APS Seminar
10/08/2013

KNOT-APPLE UNDULATOR TO REDUCE ON-AXIS POWER DENSITY

DESIGN OF A KNOT-APPLE UNDULATOR FOR SSRF

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Outline

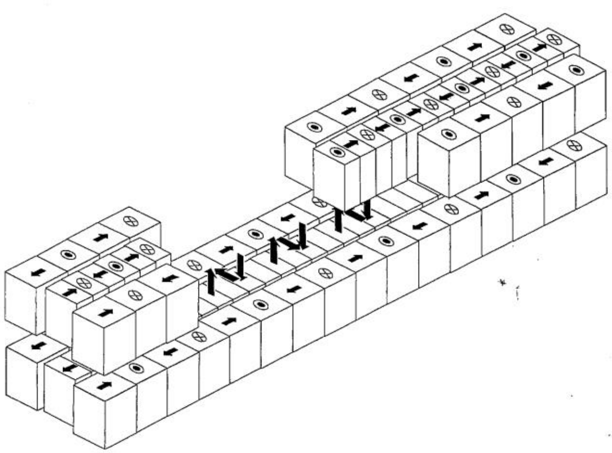
- Motivation of consideration
- Knot-undulator to Knot-APPLE undulator
- Magnetic structures
- Expected performance
- Other possible structures with better performance
- **Summary**

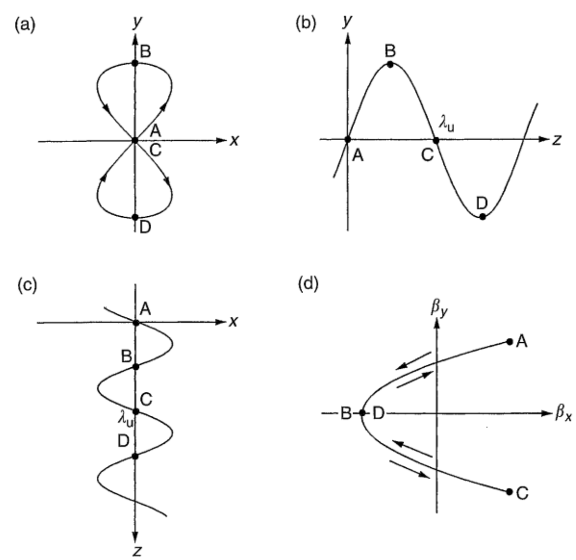
Motivation of consideration

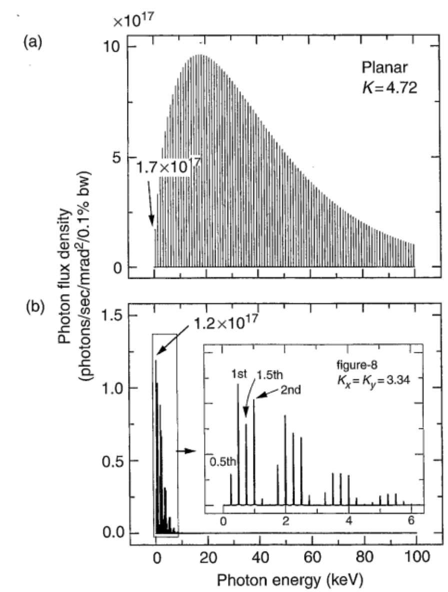
Unreasonable demand by SR users

"We need lower photon energy
at a beamline of high energy SR facility."

Pioneer : Aimed at 250 eV photon generation from 8 GeV ring
SPring-8 ⟶ Figure-8 Undulator







T. Tanaka and H. Kitamura, Nucl. Instrum. Meth. **A364**, 368 (1995).

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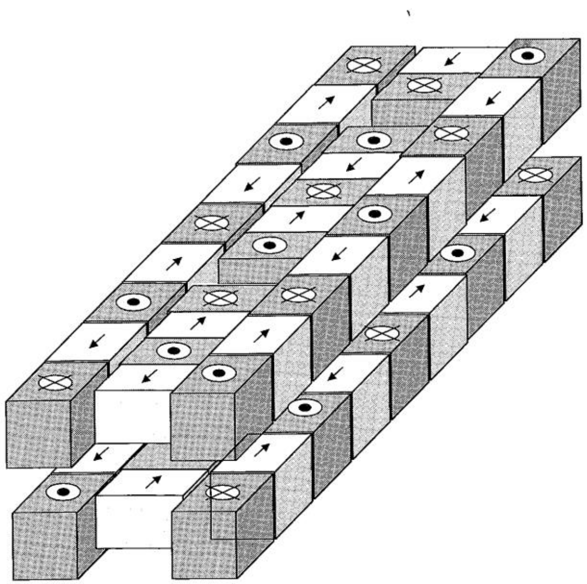
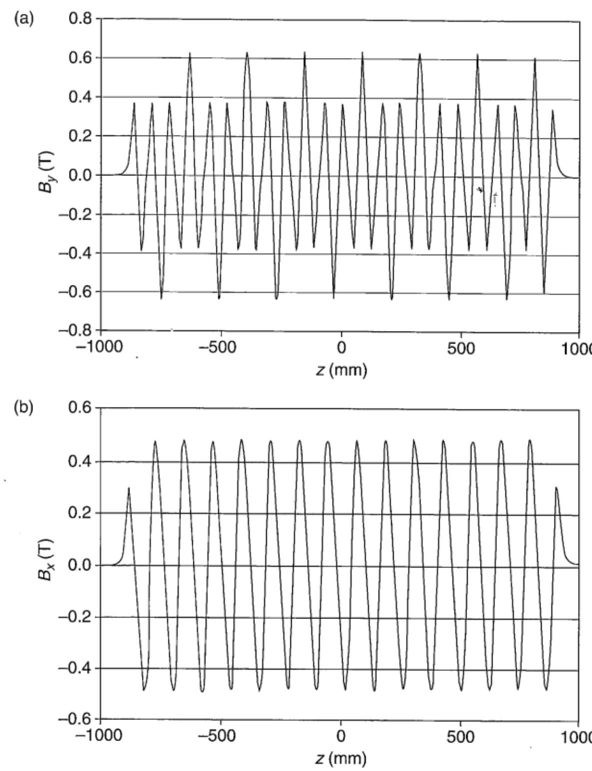
Motivation of consideration (cont.)

Similar to the Figure-8, we got an idea for reducing on-axis power density more efficiently. ⇒ PERA (in Trieste, 1997, EPAC98 Proc.)

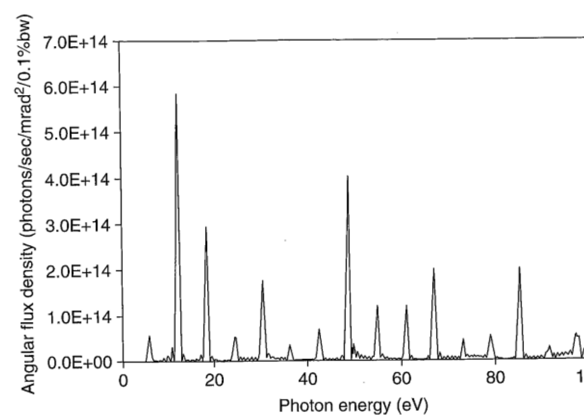




$$B_x = -B_{x0}\sin(2\pi z/\lambda_x),$$

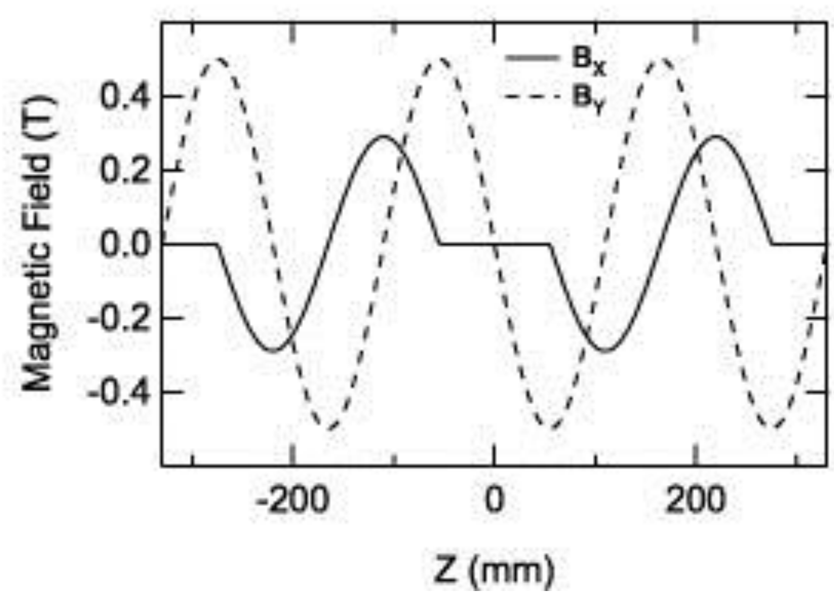
$$B_y = B_{y0}\left\{\frac{1}{2}\cos(2\pi z/\lambda_{y1}) + \frac{3}{2}\cos(2\pi z/\lambda_{y2})\right\},$$

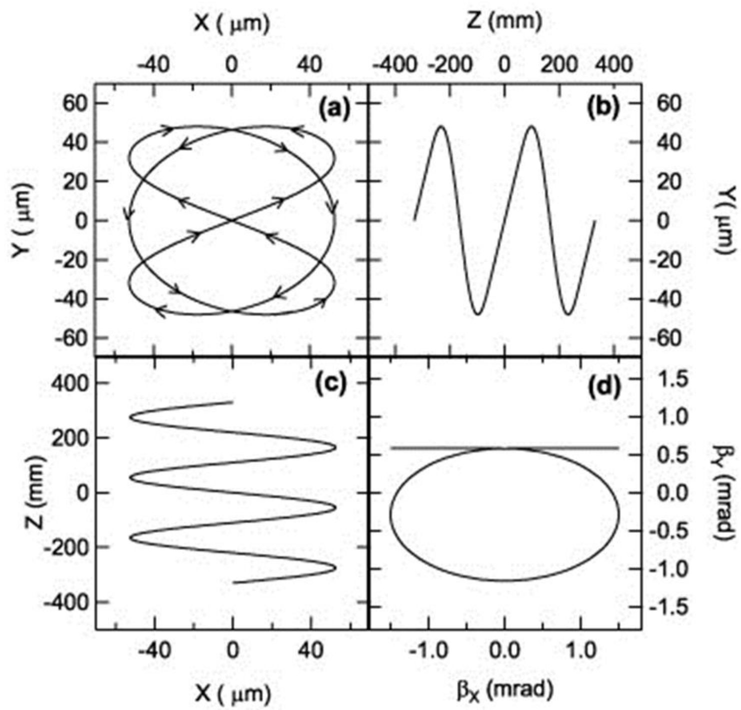
Here, $\lambda_{y1}=2\lambda_x$ and $\lambda_{y2}=2\lambda_x/3$.



Motivation of consideration (cont.)

Similar to the Figure-8, a new idea came up recently to reduce on-axis power density → Knot undulator.





S. Qiao, et al, Rev. Sci. Instrum. **80**, 085108 (2009) **No real magnetic structure is proposed.**

Motivation of consideration (cont.)

More recent "impossible" demand by users

Need

Variable polarization and small on-axis power density for all polarization states

7-70 eV photon beam from 3.5 GeV ring at SSRF by Shan Qiao

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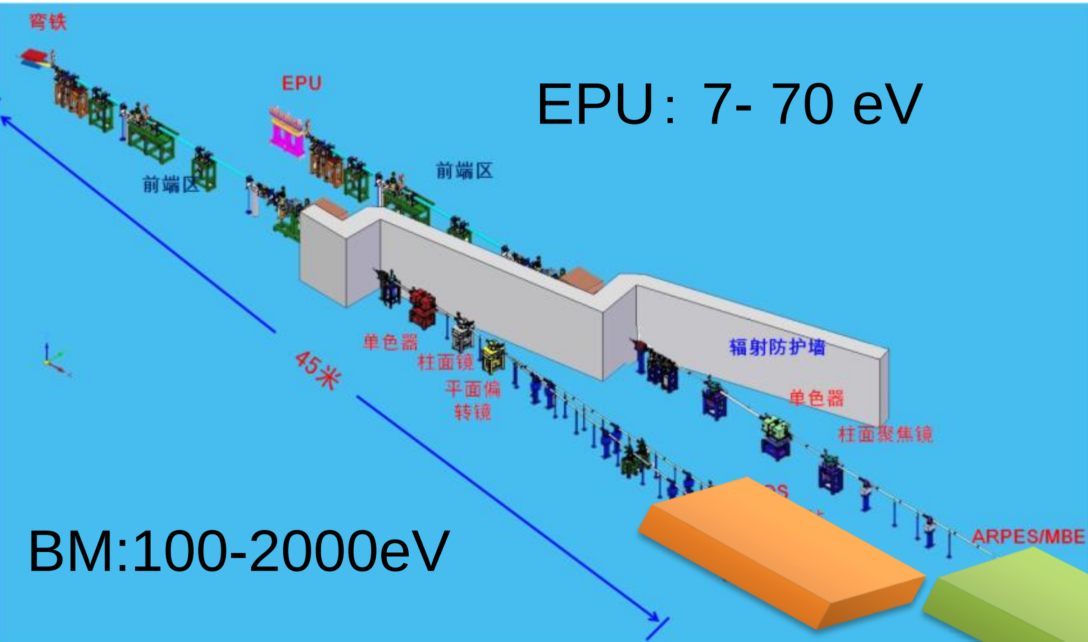
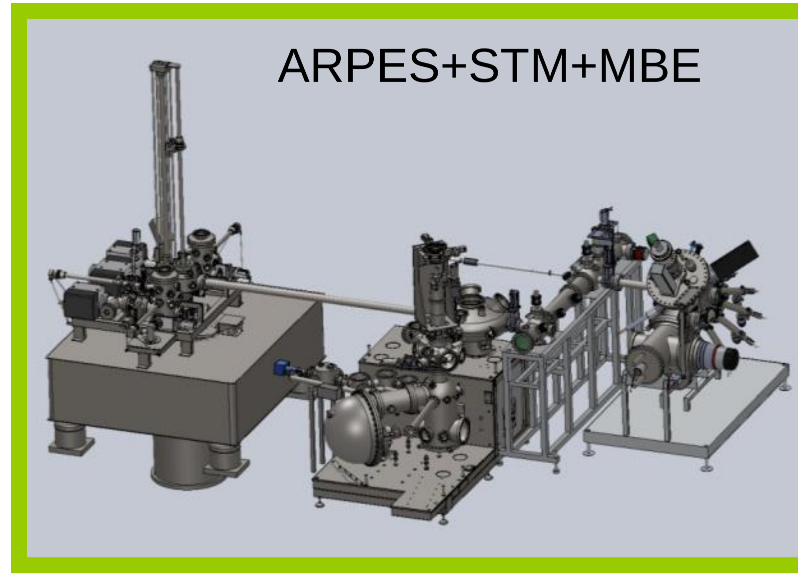
APPLE-8 or Knot-APPLE

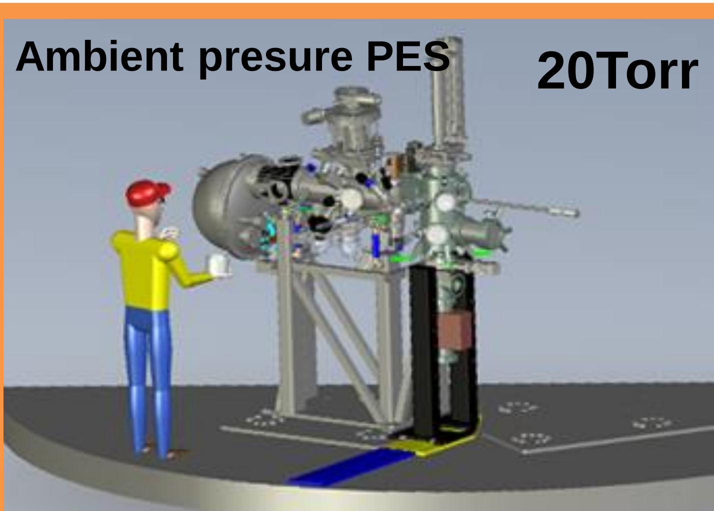
New SR source in China

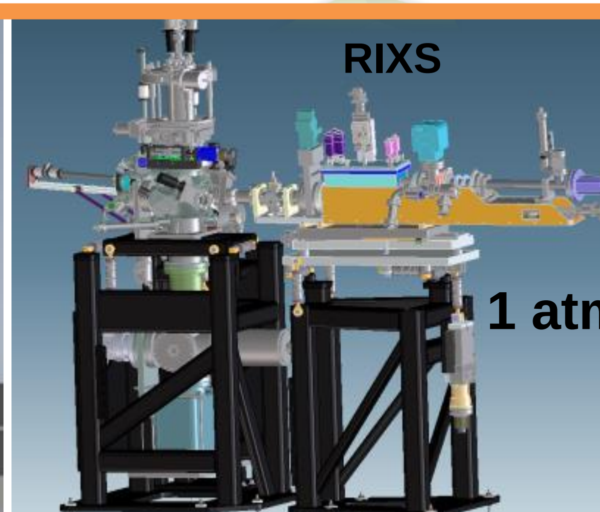
- SSRF，Shanghai Synchrotron Radiation Facility
  3.5 GeV 300 mA

Platform for electronic structure study









1 atm

1个大气压

The largest budget of NSFC

~ 27 M$, unconfirmed

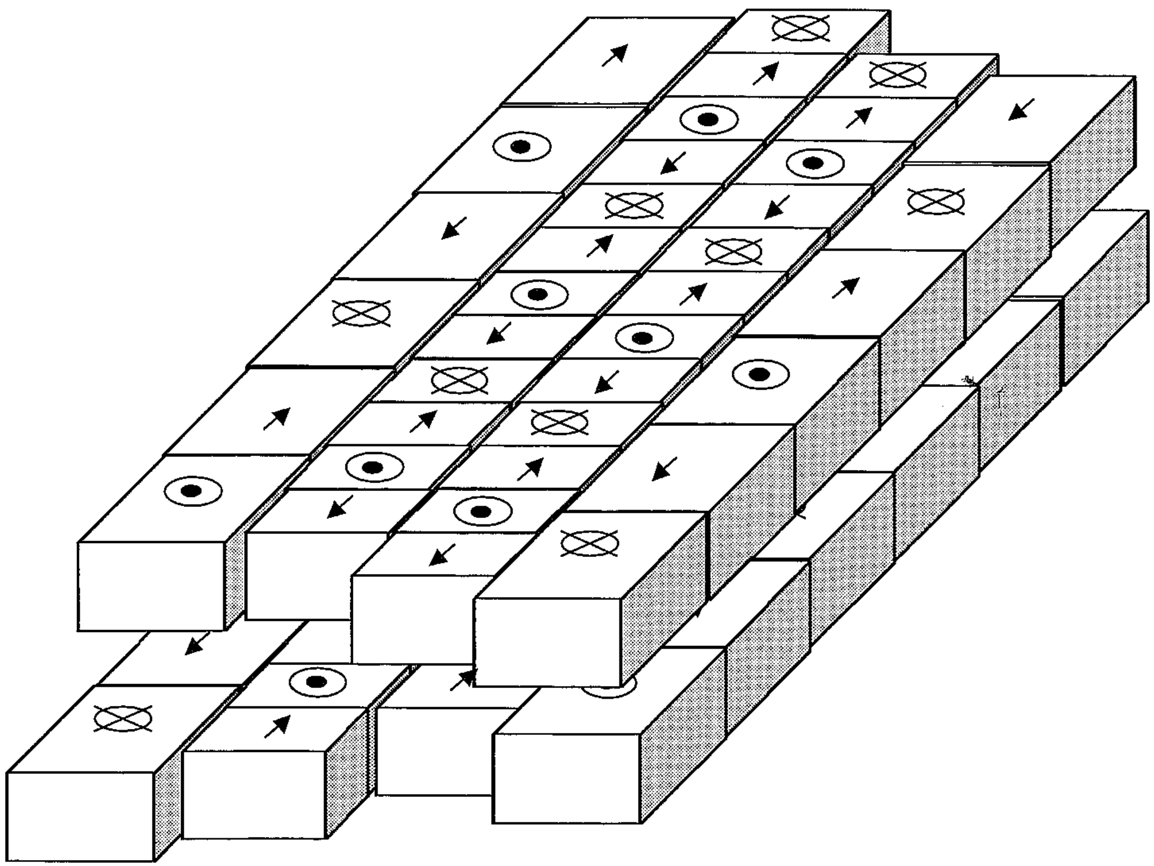
Purpose of VUV Beamline at SSRF

- Photoemission spectroscopy (PES)
- 7-100 eV， for high energy and angular resolution

Their problem

- SSRF Storage Ring : 3.5 GeV
- High *K*-value
- Intense higher order harmonics cause extremely high heat load

APPLE-8 undulator



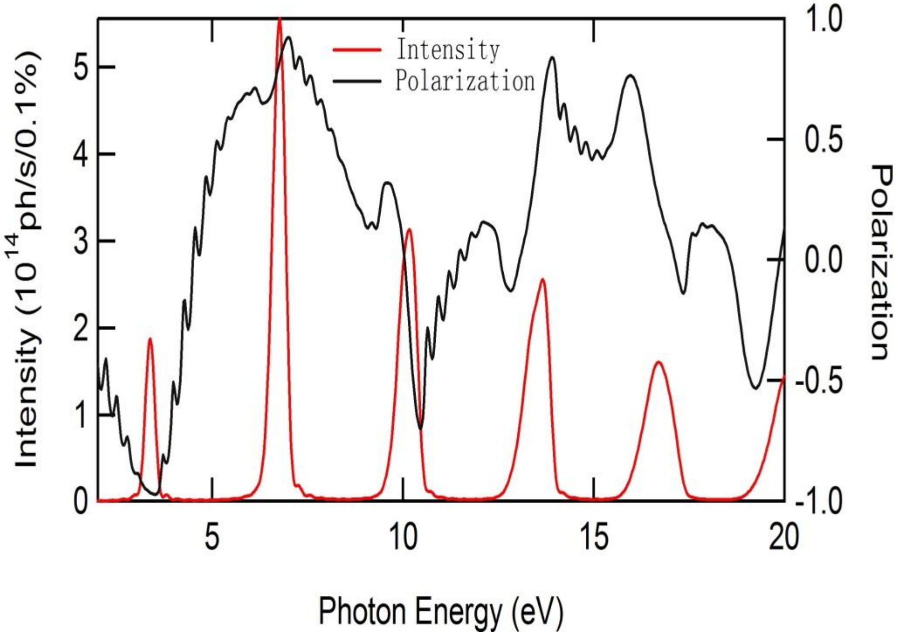
S. Sasaki, "Undulators, wigglers and their applications," pp.237-243 (Ed. by H. Onuki and P. Elleaume, Taylor & Francis Inc., New York, 2003).

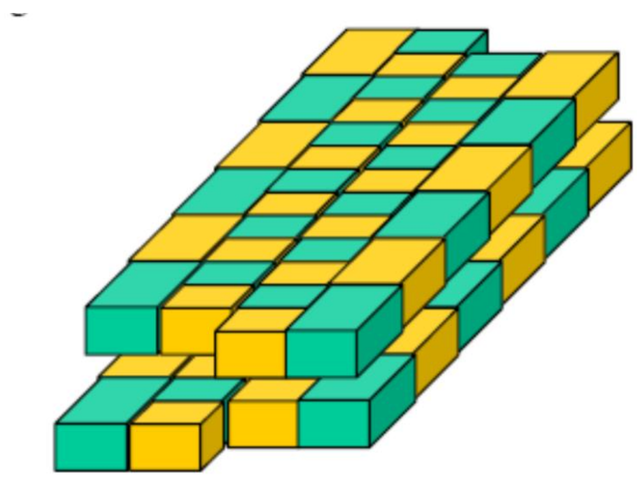
APPLE-8 problem

Their opinion

- P=82%

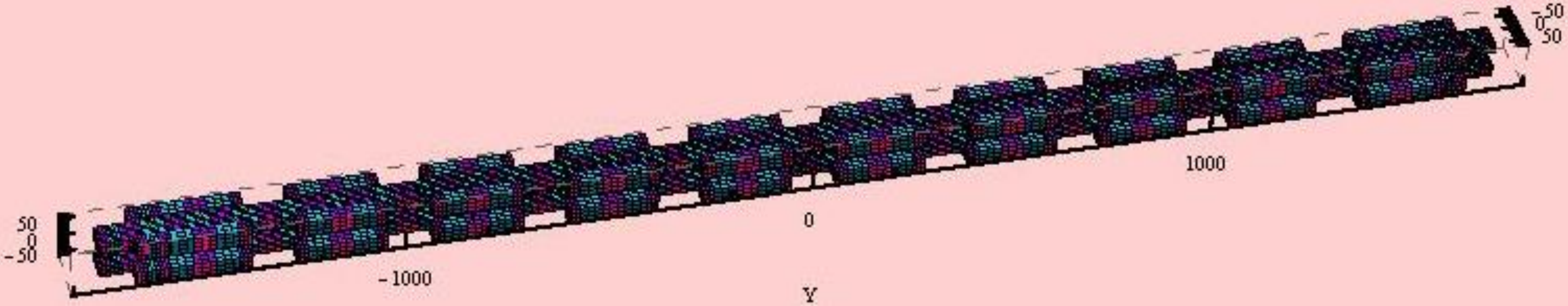
1 : 2

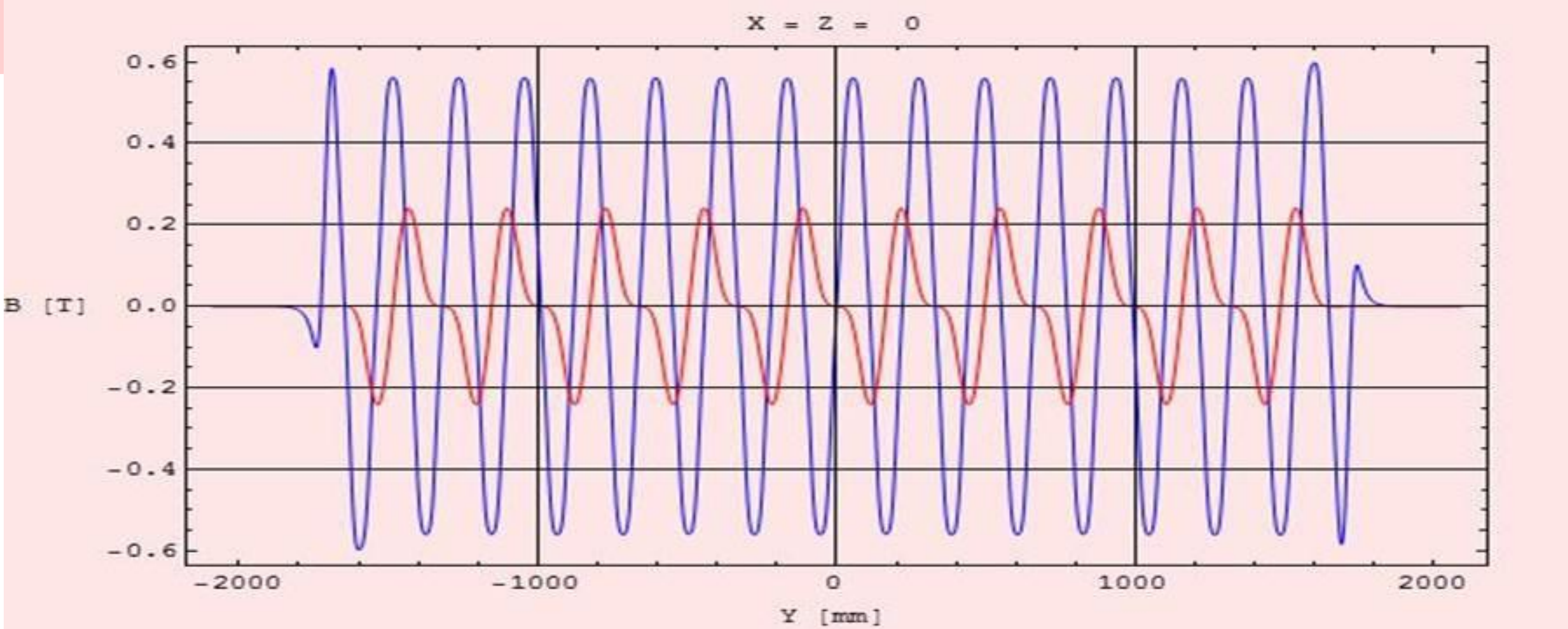




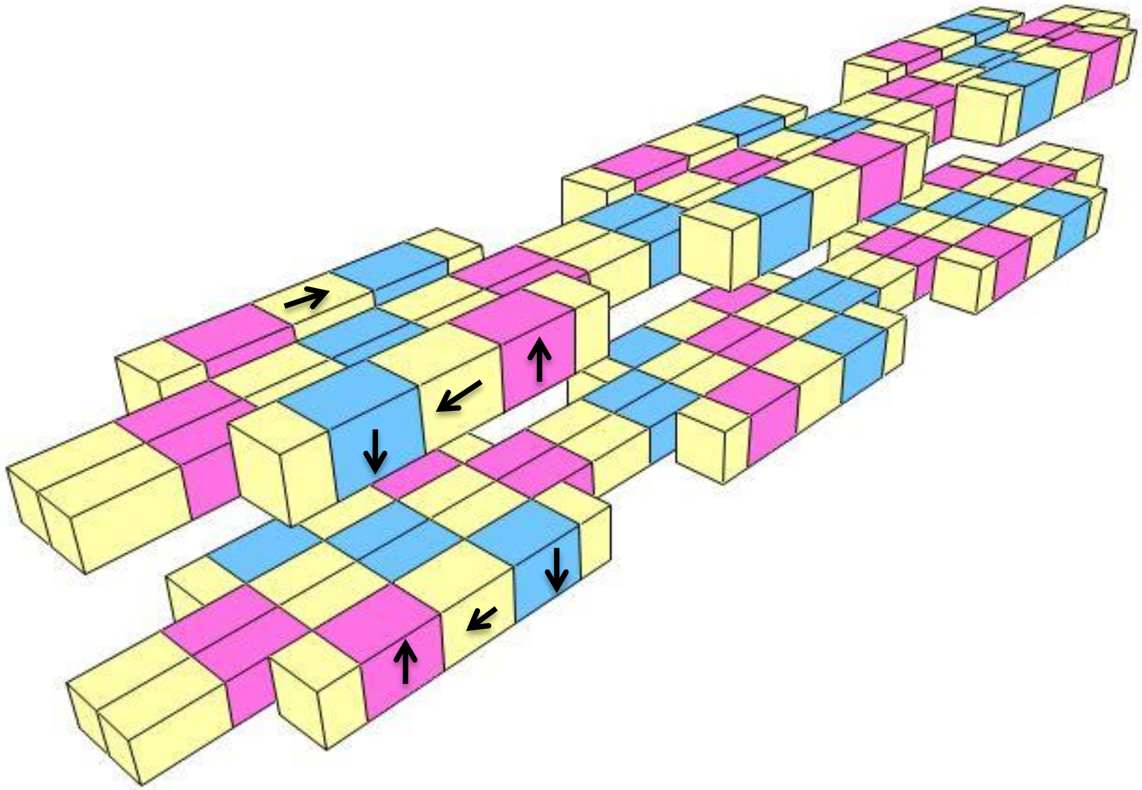
Knot-undulator to Knot-APPLE undulator

gap=40 mm, λ_v=220 mm, λ_h=330 mm



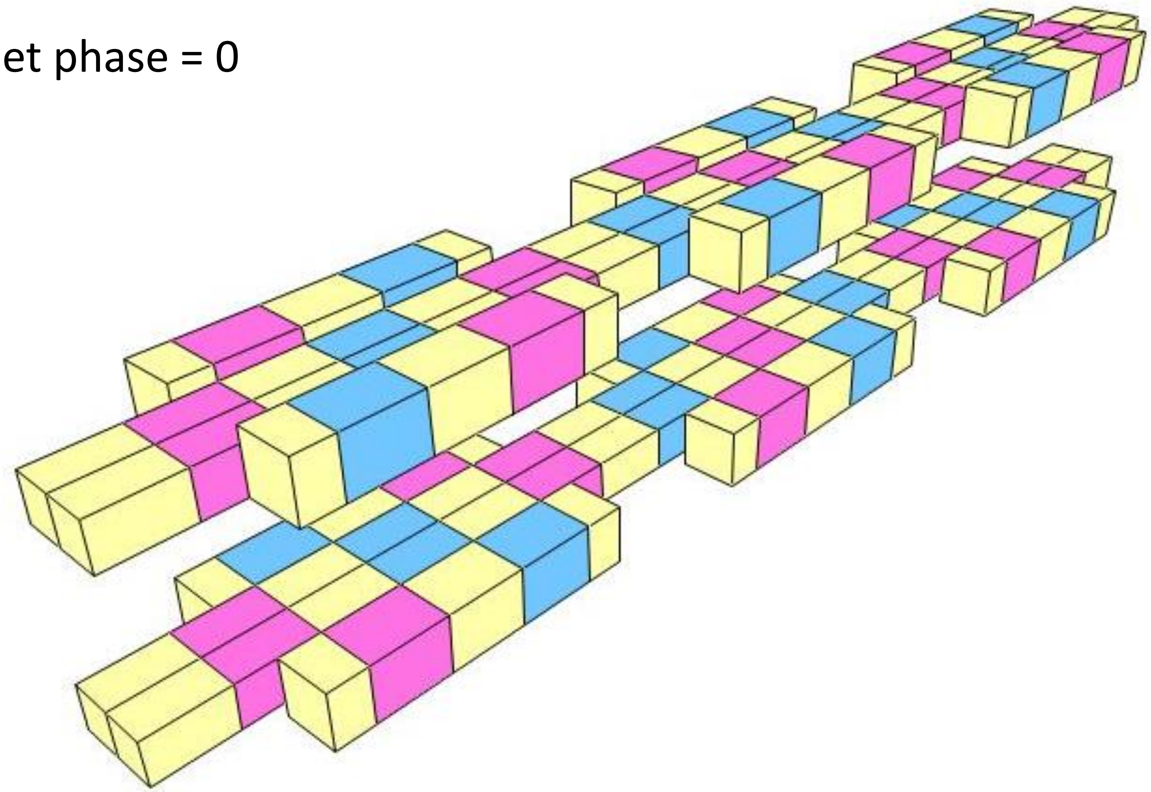


Knot-undulator to Knot-APPLE undulator



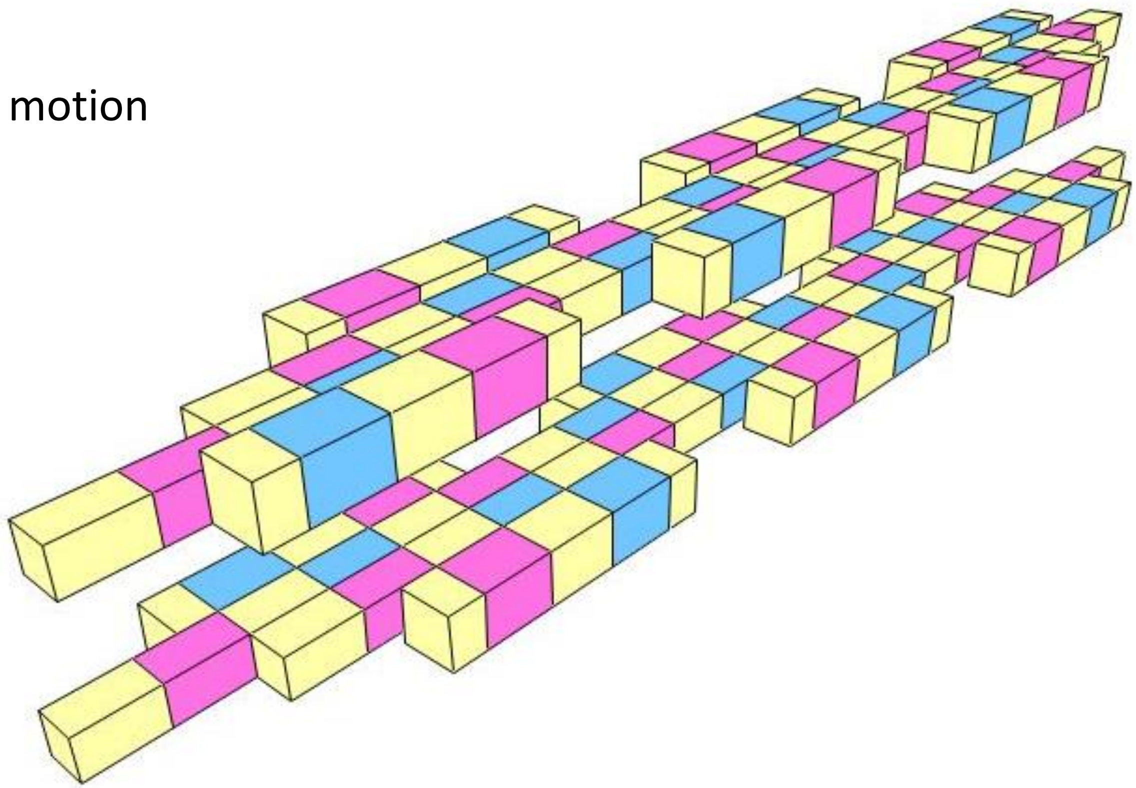
Knot-undulator to Knot-APPLE undulator

Magnet phase = 0



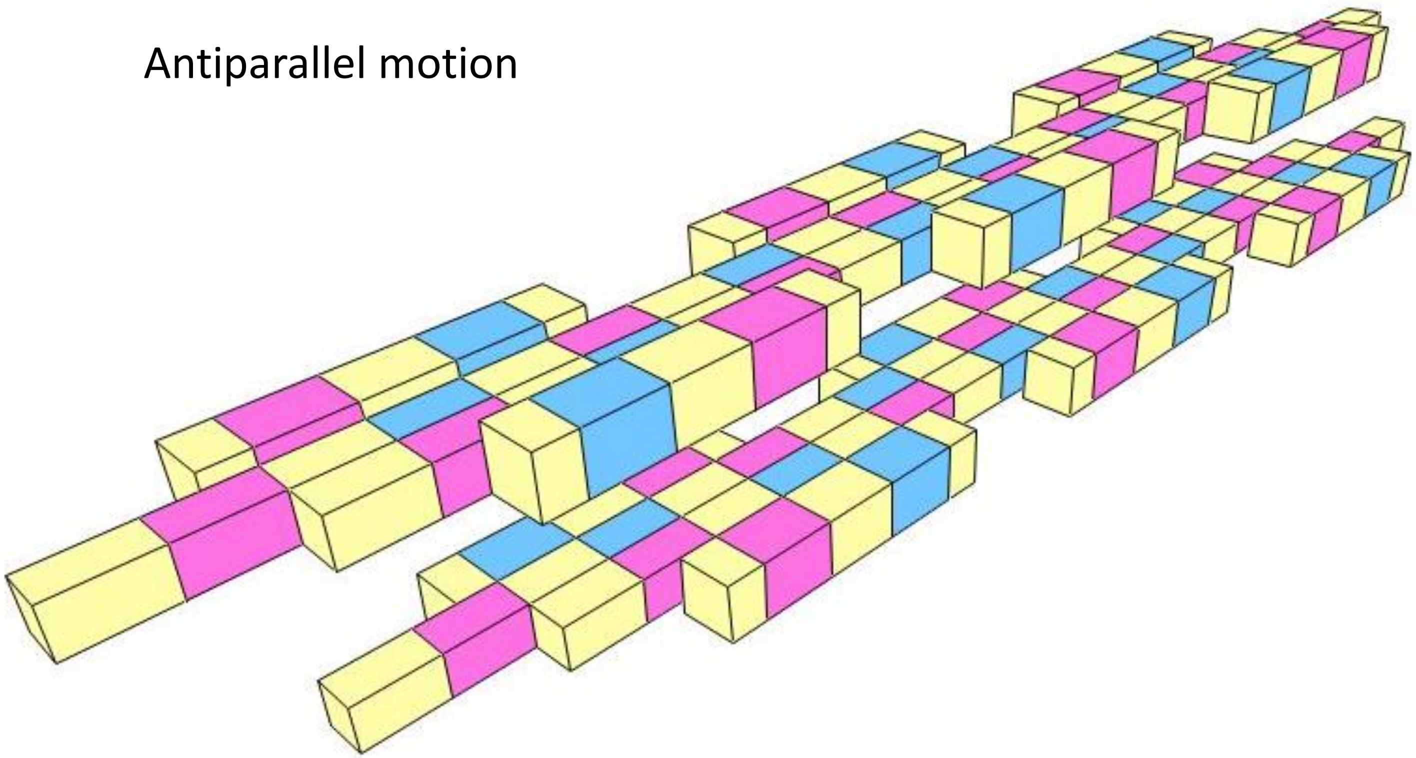
Knot-undulator to Knot-APPLE undulator

Parallel motion



Knot-undulator to Knot-APPLE undulator

Antiparallel motion



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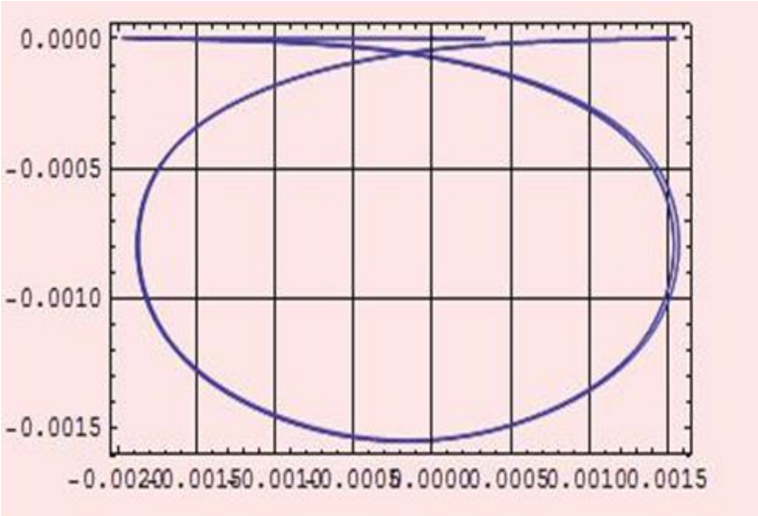
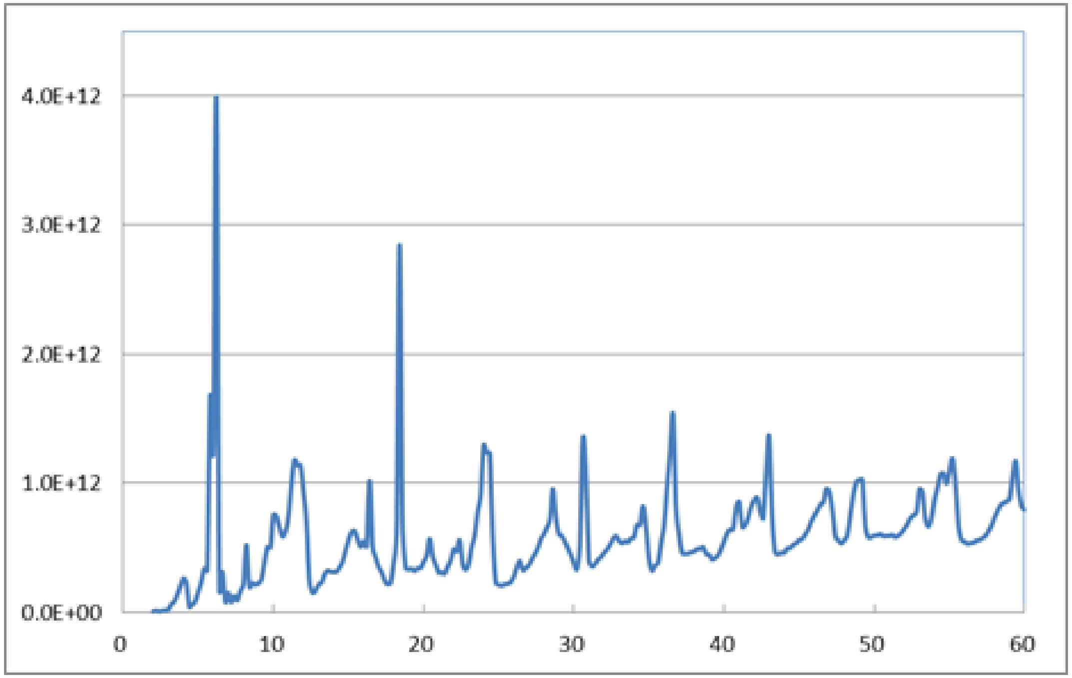
Knot-Undulator

SSRF: E=3.5 GeV, I=200 mA, ε_0=11.2 nmrad



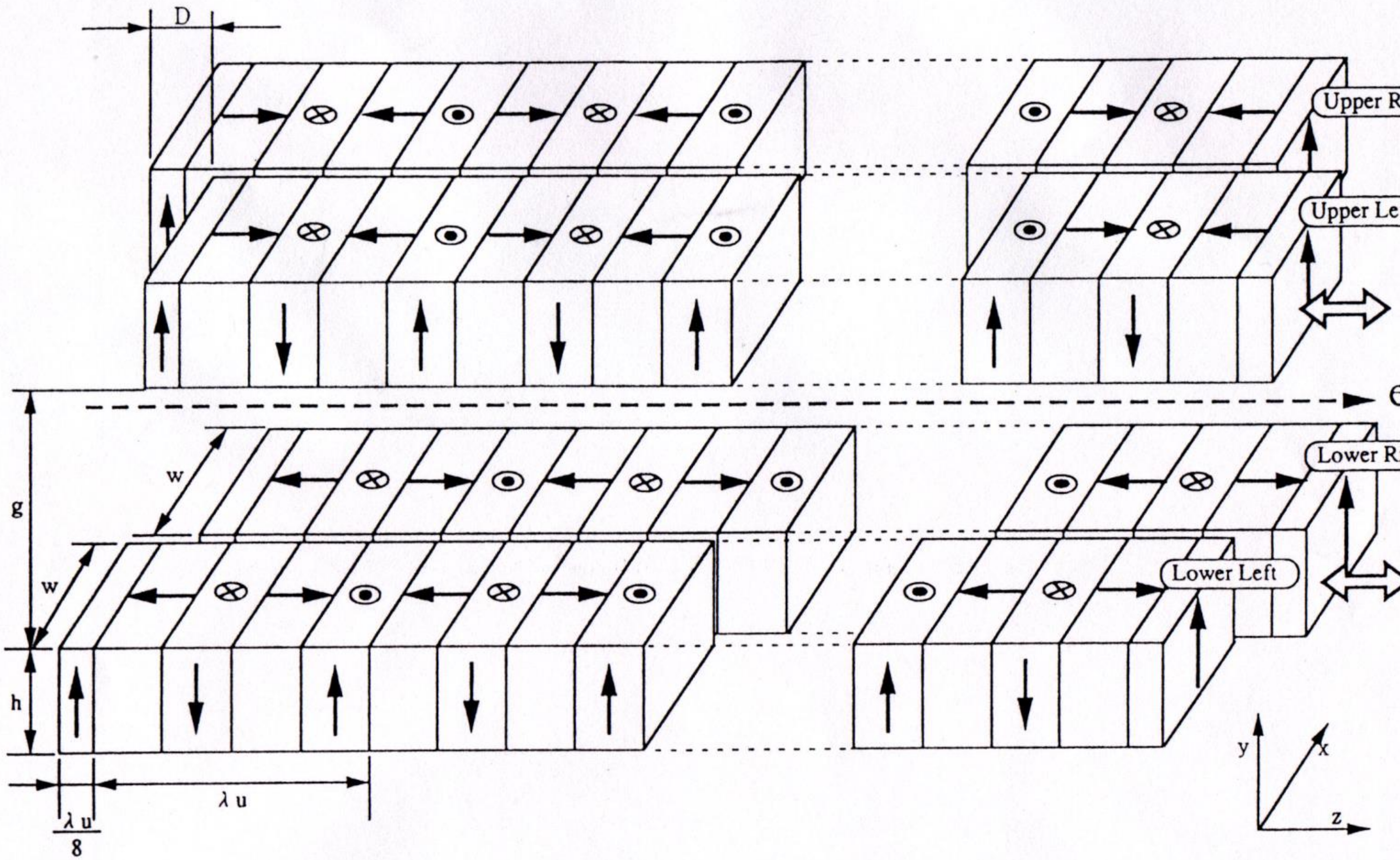
kick angle



PL≥99%

spatial flux density

APPLE-II Undulator



Schematic view of the magnetic structure for generating variably polarized undulator radiation. $D=\lambda_u/4$.

Radiation from APPLE II undulators

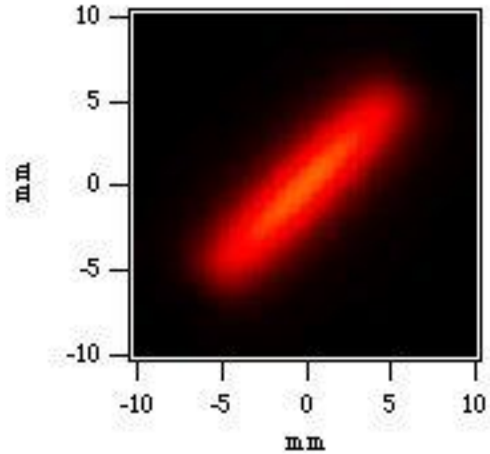
Advantage: High flexibility

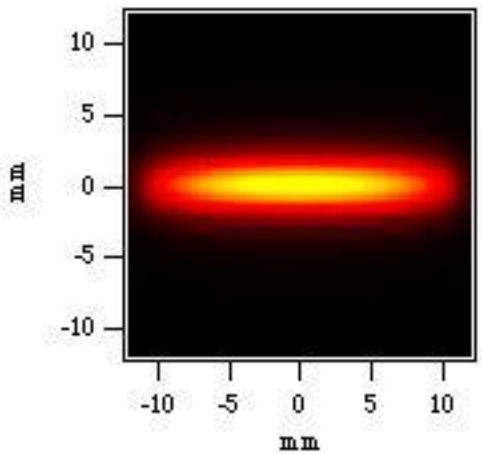
Various polarization states:

- -elliptic
- -linear inclined

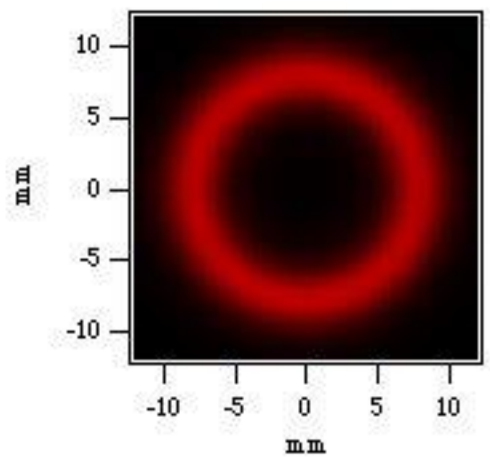
ID: ESRF-HU88 gap 16 mm,
power density @ 30m

Linear inclined

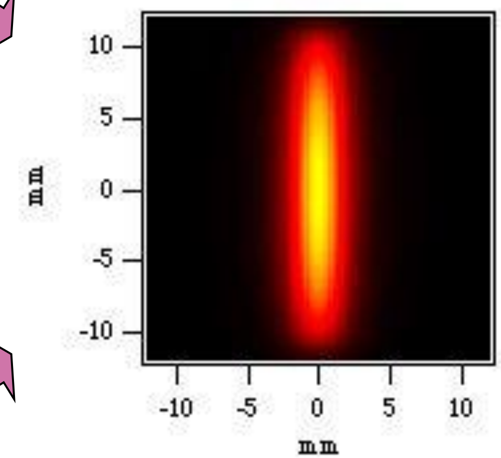




horizontal

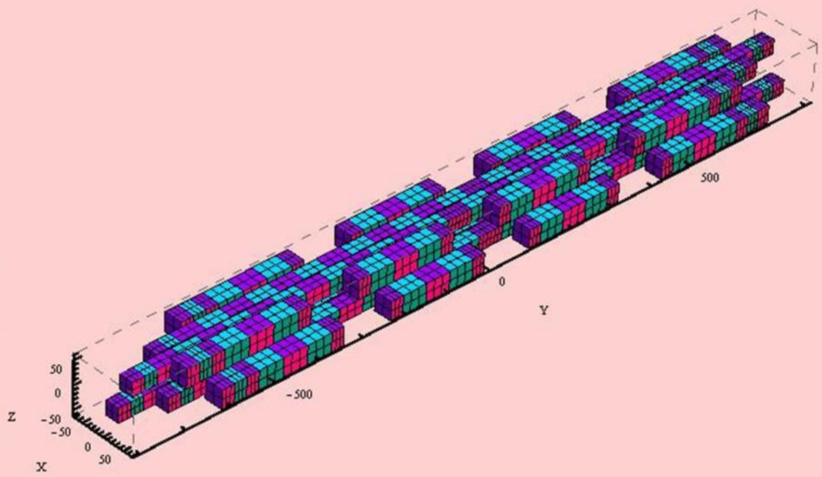


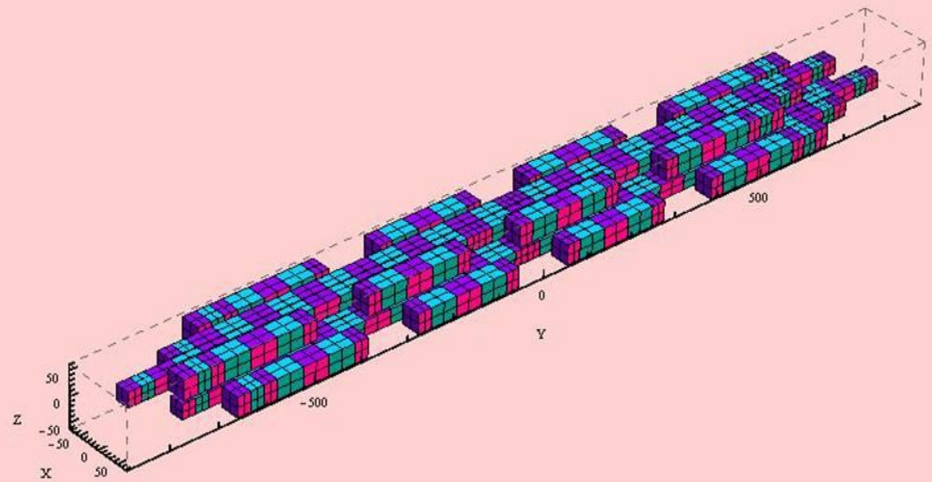
Circular



Vertical

Knot-APPLE



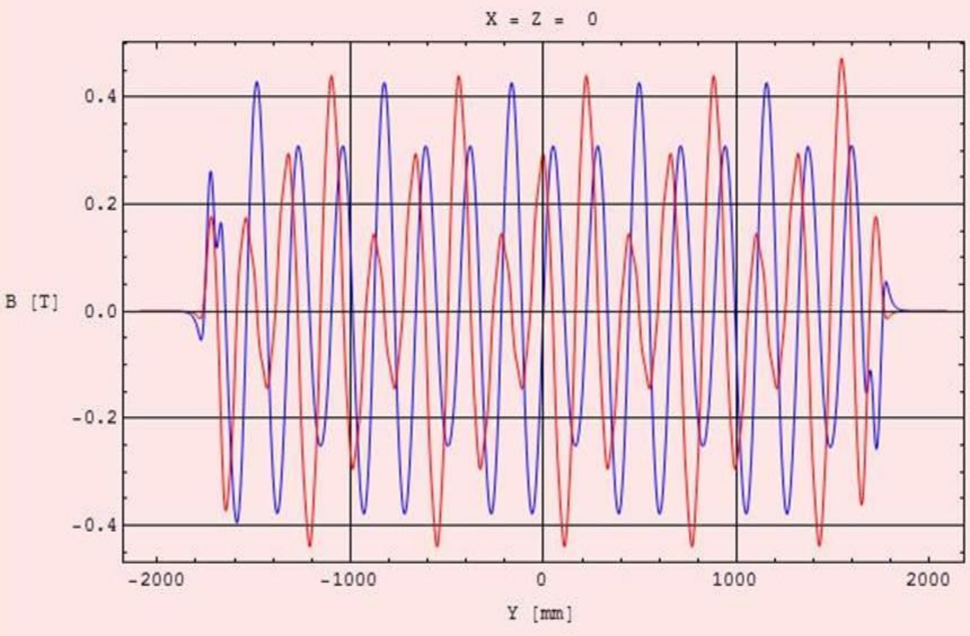


D=65 mm, parallel

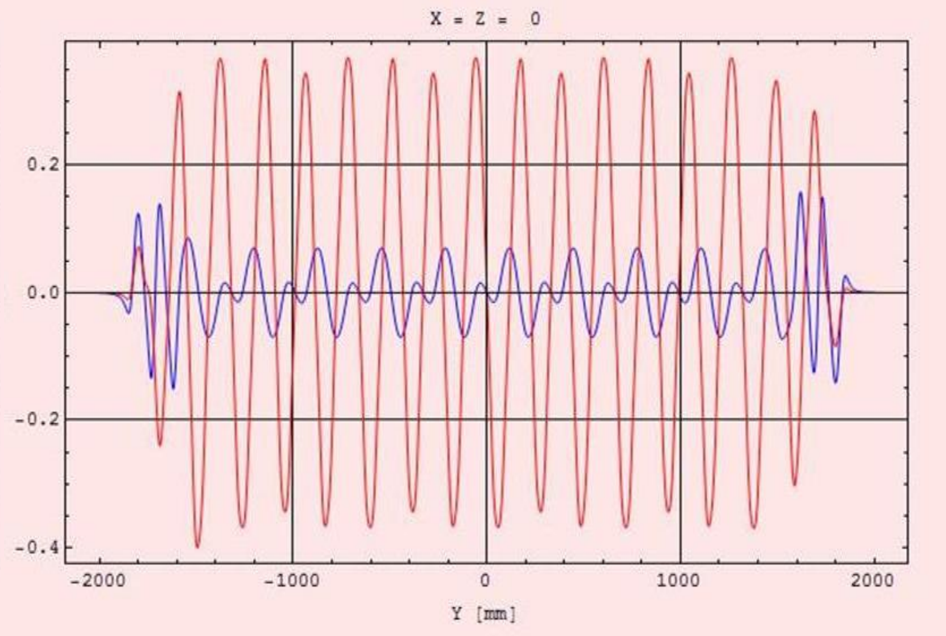
D=110 mm, antiparallel

(*D*: magnet row phase)

Knot-APPLE field

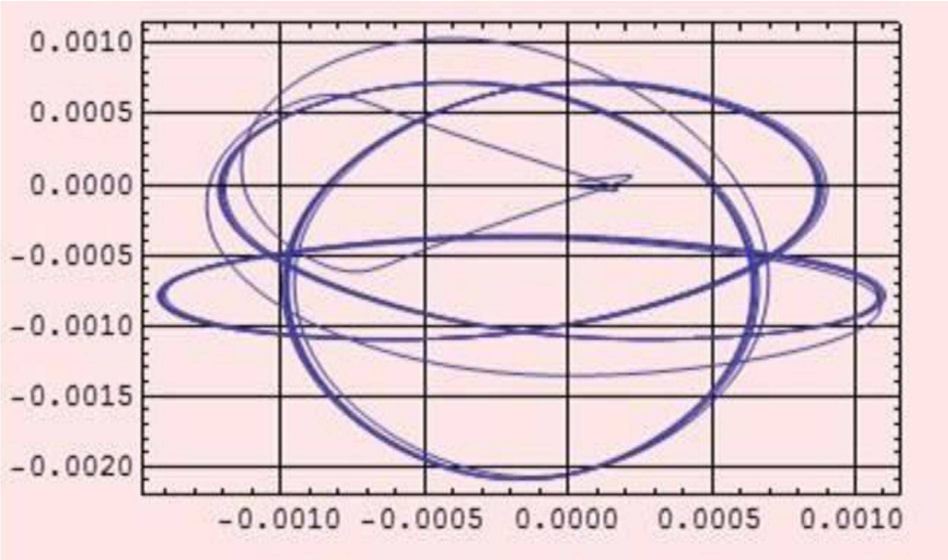


D=65 mm, parallel

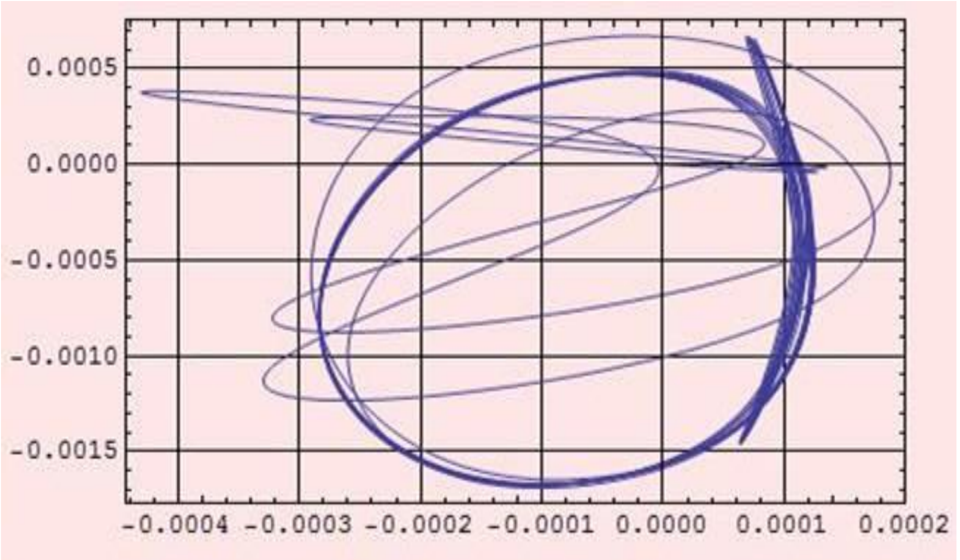


D=110 mm, antiparallel

Knot-APPLE : kick angle

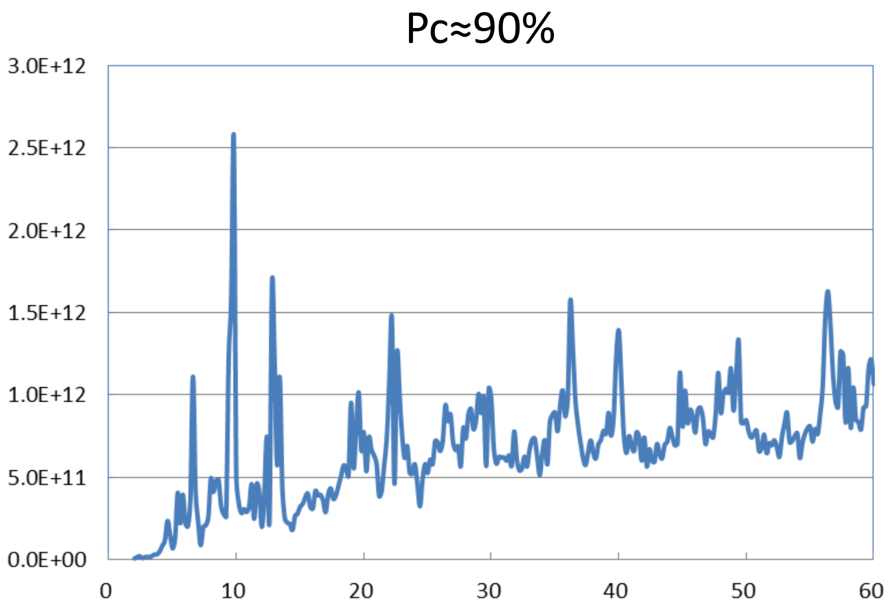


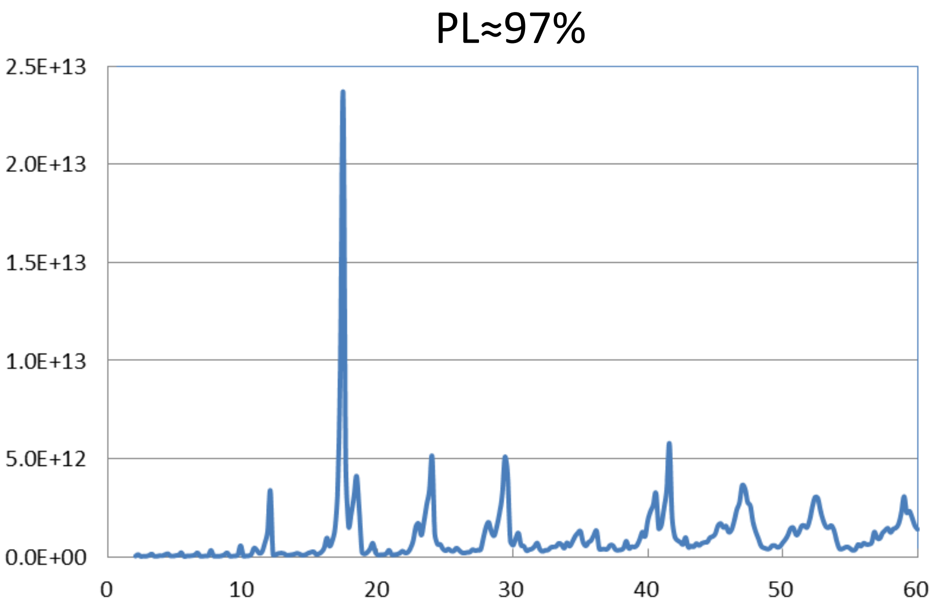
D=65 mm, parallel
circular



D=110 mm, antiparallel
vertical linear

Knot-APPLE : SFD

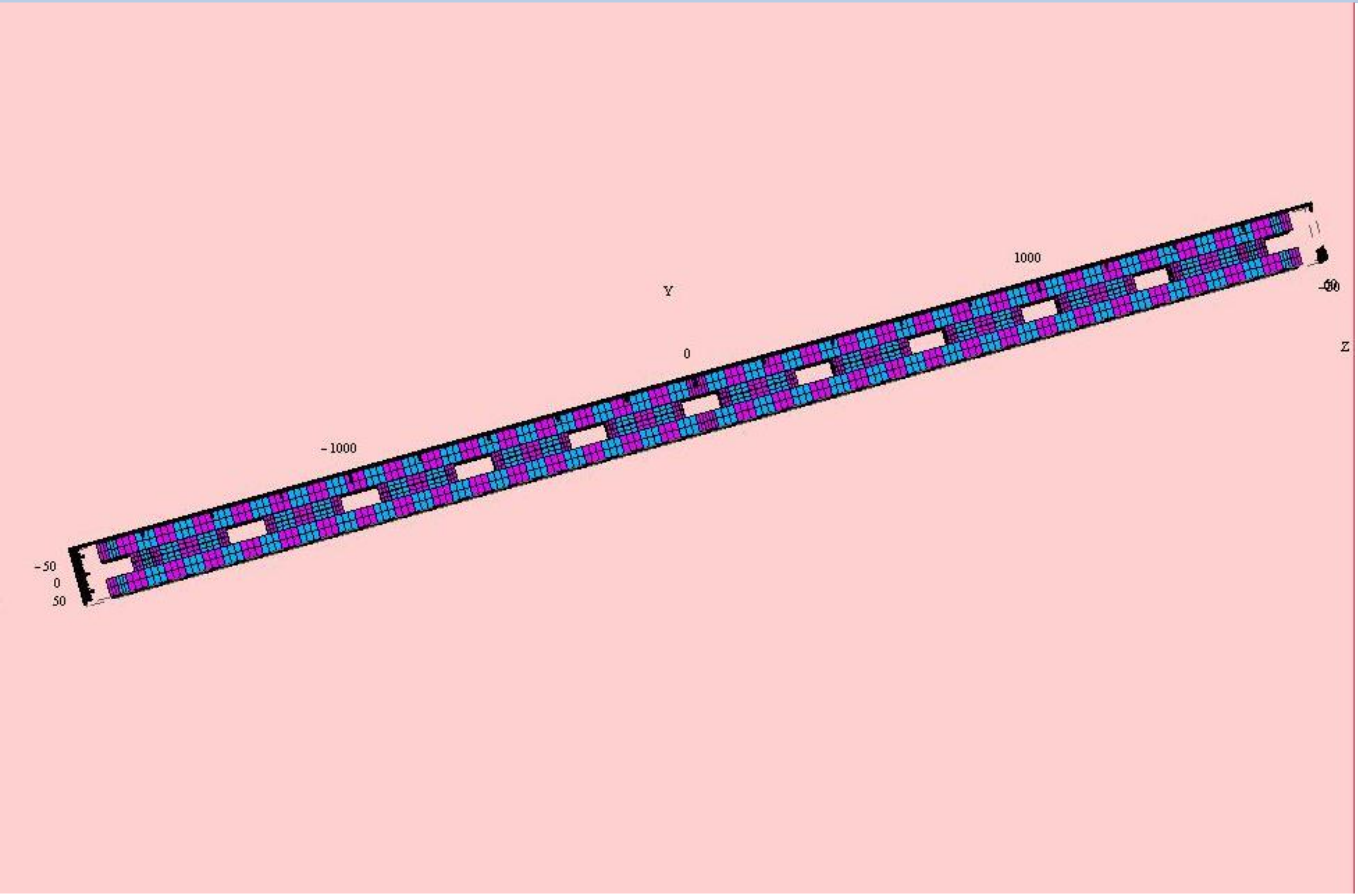




D=65 mm, parallel
circular

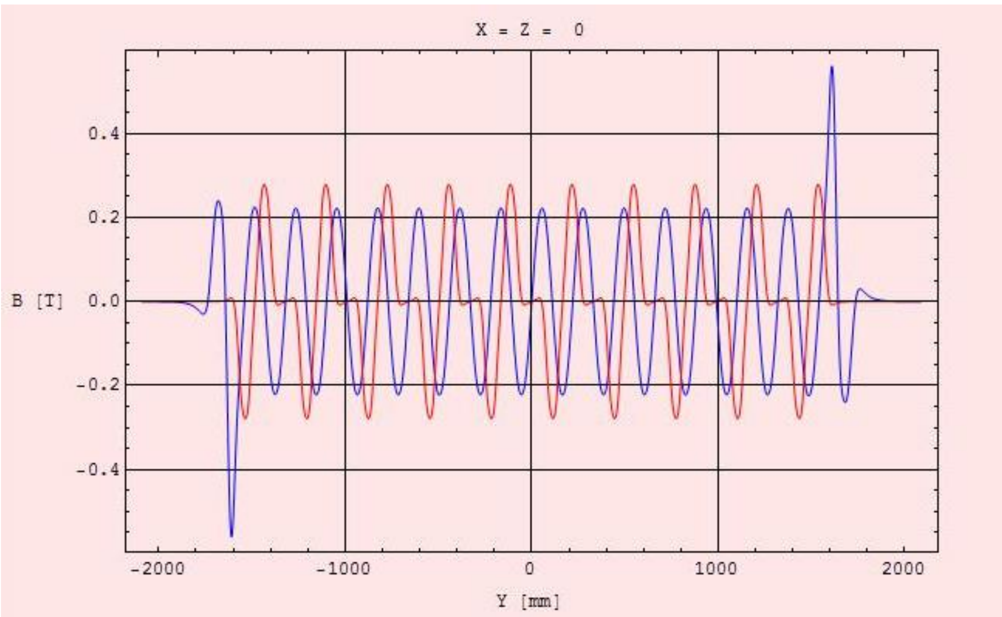
D=110 mm, antiparallel
vertical linear

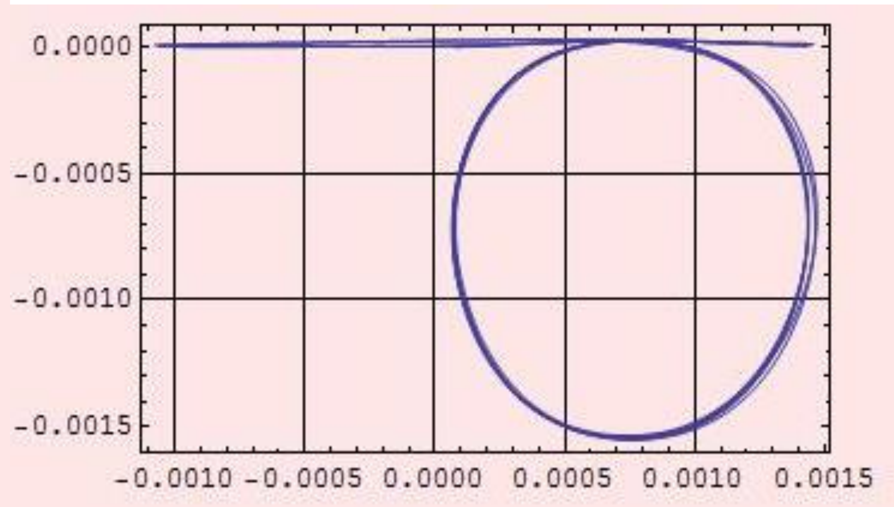
Knot-APPLE : Other structure options



Top View; D=0 mm

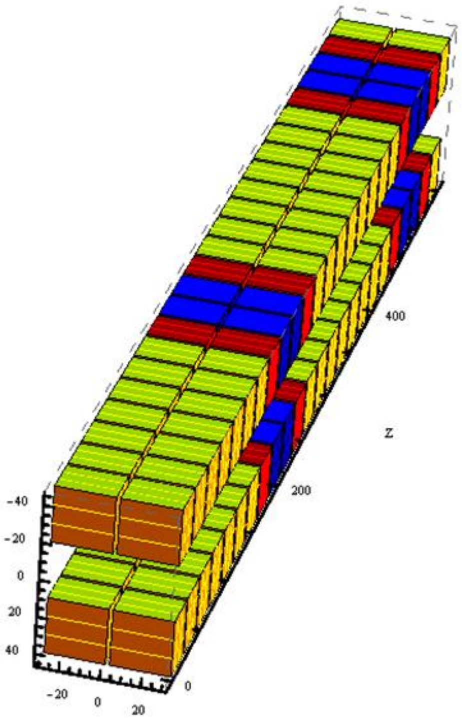
Magnetic Field and Kick Angle

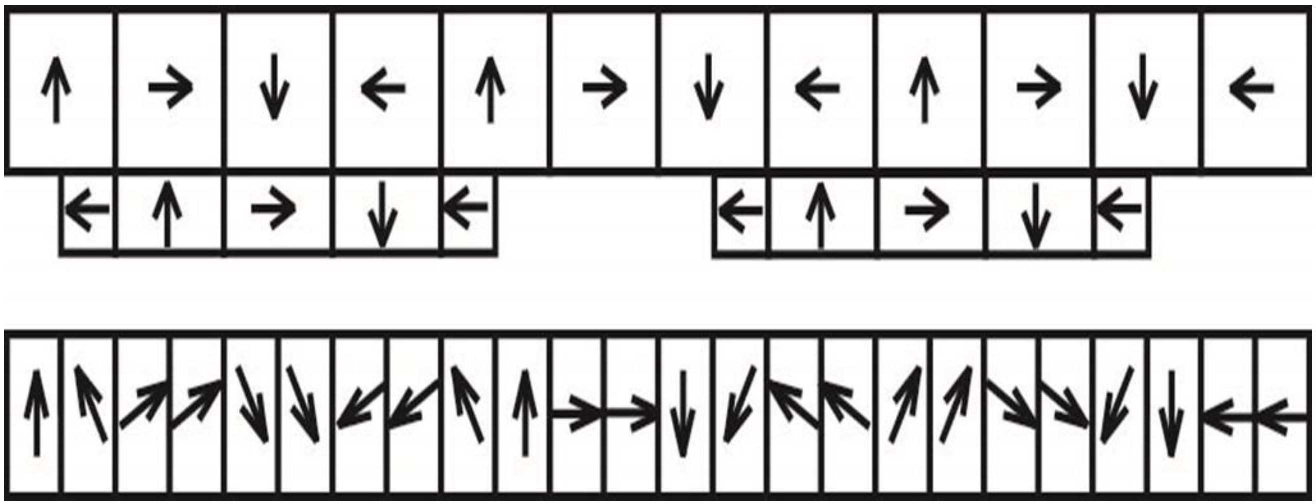




Gap = 40 mm

Knot-APPLE Structure: Option 2

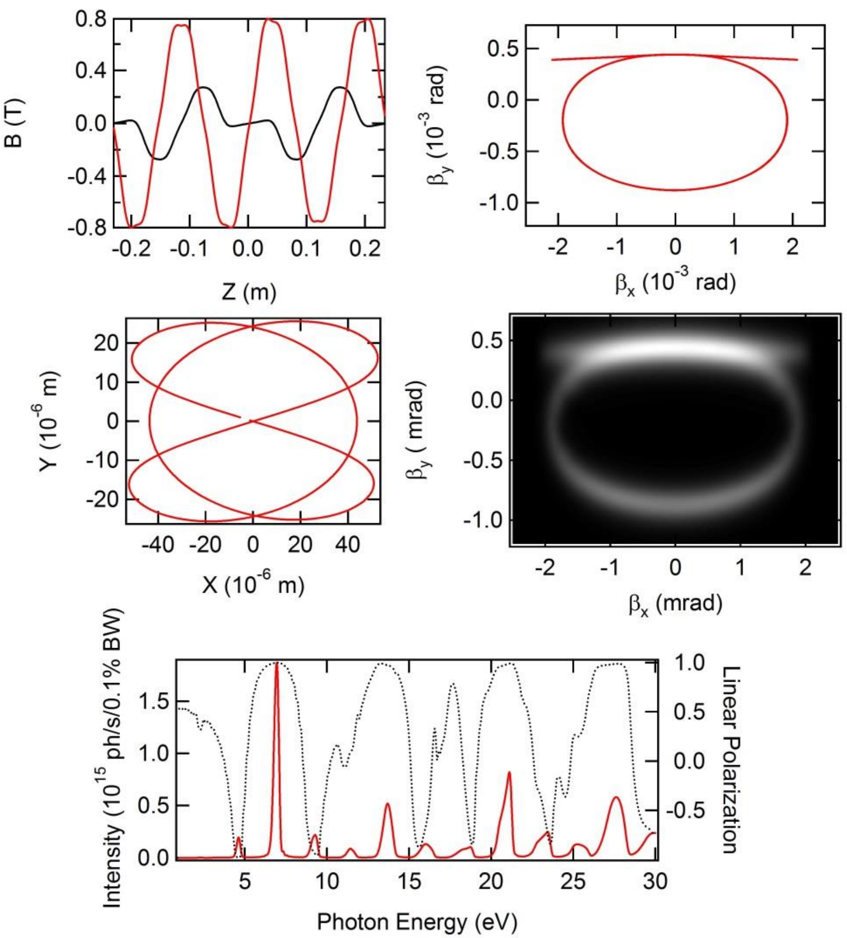




Use 4 type magnet blocks with tilted magnetization

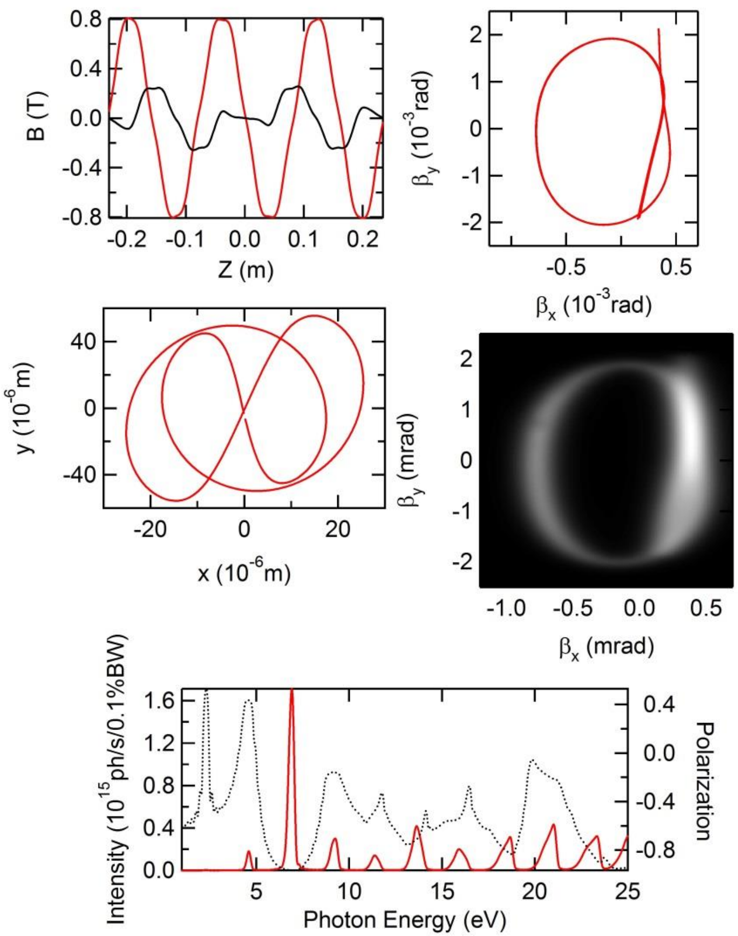
Rui Chang and Shan Qiao (SIM, CAS)

Phase=0, Gap=22 mm



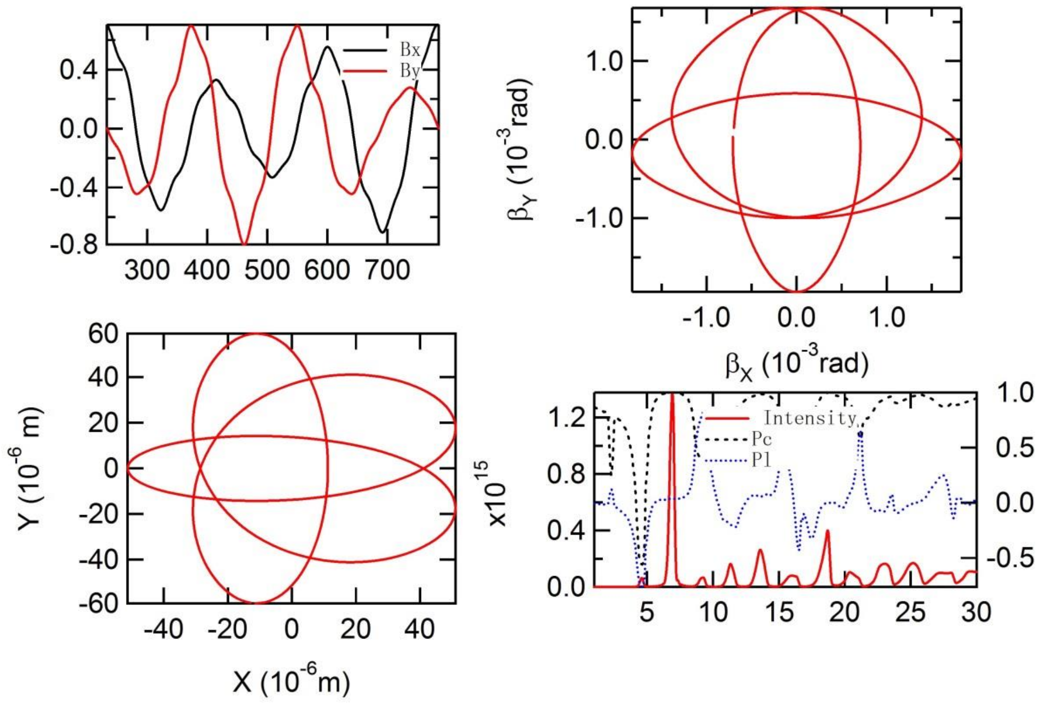
P=99.8%

Phase=±π (antiparallel), Gap=18 mm



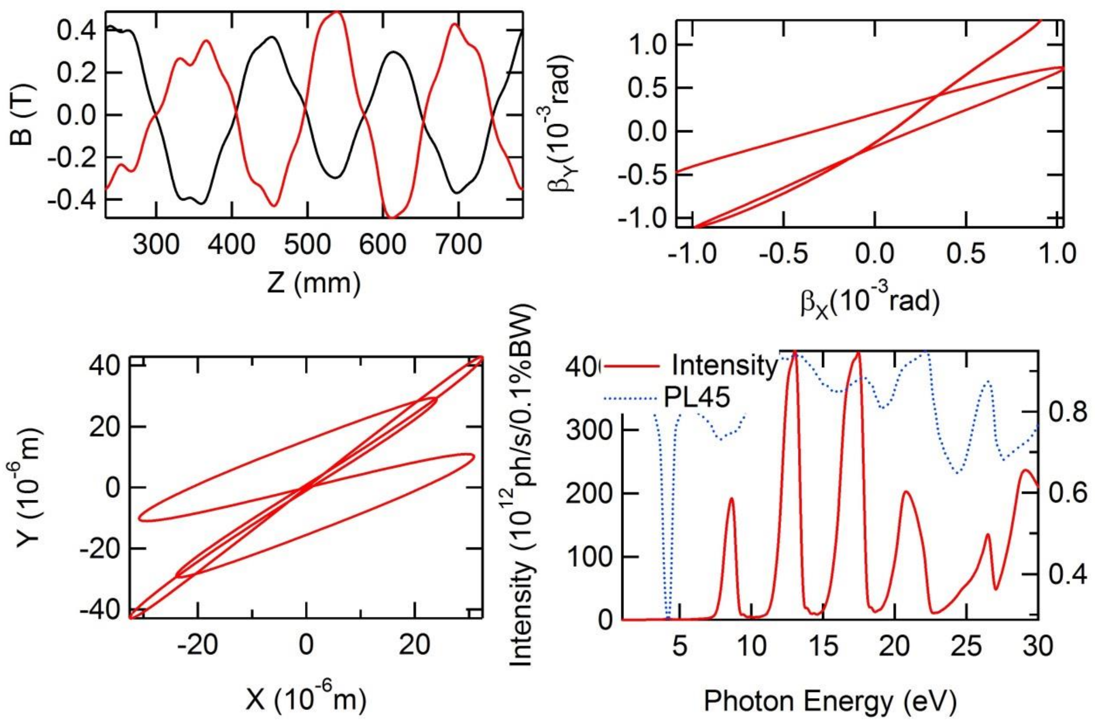
P=-96.7%

Circularly Polarized



P_c=99.8%

Linearly Polarized around 45°



P_{L45}=94%

Summary

The Knot-APPLE undulator is proposed. It is capable to vary polarization states with low on-axis power density at every polarization mode.

In a 3 GeV class light source ring, a long period (λ_u > 200 mm) undulator having a high K-value (~ 10) is required to generate ~ 10 eV photon beam.

This Knot-APPLE undulator scheme is one of the powerful solutions.

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References

- T. Tanaka and H. Kitamura, Nucl. Instrum. Meth. **A364**, 368 (1995).
- S. Sasaki, "Undulators, wigglers and their applications," pp.237-243 (Ed. by H. Onuki and P. Elleaume, Taylor & Francis Inc., New York, 2003).
- S. Qiao, et. al, Rev. Sci. Instrum., **80**, 085108 (2009).
- J. Yan and S. Qiao, Rev. Sci. Instrum, **81**, 056101 (2010).