UVSORの現状と
小型施設から眺めたSPring-8

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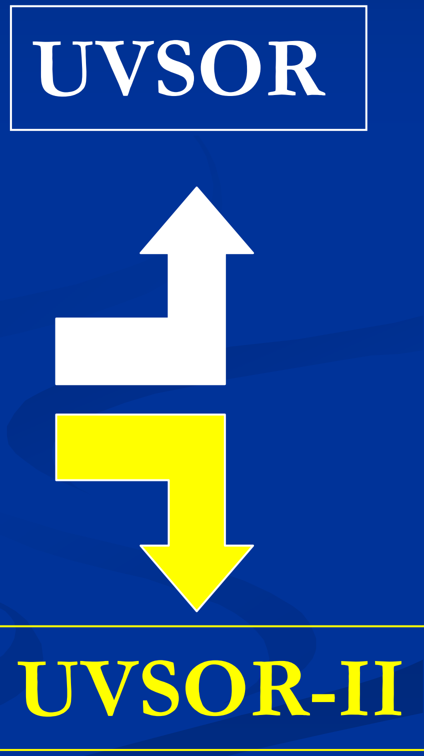
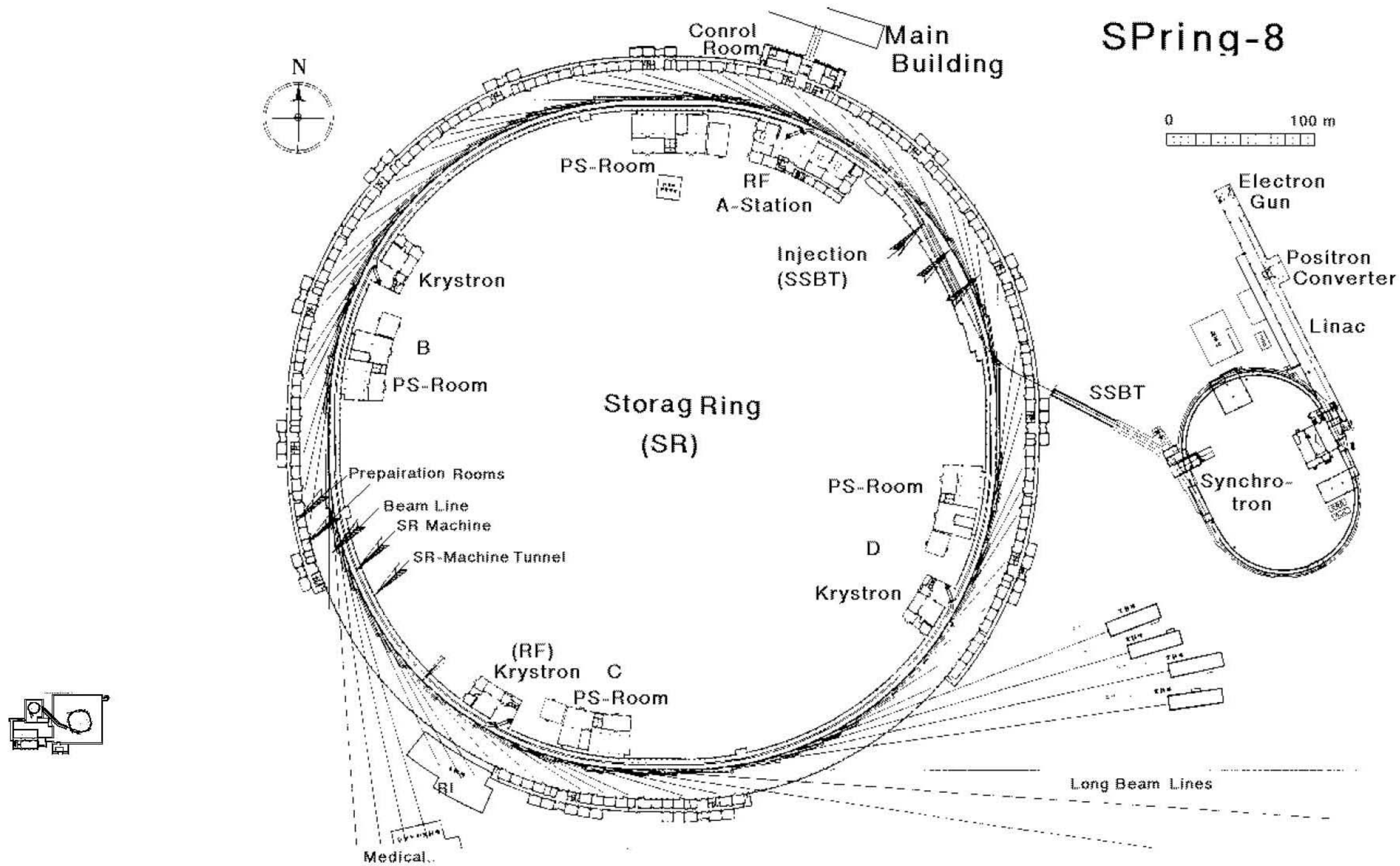
History of UVSOR Accelerators

1981	Start of Construction
1983	Commissioning of Storage Ring
1984	Installation of Undulator and Wiggler
1986	Start of Free Electron Laser
1993	FEL 1st Lasing (456 nm)
1996	Installation of Helical Undulator/Optical Klystron
	FEL Lasing at 239 nm (World Record)
2001	FEL Output Power 1.2W (World Record)
2002	Installation of 1st in-vacuum Undulator
	1st FEL Users Experiment
2003	Reconstruction to UVSOR-II
	Installation of 2nd In-Vacuum Undulator
	Commissioning of UVSOR-II
2004	New RF Cavity
2005	Reinforcement of Radiation Shield
	Start of Laser Bunch Slicing/CHG
2006	Energy Upgrade of Booster Synchrotron
	Installation of 2nd Variably Polarized Undulator
2007	Energy Upgrade of Beam Transport Line
	Start of Full Energy Injection
200X	Start of Top-up Operation



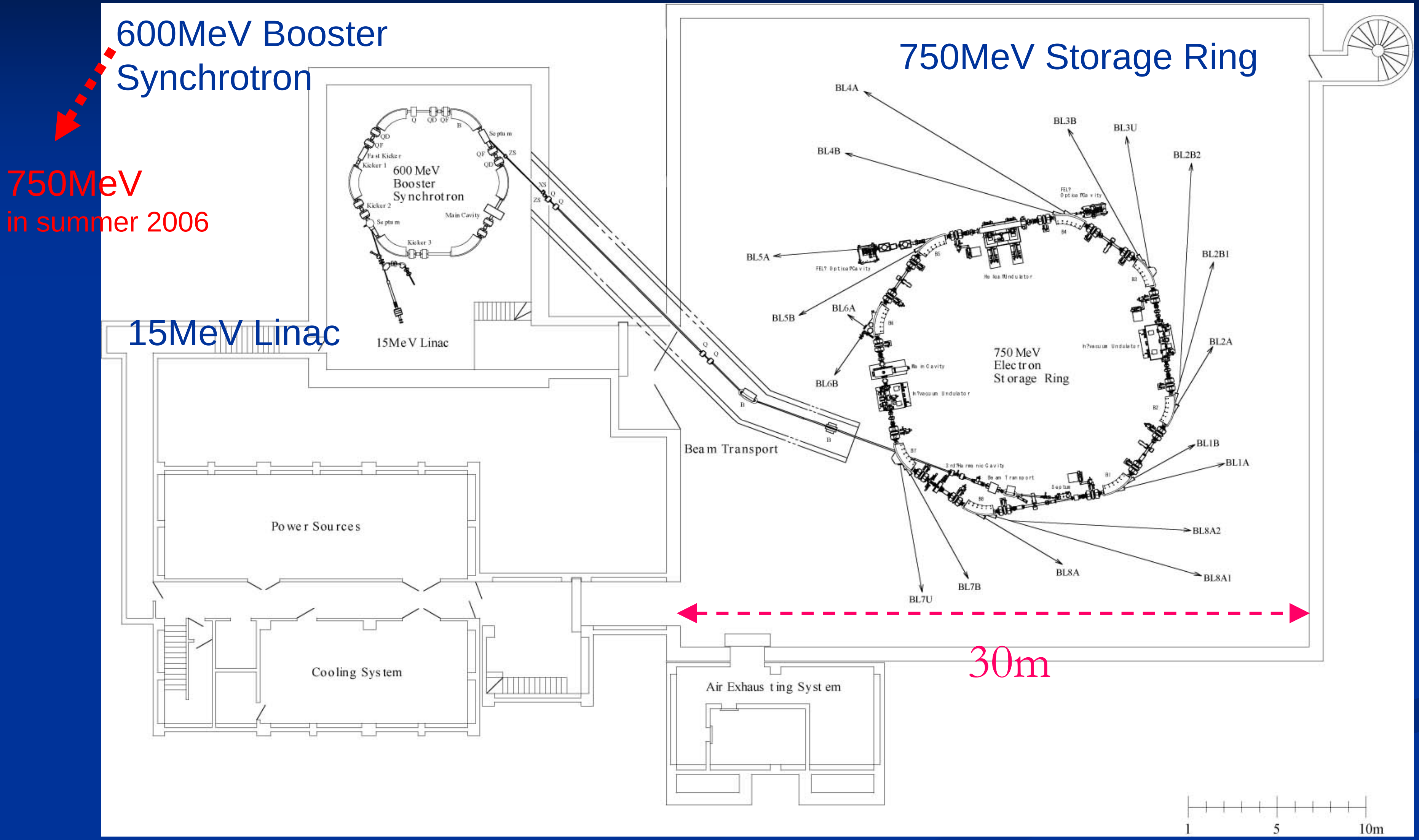
Big and Small



SPring-8 (http://www.spring8.or.jp) (C=1400m, E=8GeV, ε_{x0}=5.9nm-rad)

JASRI

UVSOR Accelerators

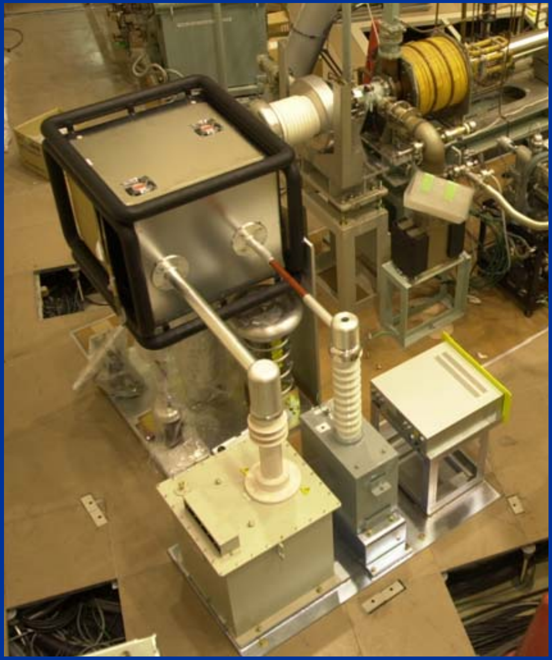


Electron Gun & Linear Accelerator

<Partly Upgraded during the UVSOR-II project>

- New Electron Gun => short pulses for single bunch injection, better emittance and energy spread
- New Klystron Pulse Modulator => better energy stability (pulse to pulse)
- New Water Cooling System => smaller energy drift

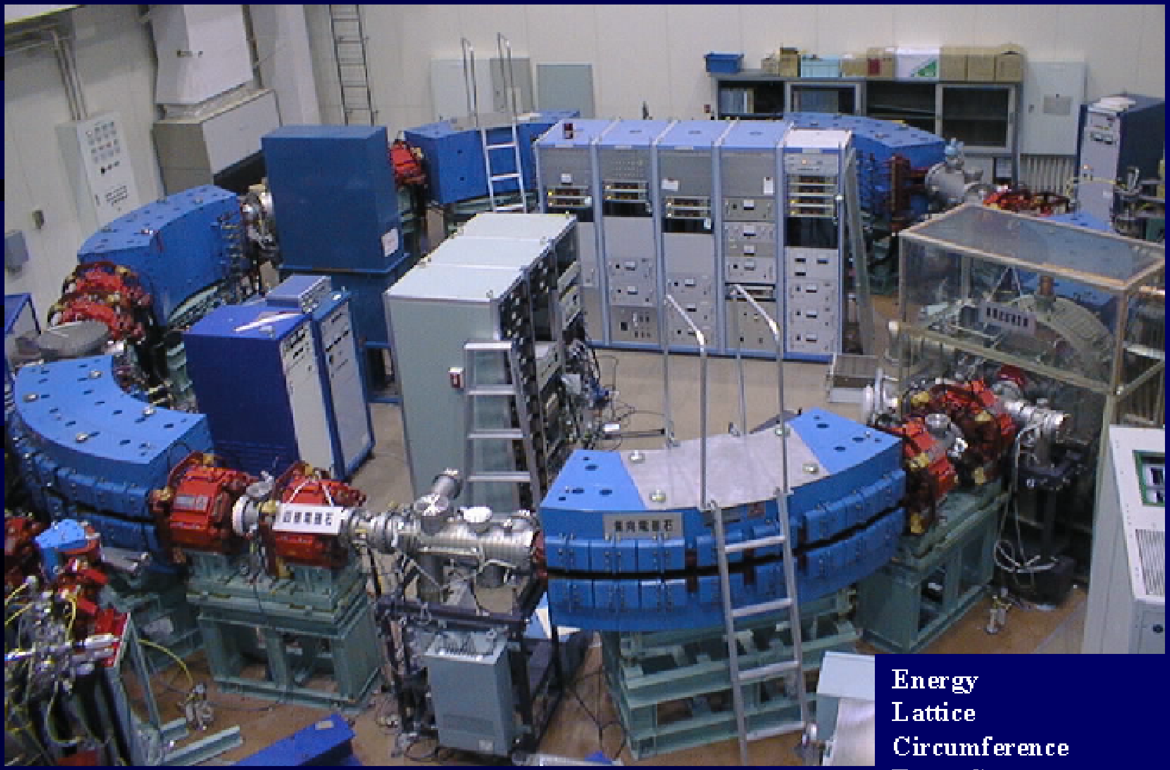
After the upgrade, the injection efficiency to the booster has increased by a factor of 3.



Booster Synchrotron

No Change during the UVSOR-II project, to make the commissioning period shorter
Energy Upgrade in 2006 to realize Full-energy Injection & Top-Up injection

UVSOR Booster SYNCHROTRON



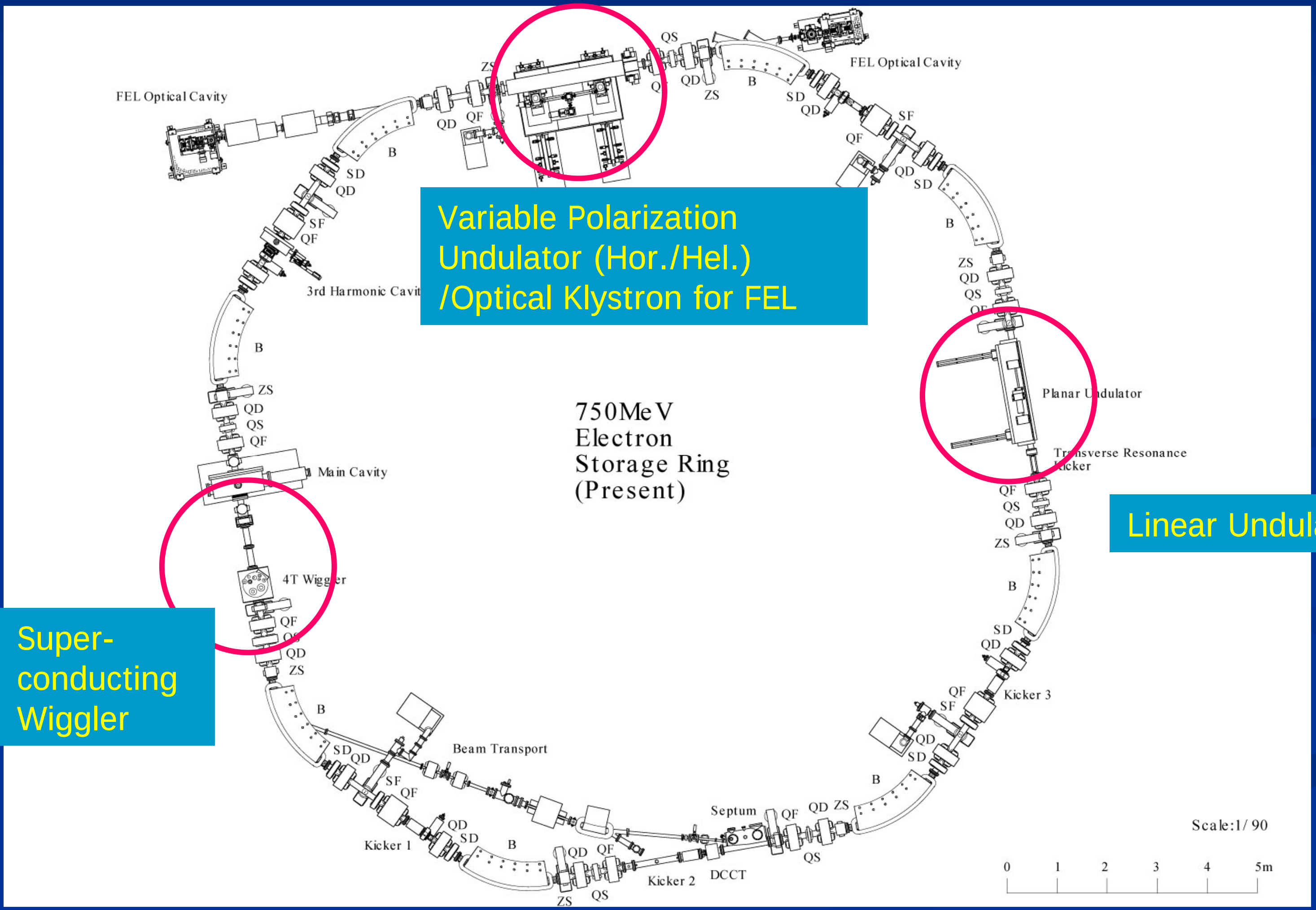
750MeV

Energy	600 MeV
Lattice	FODO ×8
Circumference	26.6 m
Beam Current	32 mA (8-bunch)
Bending Radius	1.8 m
Harmonic Number	8
RF Frequency	90.115 MHz
Repetition Rate	2.6 Hz

UVSOR before Upgrade (UVSOR-Ⅰ)

Emittance=160nm-rad

Straight Sections=3m x 4



Variable Polarization Undulator (Hor./Hel.) /Optical Klystron for FEL

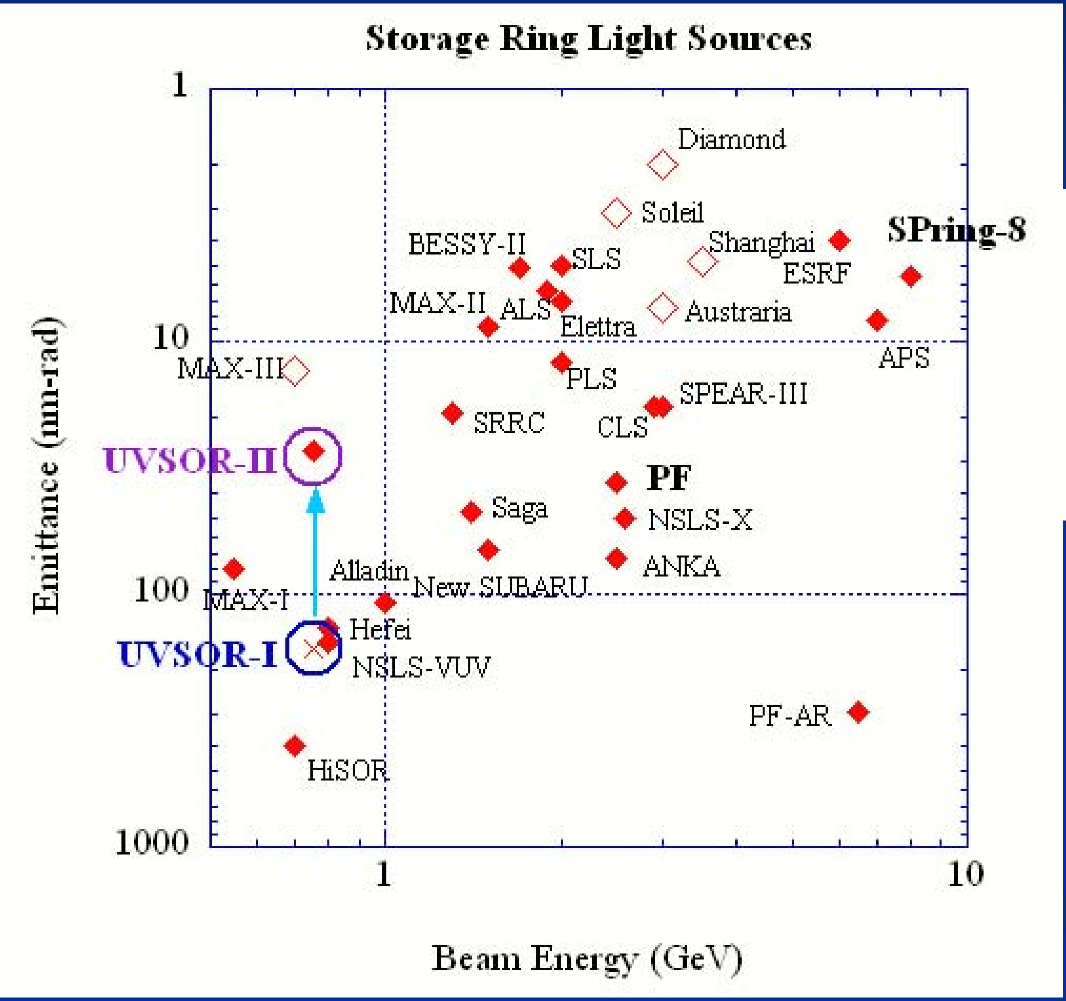
Linear Undulator

Super-conducting Wiggler

Upgrade of UVSOR Accelerators

Proposed in 2000 and funded in 2002

M. Katoh et al., NIM A **467-468** (2001), 68-71

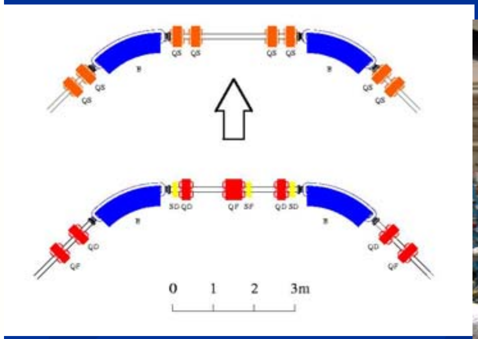


2003

Upgrade of Magnetic Lattice

Emittance
160nm-rad => 27nm-rad
Straight Sections
3mx4 => 4mx4+1.5mx4
New Undulators

UVSOR＝＞UVSOR-II



2005

Upgrade of main RF cavity

V_{rf}=46kV => 150 kV

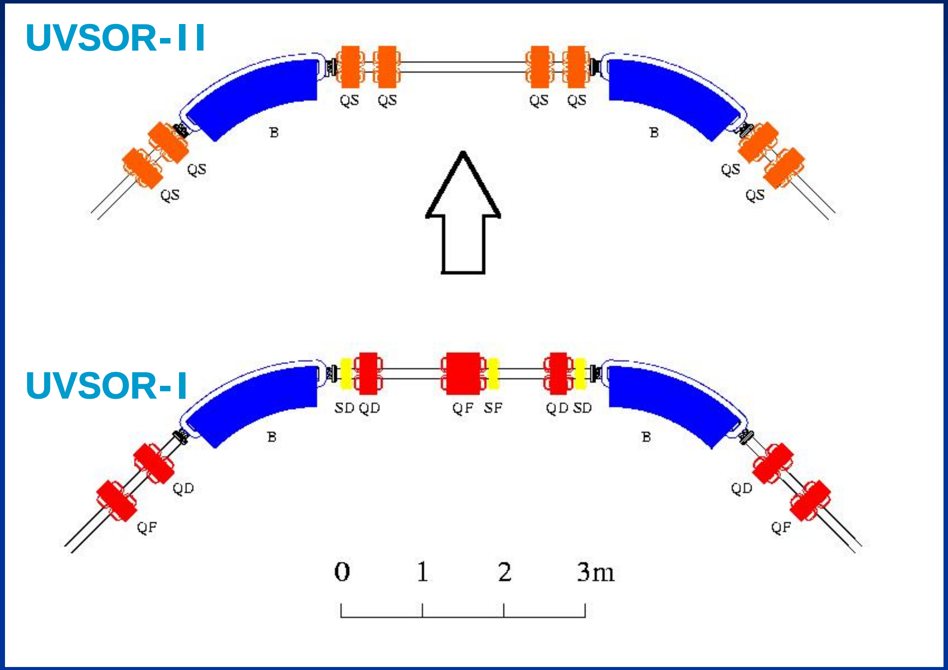
2006

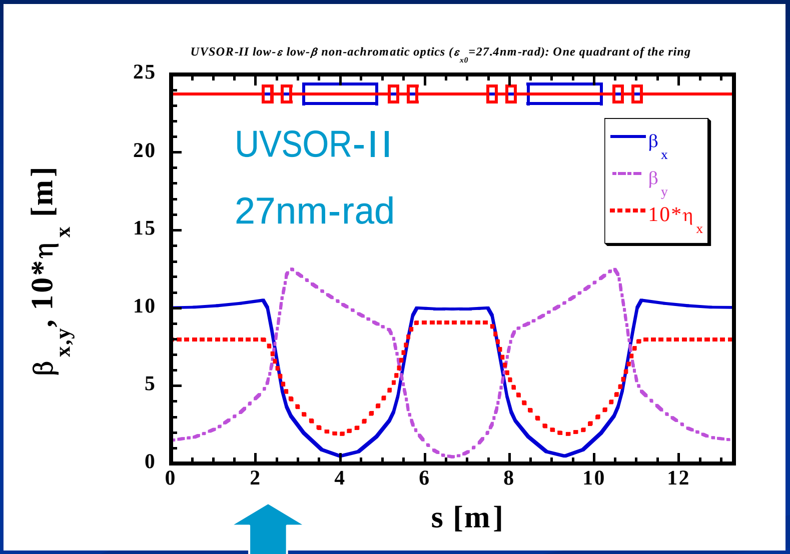
Energy Upgrade of Booster Synchrotron
Installation of new undulator
Reinforcement on Radiation Shield
=> Top-Up Operation

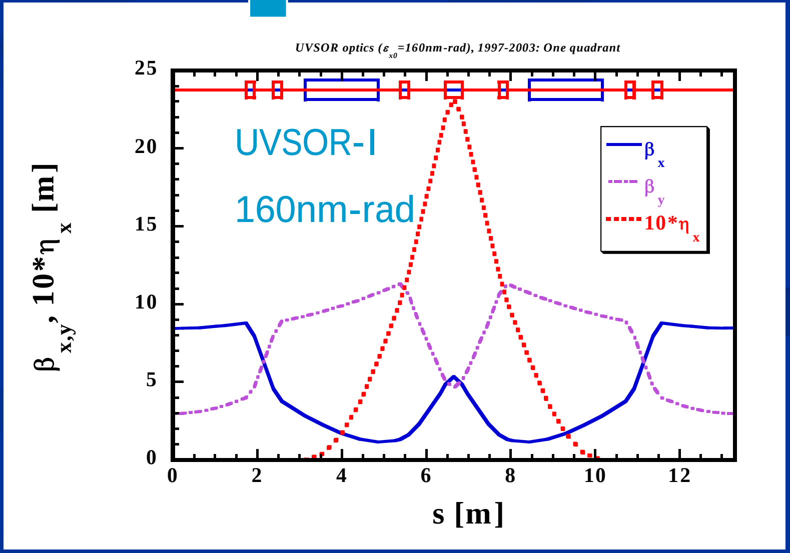
・・・・・・・・・

Upgrade of Magnetic Lattice

low-ε, more straight sections, low-β_y at s.s.

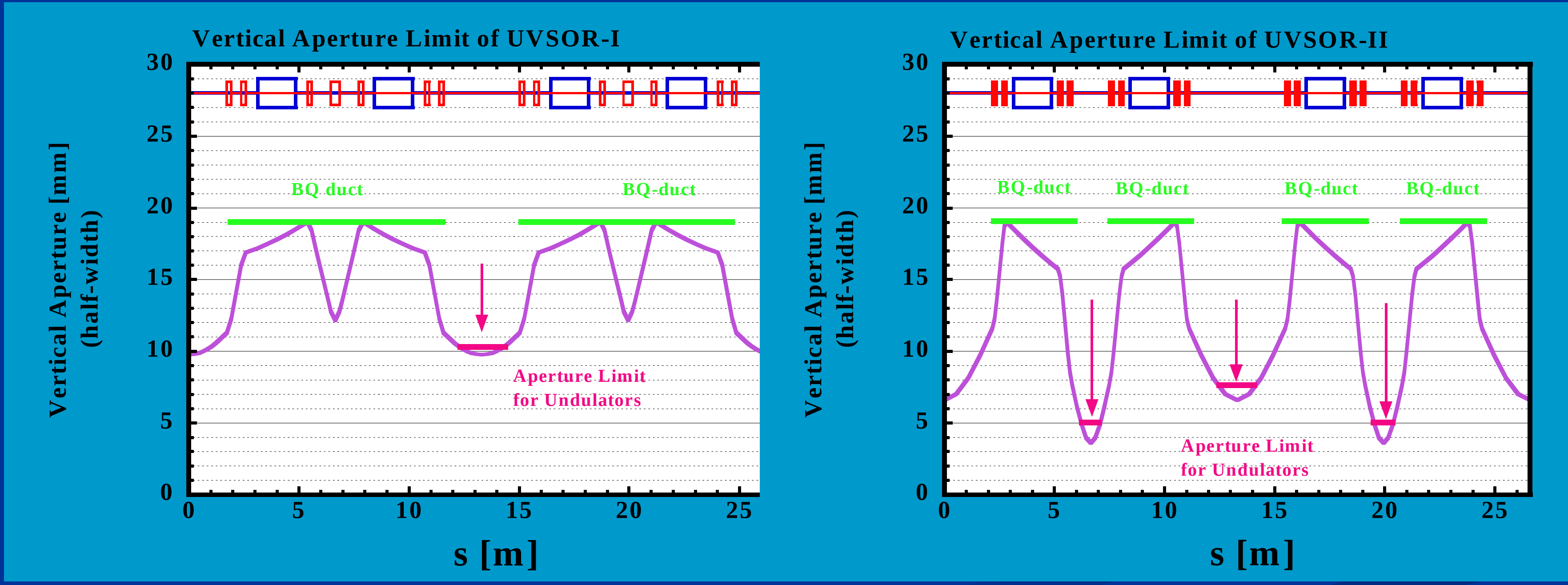






Quadrupole/Sextupole Combined-function Magnet for new Lattice

Vertical Aperture Limit

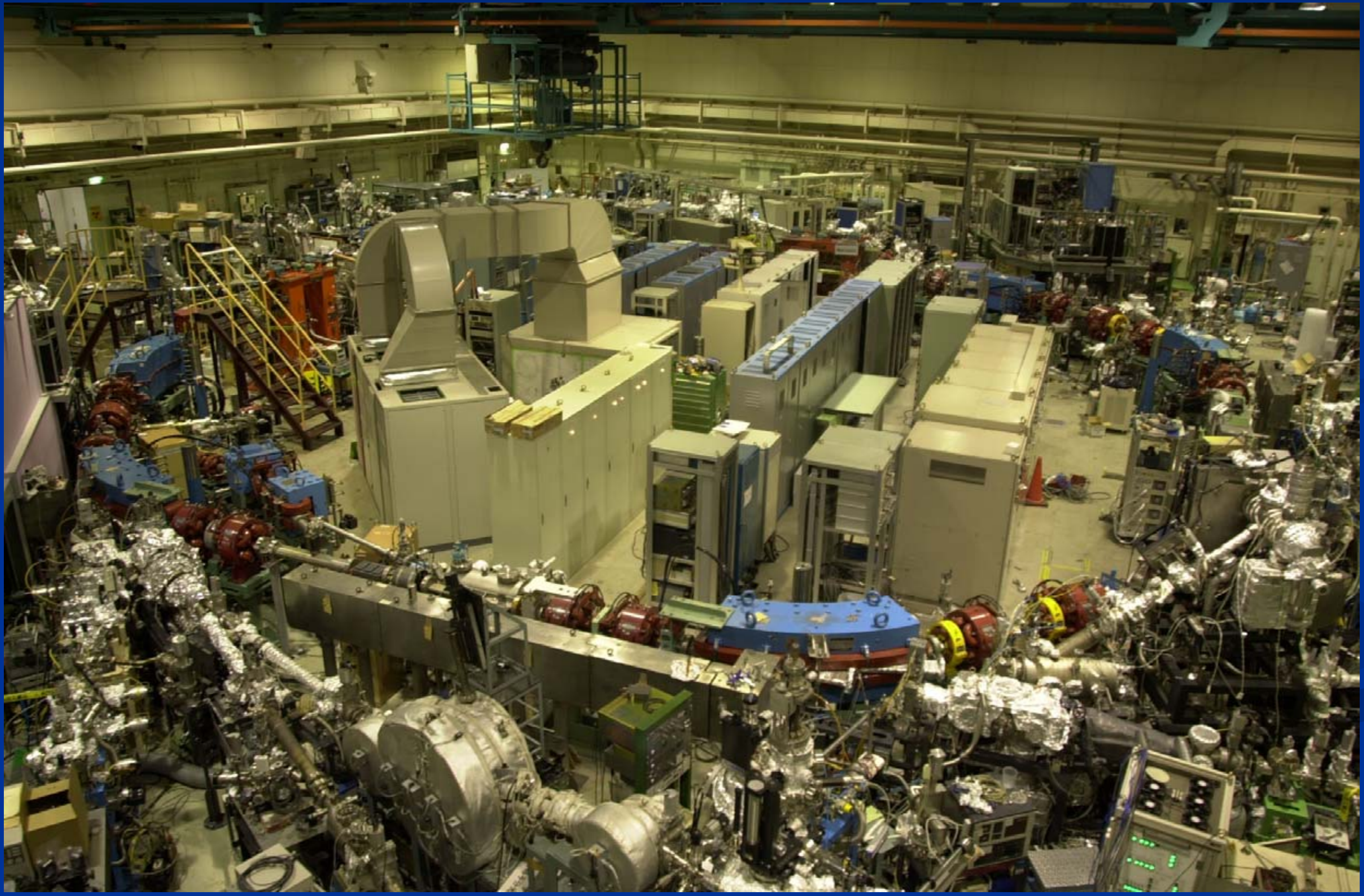


UVSOR-I → UVSOR-II

One half of the ring is shown.

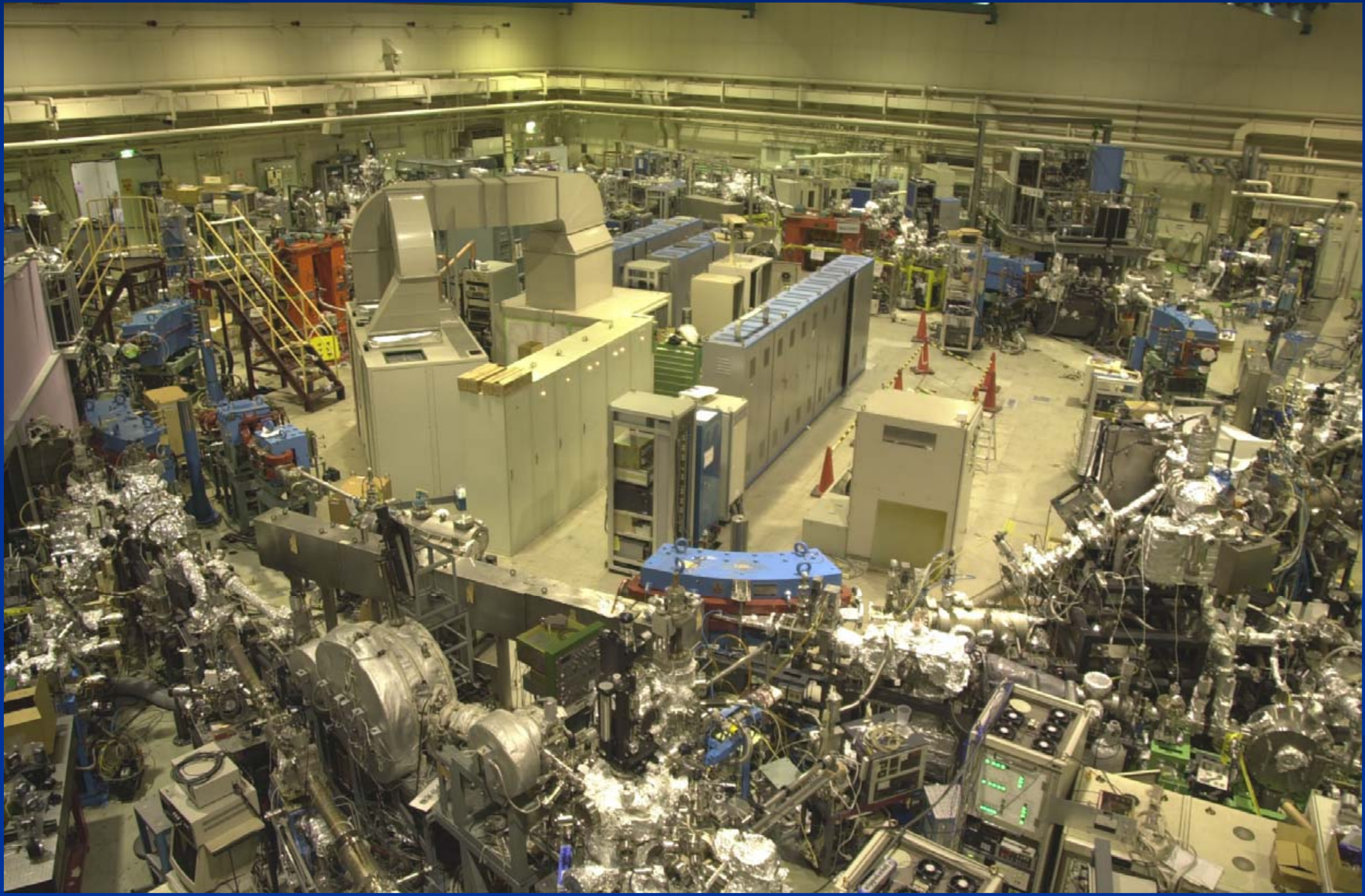
One half of the ring is shown.

UVSOR-I just before the reconstruction
（March, 2003）

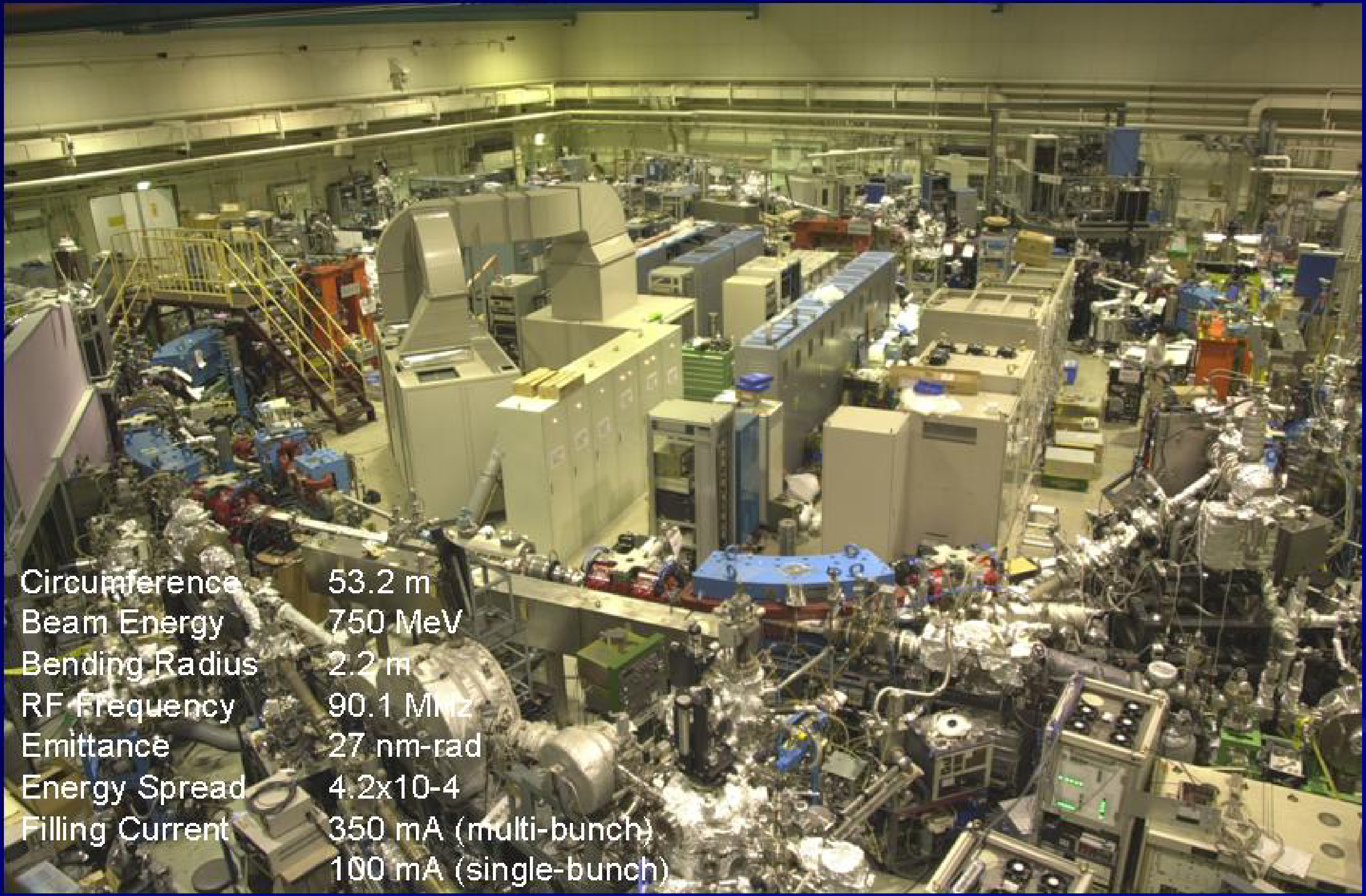


UVSOR-I → UVSOR-II

（April, 2003）



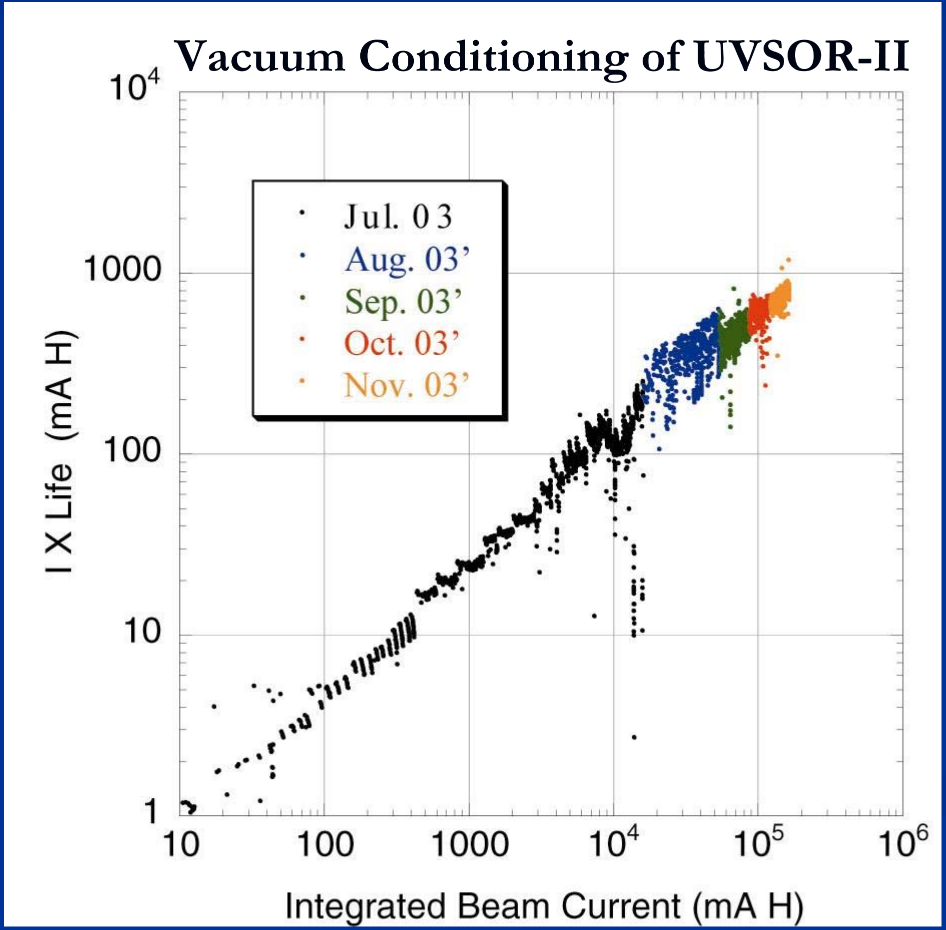
UVSOR-II just after the reconstruction (July, 2003)

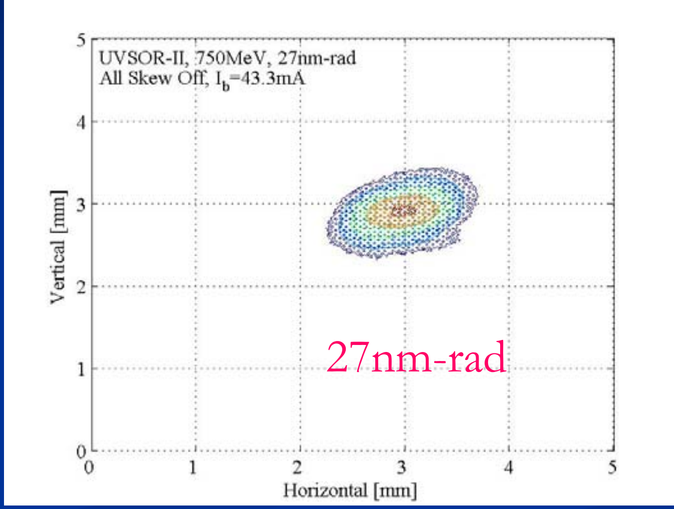


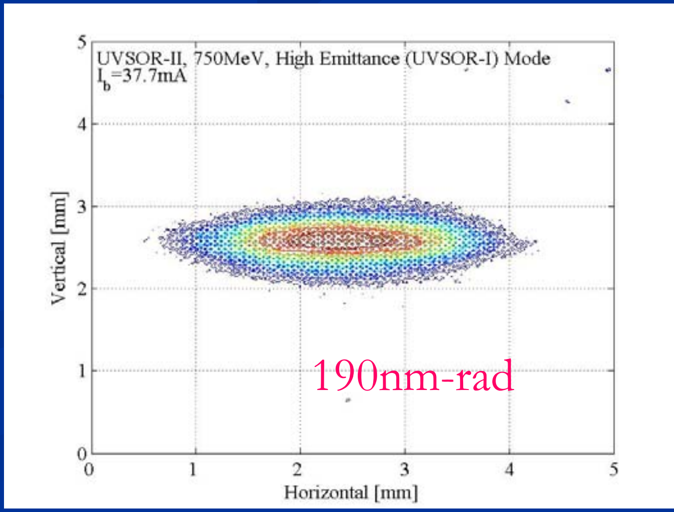
The reconstruction was completed within three months.

Commissioning of UVSOR-II

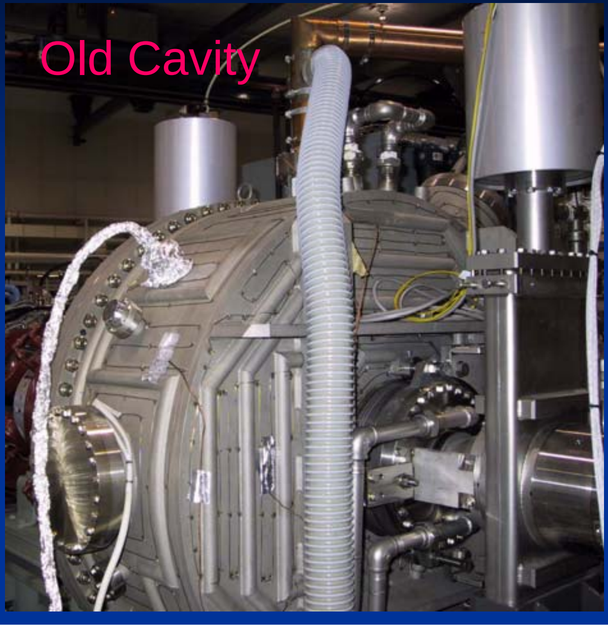
Commissioning of UVSOR-II was completed within two months.







New RF Cavity

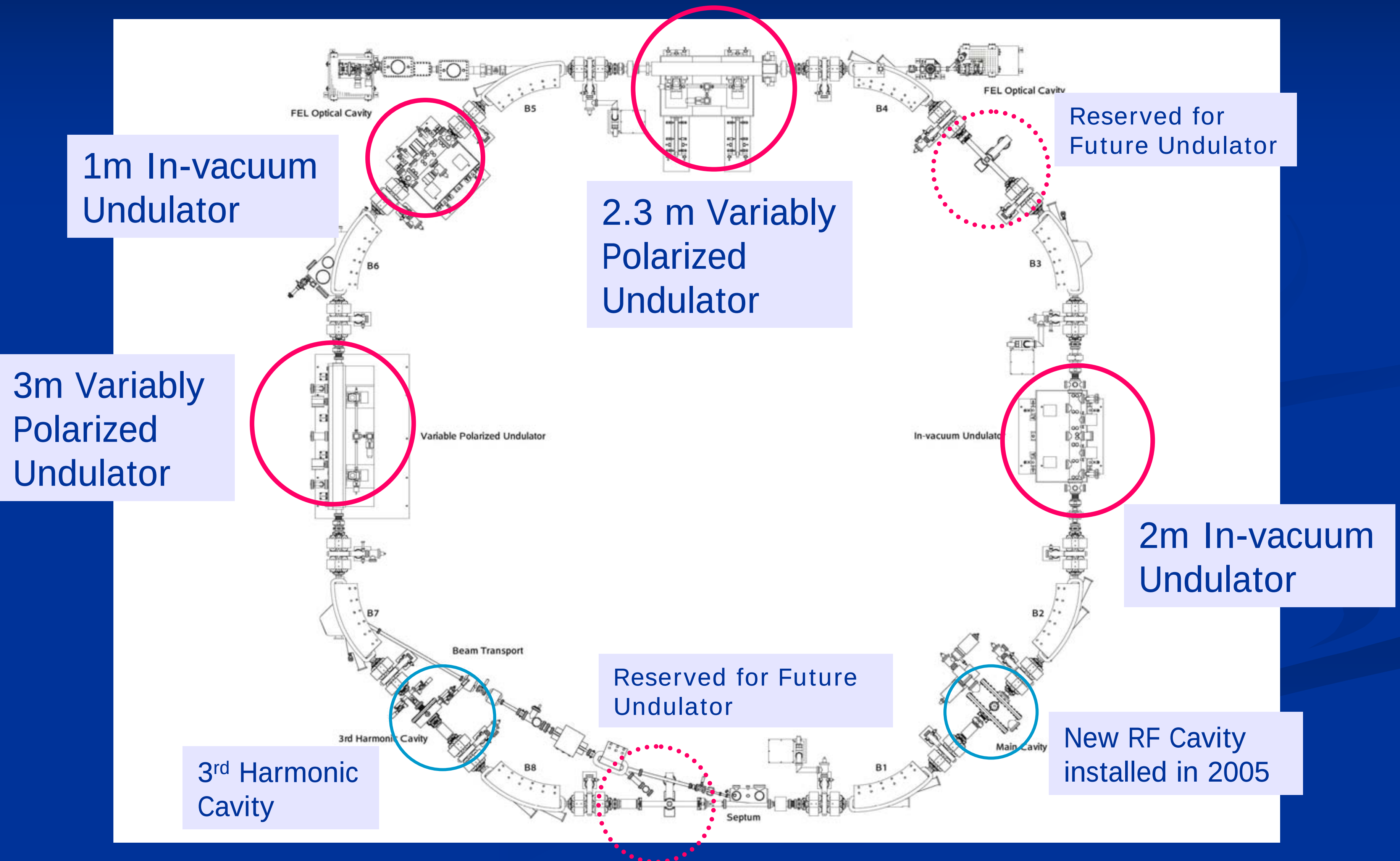


Frequency	90.1 MHz
RF Voltage	55 kV (Routine)
Shunt Impedance	500 kΩ
Quality Factor	8000 (Unloaded)
Cavity Structure	Re-entrant × 1
Diameter and Length	(1000 mm, 420mm)
Material	SUS + Copper
$I \cdot \tau_{Touschek}$ (multibunch)	1650 mA·H

Frequency	90.1 MHz
RF Voltage	150 kV ~ 200 kV
Shunt Impedance	2.9 MΩ (Superfish)
Quality Factor	23800 (Unloaded, Superfish)
Cavity Structure	Re-entrant × 1
Diameter and Length	(964 mm, 400mm)
Material	Copper
$I \cdot \tau_{Touschek}$ (multibunch)	5200 mA·H

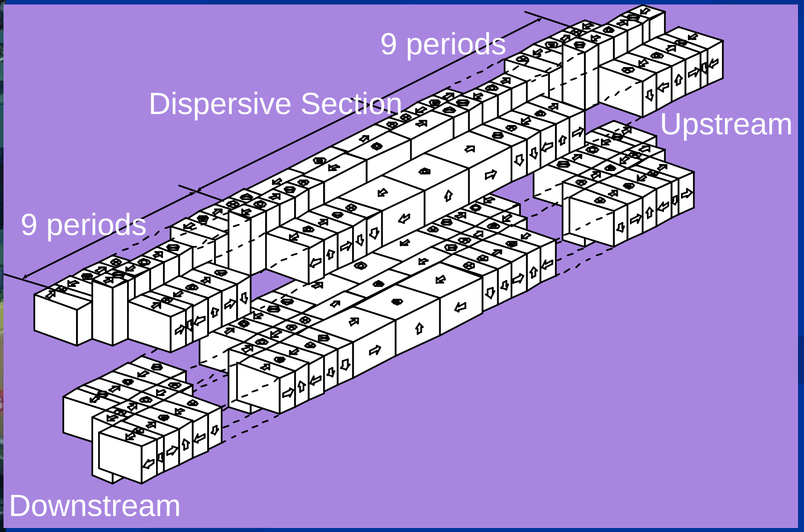
UVSOR-II Nov. 2006

Electron Energy	750 MeV
Emittance	27nm-rad
Straight Sections	4mx4+1.5mx4
Filling Beam Current	350 mA (multi-bunch)
Injection Interval	6 hours

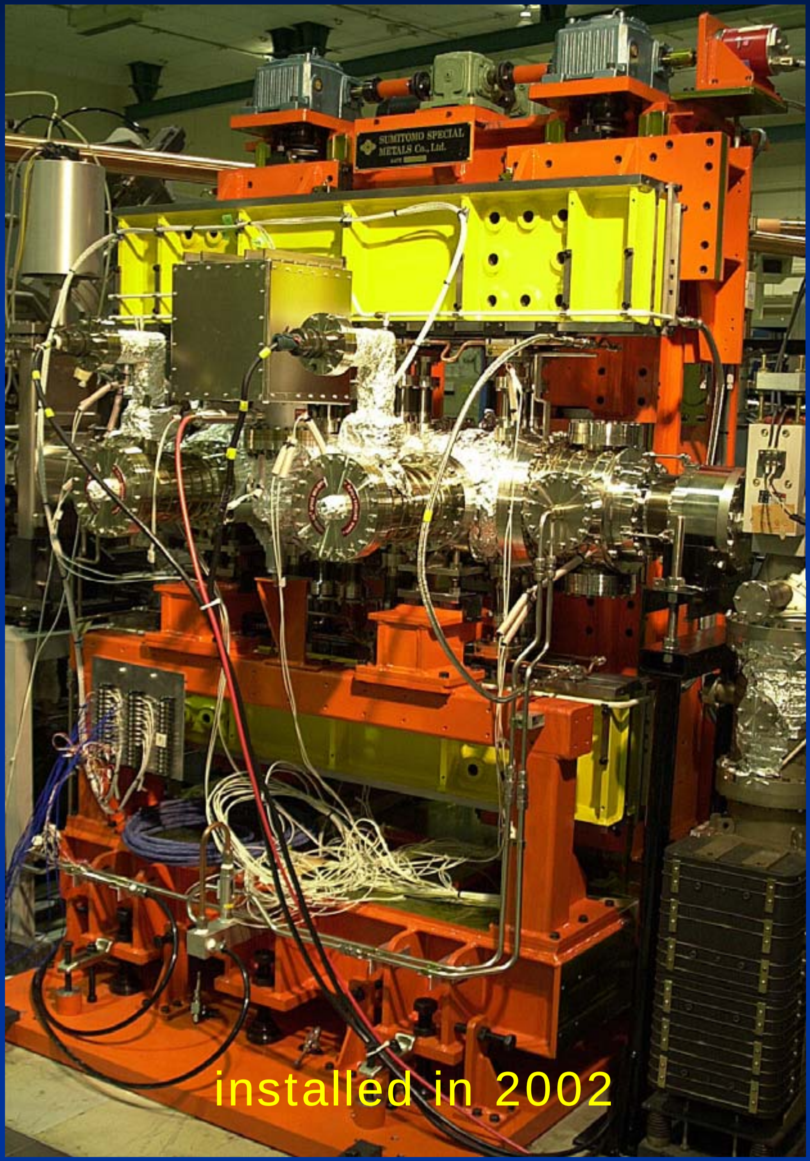


UVSOR-II BL5U
Variavle Polarization Undulator/Optical Klystron

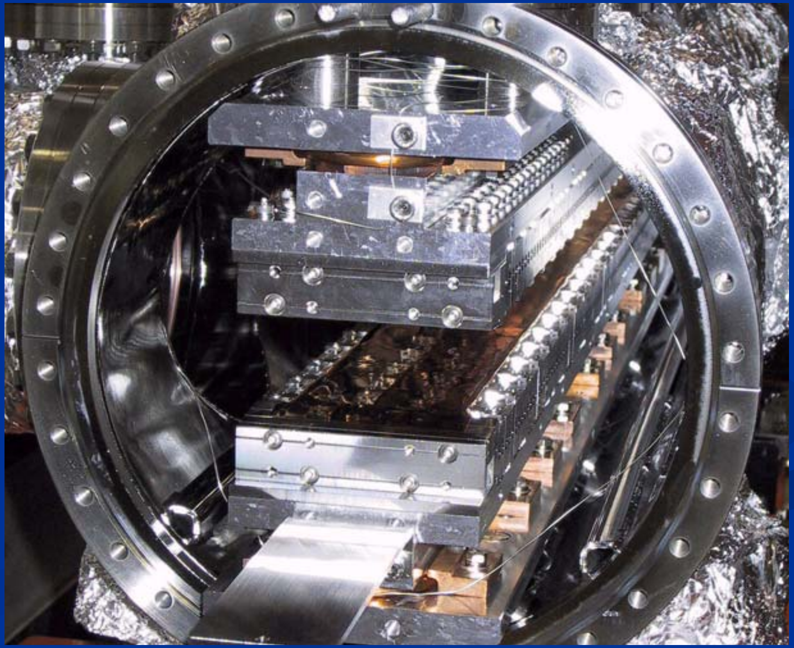
Number of periods	18
Period length	110 mm
Length of dispers. part	302.5 mm
Total Length	2351.2 mm
Remanent field	1.3 T
Magnetic gap	30–150mm
Deflection parameter (K)	
(helical mode)	0.07 – 4.6
(linear mode)	0.15 – 8.5



UVSOR-II BL6U In-Vacuum Undulator

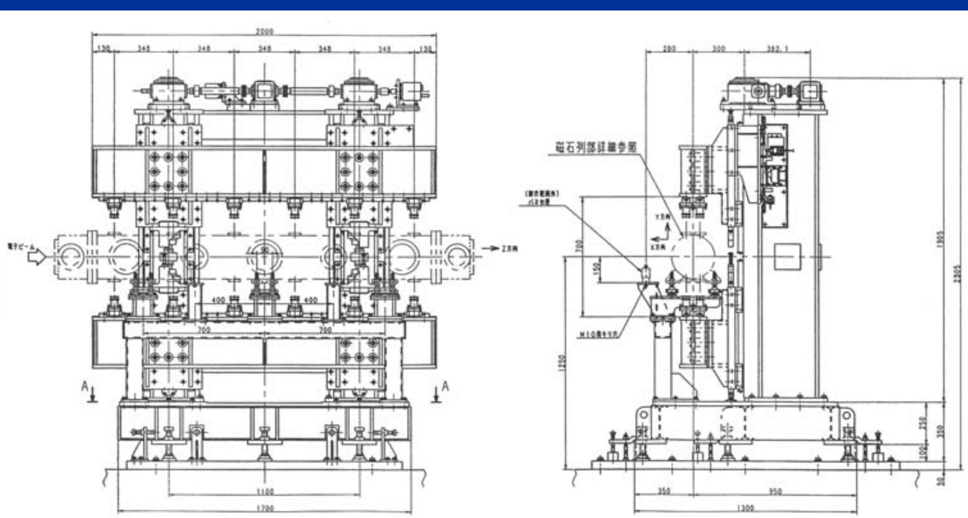


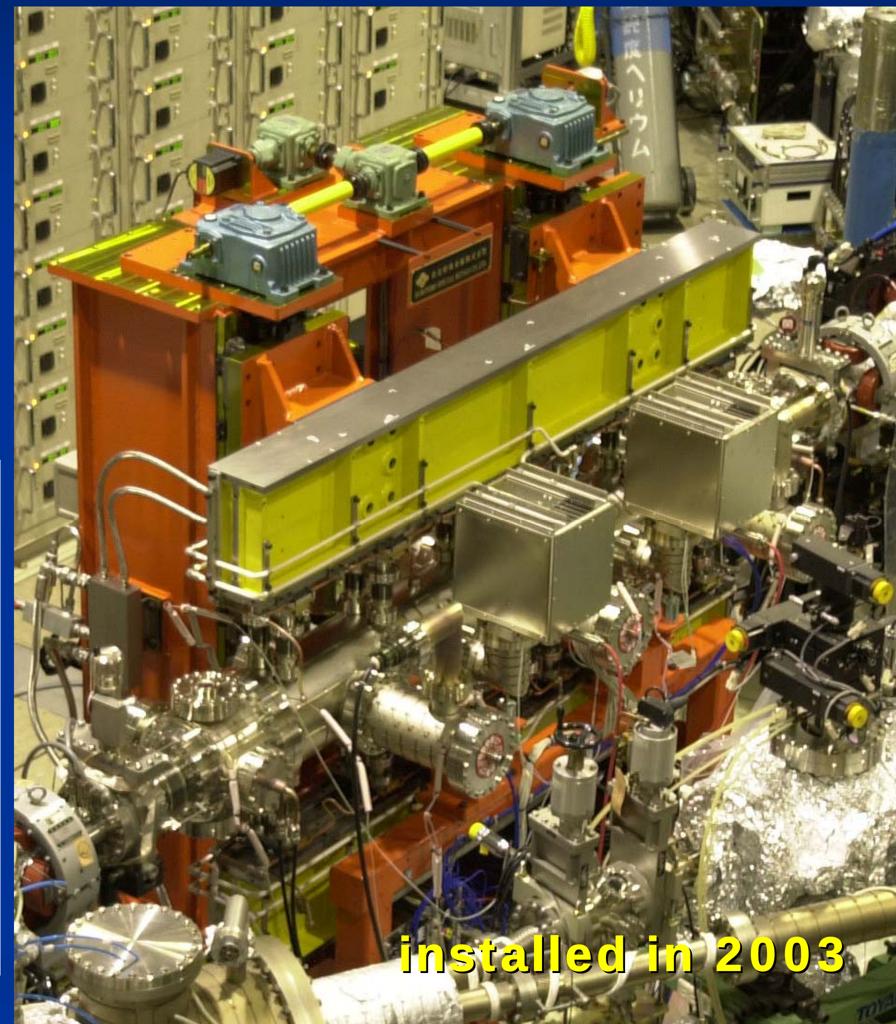
Magnet Type	**Pure Permanent (Nd-Fe-B)**
Remanent Field	**1.17 Tesla**
Period Length	**36 mm**
Number of Periods	**26**
Magnetic Length	**936 mm**
Overall Length	**1.4 m (flange to flange)**
Pole Gap	**8 – 40 mm**
Polarization	**linear (horizontal)**



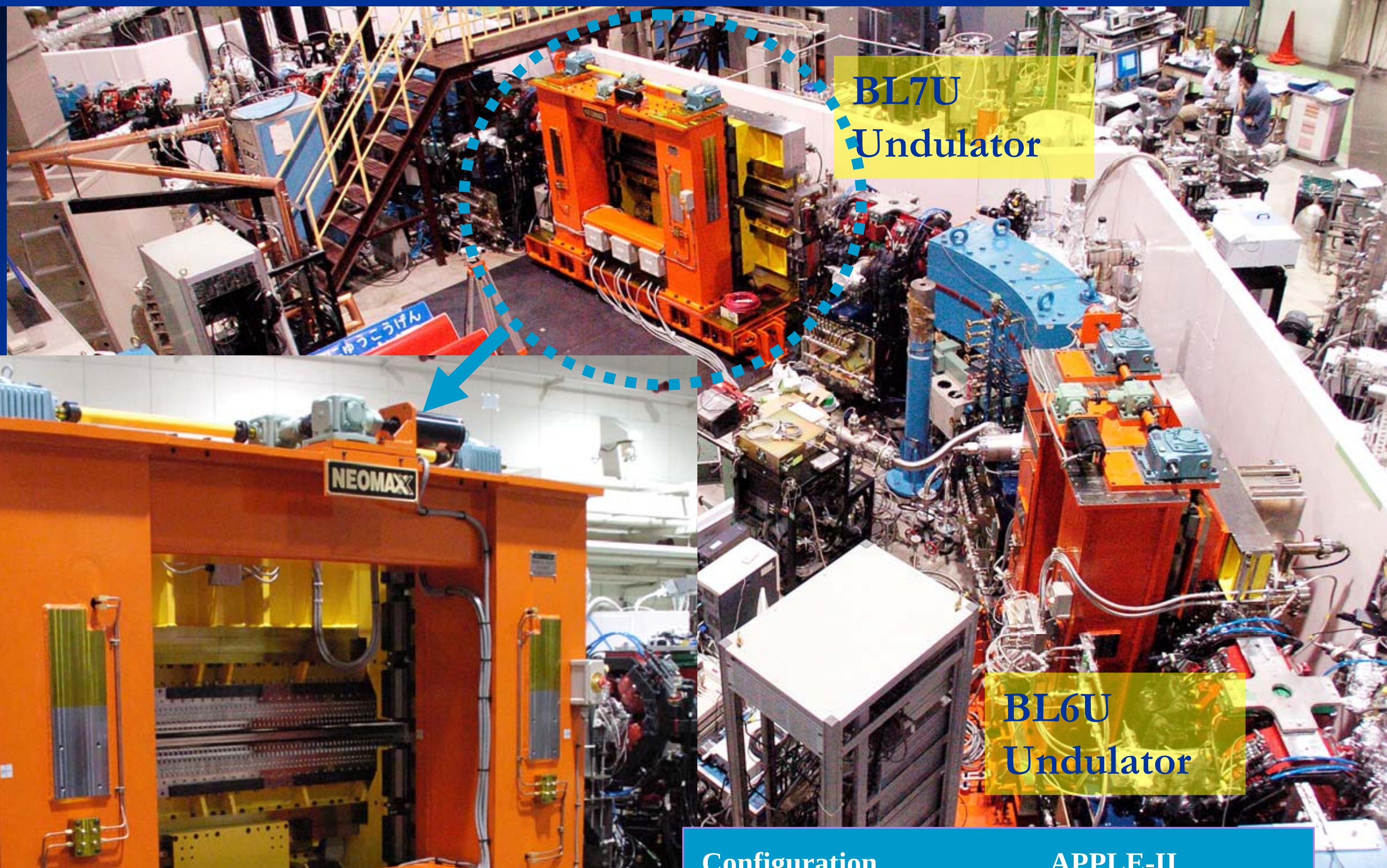
UVSOR-II BL3U In-vacuum Undulator

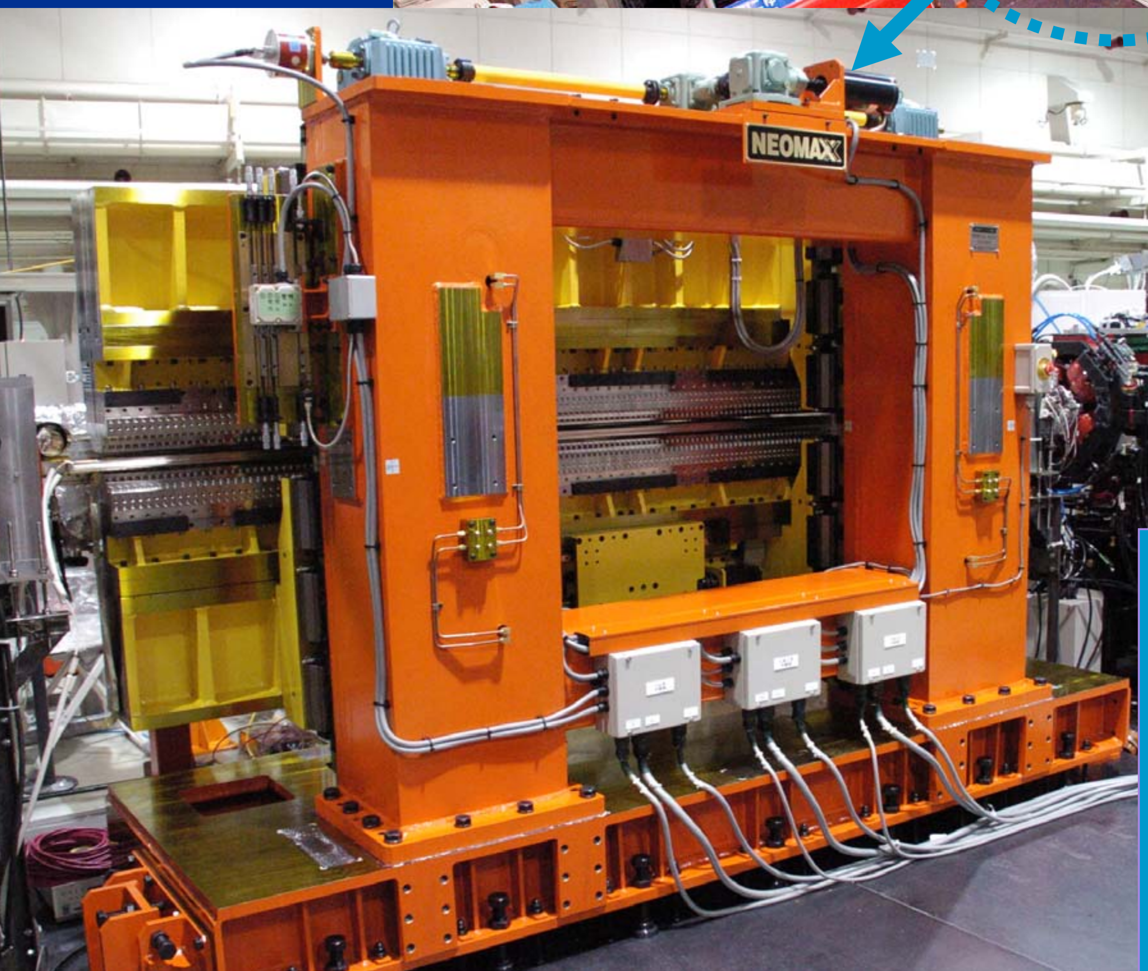
Magnet Type	**Pure Permanent (Nd-Fe-B)**
Remanent Field	**1.17 Tesla**
Period Length	**38 mm**
Number of Periods	**50**
Magnetic Length	**1900 mm**
Overall Length	**2.4 m (flange to flange)**
Pole Gap	**8 – 40 mm**
Polarization	**linear (horizontal)**





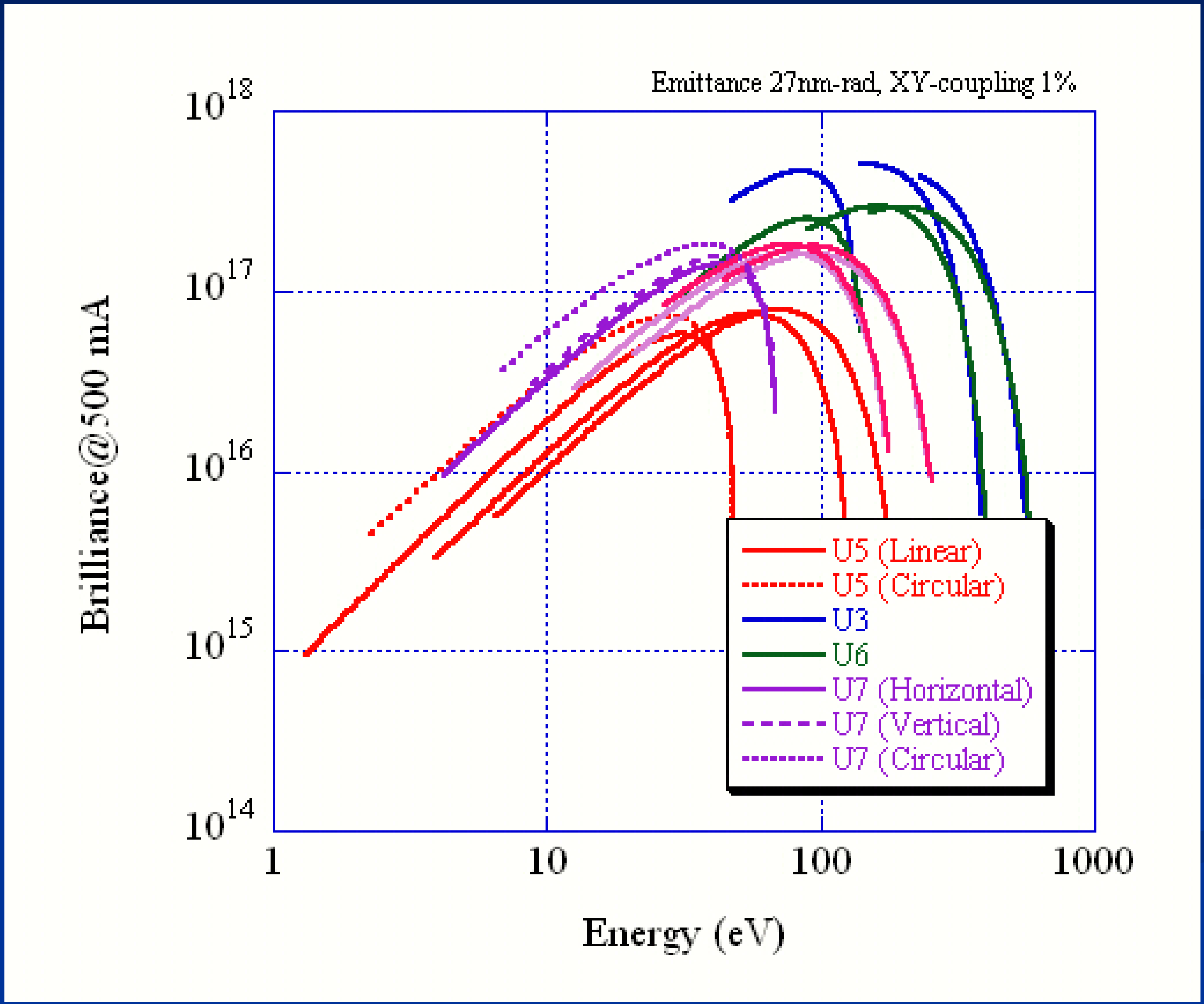
BL7U Variable Polarization Undulator



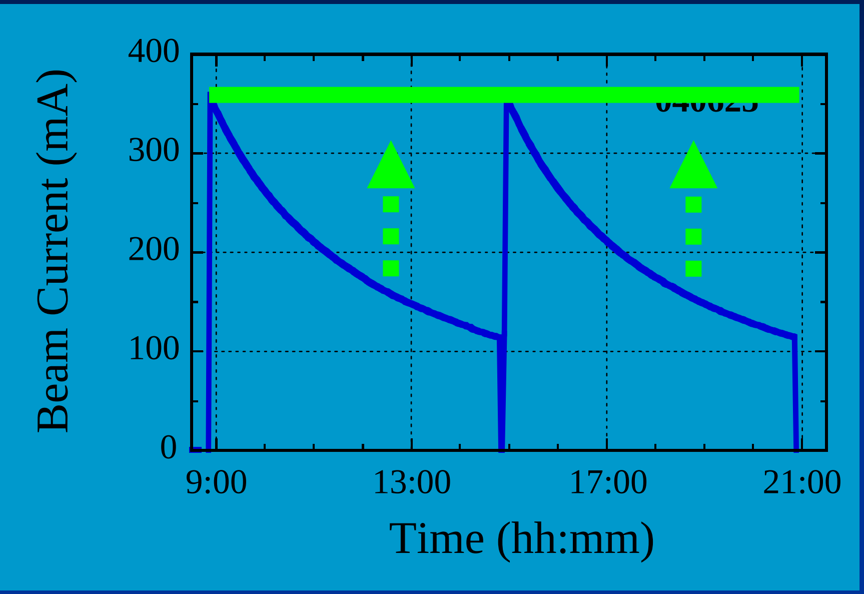


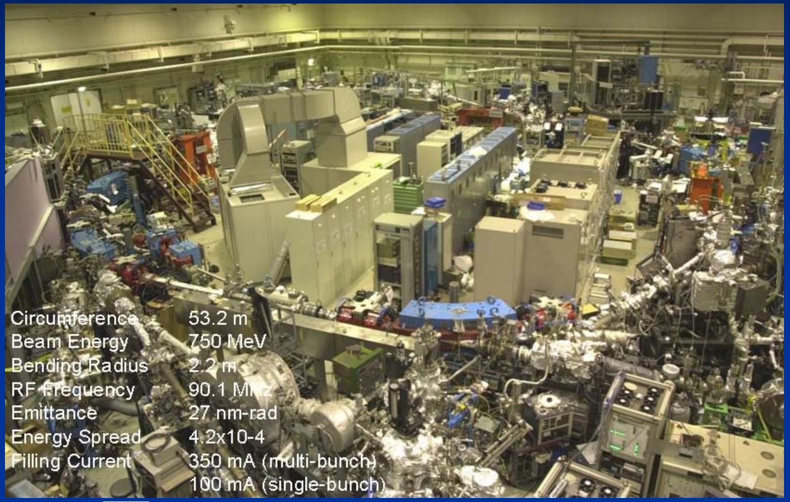
Configuration	APPLE-II
Polarization	Hor/Ver/Helical
Number of periods	40
Period length	76 mm
Total Length	3040 mm
Remanent field	1.3 T
Magnetic gap	24 – 200 mm
Deflection parameter (K)	
(horizontal mode)	max. 5.4
(vertical mode)	max. 3.6
(helical mode)	max. 3.0

SR Spectra of UVSOR-II

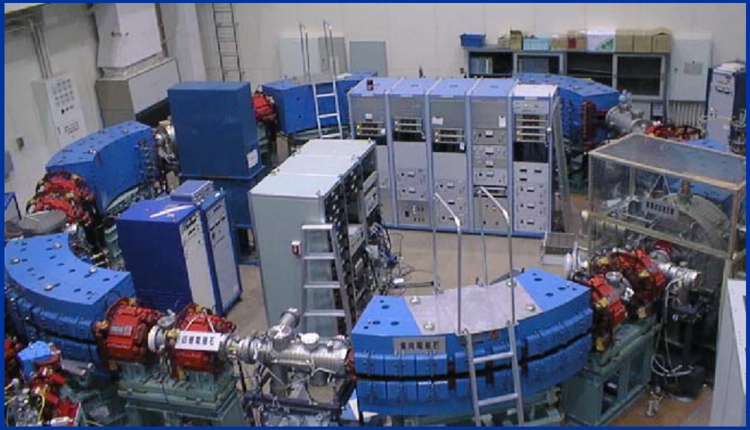


Top-Up Operation at UVSOR-II



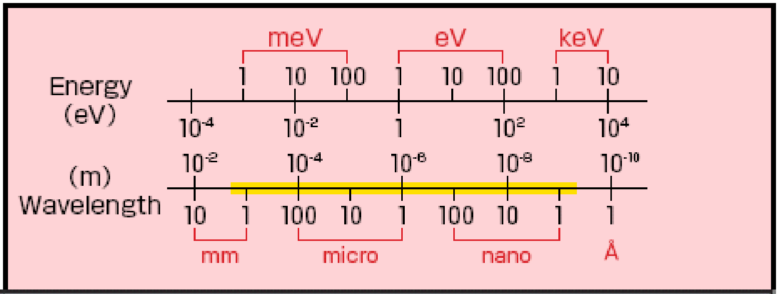


Reinforcement of Radiation Shielding (2005-2006)



Energy Upgrade of Booster Synchrotron by replacing Magnet Power Supply in 2006

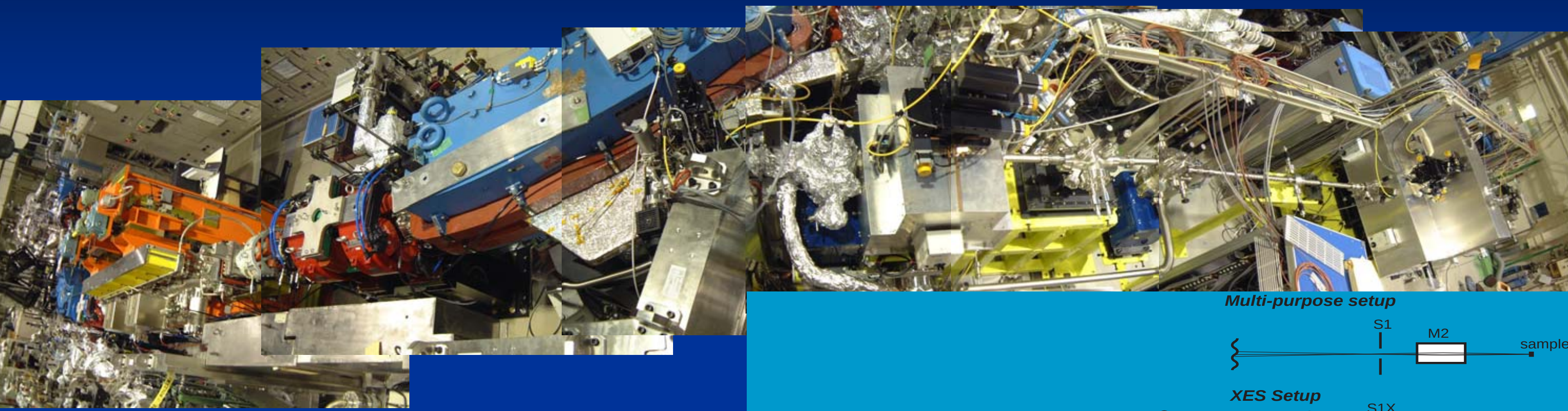
Beamlines at UVSOR-II

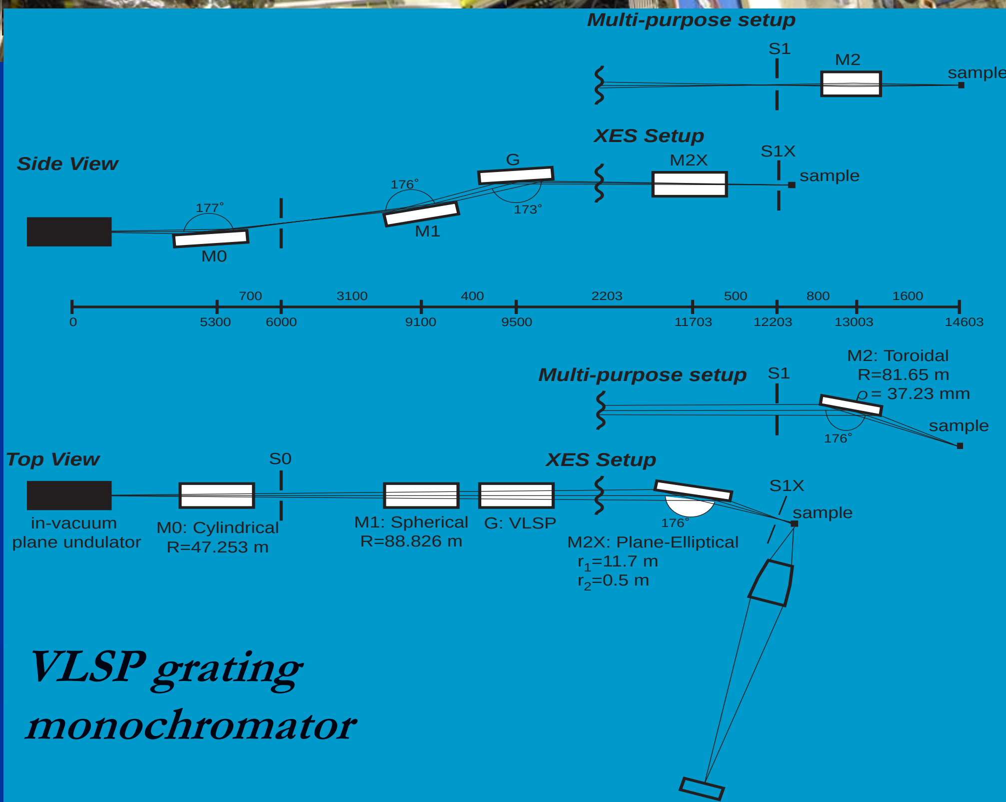


Beamline	Monochromator	Photon Energy Region
BL1A	Double Crystal	600eV – 4keV
BL1B	1-m Seya-Namioka	1.9eV – 40eV
BL2B	18-m Spherical Grating	20eV – 200eV
BL3U	Varied-line-spacing Plane Grating	40eV – 600eV
BL4A1	Multi-layered mirror	50eV – 95eV
BL4A2	None (Filter, Mirror)	
BL4B	Varied-line-spacing Plane Grating	80eV – 800eV
BL5U	SGM-TRAIN	5eV – 250eV
BL5B	Plane Grating	5eV – 600eV
BL6B	Martin-Puplett & Michelson FT-IR	0.25meV – 2.5eV
BL7U	10-m Normal Incidence	6eV – 40eV
BL7B	3-m Normal Incidence	1.2eV – 30eV
BL8B1	15-m Constant Deviation SGM	30eV – 600eV
BL8B2	Plane Grating	1.9eV – 150eV

In-vacuum Undulator Beamline BL3U

T. Hatsui, N. Kosugi et al., presented at SRI2006



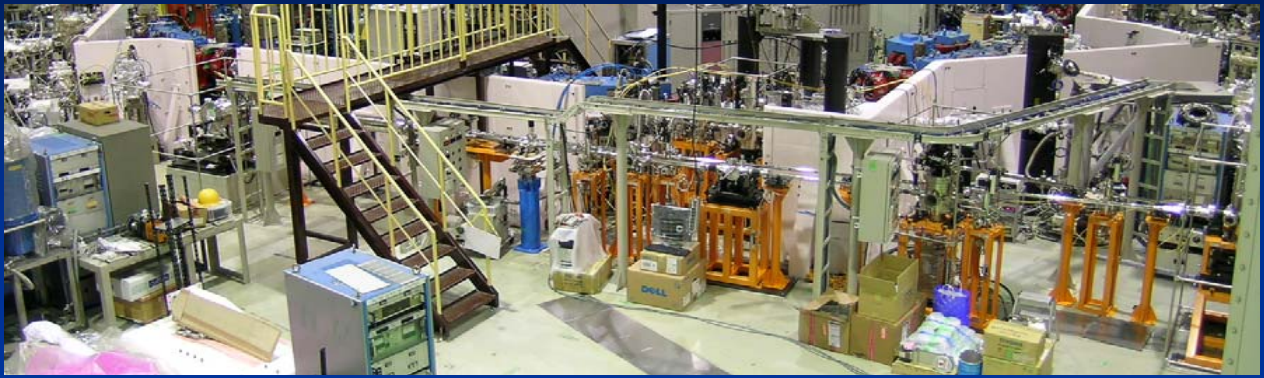


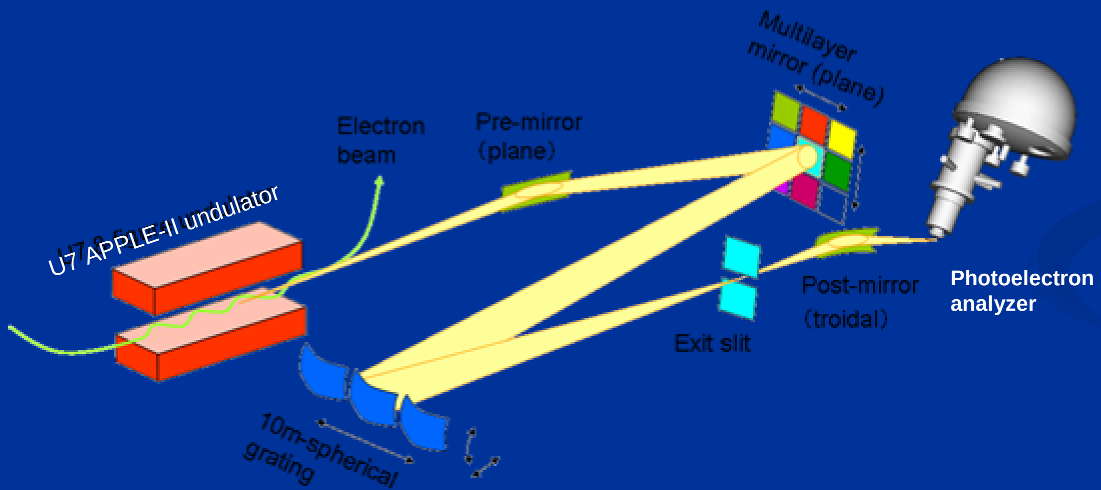
VLSP grating monochromator

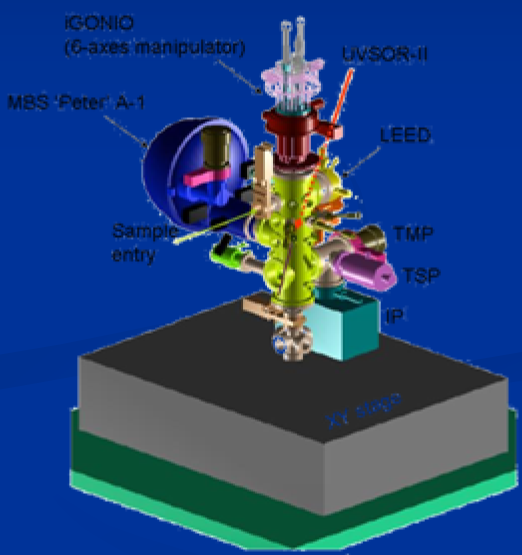
E/ΔE>8000 @400 eV
E/ΔE>10000 @60 eV

High-resolution 3D-ARPES beamline (BL7U)

S. Kimura et al., presented at SRI2006







•Tunable photon + High flux + High resolution + Variable polarization (H, V) + ARPES

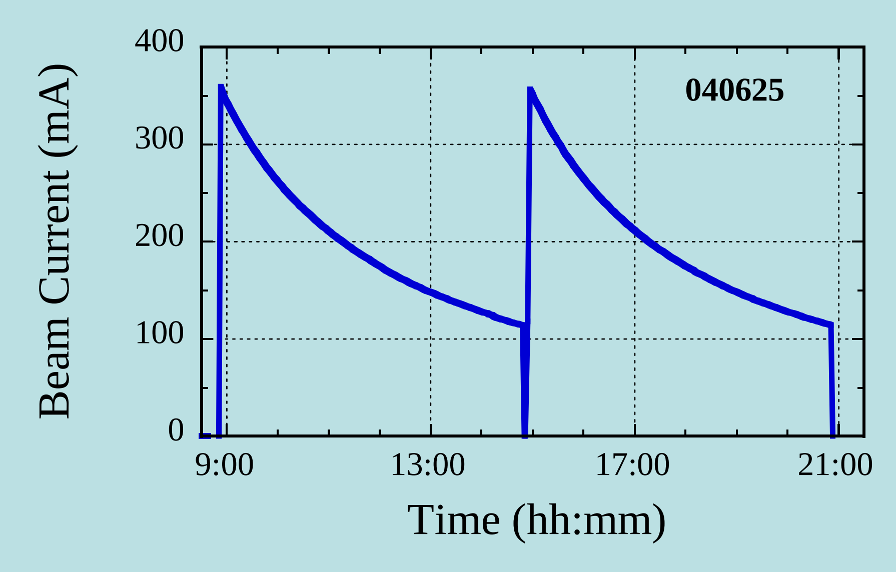
⇒ **To elucidate 3D Fermi surface**

•Electronic structure in sub-μm-scale domains and its spatial imaging.

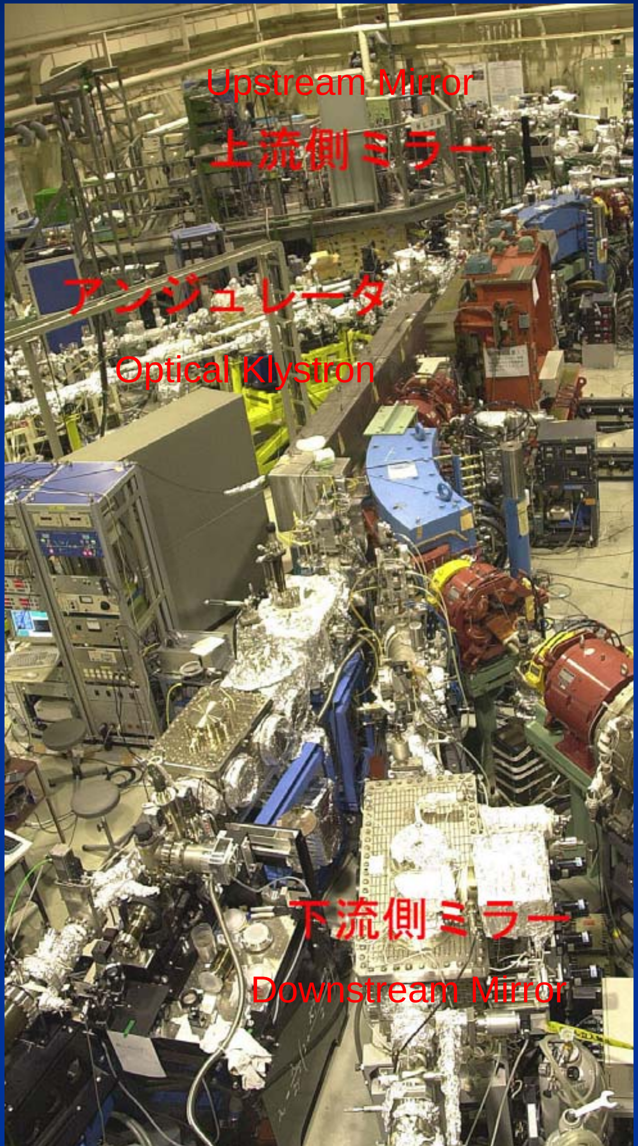
⇒ **To evaluate the origin of functionalities.**

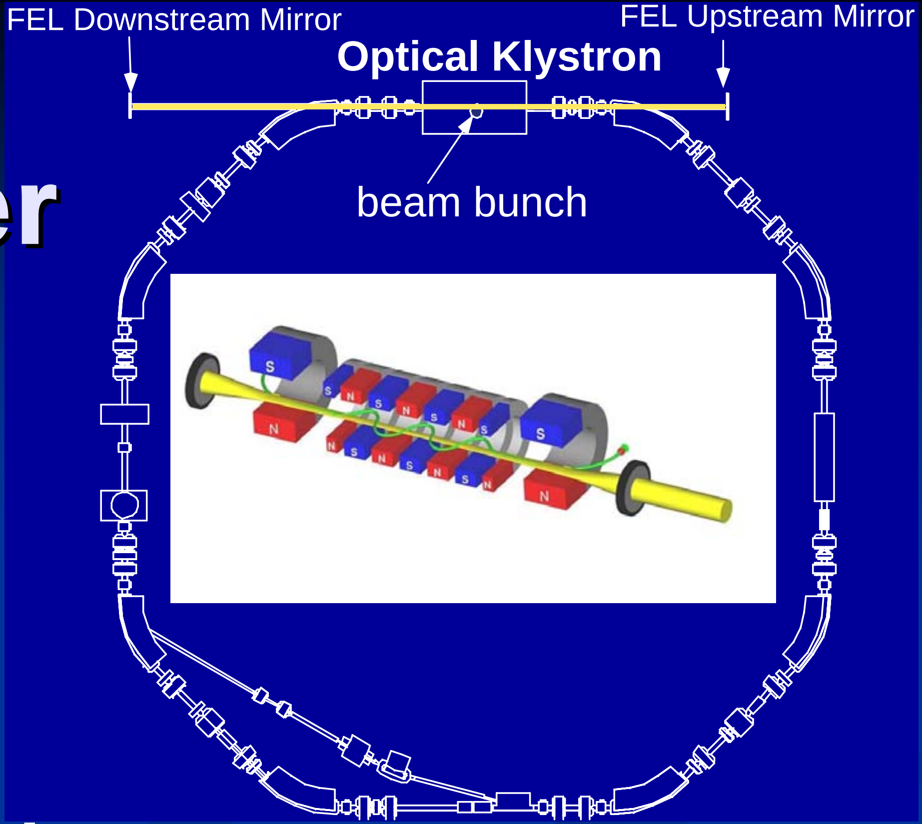
Operation Status of UVSOR-II

- Annual Schedule
  - 1 or 2 month shut-down in spring for maintenances & improvements
  - 2 week shut-down around the New Years day
  - 1 week shut-down in autumn for maintenance
  - About 40 weeks for users time. A few weeks are for single bunch users.
  - 2 weeks dedicated for machine study
  - A few weeks for commissioning if necessary
- Weekly Schedule
  - Monday =＞Machine Study
  - Tuesday to Friday =＞Users Time
  - Saturday =＞Machine Study if necessary
- Daily Schedule
  - From 9 am to 9 pm
  - In multi-bunch mode
    - Injection twice (9 am, 3 pm)
    - Filling Current 350mA
  - In single bunch mode
    - Injection three times (9am, 1pm, 5pm)
    - Filling Current 100 mA



UVSOR-II Free Electron Laser





Laser	
Wave Length	215～800 nm
Spectral Band Width	$\sim 10^{-4}$
Polarization	Circular/Linear
Pulse Rate	11.26 MHz
Max. Average Power	～1 W
Optical Cavity	
Type	Fabry-Perot
Cavity Length	13.3 m
Mirror	HfO_2, Ta_2O_5 ,Al_2O_3multi-layer
Optical Klystron	
Polarization	Circular/Linear
Length	2.35 m
Period Length	11 cm
Number of Periods	9 + 9

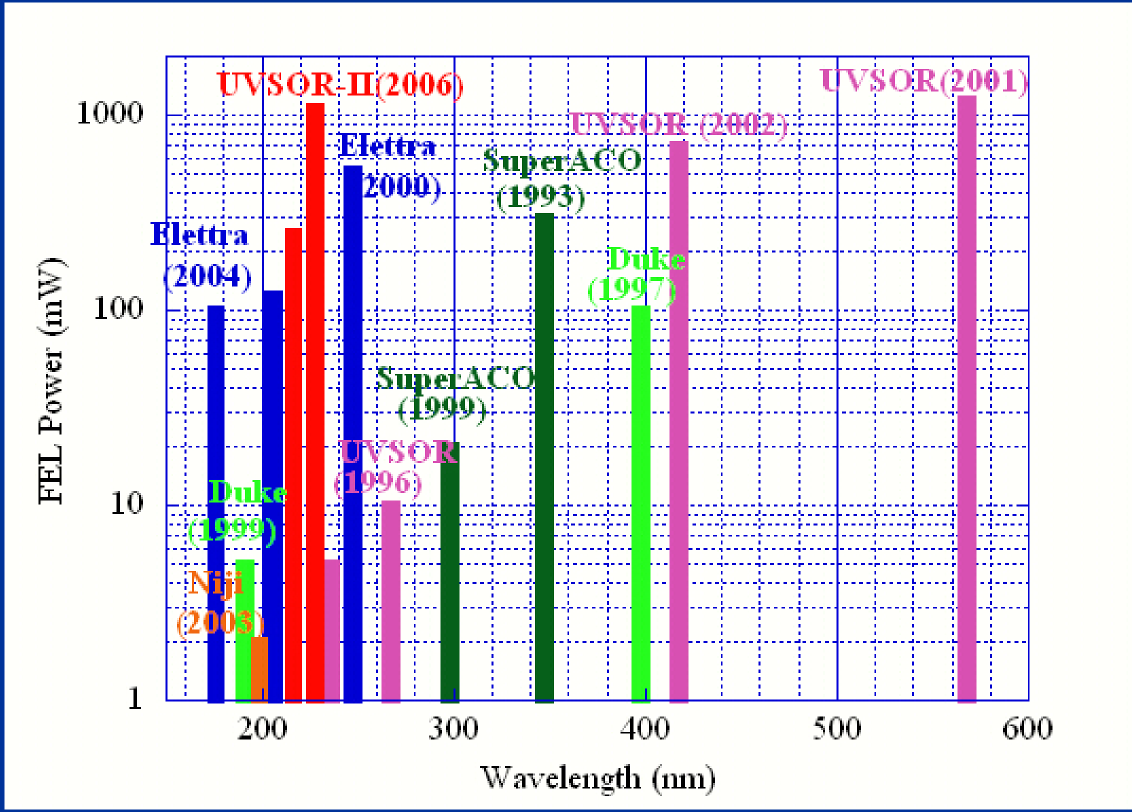
UVSOR-II FEL

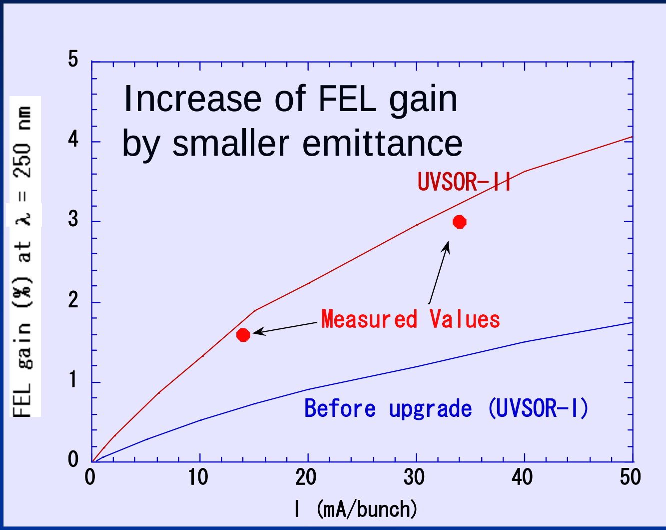
Higher Power in Deep UV

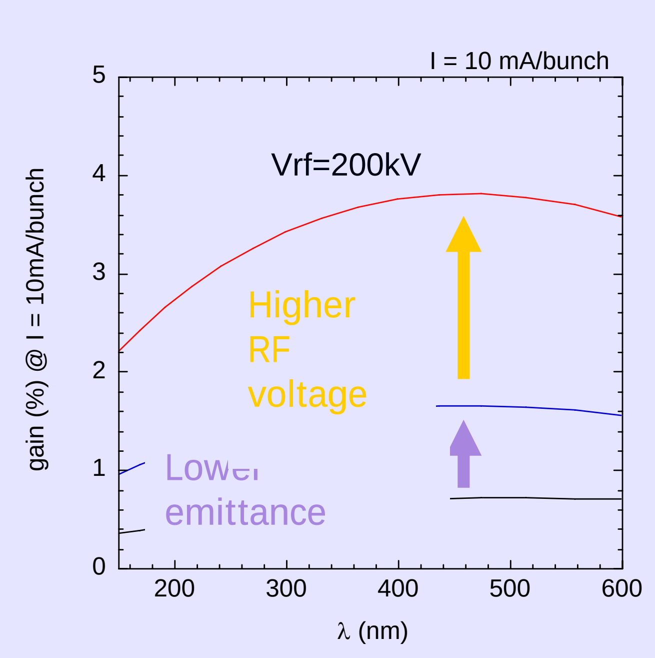
M. Hosaka et al., NIM A528 (2004), 291-295

FEL gain was increased by the smaller emittance and the higher RF voltage.

Average Output Power of Storage ring FELs in the world

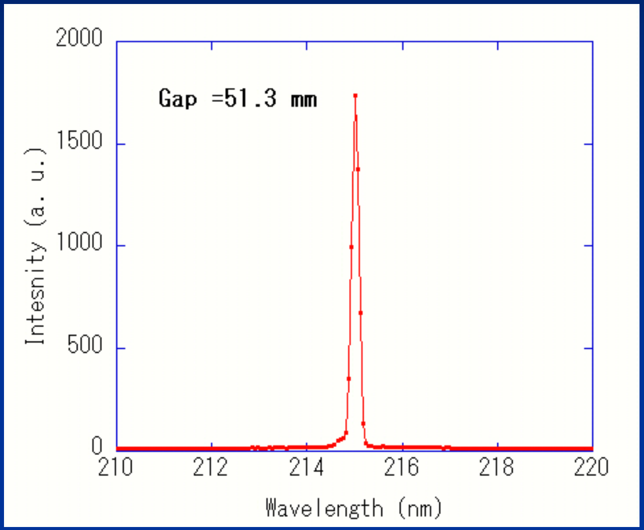


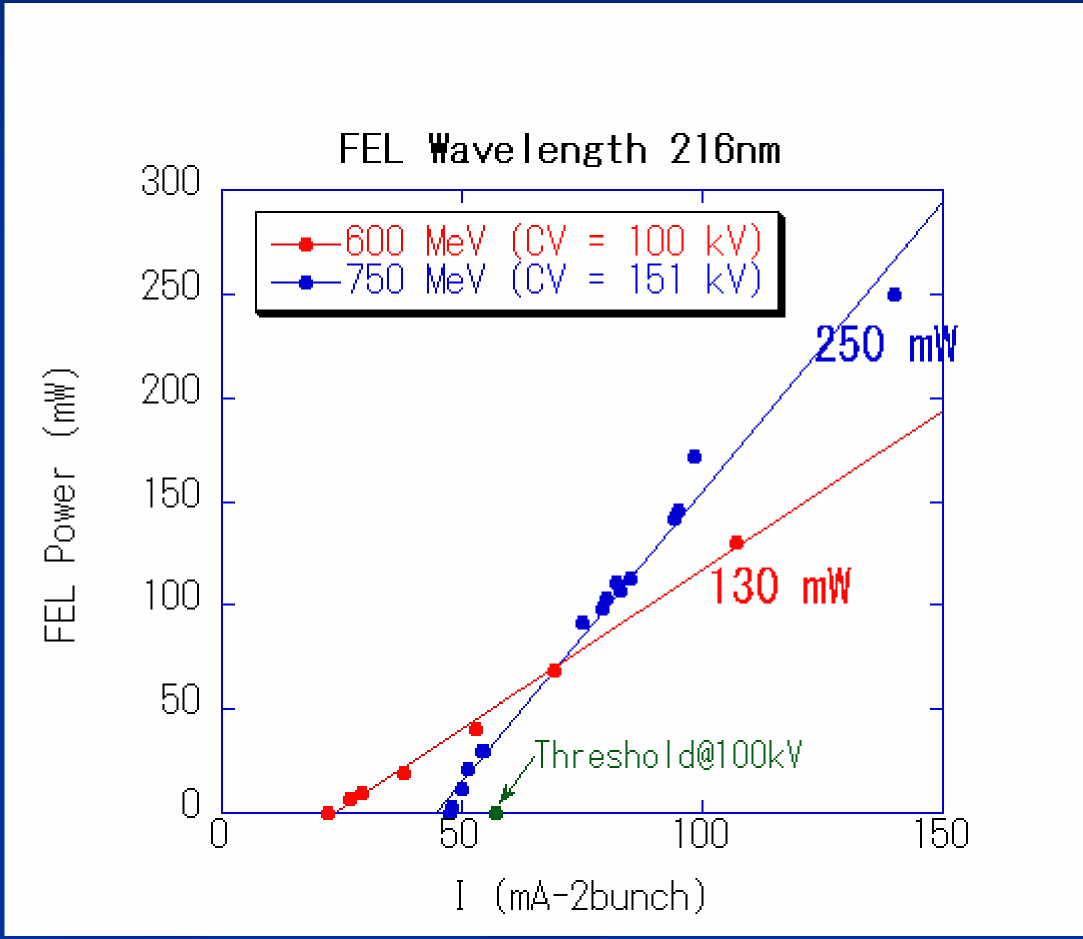


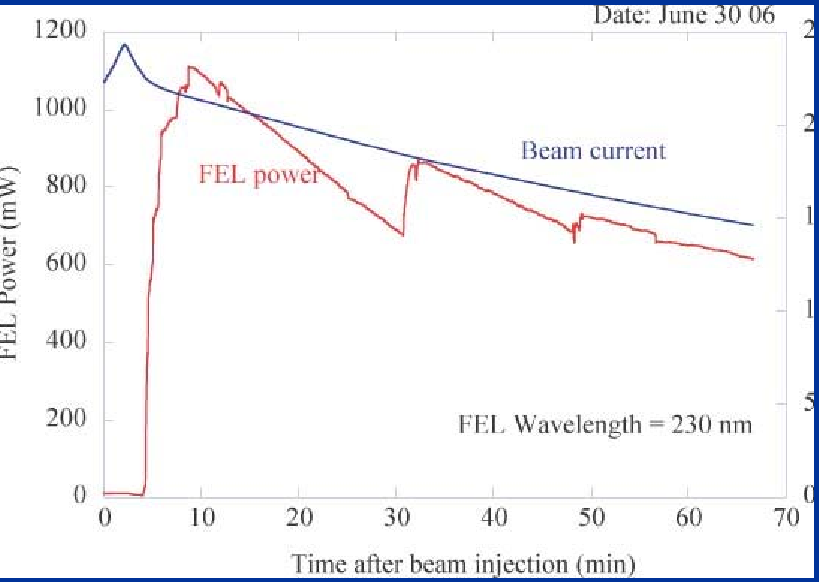


Lasing at 750 MeV

Higher Output Power and Longer Beam Lifetime

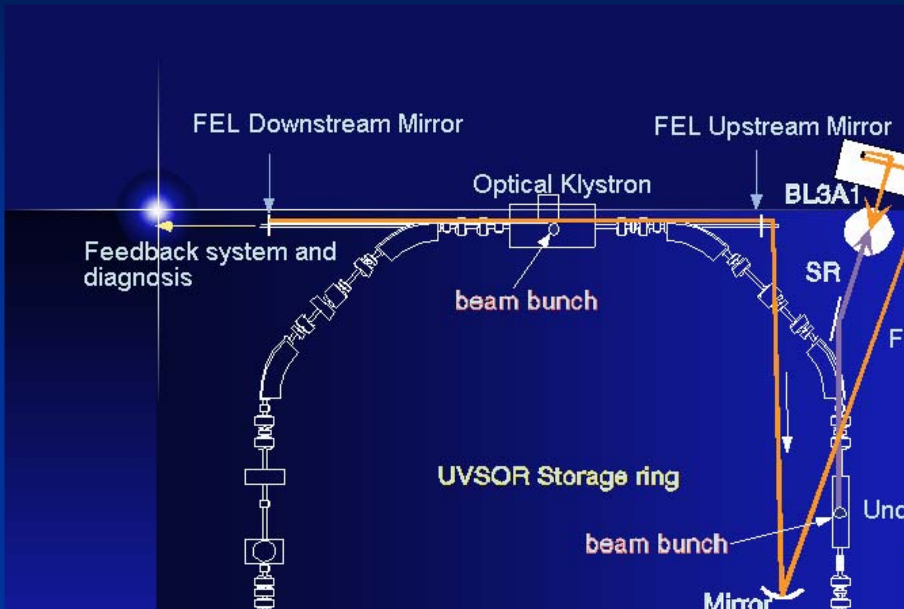


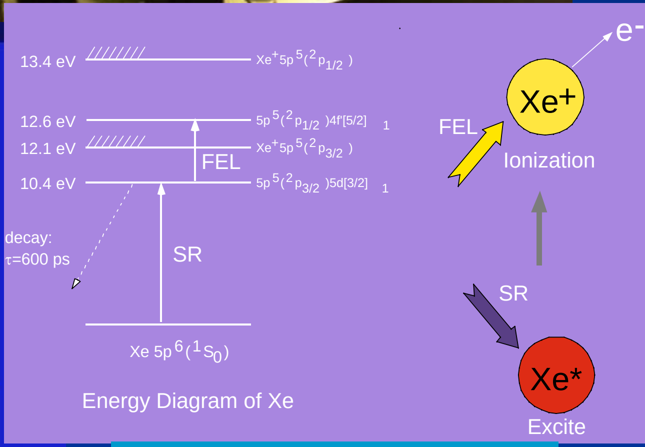


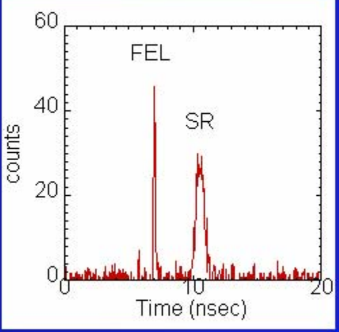


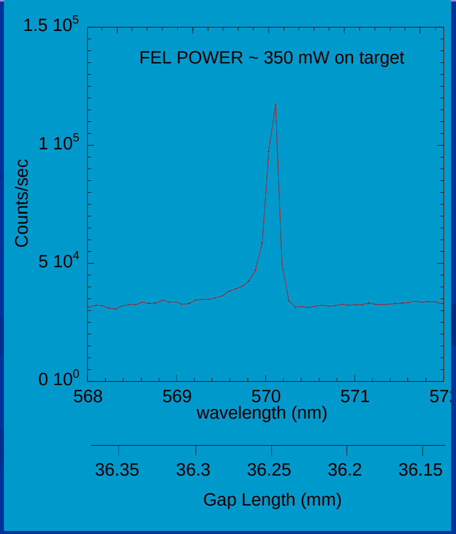
Pump(SR)–Probe(FEL) Experiment

T. Gejo et al., NIM A 528 (2004), 627-631



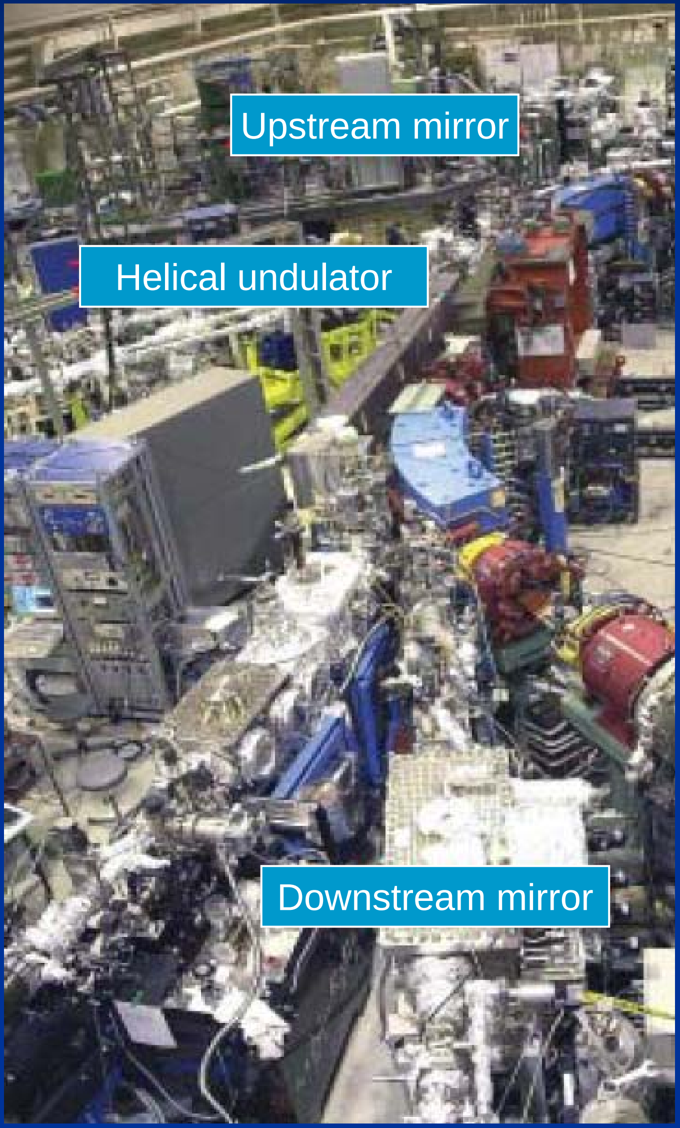






Measurements of Photoelectric Magnetic Dichroism

Cs- or Gd-free Ni/Cu(001) using FEL at UVSOR-II

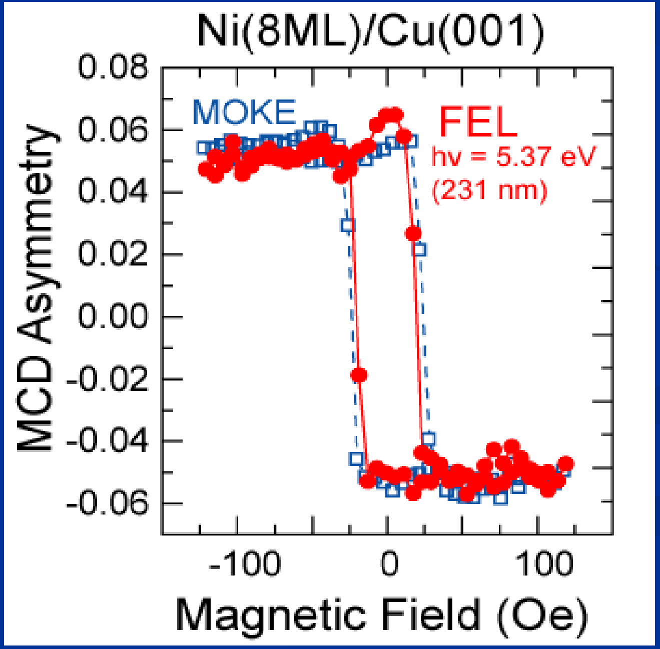


T. Nakagawa, T. Yokoyama, M. Hosaka, and M. Katoh, Rev. Sci. Instrum., (accepted).

FEL from helical undulator (5U)
inherently circularly polarized

Strong intensity ~100-500 mW

Tunable HfO_2/SiO_2 multilayer mirror λ ~ 230nm

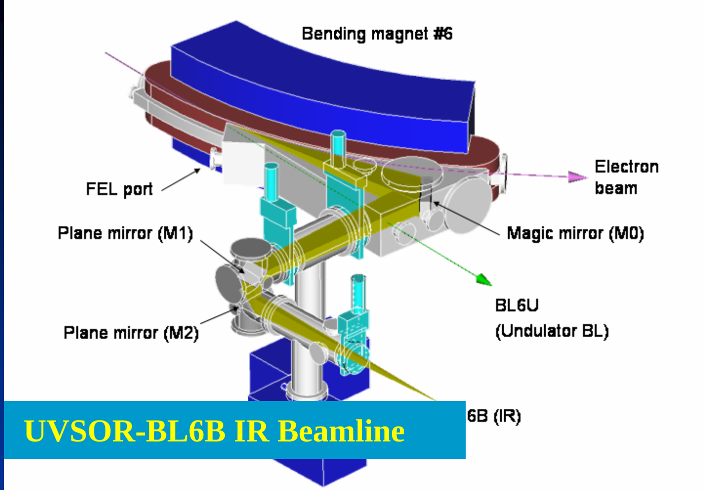


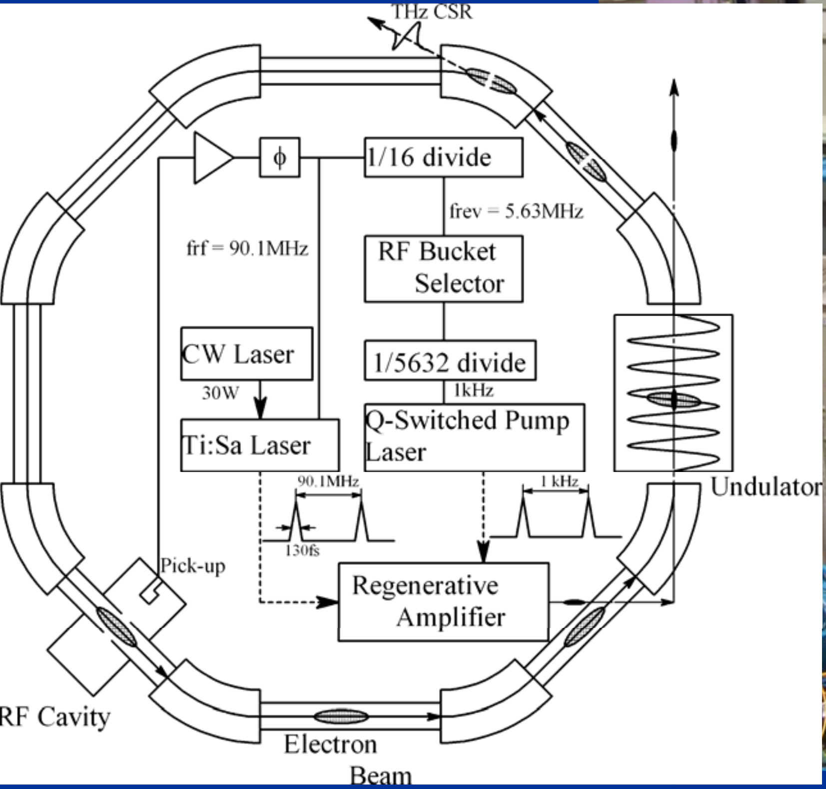
MCD asymmetry
as much as ~5%

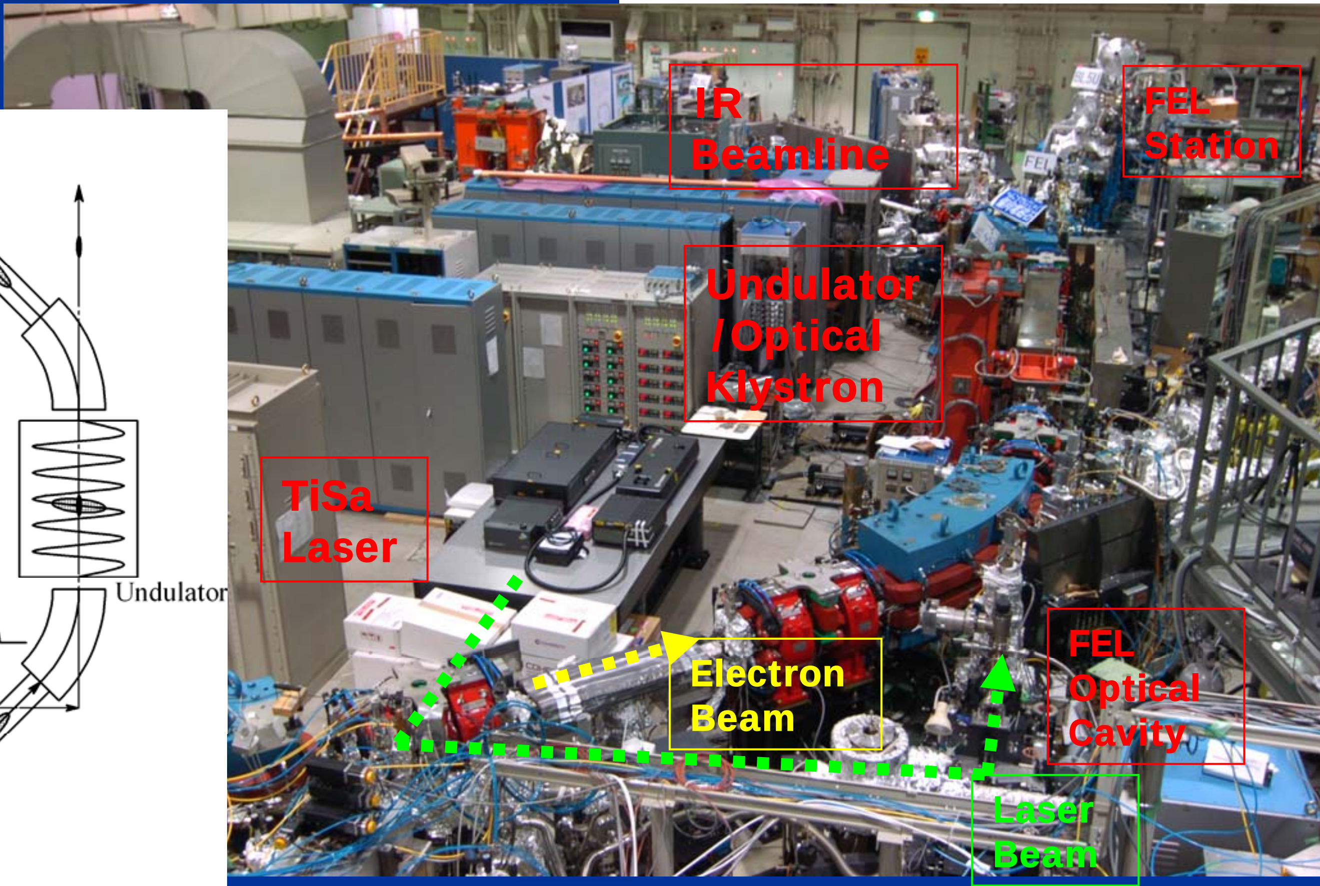
Possibility of adsorbate induced enhancement of threshold photoemi-ssion MCD is eliminated.

Laser Bunch Slicing & Coherent Harmonic Generation at UVSOR-II

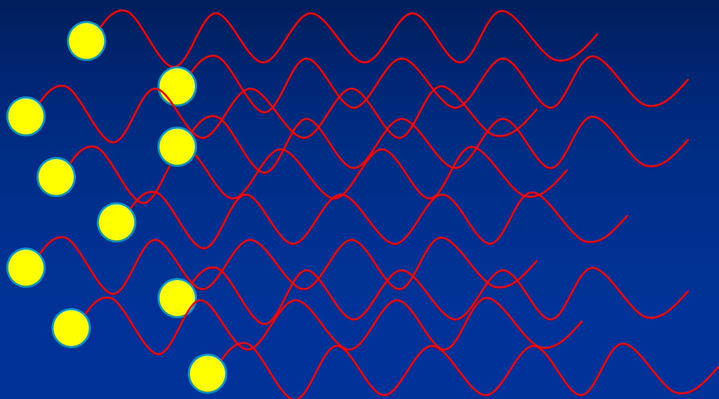
Collaborators; S. Kimura (UVSOR), Y. Takashima, M. Hosaka (Nagoya U.), T. Takahashi (Kyoto U.), T. Hara (RIKEN/SPring-8), M. E. Couprie, M. Labat, G. Lambert (CEA), S. Bielawski, C. Szwaj (U. Sci. Tech. Lille)







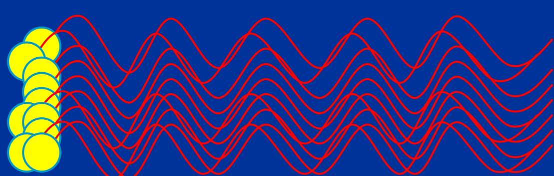
通常のシンクロトロン放射

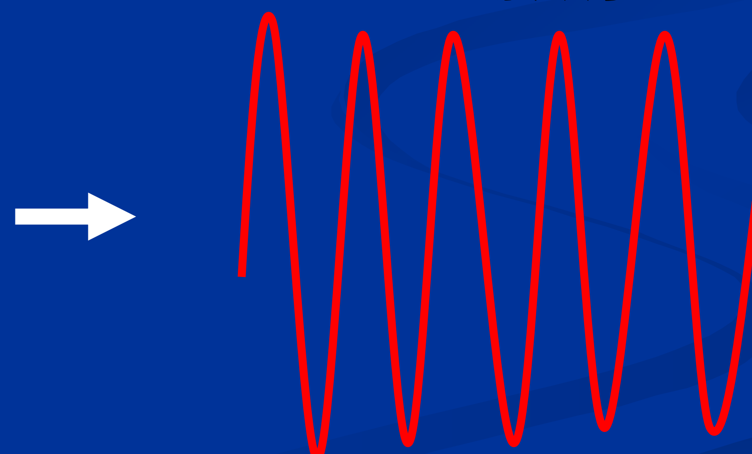


位相がばらばらの光の集まり

（光のエネルギー）∝（電子の数）

コヒーレントなシンクロトロン放射



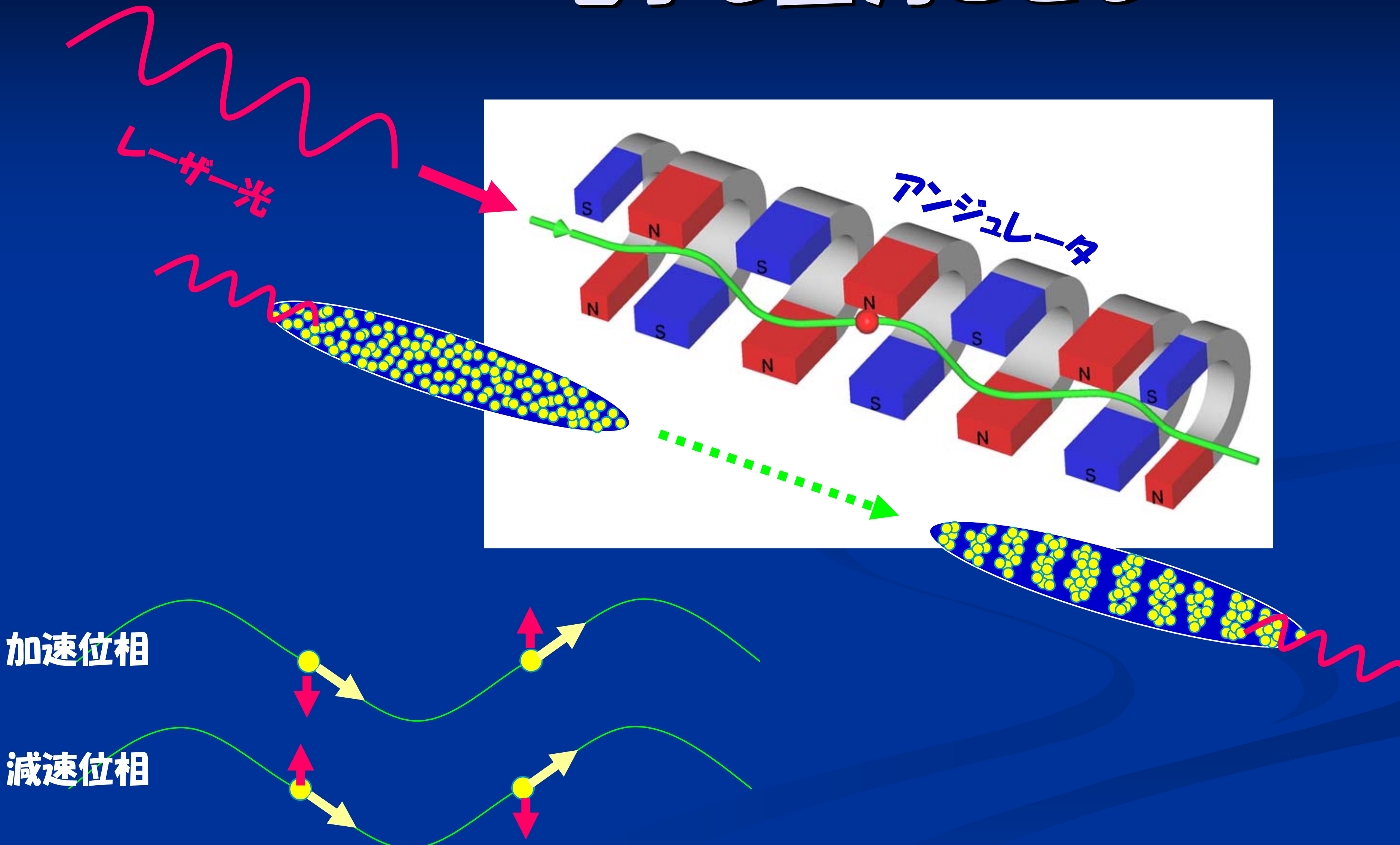


電子群が光の波長よりも
小さな空間に集まっている。

位相のそろった光

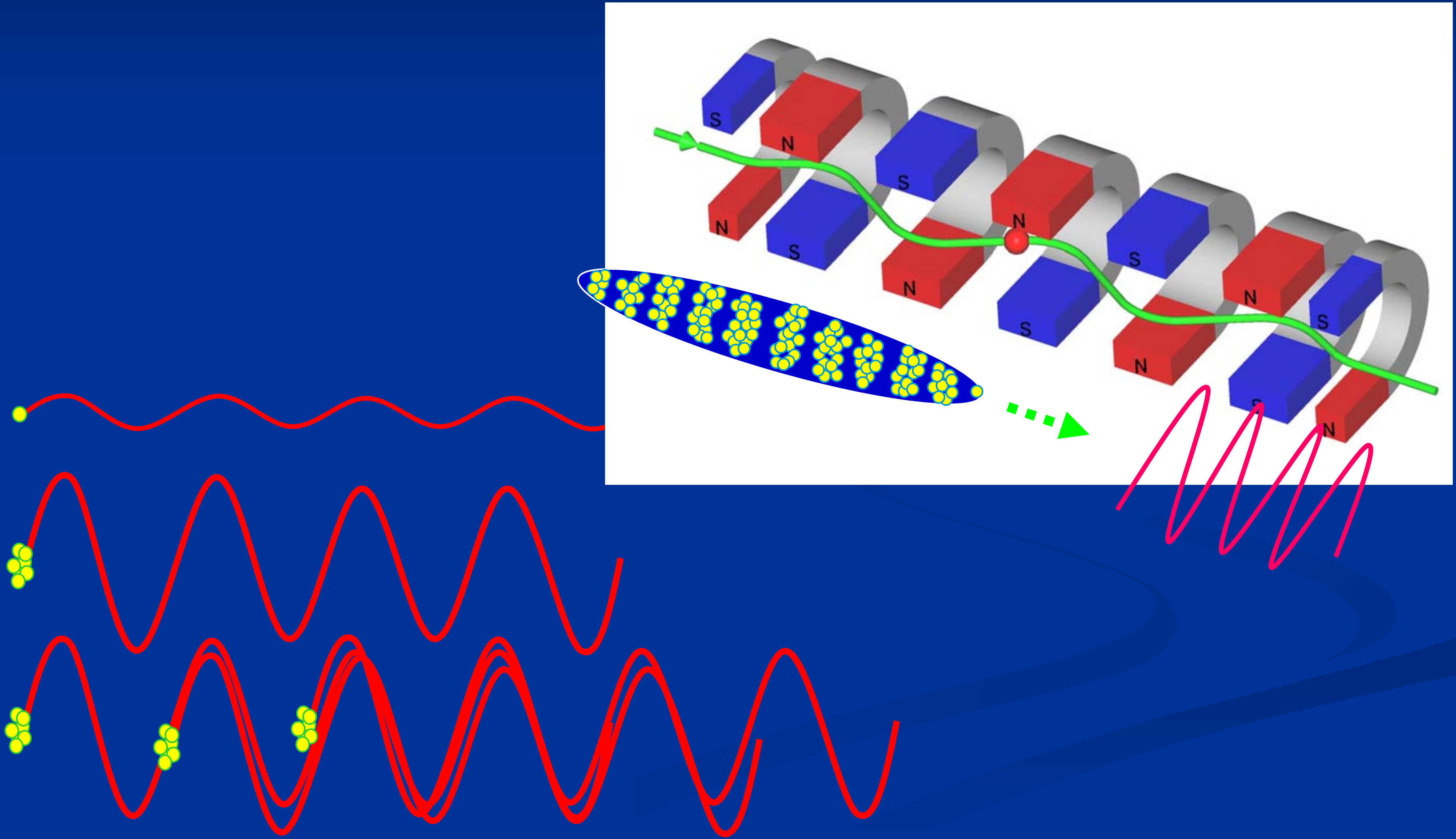
（光のエネルギー）∝（電子の数の二乗）

電子を整列させる

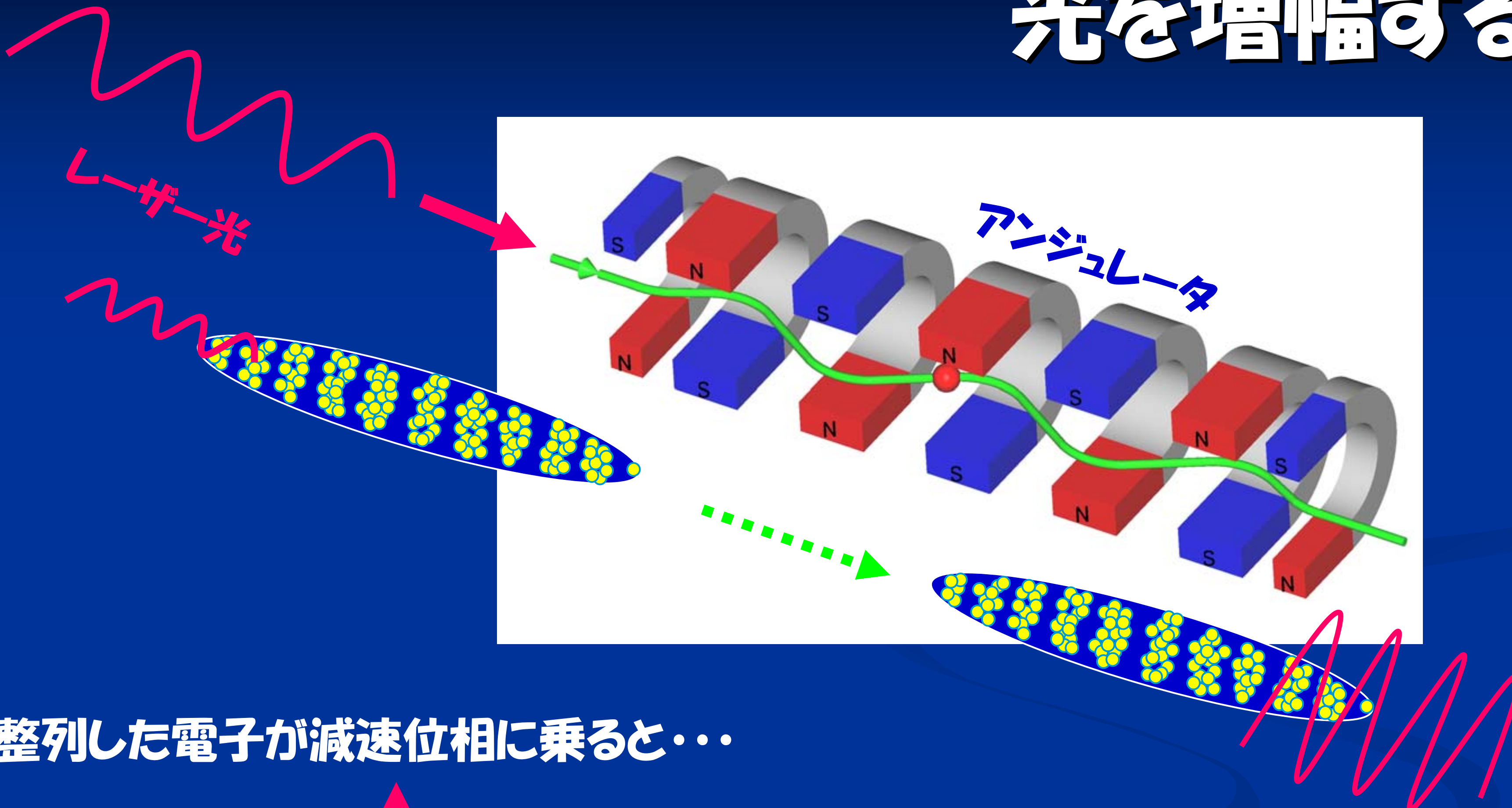


アンジュレータ中での電子とレーザー場の相互作用

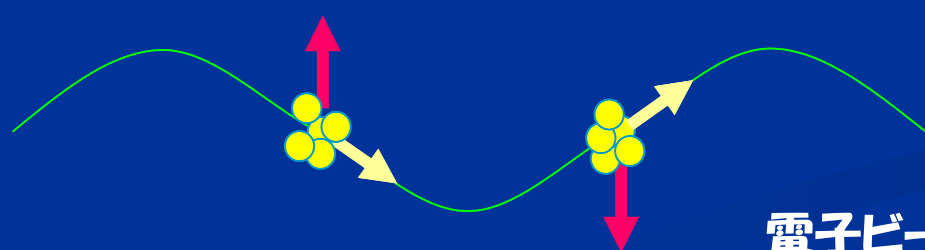
整列した電子群は
コヒーレントシンクロトロン放射する



整列した電子群は光を増幅する



整列した電子が減速位相に乗ると・・・

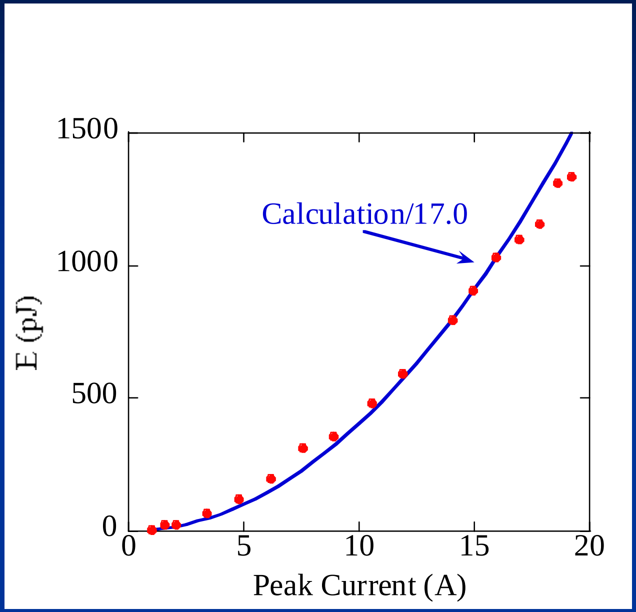


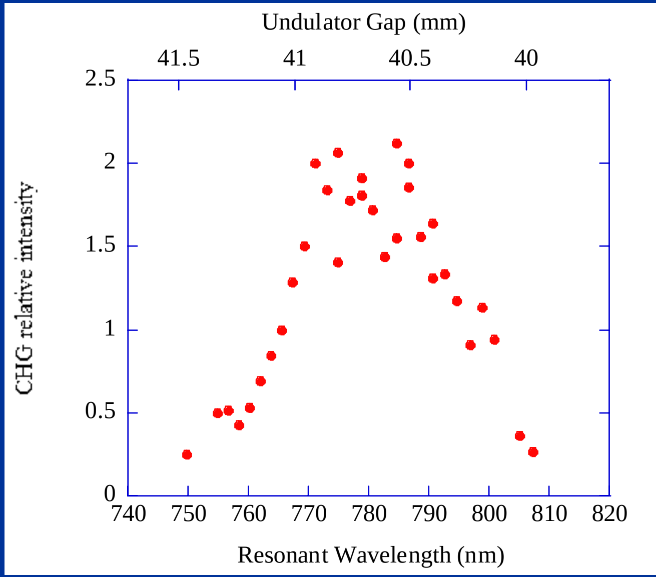
電子ビームがエネルギーを失う

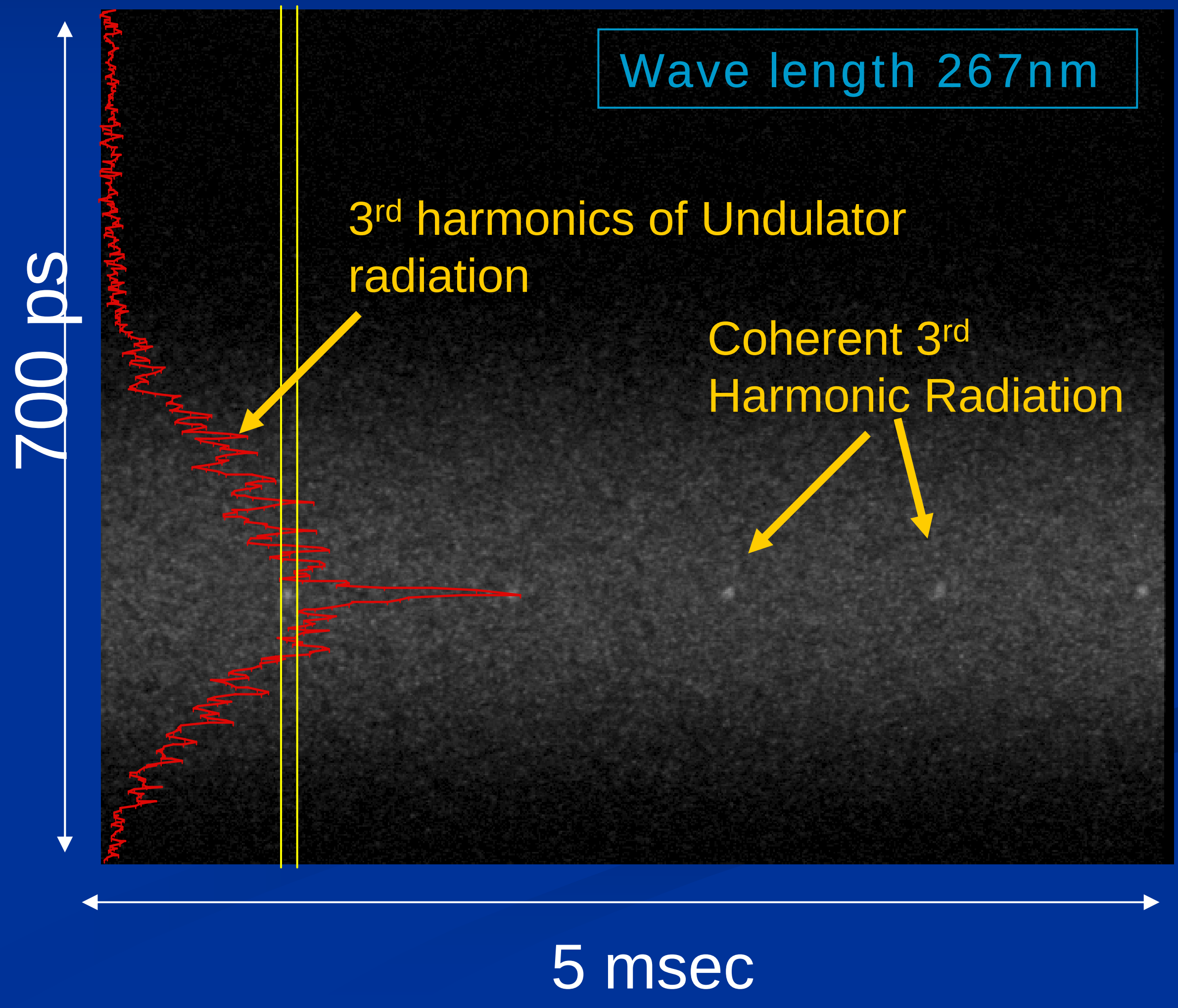
⇒　電磁場がそのエネルギーを受け取る

Coherent Harmonic Generation

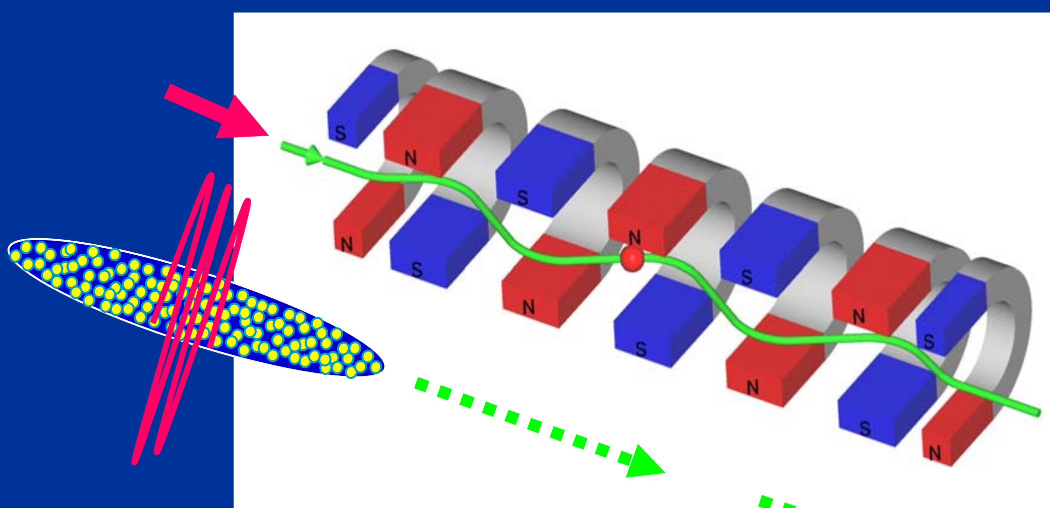
M. Labat et al., submitted to Phys. Rev. STAB

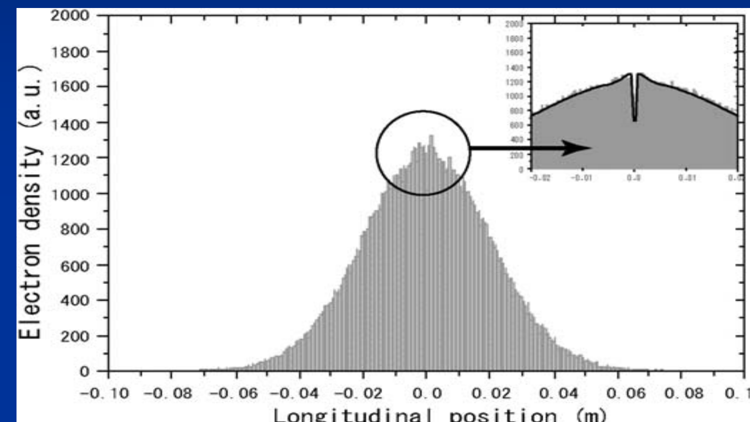


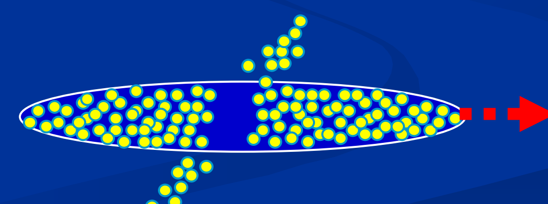


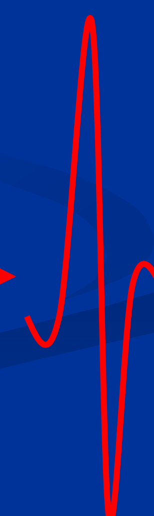


極短パルスレーザーで電子パルスを切る





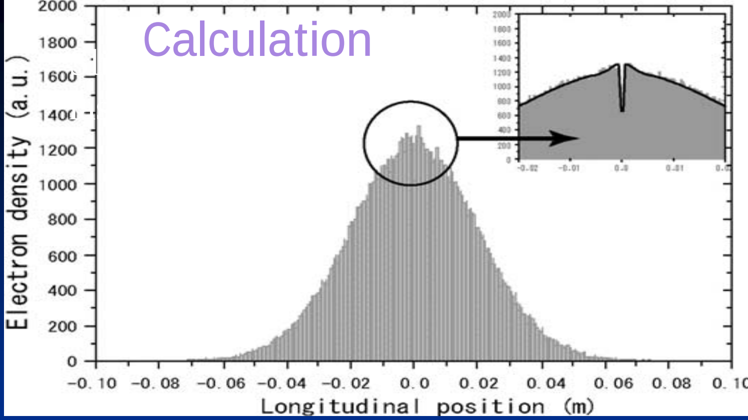


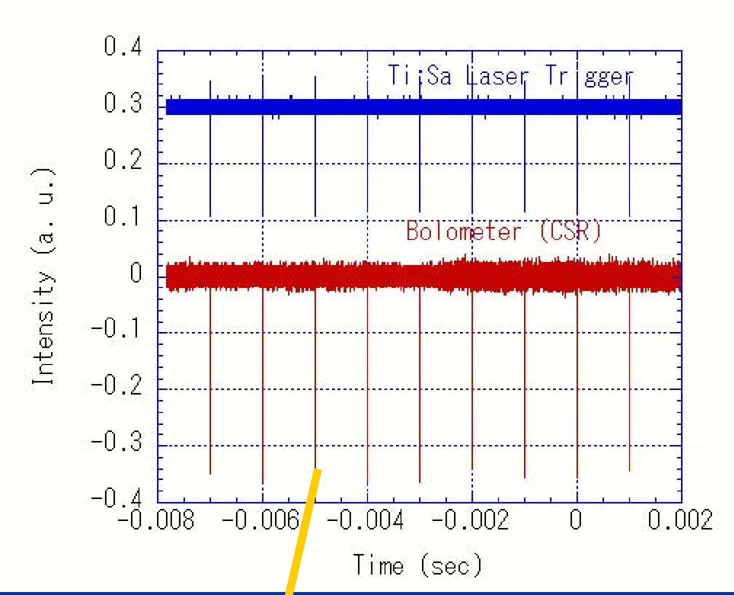


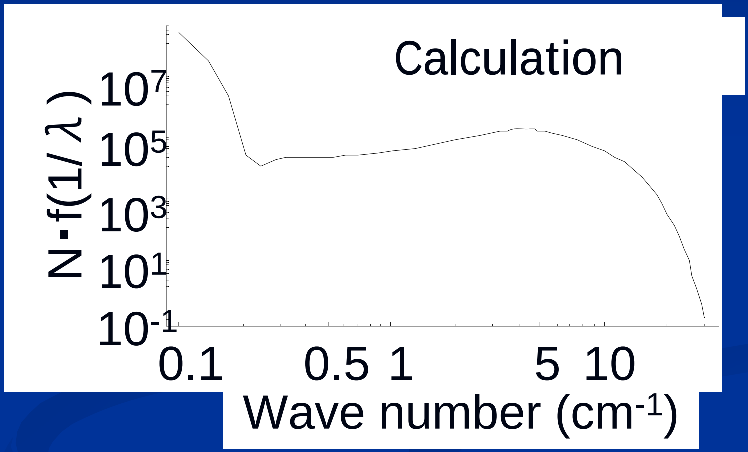
切り取られた穴と同程度の波長
でコヒーレント放射する。

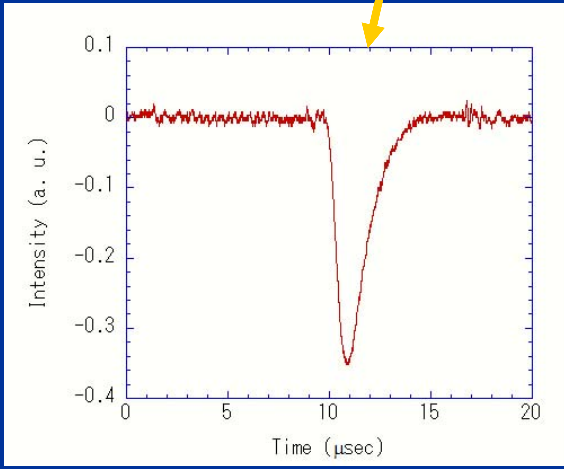
Coherent Terahertz Radiation by Laser Bunch-Slicing

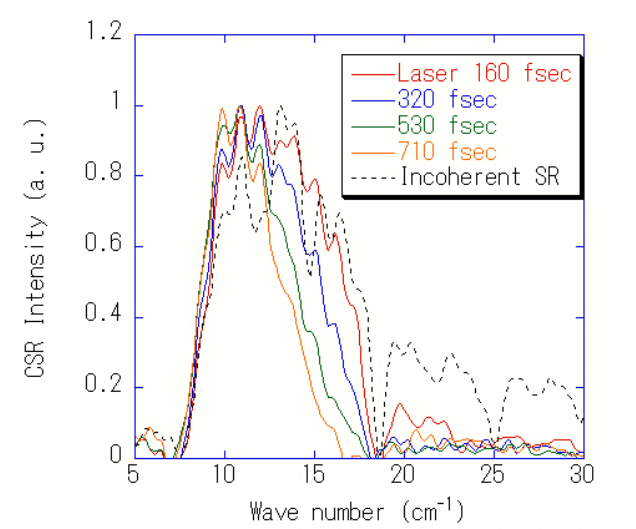
M. Shimada et al. presented at EPAC2006

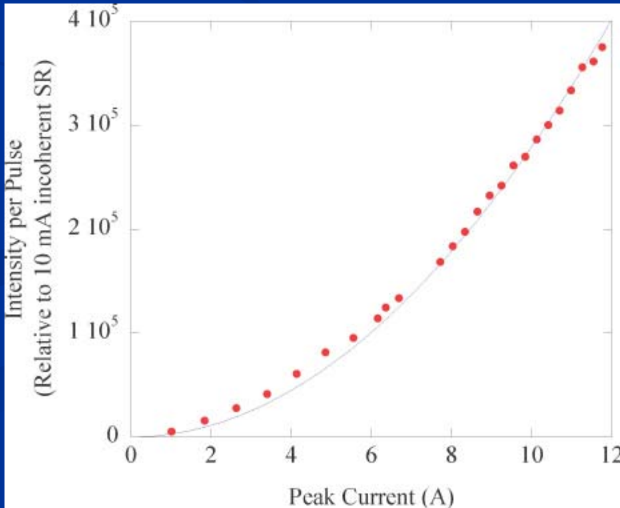






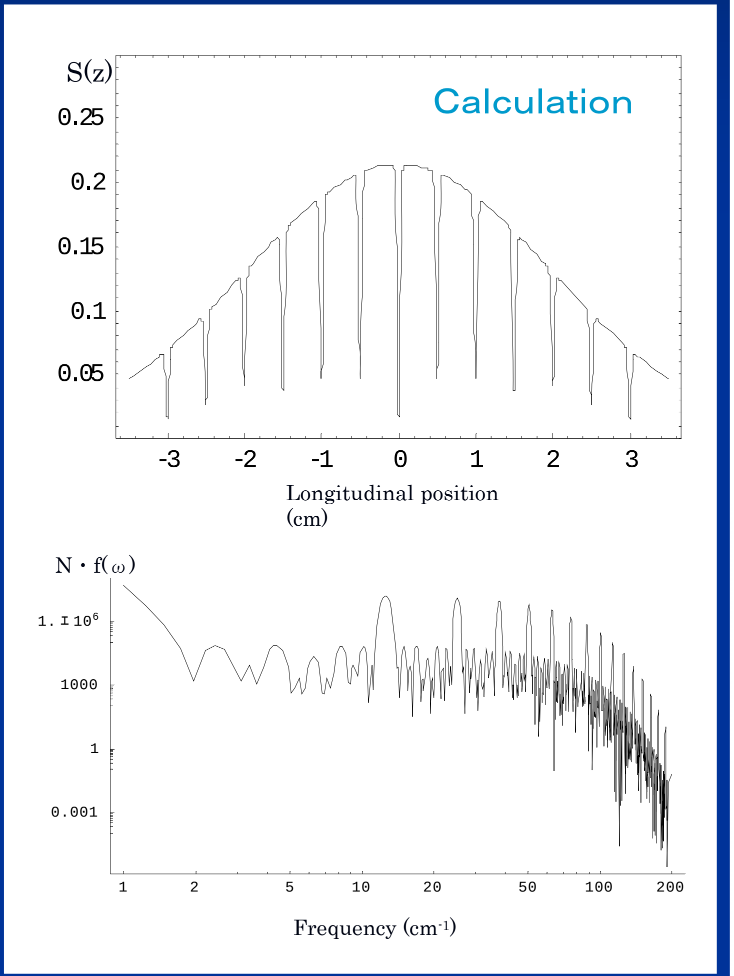


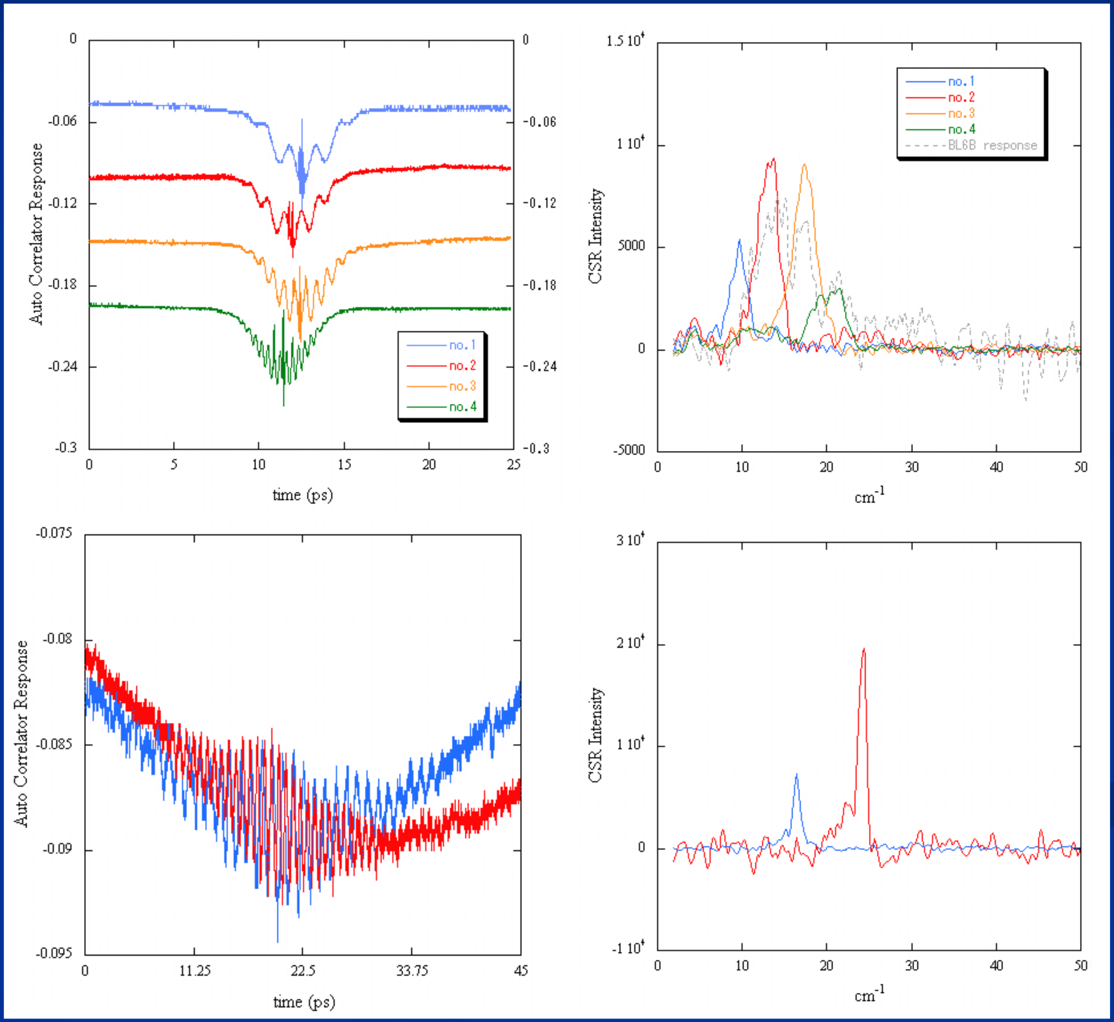




Narrow-band and Tunable Coherent Terahertz Radiation by Laser Bunch Slicing

Collaborating with M. Hosaka, Y. Takashima (Nagoya U.), S. Bielawski, C. Szwaj, C. Evain (U. Sci. Tech de Lille), S. Kimura (UVSOR), T. Takahashi (Kyoto U.)





Experiment (Dec. 2006)

Accelerator Division of UVSOR

UVSOR Accelerator Group

Professor

M. KATOH

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A. Mochihashi

Engineers

J. Yamazaki, K. Hayashi

Guest associate professor

T. Hara (RIKEN/SPring-8)

Post doctoral fellow

M. Shimada

Collaborators

S. Kimura (UVSOR), Y. Takashima, M. Hosaka (Nagoya U.), T. Takahashi (Kyoto U.), M. E. Couprie, M. Labat, G. Lambert (Soleil), S. Bielawski, C. Szwaj, C. Evain (U. Sci. Tech. Lille), ・・・・・・・・・

SPring-8への期待

- 長直線部の活用
- 地球に優しく
- 加速器技術の継承・移転