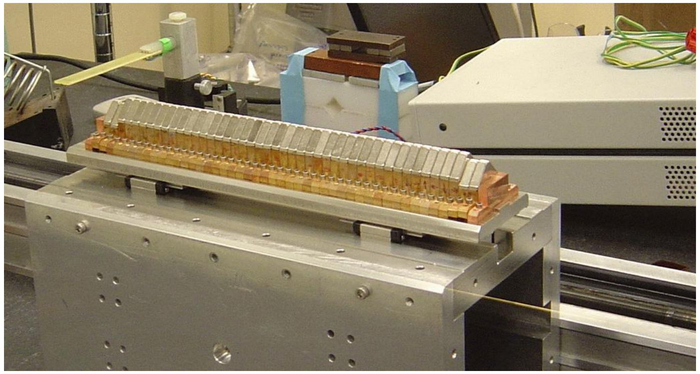
- PPM structure
- NbFeB (40SH) Br =1.25T, Hci > 20Koe
- Period 24mm
- Length ~ 30cm
- Bmax (designed) in helical mode ~1.0T
- Bmax (designed) in planar ~ 1.4T



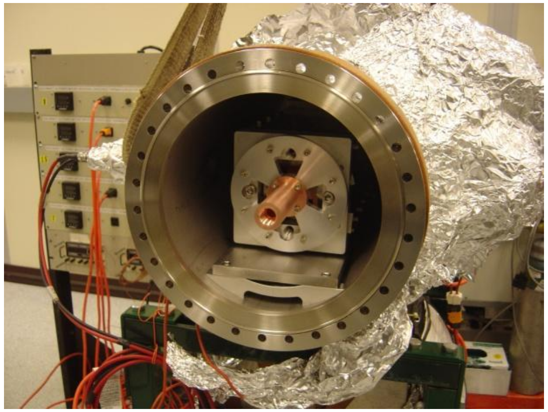
Assembly start



Test assembly and dimensions check



Magnet field measurement and tuning

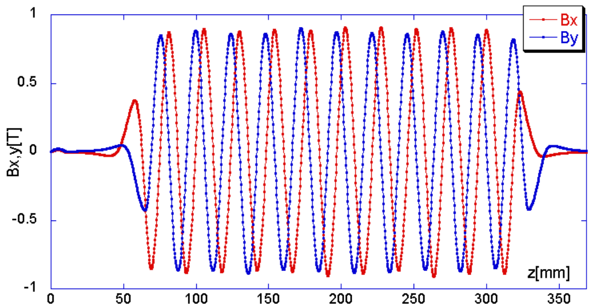


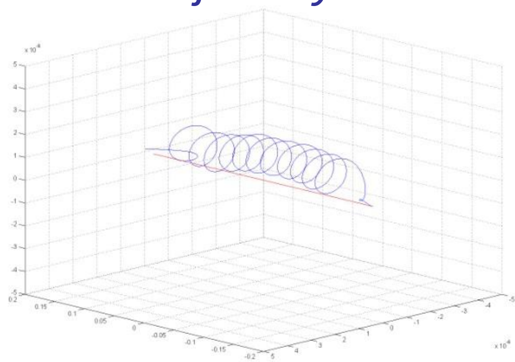
Model in vacuum vessel

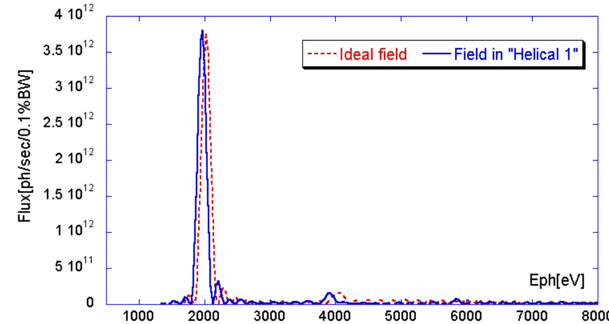
Transport to BNL

Model characteristics: magnetic field in helical mode

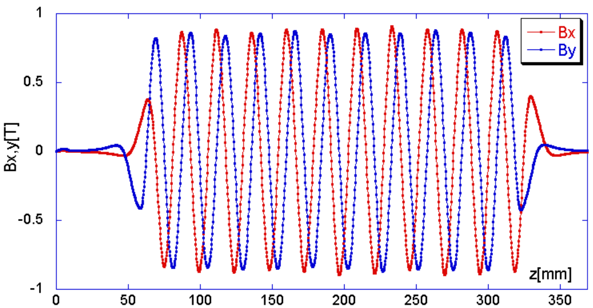
Measured field components | *Trajectory* | *X-ray Spectra*

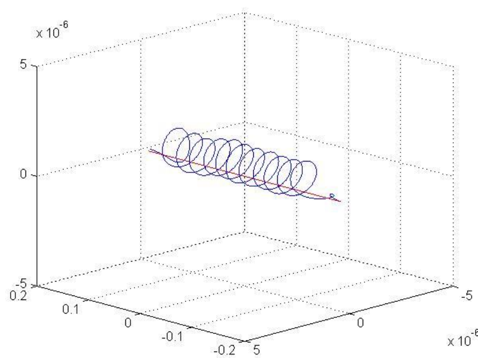


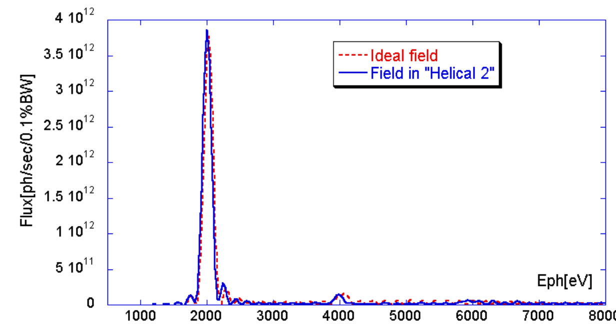




Helical mode, left circular polarization (phase between vertical and horizontal pairs 90^0)



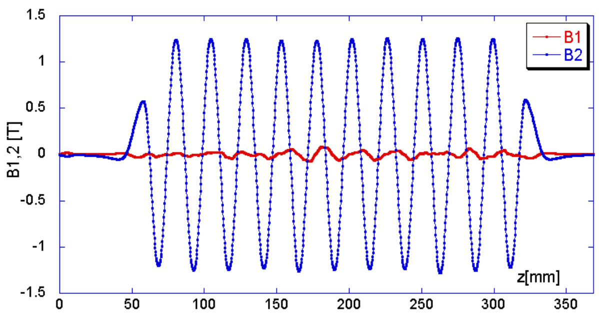


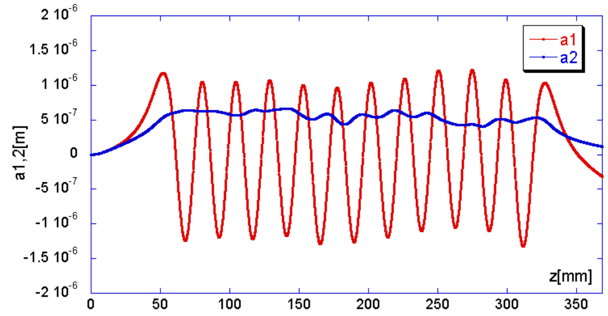


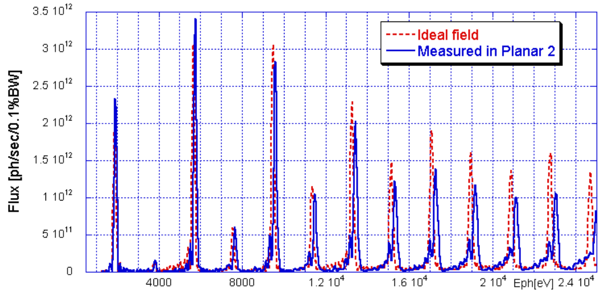
Helical mode, right circular polarization (phase between vertical and horizontal pairs -90^0)

Model characteristics: magnetic field in planar mode

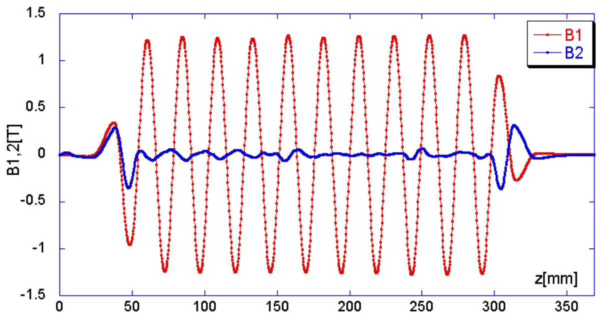
Measured field components | *Trajectory* | *X-ray Spectra*

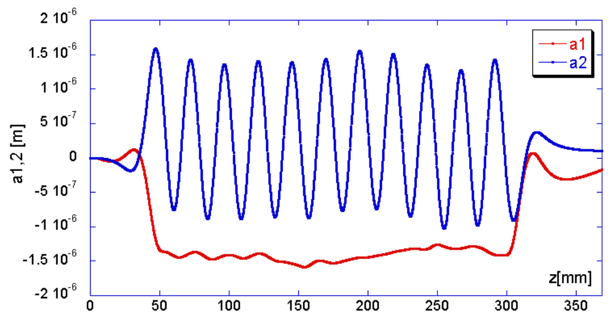


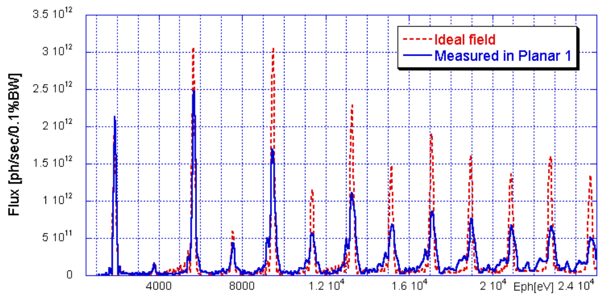




Planar mode, - 45deg linear polarization (phase between vertical and horizontal pairs 180deg)







Planar mode, +45deg linear polarization (vertical and horizontal pairs in phase)

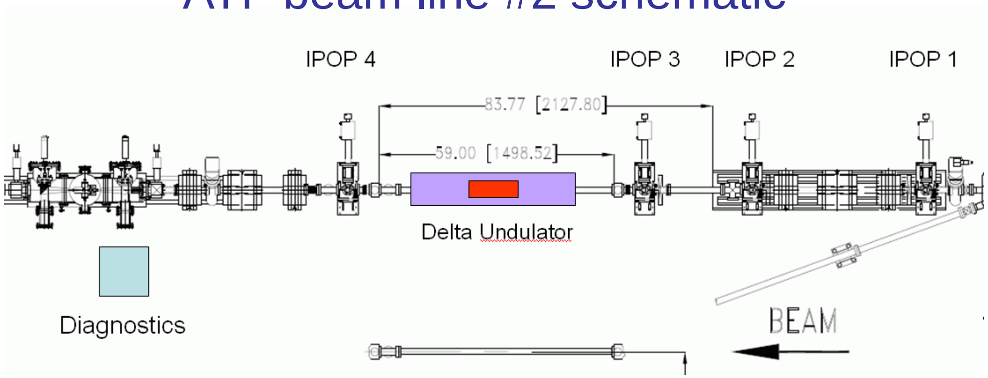
Note: B1 and B2 two orthogonal field component tilted relative horizontal and vertical axis by 45deg.

Test goals and beam test setup at ATF (BNL)

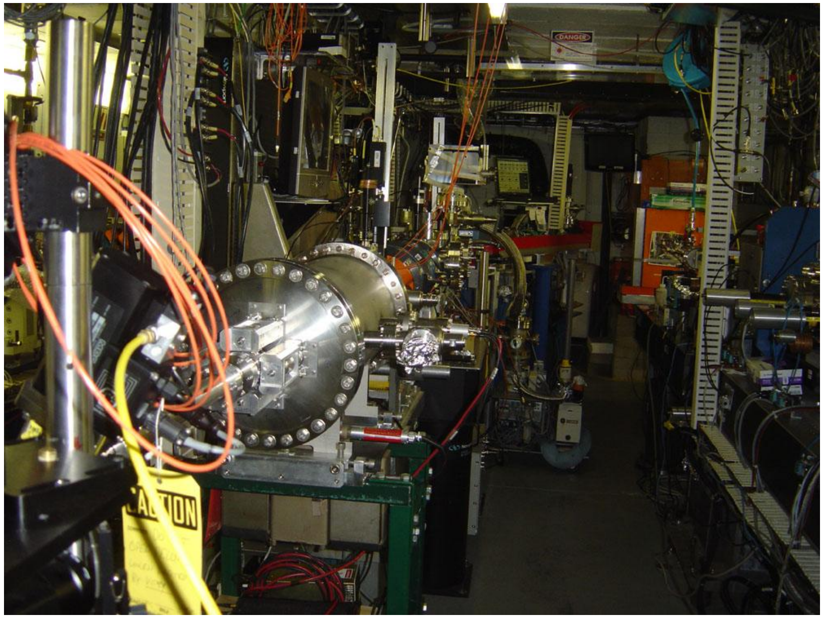
Two goals for the test:

1. Get experience in transportation, installation, test mechanics.
   (No problems with transportation and installation, mechanics work OK)
2. Characterize (verify) undulator radiation properties

ATF beam line #2 schematic



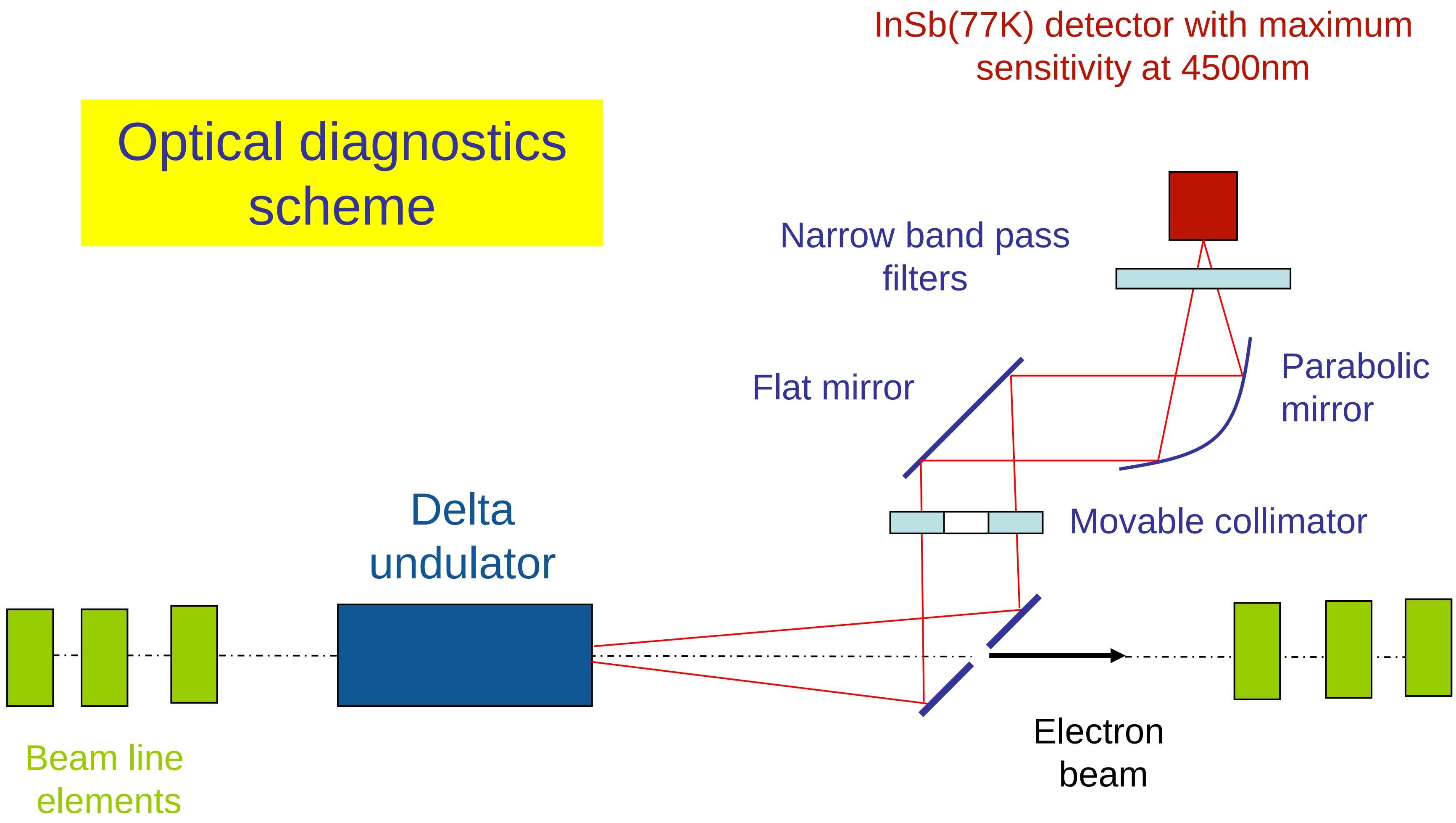
ATF beam parameters:
- Energy in range from 52MeV to 72MeV
- Normalized emittance 1e-6 m*rad
- Bunch charge ~ 500pC
- Repetition rate ~ 1.3 pulse/sec



Delta undulator installed in BL2 at ATF.

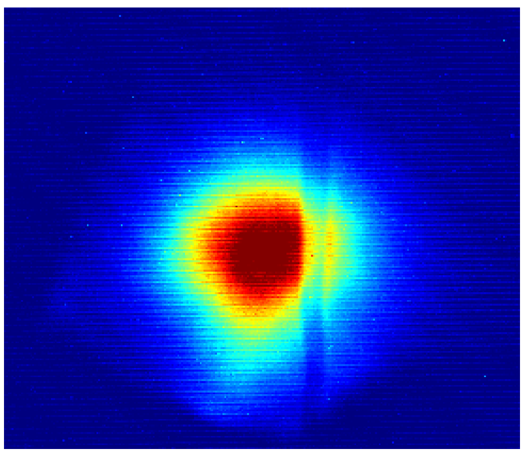
Beam test setup at ATF (BNL)

Optical diagnostics scheme



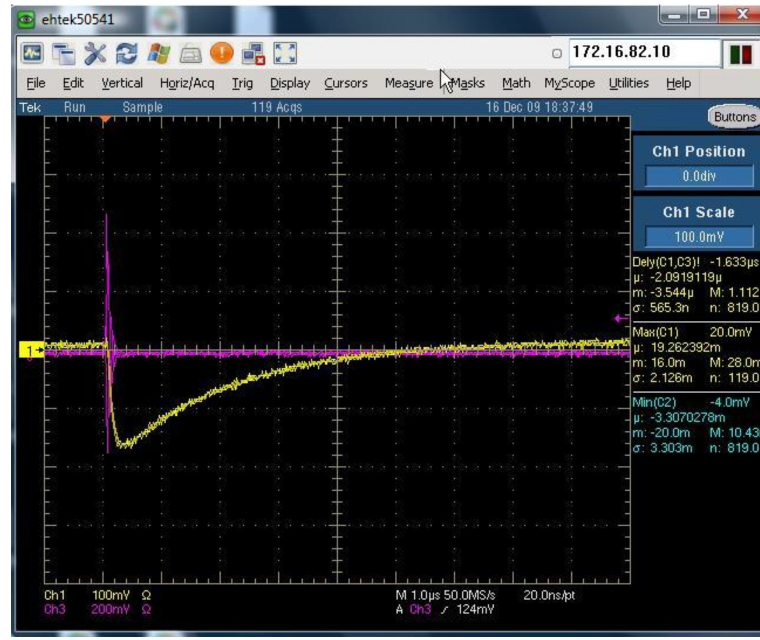
Beam test result

Beam tuning



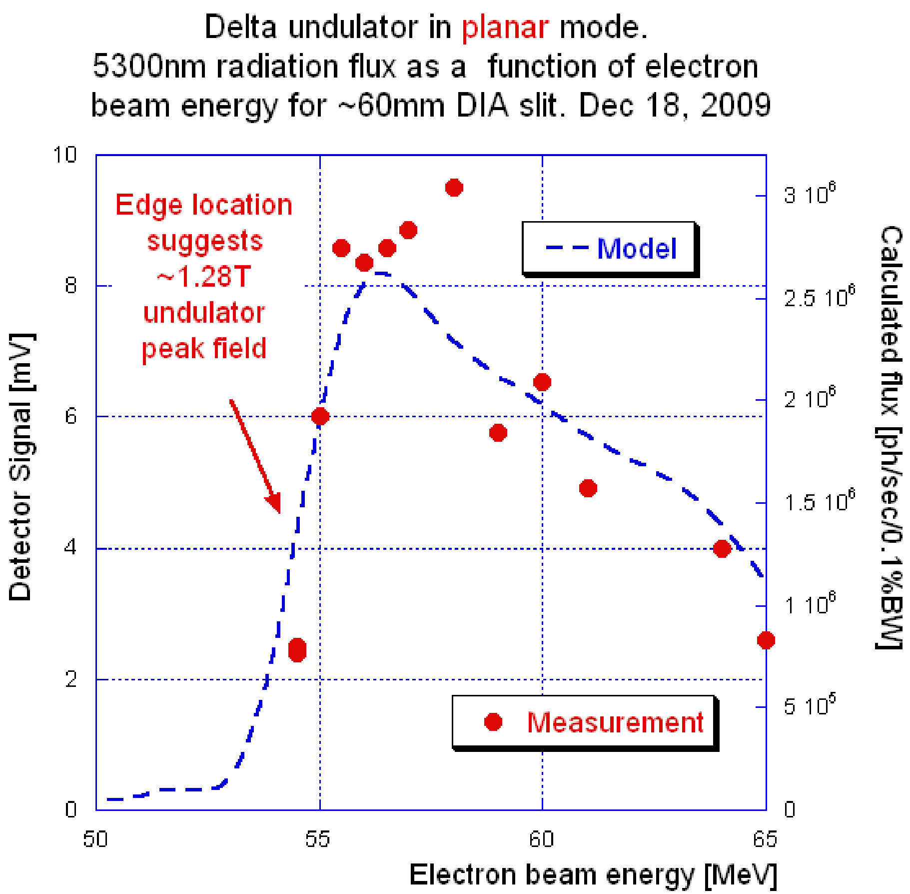
Electron beam downstream of undulator

After short tuning by experts, electron beam was transported through the undulator (5mm bore) and infrared undulator radiation was detected by InSb(77K) sensor.



Infrared radiation detected by InSb sensor

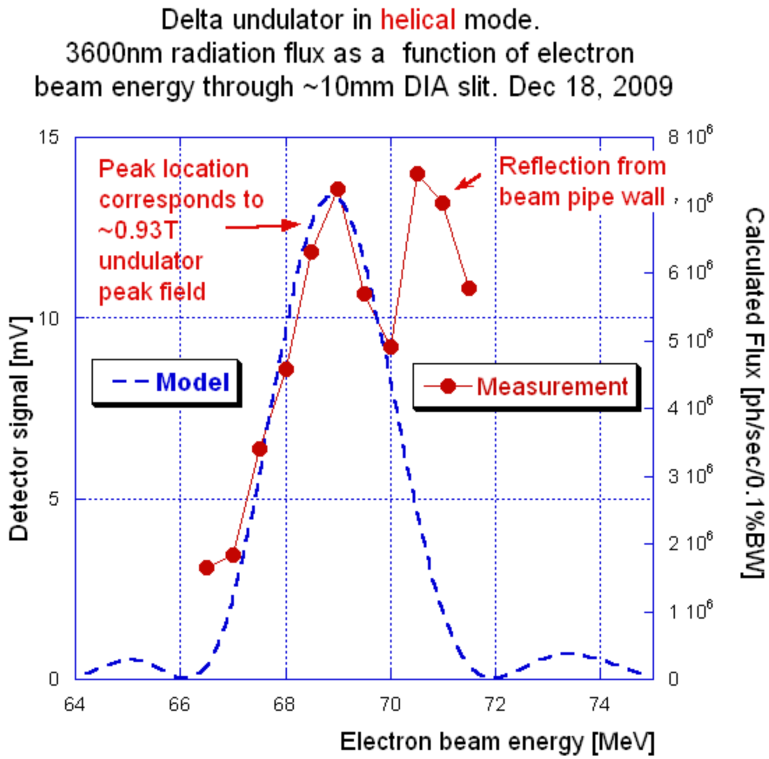
Beam test result:
Planar mode / linear polarized radiation

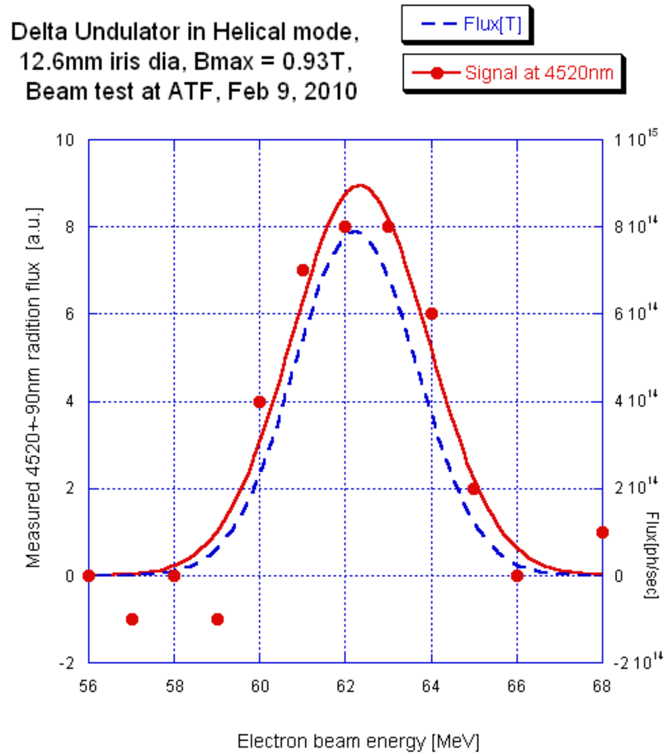


5300nm wavelength radiation intensity on axis as function of the electron beam energy.

Signal confirmed 1.28T peak field in undulator in planar mode !

Beam test result:
Helical mode / circular polarized radiation





y = m1 *exp(-(m0-m2)^ 2/2/m3...

	Value	Error
m1	8.9508	0.73615
m2	62.335	0.15164
m3	1.5974	0.15223
Chisq	9.1859	NA
R	0.96656	NA

y = m1 *exp(-(m0-m2)^ 2/2/m3...

	Value	Error
m1	7.8822e+14	1.7462e+13
m2	62.242	0.036678
m3	1.4336	0.036676
Chisq	5.1658e+27	NA
R	0.99723	NA

3600nm wavelength radiations on axis as a function of electron beam energy.

4520nm wavelength radiations as a function of electron beam energy.

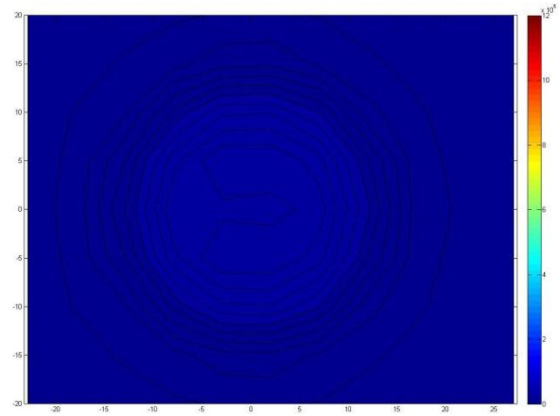
Both measurements confirmed 0.93T field amplitude in helical mode

Beam test result: 4520nm radiation spatial distribution as a function of electron beam energy (model prediction)

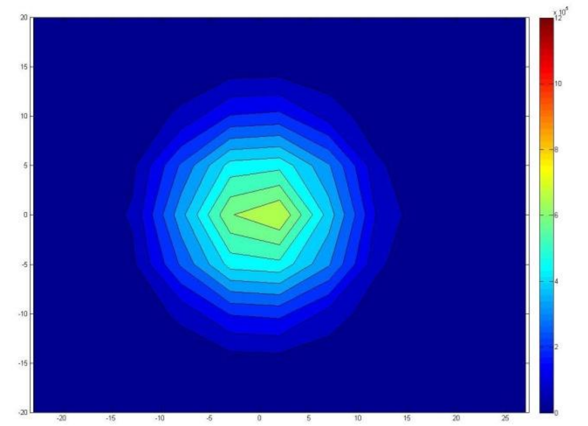
Radiation cone spatial distribution as function of beam energy modeled for collimator 2D scan. Undulator in helical mode (circular polarized radiation)

Scanning range: -20+20mm, -23+27mm, step 5mm, collimator 12.7mm diameter

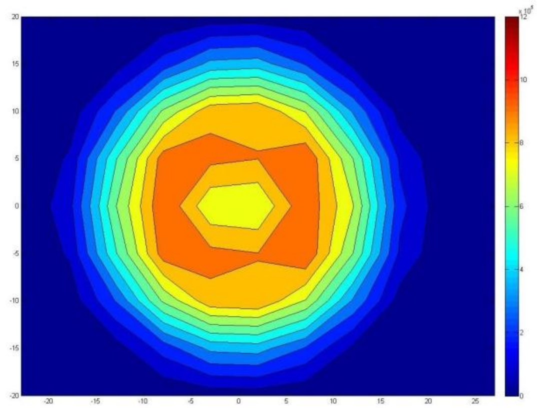
At 62MeV beam energy fundamental harmonic wave length ~4520nm.



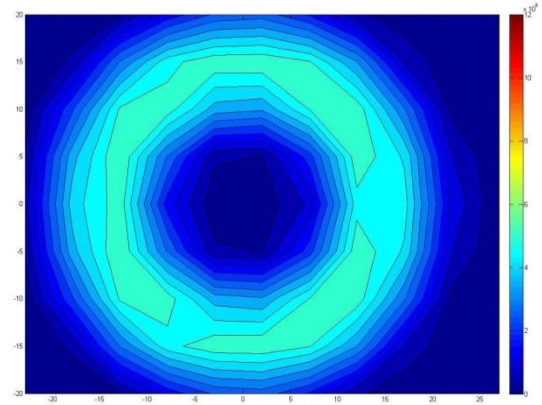
Eb = 58MeV



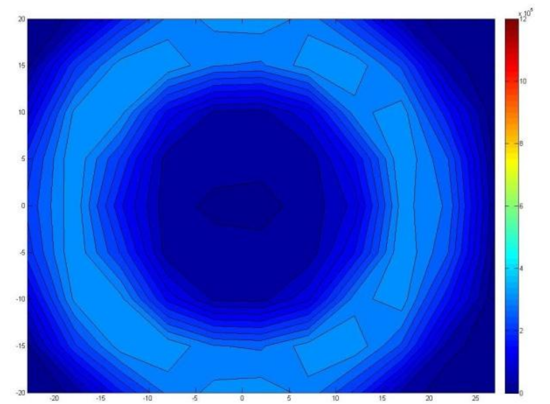
60 MeV



62 MeV



64 MeV

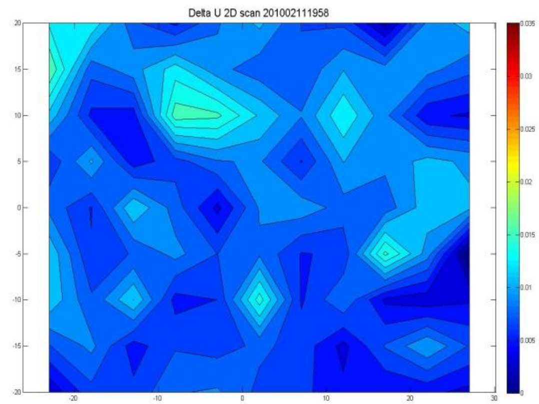


66 MeV

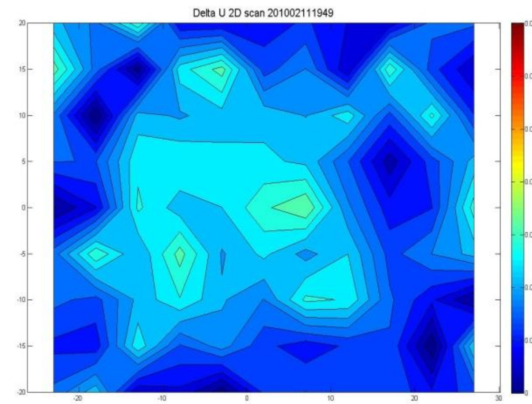
Beam test results: 4520nm radiation spatial distribution as a function of electron beam energy (Observation)

Radiation cone spatial distribution as function of beam energy measured with collimator 2D scan.

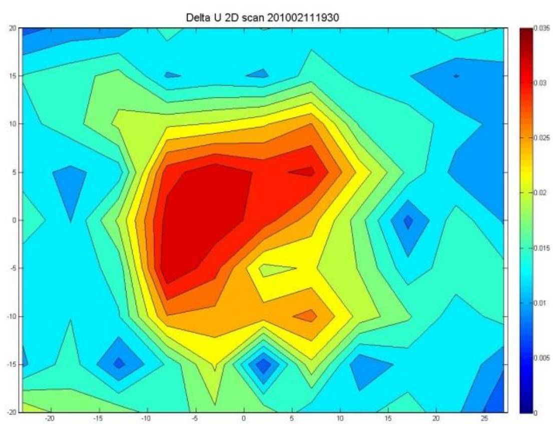
Scanning range -20+20mm by -23+27mm, 5mm step, 12.7mm collimator diameter.



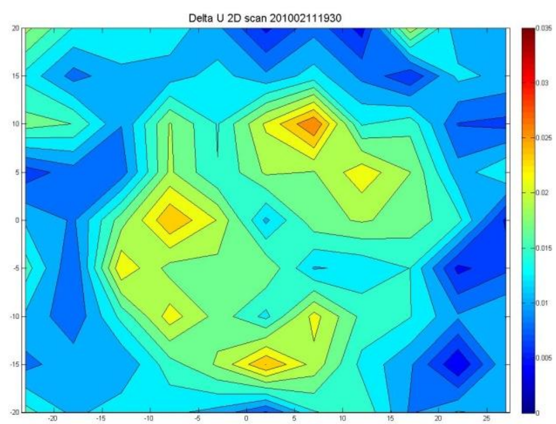
Eb = 58MeV



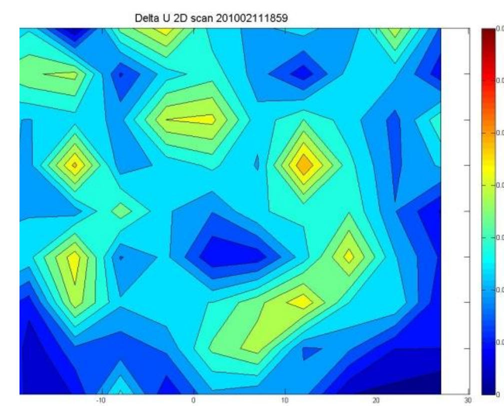
60 MeV



62 MeV



64 MeV



66 MeV

Conclusion

1. Delta Undulator magnet model was successfully tested with beam at ATF in BNL.

2. The test confirmed the measured undulator peak field 0.93T in helical mode and 1.27T in planar as well as the field quality. It also demonstrated satisfactory of mechanical and vacuum properties of the magnet.

Main results to be published in NIM A as Proceedings of Synchrotron Radiation Instrumentation Conference, Sept 21-24, 2010, Chicago, Illinois.

Acknowledgment

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Beam test

Encountered problem:

Undulator field focusing effect

$$\frac{1}{f} = \frac{B_{max}^2 L}{2 \cdot (B\rho)^2};$$

where f is a focal length; B_{max} - undulator peak field; L - undulator length; $B\rho$ - beam stiffness ;

For undulator in planar mode and 60MeV beam it gives:

$f = 17cm;$ focus in one plane

For helical mode and 60MeV beam:

$f = 31cm;$ focus in both planes

Strong focusing in planar mode made beam line optics match very difficult. Higher beam energy would be better.