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X-ray Nano Probes for Nano Materials at TPS

Tseng, Shao-Chin

2016/3/4 NTHU-Physics

Outline

- Synchrotron Light Source
- Application of Synchrotron Light
- X-ray nano probe at TPS

“Light” is indispensable to man‘s exploration of nature.

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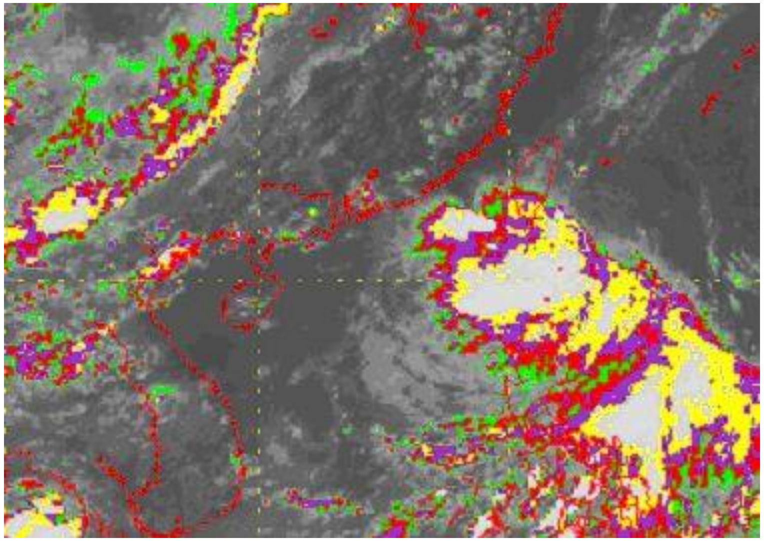
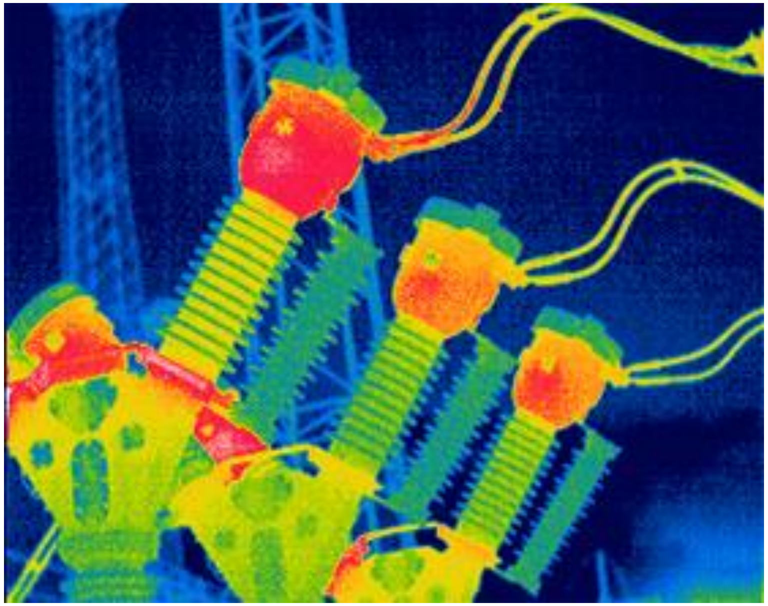
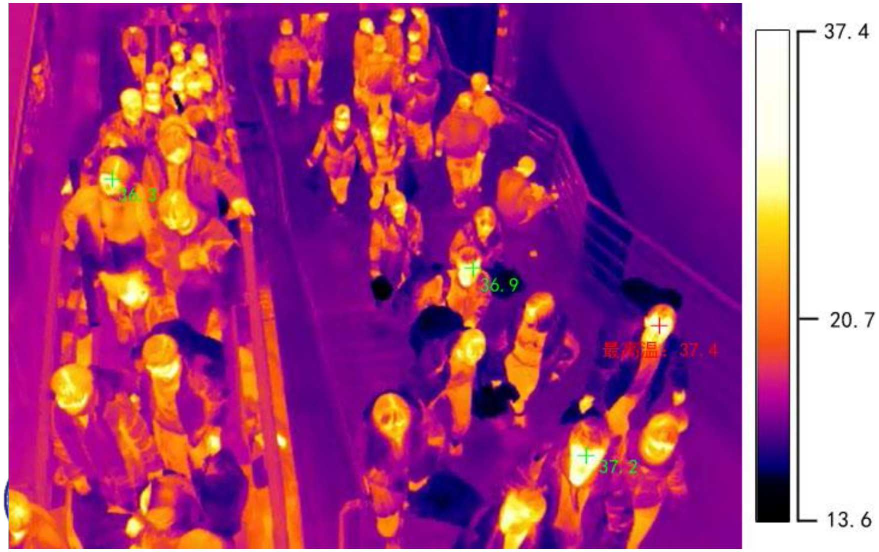
Invisible light: IR and X-ray…



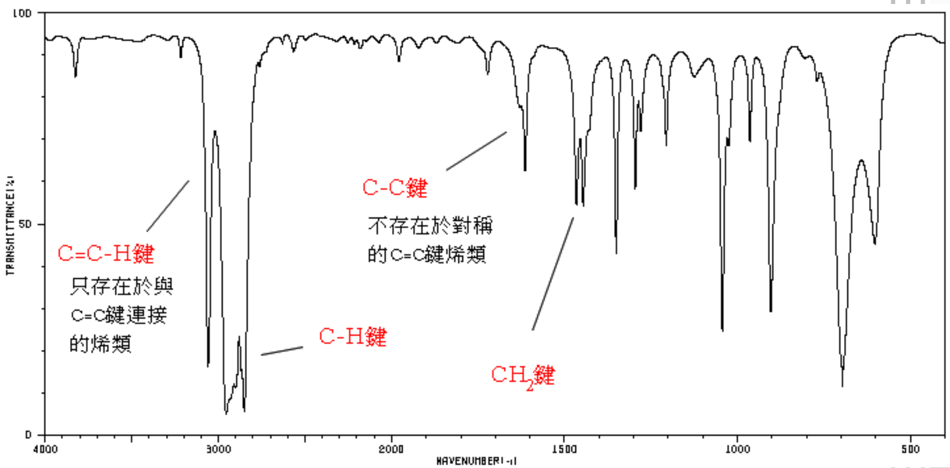
http://www.hko.gov.hk/prtver/html/docs/education/edu02rga/radiation/radiation_02-c.shtml



http://www.yingfukeji.com/appl/grid.html

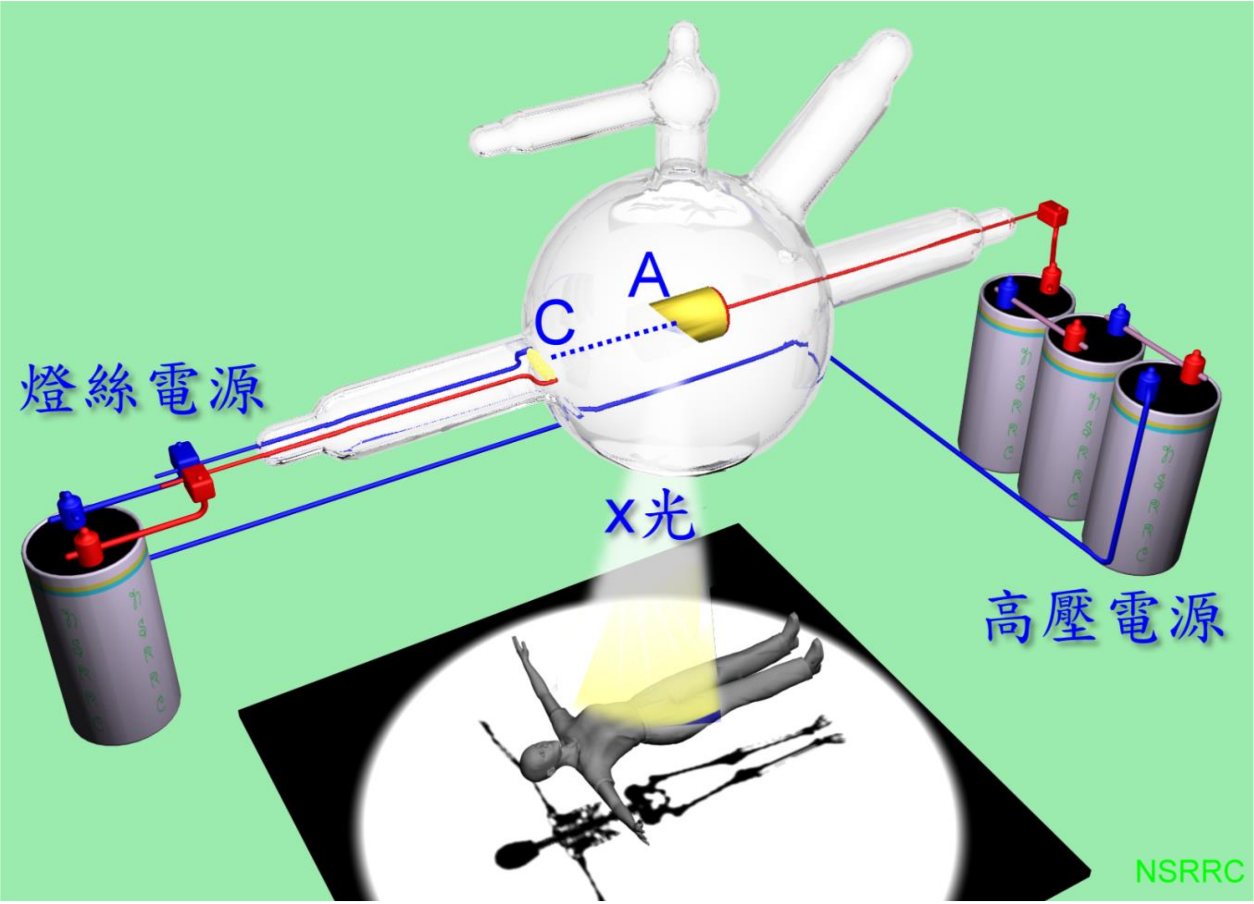


http://www.uv-teck.com/Ttwjy



http://smallcollation.blogspot.tw/2014/02/infrared-spectroscopy-of-alkanes.html#gsc.tab=0

Rontgen used a simple accelerator to discover X-rays



1895

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Hand mit Ringen (Hand with Rings): Wilhelm Rontgen's first "medical" X-ray, of his wife's hand, taken on 22 December 1895 and presented to Ludwig Zehnder of the Physik Institut, University of Freiburg, on 1 January 1896.

http://en.wikipedia.org/wiki/X-ray

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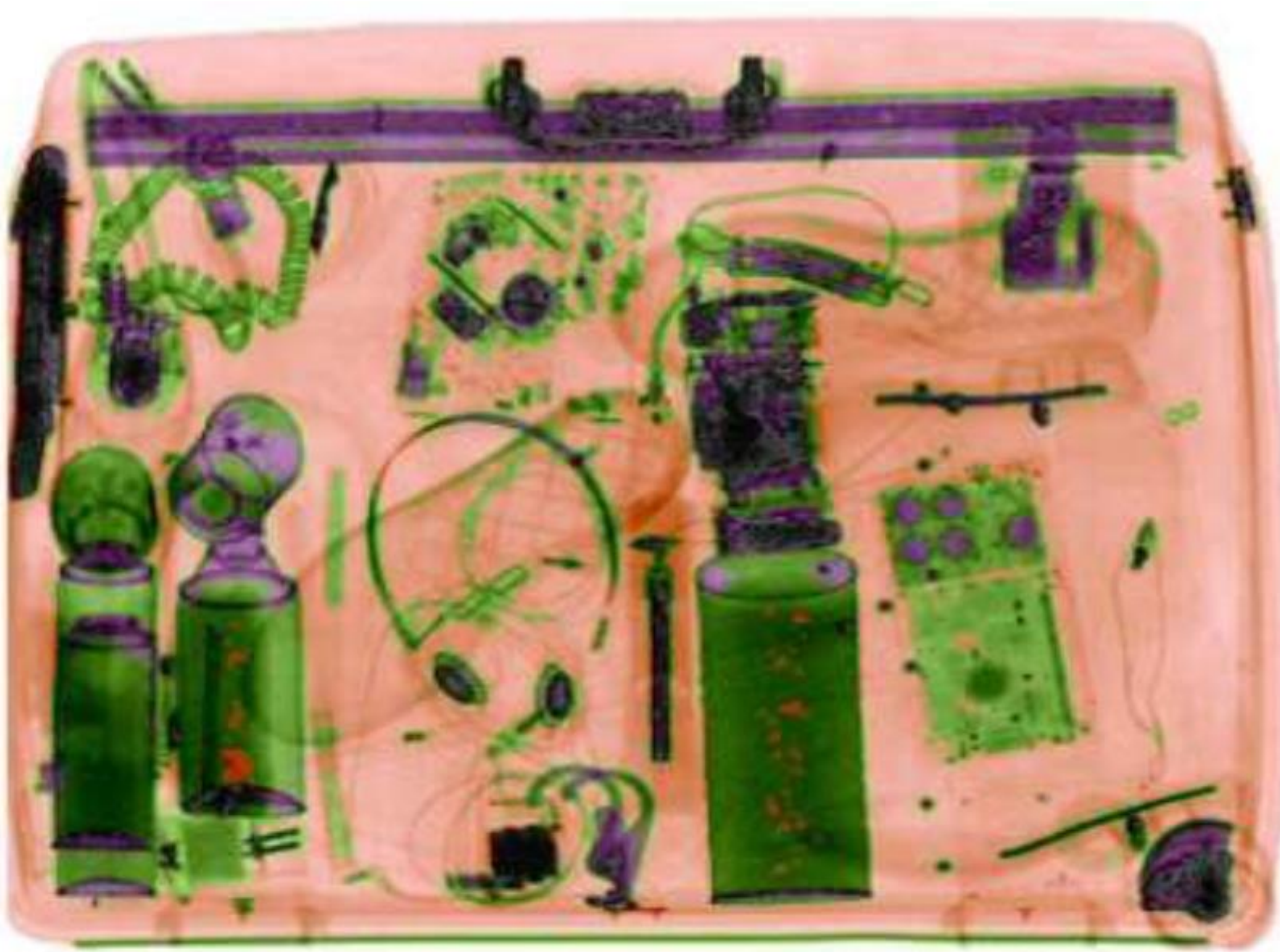
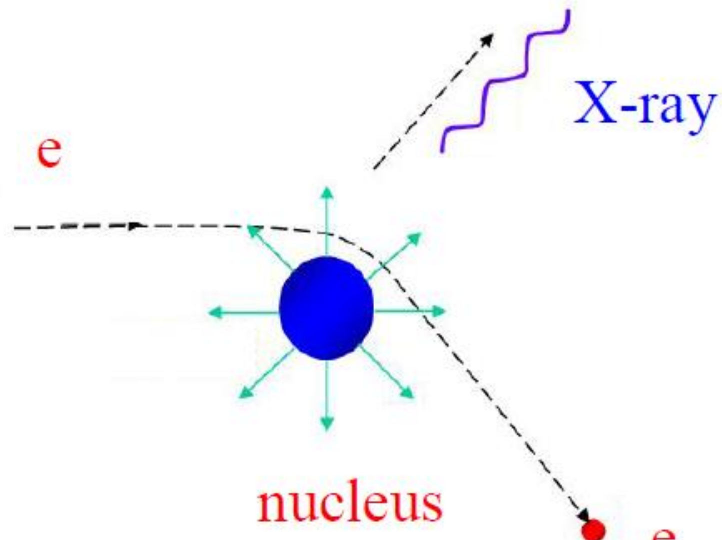
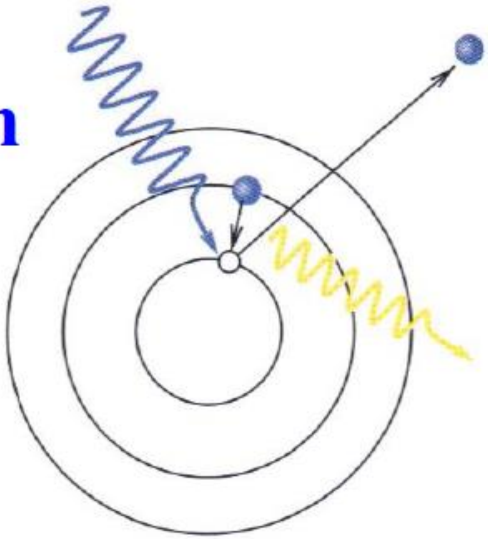
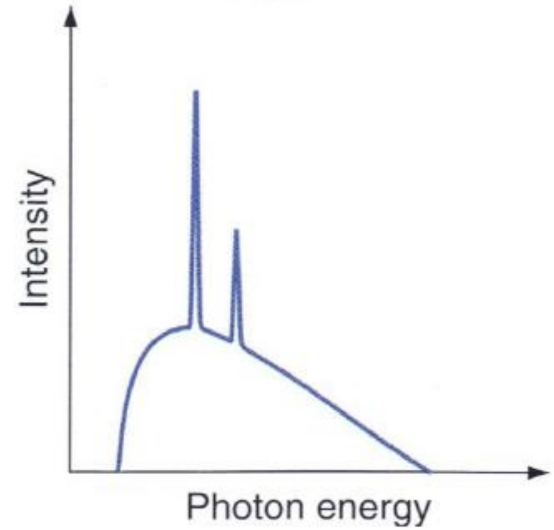


http://snallabolaget.com/?page_id=666

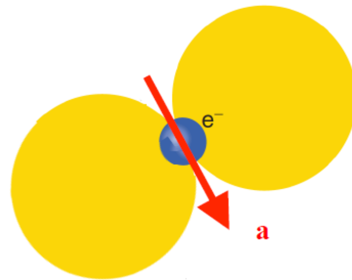
Characteristic X-ray emission



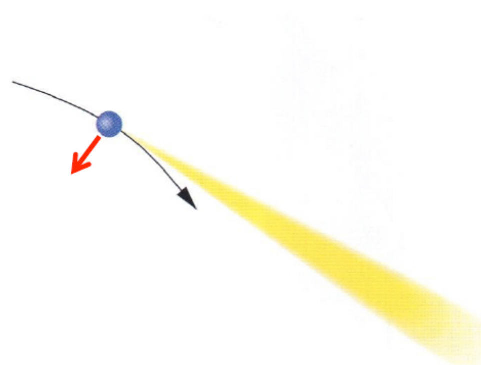




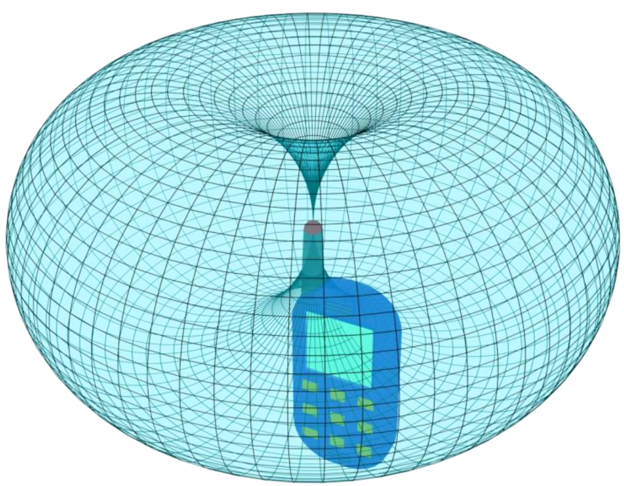
Electromagnetic wave from a moving charge

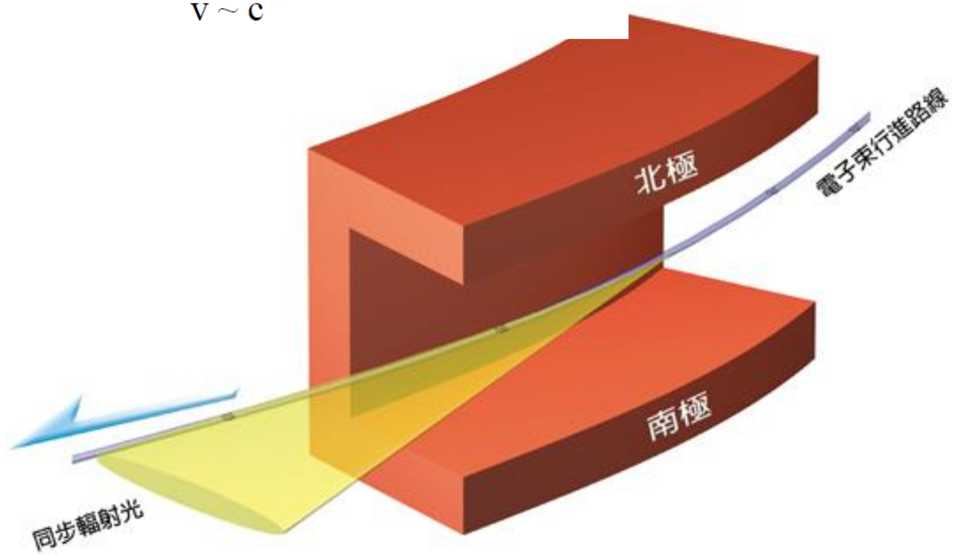


v << c



v ~ c

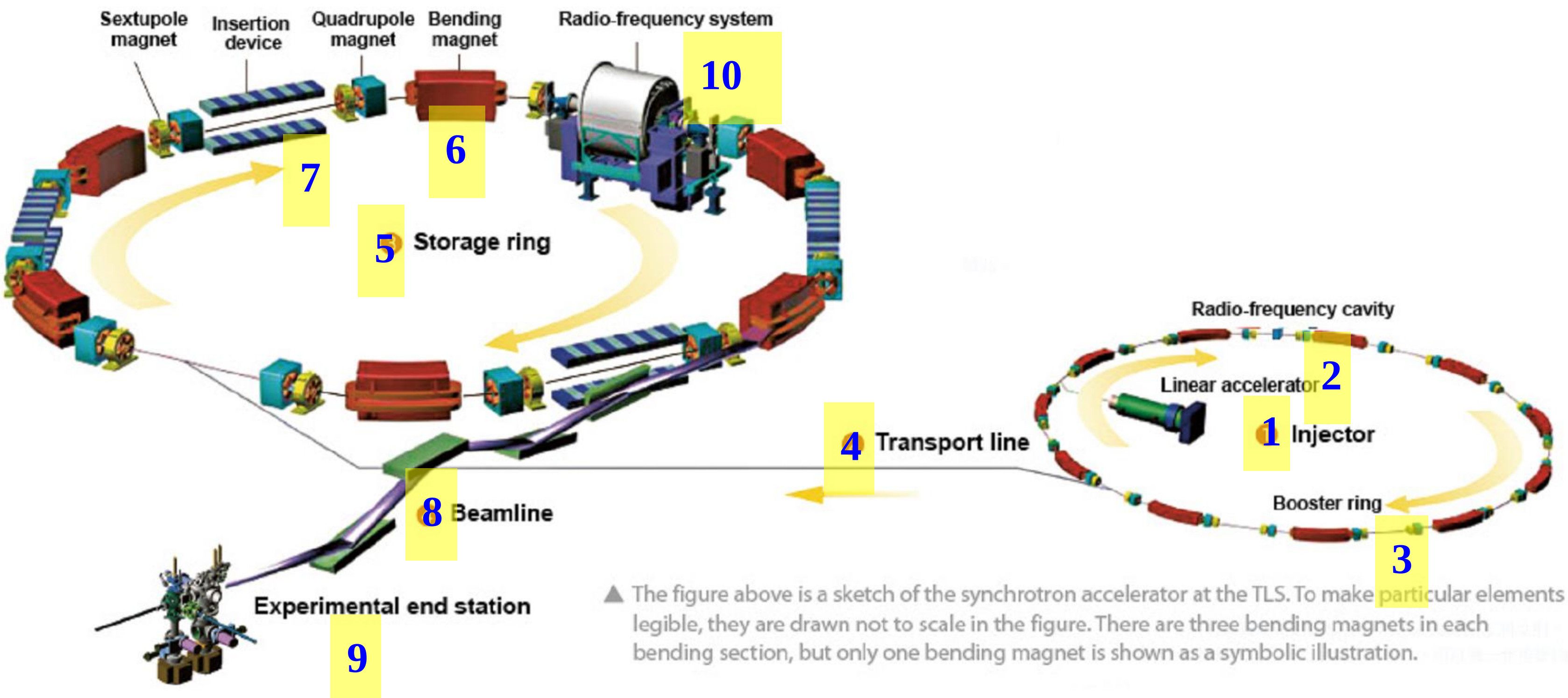




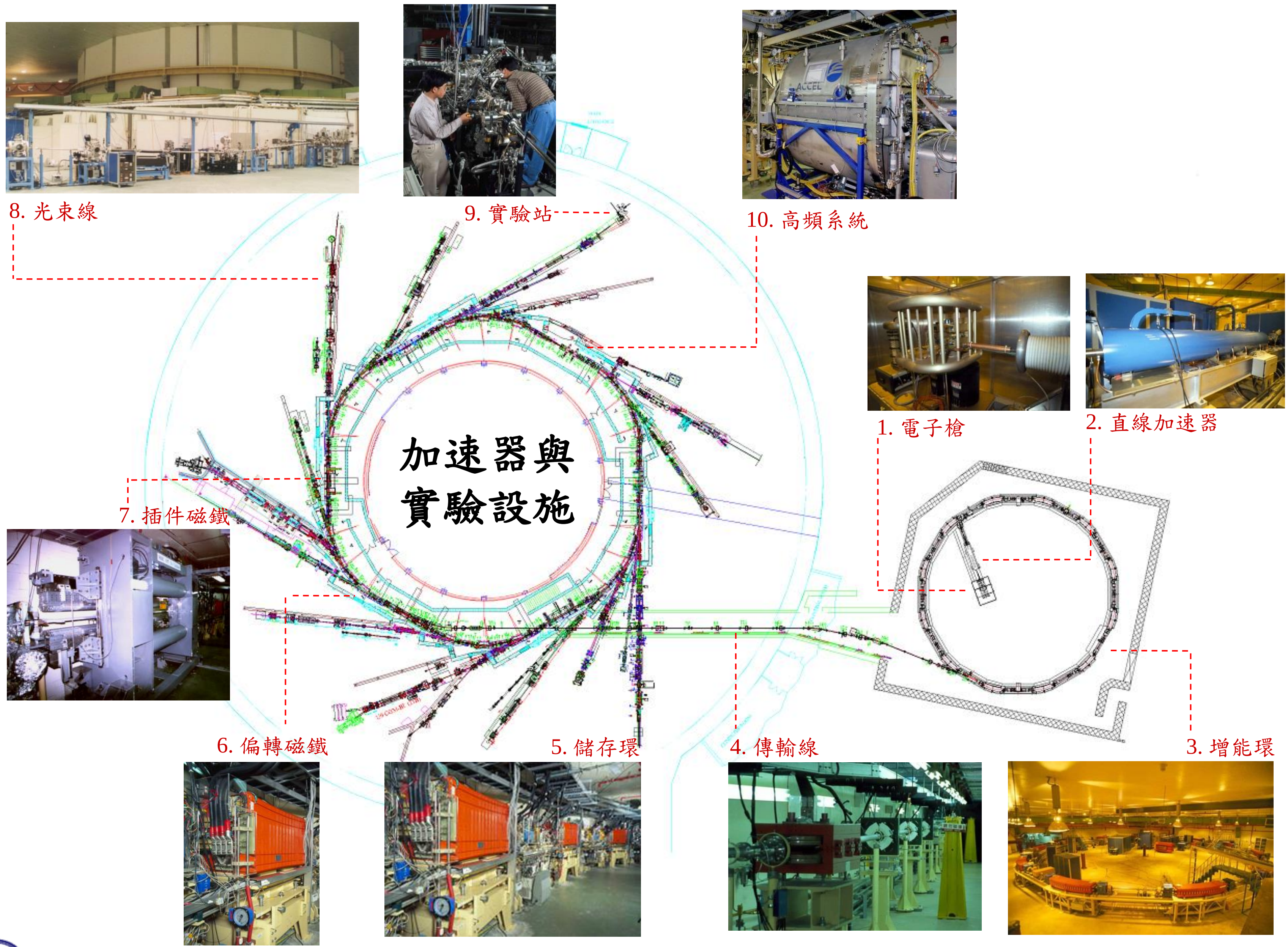
二極偏轉磁鐵

同步加速器光源的原理

- 電子在電子槍(1)內產生，經過直線加速器(2)加速至能量為5,000萬電子伏特。
- 電子束進入增能環(3)後，繼續增加能量至15億電子伏特(1.5GeV)，速度非常接近光速(0.99999995倍)。
- 電子束經由傳輸線(4)進入儲存環(5) 。
- 當儲存環累積足夠的電子束後，經由各個磁鐵的導引與聚焦，電子束在偏轉磁鐵(6)及插件磁鐵(7)發出同步加速器光源，經由光束線(8)將光源引導至實驗站(9)進行實驗。
- 電子束在發出同步加速器光源後，要靠高頻腔(10)來補充失去的能量。



▲ The figure above is a sketch of the synchrotron accelerator at the TLS. To make particular elements legible, they are drawn not to scale in the figure. There are three bending magnets in each bending section, but only one bending magnet is shown as a symbolic illustration.



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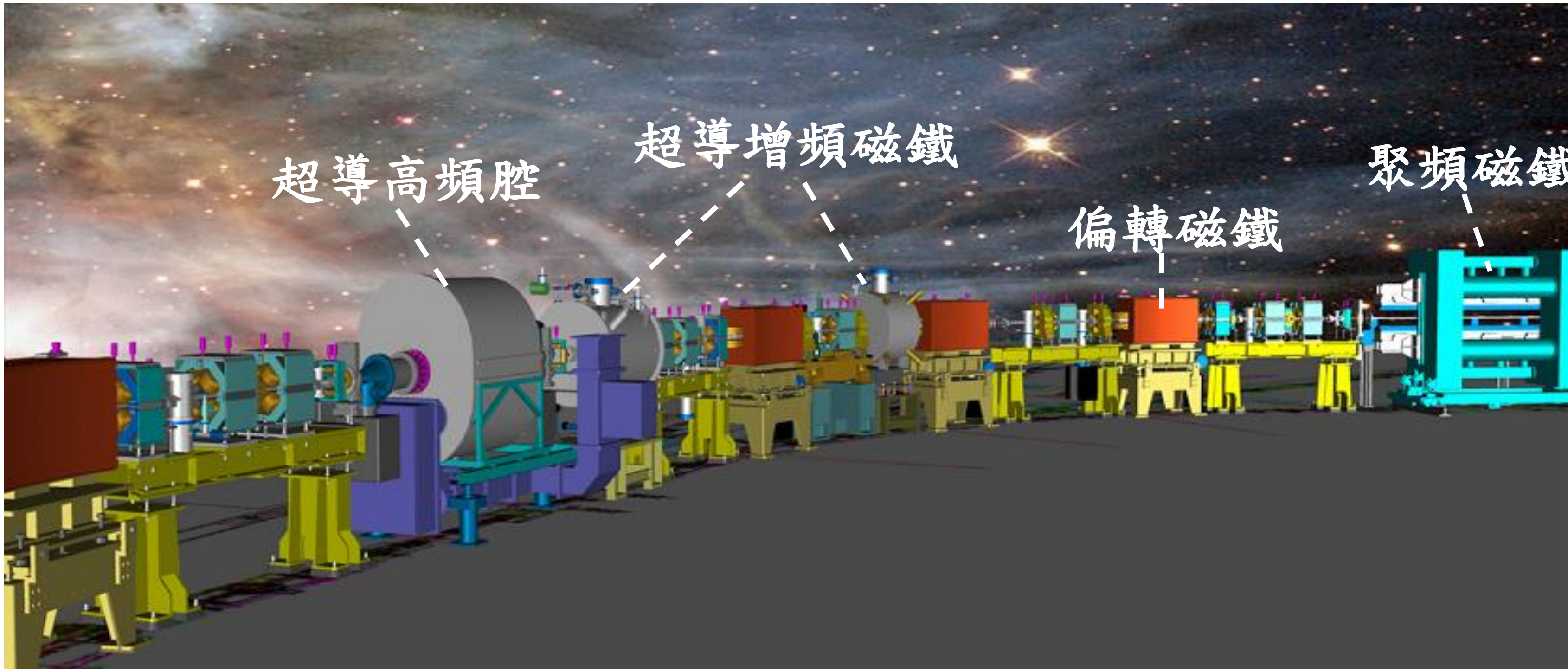
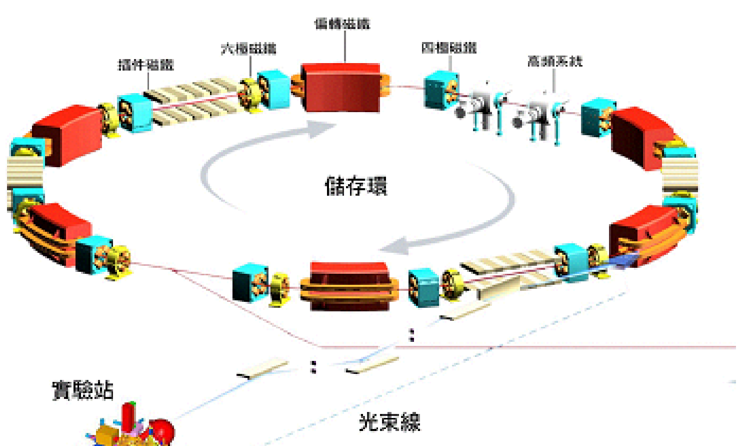
儲存環 3D 圖





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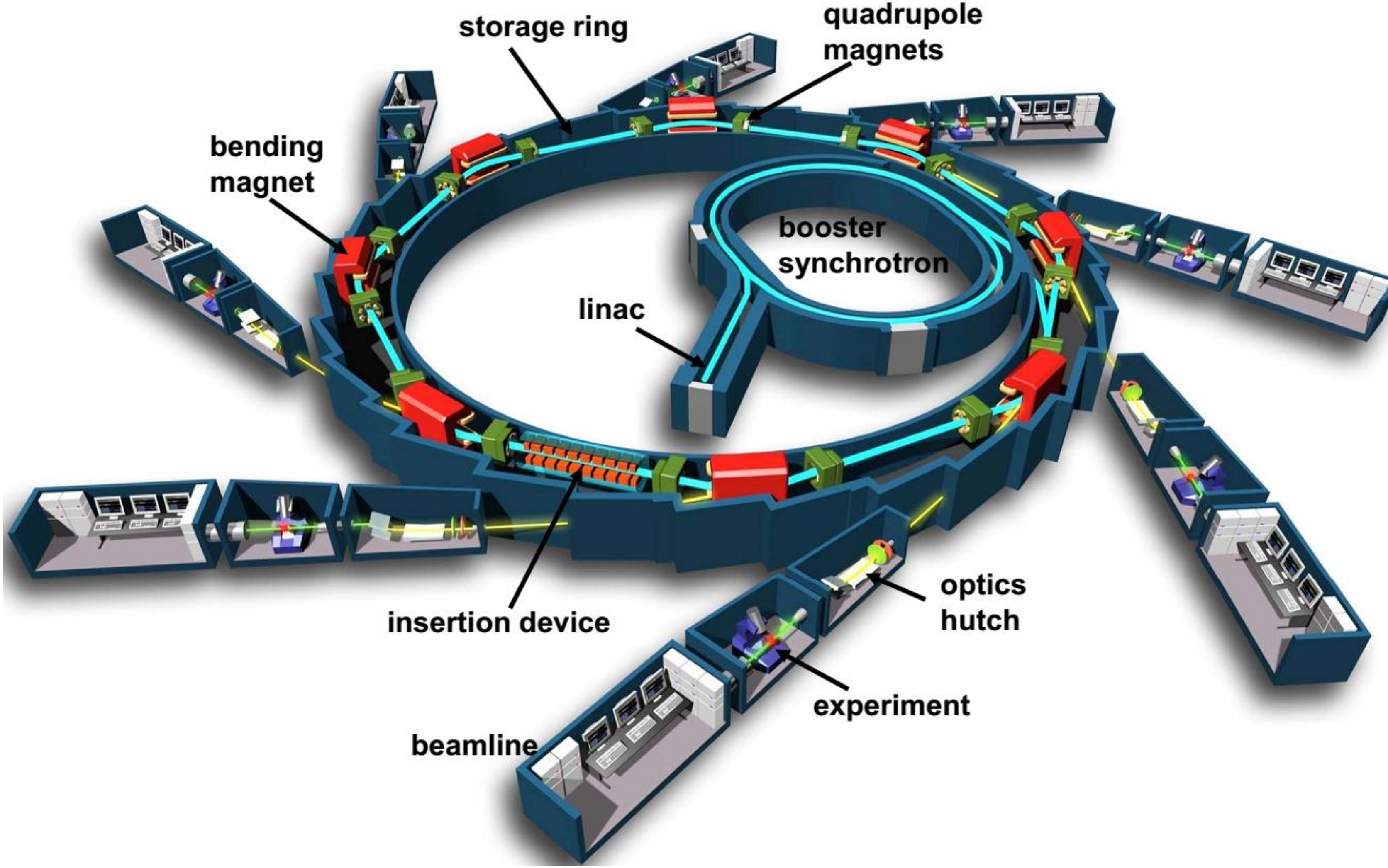
A Synchrotron Step by Step



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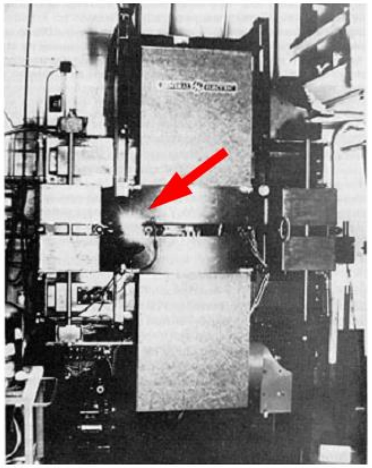
A brief history



- First observed:

  1947, General Electric, 70 MeV synchrotron

- First user experiments:

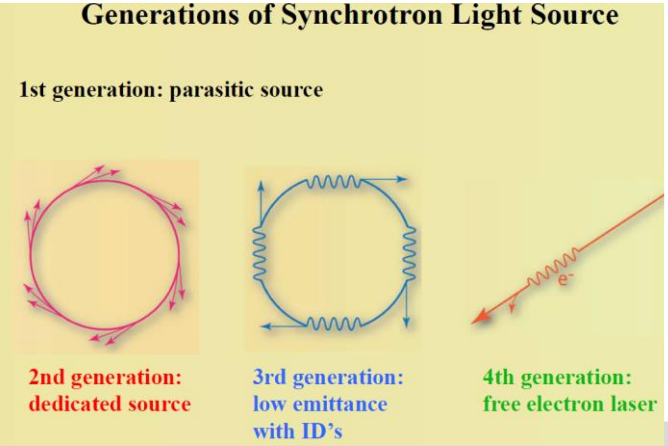
  1956, Cornell, 320 MeV synchrotron

- First insertion Device:

  1979, 7 pole wiggler, SSRL

- 1^{st} generation light sources: high energy physics synchrotrons and storage rings used parasitically for synchrotron radiation – eg DESY (Germany), INS-SOR (Tokyo), SPEAR (USA), (1960's, 1970's)
- 2^{nd} generation light sources: purpose built synchrotron light sources, eg Photon Factory, NSLS, Daresbury (1980s onwards)
- 3^{rd} generation light sources: optimised for high brilliance with low emittance and Insertion Devices; SPRing-8,ESRF, APS, Diamond, …(1990's onwards)
- Free Electron Laser sources: FLASH (Germany), LCLS (USA), SACLA (Japan), FERMI (Italy) … (2000's)
- Next??

2015 Cheiron School



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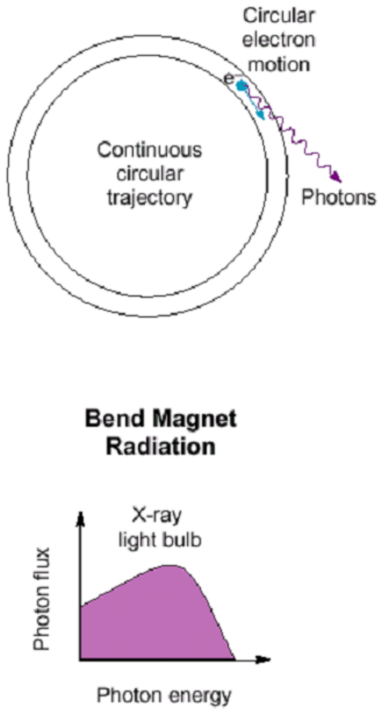
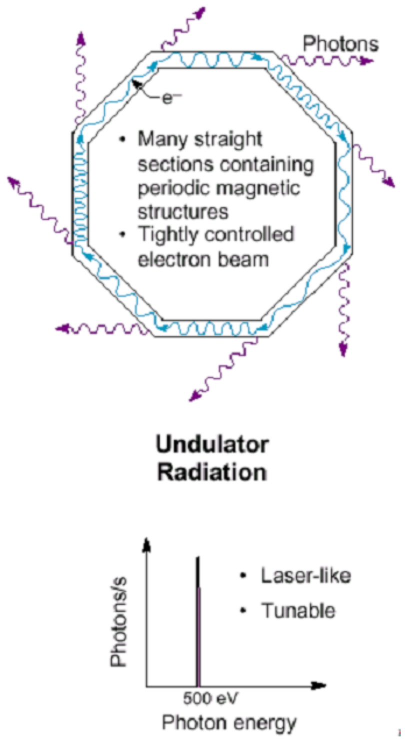
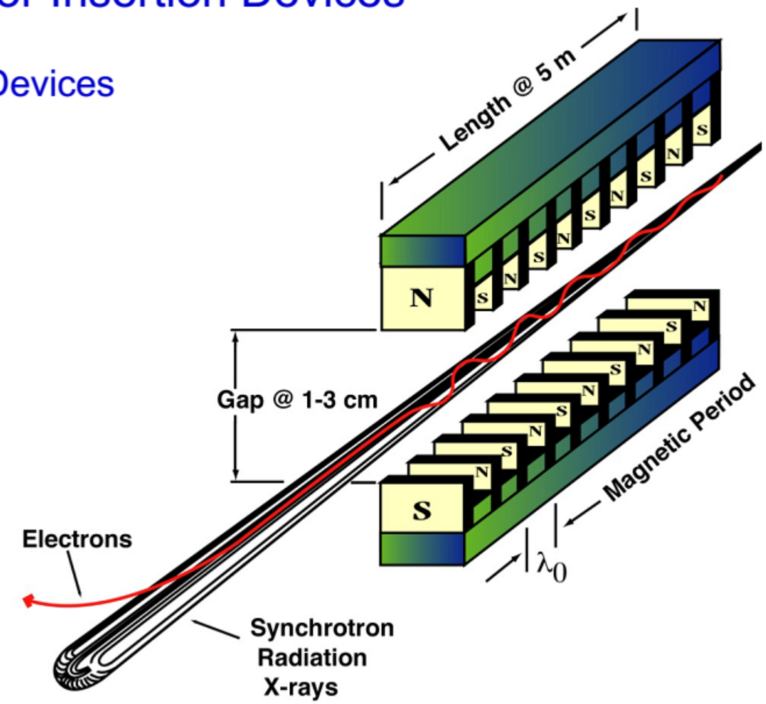
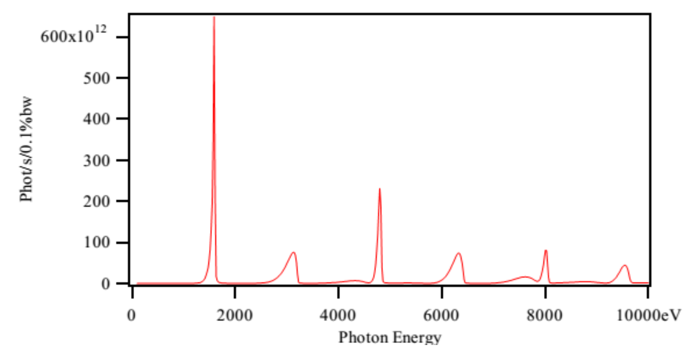
Third Generation Sources: Undulator Insertion Devices









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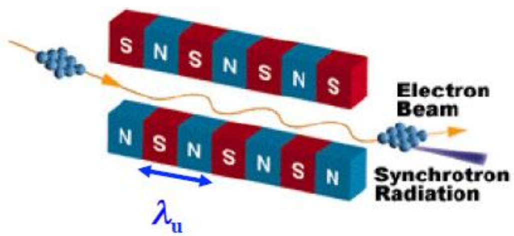
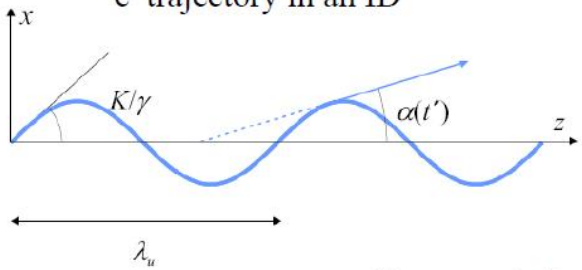
Angular distribution of synchrotron radiation emitted from various magnets

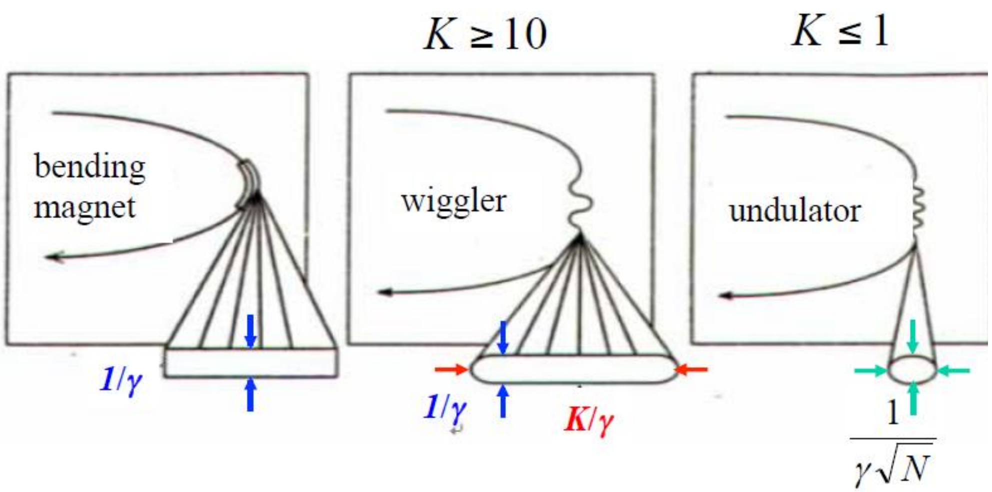
Wiggler or undulator

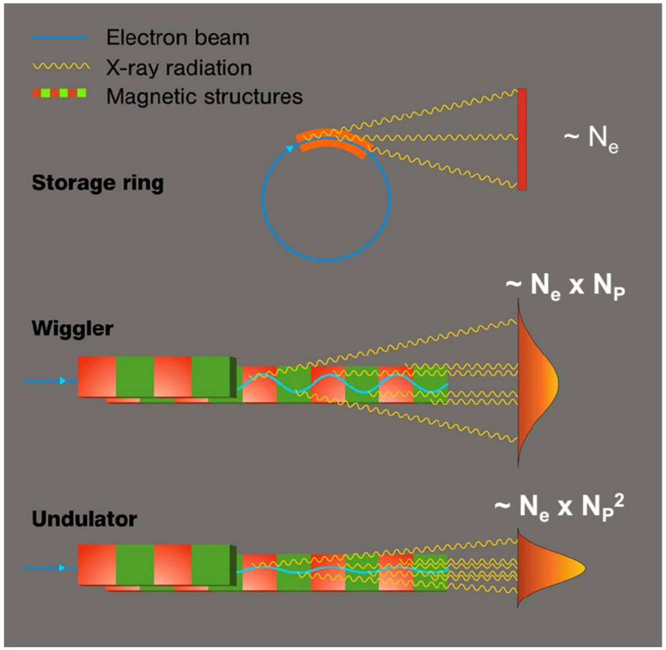


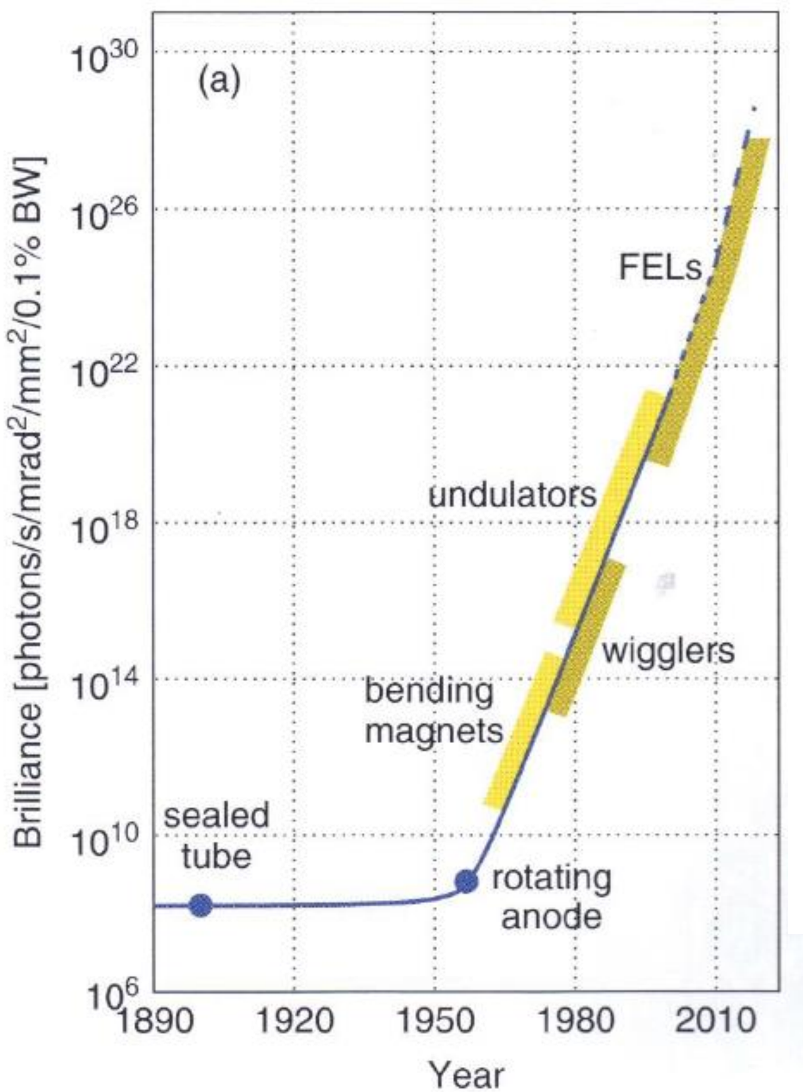
e- trajectory in an ID

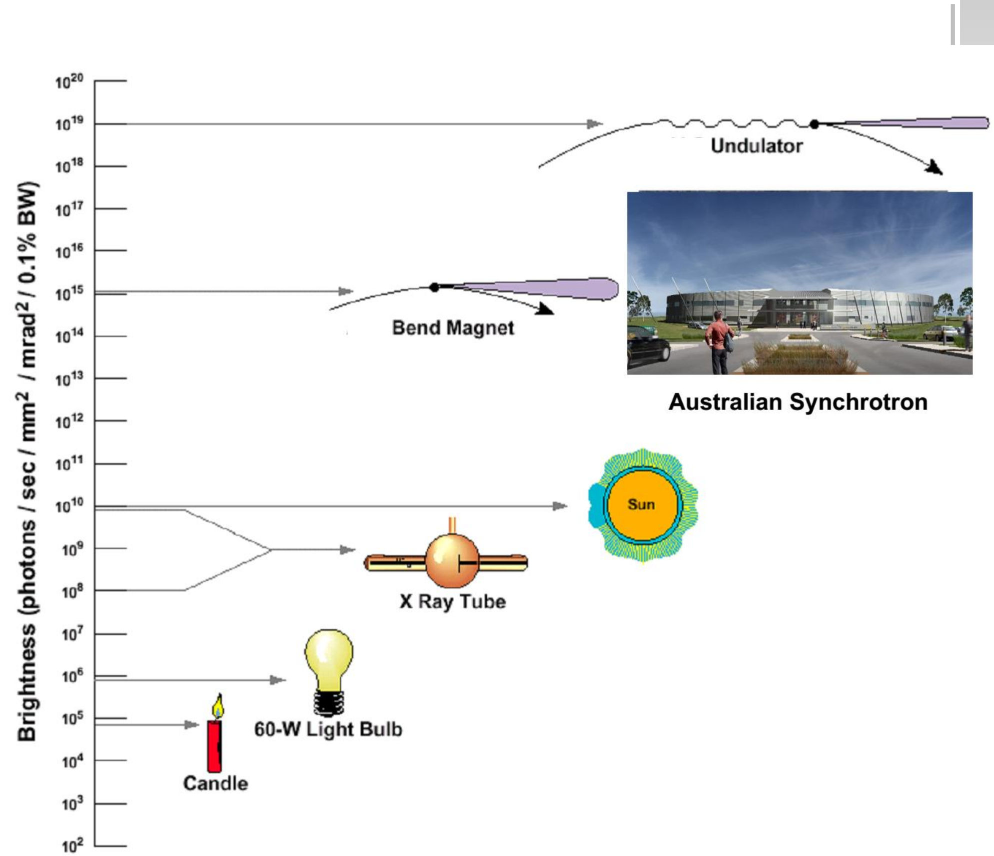


$K = \alpha_{max.} / \gamma^{-1}$





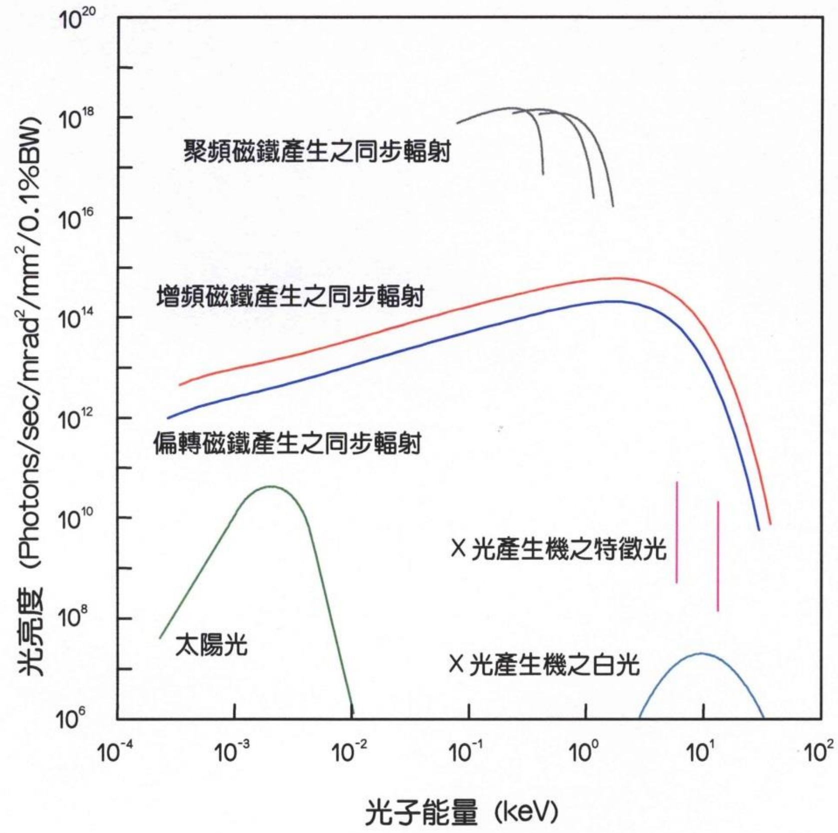

(a)
Brilliance [photons/s/mrad²/mm²/0.1% BW]
10^{30}
10^{26}
10^{22}
10^{18}
10^{14}
10^{10}
10^{6}
FELs
undulators
wigglers
bending magnets
sealed tube
rotating anode
1890
1920
1950
1980
2010
Year


Brightness (photons / sec / mm² / mrad² / 0.1% BW)
10^{20}
10^{19}
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
Undulator
Bend Magnet
Australian Synchrotron
Sun
X Ray Tube
60-W Light Bulb
Candle

Unique Features of Synchrotron Light Source

- **High intensity**
- **Continuous spectrum**
- **Excellent collimation**
- **High polarization**
- **Pulsed-time structure**

以X光為例，同步加速器光源在這個波段的亮度比傳統X光機還要強百萬倍以上！過去需要幾個月才能完成的實驗，現在只需幾分鐘便能得到結果。以往因實驗光源亮度不夠而無法探測的結構，現在藉由同步加速器光源，都可分析得一清二楚，也因此得以開發新的研究領域。



- 光子能量：一般單位爲電子伏特(eV)，一電子伏特爲電子在真空中通過一伏特電位差所獲得的能量。
- 光亮度：指單位時間內通過單位立體角的單位頻寬光子數。

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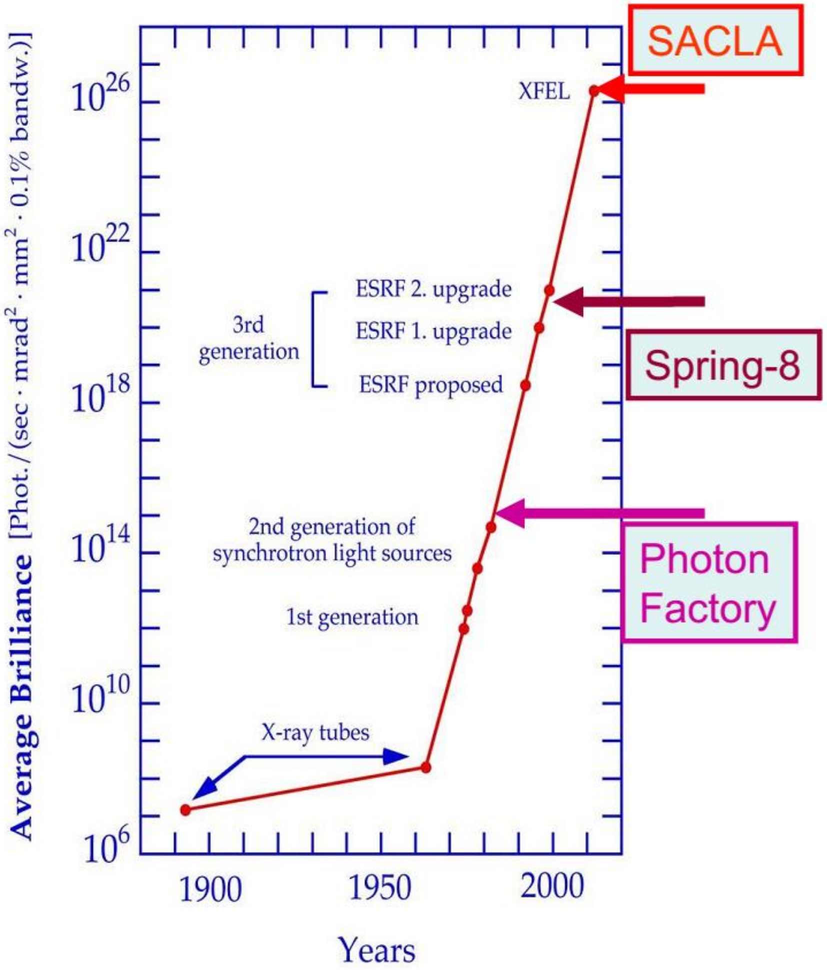
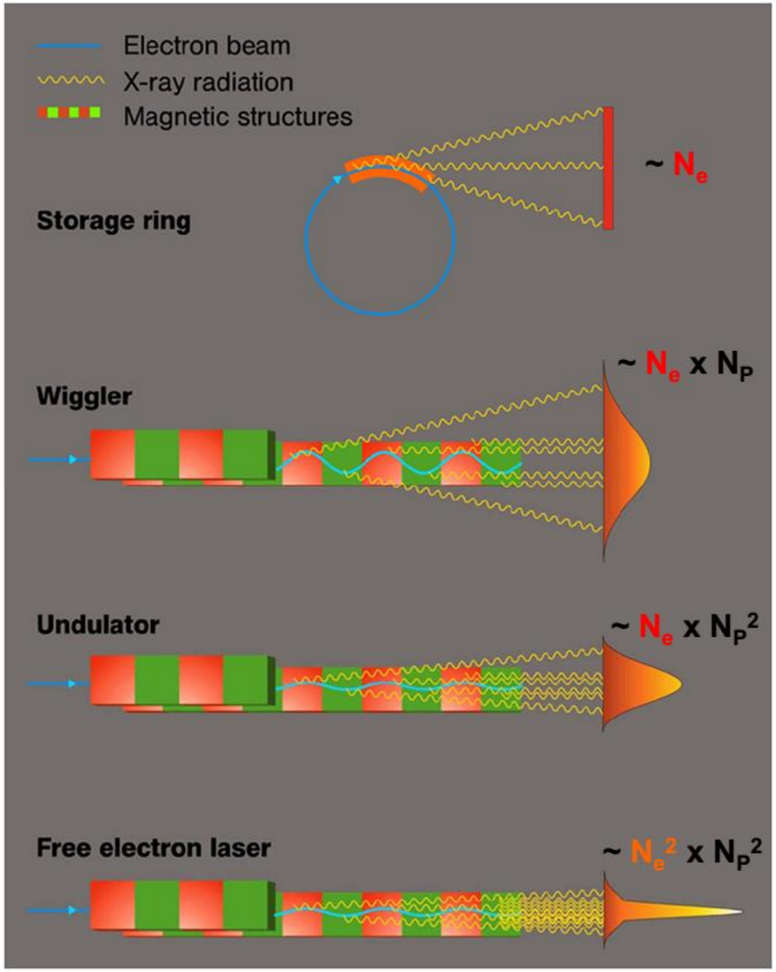
Next Step - X-ray Lasers?   Yes ➔ FELs





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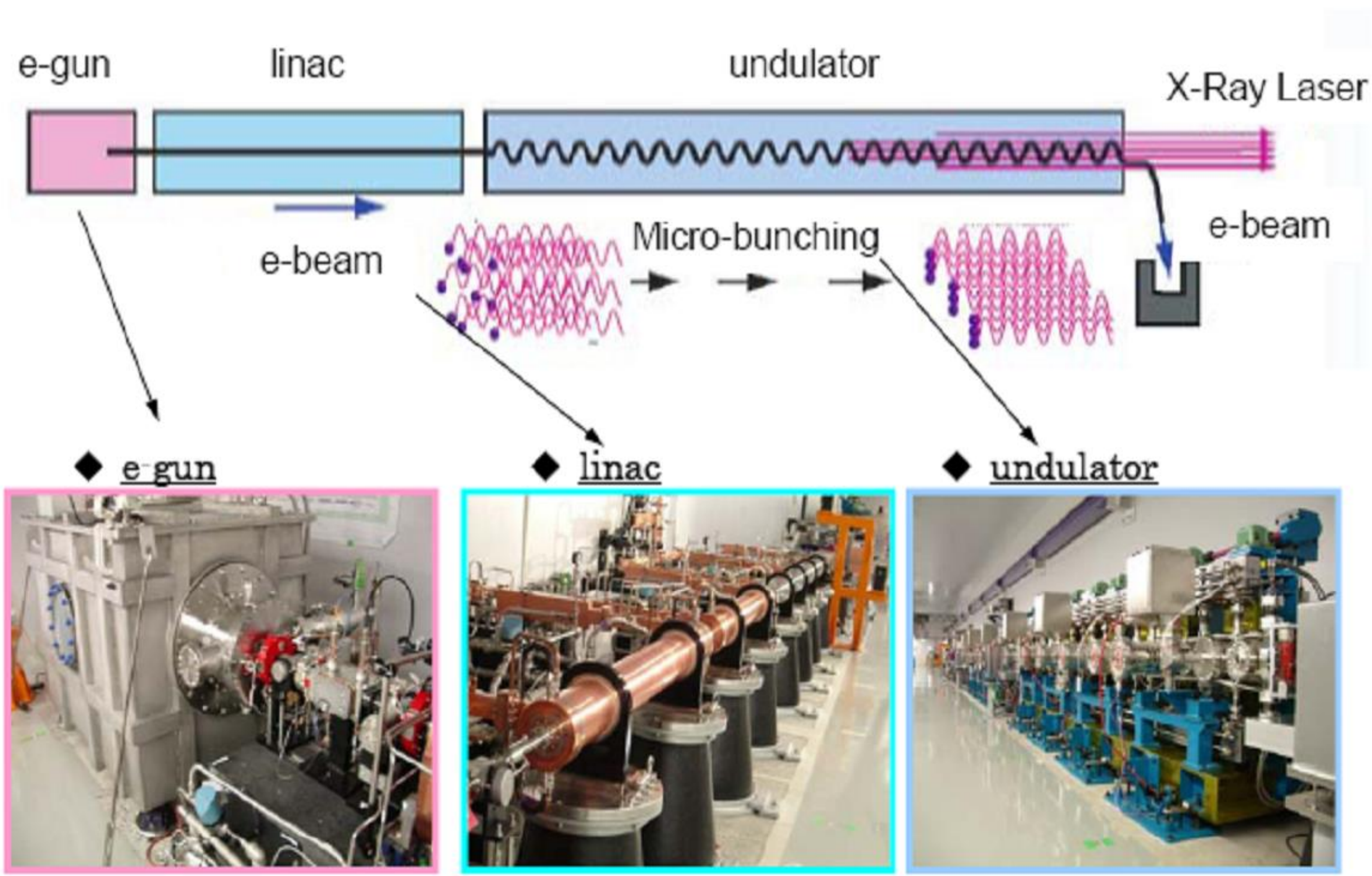
Linac-Based Free Electron Laser
Self-Amplified Spontaneous Emission (SASE)

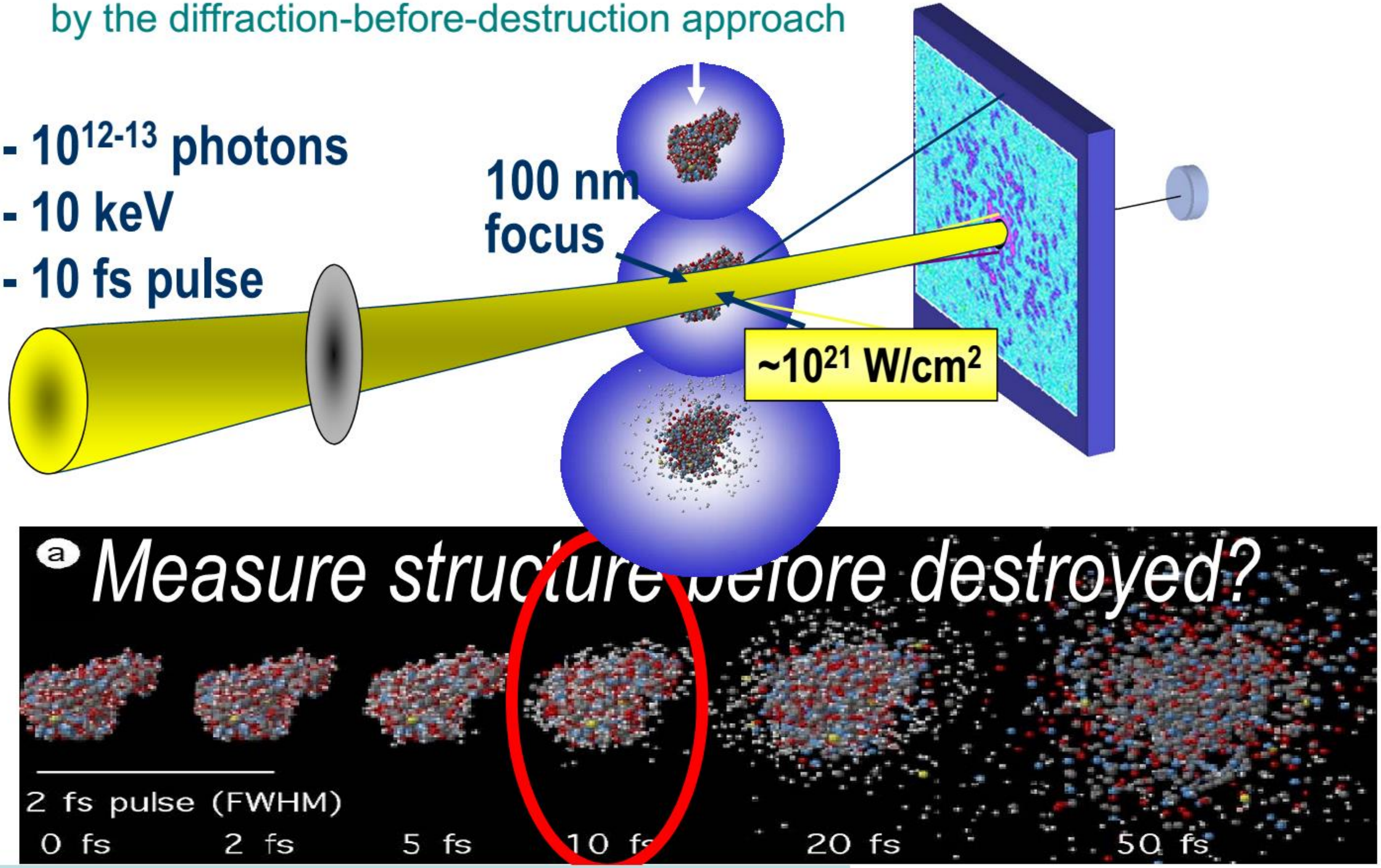



SACLA 1st beamline: 90m Undulator
2012 Cheiron School Tour

Coherent diffractive imaging of single particles

by the diffraction-before-destruction approach

- $10^{12\text{-}13}$ photons
- 10 keV
- 10 fs pulse



Calculations. in vacuum Neutze et al., Nature 2000

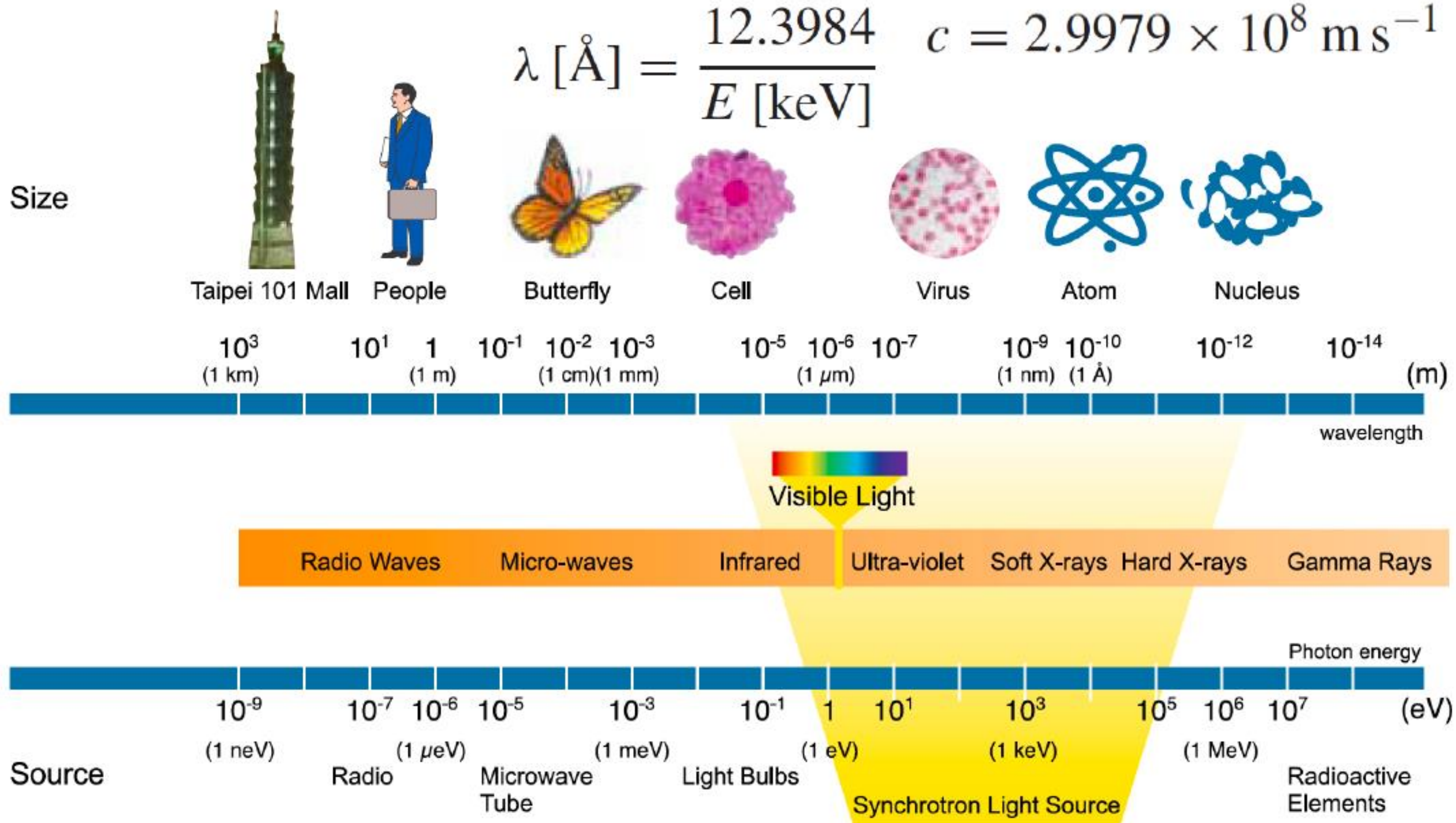
$$E = h\nu = hc/\lambda,$$

$$h = 6.626 \times 10^{-34}\ \mathrm{J\,s}$$

$$c = 2.9979 \times 10^{8}\ \mathrm{m\,s^{-1}}$$

Electromagnetic Spectrum

$$\lambda\,[\text{Å}] = \frac{12.3984}{E\,[\mathrm{keV}]}$$



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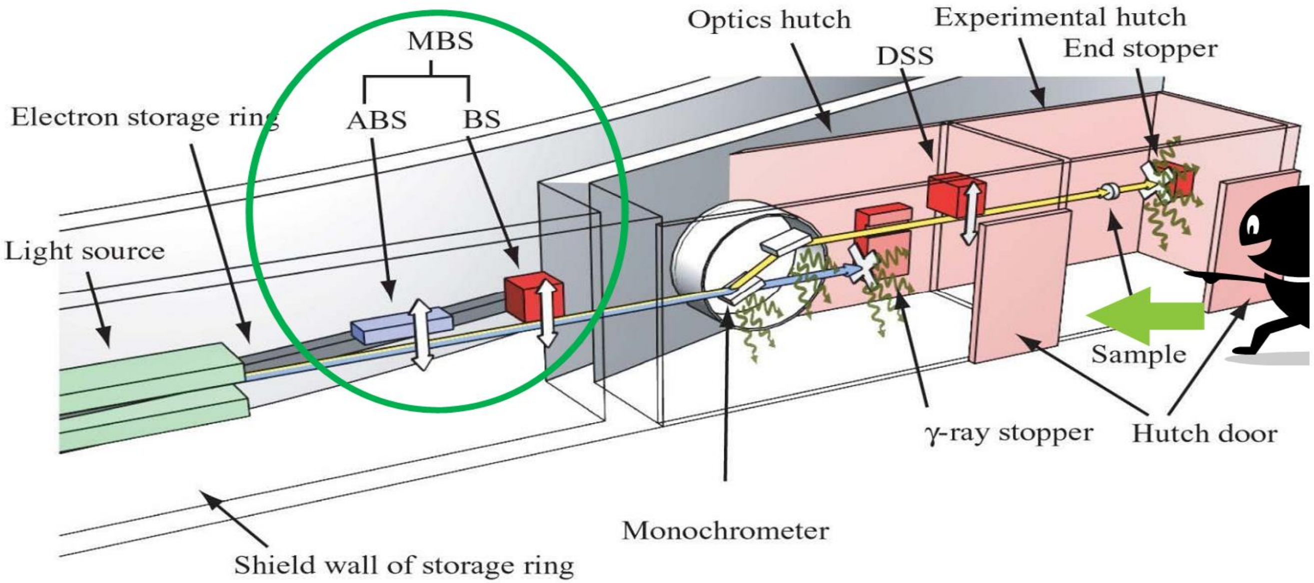
Beamline



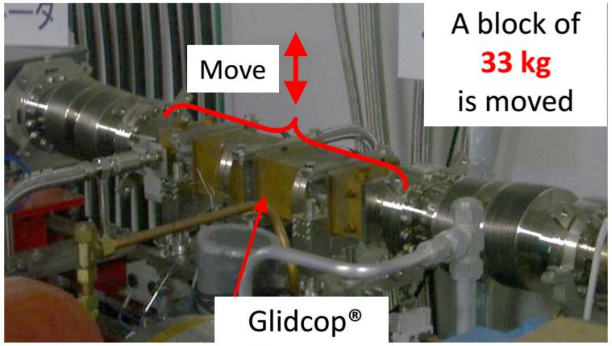
For safety

When we operate a main beam shutter (MBS), what happens ?

X-ray → **Absorber (Abs)** → **Beam shutter (BS)**

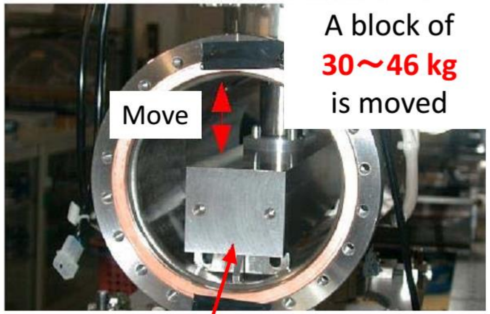
to protect BS from heat load

to shield you against radiation



A block of **33 kg** is moved

Glidcop®
(copper that is dispersion-strengthened with ultra-fine particles of aluminum oxide)



A block of **30～46 kg** is moved

Heavy metal
(alloy of tungsten)

the thermal conductivity not so high

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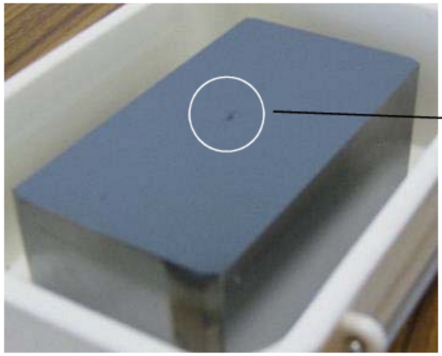
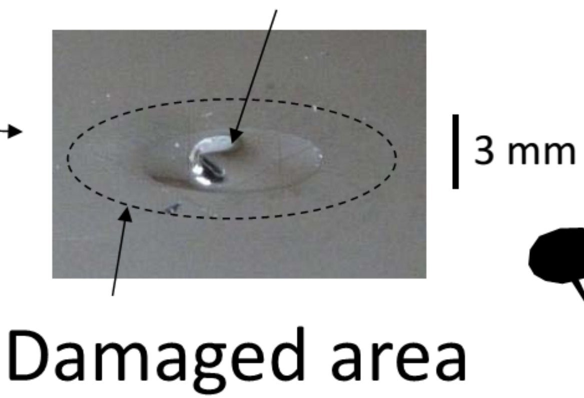
If an optical component is irradiated by too much power ....

One user opened FE slit excessively.

2kW

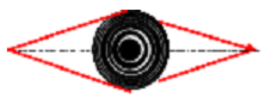
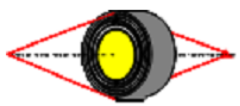


LN2-cooled Si crystal



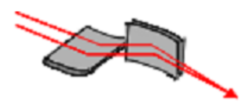
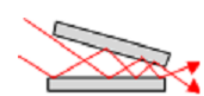
Slit : *"Too much is as bad as too little"*

Overview of x-ray focusing devices

Diffraction	focus size, focal length [energy]	energy range	aberration -coma -chromatic -figure error
 Fresnel Zone Plate	12 nm, f = 0.16 mm [0.7 keV], 30 nm, f = 8 cm [8 keV]	soft x-ray hard x-ray	-coma small -chromatic exist -figure error small
 Sputter sliced FZP	0.3 μm, f = 22 cm [12.4 keV], 0.5 μm, f = 90 cm [100 keV]	8-100 keV	-coma small -chromatic exist -figure error large→small
 Bragg FZP	2.4 μm, f = 70 cm [13.3 keV]	mainly hard x-ray	-coma small -chromatic exist -figure error small
 Multilayer Laue Lens	16 nm(1D), f = 2.6 mm [19.5 keV], 25nm × 40nm, f=2.6mm,4.7mm [19.5 keV]	mainly hard x-ray	-coma large -chromatic exist -figure error small

Refraction	focus size, focal length [energy]	energy range	aberration -coma -chromatic -figure error
 Pressed Lens	1.5 μm, f = 80 cm [18.4 keV], 1.6 μm, f = 1.3 m [15 keV]	mainly hard x-ray	-coma small -chromatic exist -figure error large
 Etching Lens	47nm × 55nm, f = 1cm, 2cm [21 keV]	mainly hard x-ray	-coma small -chromatic exist -figure error small

Reflection

 Kirkpatrick-Baez Mirror	7 nm × 8nm, f=7.5cm [20 keV]	soft x-ray hard x-ray	-coma large -chromatic not exist -figure error small
 Wolter Mirror	0.7 μm, f = 35 cm [9 keV]	<10 keV	-coma small -chromatic not exist -figure error large
 X-ray Waveguide	95 nm, [10 keV]	soft x-ray hard x-ray	-coma large -chromatic not exist -figure error large

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World Map of Synchrotron Facilities

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Outline

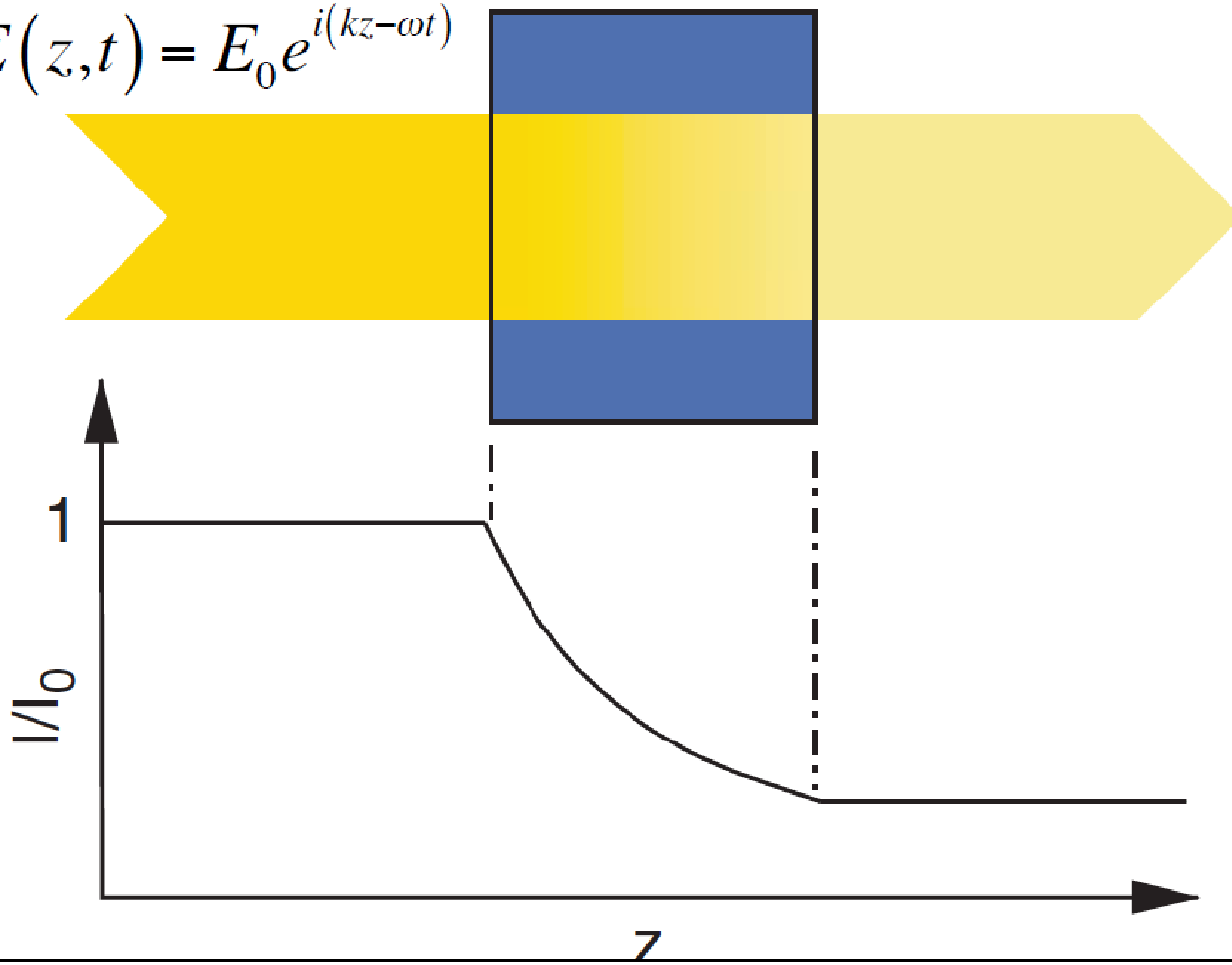
- Synchrotron Light Source
- Application of Synchrotron Light
- X-ray nano probe at TPS

Absorption

$$E(z,t) = E_0 e^{-n_I kz} e^{i(n_R kz-\omega t)}$$

$$E(z,t) = E_0 e^{i(kz-\omega t)}$$

$$\frac{I}{I_0} = e^{-\mu z}$$



absorption coefficient

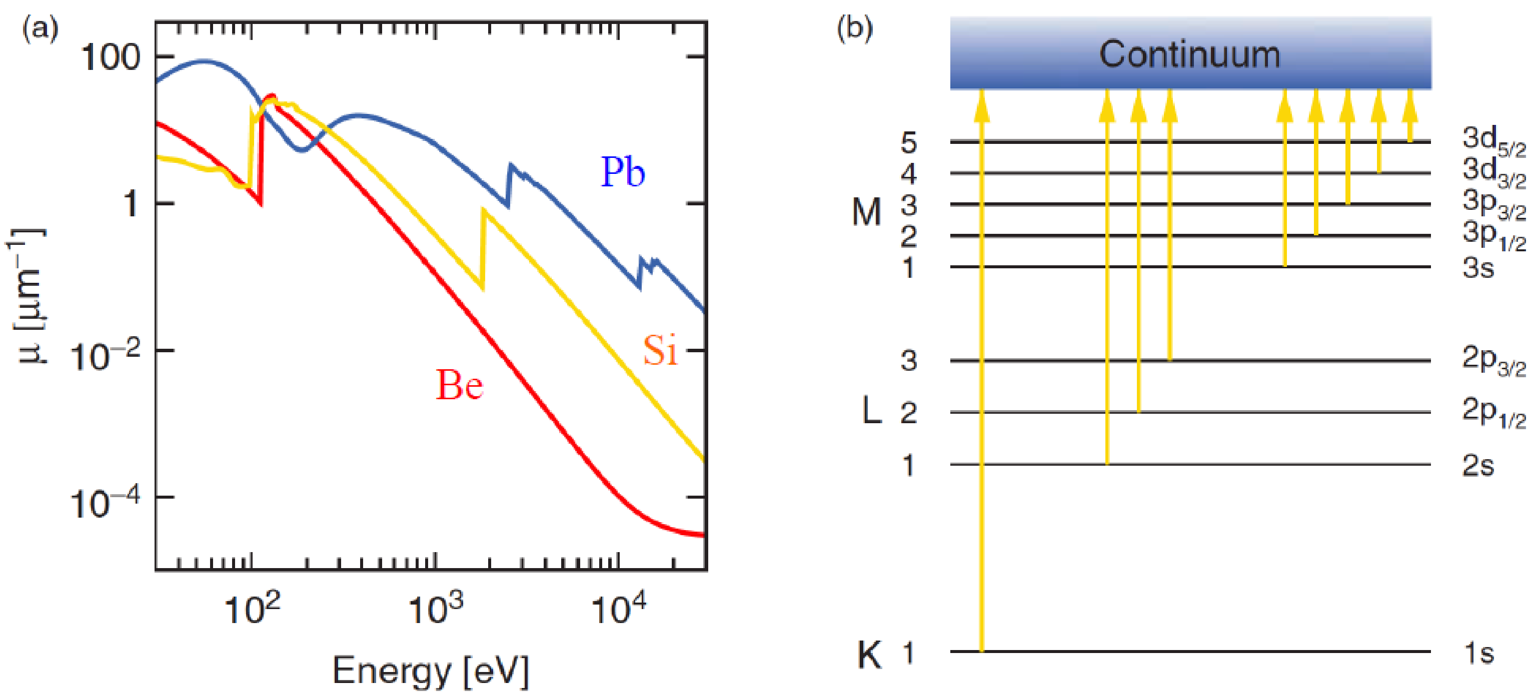
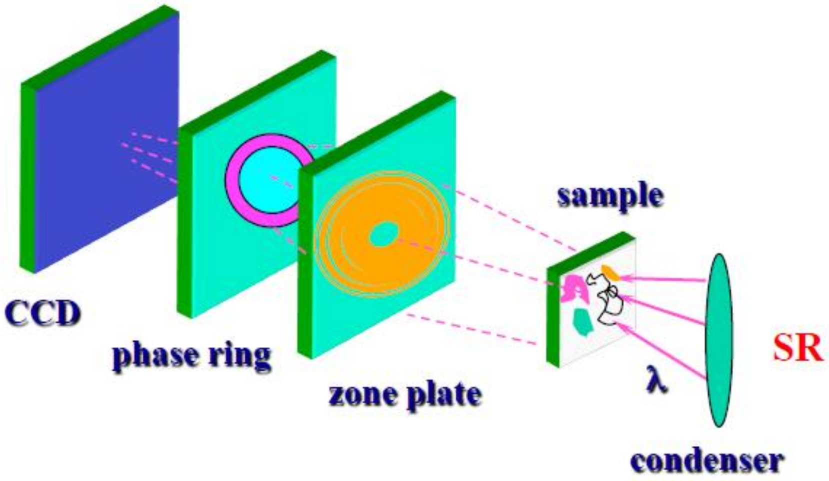


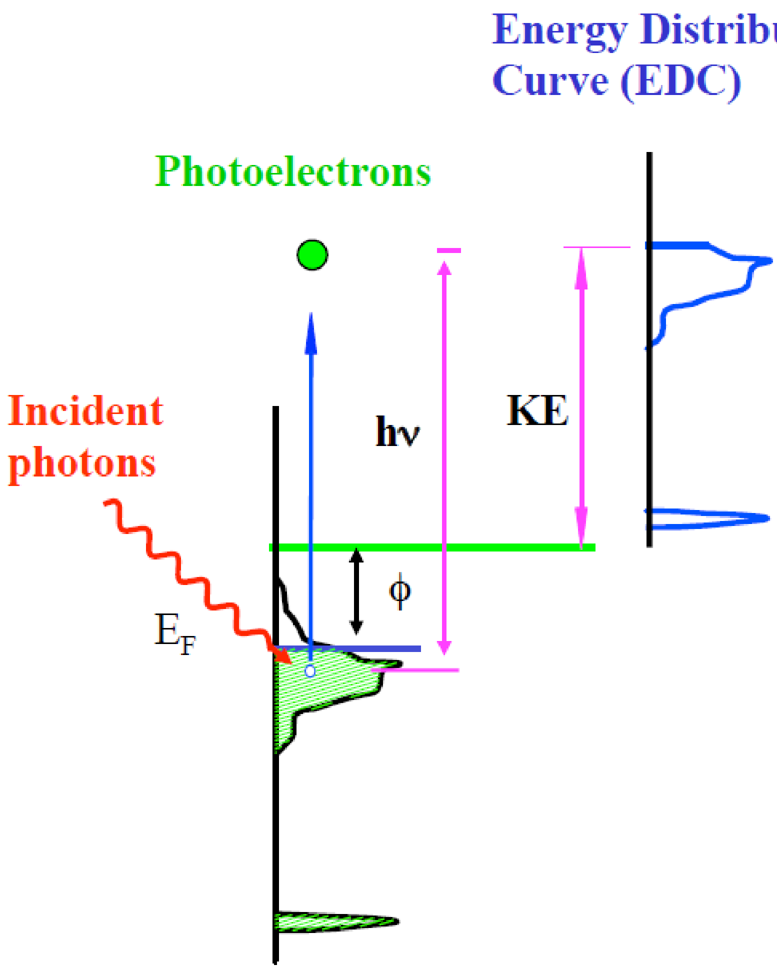
Figure 2.16 *(a) The x-ray absorption coefficient μ for beryllium (red curve), silicon (yellow) and lead (blue) as a function of the photon energy. (b) Sharp increases in the absorption occur when the photon energy is just sufficient to eject the electron from the electronic orbital to the continuum. The x-ray absorption (left) and atomic orbital labellings (right) are shown.*

Transmission X-ray Microscope (TXM)



energy: 8 keV
3D tomography
spatial resolution = 60 nm

Photoemission Spectroscopy



$$KE = h\nu - BE - \phi$$

$$\frac{d\sigma}{d\Omega} \propto \sum \left| \left\langle \Psi_f \middle| A \cdot P \middle| \Psi_i \right\rangle \right|^2 \cdot \delta\left(E_f - E_i - h\nu\right)$$

Selection rule: $\Delta\, l = \pm 1$

$\Delta\, m_l = 0$ (linearly polarized)

$\Delta\, m_l = +1$ (L. circularly polarized)

$\Delta\, m_l = -1$ (R. circularly polarized)

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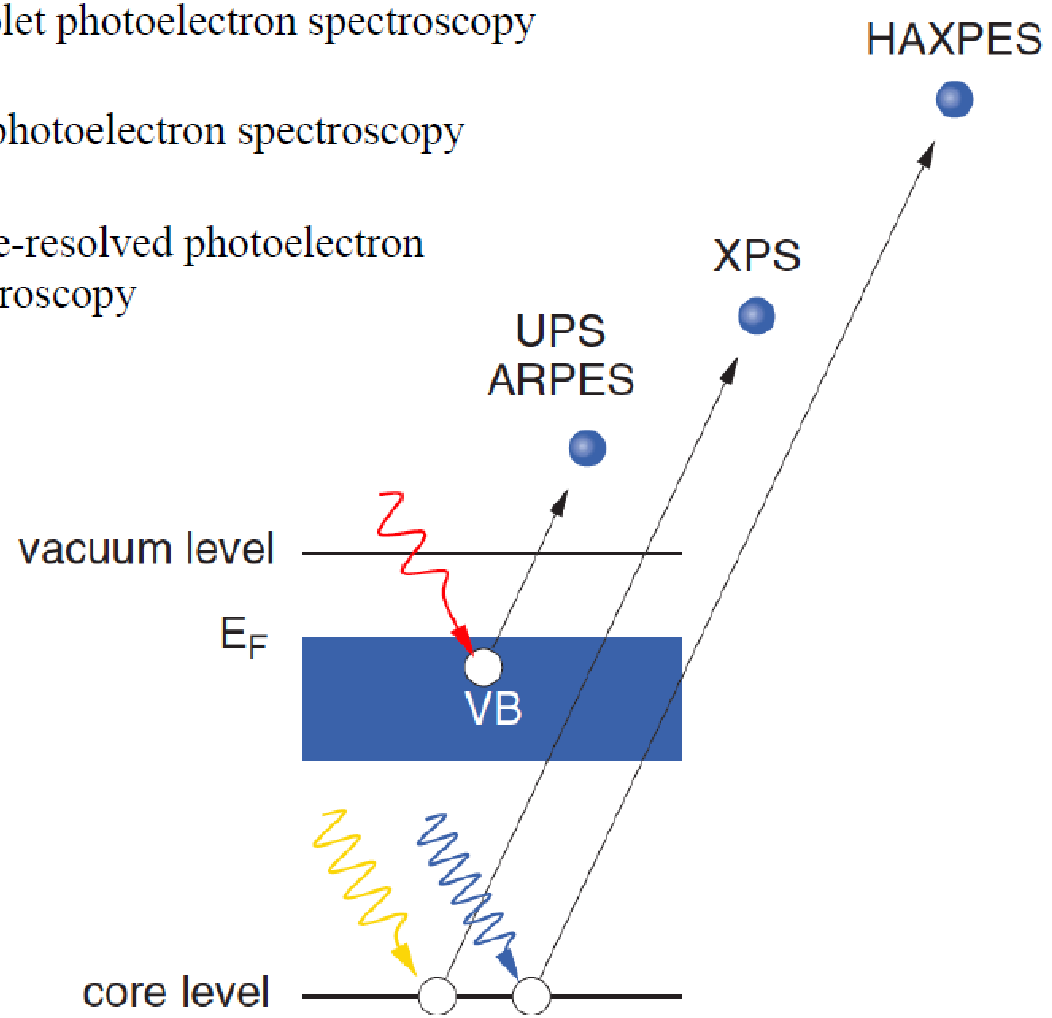
HAXPES = Hard X-ray photoelectron spectroscopy

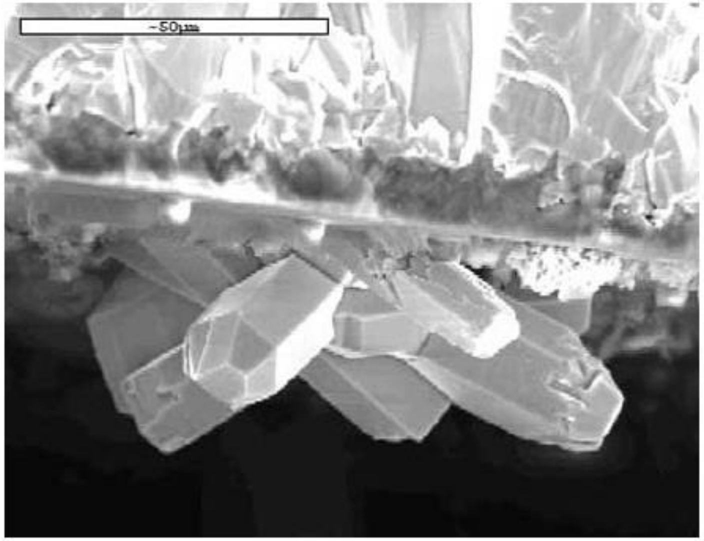
UPS = ultraviolet photoelectron spectroscopy

XPS = X-ray photoelectron spectroscopy

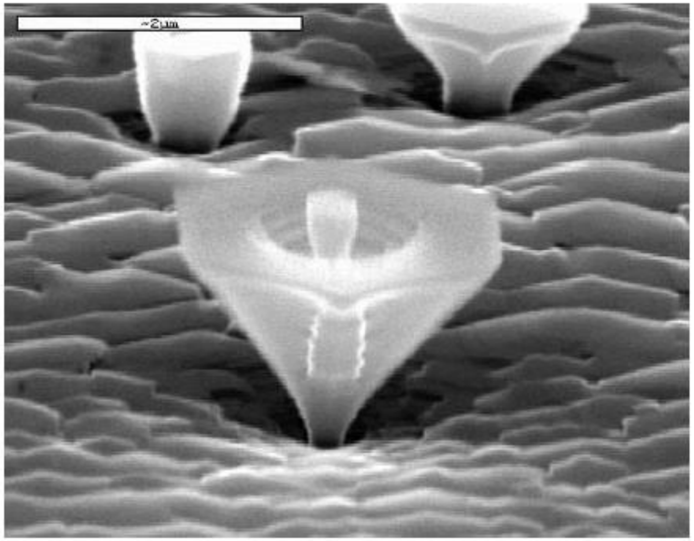
ARPES = angle-resolved photoelectron spectroscopy



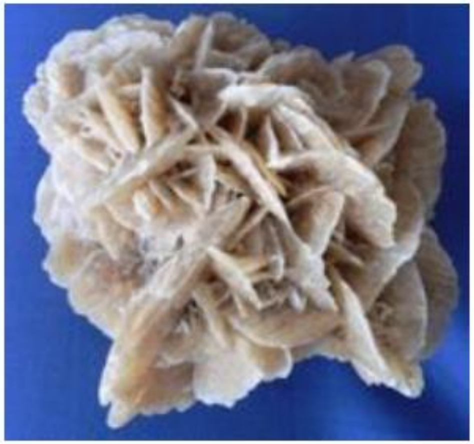
"Crystals"



GaN (hexagonal) crystal cluster grown by hydride vapor phase epitaxy



AlN pyramids grown by MBE



Sand Rose of gypsum (石膏) crystals

Bragg Law - X-ray reflected by the (hkl) planes

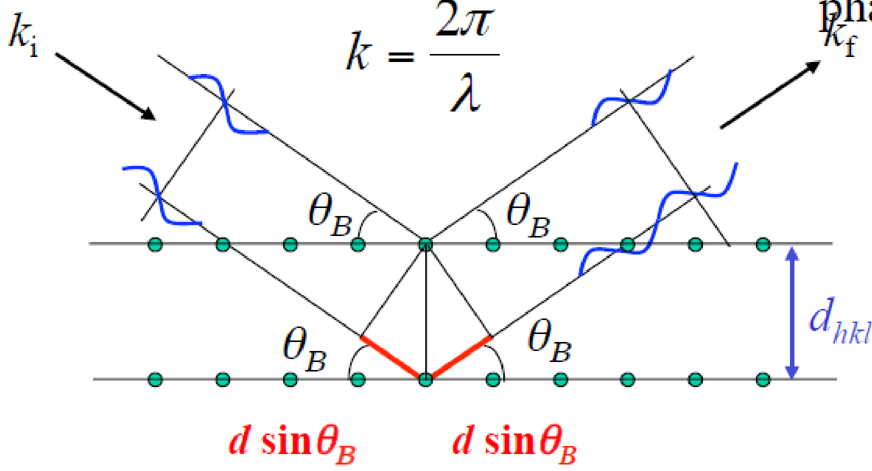
$$\vec{E} = E_0 e^{i(\vec{k}\cdot\vec{r} - \omega t)}$$

$$k = \frac{2\pi}{\lambda}$$

Path Difference $L = 2d_{hkl}\, sin\theta_B$

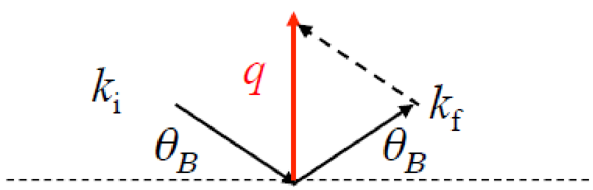
Constructive interference: $L = n\lambda$

phase difference $\phi = k\,L$



Bragg Law: $2d_{hkl}\, sin\theta_B = n\lambda$

$$2\pi \frac{2}{\lambda} \sin\theta_B = 2\pi \frac{1}{d_{hkl}} = G_{hkl}$$



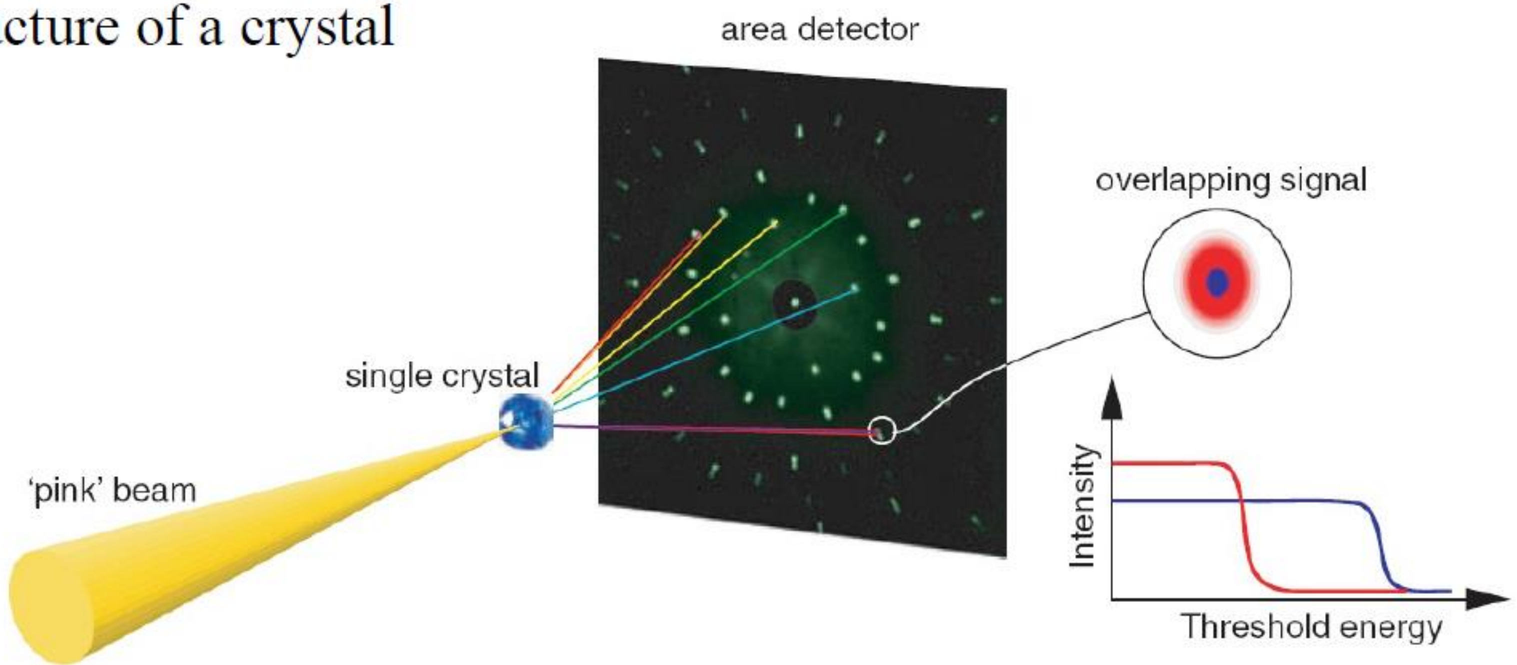
scattering vector $\vec{q} = \vec{k}_f - \vec{k}_i \quad q = 2\frac{2\pi}{\lambda}\sin\theta_B$

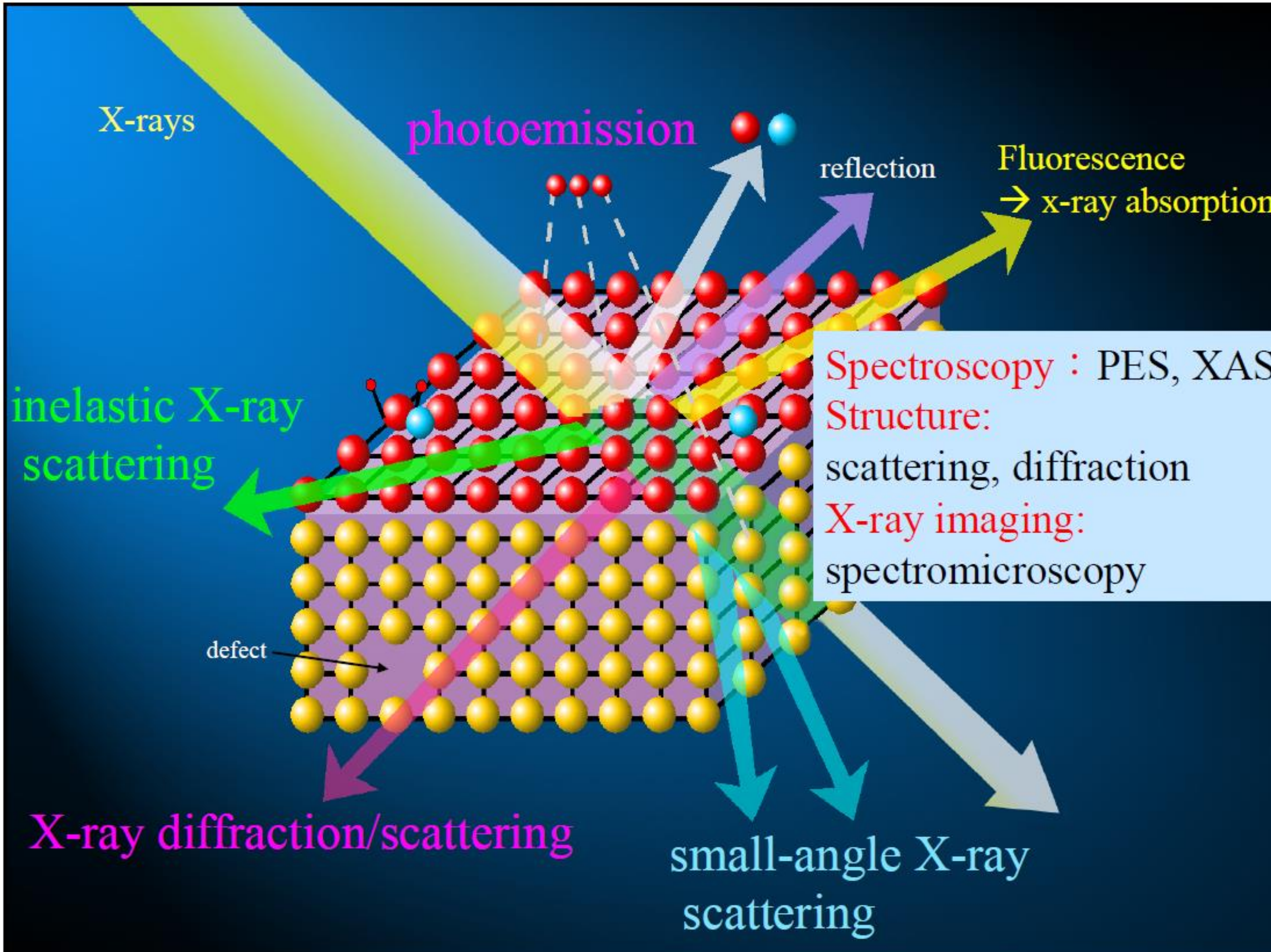
$$q = G_{hkl}$$

In terms of diffraction, two key characteristics of a set of crystal planes :
$1/d$ and orientation

Single Crystal Diffraction - Laue Diffraction

- Method: stationary
- Light source: a polychromatic 'pink' beam (e.g. ΔE <1 keV @ 10 keV)
- Applications: orient single crystals, determine their crystal quality, dynamical studies of transient crystalline states (time-resolved study)
- Disadvantage: not well-suited for determining the full atomic structure of a crystal





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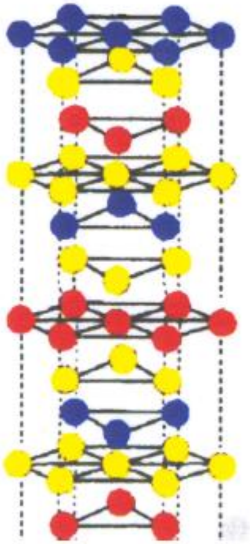

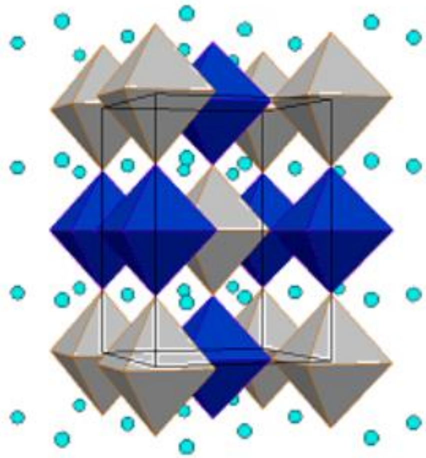

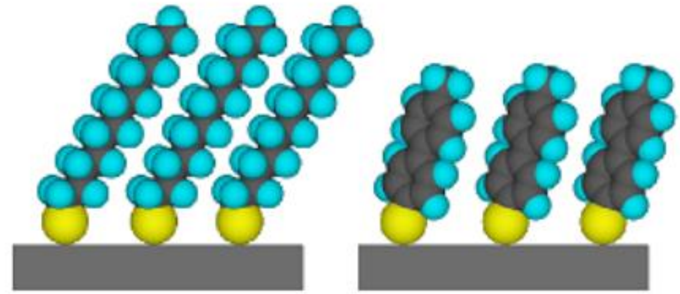

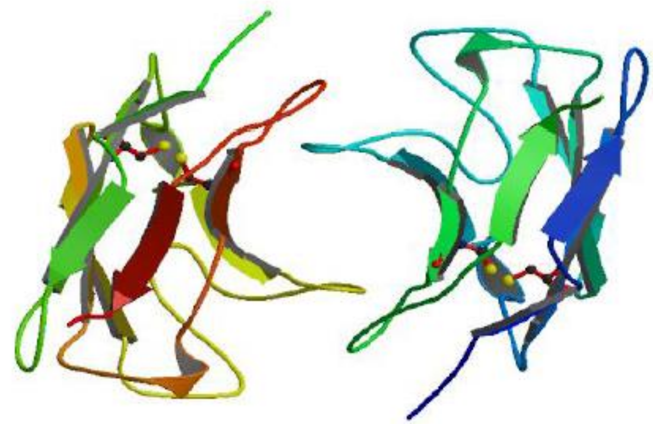

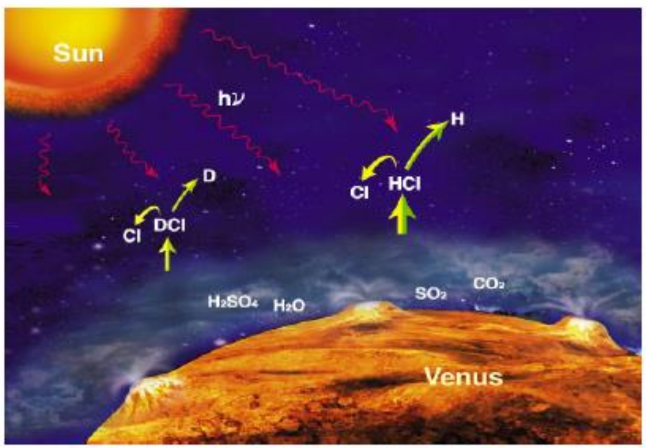

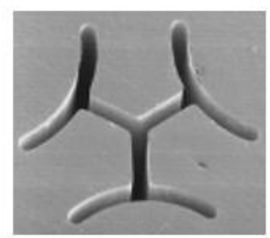

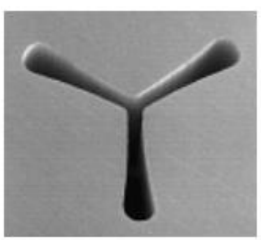

Synchrotron light source is a powerful tool for basic and applied studies in physics, chemistry, materials, biology and medicine, and their many subfields.

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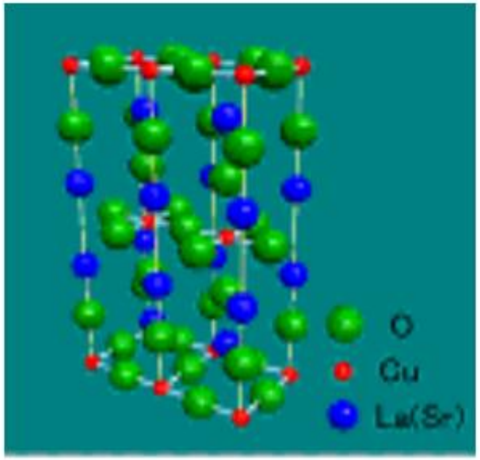
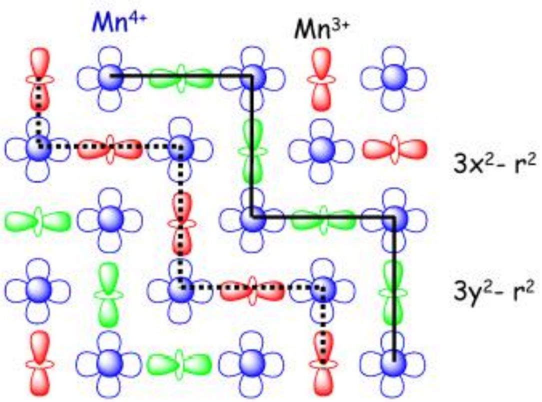
Condensed-Matter Physics



Electronic properties of novel materials can be revealed with X-ray scattering.



$La_{0.5}Sr_{1.5}MnO_4$

(Source: website of Railway Technical Research Institute, Japan)

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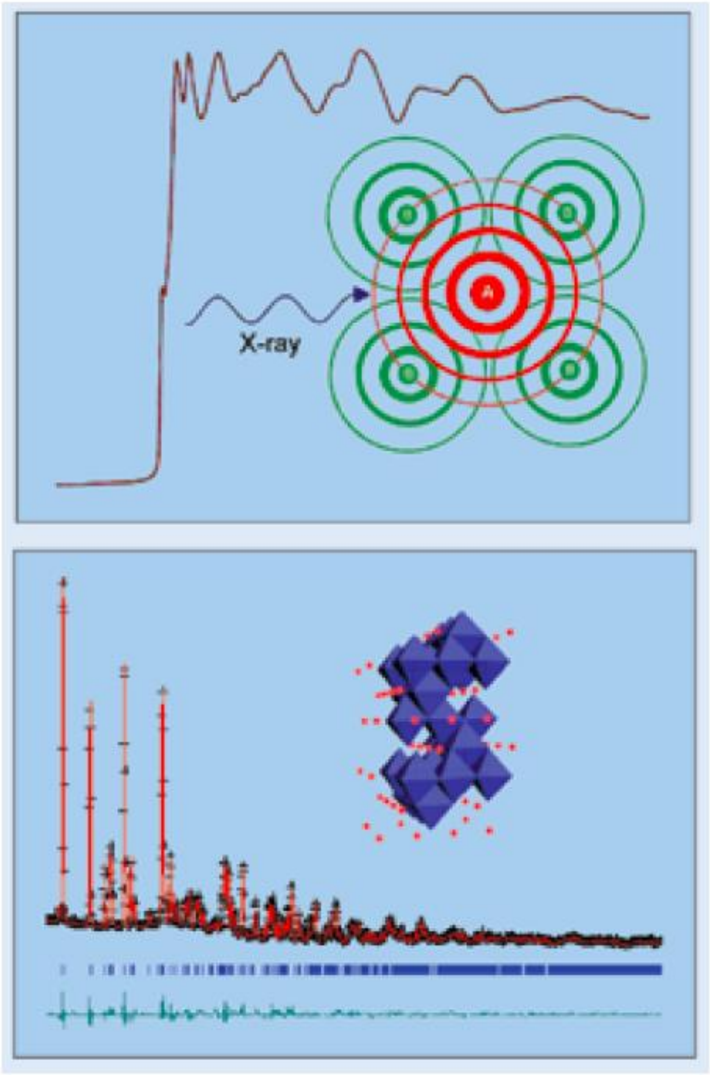
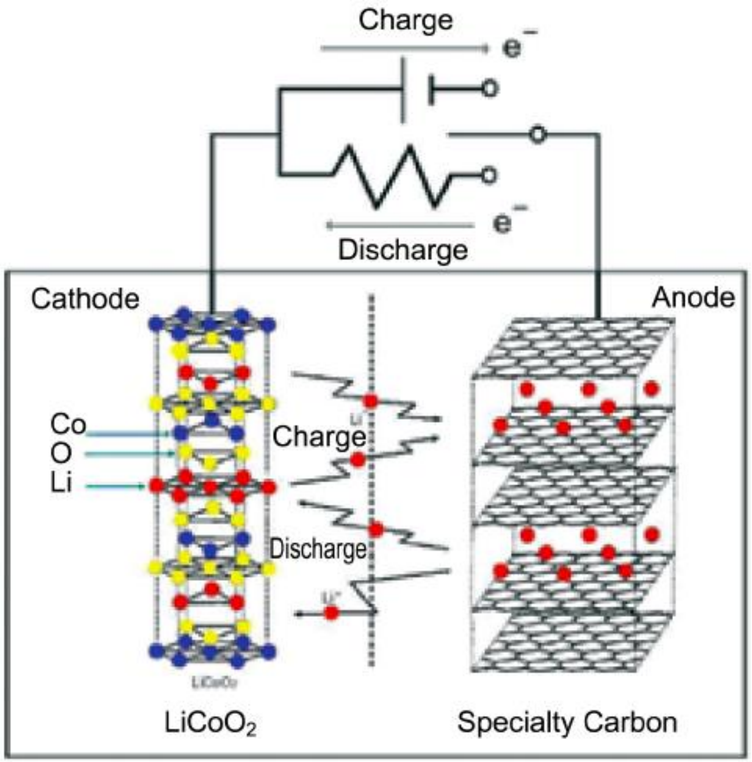
Energy Science





structure ←→ electrochemical properties of electrode

develop novel electrode materials.

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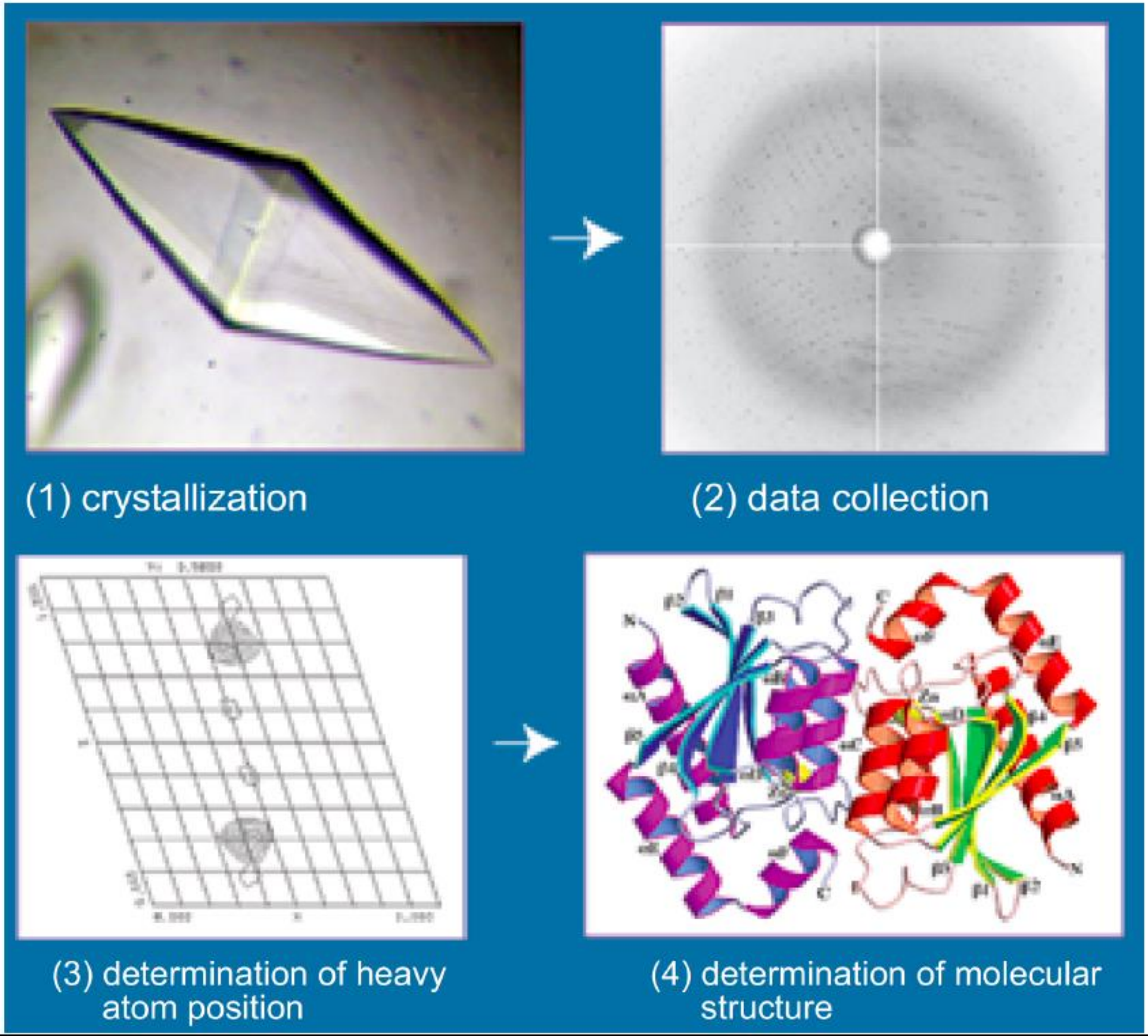
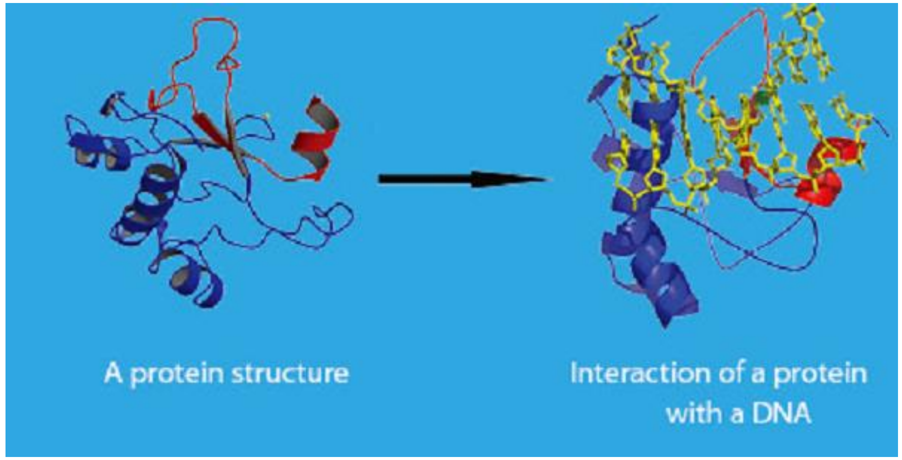
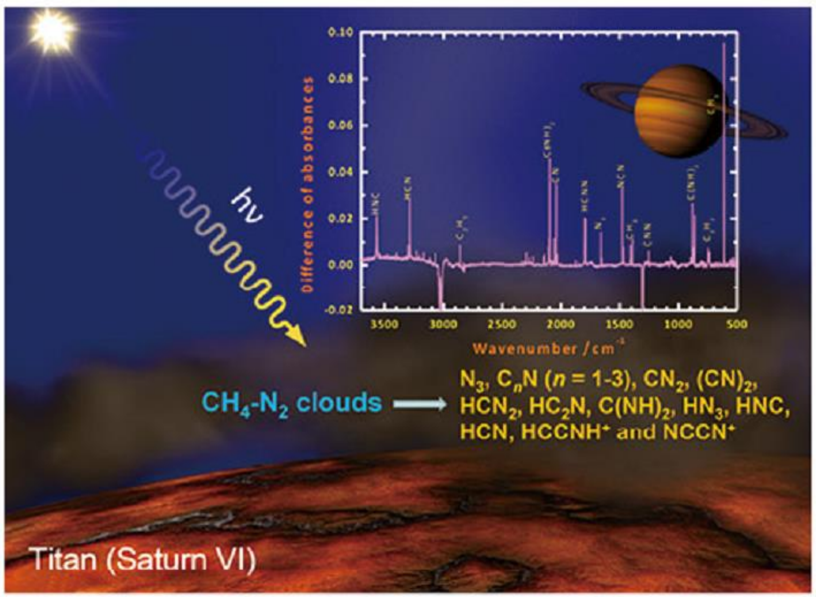
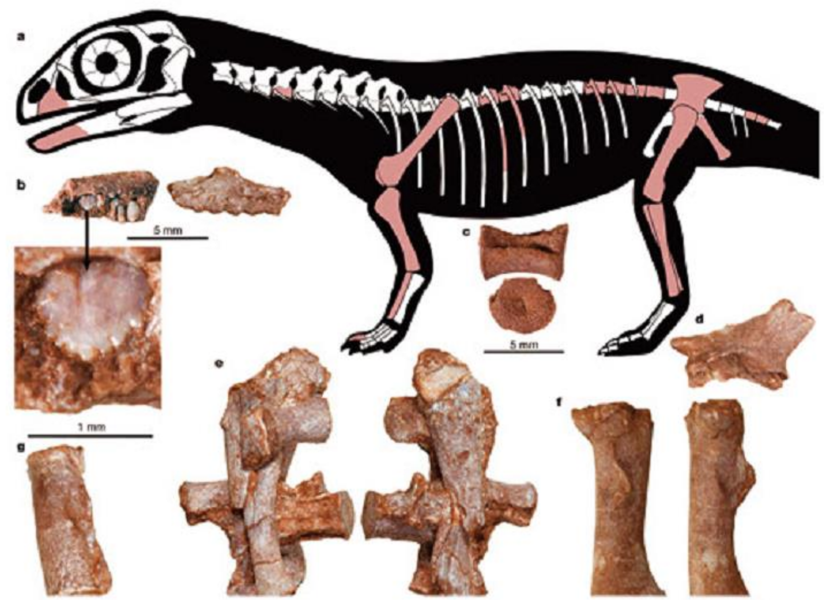
Biological structure: protein crystallography









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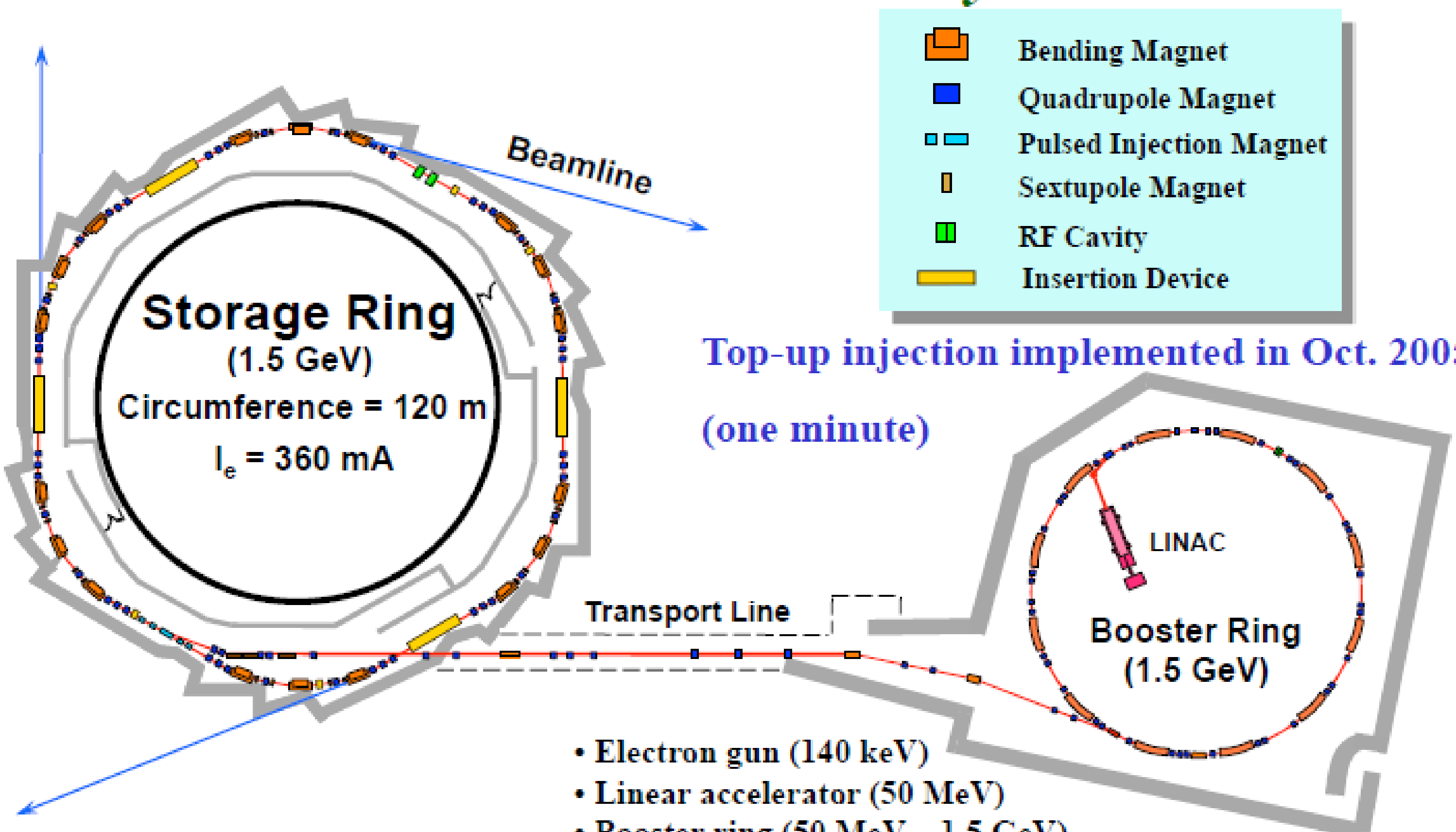
Taiwan Light Source (TLS)

Accelerator Facility



Top-up injection implemented in Oct. 2005 (one minute)

- Electron gun (140 keV)
- Linear accelerator (50 MeV)
- Booster ring (50 MeV ~ 1.5 GeV)

TLS Experimental Hall

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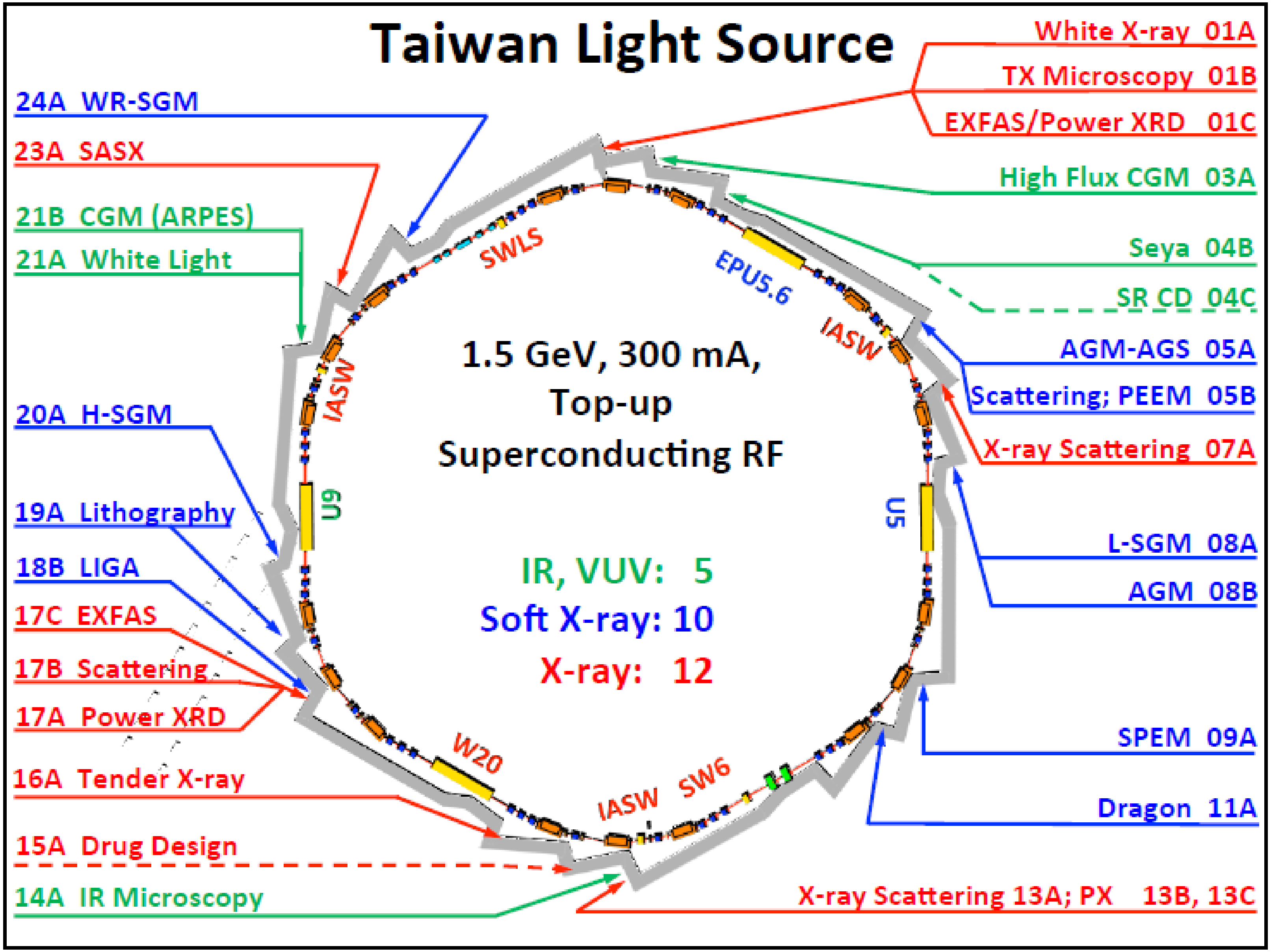

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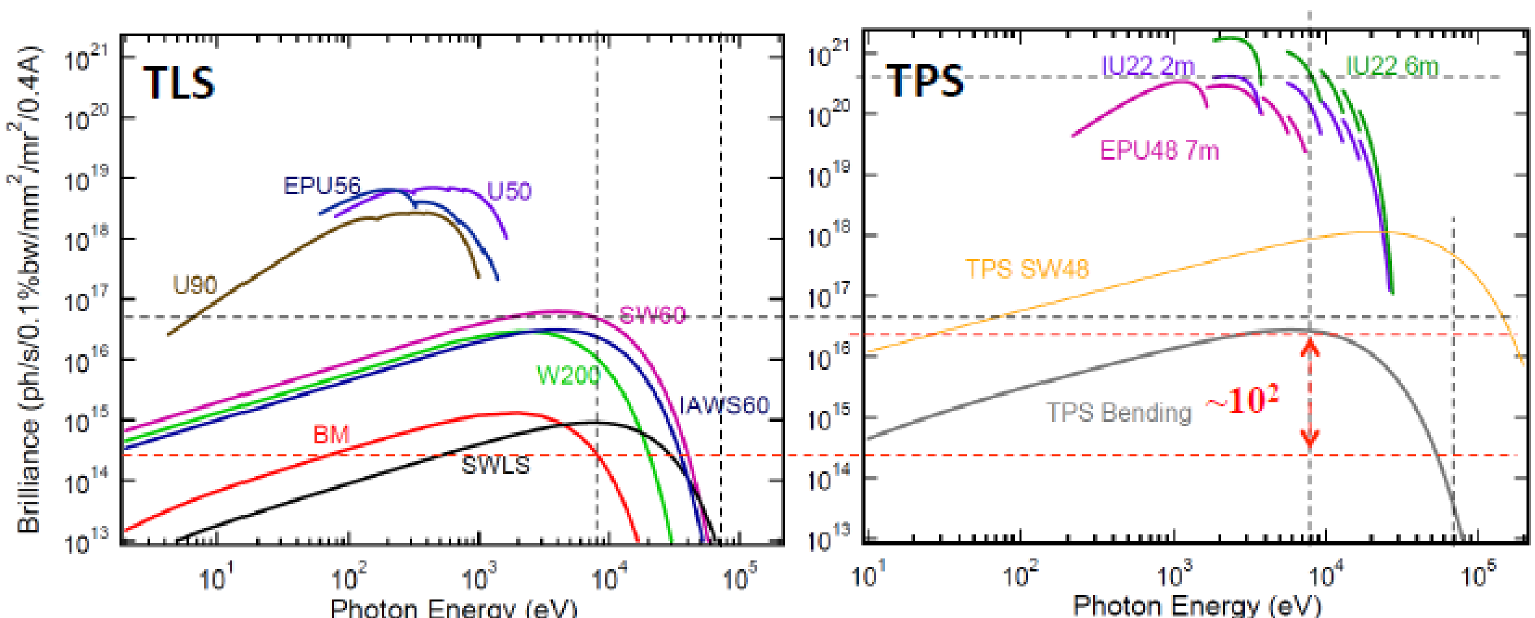
NSRRC is constructing a low-emittance synchrotron-based light source, Taiwan Photon Source (TPS)

Comparison of Brilliance between TLS and TPS

The X-ray spectrum (photon energy 8 keV - 70 keV):

the brightness of bending magnet $>10^2$.

the brightness of IDs: 4～6 orders of mag.



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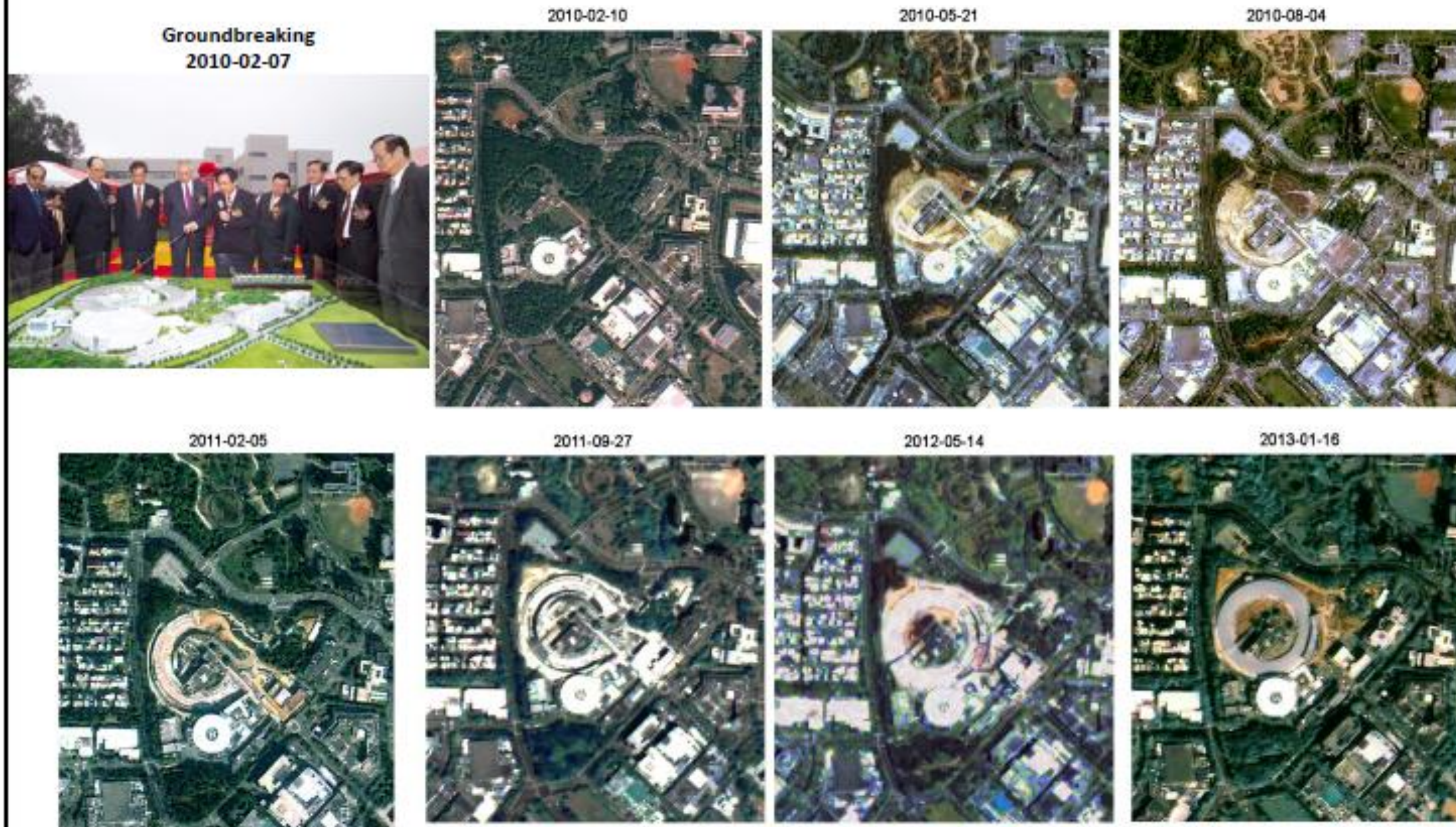
中心現址衛星圖
(太空中心提供)




Civil Construction of TPS

Taiwan Photon Source (TPS)

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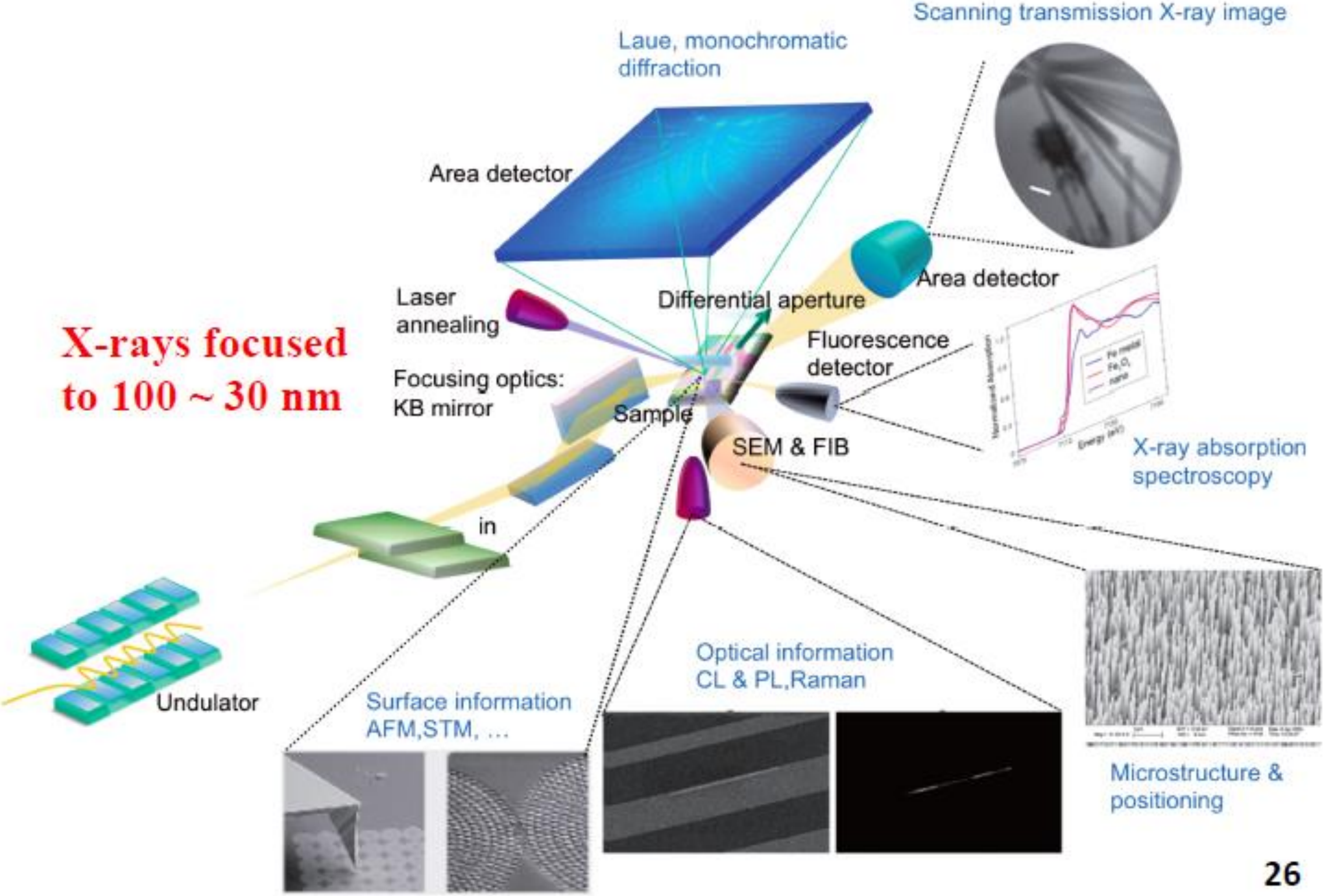
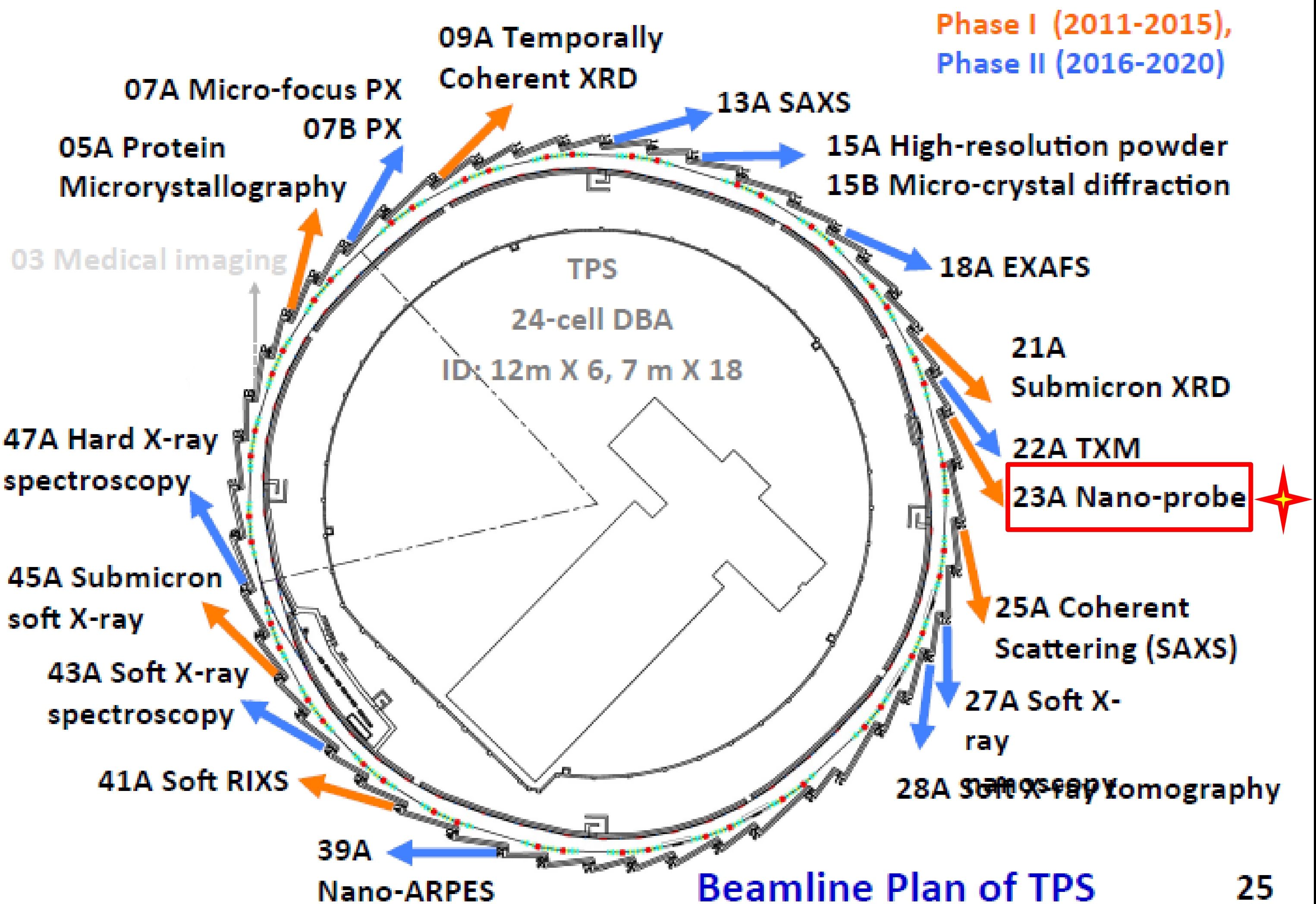
TPS will brighten the future of scientific discovery.



The user operation of the TPS will begin in 2015.



Beamline Plan of TPS

Outline

- Synchrotron Light Source
- Application of Synchrotron Light
- X-ray nano probe at TPS

X-ray Methods:
With tens-nm resolution (incoherent)

TAIWAN TPS 23A

- nano-XRF (x-ray fluorescence)
  - Element-specific nanoimaging
- nano-XAFS (x-ray absorption fine structures)
  - Local electronic structure
  - Local chemical environments
  - Element-specific, averaged over nano-size area
- nano-XEOL (x-ray excited optical luminescence)
  - X-ray-to-visible down-conversion efficiency in nano phosphor
- nano-PXM (projection x-ray microscopy)
  - Absorption and phase contrast x-ray images

Beyond sub-ten-nm resolution (coherent)

- nano-CXDI (coherent x-ray diffraction imaging)
- Bragg-ptychograpgy
  - strain dynamics in nano-devices

Beamline specification

- Energy range：4 - 15 keV
- Photon flux：$10^{10} \sim 10^{11}$ photons/sec
- Energy resolution：$< 2 \times 10^{-4}$ with Si(111) crystals
- Beam size：$\sim$ 40 nm at 10 keV (H × V, FWHM)
- High-order harmonic contamination：$\leqq 1 \times 10^{-4}$
- Energy scanning capabilities.

Other than X-rays

- SEM (SE, EDS, CL with high spatial resolution)
- Fly scanning
- Nanomotors (optional)
- Sample environment -heat, electric, L-He (optional)

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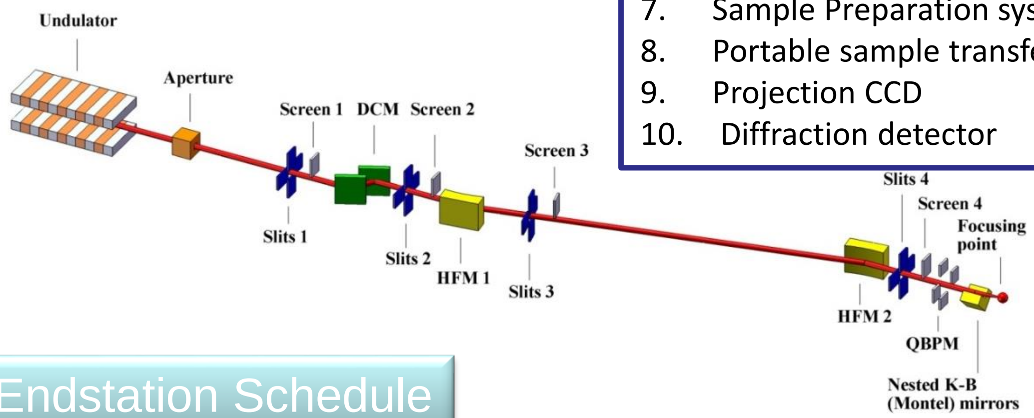
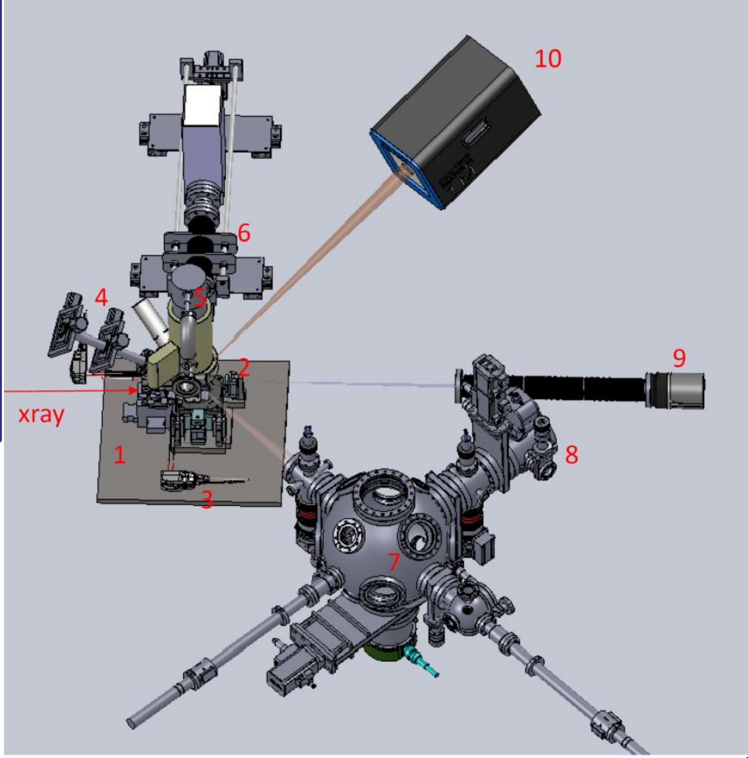
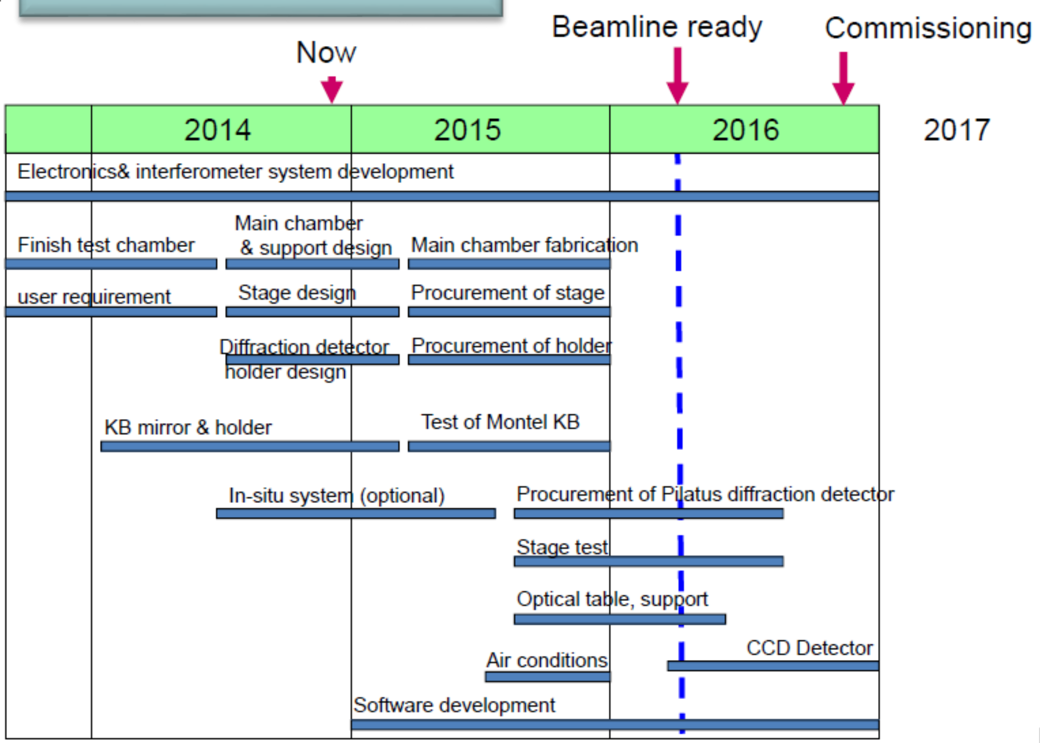
TPS 23A XNP

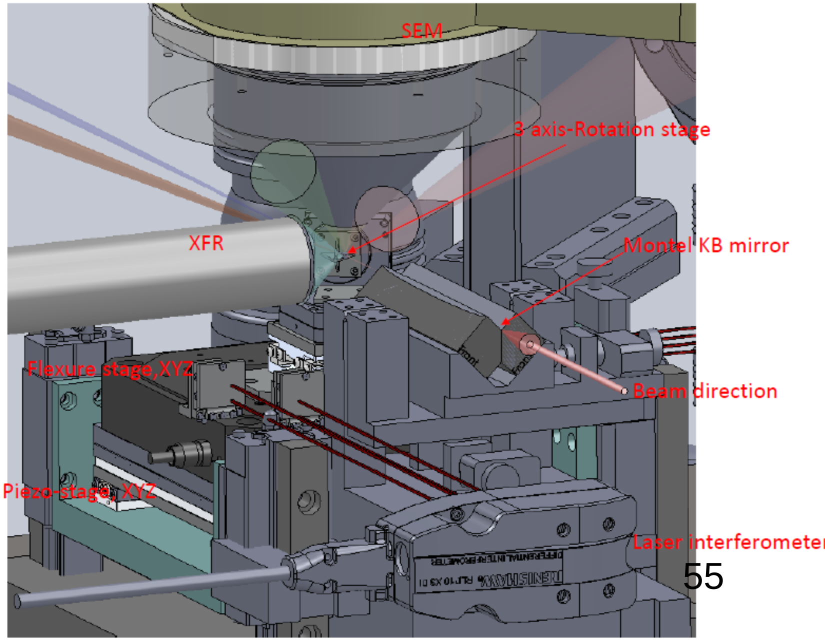
1. Montel mirror
2. Sample Stage
3. Laser interferometer
4. XEOL
5. SEM
6. EDS
7. Sample Preparation system
8. Portable sample transfer
9. Projection CCD
10. Diffraction detector





Endstation Schedule



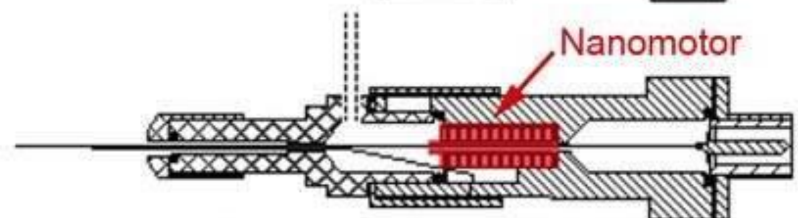


Nanomotor probe

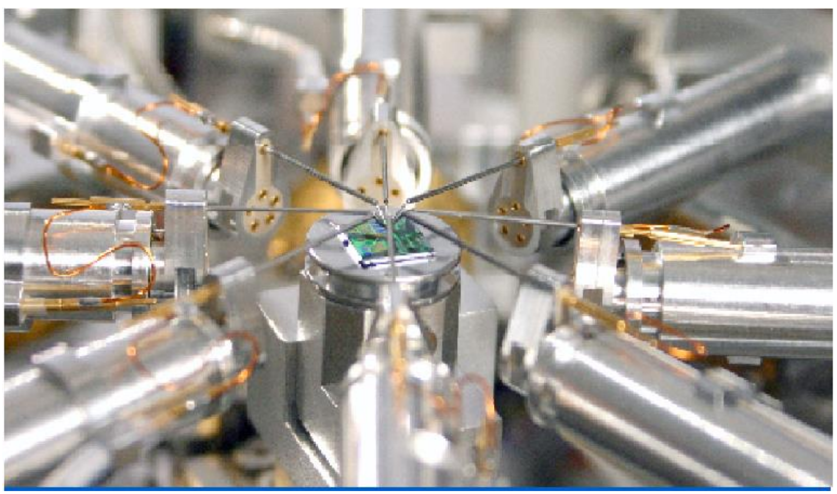
Cone Angle: 16.5°, Diameter: 25nm

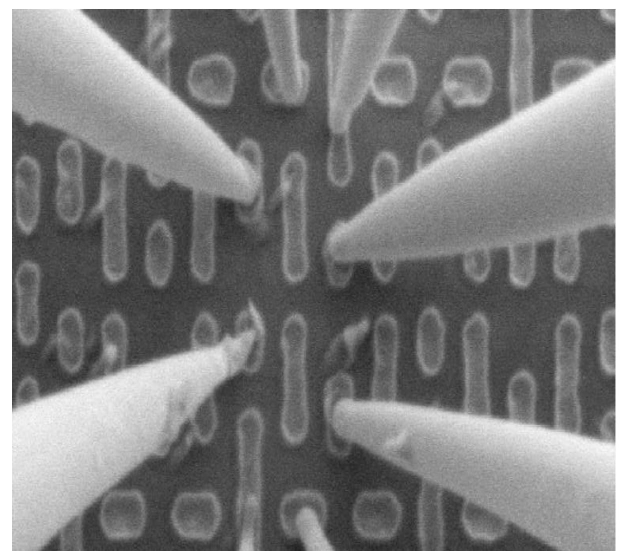
Cone Angle: 5.4°, Diameter: 6nm

NT:600,000

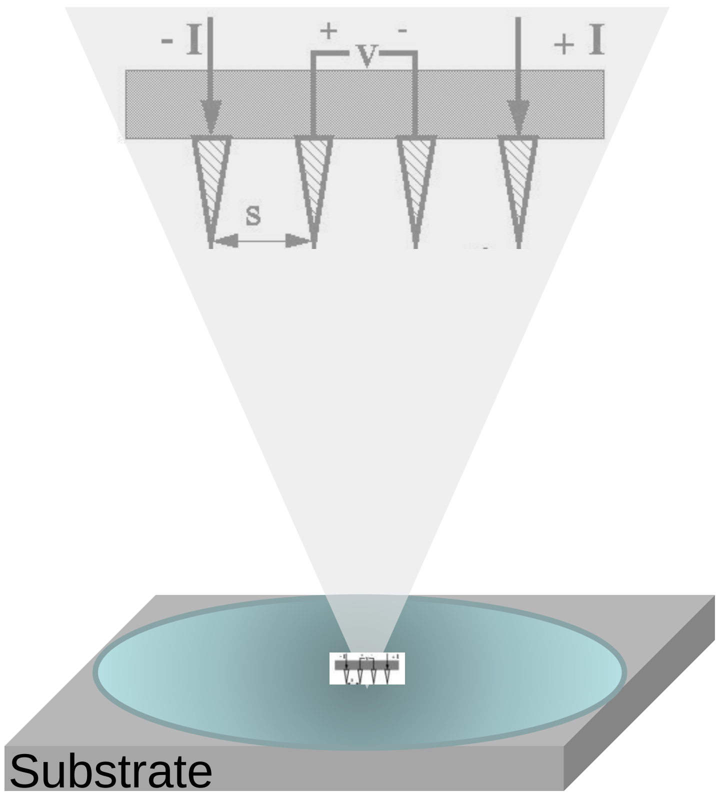


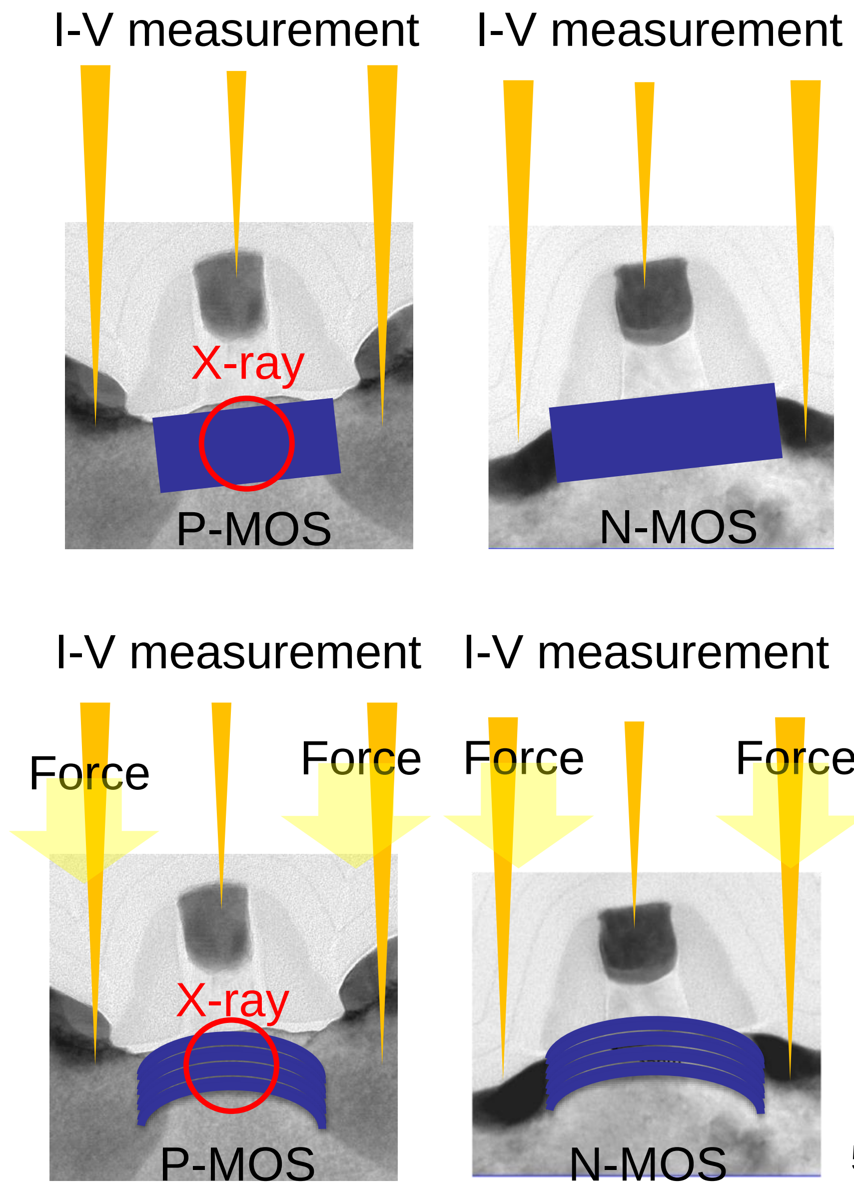
Moving 5nm-100um





Nanomotor Probe Application





Nanometer can construct
the 4-point probe

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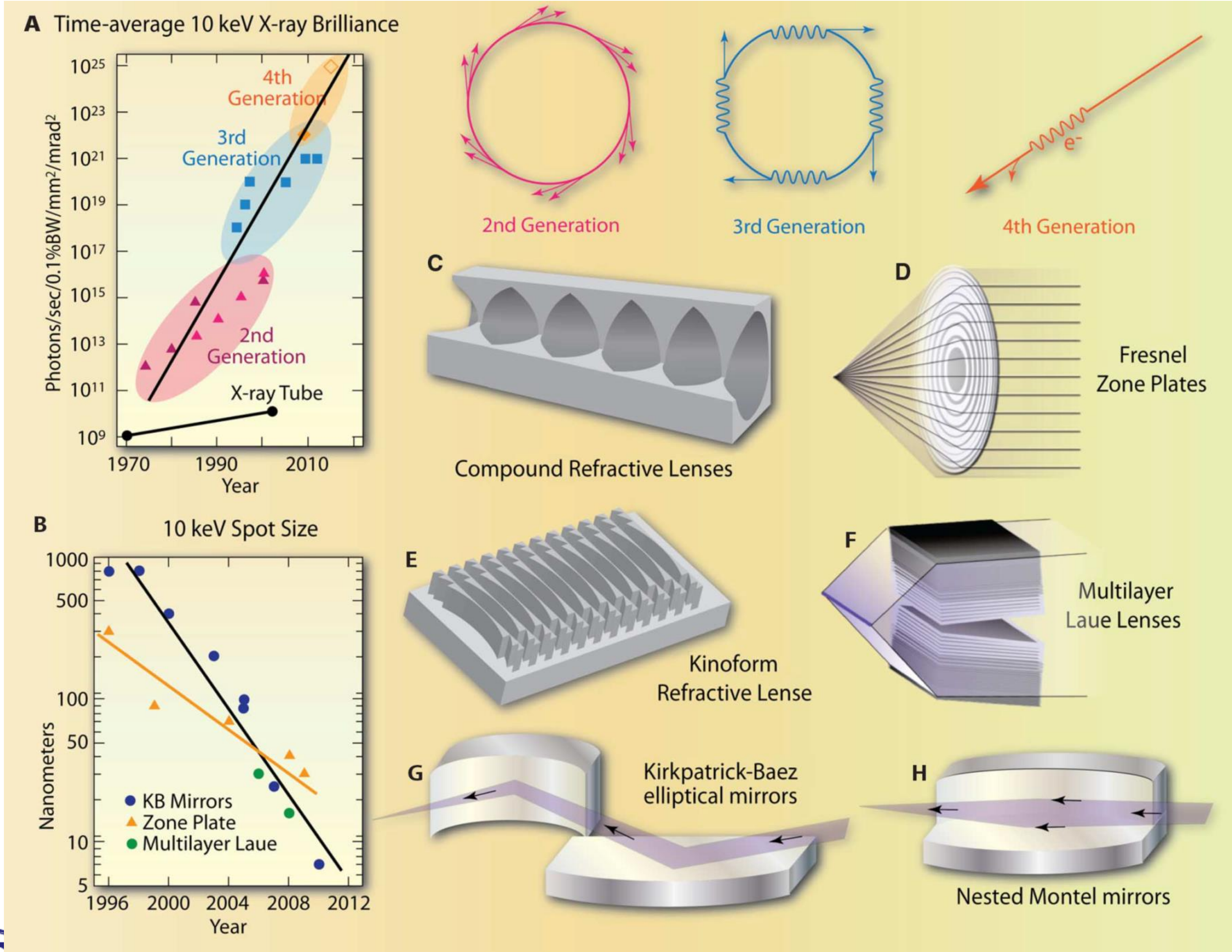
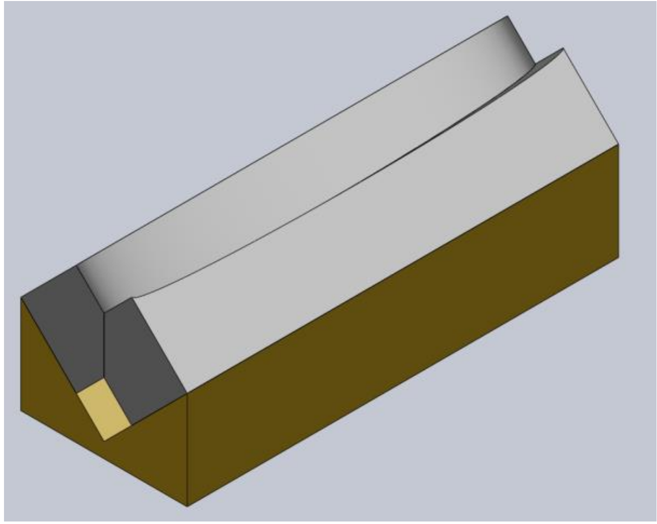

A Time-average 10 keV X-ray Brilliance
Photons/sec/0.1%BW/mm²/mrad²
10^25
10^23
10^21
10^19
10^17
10^15
10^13
10^11
10^9
1970
1990
2010
Year
4th Generation
3rd Generation
2nd Generation
X-ray Tube
2nd Generation
3rd Generation
4th Generation
e-
B 10 keV Spot Size
Nanometers
1000
500
100
50
10
5
1996
2000
2004
2008
2012
Year
KB Mirrors
Zone Plate
Multilayer Laue
C
Compound Refractive Lenses
D
Fresnel Zone Plates
E
Kinoform Refractive Lense
F
Multilayer Laue Lenses
G
Kirkpatrick-Baez elliptical mirrors
H
Nested Montel mirrors

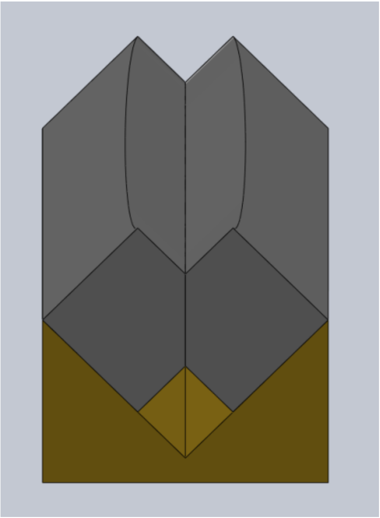
Montel Nested KB Mirror @TPS-23A

- **Montel nested KB mirror @ APS**:
  - Focal spot: 100 nm

- **Challenges**:
  - Gap between mirrors
  - Slope error

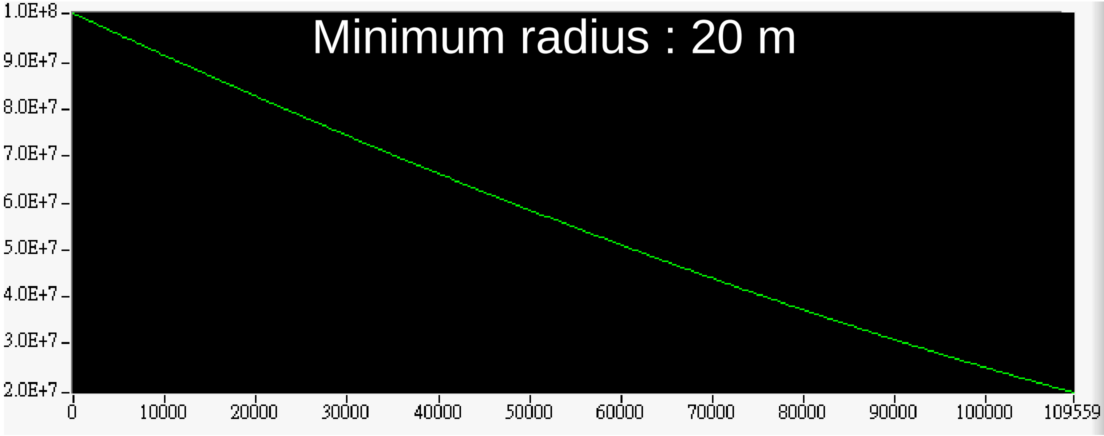
➔ Overcome by **Elastic Emission Machining (EEM)**

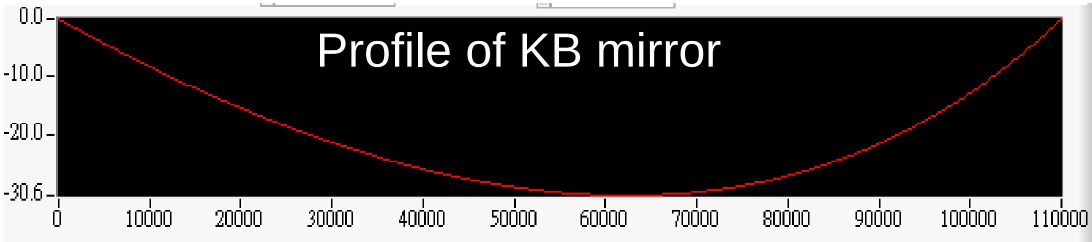




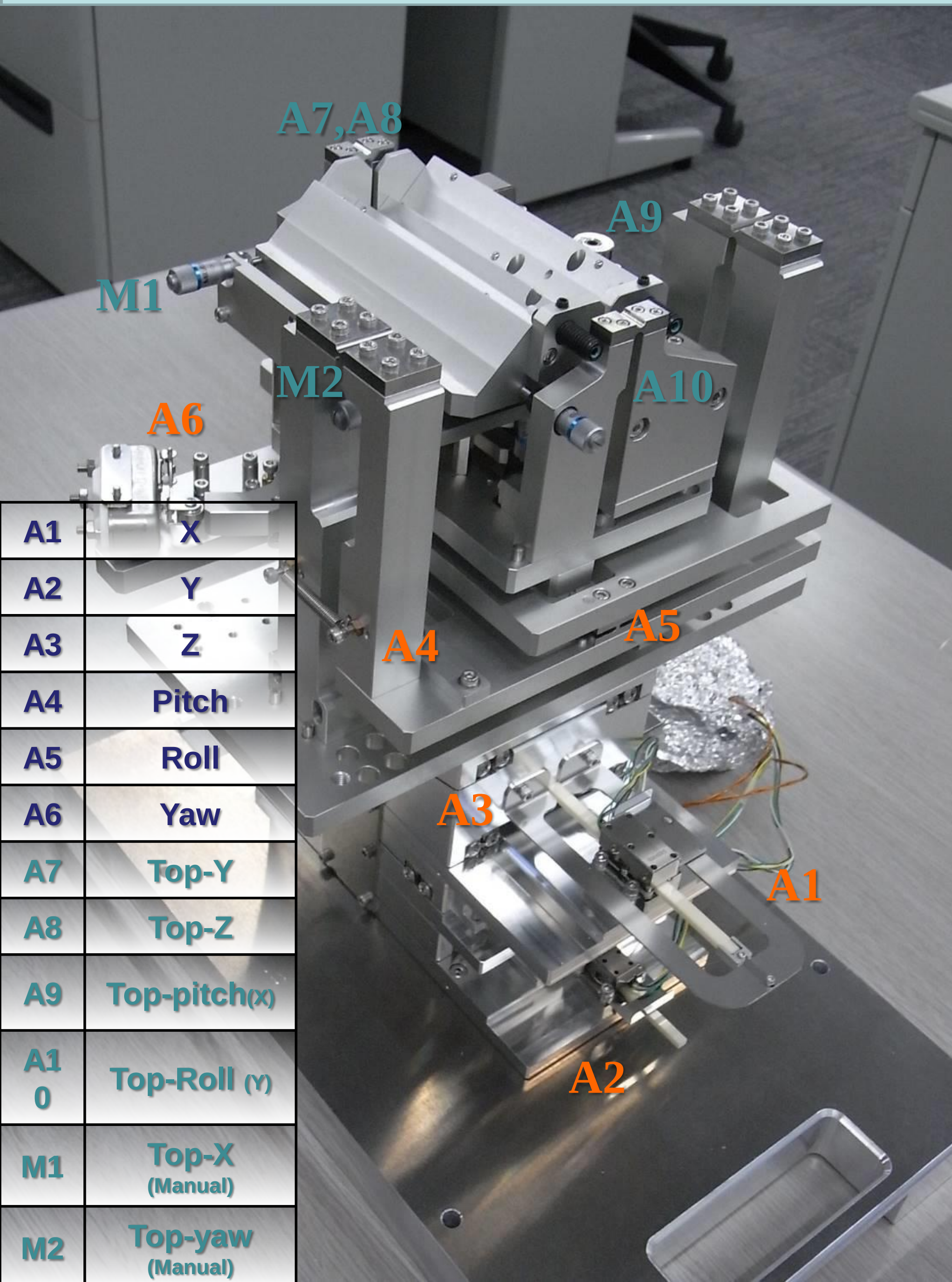
- **Montel nested KB mirror @ TPS**:

Objective distance	**69 m**
Focus length	**11 cm**
Mirror length	**11 cm**
Slope error (RMS)	**< 0.05 μrad**
Incident angle	**4 mrad**
Coating	**Rh**
Material	**silica**
Working Distance	**5.5 cm**

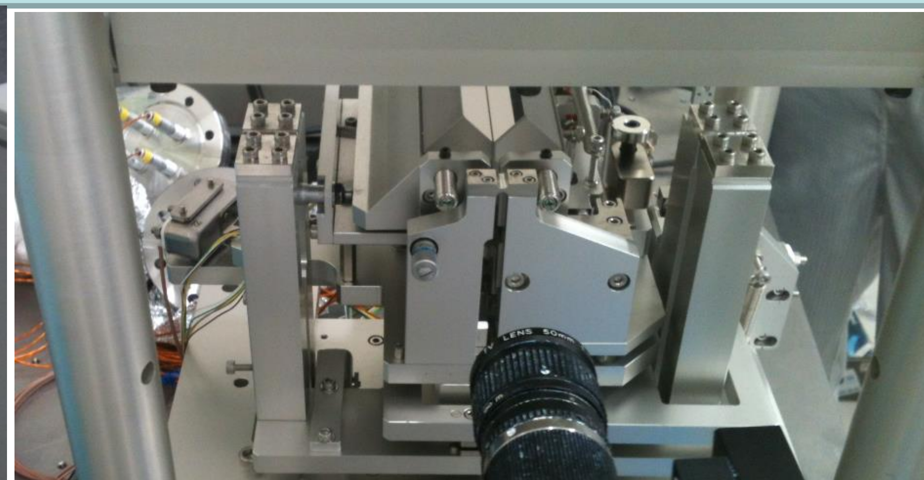




Montel KB Montel Mirror and Holders



A1	X
A2	Y
A3	Z
A4	Pitch
A5	Roll
A6	Yaw
A7	Top-Y
A8	Top-Z
A9	Top-pitch(x)
A10	Top-Roll (Y)
M1	Top-X (Manual)
M2	Top-yaw (Manual)



Montel Mirror on the holder

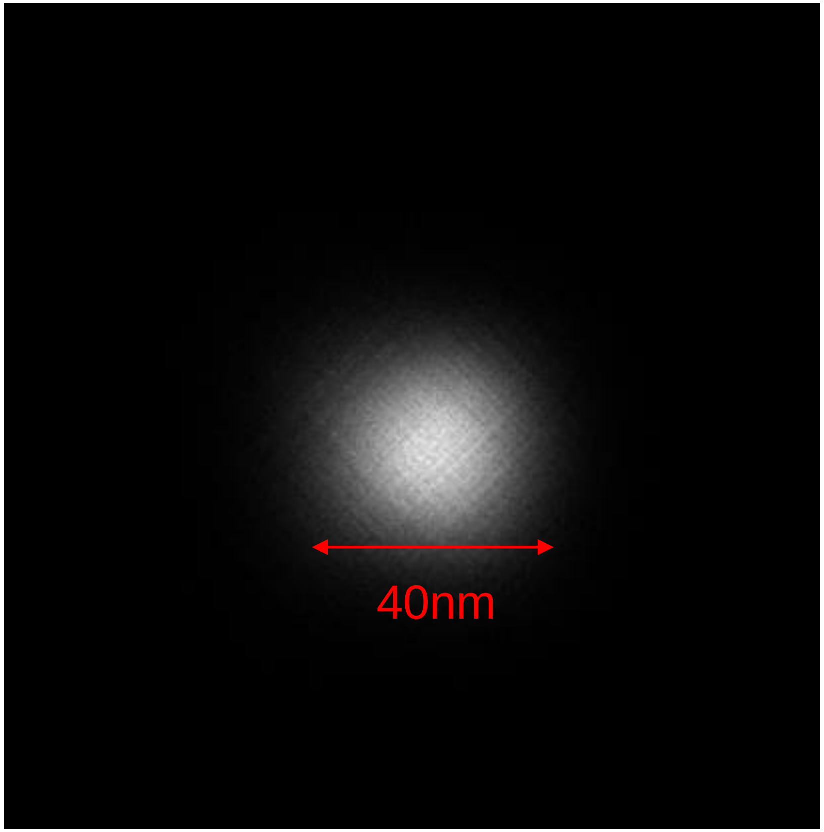
Gap imaged by microscope

June 2015, at JTEC

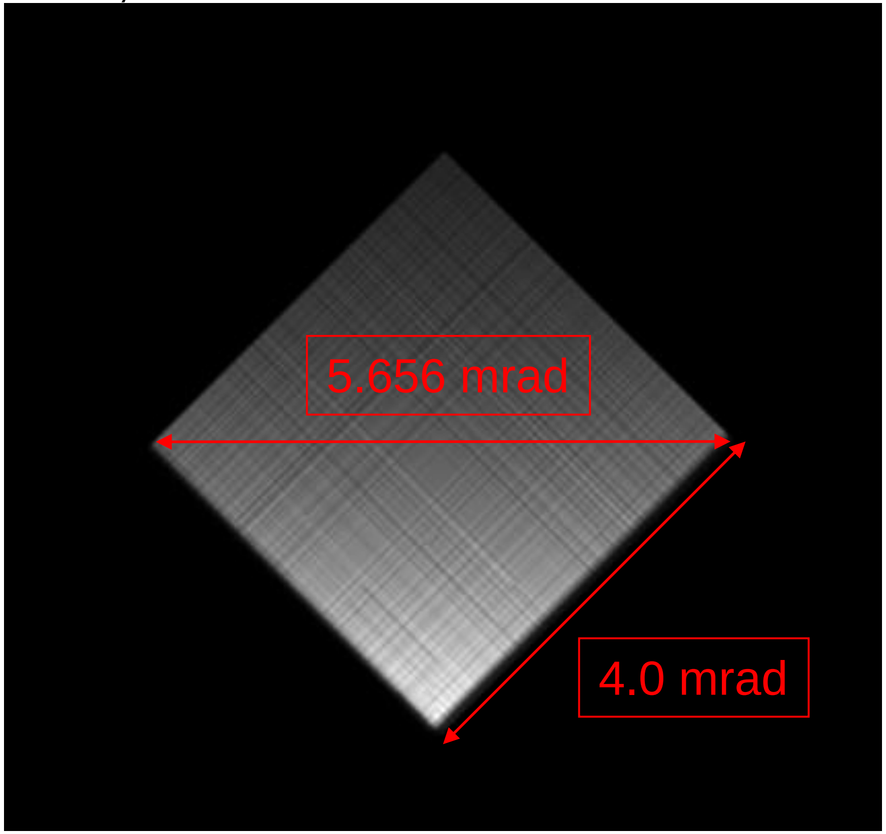
Simulation of Focus Spot

Simulation at 10 keV, average reflection=0.802, by ray tracing

Source size	12.5 μm x 12.5 μm
Source divergence	6μrad x 6μrad
FHWM	32nm x 32nm,



Simulated
Focus spot size



Simulated
Divergence

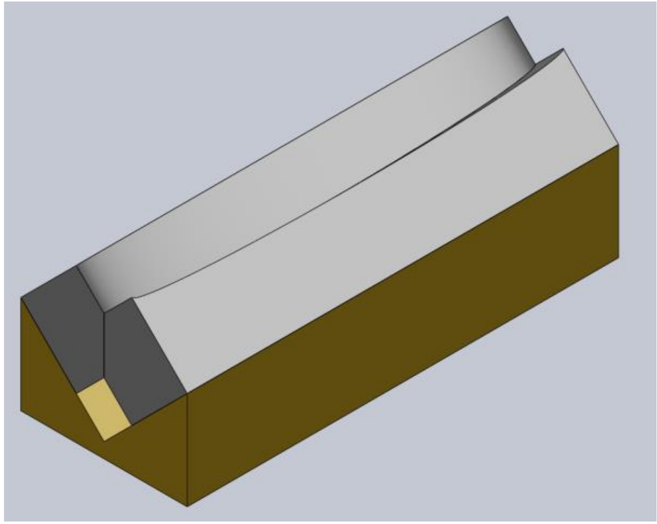
By Gung-Chian Yin

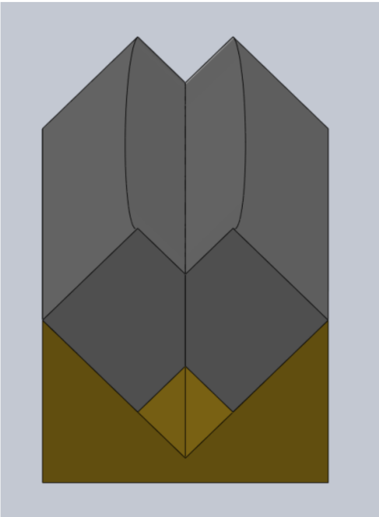
Montel Nested KB Mirror @TPS-23A

- **Montel nested KB mirror @ APS**:
  - Focal spot: 100 nm

- **Challenges**:
  - Gap between mirrors
  - Slope error

➔ Overcome by **Elastic Emission Machining (EEM)**





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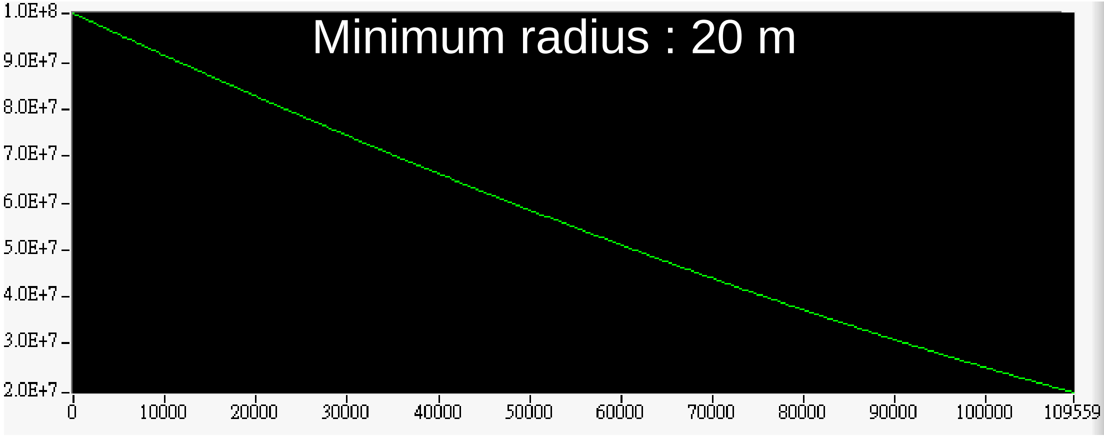
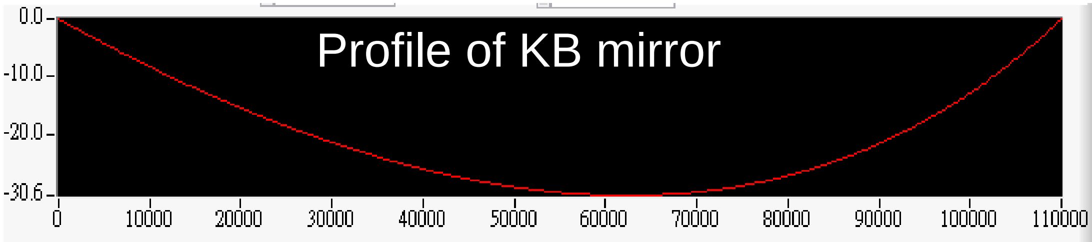
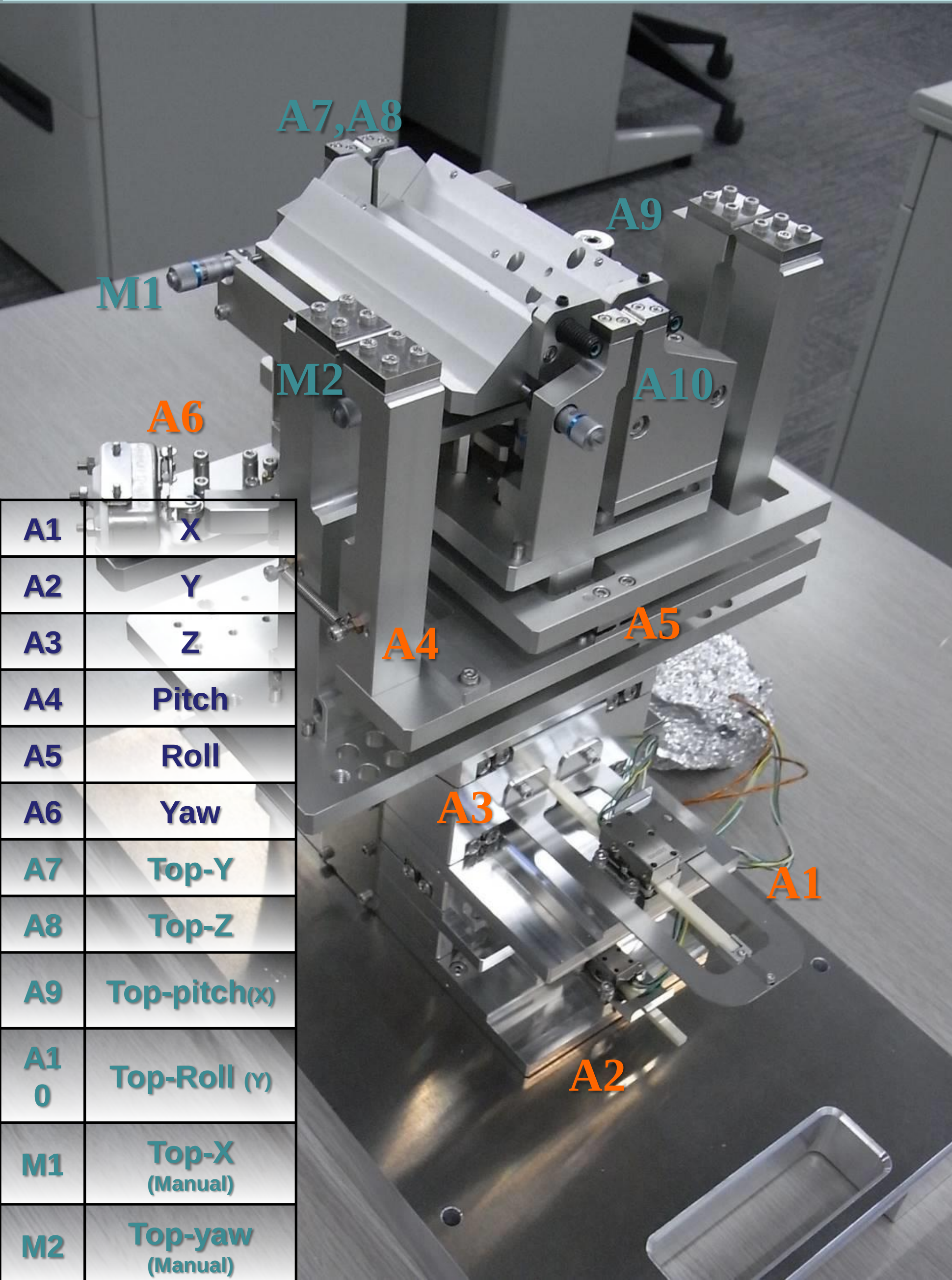
Material	**silica**
Working Distance	**5.5 cm**

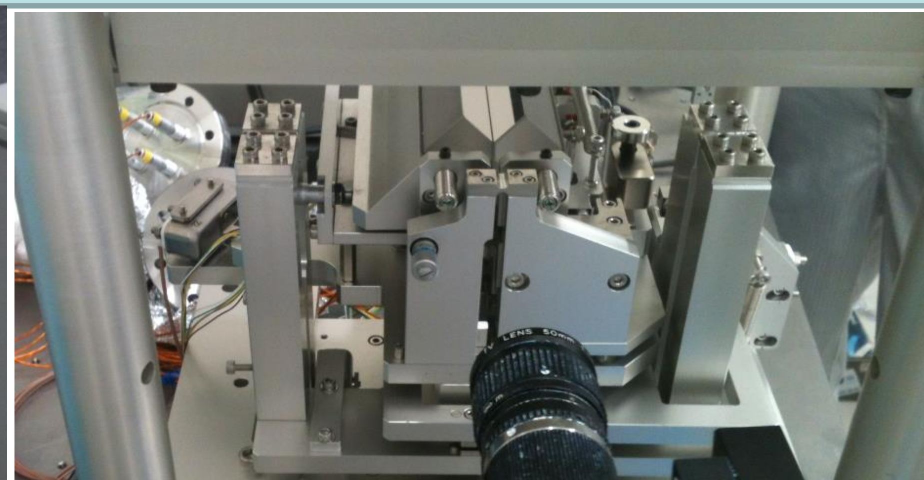




Montel KB Montel Mirror and Holders



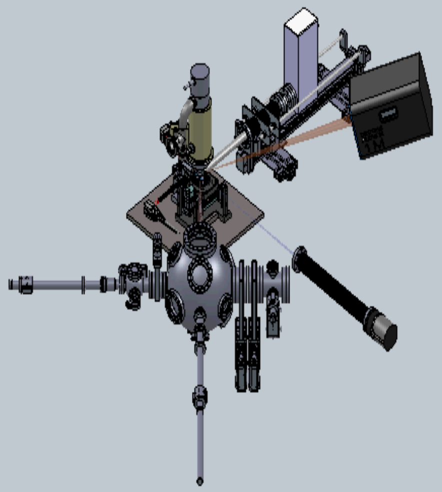
A1	X
A2	Y
A3	Z
A4	Pitch
A5	Roll
A6	Yaw
A7	Top-Y
A8	Top-Z
A9	Top-pitch(x)
A10	Top-Roll (Y)
M1	Top-X (Manual)
M2	Top-yaw (Manual)



Montel Mirror on the holder

Gap imaged by microscope

June 2015, at JTEC



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nano-XRF (x-ray fluorescence)

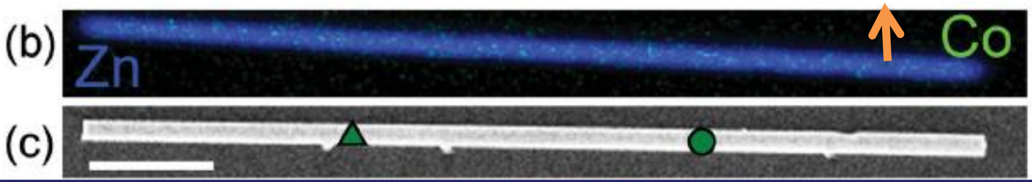
Element-specific nano-imaging

Doping of ZnO NWs by transition metal Co.
Application : Spintronic device
Want to know:

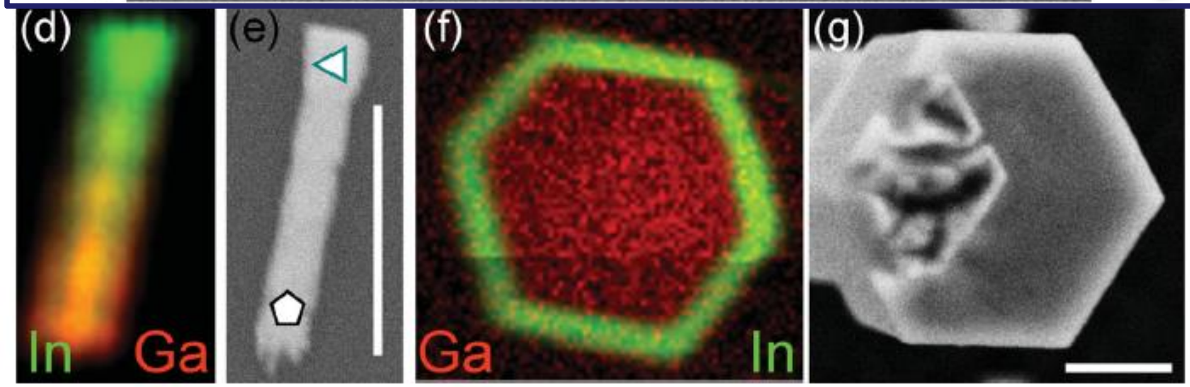
- Distribution
- Short structure order
- Elemental composition

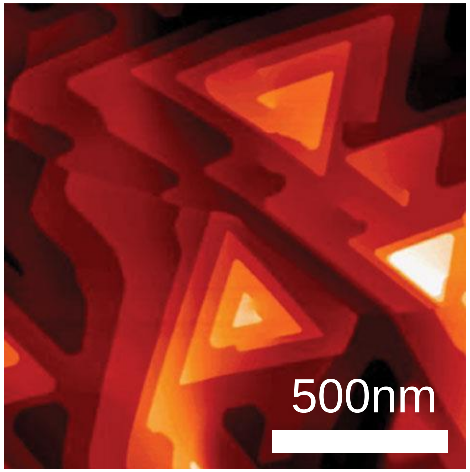
- ➢ Pink beam mode at 12 KeV
- ➢ Pixel size : 25 x 25 nm^2
- ➢ Accumulation time : 0.5 sec/point
- ➢ beam size : 60 x 60 nm^2 (V x H)

Vapour-liguid-solid process
Nano Lett. 2011, 11, 5322–5326



Doping method:
Ion implantation
and thermal annealing
Elemental map of XRF
SEM





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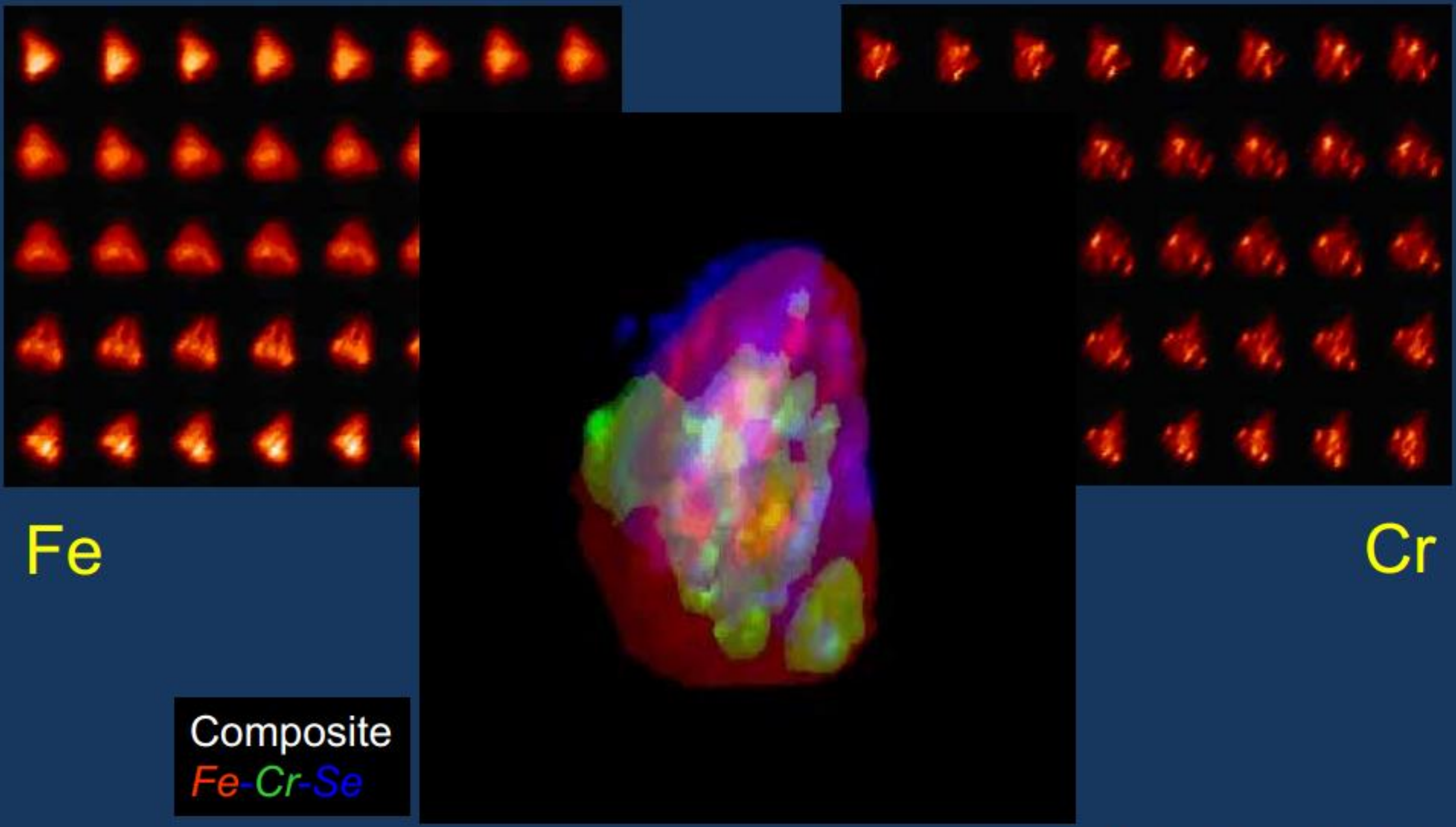
High resolution XRF tomography

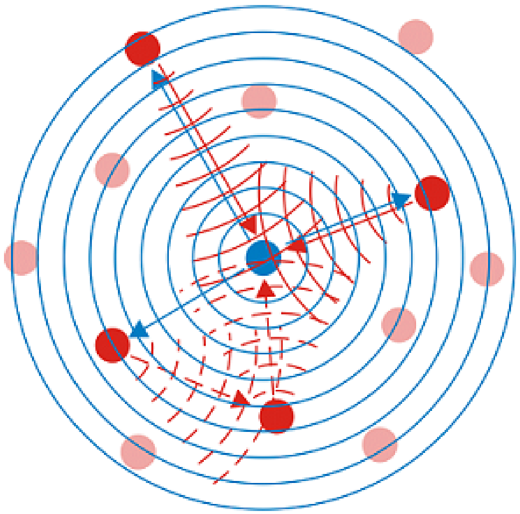
Pixel size: 100 nm, sample rotation 0-180° (4.5° / image)

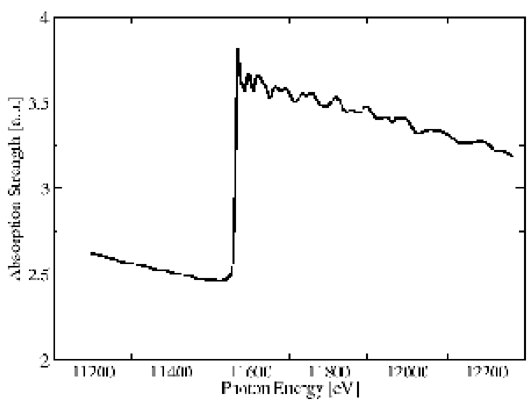


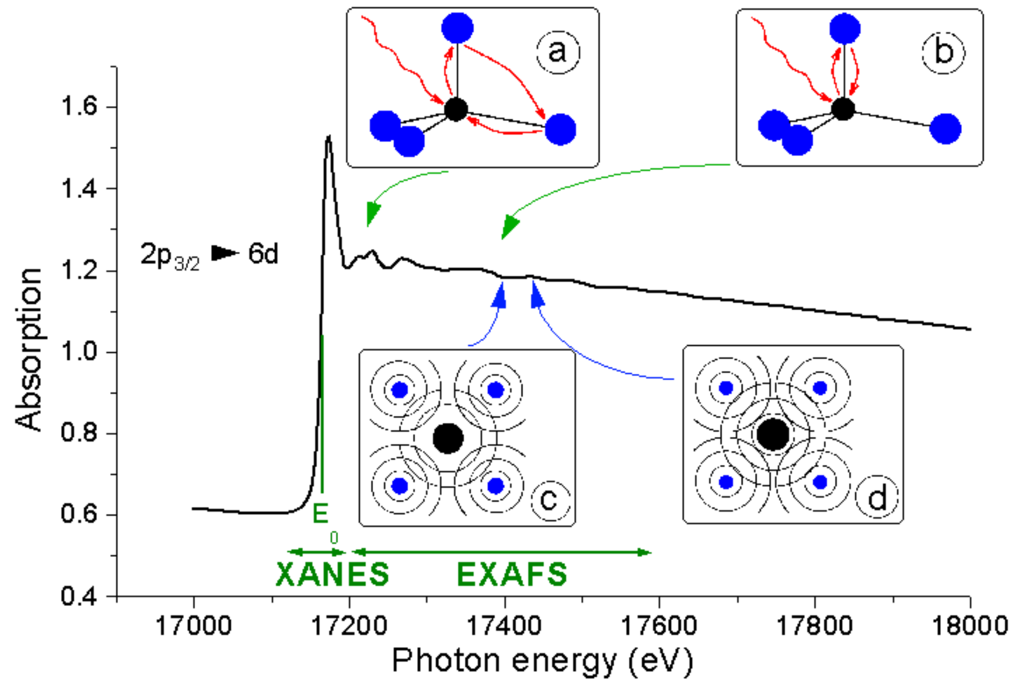
Silversmit *et al.*, *Anal. Chem.* 81 (2009)

nano-XAFS (x-ray absorption fine structures)

– Local electronic structure
– Local chemical environments
– Element-specific, averaged over nano-area







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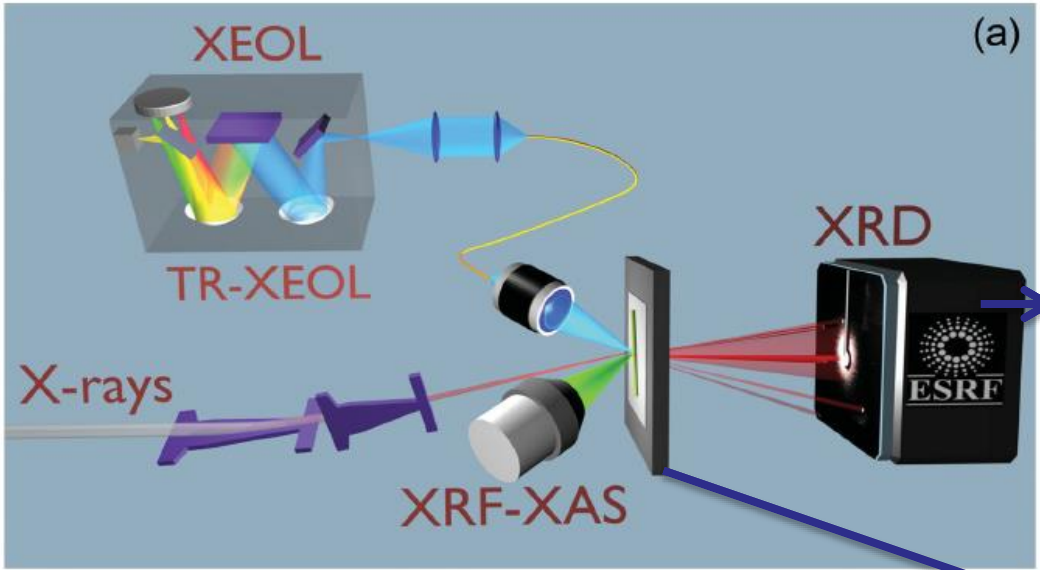
ESRF ID16B methods

XEOL
- Multimode optical fiber
- UV-VIS : linear CCD Si detector
- Si avalanche photodiode (id100 from id-Quantique)



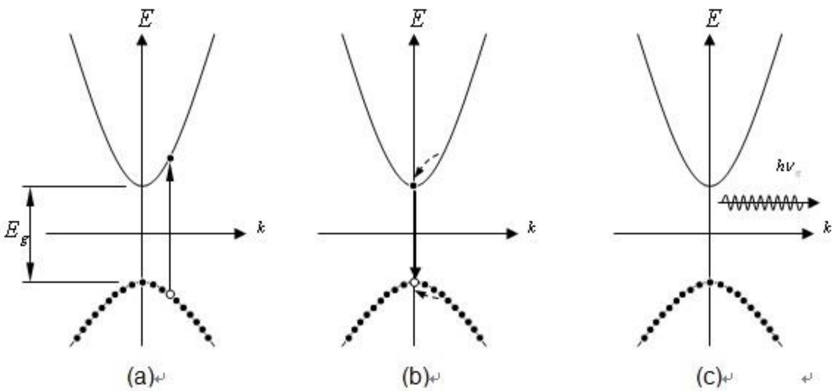
XRD
- The XRD signal was measured using a fast readout low noise (FReLoN) CCD detector.
- The CCD images were processed using Fit2D software to generate the standard diffractograms.
- Using the experimental parameters derived from the measurement of an Al2O3 reference sample.

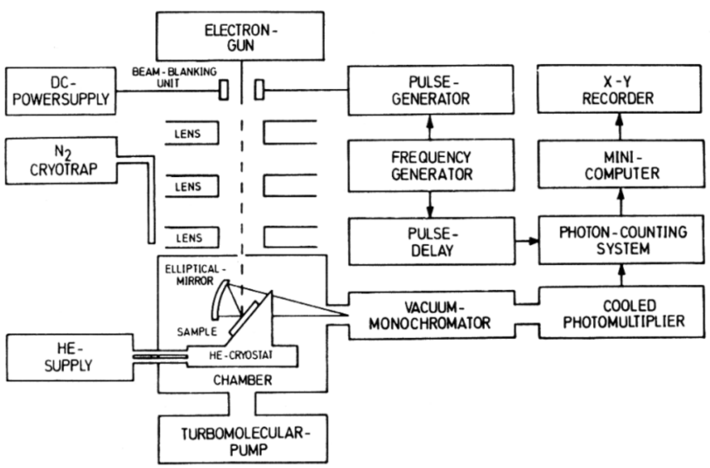
XRF
- XRF signal was collected at 15°
- The elemental composition of the NWs was estimated by fitting the XRF spectra using the PyMca program.
- XANES spectra were recorded in X-ray fluorescence mode with a step size of 1 eV and integration times determined by the counting statistics.
- The data analysis was performed using the IFEFFIT package.

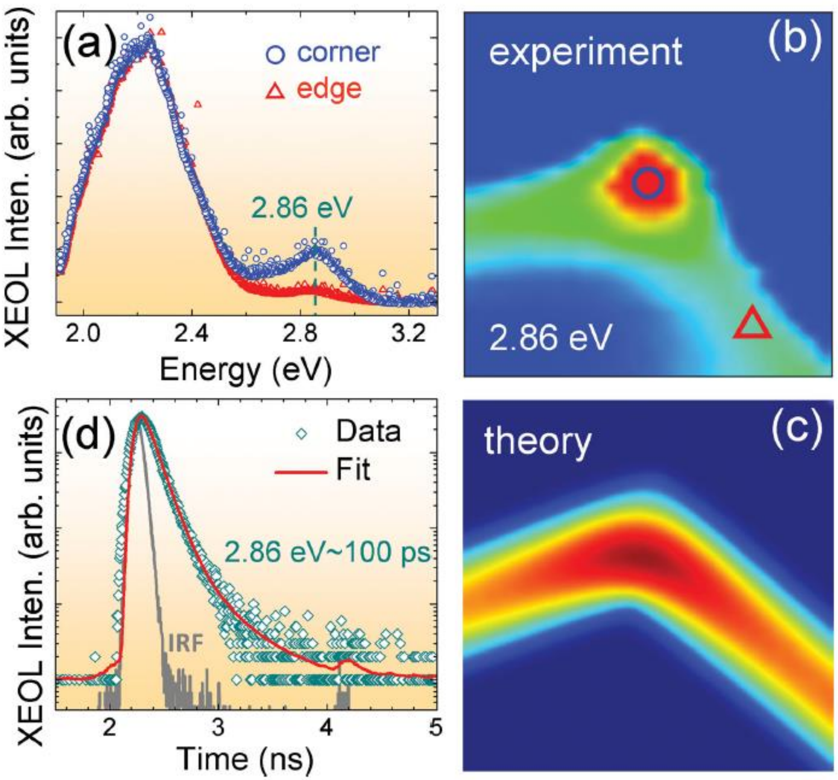
- 200 nm thick SiN membranes.
- Without XRF background signal
- X-ray diffraction can be transmitted

Adv. Mater. **2014**,
DOI: 10.1002/adma.201304345

nano-XEOL (x-ray excited optical luminescence) & CL (cathodoluminescsnce)







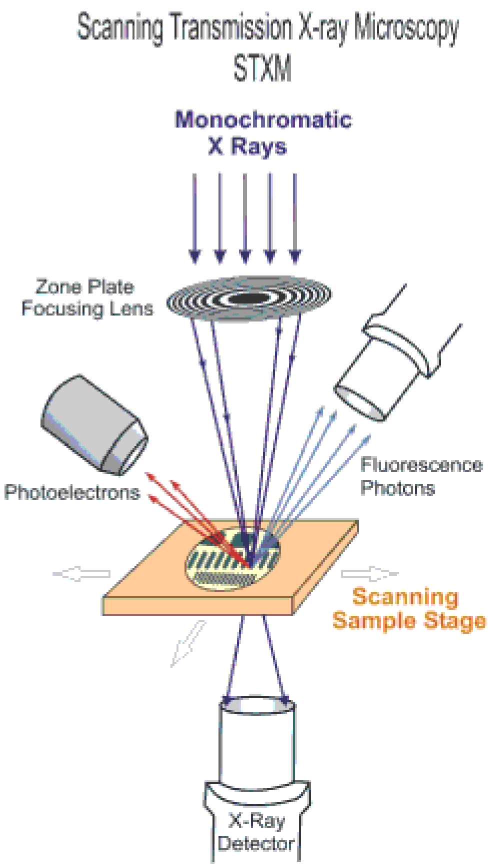
XEOL: 1.nano-area

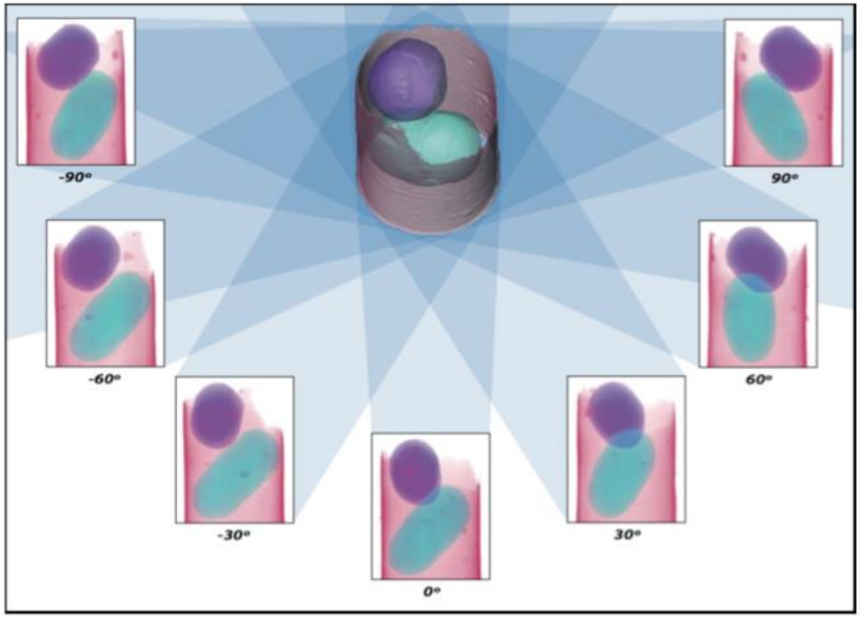
2.multi-layer, buried layer

Doping species, Band gap, Defect band, Charge transport

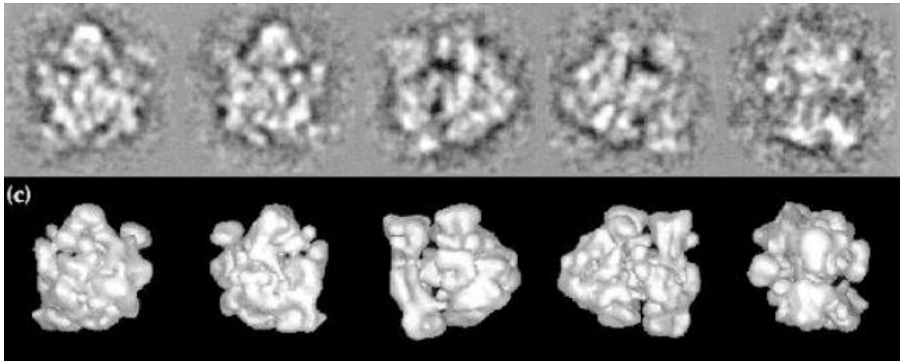
nano-PXM (projection x-ray microscopy)

– Absorption and phase contrast x-ray images

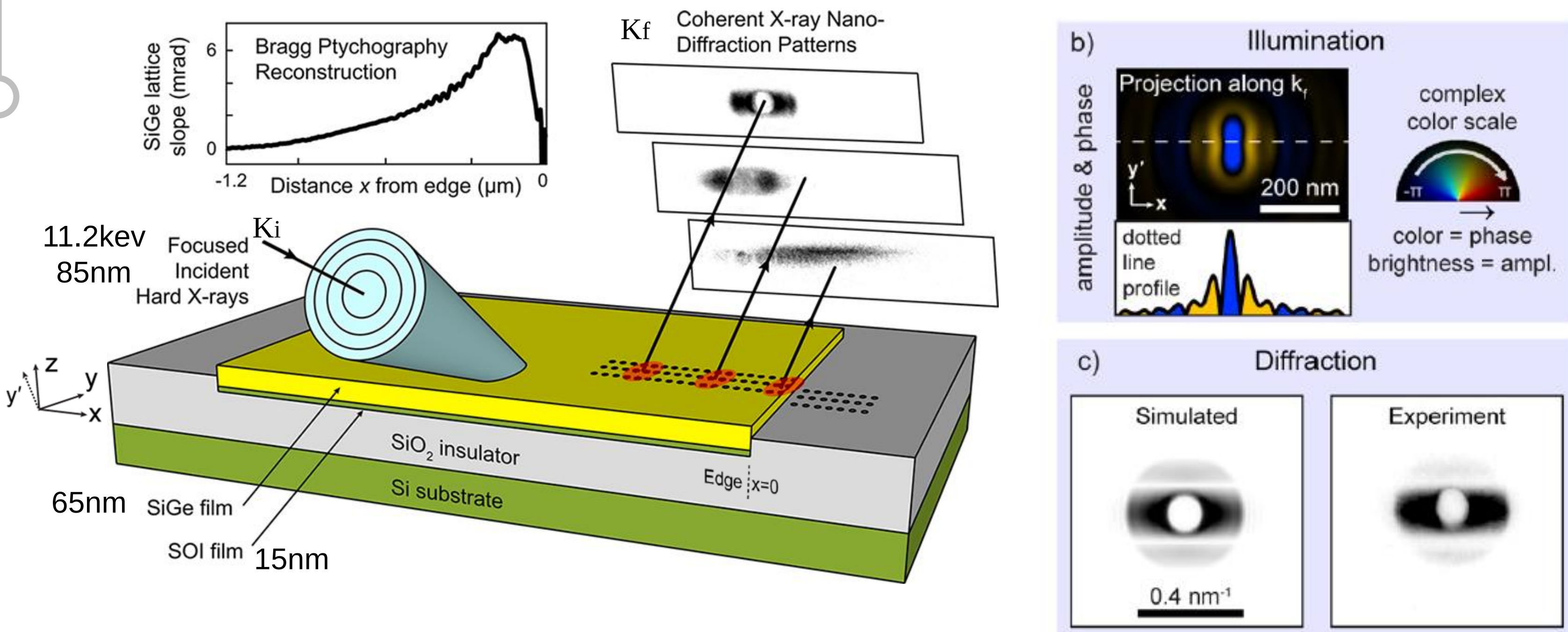




TRENDS in Cell Biology



X-ray Bragg projection ptychography from thin film heterostructures



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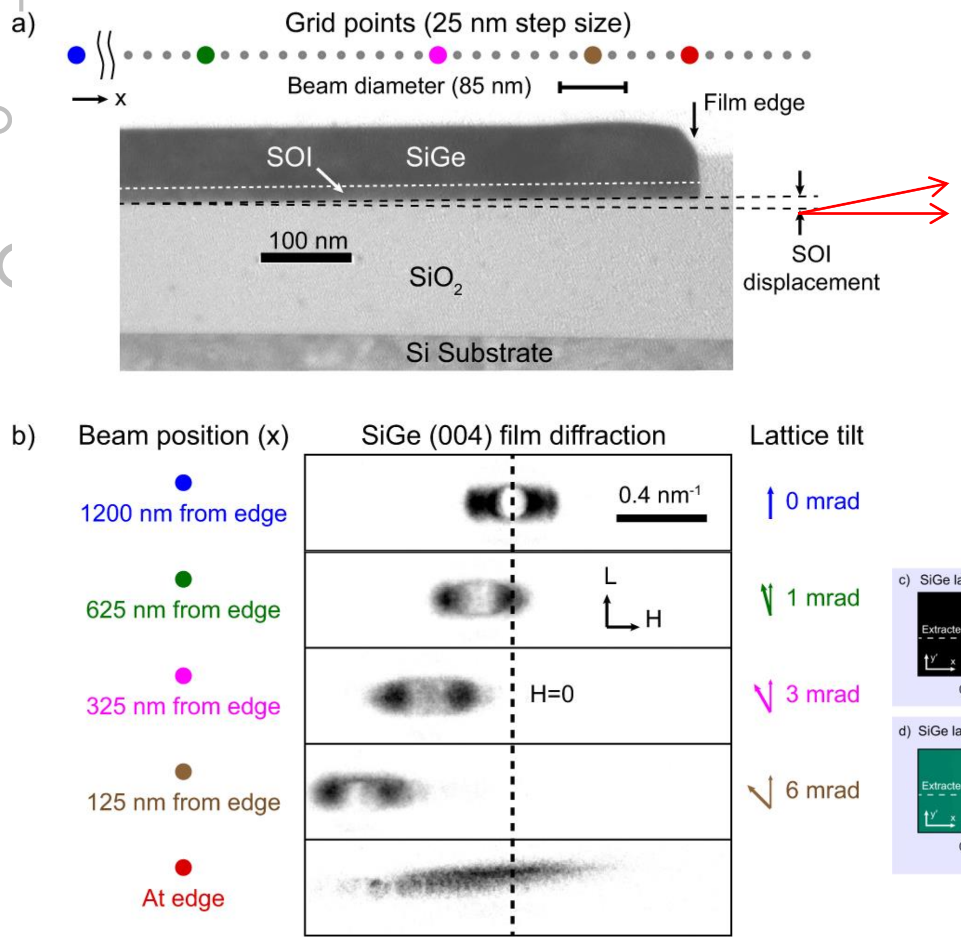
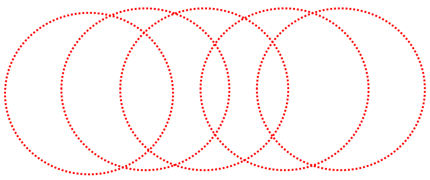
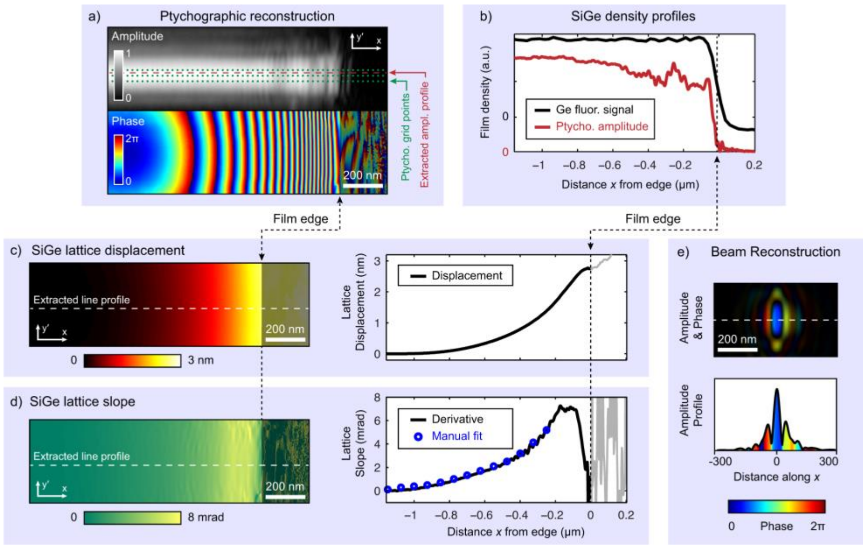
Focused beam Bragg diffraction near the device edge





70% spatial overlap



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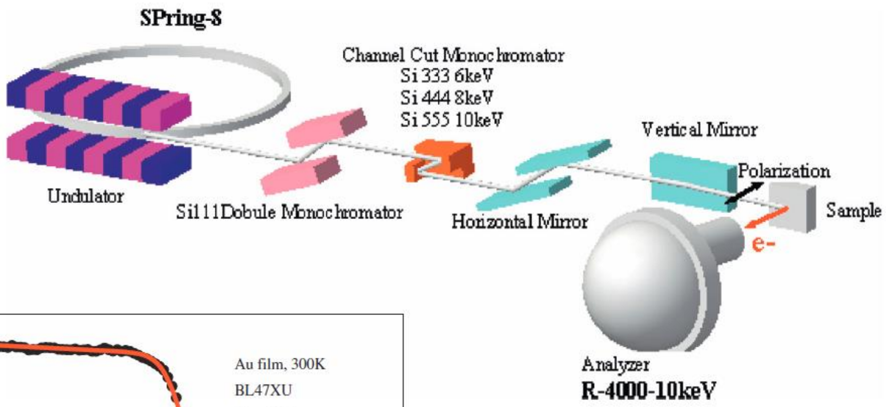
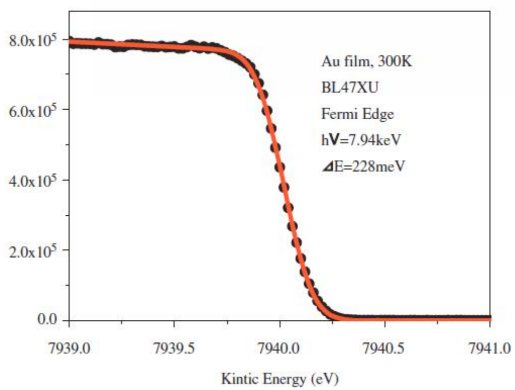
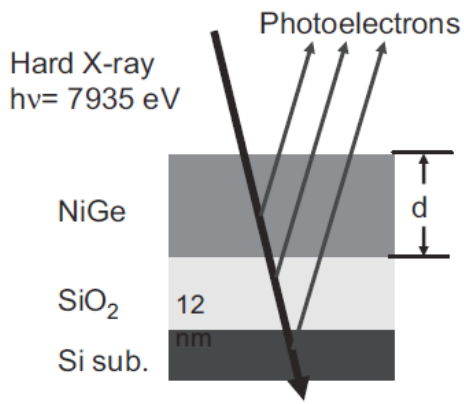
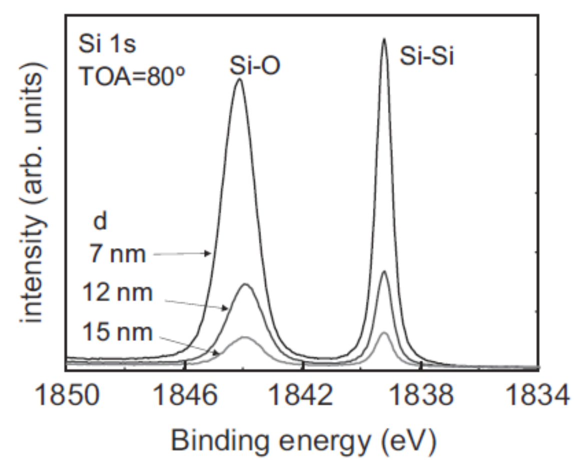
Upgrade: Hard X-ray photoelectron spectroscope(HXPS) at XNP



HXPS: Several keV to 15 keV to increase bulk sensitivity for bulk electronic structure and buried interface.







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K. Kobayashi, *Nuclear Instruments and Methods in Physics Research* A 601 (2009) 32–47

Applications

Solid state physics

- Strongly correlated electron systems

YbAl3, YbInCu4, YbCu2Si2

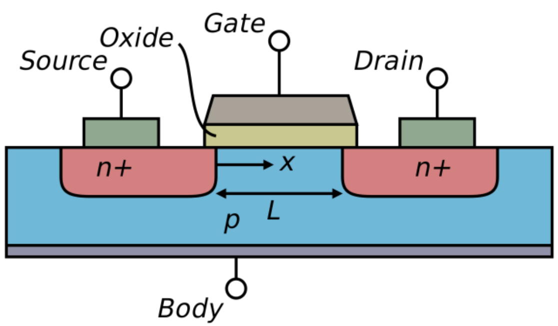
La1-xSrxMnO3 (LSMO)

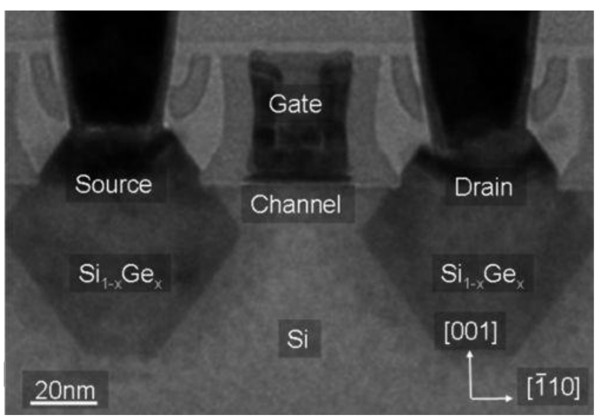
- Spintronics

LaVO3, LaAlO3, Fe3-xMxO4(M=Mn, Zn)

- Compound semiconductors

InGaZnO, GaCrN, InN, ZnMgO





M. Chu, *et al.*, Annu. *Rev. Mater. Res.* 39 (2009) 203-229

High-k gate stacks

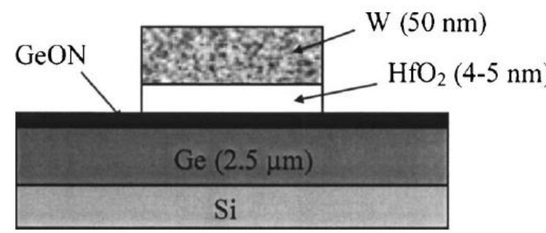
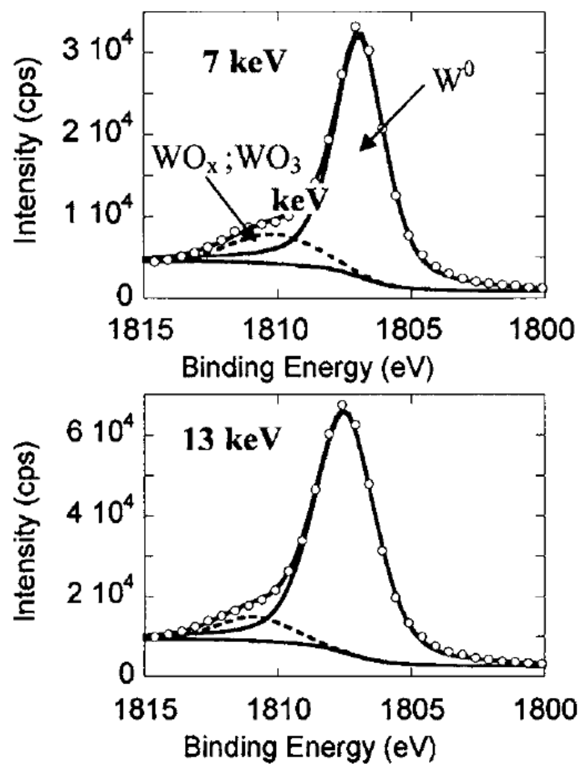
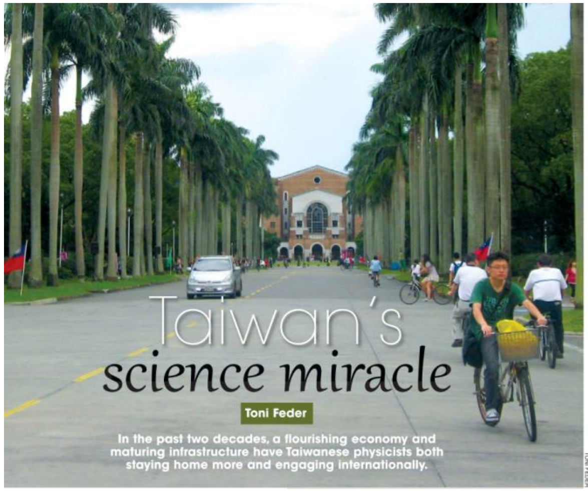


FIG. 1. Diagram of the W/HfO_2/GeON/Ge stack.



房價
每間單人住宿價為NT$700/天，雙人住宿價為NT$1,000/天;四人房價為NT$1,500/天。

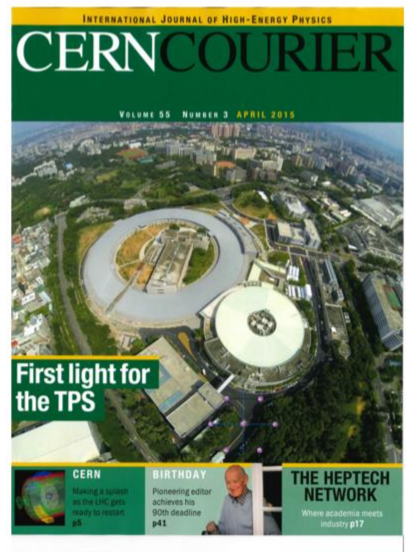
房型	實景	間數	房間坪數	收費	備註
二張單人床		30	6	1,000元/晚	單人住宿一律 NT $700 元
四張單人床		1	12	1,500元/晚	
交誼廳		4	10		一至四樓
餐廳		2	7		三至四樓



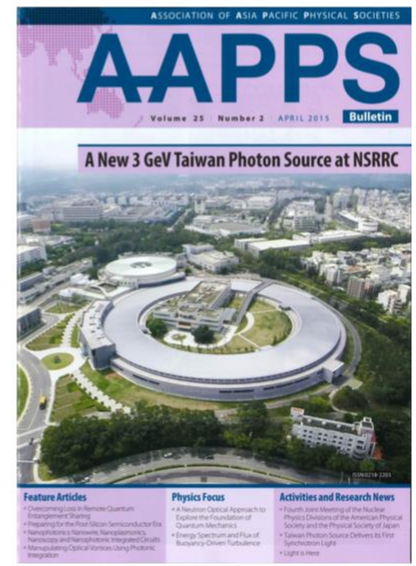
March 2014 Physics Today

「科學」期刊(104年1月30日)

「自然光子學」期刊(104年5月專文)



「CERN科學通訊」期刊(104年4月號封面)



「亞太物理學會聯合會刊」期刊(104年4月號封面)

國家同步輻射研究中心
National Synchrotron Radiation Research Center

SR International Course

AOFSRR Activities

國家同步輻射研究中心
National Synchrotron Radiation Research Center

AOFSRR Cheiron School 2015

ver. 2015/07/15

Sep.10 Thu.

Time	Sep.10 Thu.
15:00 – 18:00	Registration
18:00 – 19:30	*Dinner*
19:30 – 20:30	**Welcome at Guesthouse**

Sep.11 Fri.

Time	Sep.11 Fri.
9:00 – 9:20	**Opening Remarks**
9:20 – 10:00	**Lec. 1 Overview of SR and AOFSRR R. Garrett (ANSTO)**
10:00 – 10:20	*Coffee Break*
10:20 – 11:40	**Lec. 2 Ring Accelerator Physics H.Tanaka (RIKEN)**
11:40 – 12:30	*Lunch*
12:30 – 13:50	**Lec. 3 Light Source (1) T. Tanaka (RIKEN)**
13:50 – 14:40	**Safety Education**
14:40 – 15:50	**Participants' Self-Introduction**
	Move to Central Blg.
16:00 – 18:00	**Site tour SPring-8**
	Move to Houkou-kan
18:00 – 19:30	**Welcome Reception at Houkou-kan**

Sep.12 Sat.

Time	Sep.12 Sat.
9:00 – 10:20	**Lec. 4 Light Source (2) T. Tanaka (RIKEN)**
10:20 – 10:40	*Coffee Break*
10:40 – 12:00	**Lec. 5 Hard X-ray Beamline Optics H. Ohashi (JASRI)**
12:00 – 13:20	*Lunch*
13:20 – 14:40	**Lec. 6 EUV, Soft and Hard X-ray Optics and Beamlines D. Attwood (Univ. California)**
14:40 – 15:00	*Coffee Break*
15:00 – 16:20	**Lec. 7 X-ray Diffraction M. Takata (Tohoku Univ.)**
16:20 – 16:40	*Coffee Break*
16:40 – 18:00	**Lec. 8 Coherence D. Attwood (Univ. California)**
18:00 – 19:30	Dinner

Sep.13 Sun.

Time	Sep.13 Sun.
9:00 – 10:20	**Lec. 9 Hard and Soft X-ray Microscopy D. Attwood (Univ. California)**
10:20 – 10:40	*Coffee Break*
10:40 – 12:00	**Lec. 10 Small-Angle Scattering N. Yagi (JASRI)**
12:00 – 13:00	*Lunch*
13:00 – 17:30	**Discussion with SPring-8 Staff**
17:30 – 19:30	*Dinner*

Sep.14 Mon.

Time	Sep.14 Mon.
9:00 – 10:20	**Lec. 11 Detectors R. Lewis (Monash Univ.)**
10:20 – 10:40	*Coffee Break*
10:40 – 12:00	**Lec. 12 Earth Science T. Yagi (Univ. Tokyo)**
12:00 – 13:10	*Lunch*
13:10	*1F Lobby, Main Bldg.*
13:20 – 15:00	**Meet the Experts Part 1**
15:00 – 15:20	Move to SACLA
15:20 – 15:40	*School Photo*
15:40 – 17:00	**Lec. 13 XFEL K. Tono (JASRI) and T. Inagaki (RIKEN)**
17:00 – 18:00	**Site Tour SACLA**
18:00 – 19:30	*Dinner*

Sep.15 Tue.

Time	Sep.15 Tue.
8:00 – 21:00	**Kyoto Excursion**

Sep.16 Wed.

Time	Sep.16 Wed.
9:20	*1F Lobby, Main Bldg.*
9:30 – 10:50	**Meet the Experts Part 2**
11:00 – 12:20	**Lec. 14 XAFS P. Fons (AIST)**
12:20 – 13:20	*Lunch*
13:20 – 14:40	**Lec 15 Inelastic Scattering M. Dean (BNL) / Lec 16 Infrared F. Borondics (Soleil)**
14:40 – 15:00	*Coffee Break*
15:00 – 16:20	**Lec 17 Medical Imaging R. Lewis (Monash Univ.) / Lec 18 Photoemission Spectroscopy S-J. Tang (National Tsing Hua Univ.)**
16:20 – 16:40	*Coffee Break*
16:40 – 18:00	**Lec 19 Protein Crystallography J. M. Guss (Univ. Sydney) / Lec 20 Soft X-ray Absorption Spectroscopy P. Krüger (Chiba Univ.)**
18:00 – 19:30	*Dinner*
19:30 – 20:30	**SPECTRA Workshop**

Sep.17 Thu.

Time	Sep.17 Thu.
9:30 – 17:30	**BL Practical Part 1**
17:30 – 18:30	*Dinner*
18:30 – 20:00	**Tea Ceremony**

Sep.18 Fri.

Time	Sep.18 Fri.
9:30 – 17:30	**BL Practical Part 2**
17:30 – 18:00	*Move to Houkou-kan*
18:00 – 19:30	**Farewell at Houkou-kan**

Sep.19 Sat.

Time	Sep.19 Sat.
	Guest House Check-out
9:00 – 10:20	**Lec. 21 Atomic and Molecular Physics at SACLA K. Ueda (Tohoku Univ.)**
10:20	*Break*
10:30 – 11:00	**Lec. 22 Future of SR T. Ishikawa (RIKEN)**
11:00 – 11:30	**Closing Remarks**
11:30 – 12:20	*Lunch*
12:30	*Bus leaves for KIX*

☆ Parallel Lectures

SPring-8 Cafeteria Opening Hour: Breakfast: 8:00-9:30
Lunch: 11:30-14:00
Dinner: 17:30-19:30

Enjoy the Cheiron School!

Thanks to many people for slides
Particularly Edgar Weckert, DESY

2015 Cheiron School

IUCr KEK JASRI RIKEN AOF Synchrotron Radiation


Thanks for your attentions