Insertion Devices for PETRA III

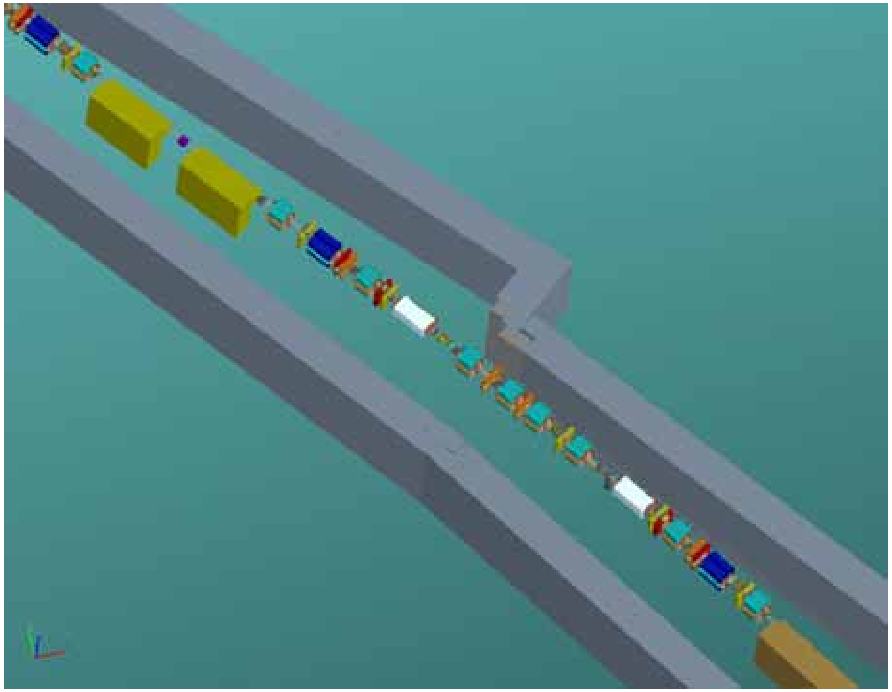
Markus Tischer, 30.01.06

Undulators in the new Octant

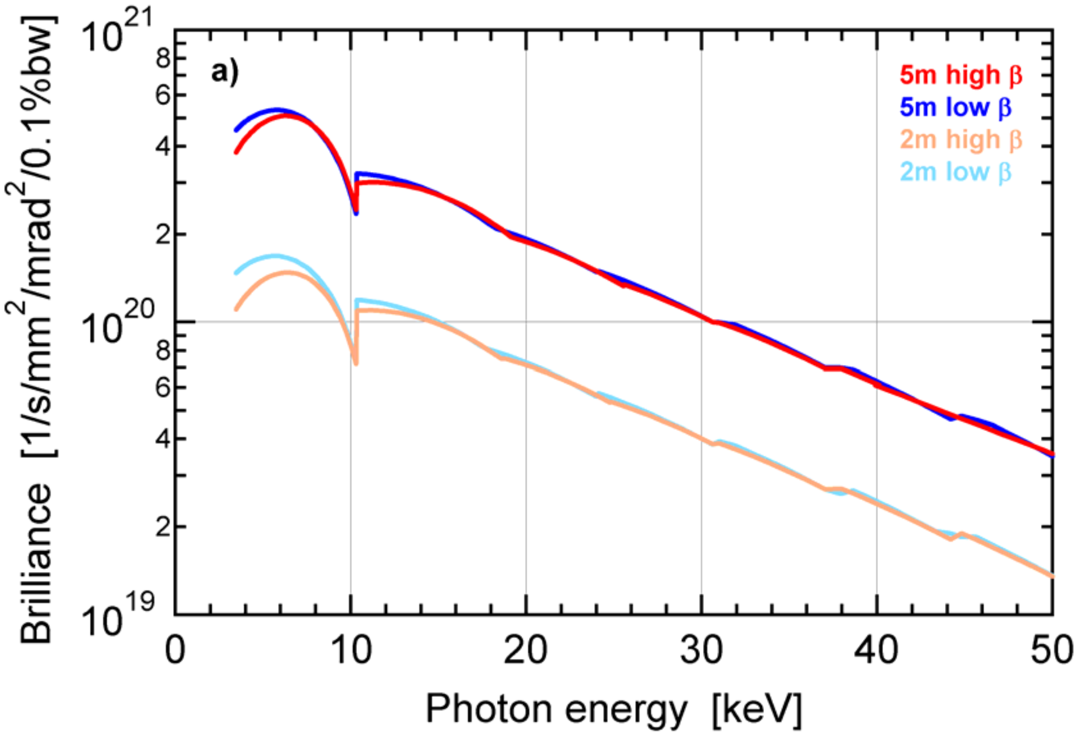
- 14 Undulator radiation sources (IDs):
  3 IDs for 3 normal straight sections (**5m**)
  10 IDs for 5 canted straight sections (**2m**)
  1 ID for the long straight section (**20m**)

- **Magnetic design, mechanics, control system** for **6 different undulator types**:

Conventional IDs (10 St.) :	• **Standard**-IDs (2+5m),	• **Spectroscopy**-IDs (2m)
Special devices (1× each) :	• **High-energy** ID (5m),	• **Quasi-periodic** ID (2m),
	• **Apple2** ID (5m),	• **20m-ID** (4×5m)



Planar IDs - Properties



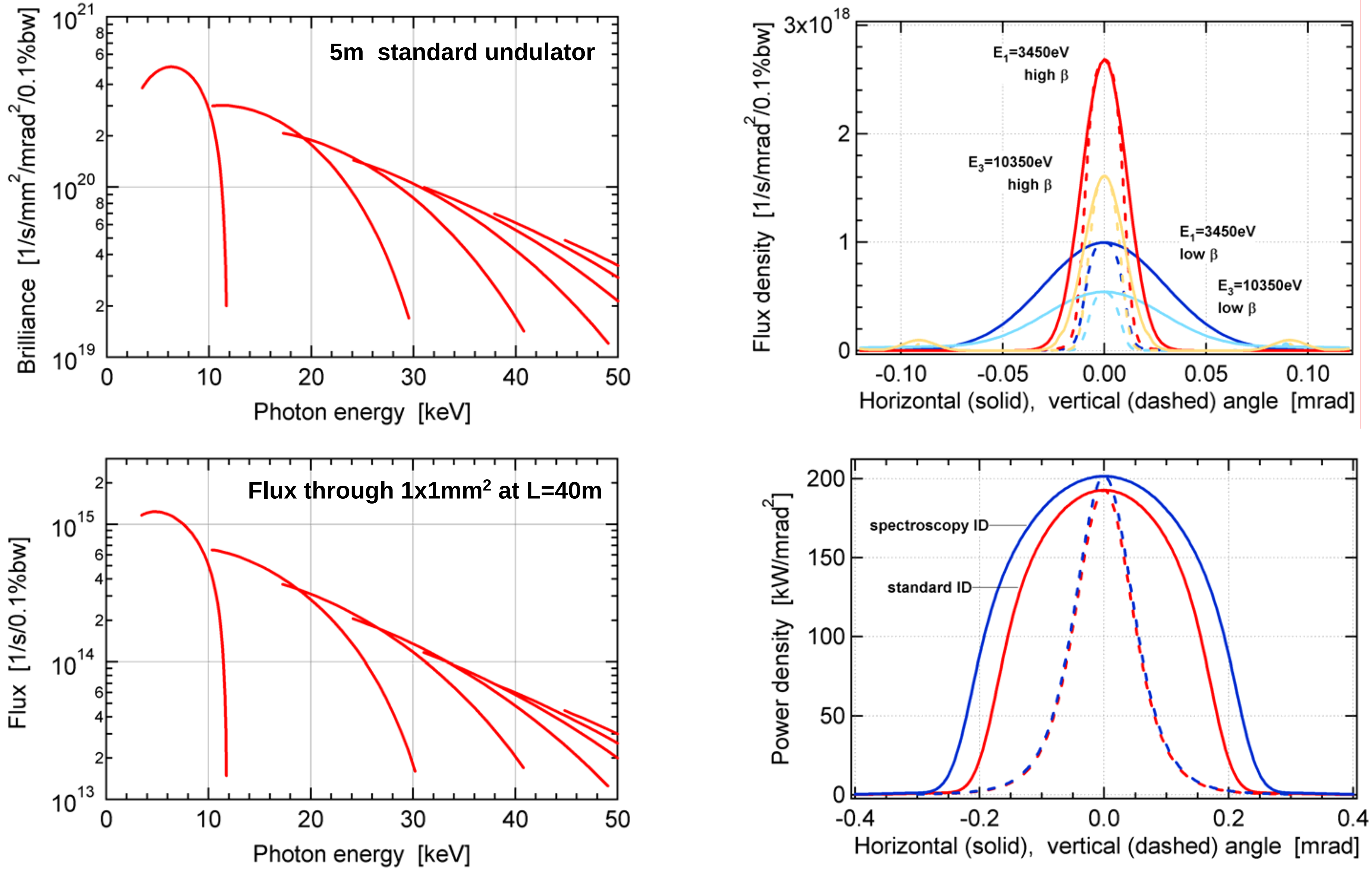
Standard ID : (5m length)

- **Source size at 10keV**
  140 × 5.6 μm^2 ,
  7.9 × 4.1 μrad^2
- **Power density**
  0.2 W/μrad^2
- **Power in 1×1mm^2 (L = 40m)**
  120 W

- **Standard ID**
  K_{max} := 2.2 (← tunability demand)
  λ_U = 29 mm
  B_0 = 0.81 T
  E_1 = 3450 eV
  P_{tot} = 7.5 kW (@ 5m length)

- **Spectroscopy ID**
  K_{max} = 2.7
  λ_U = 31.4 mm
  B_0 = 0.91 T
  E_1 := 2400 eV (← user demand)
  P_{tot} = 3.8 kW (@ 2m length)

Planar IDs - Properties (2)



Development of planar undulators

- **Common Development for PETRA III & XFEL**

  - magnet design & field terminations

  - universal gap mechanics

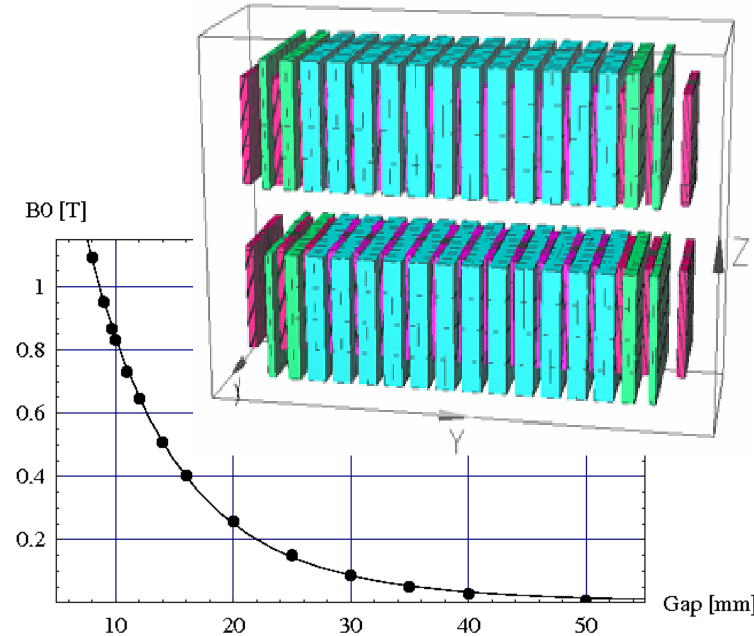
  - motion control system

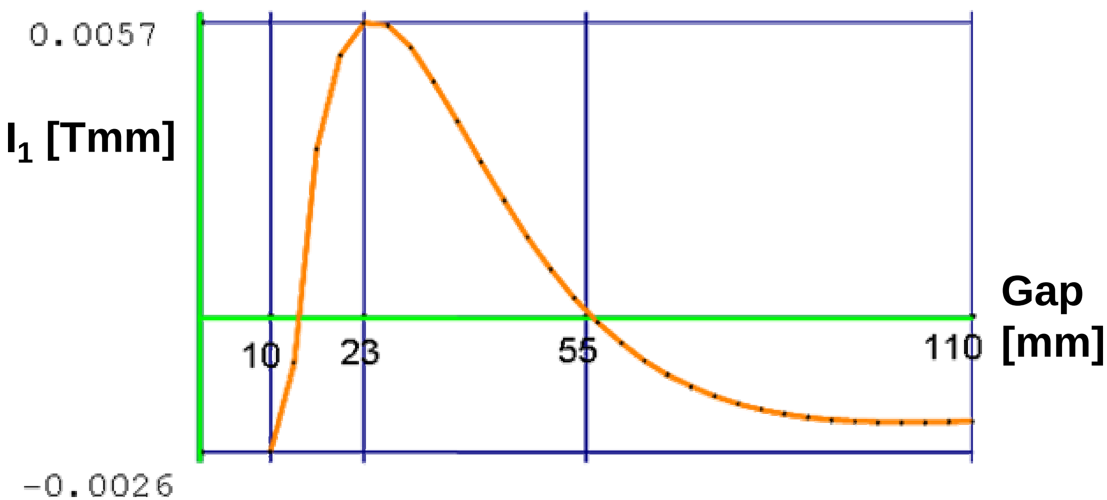
- **Prototype undulator in the procurement phase**

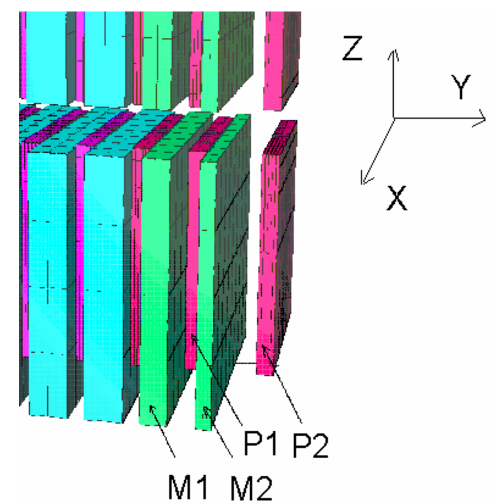
Magnet Design

- **Periodic part**:
  optimize peak field, transverse field roll-off, magnet material, demagnetizing fields

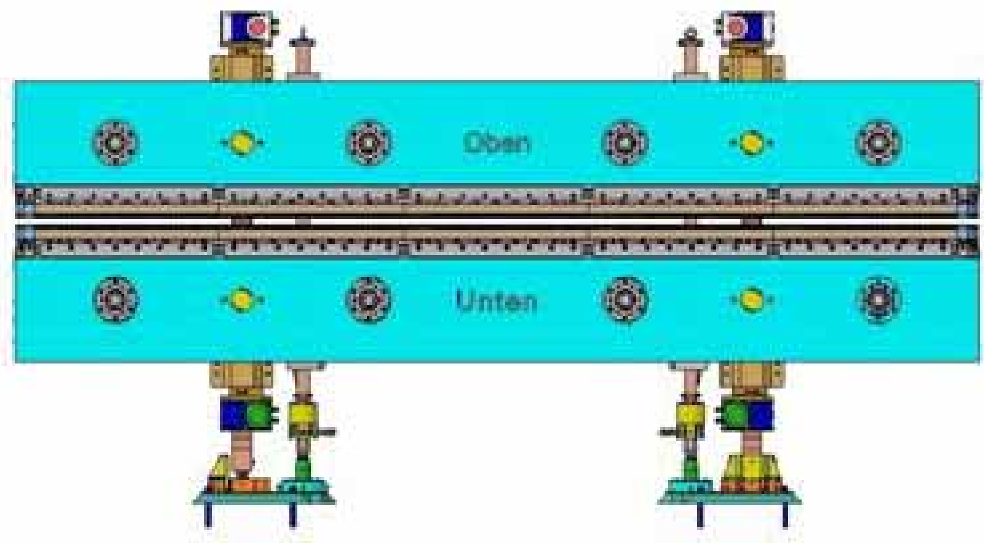
- **End structure** :
  Minimize gap dependence of 1st field integral (kick)
  realize gap-independent trajectory in the undulator
  Problem: different iron saturation at center and ends
  ➔ ΔI1(gap) ~ 0.01Tmm (0.5µrad)

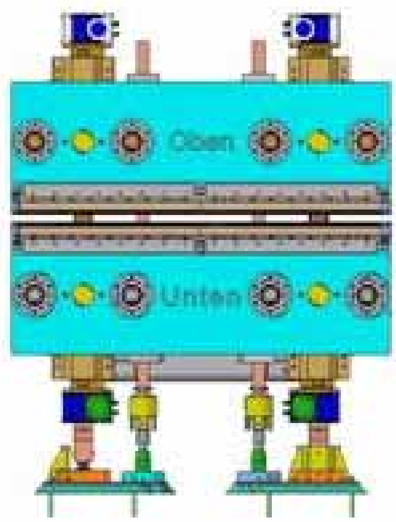


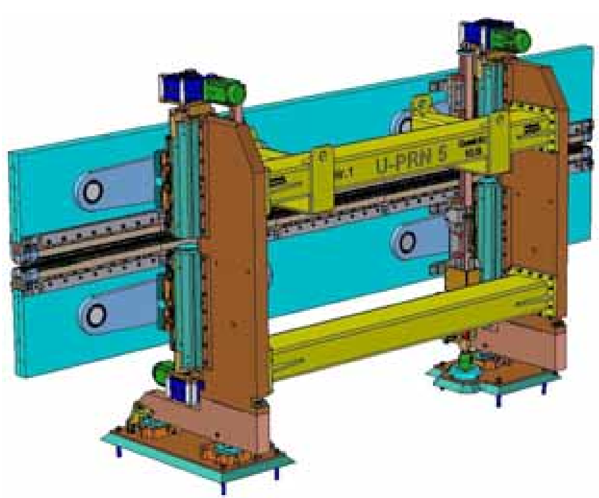




Gap Mechanics (1)







- **Requirements**

  Minimum girder deformation ~1µm

  Temperature insensitive

  Magnetic forces up to 160kN

  Gap accuracy of ~1µm

  Taper up to 1mm

- **Concept** (ZM1, since Sept.04)

  4-fold girder support

  Decoupling of guiding and load support

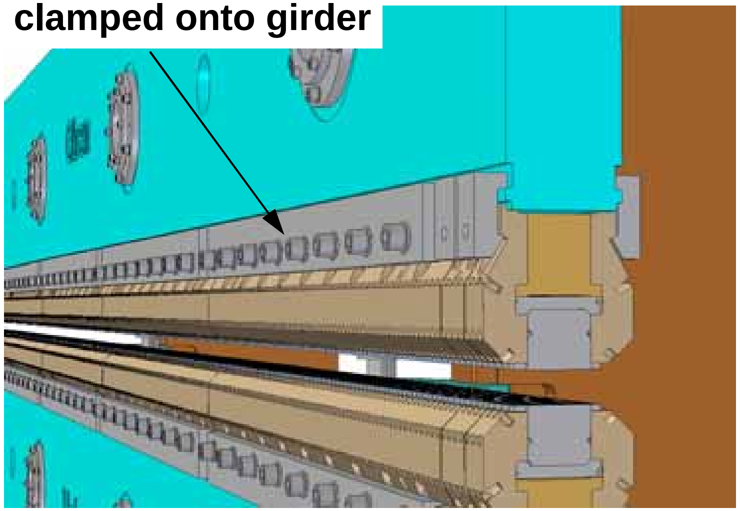
  4-axis drive

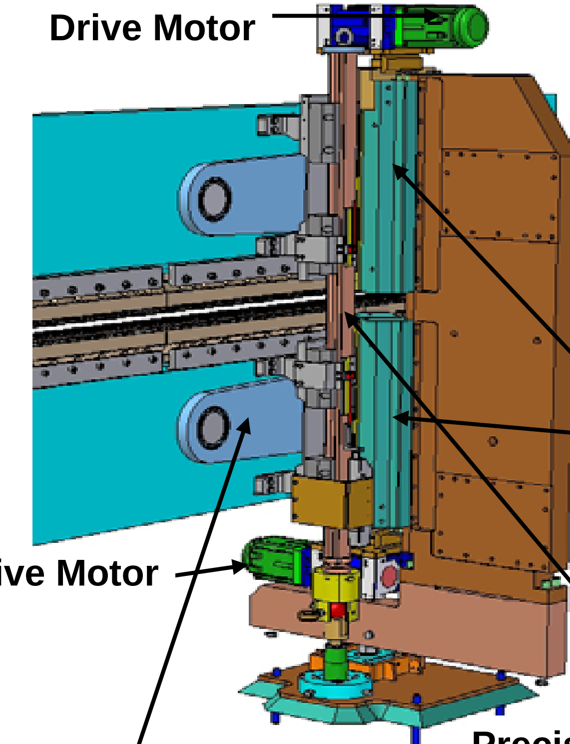
XFEL-specifications:

$\Delta K/K = 8^* 10^{-5} \Rightarrow$

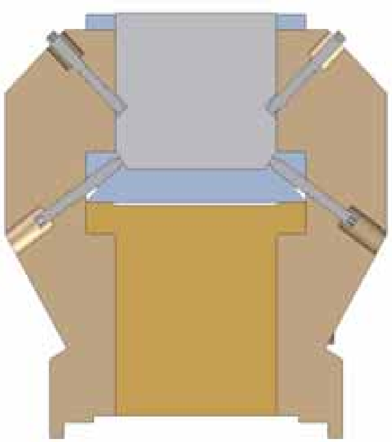
Temp. :	**$\Delta T = 0.08$ K**
Justage:	**$\Delta y = 100$ µm**
Taper:	**$\Delta g = 1$ µm**
Gap:	**$\Delta g = 1$ µm**

Gap-Mechanics (2)





Based on experience with the VUV-FEL undulators



Tuning of the magnet structure:

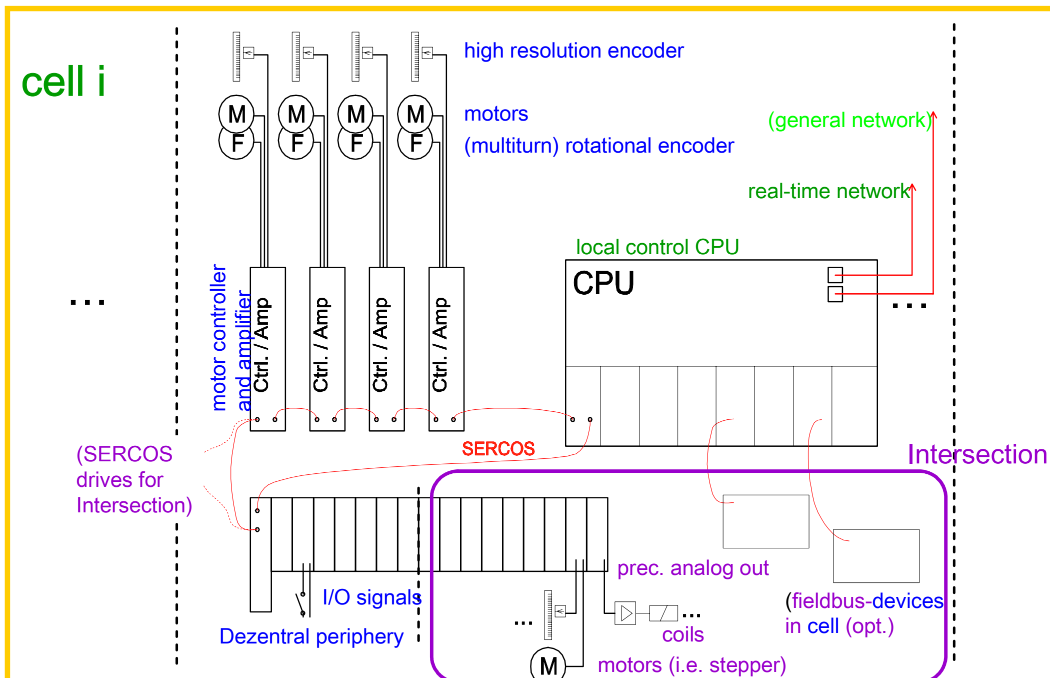
- **pole height adjustment by ±0.3mm**
- **possibly ±1mrad tilt**

Control System (1)

Requirements & Concept:

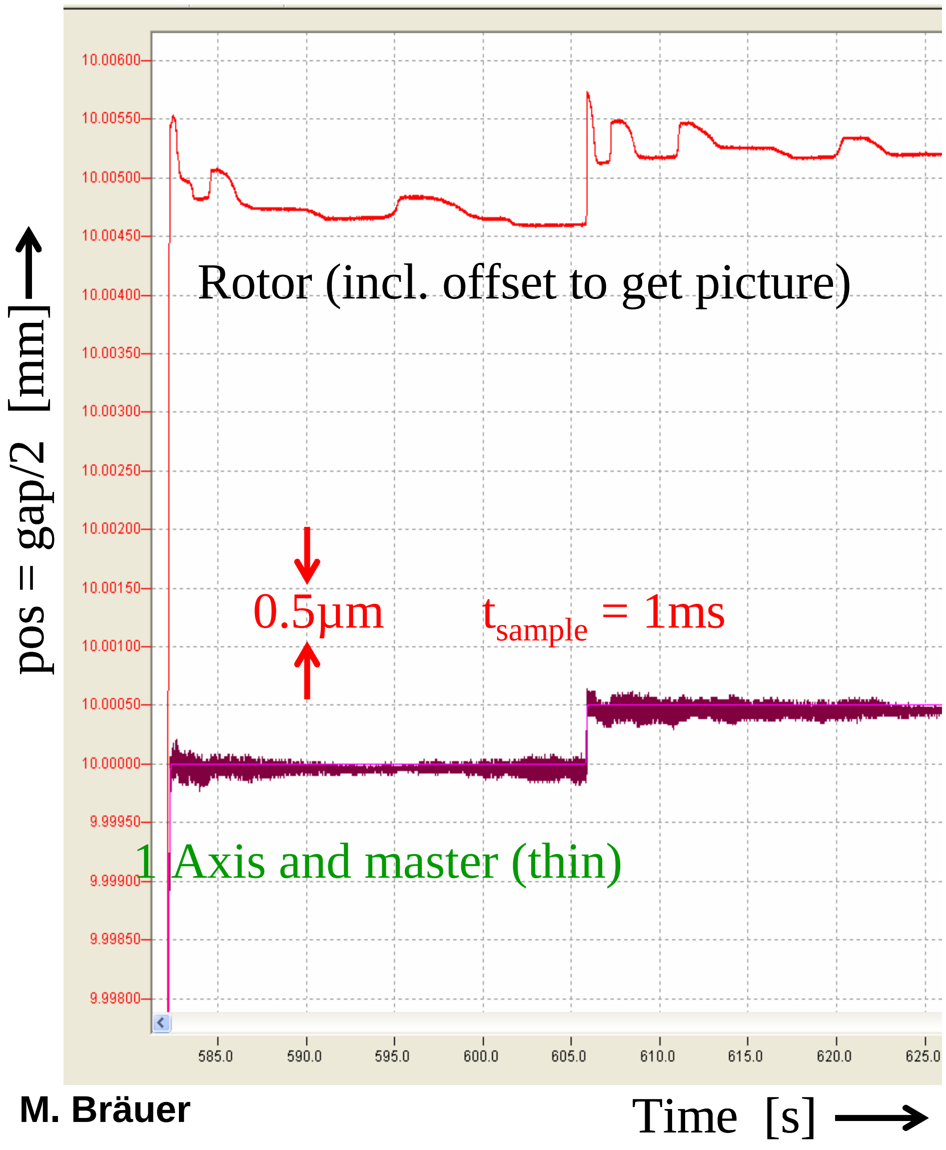
- synchronized gap movements
- comprise the modular setup => cells
- high reliability
- allow complex movement-schemes
- movements with high dynamics
- long-term availability of components

Experimentally ⟷ proven



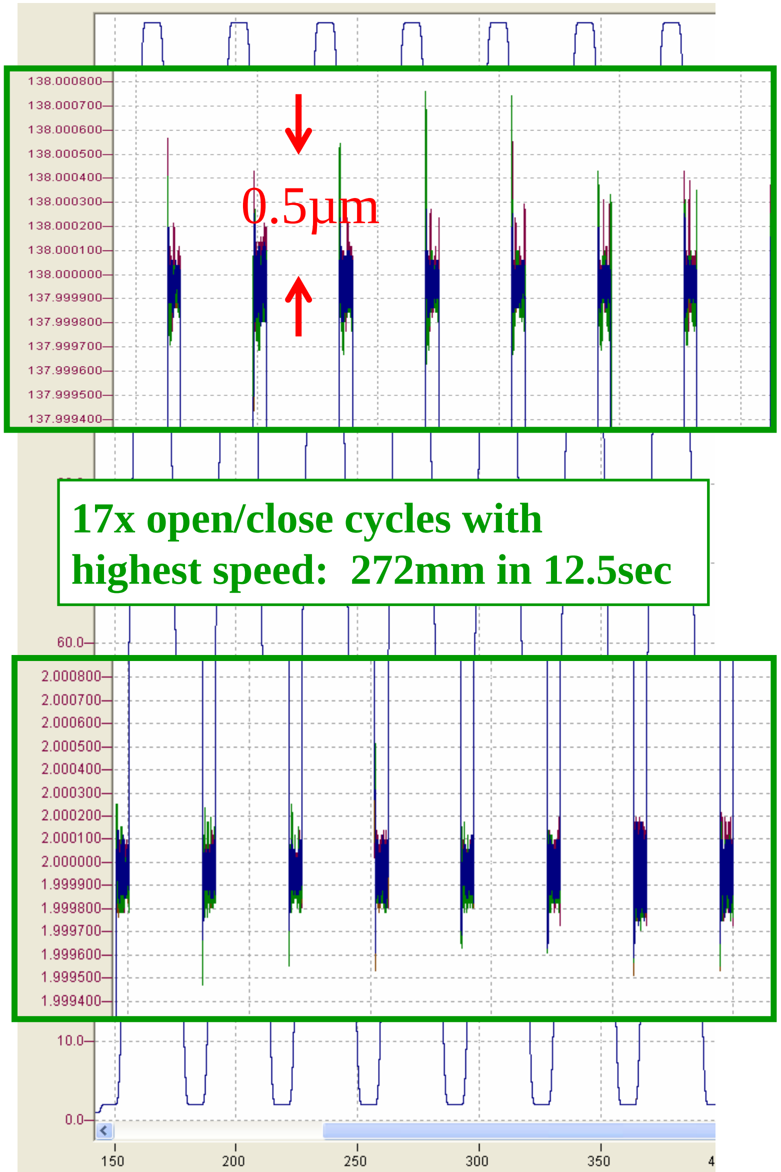
Intersection not fully defined ⟹ need maximal flexibility

M. Bräuer



Rotor (incl. offset to get picture)
0.5µm
t_{sample} = 1ms
1 Axis and master (thin)
pos = gap/2 [mm]
Time [s]

M. Bräuer



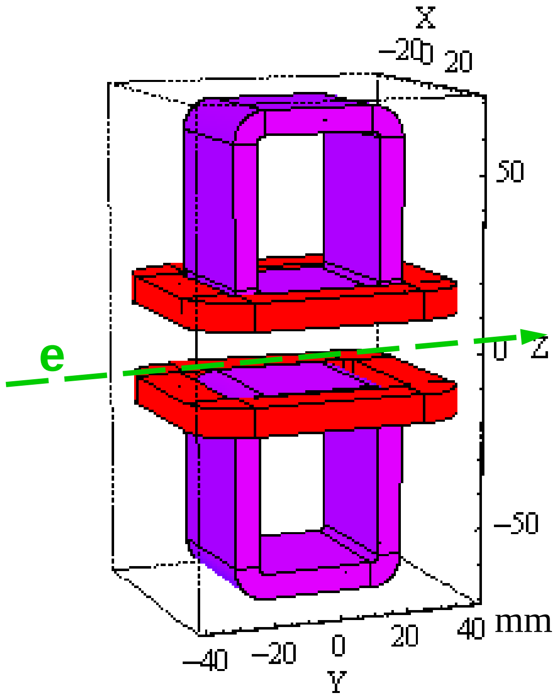
0.5µm
17x open/close cycles with highest speed: 272mm in 12.5sec

Steerers

- **active compensation of residual field integral (trajectory) changes**

- **air coils = hysteresis-free !**
- **very compact**
- **small adjustment range**
- **moderate field homogeneity**
- **integrated in ID control system**

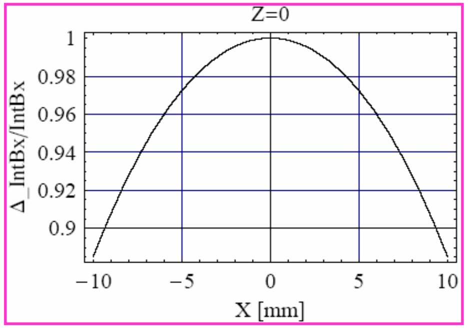
- **first prototype completed**
  → 2 pairs used at VUV-FEL



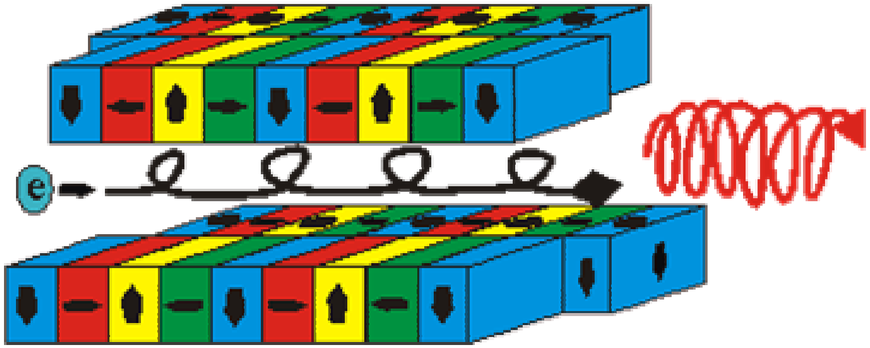
horizontal steerer: B_z=4.2mT, $IntB_z$=0.22Tmm (2.2Gm)

vertikal steerer: B_x=2.7mT, $IntB_x$=0.22Tmm (2.2Gm)

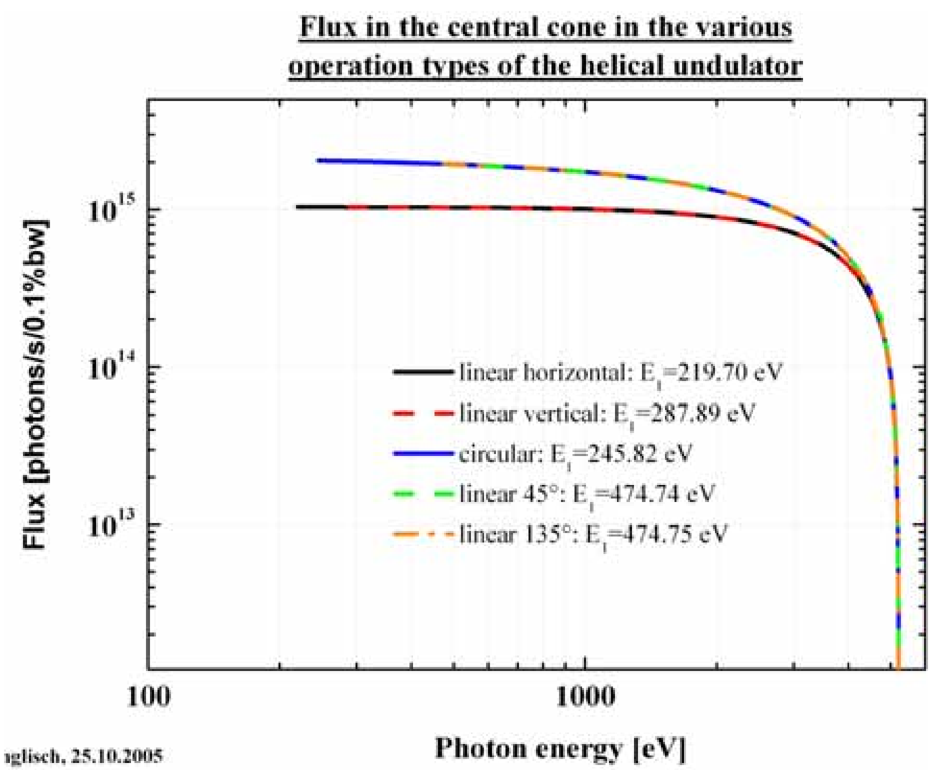
for j=2.03A/mm² at 69% fill factor … j → 3 A/mm² might work



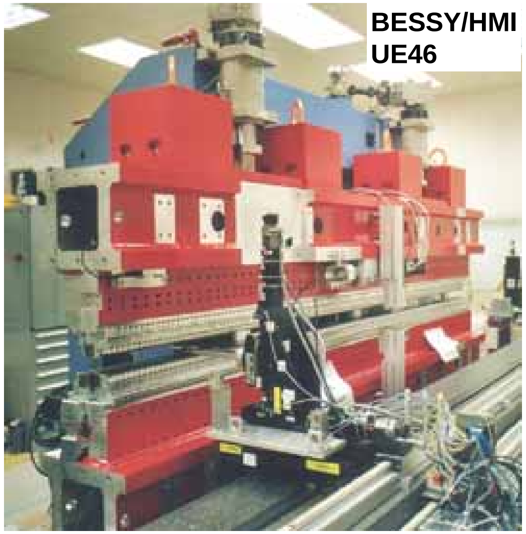
Special IDs – APPLE2 (1)



Operation mode	Shift[mm]	B_{eff}[T]	K_{eff}	E_1[eV]
Hor. linear	00.0	1.10	6.7	220
Vert. linear	32.8	0.95	5.8	288
Circular	18.1	1.04	6.4	246
45 ° linear	17.3	0.73	4.5	475
135° linear	17.3	0.73	4.5	475



λ_U = 65.6mm, L = 5m , Gap = 11mm



to be built in cooperation with BESSY

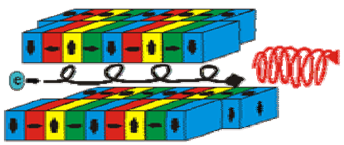
U. Englisch

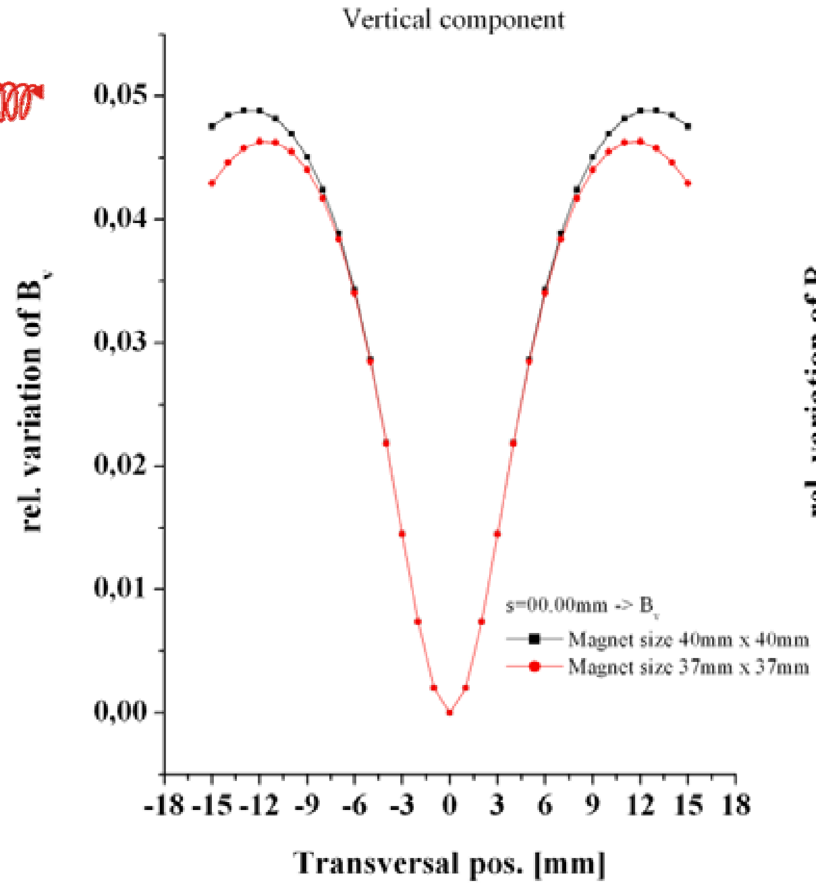
Special IDs – APPLE2 (2)

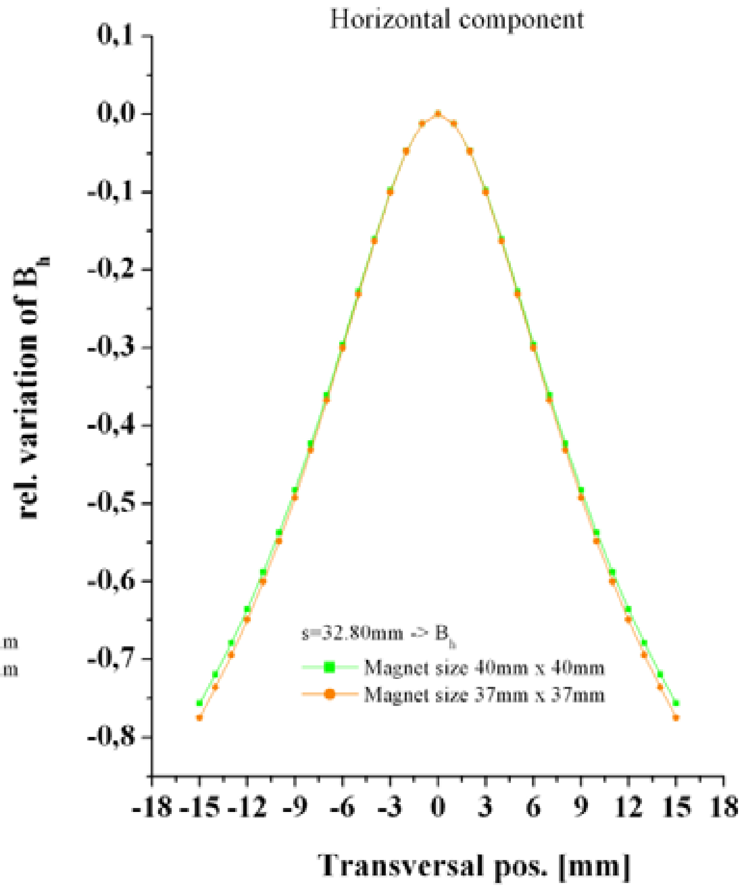
… implications 1)

Magnetic field components as a function of the transversal position

„field roll-off“







U. Englisch

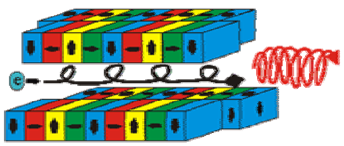
➔ decreases dynamic aperture, but can be handled (e.g. SLS, BESSY, ESRF …)

Special IDs – APPLE2 (3)

… implications 2)

Forces acting on the lower girder of an UE with λ_u = 65.6 mm

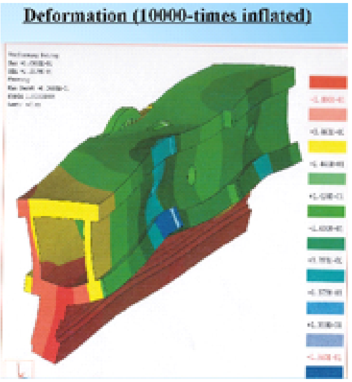
- ■ antiparallel motion
- ● parallel motion

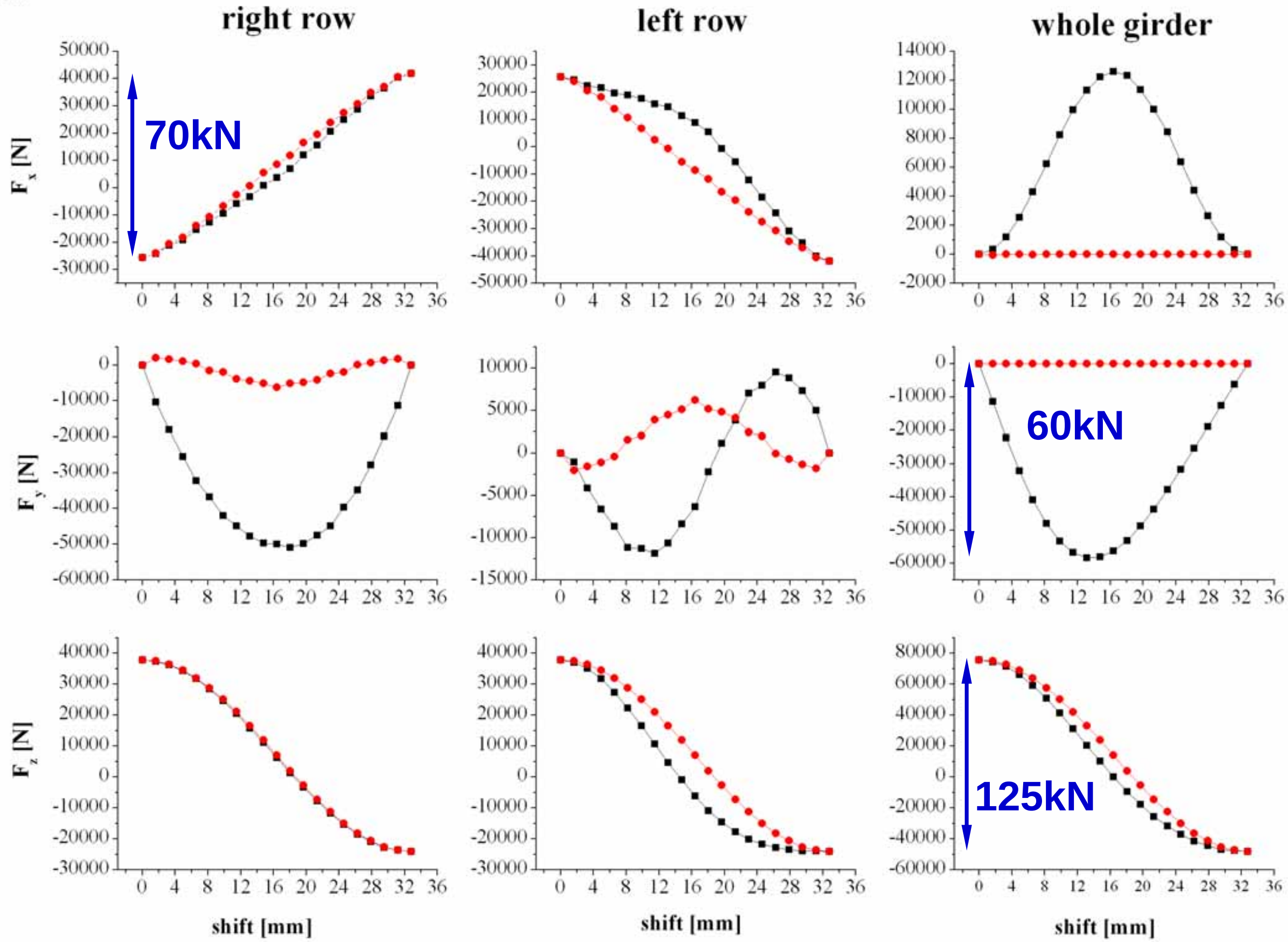


transversal force F_x

longitudinal force F_y

vertical force F_z

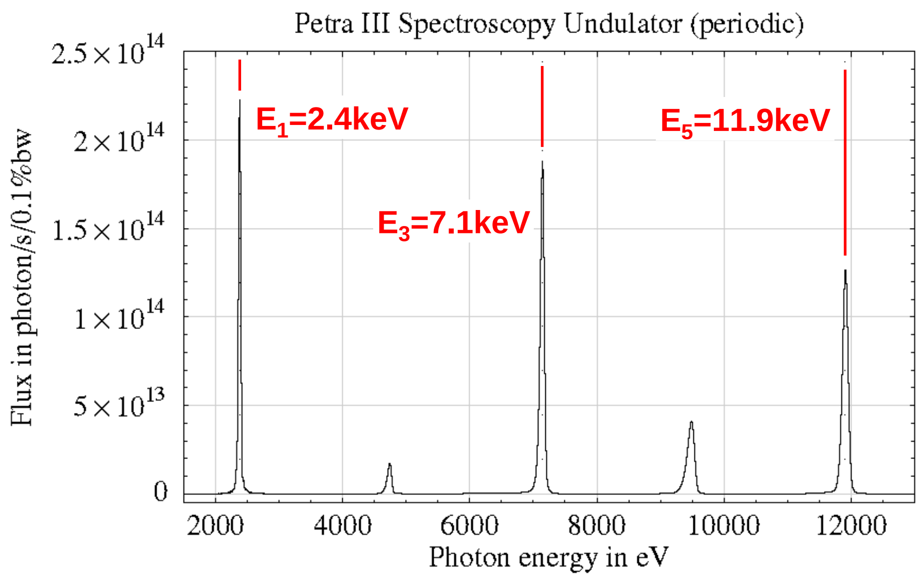




U. Englisch

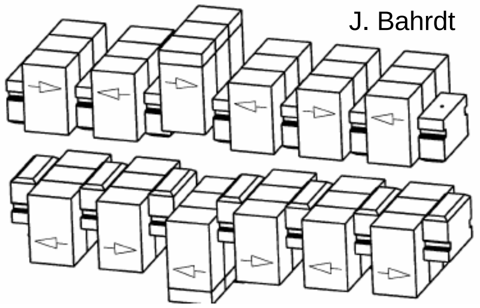
➔ **needs modification of the gap mechanics to cope with the extra forces**

Special IDs – Quasiperiodisches ID (1)



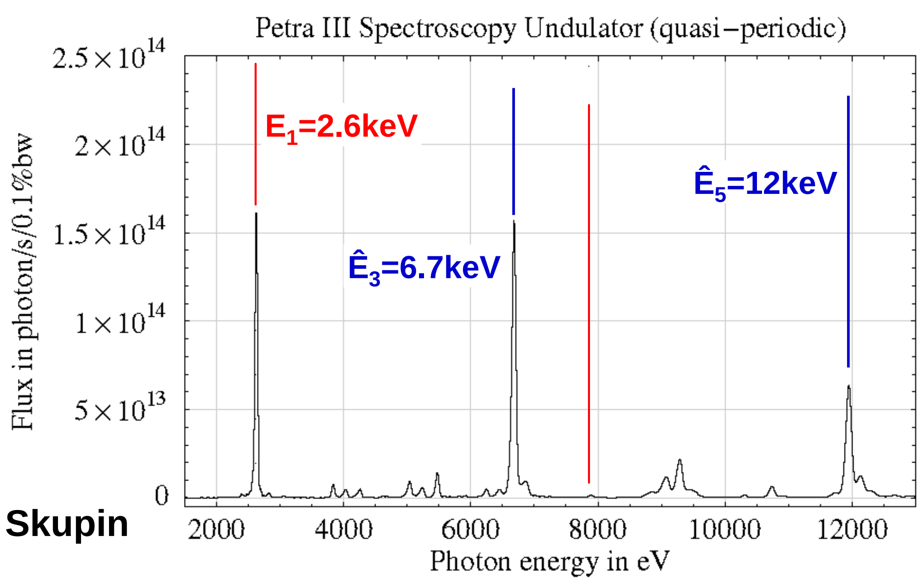
Shift of the higher harmonics towards non-integer multiples

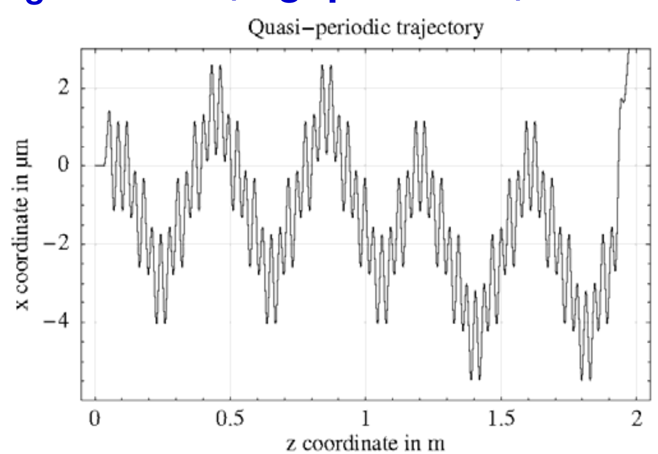
- **Suppression of higher order radiation**
- **realized by modification of distinct magnets**
- **otherwise like the „Spectroscopy“-ID**



J. Bahrdt

λ_U=31.4mm, gap=9.5mm, L=2m





J. Skupin

Special IDs – Quasiperiodisches ID (2)

Goals:

Suppress 3rd order radiation

Maximize intensity of shifted 3rd harmonic (E_3')

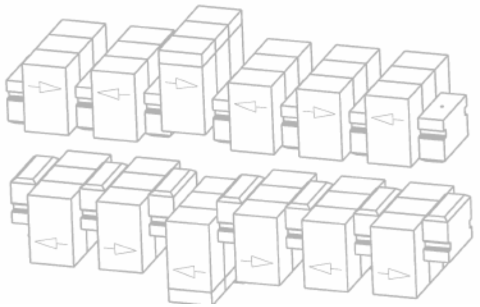
Suppress the 3rd harmonic of E_3'

Preliminary Results:

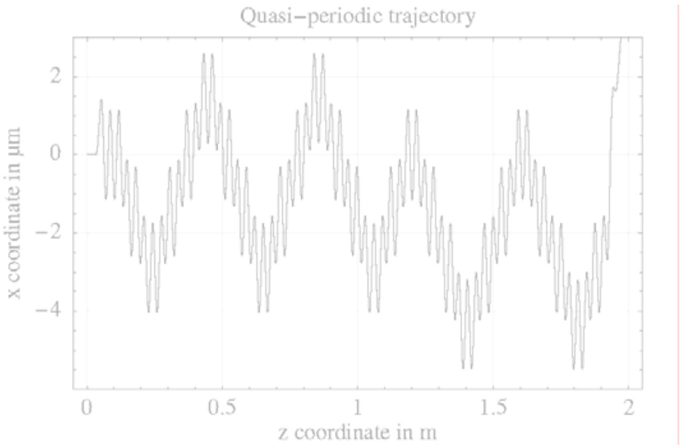
28% intensity reduction of 1st harmonic

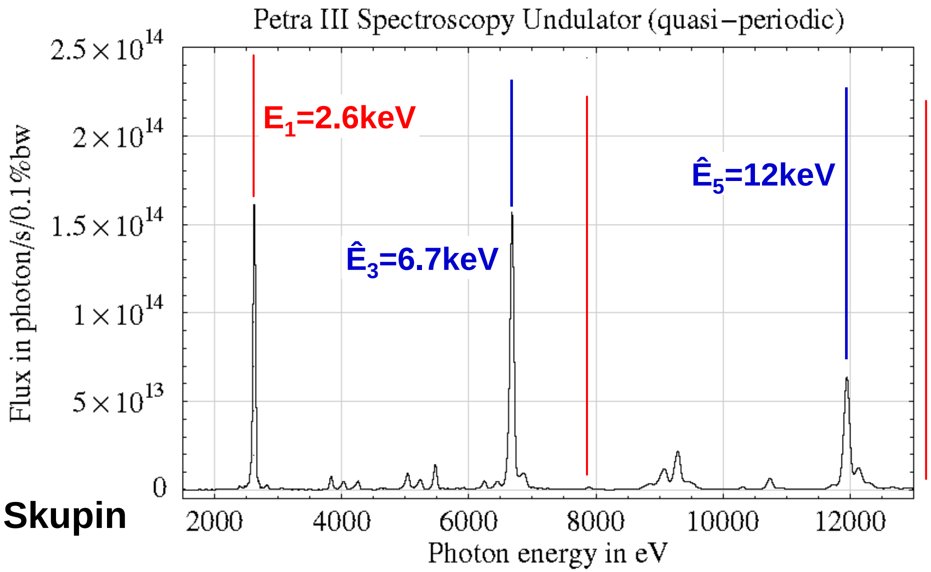
99% reduction of 3rd harmonic contribution

Slightly less suppression for the real device



λ_U=31.4mm, gap=9.5mm, L=2m

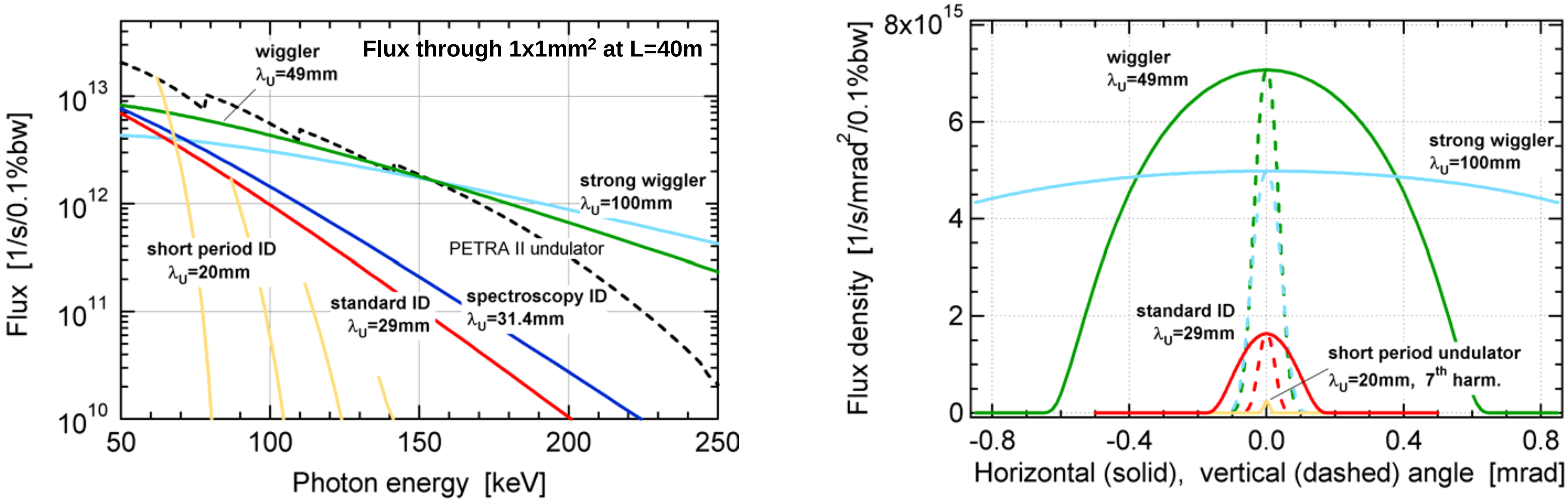




J. Skupin

Hard X-ray Undulator

Different options, still in discussion



Alternative options

for small beam foci (30x30µrad^2 or smaller): **Short period** undulators

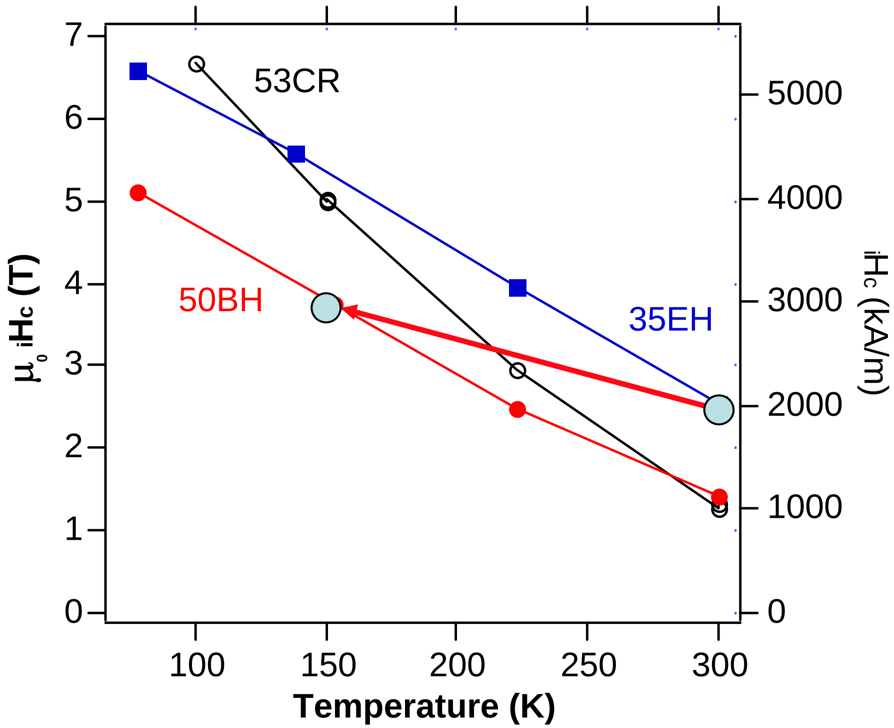
- **In-vacuum** undulator (300K) : beneficial for small beam foci at high energies!
- **Cryo-In-vacuum** undulator (T=150K) : present developments at various places promising!
- **Superconducting** undulator (T=4K) : best once technologically established

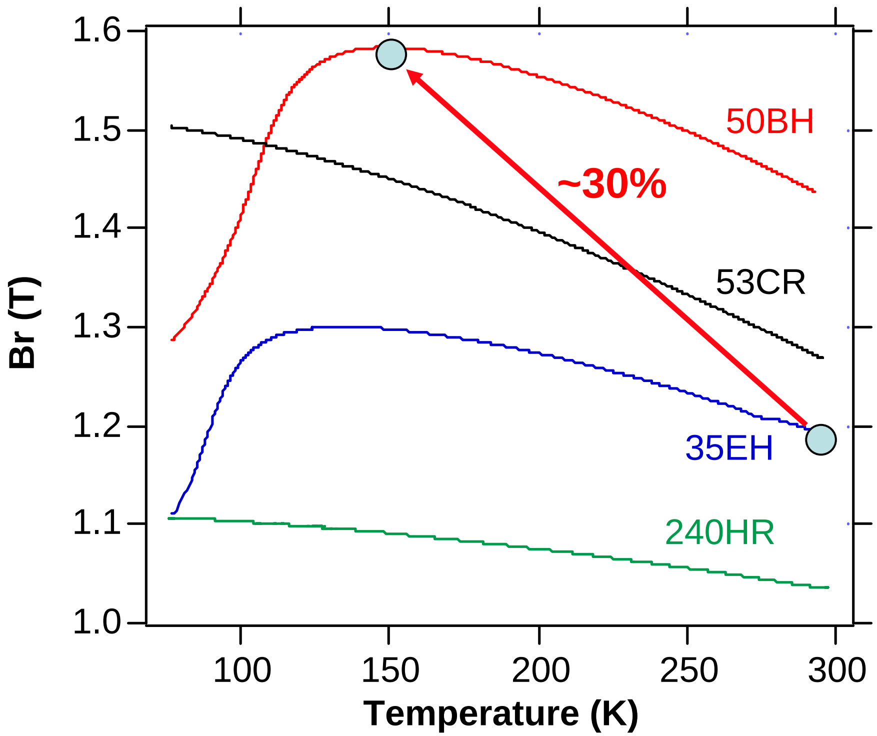
Cryogenic In-Vacuum Undulator

T. Hara, SPring-8, WUS2005,
PRST-AB 7 (2004)

Concept of cryogenic insertion devices

- Increased coercivity at cryogenic temperatures (> 77K) => choice of high B_r material, high resistance against demagnetization.
- Increased remanent field (B_r)

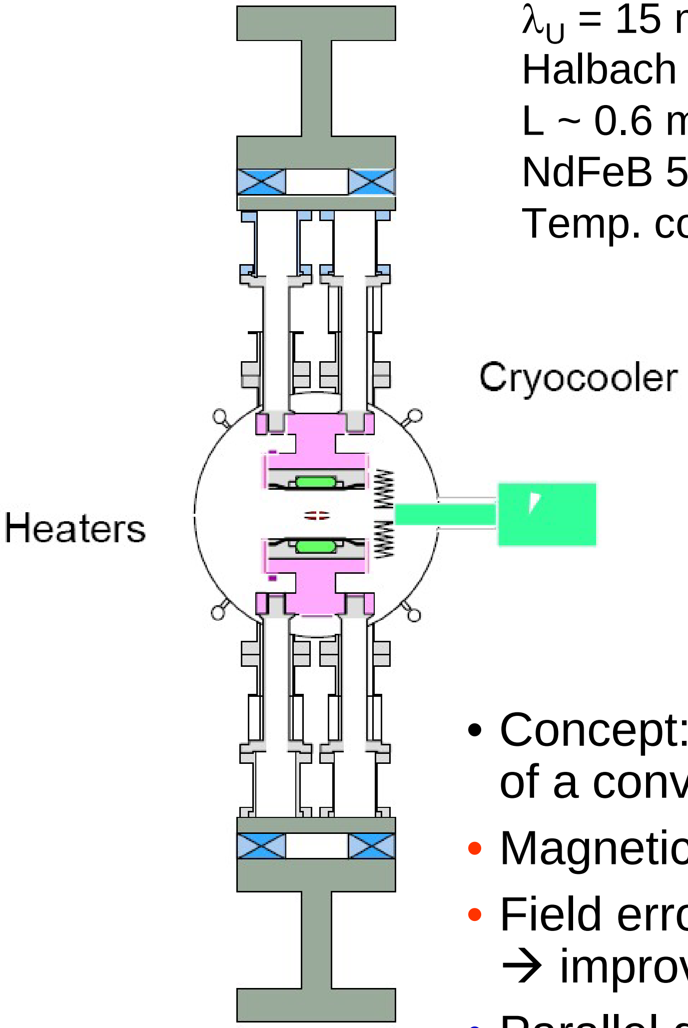


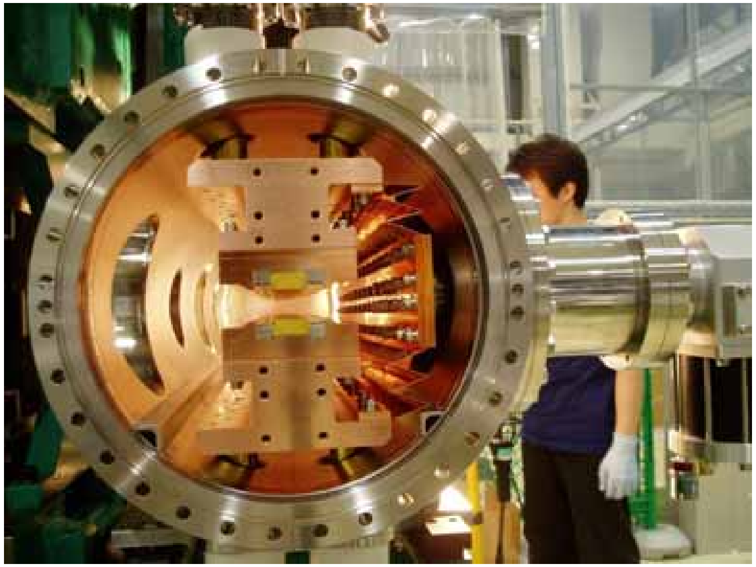


Cryogenic In-Vacuum Undulator

T. Hara, SPring-8, WUS2005,
PRST-AB 7 (2004)

Prototype
λ_U = 15 mm
Halbach ppm
L ~ 0.6 m
NdFeB 50BH
Temp. controlled by heaters





- Concept: Adding a cryocooler and modifying support shafts of a conventional in-vacuum undulator.
- Magnetic properties according expectations
- Field errors due to thermal deformation
  → improve mechanics & isolation
- Parallel developments at ESRF and NSLS

Cryo-In-Vacuum ID for hard X-rays

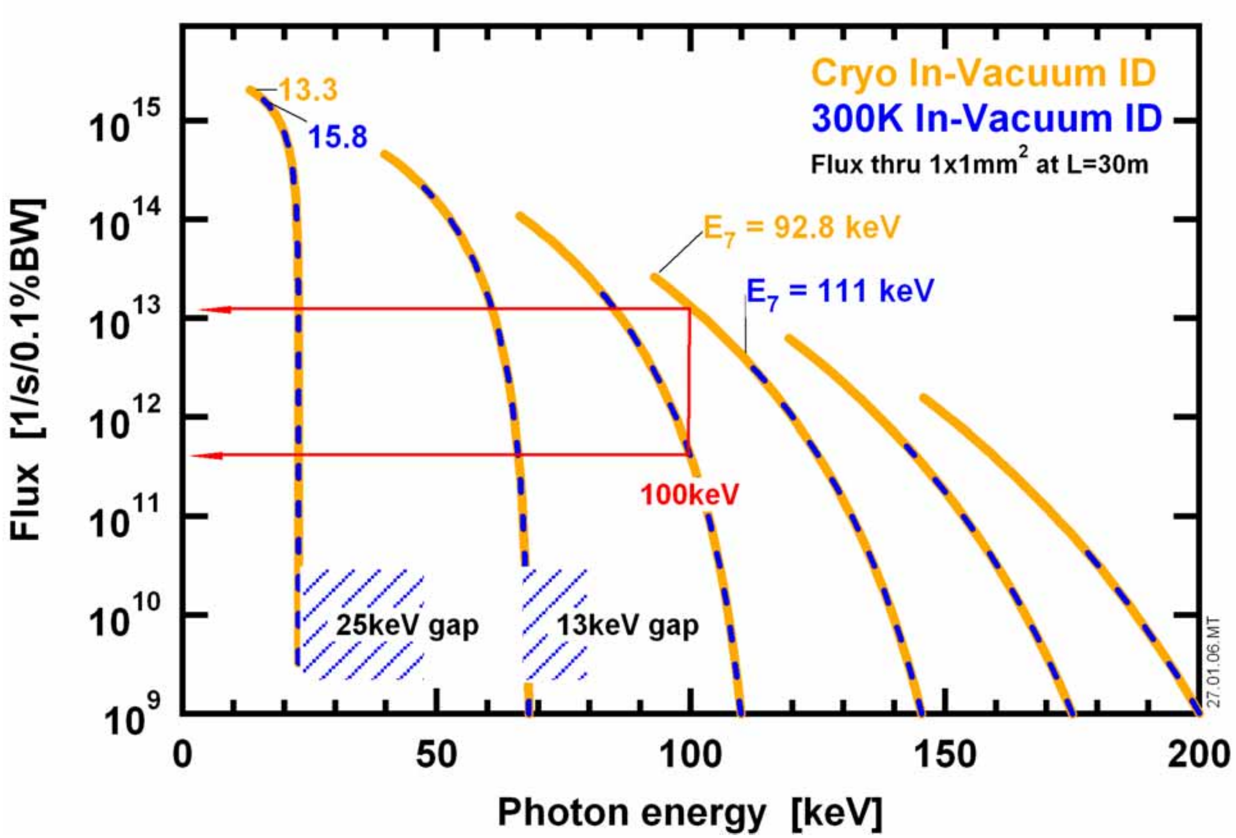
for PETRA III: parameters ~like SPring8

gap = 5.5mm
NdFeB 50BH
λ_U = 15mm
T = 150K
L = 4m
M_r ~ 1.55T
B_0 = 0.86T
K = 1.2
E_1 = 13.3 keV

for comparison:

In-Vacuum ID, T=300K

gap = 5.5mm
λ_U = 15mm
L = 4m
B_0 = 0.67T
K = 0.93
E_1 = 15.8 keV



Cryo-In-Vacuum ID for hard X-rays

for PETRA III: parameters ~like SPring8

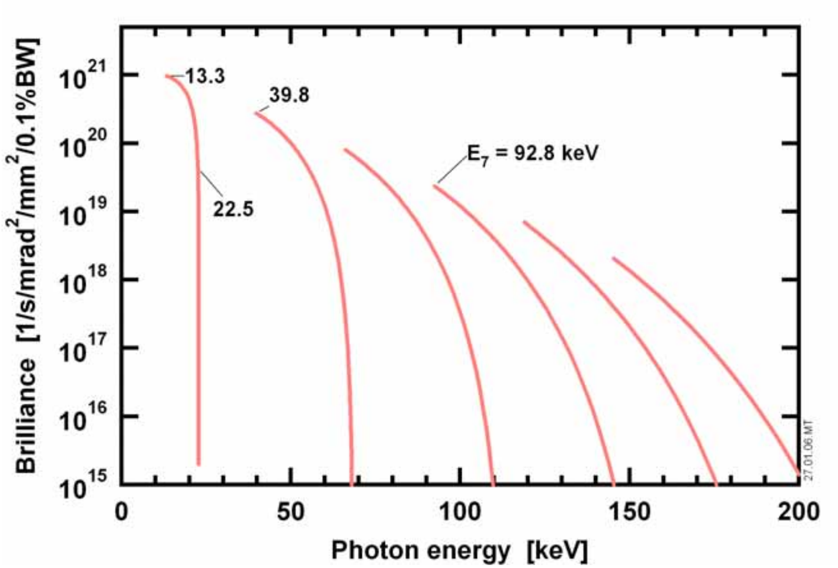
gap = 5.5mm NdFeB 50BH

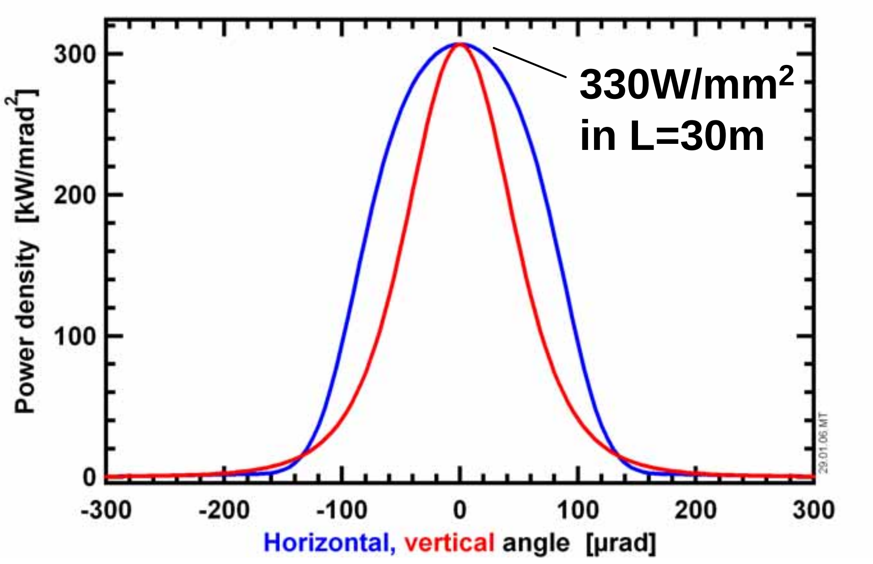
λ_U = 15mm T = 150K

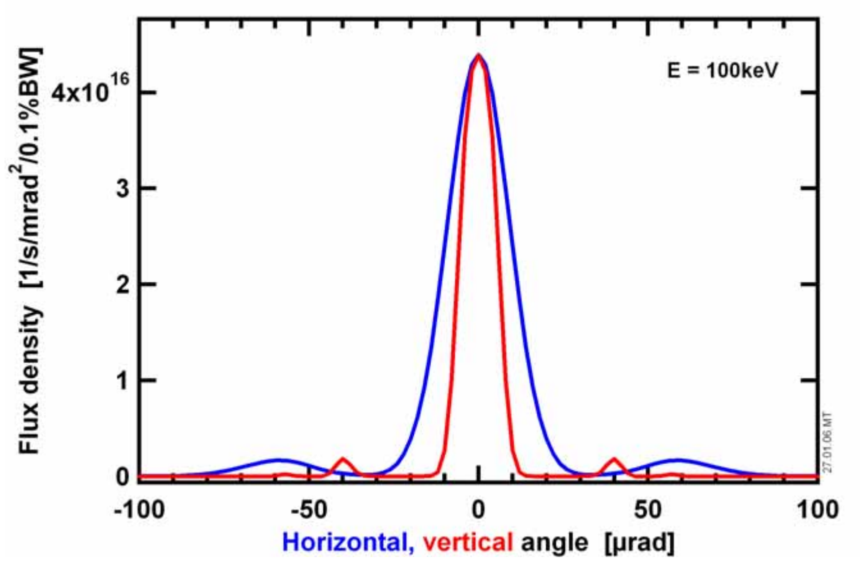
L = 4m

B_0 = 0.86T K = 1.2

P_{tot} = 6.7kW



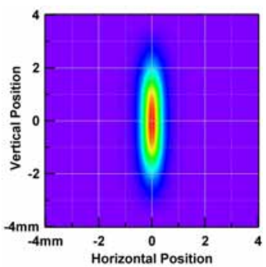


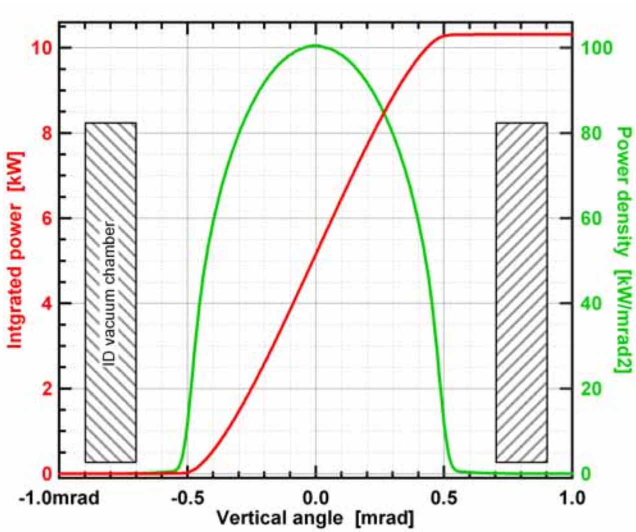


IDs – Straights – Front Ends

… implications:

APPLE2: Linear vertical mode

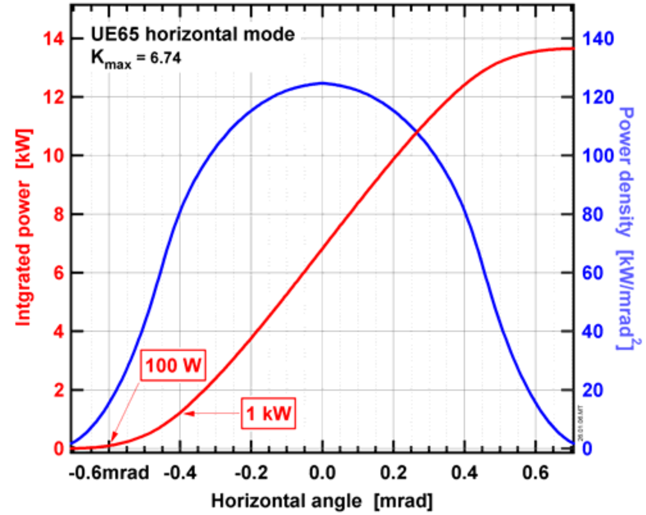


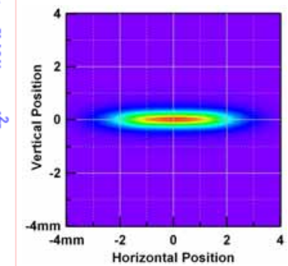


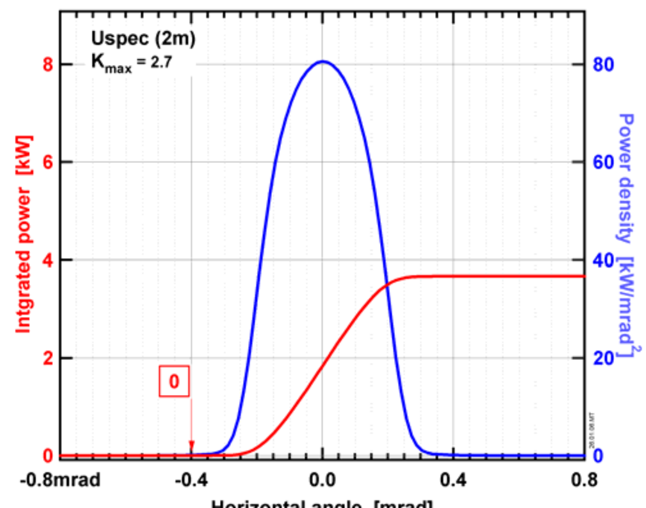
➔requires large vertical aperture in ID chamber and front end until 1st absorber

➔chamber cooling if necessary (Bessy)

5m long straights:







2m canted straights

Thanks