TAIWAN PHOTON SOURCE

X-ray Nanoprobe Beamline for Nanoscale Physics Research

Tseng, Shao-Chin
2019/09/26

X-ray Image Group
Experiment Facility Division
NSRRC

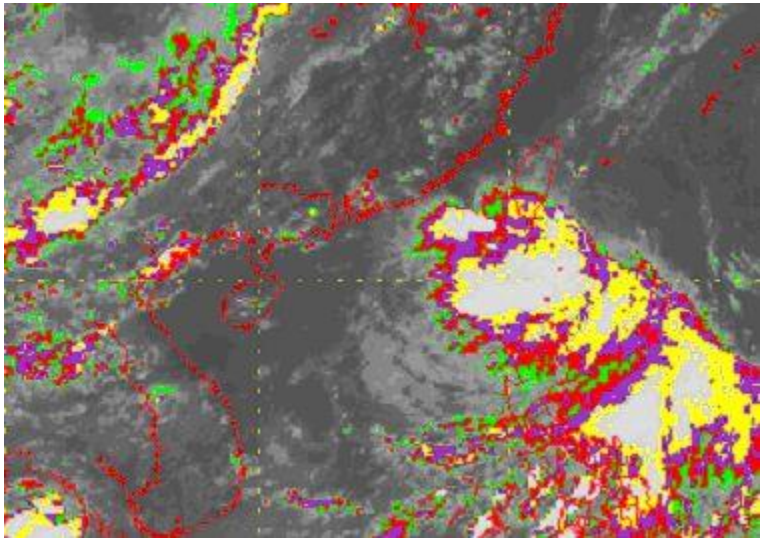
Outline

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

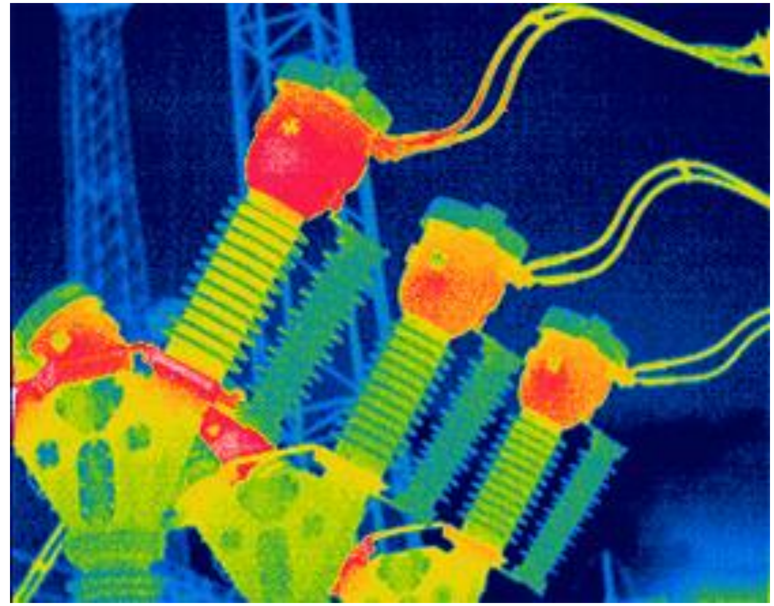
“Light” is indispensable to man‘s exploration of nature.

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

Invisible light: IR and X-ray…

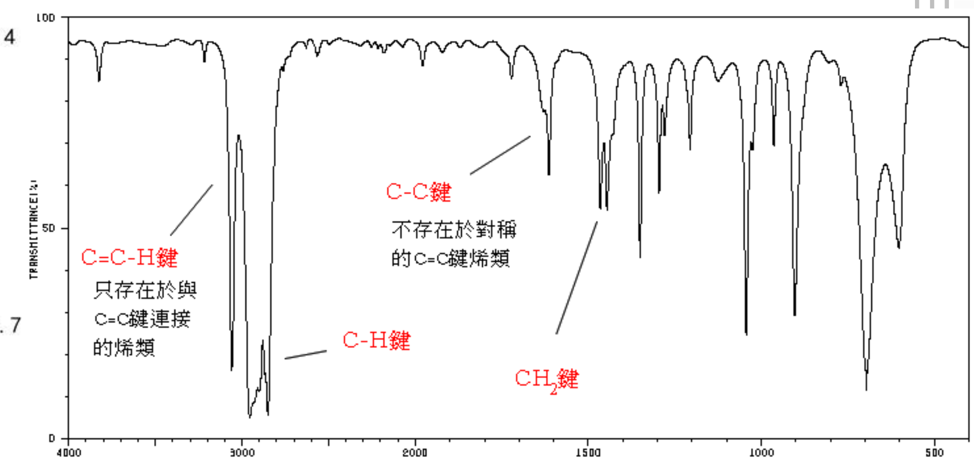


http://www.hko.gov.hk/prtver/html/docs/education/edu02rga/radiation/radiation_02-c.shtml



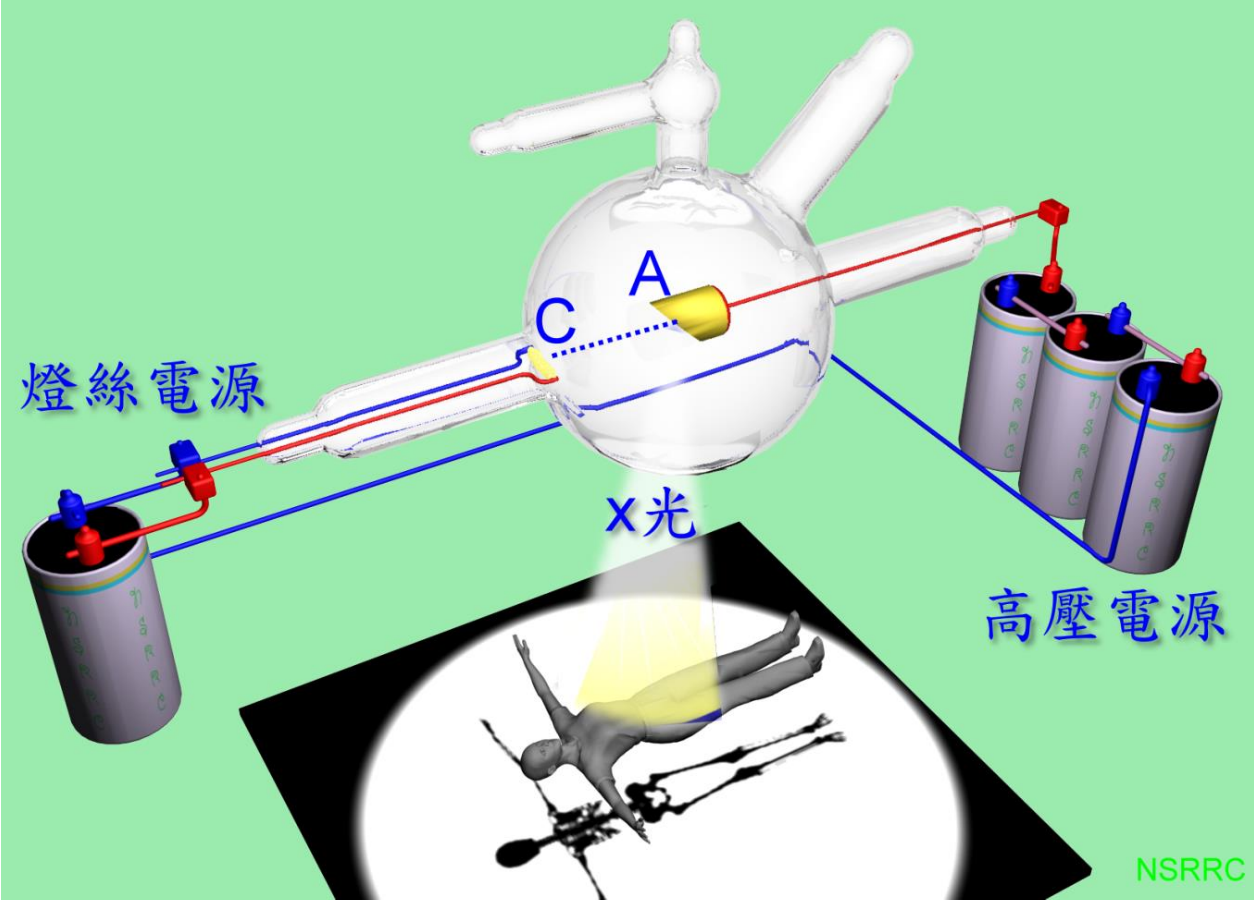
http://www.yingfukeji.com/appl/grid.html

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



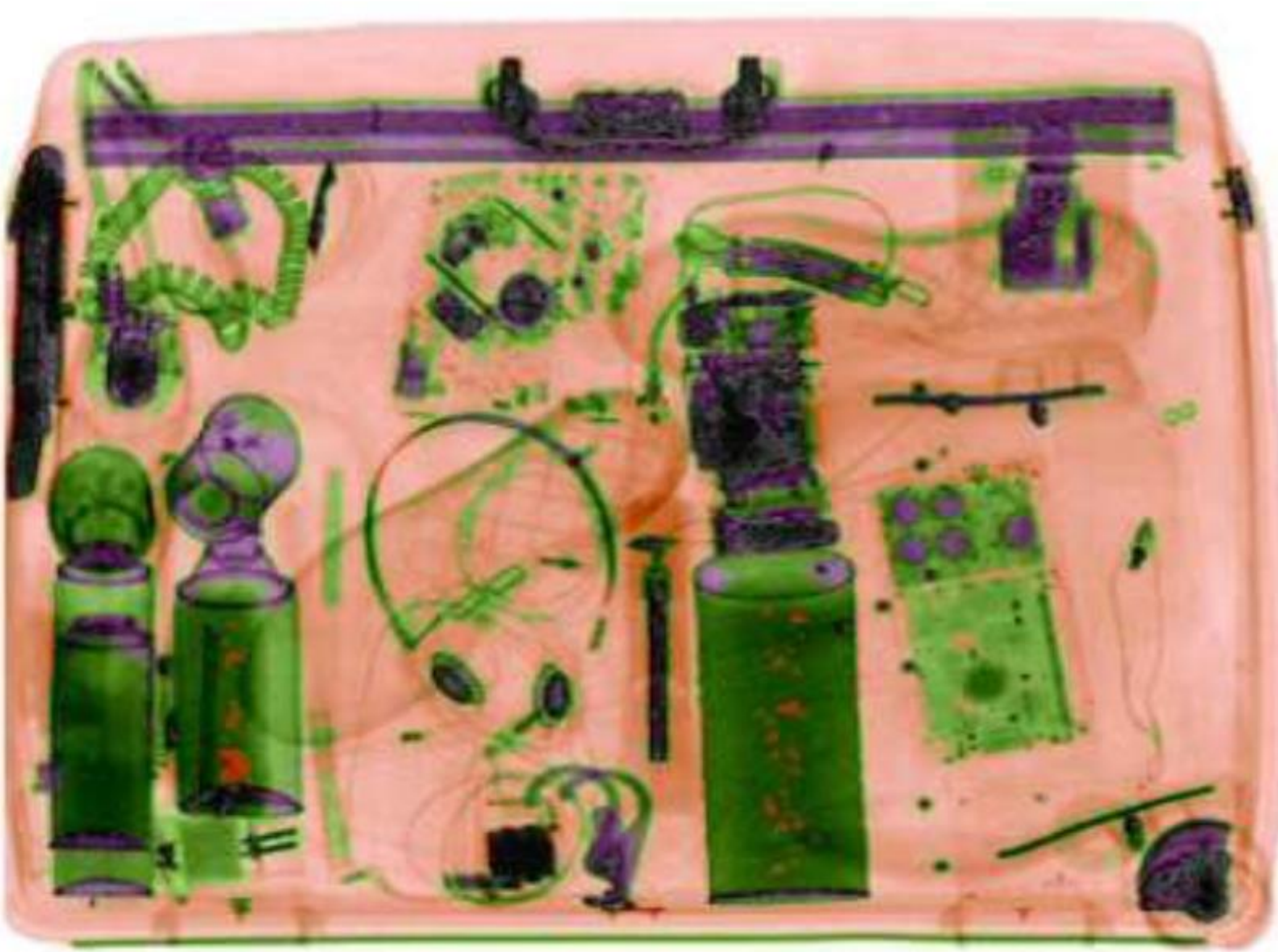
1895

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

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

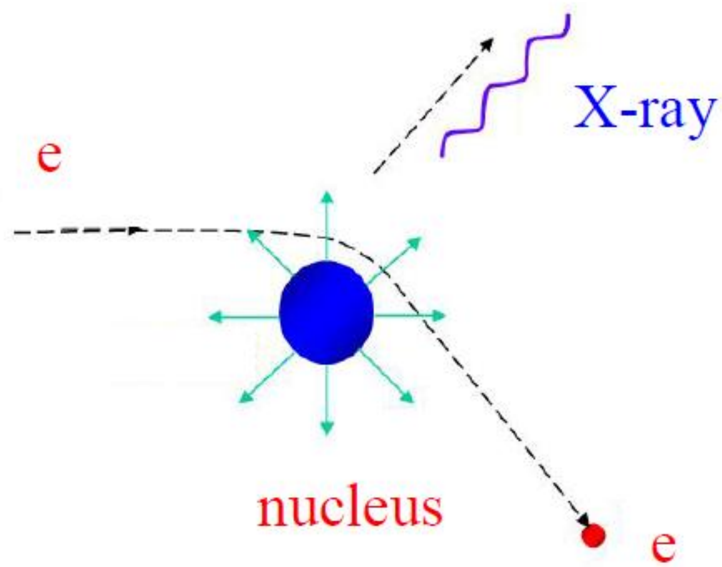
國家同步輻射研究中心
National Synchrotron Radiation Research Center

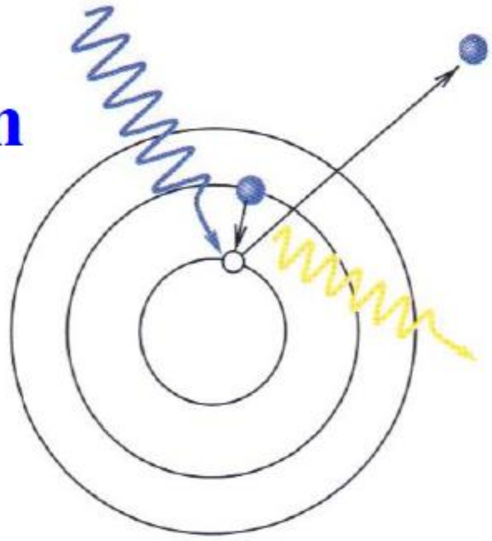


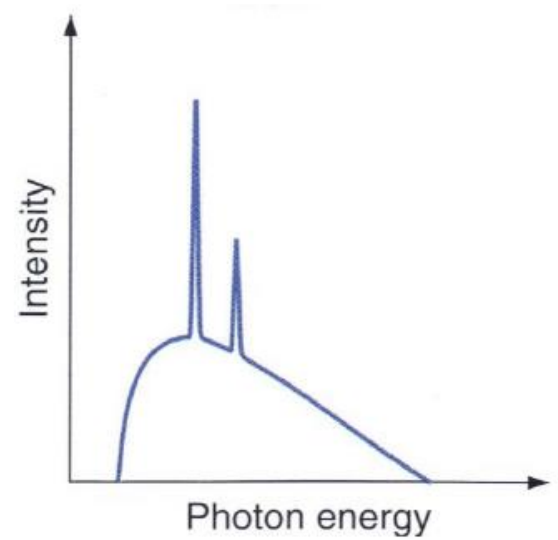
http://snallabolaget.com/?page_id=666

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

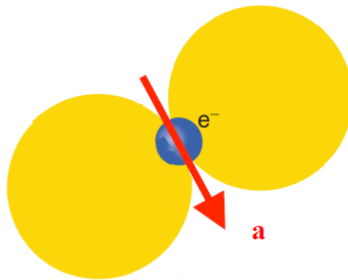
Characteristic X-ray emission



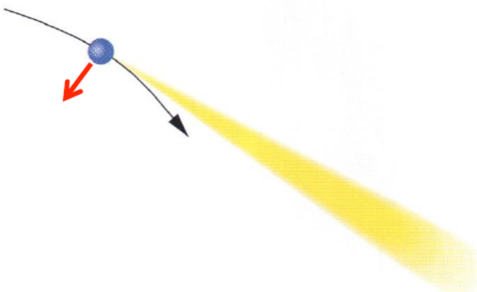




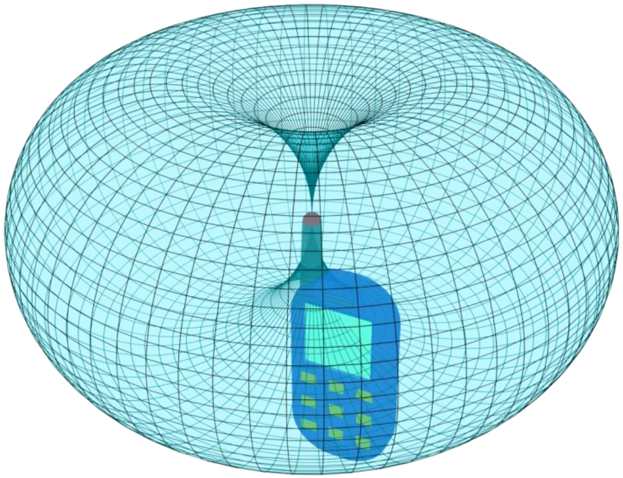
Electromagnetic wave from a moving charge

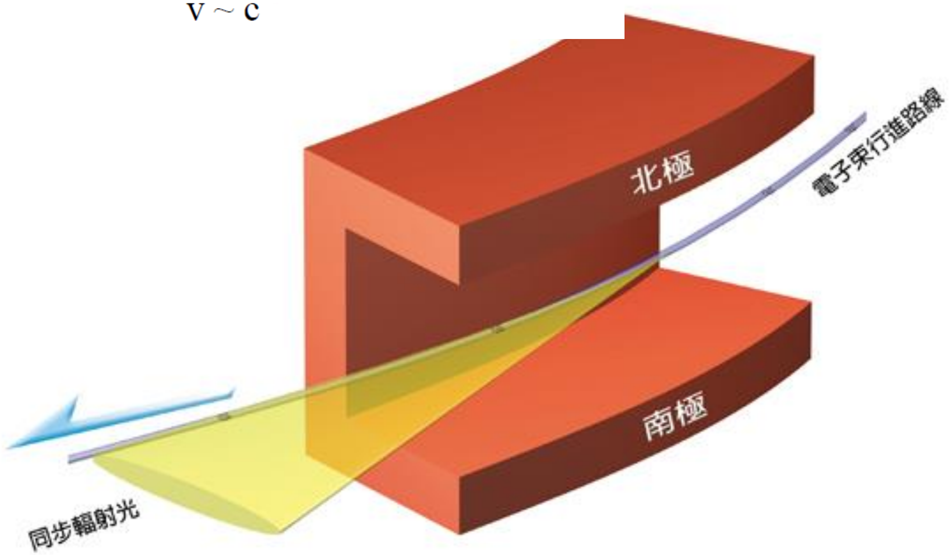


v << c



v ~ c

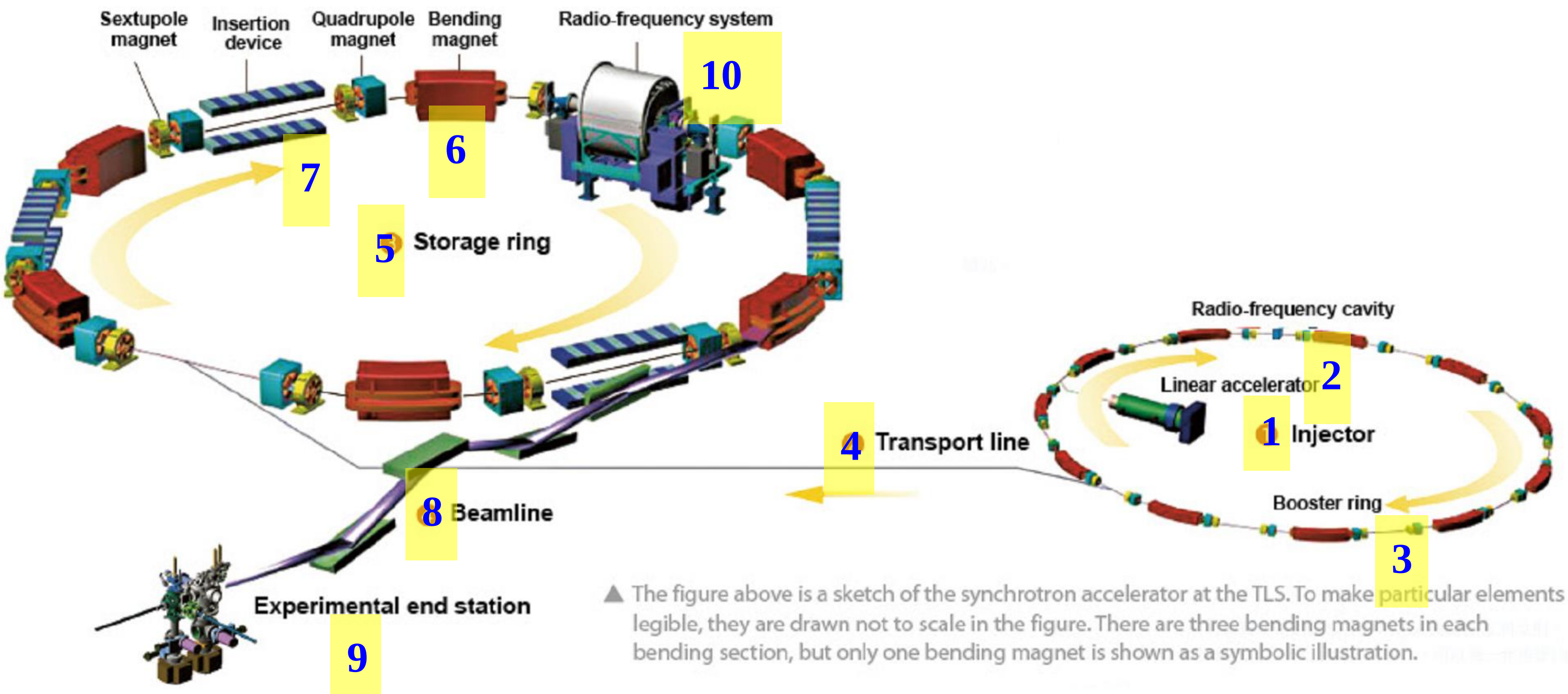




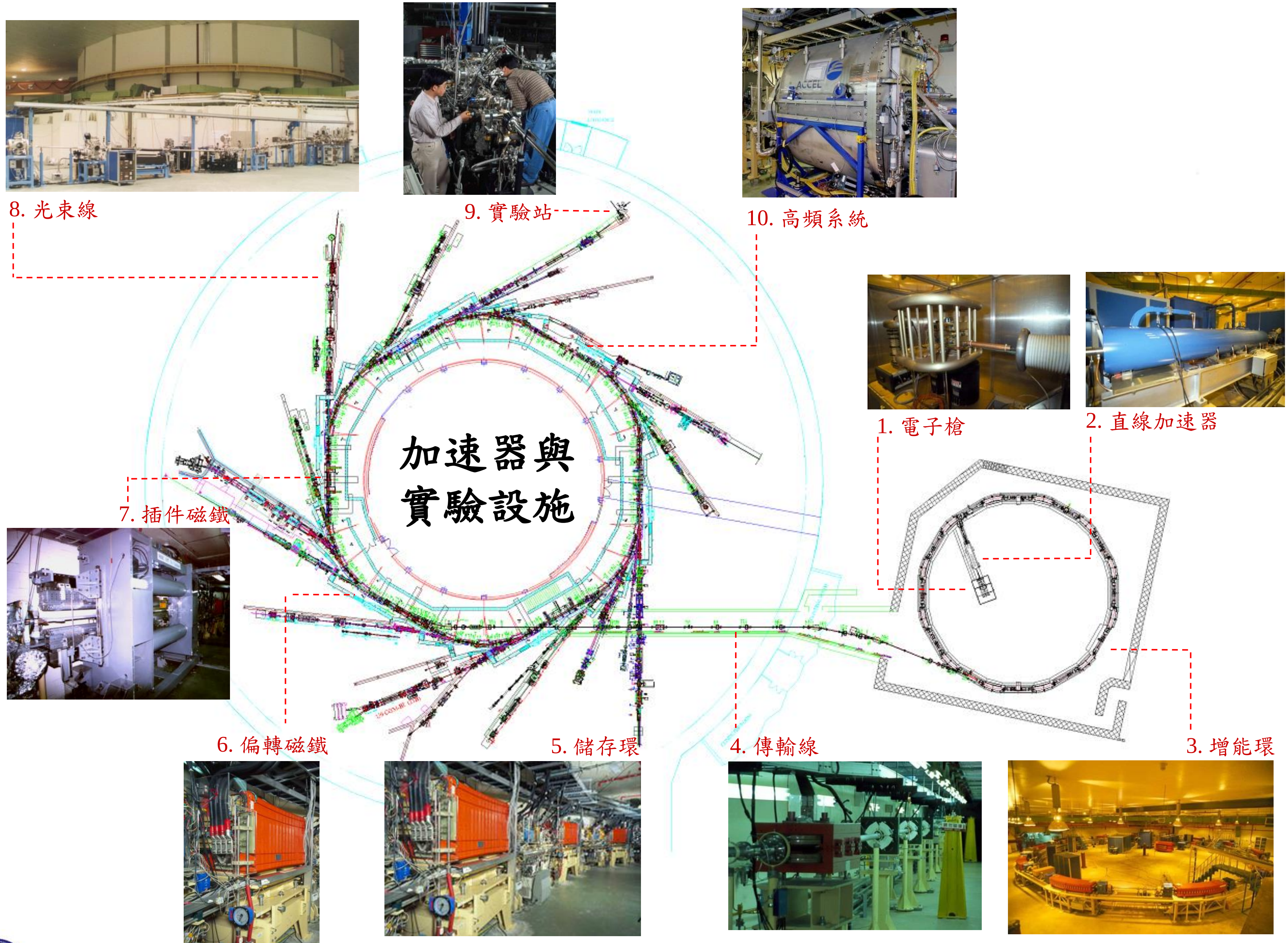
二極偏轉磁鐵

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。

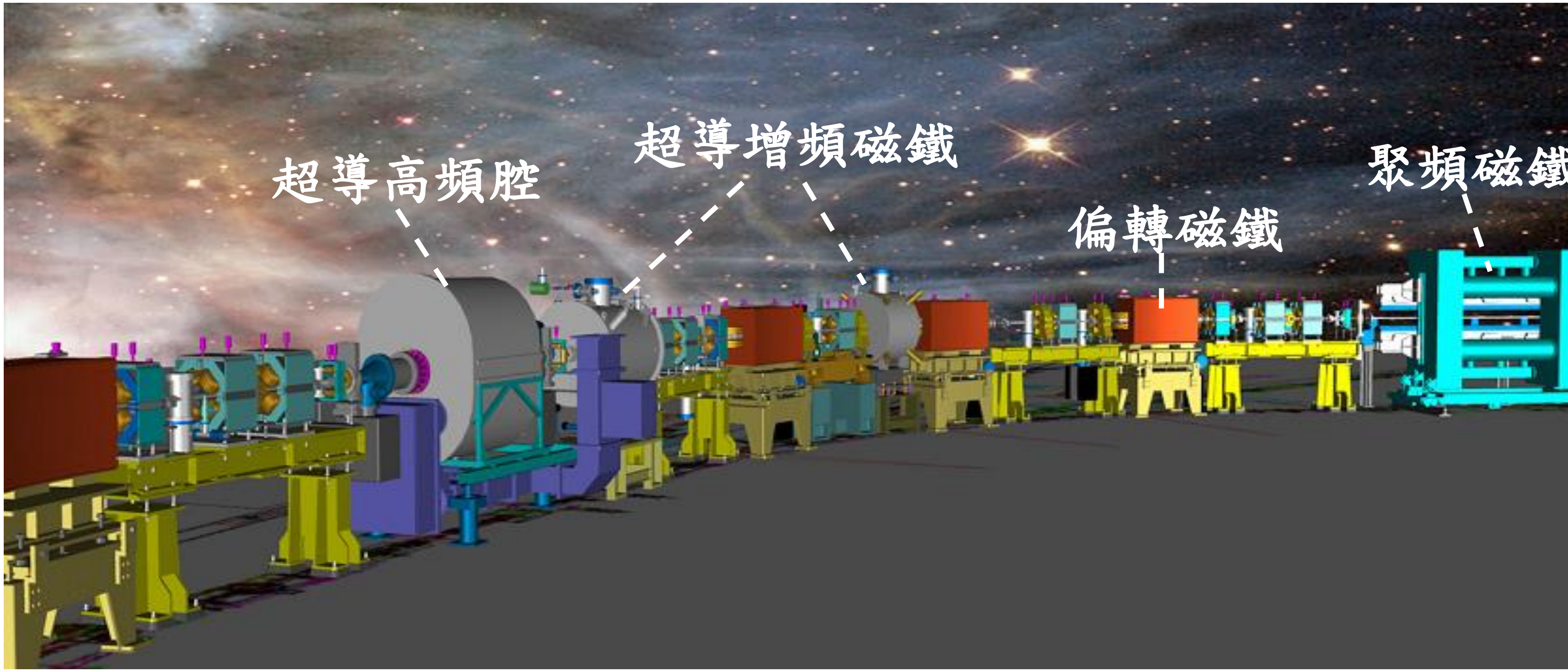


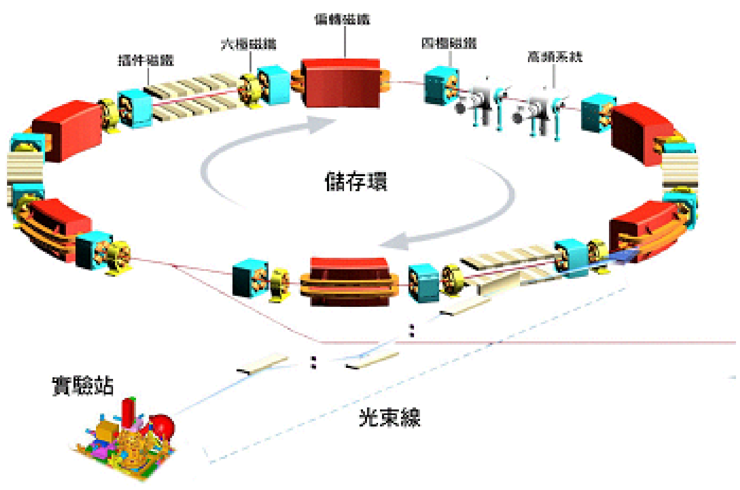
▲ The figure above is a sketch of the synchrotron accelerator at the TLS. To make particular elements legible, they are drawn not to scale in the figure. There are three bending magnets in each bending section, but only one bending magnet is shown as a symbolic illustration.



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

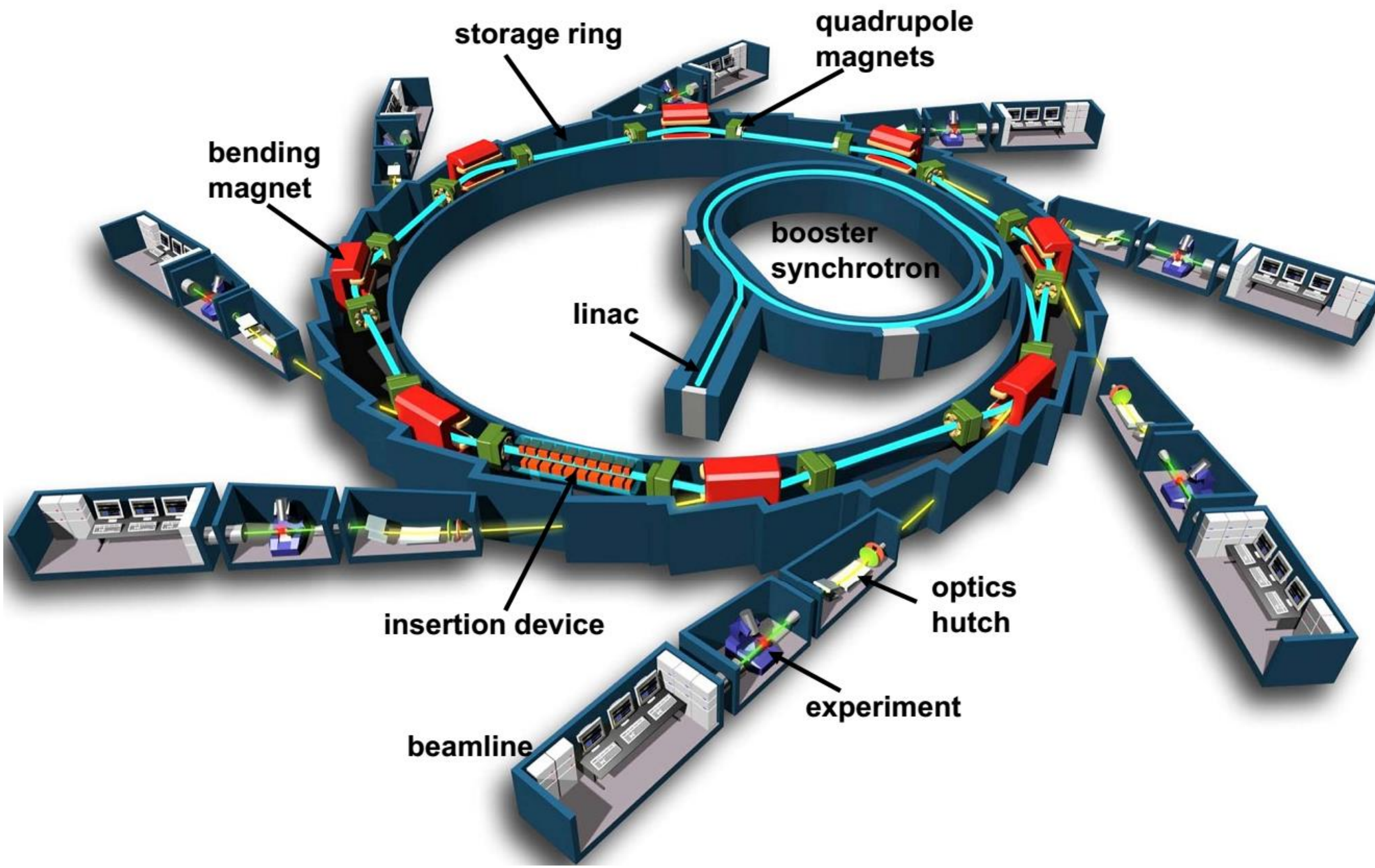
儲存環 3D 圖





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

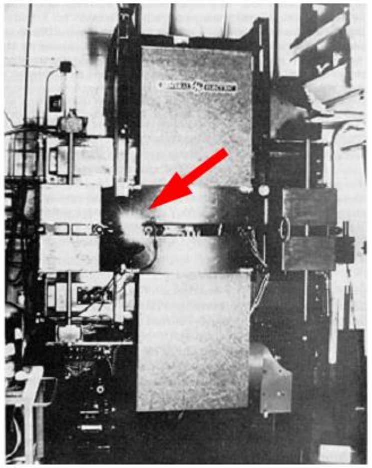
A Synchrotron Step by Step



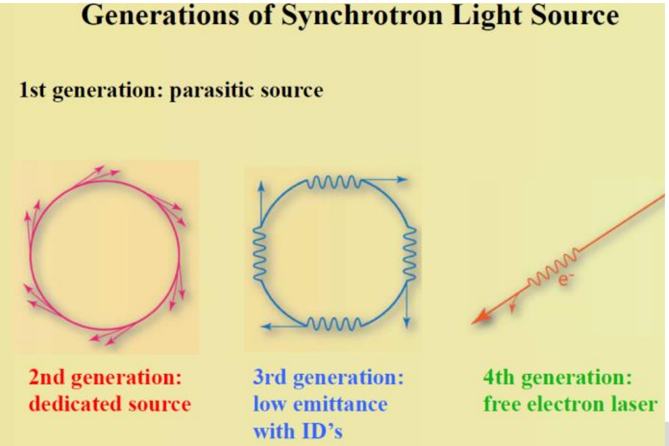
國家同步輻射研究中心
National Synchrotron Radiation Research Center

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



- 1st 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)
- 2nd generation light sources: purpose built synchrotron light sources, eg Photon Factory, NSLS, Daresbury (1980s onwards)
- 3rd 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??



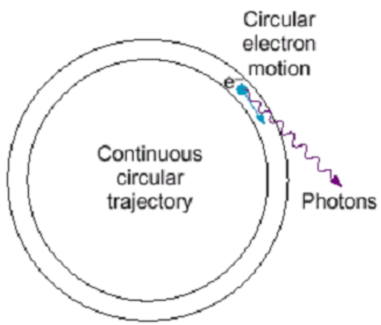
2015 Cheiron School

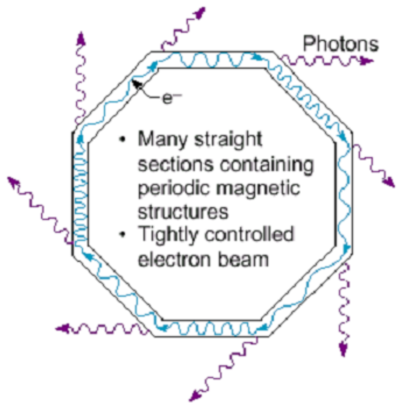
國家同步輻射研究中心
National Synchrotron Radiation Research Center

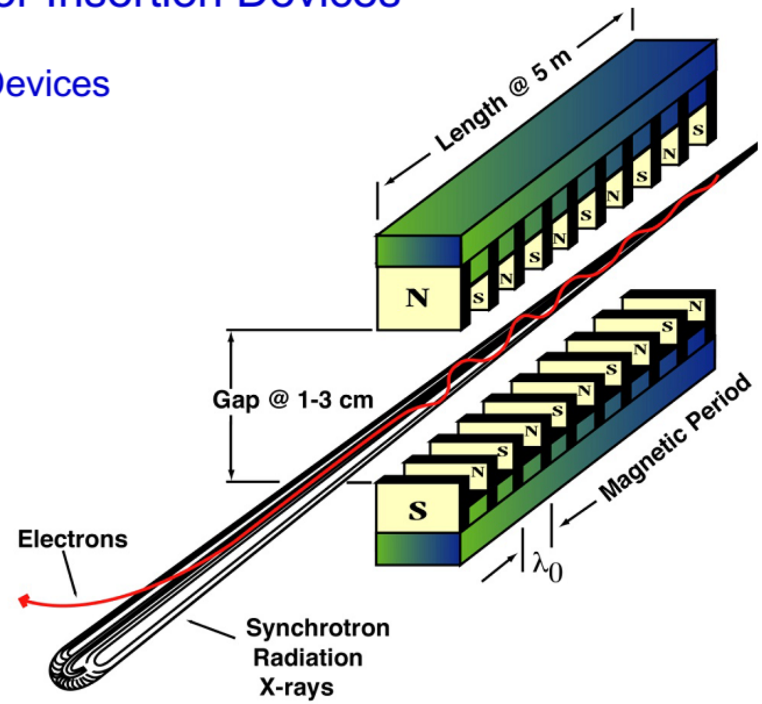
Third Generation Sources: Undulator Insertion Devices

1^{st}, 2^{nd} Generation

3rd Generation: Insertion Devices

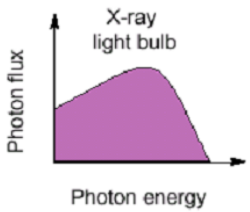


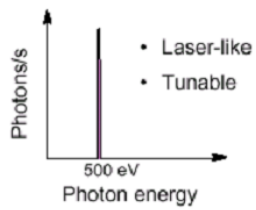


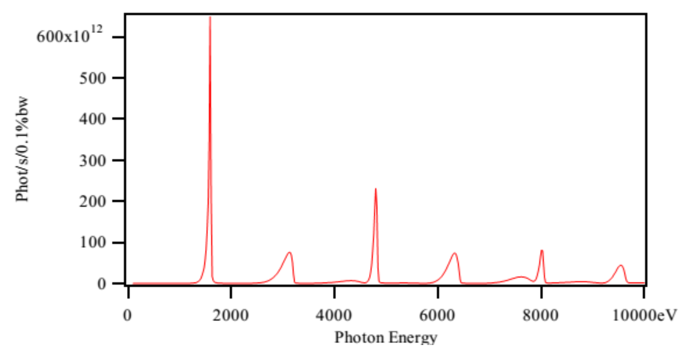


Bend Magnet Radiation

Undulator Radiation

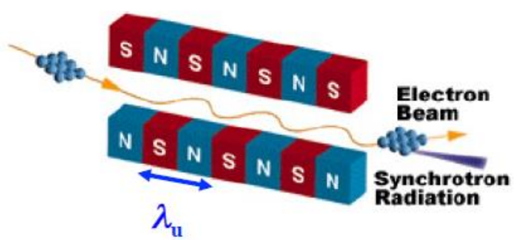


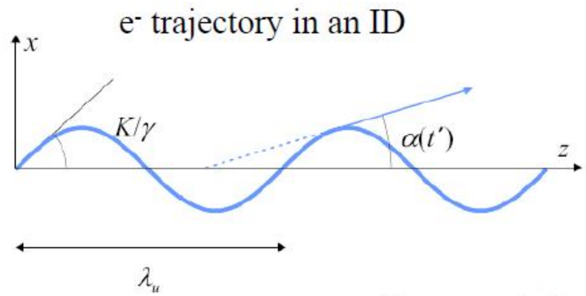




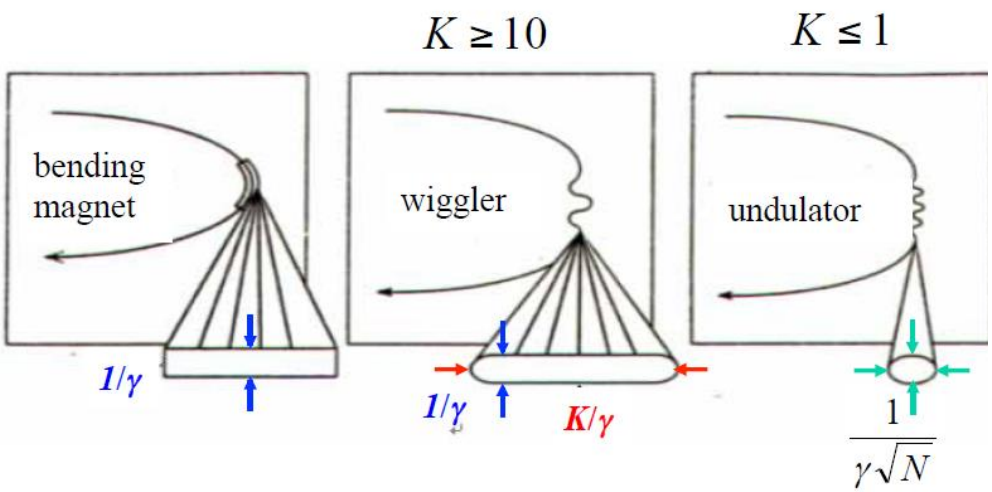
Angular distribution of synchrotron radiation emitted from various magnets

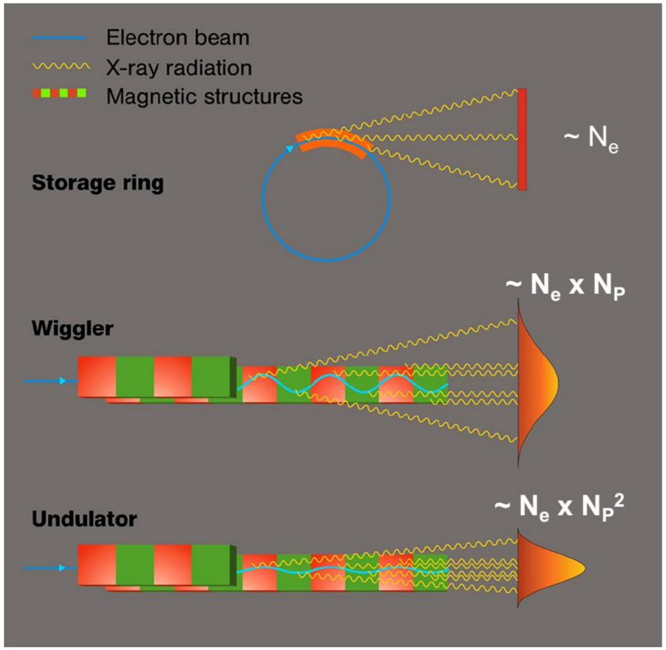
Wiggler or undulator

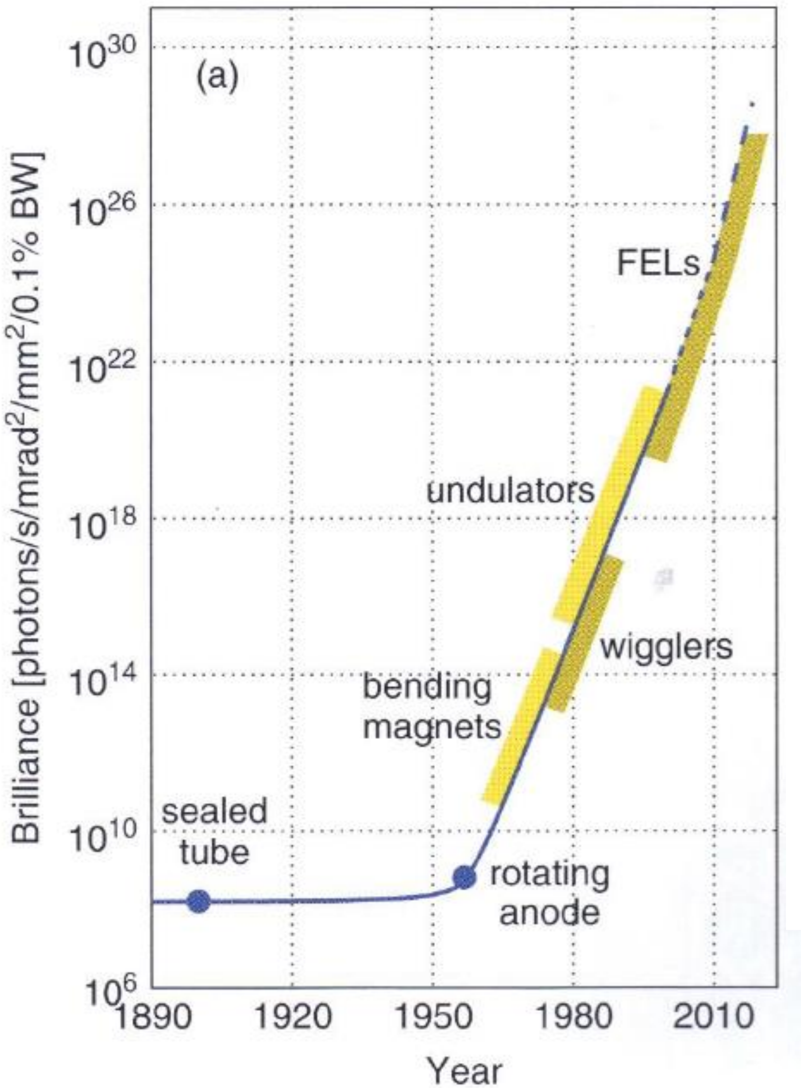




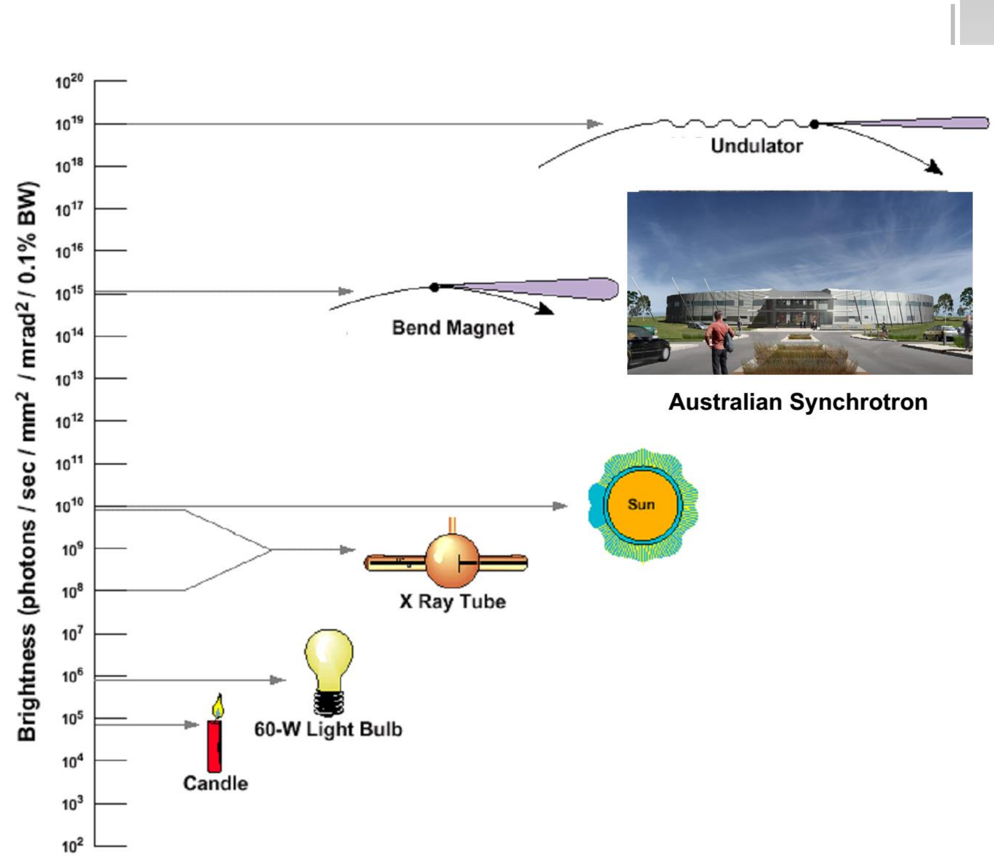
$K = \alpha_{max.} / \gamma^{-1}$







(a)
Brilliance [photons/s/mrad^2/mm^2/0.1% 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

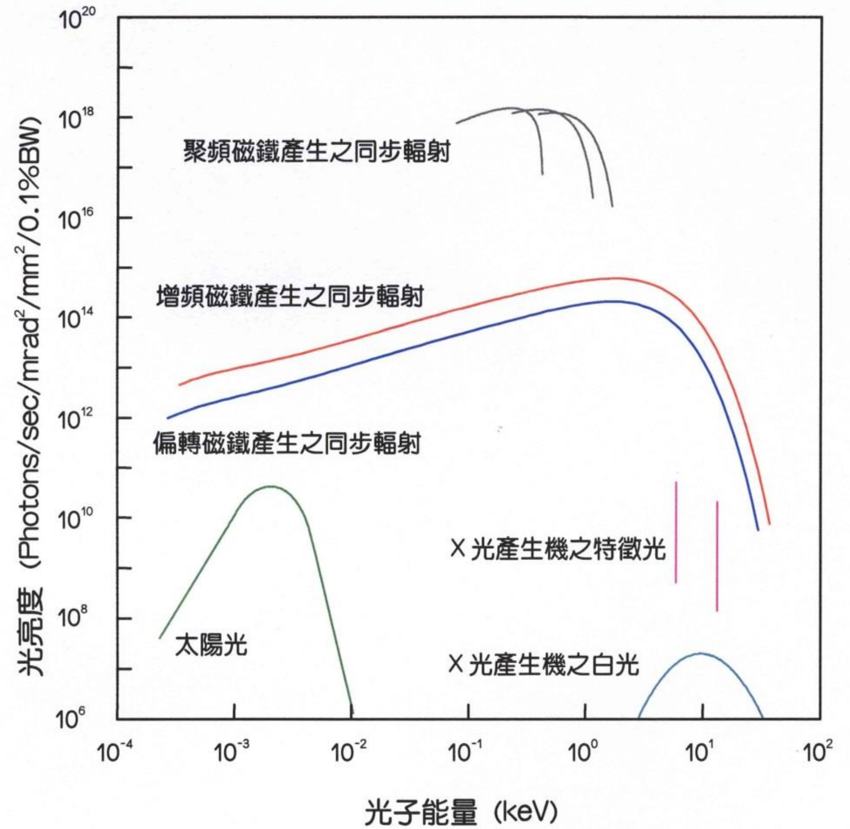


Brightness (photons / sec / mm^2 / mrad^2 / 0.1% BW)
10^{20}
10^{19}
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
Undulator
Bend Magnet
Australian Synchrotron
Sun
X Ray Tube
60-W Light Bulb
Candle

Unique Features of Synchrotron Light Source

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

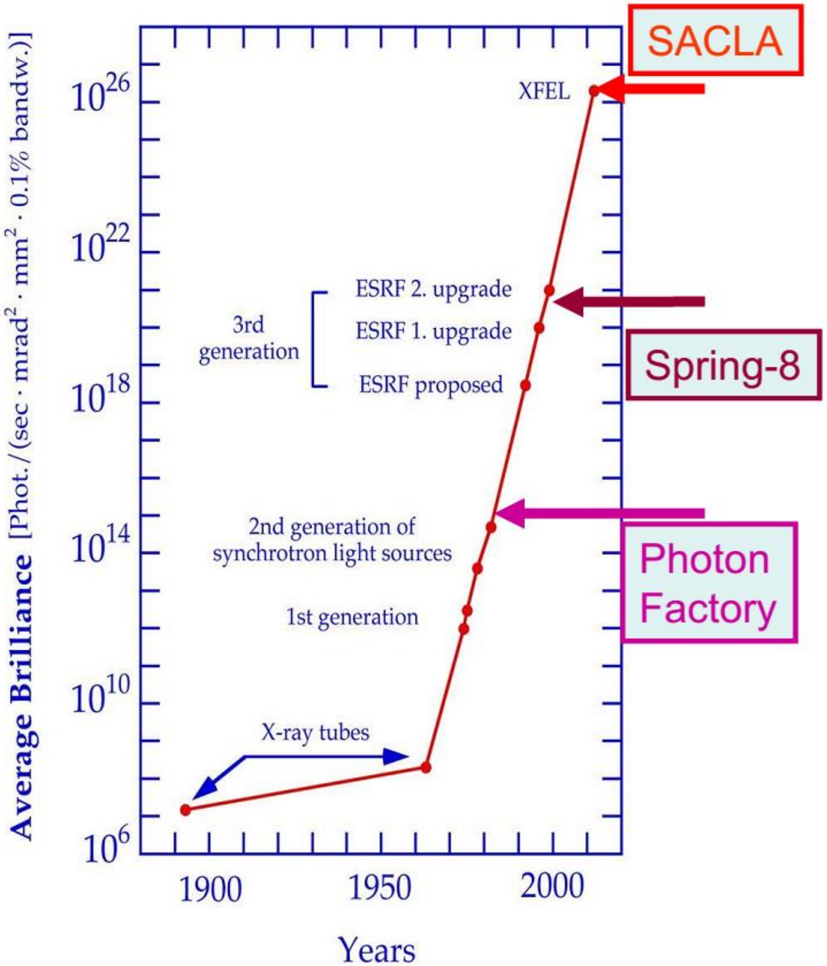
以X光為例，同步加速器光源在這個波段的亮度比傳統X光機還要強百萬倍以上！過去需要幾個月才能完成的實驗，現在只需幾分鐘便能得到結果。以往因實驗光源亮度不夠而無法探測的結構，現在藉由同步加速器光源，都可分析得一清二楚，也因此得以開發新的研究領域。

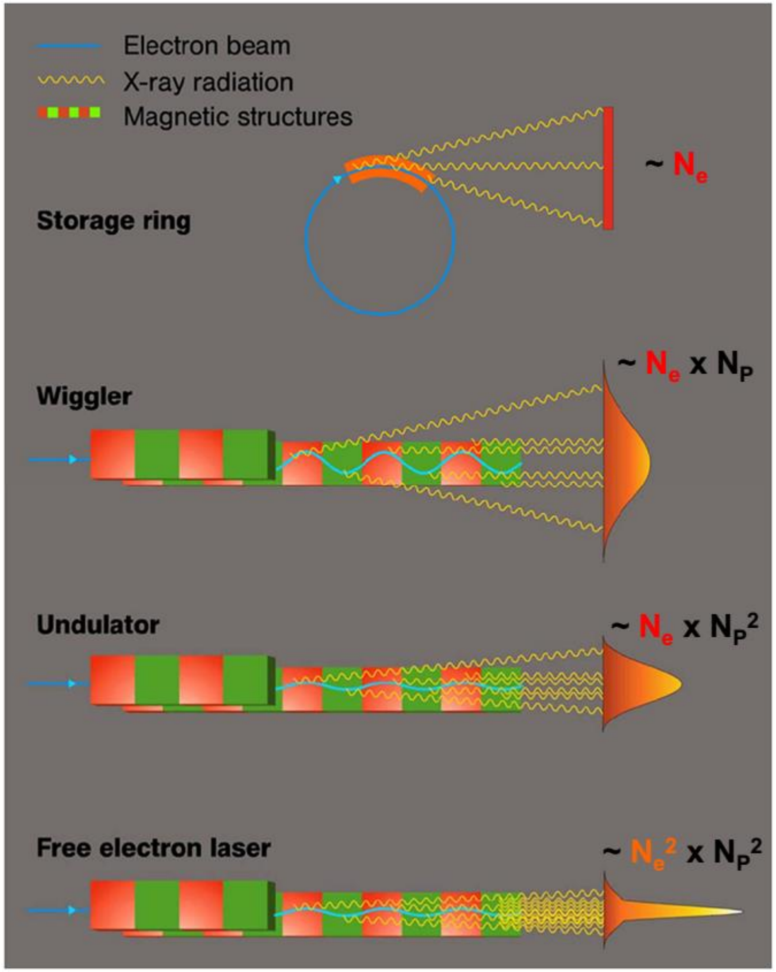


- 光子能量：一般單位爲電子伏特(eV)，一電子伏特爲電子在真空中通過一伏特電位差所獲得的能量。
- 光亮度：指單位時間內通過單位立體角的單位頻寬光子數。

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

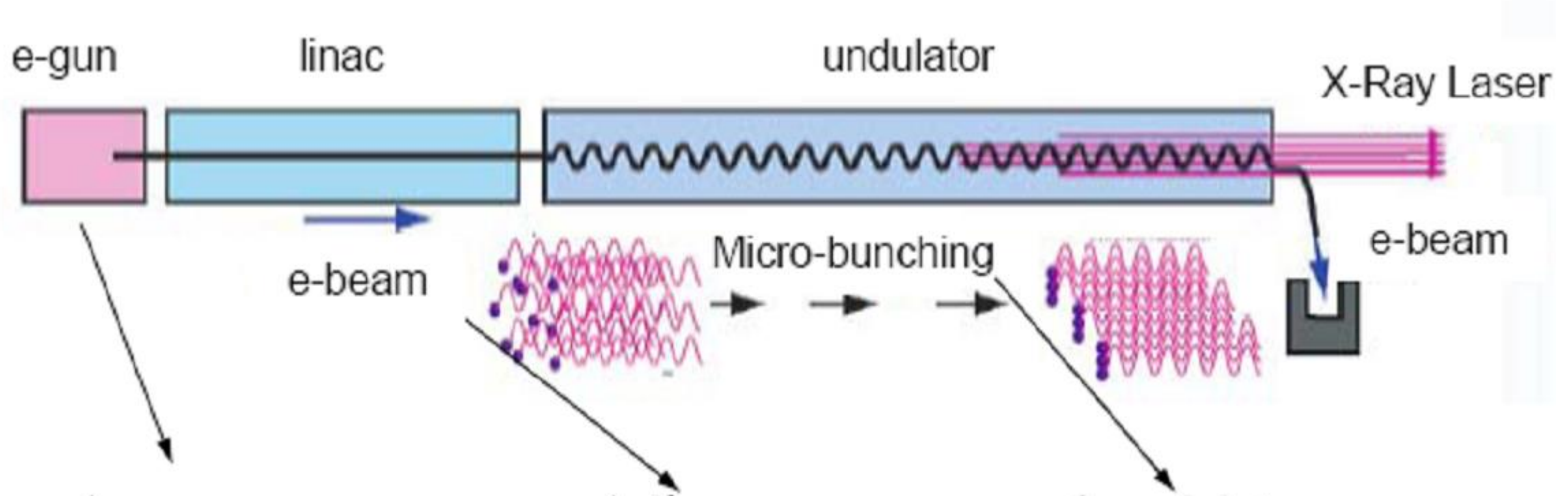
Next Step - X-ray Lasers? Yes ➔ FELs



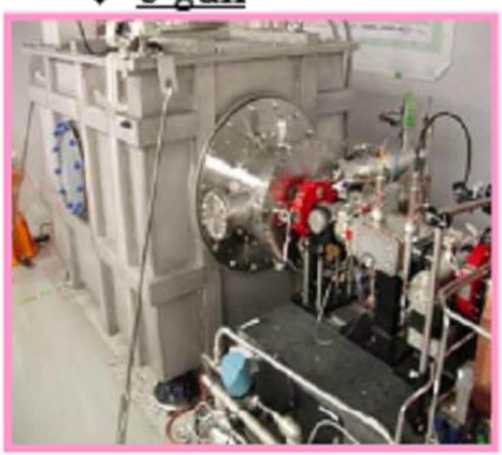


國家同步輻射研究中心
National Synchrotron Radiation Research Center

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



◆ e-gun



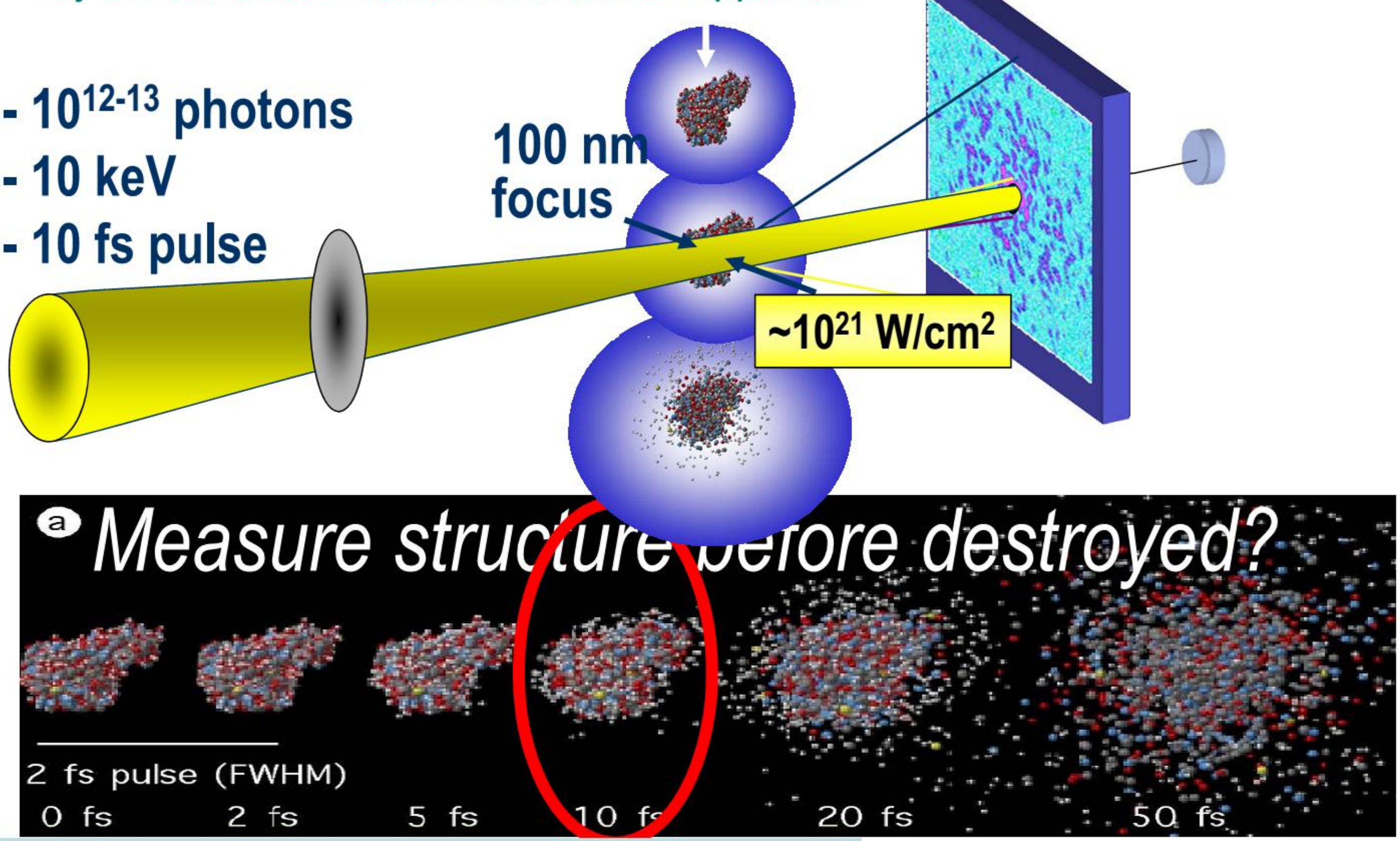
◆ linac

◆ undulator


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

Coherent diffractive imaging of single particles

by the diffraction-before-destruction approach



Calculations. in vacuum Neutze et al., Nature 2000

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

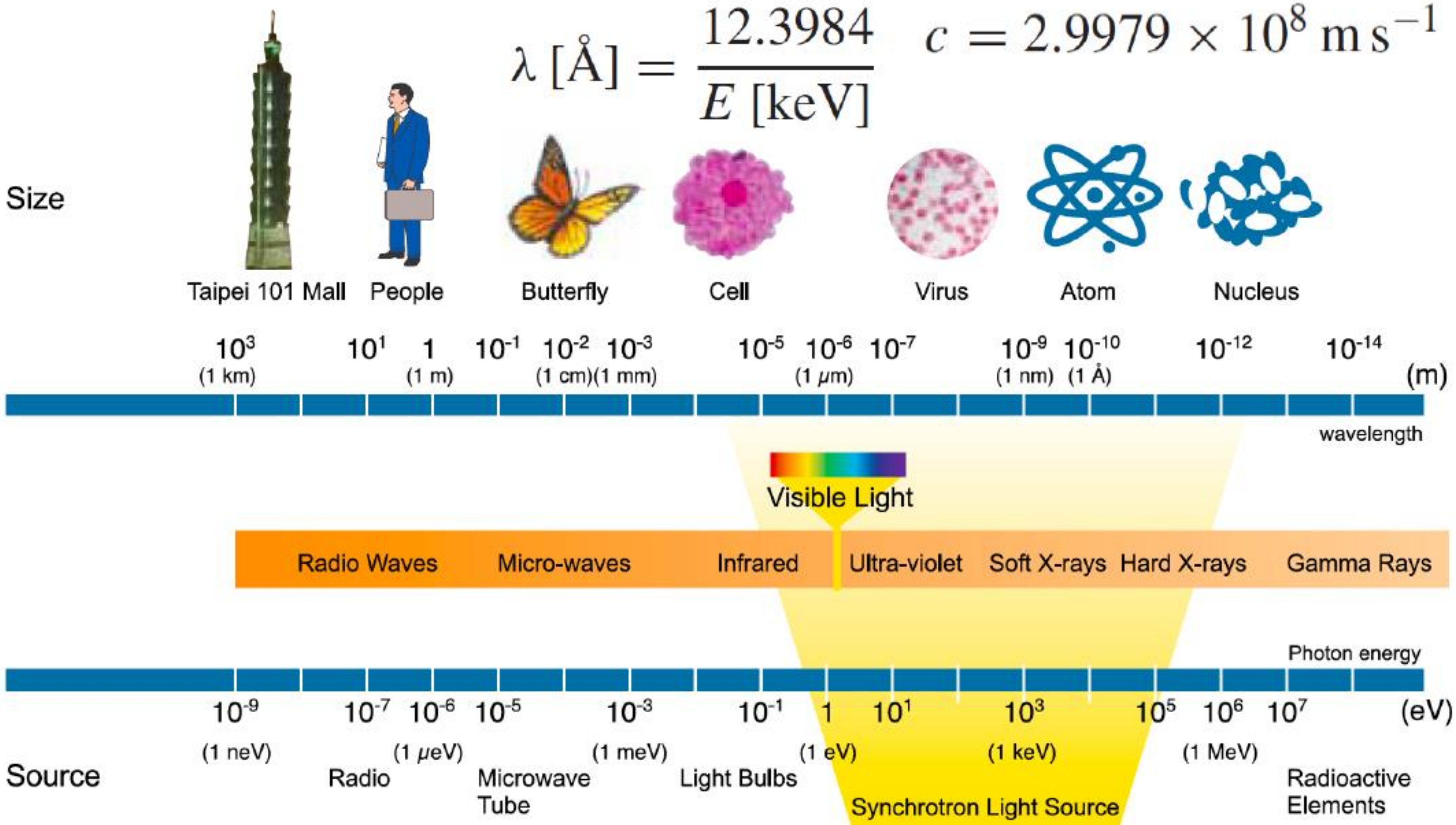
$$E = h\nu = hc/\lambda,$$

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

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

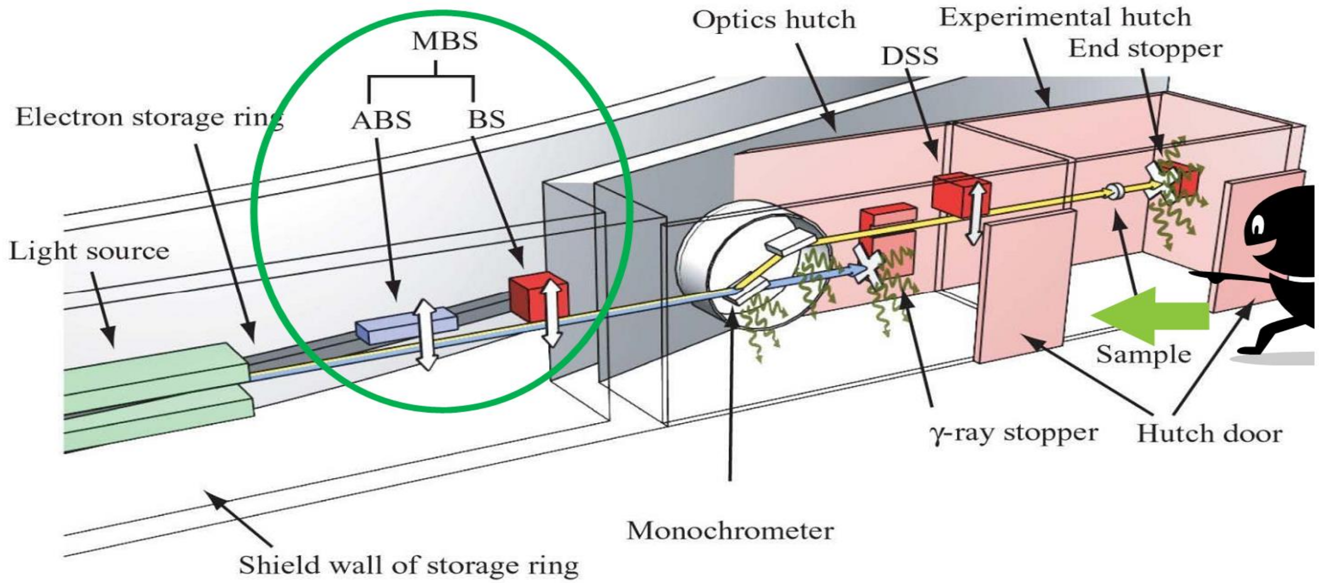
Electromagnetic Spectrum

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



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

Beamline

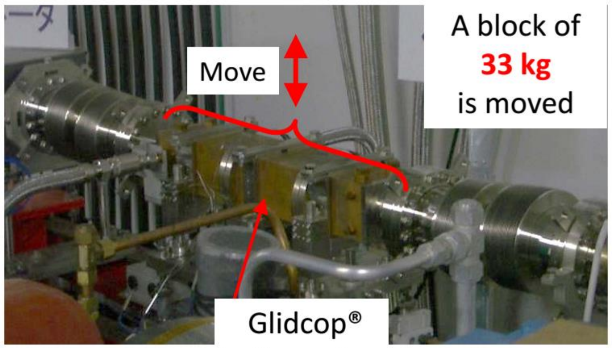


For safety

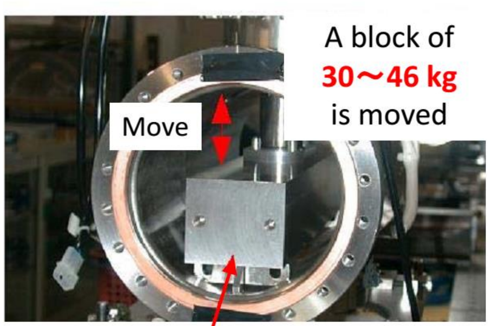
When we operate a main beam shutter (MBS), what happens ?

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

to protect BS from heat load | *to shield you against radiation*



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



Heavy metal (alloy of tungsten)

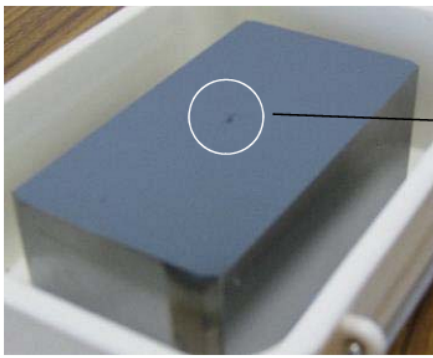
the thermal conductivity not so high

國家同步輻射
National Synchrotron Radiatio

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

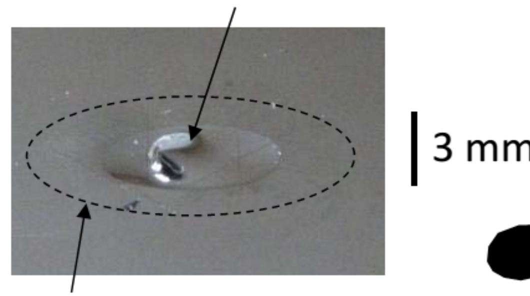
One user opened FE slit excessively.

2kW



LN2-cooled Si crystal

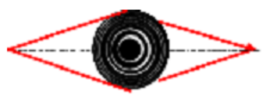
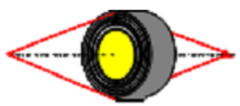
Melted



Damaged area

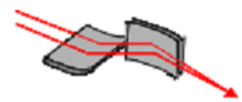
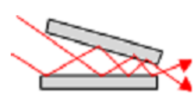
Slit : *"Too much is as bad as too little"*

Overview of x-ray focusing devices

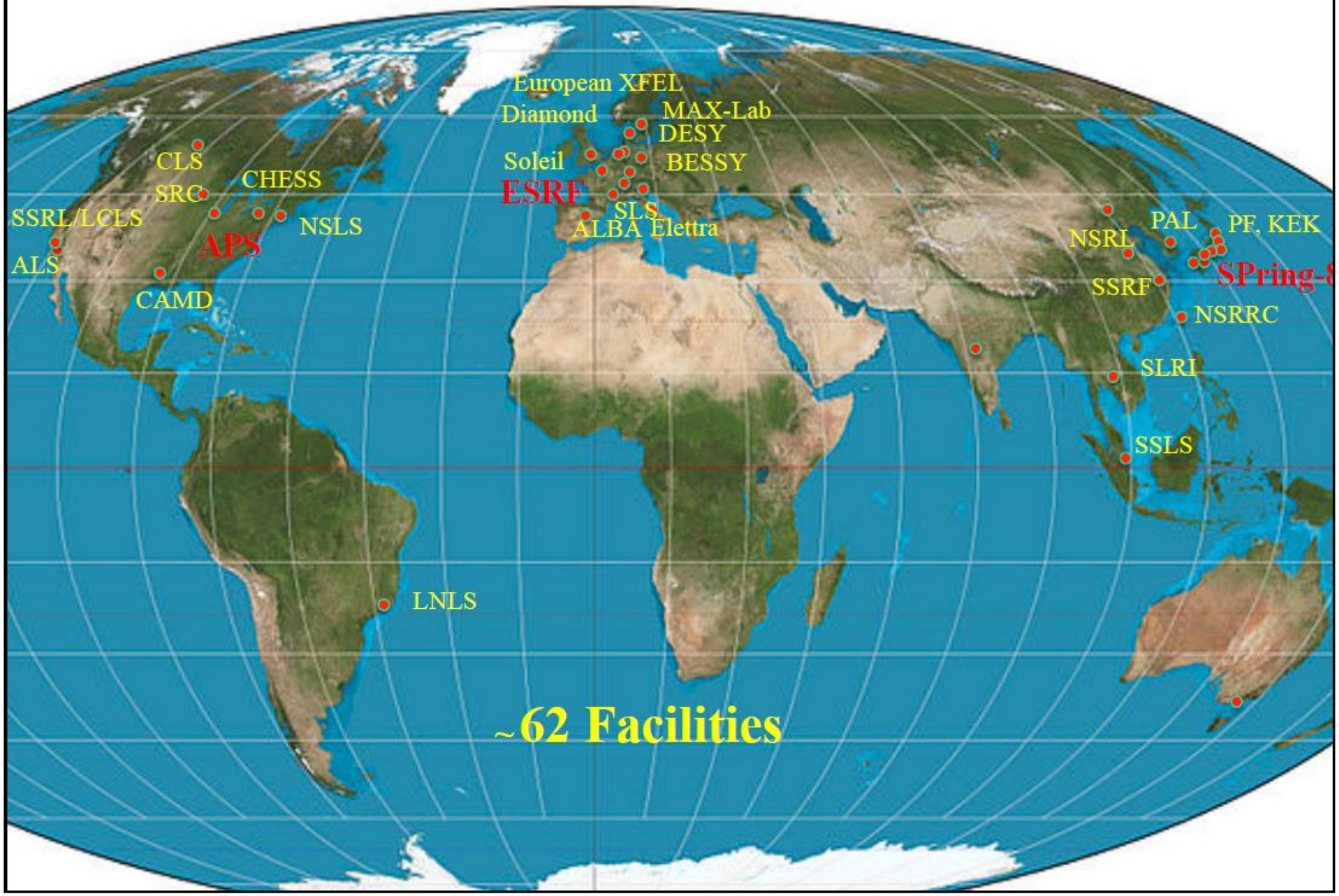
Diffraction	focus size, focal length [energy]	energy range	aberration -coma -chromatic -figure error
 Fresnel Zone Plate	12 nm, f = 0.16 mm [0.7 keV], 30 nm, f = 8 cm [8 keV]	soft x-ray hard x-ray	-coma small -chromatic exist -figure error small
 Sputter sliced FZP	0.3 μm, f = 22 cm [12.4 keV], 0.5 μm, 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

World Map of Synchrotron Facilities



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

Outline

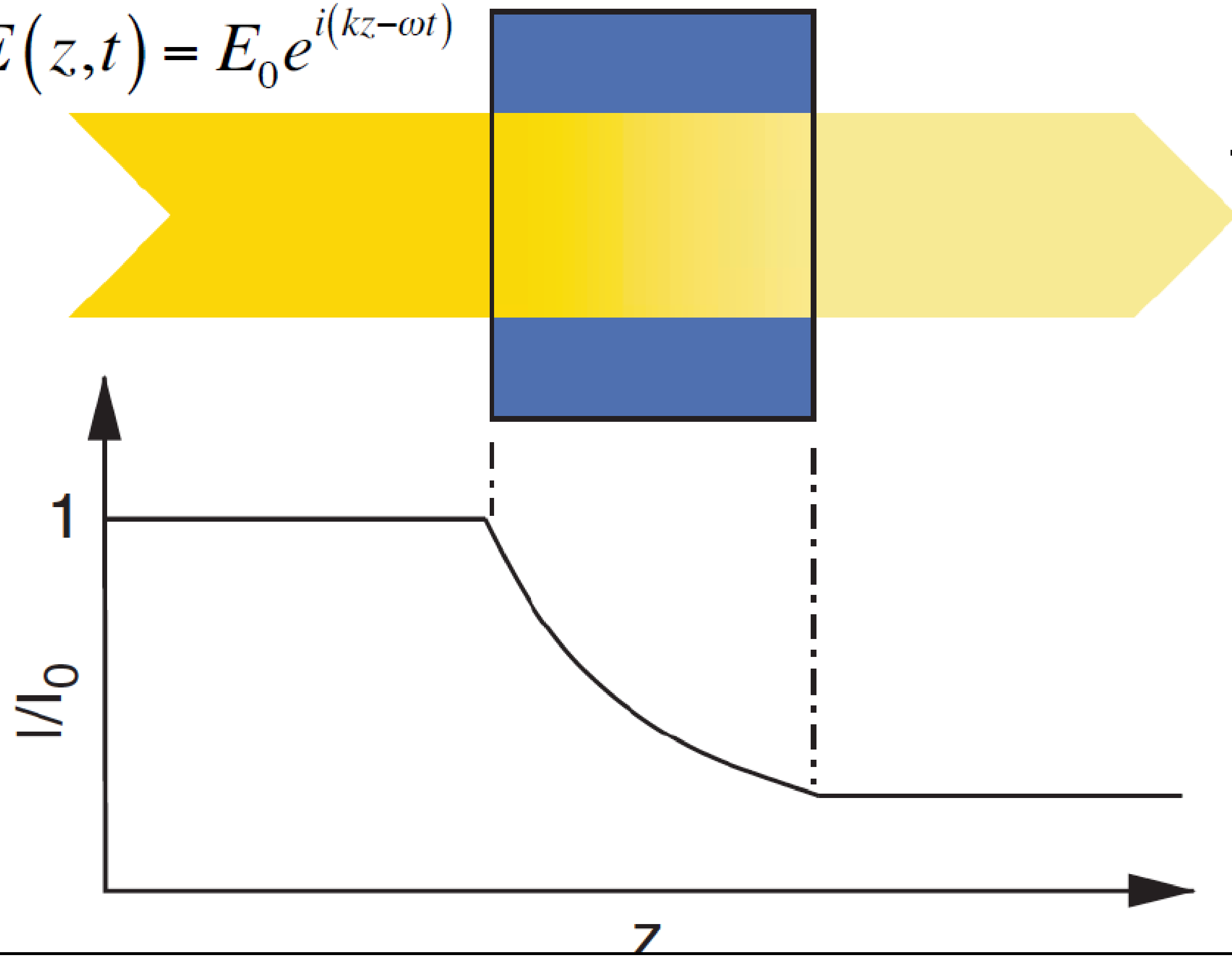
- Synchrotron Light Source
- Application of Synchrotron Light
- X-ray nano probe at TPS

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

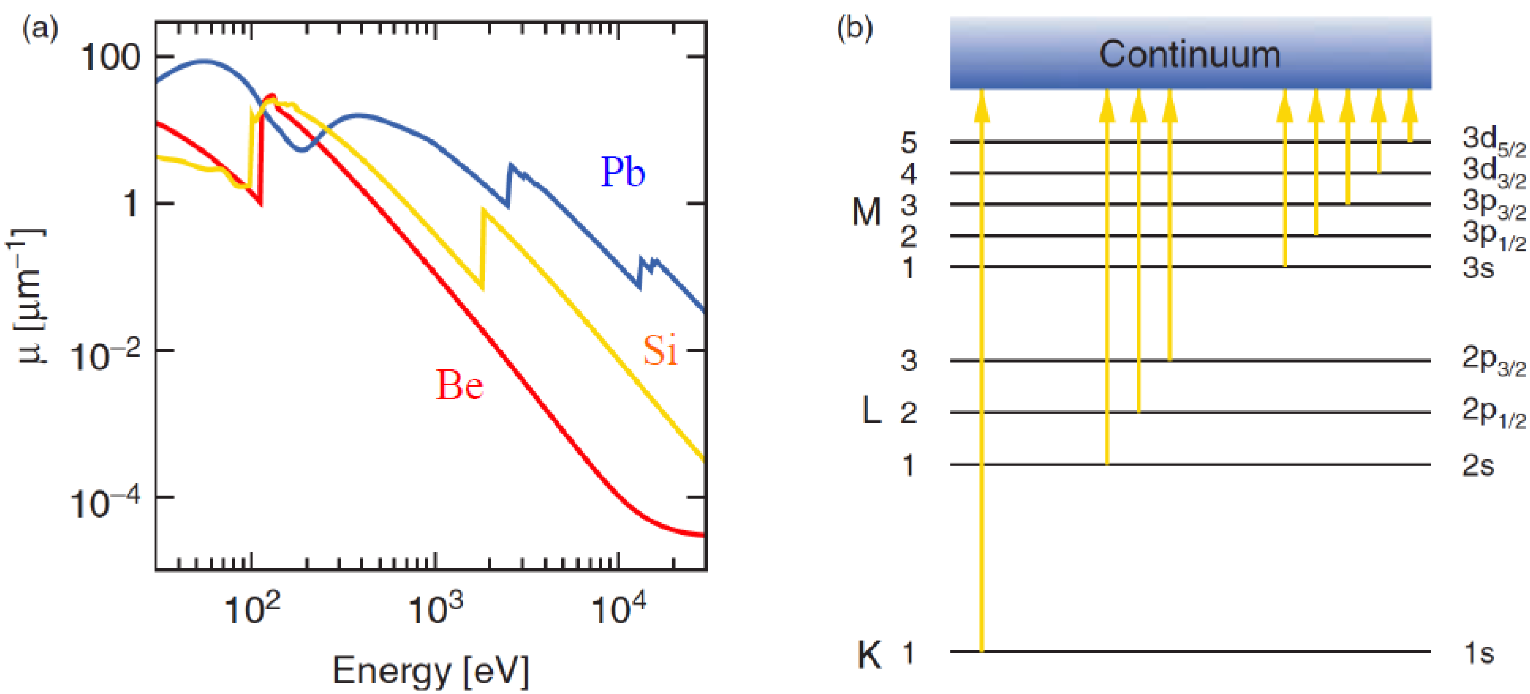
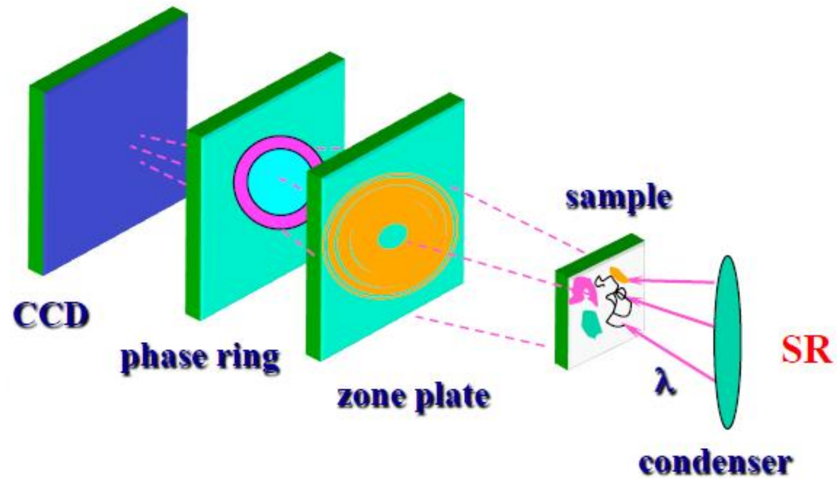


Figure 2.16 *(a) The x-ray absorption coefficient μ for beryllium (red curve), silicon (yellow) and lead (blue) as a function of the photon energy. (b) Sharp increases in the absorption occur when the photon energy is just sufficient to eject the electron from the electronic orbital to the continuum.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

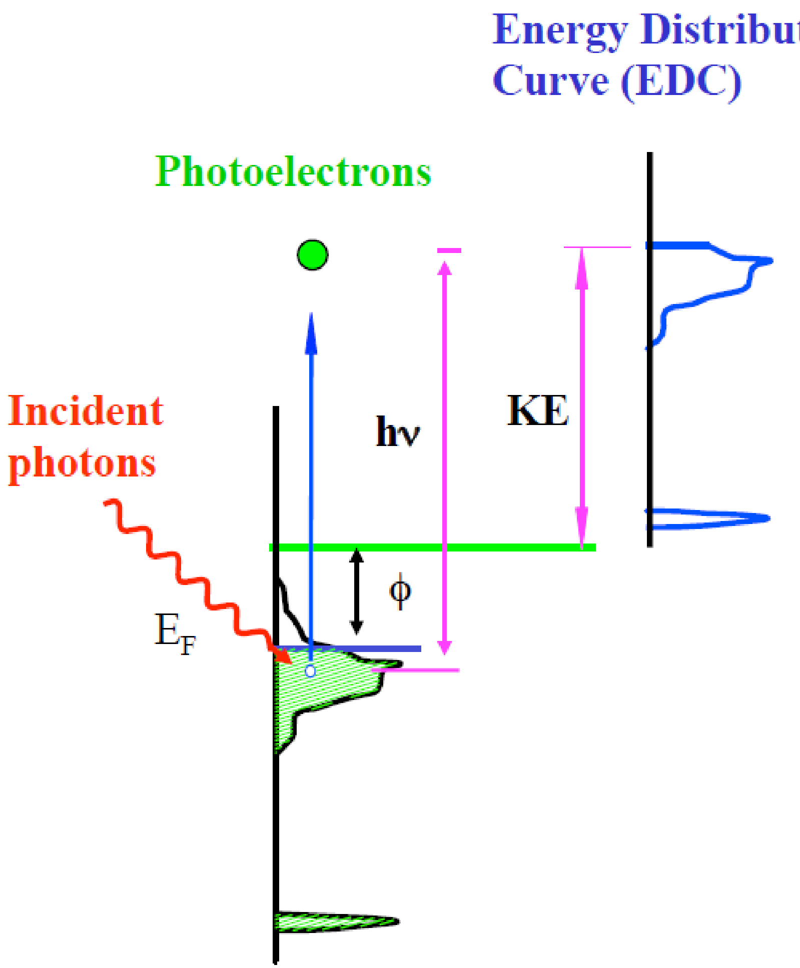
國家同步輻射研究中心
National Synchrotron Radiation Research Center

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)

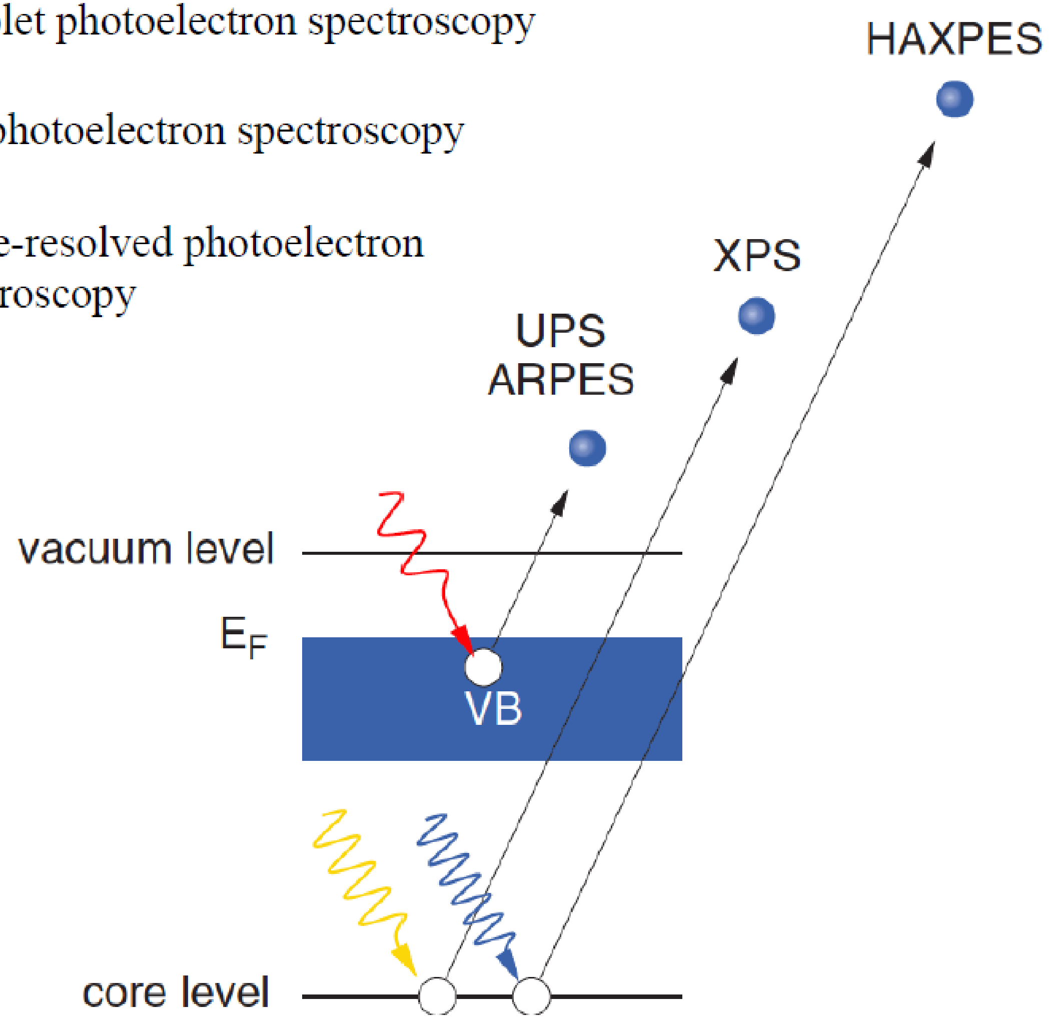
$\Delta m_l = -1$ (R. circularly polarized)

HAXPES = Hard X-ray photoelectron spectroscopy

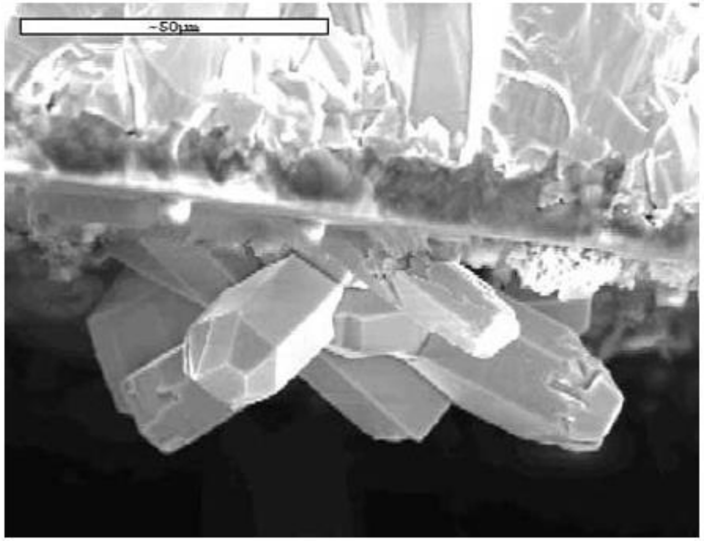
UPS = ultraviolet photoelectron spectroscopy

XPS = X-ray photoelectron spectroscopy

ARPES = angle-resolved photoelectron spectroscopy

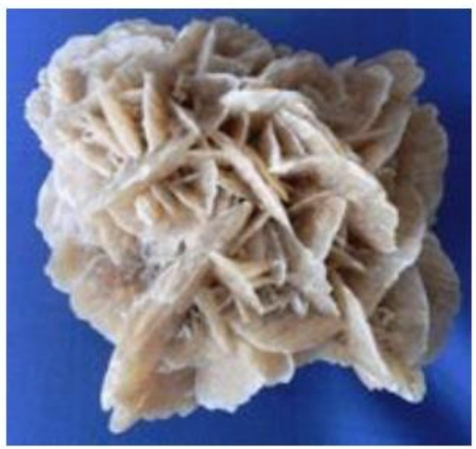


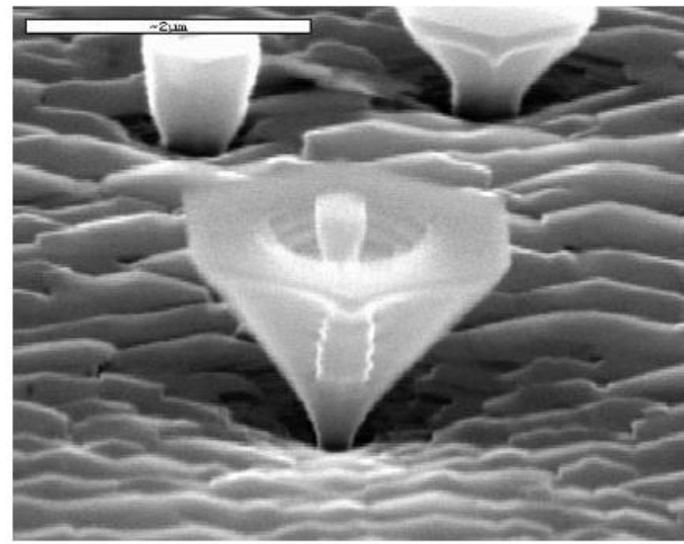
"Crystals"



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

Sand Rose of gypsum (石膏) crystals





AlN pyramids grown by MBE

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

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

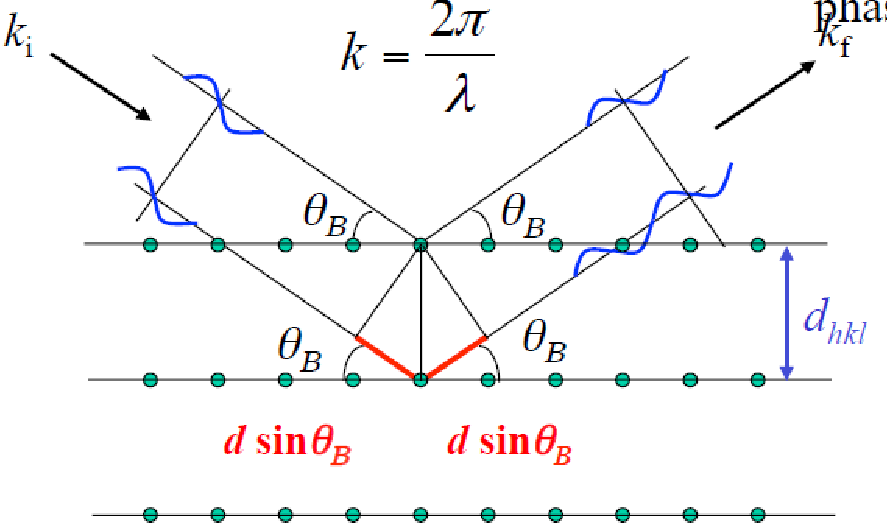
$$\vec{E} = E_0 e^{i(\vec{k}\cdot\vec{r}-\omega t)}$$

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

Constructive interference: $L = n\lambda$

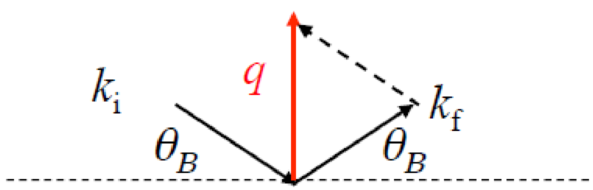
phase difference $\phi = k\,L$

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



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

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



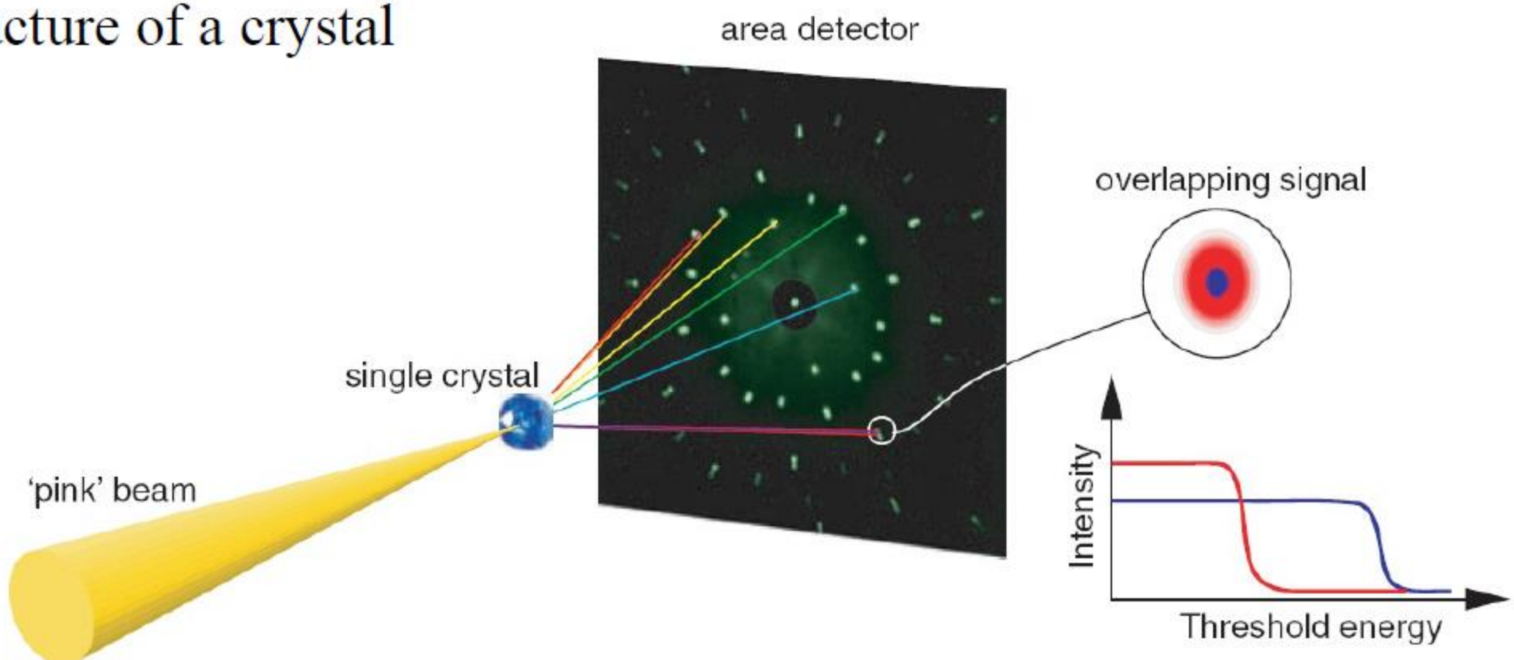
scattering vector $\vec{q} = \vec{k}_f - \vec{k}_i \quad q = 2\frac{2\pi}{\lambda}\sin\theta_B$

$$q = G_{hkl}$$

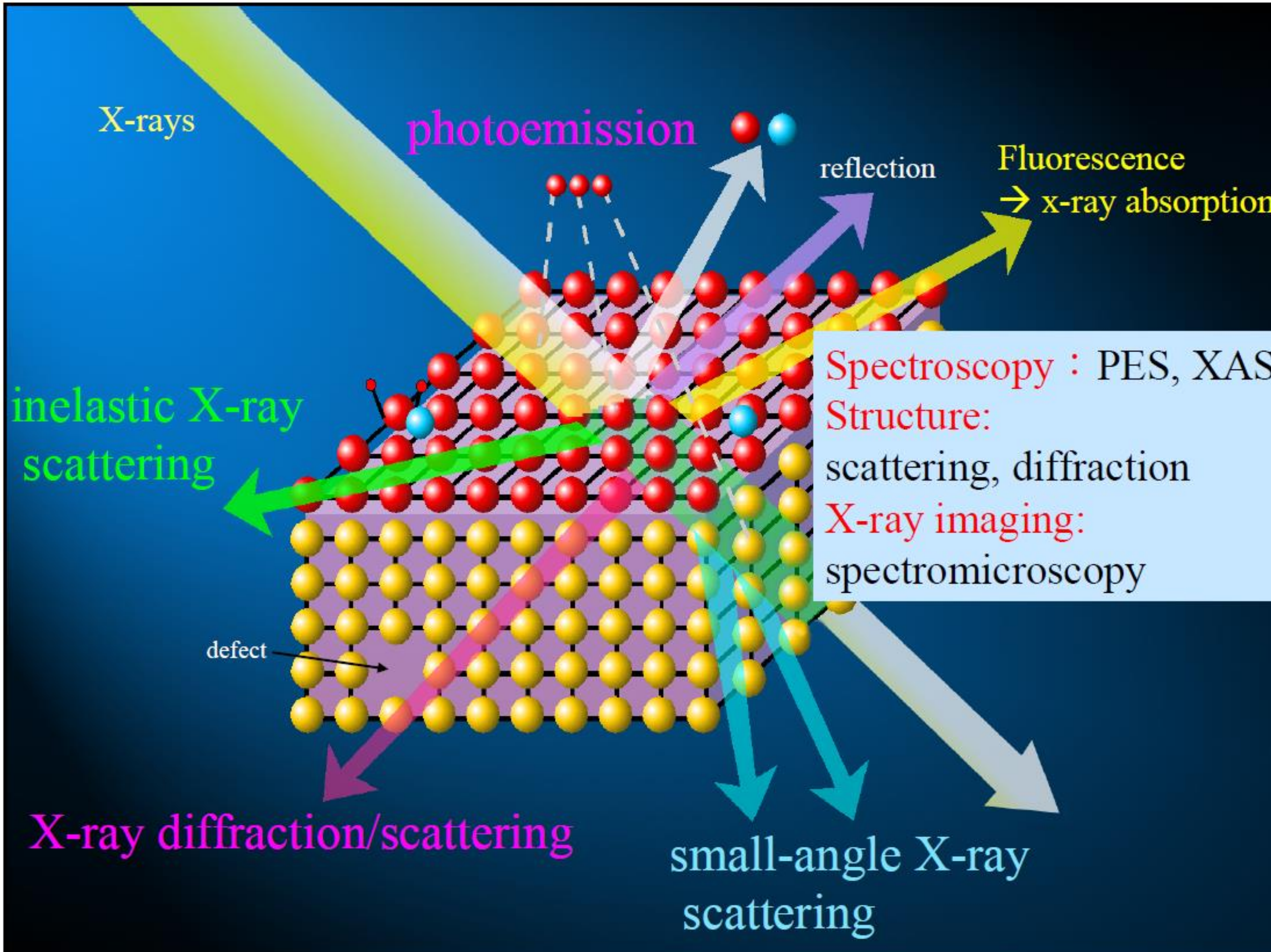
In terms of diffraction, two key characteristics of a set of crystal planes :
$1/d$ and orientation

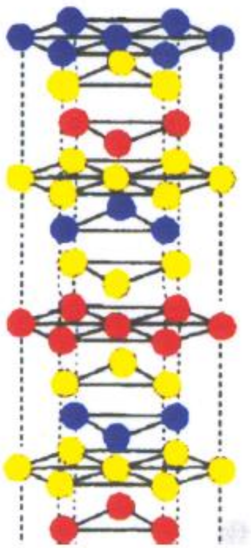
Single Crystal Diffraction - Laue Diffraction

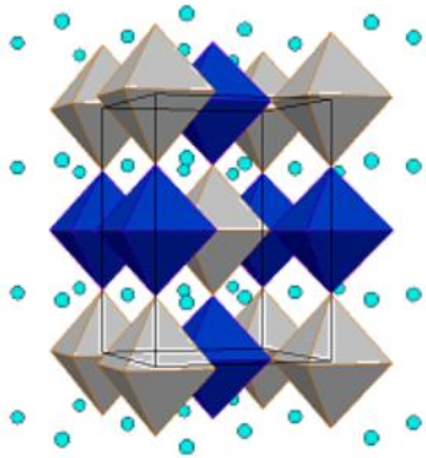
- Method: stationary
- Light source: a polychromatic 'pink' beam (e.g. ΔE <1 keV @ 10 keV)
- Applications: orient single crystals, determine their crystal quality, dynamical studies of transient crystalline states (time-resolved study)
- Disadvantage: not well-suited for determining the full atomic structure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

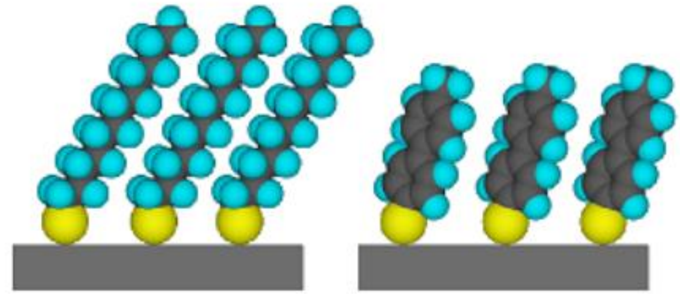


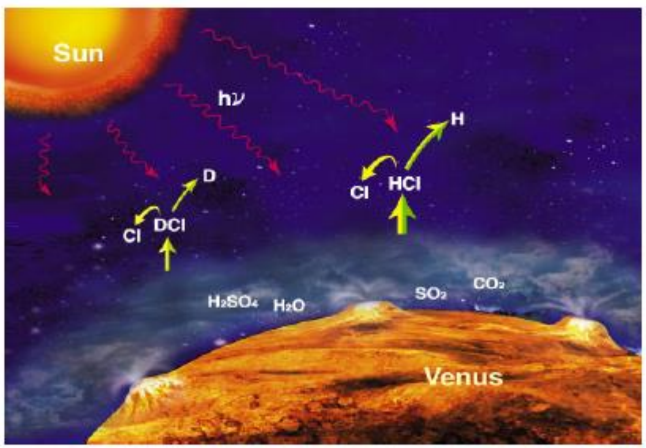
國家同步輻射研究中心
National Synchrotron Radiation Research Center

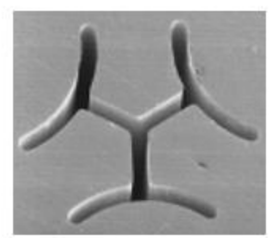

X-rays
photoemission
reflection
Fluorescence
→ x-ray absorption
inelastic X-ray
scattering
defect
X-ray diffraction/scattering
small-angle X-ray
scattering
Spectroscopy：PES, XAS
Structure:
scattering, diffraction
X-ray imaging:
spectromicroscopy

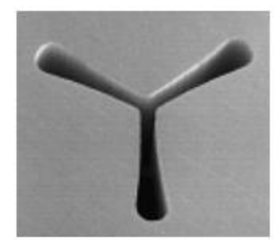








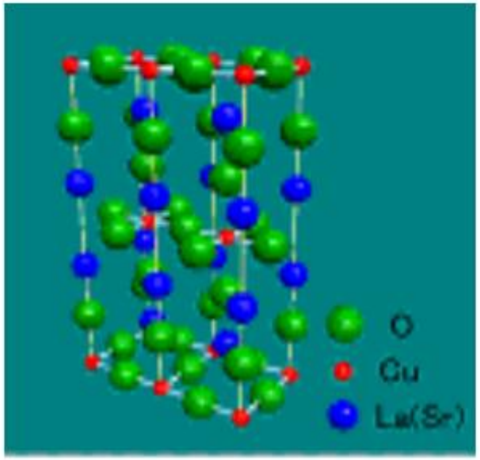




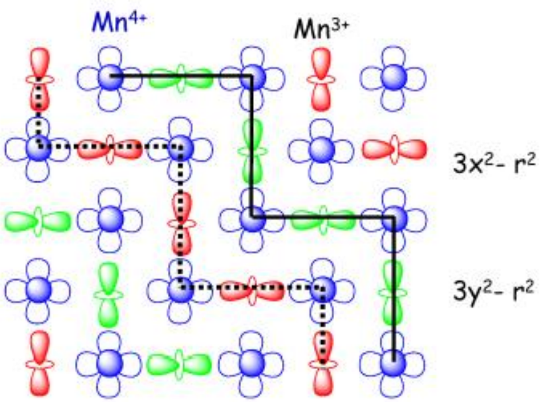
Synchrotron light source is a powerful tool for basic and applied studies in physics, chemistry, materials, biology and medicine, and their many subfields.

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

Condensed-Matter Physics



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

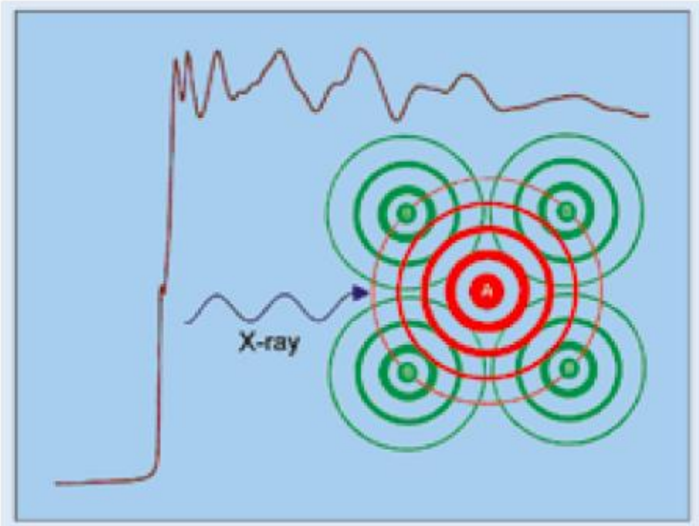


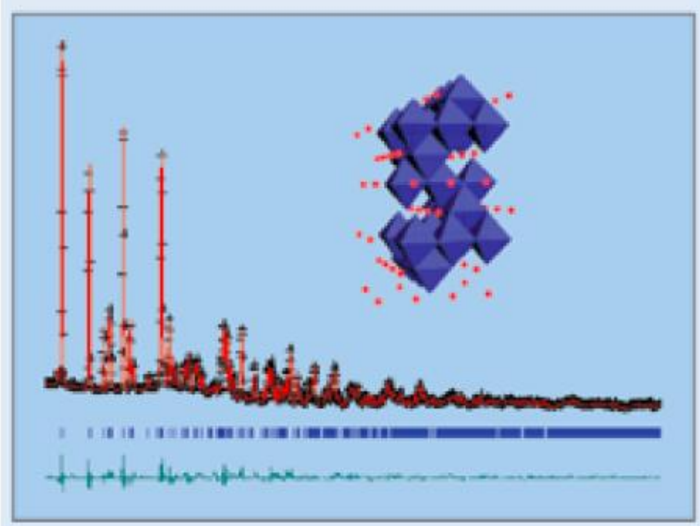
$La_{0.5}Sr_{1.5}MnO_4$

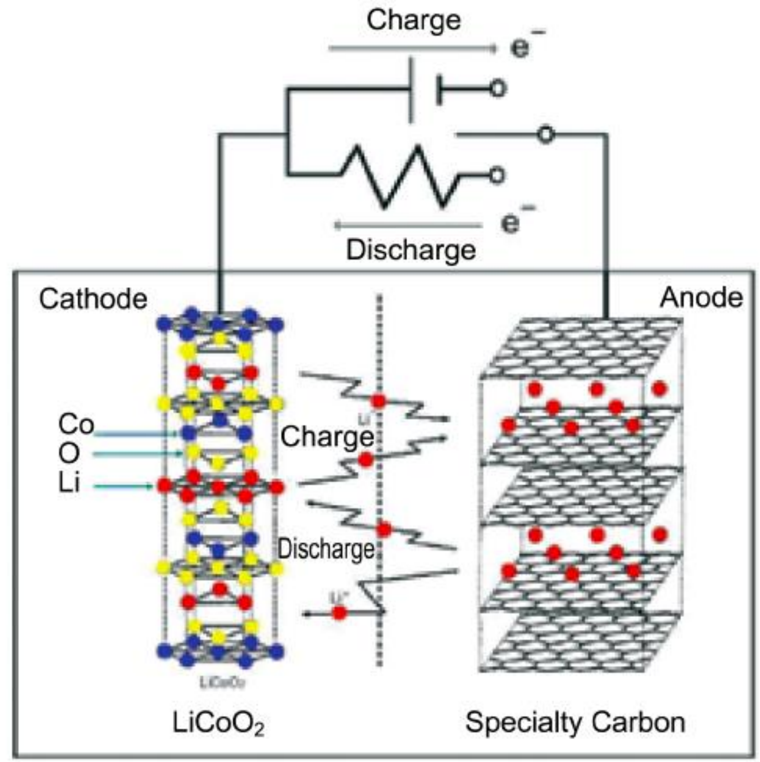
(Source: website of Railway Technical Research Institute, Japan)

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

Energy Science



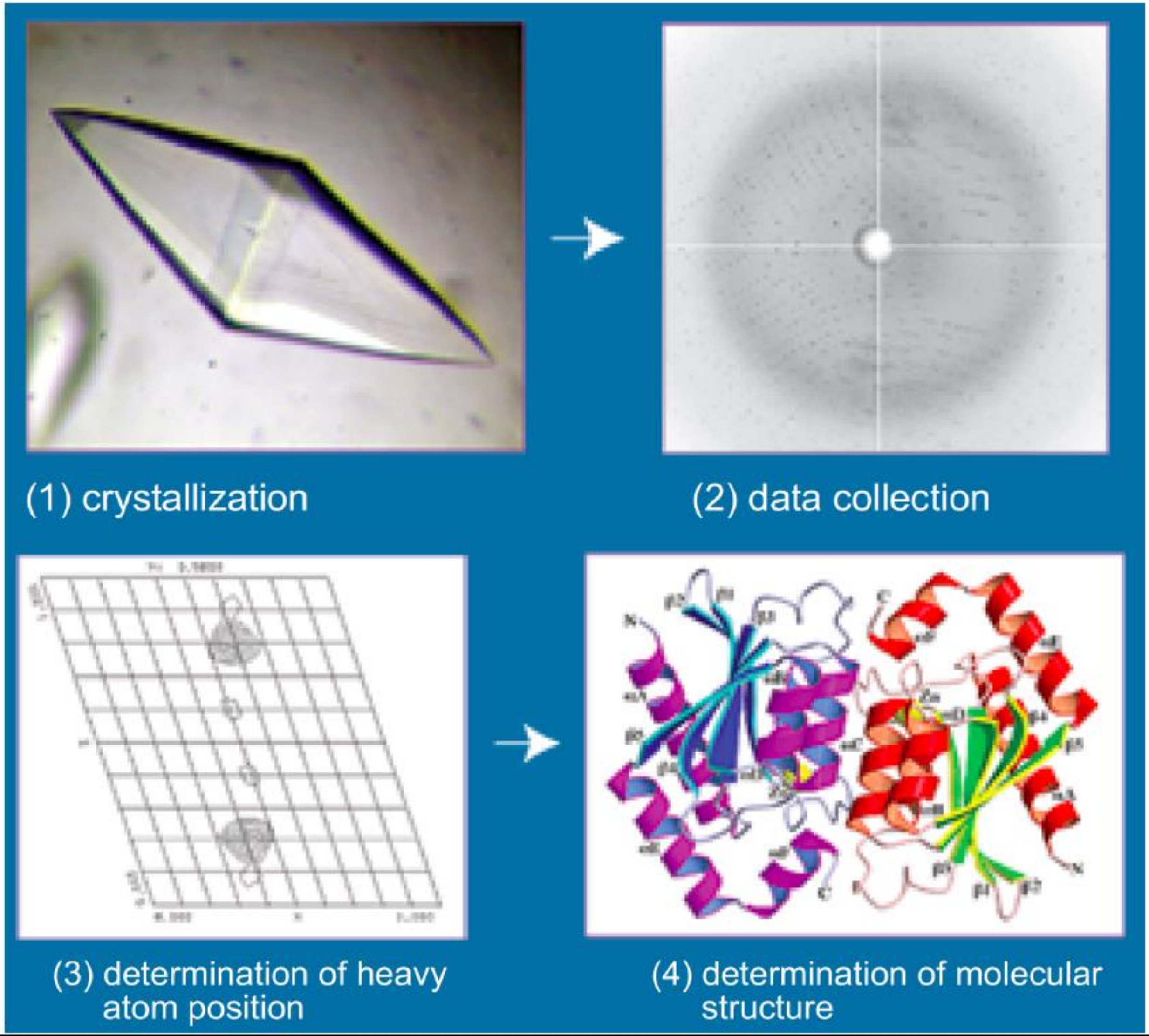


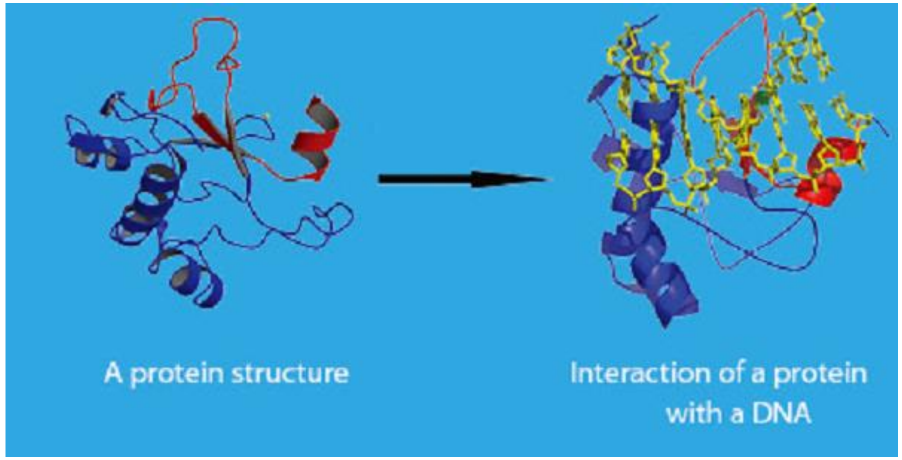


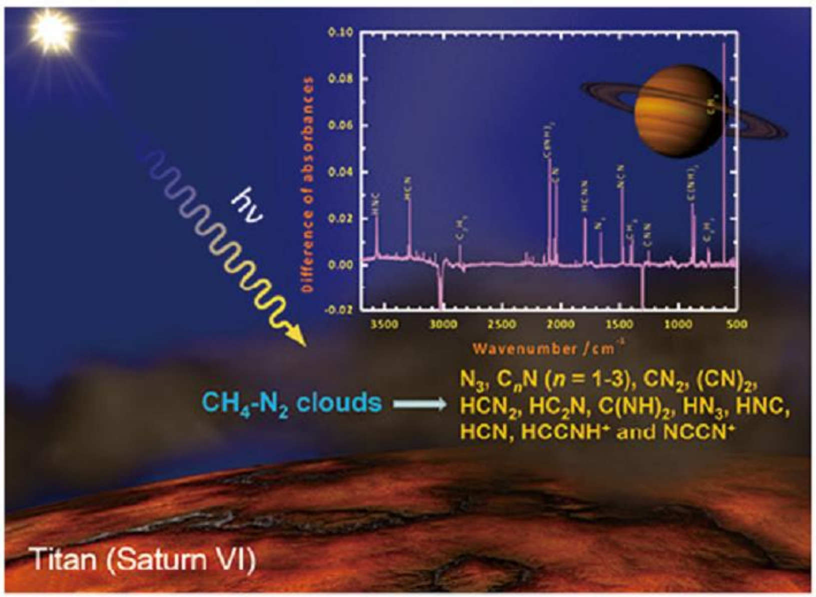
structure ←→ electrochemical properties of electrode

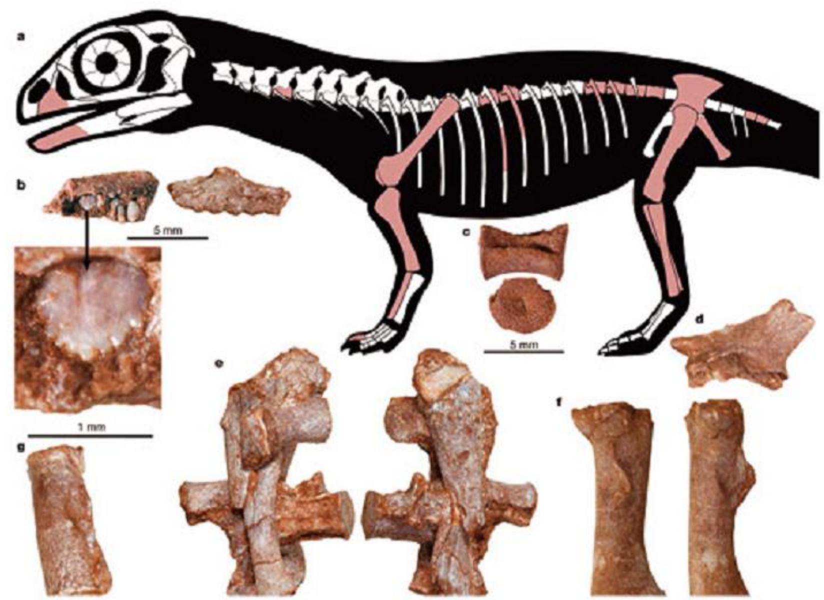
➡ develop novel electrode materials.

Biological structure: protein crystallography





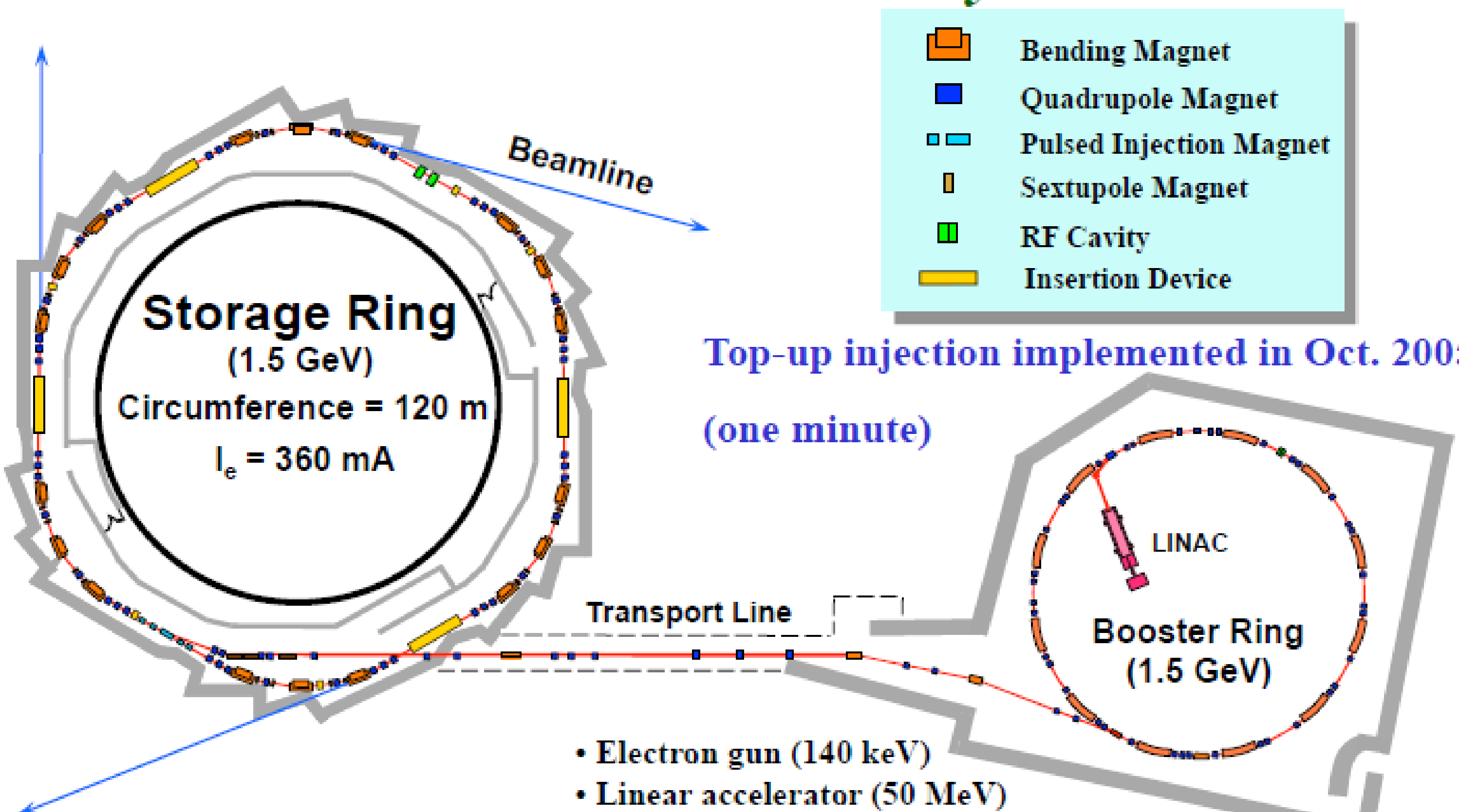




國家同步輻射研究中心
National Synchrotron Radiation Research Center

Taiwan Light Source (TLS)

Accelerator Facility



Top-up injection implemented in Oct. 2005

(one minute)

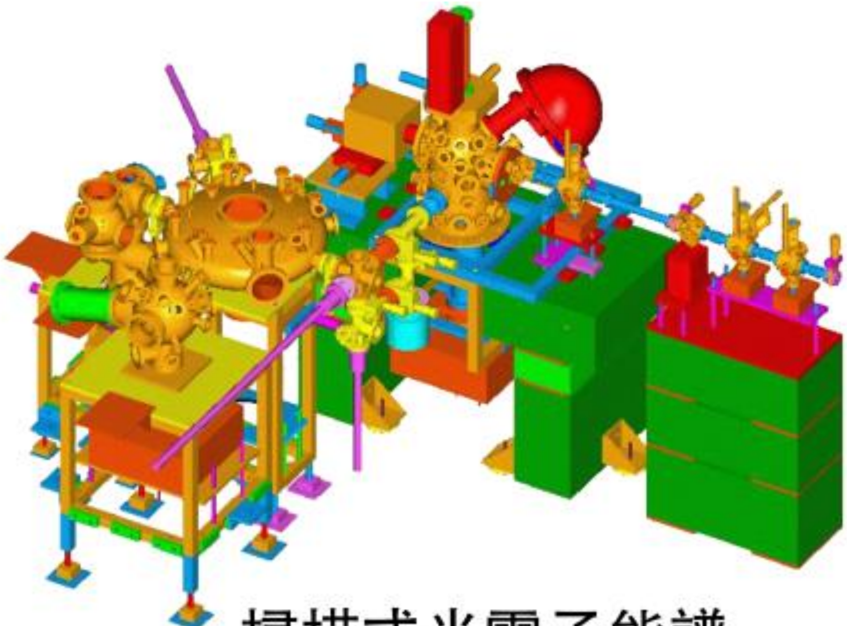
- Electron gun (140 keV)
- Linear accelerator (50 MeV)
- Booster ring (50 MeV ~ 1.5 GeV)

TLS Experimental Hall

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

掃描式光電子能譜顯微術

(Scanning Photoelectron Microscopy; SPEM)



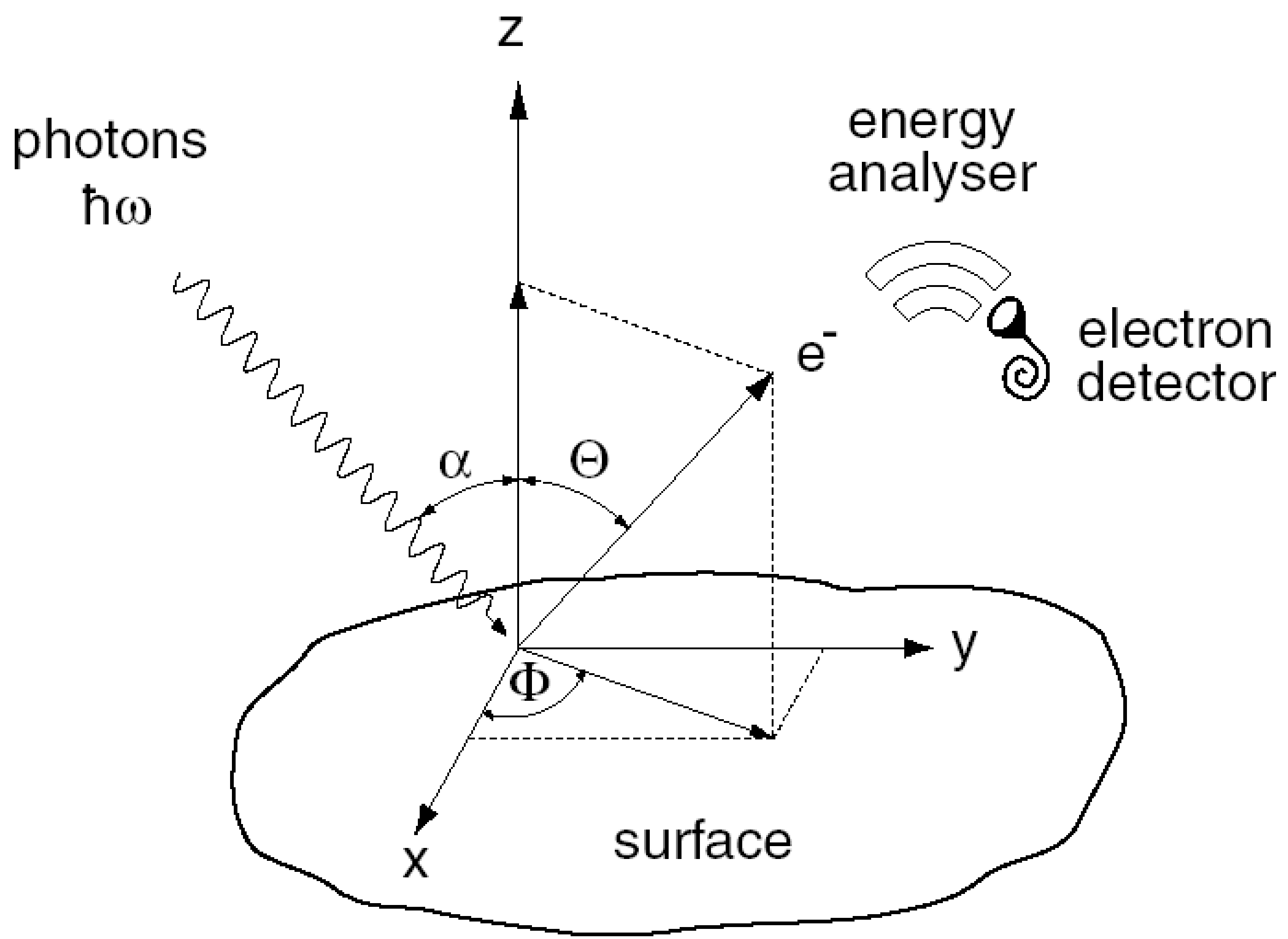
掃描式光電子能譜
顯微實驗站

為何發展光電子能譜顯微術？

小尺度結構分析：STM，TEM，SEM…等

小尺度成份分析：**SPEM**

光電子能譜術（Photoemission Spectroscopy）



典型 ESCA 能譜

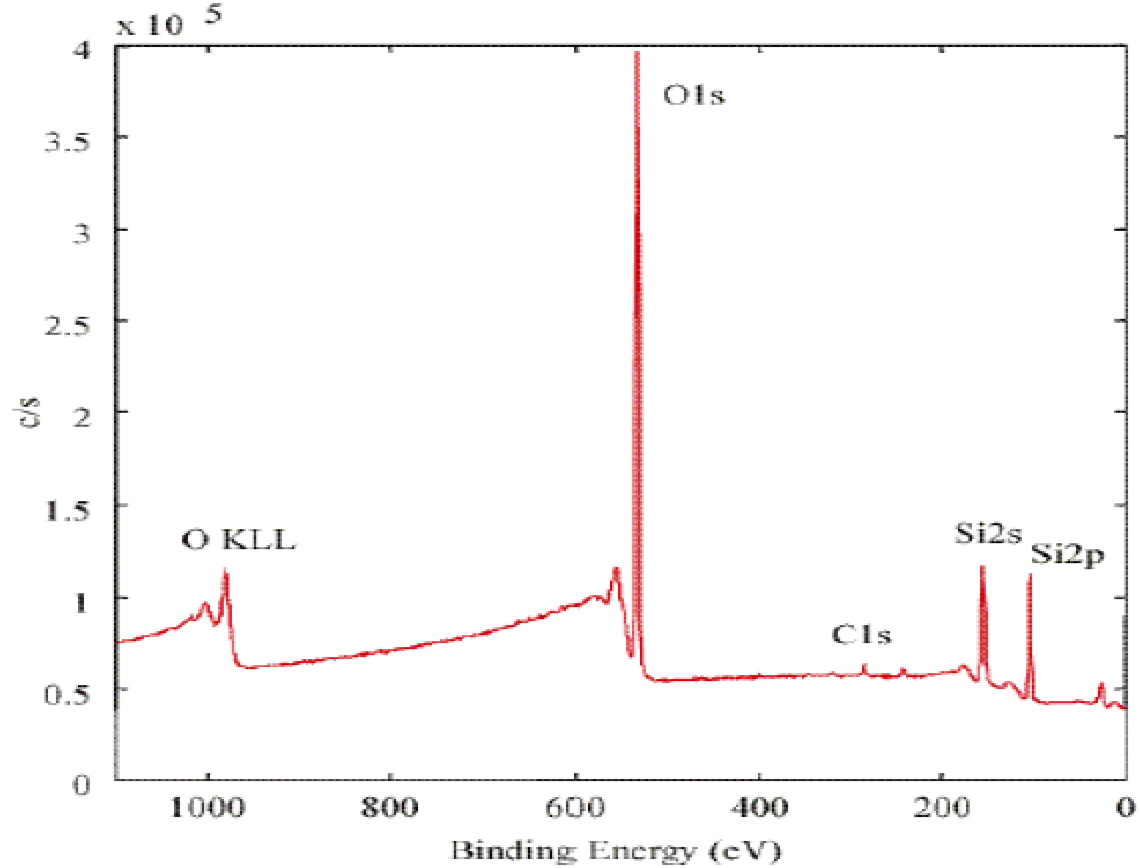
BE = hv- KE-eΦ

BE: 束縛能

hv:入射光能量

KE:電子動能

eΦ:功函數



Survey Spectrum of Silicon Wafer

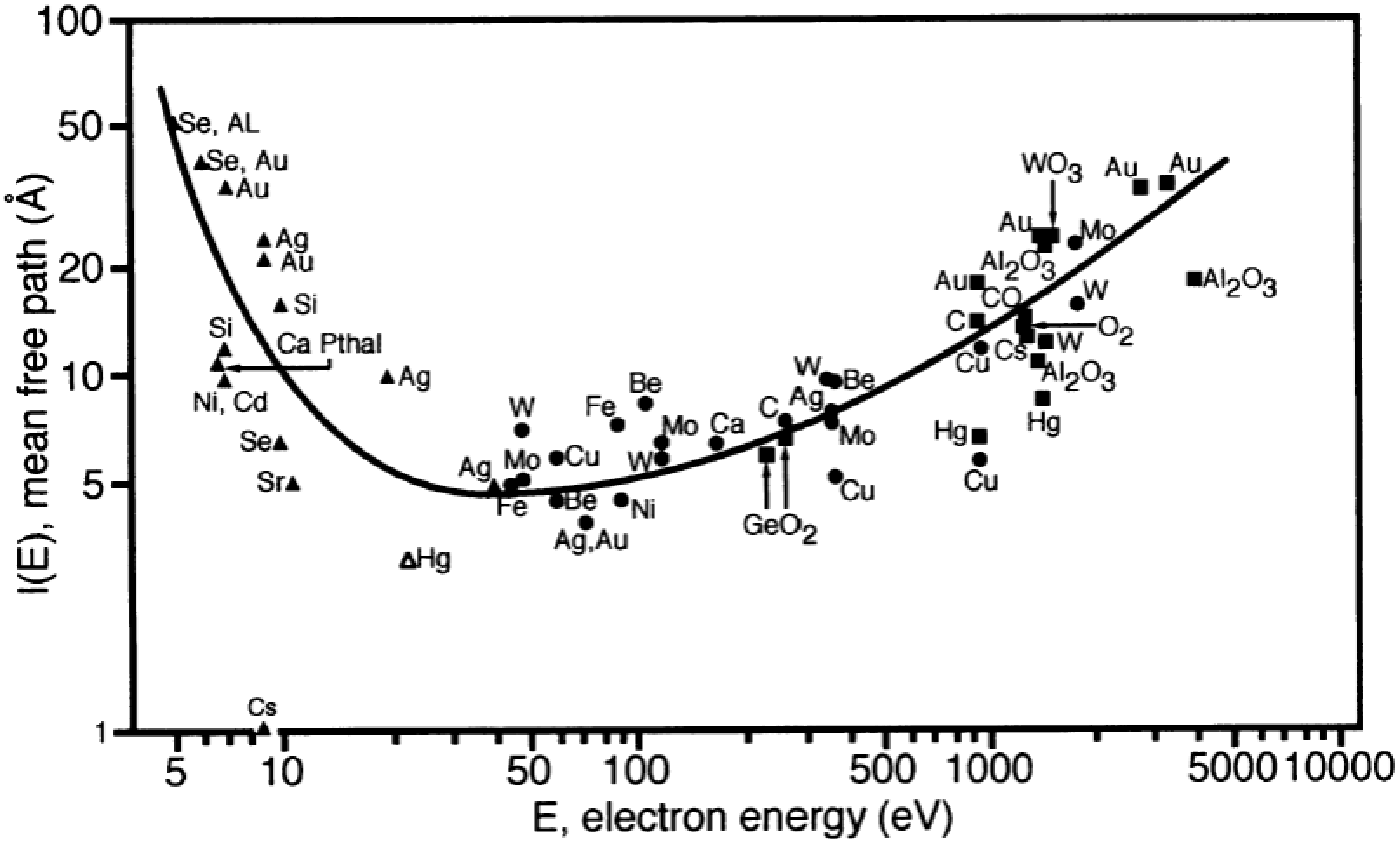
光電子發射之特性：

1.非破壞性

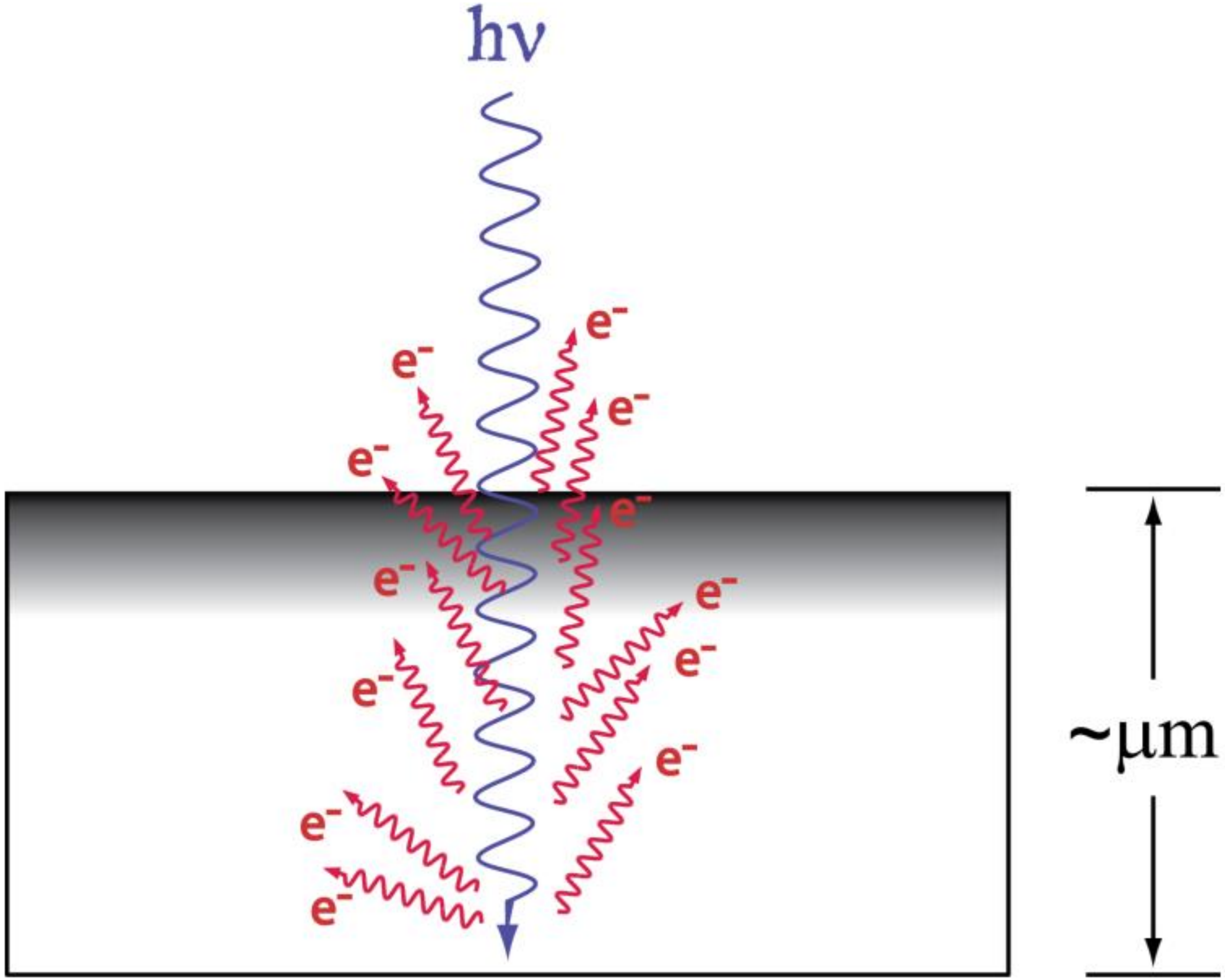
2.表面分析技術

3.具化學鍵結分辨能力

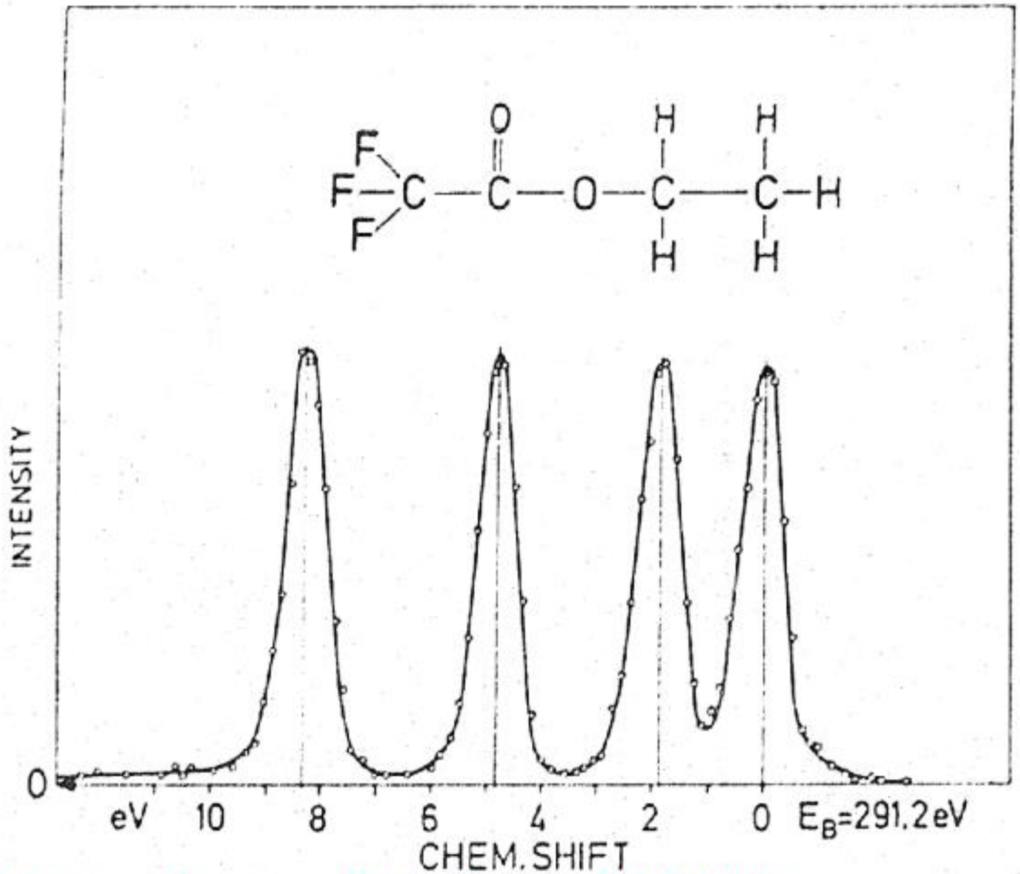
Universal Curve



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


hν
e⁻
~μm

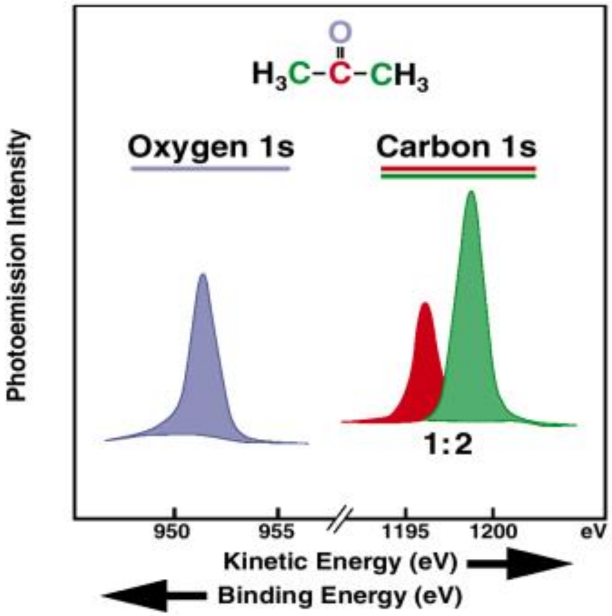
化學位移(Chemical Shifts)



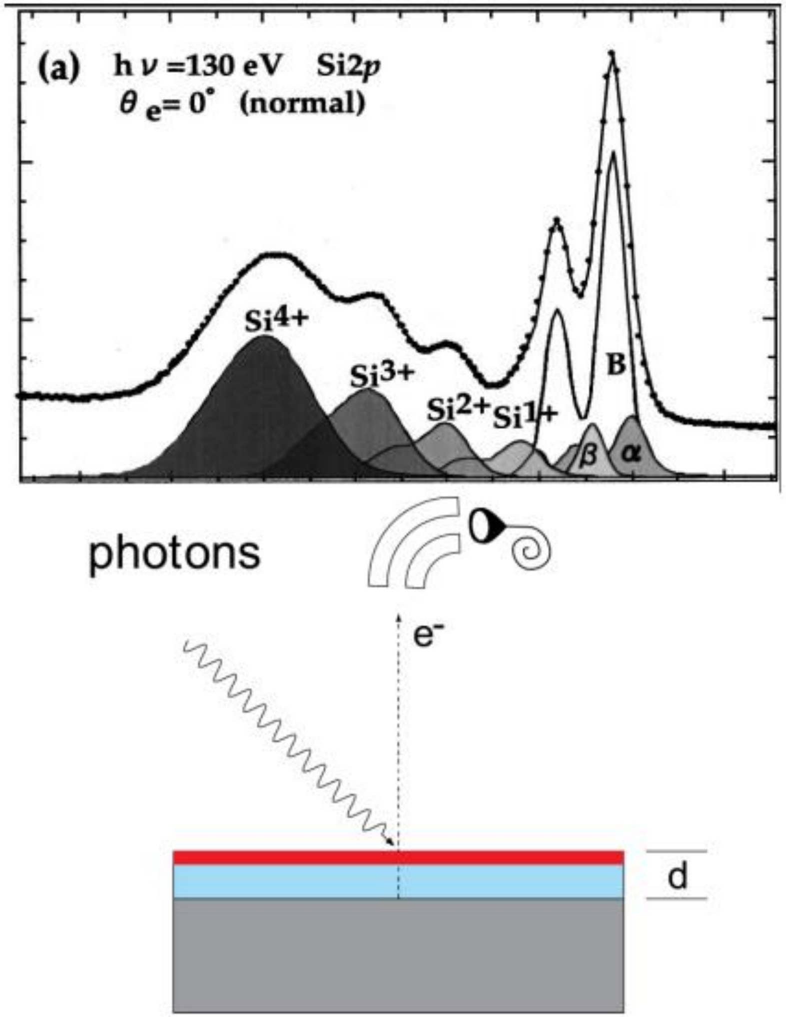
J. Electron. Spectrosc. Relat. Phenom., **2**(1974)405
Rev. Mod. Phys., **54**(1982)709

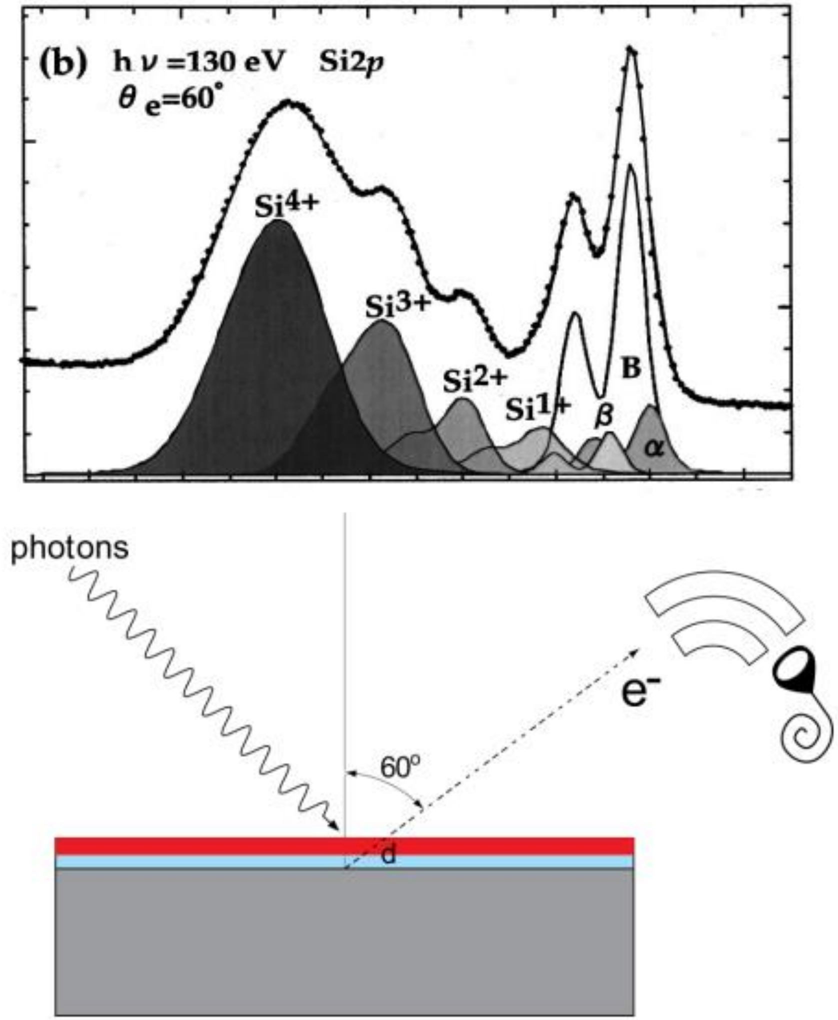
Provides information about

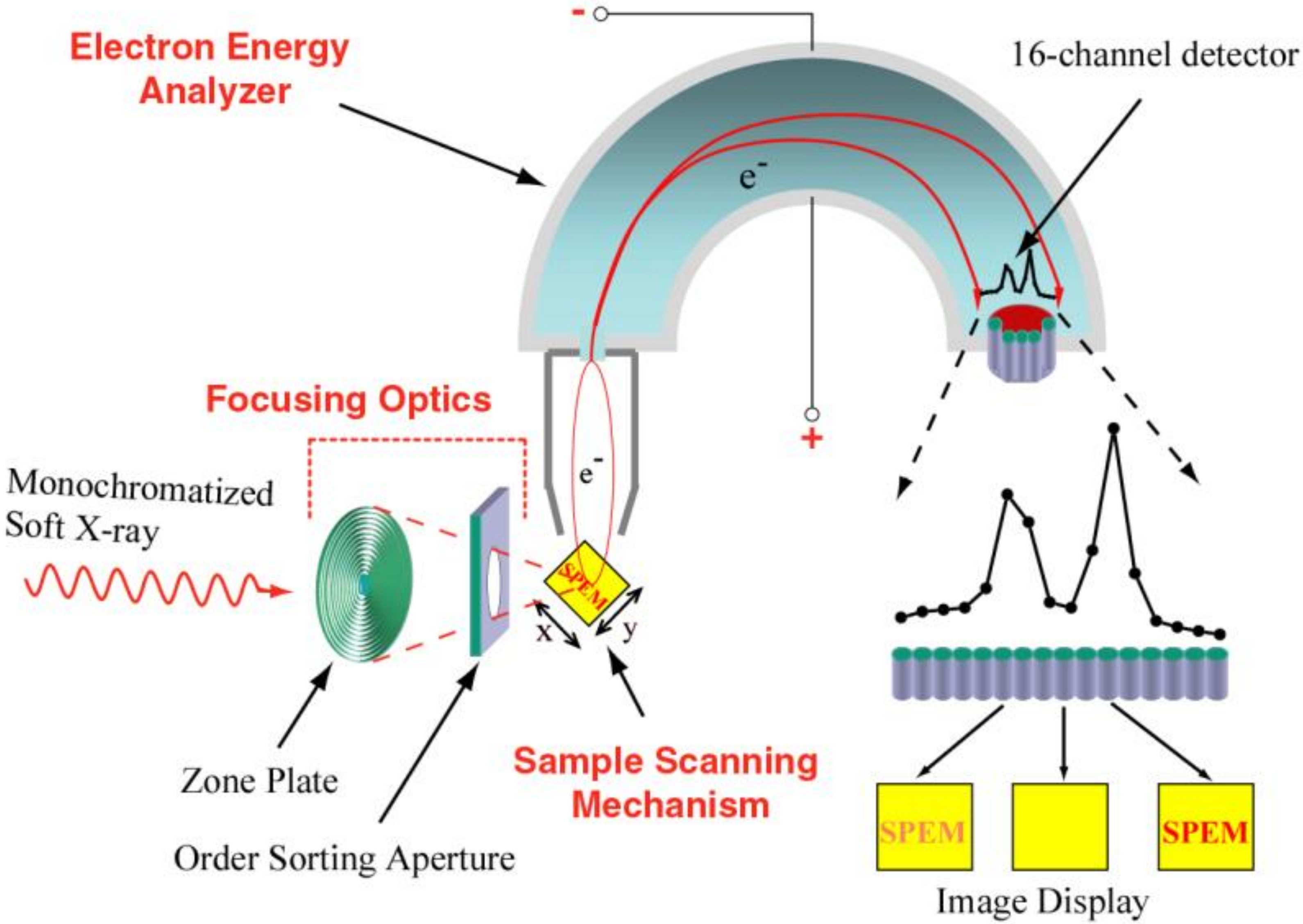
- Kind of atom
- Number of atoms
- Chemical shift



6 Å SiO_2 grown on Si(100)

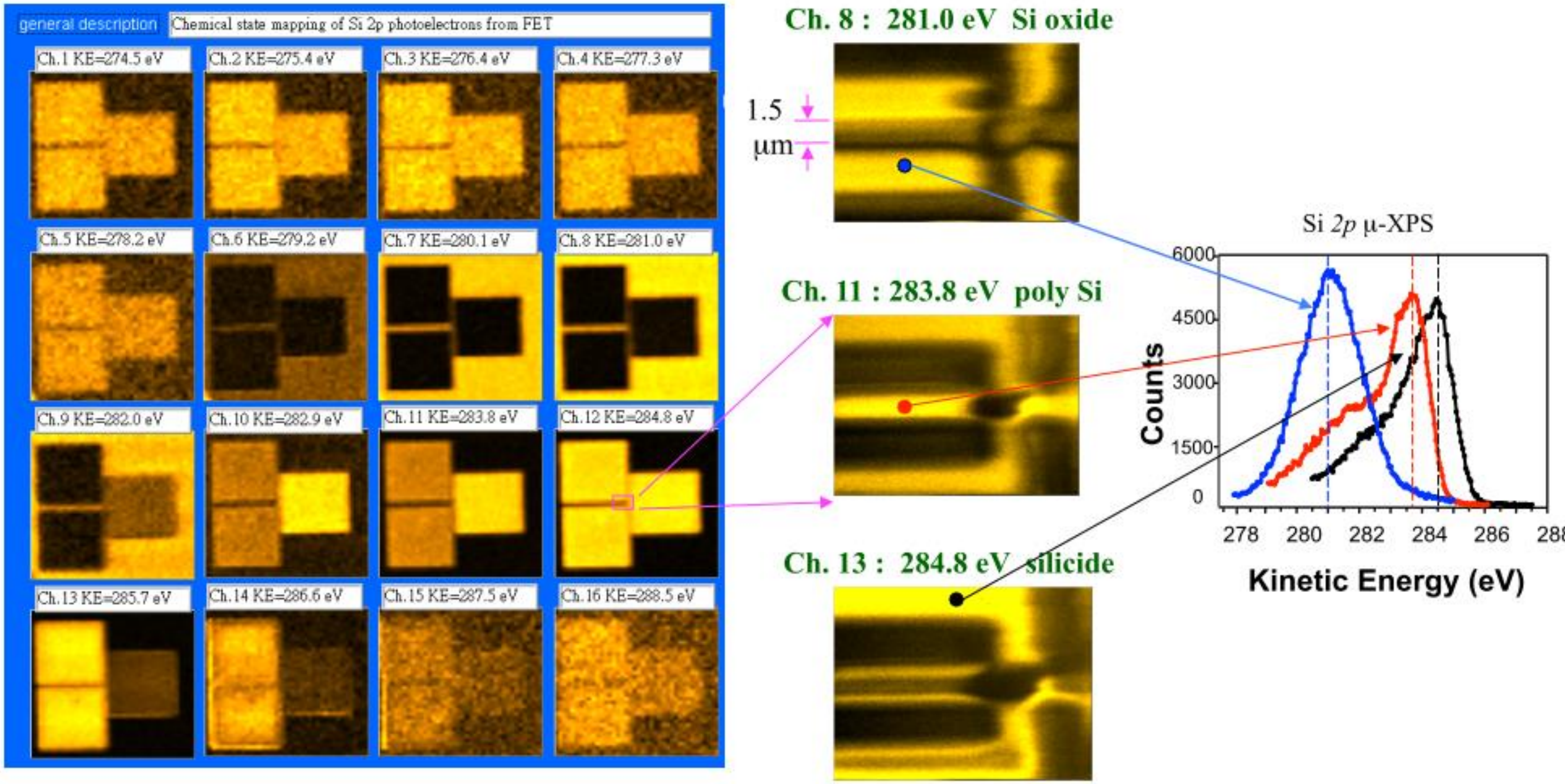






國家同步輻射研究中心
National Synchrotron Radiation Research Center

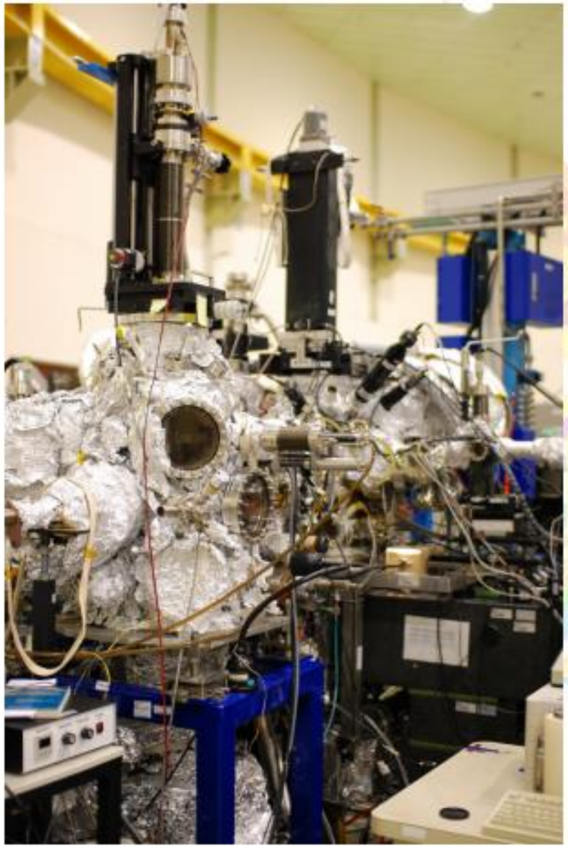
Parallel Imaging for Chemical State Mapping (PICSM)

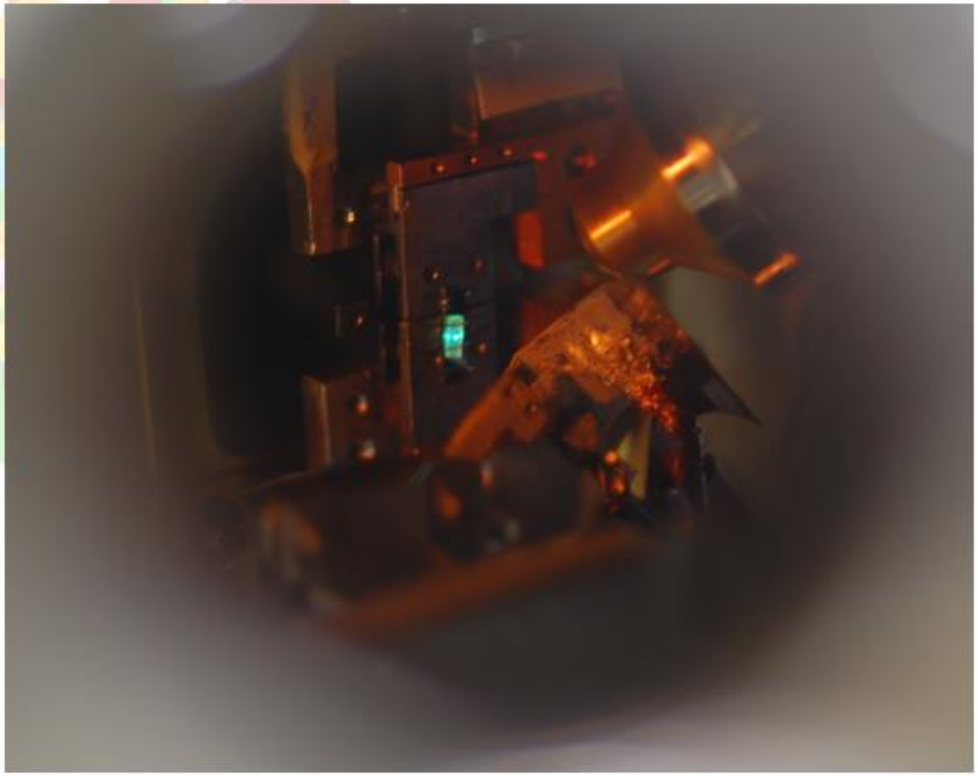


MOSFET 240 μm × 240 μm

12 μm × 12 μm, 0.1 μm/pixel

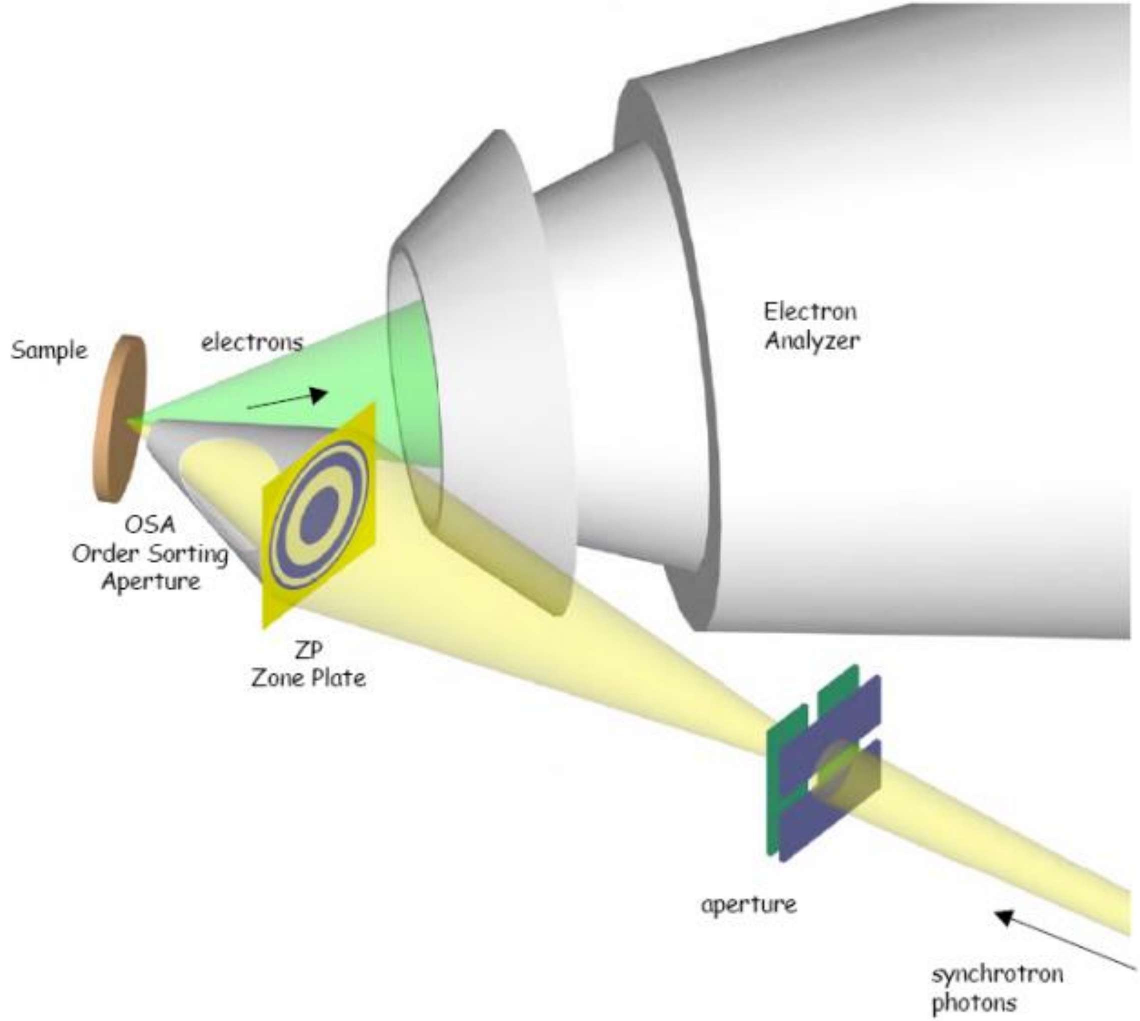
SPEM 實驗站

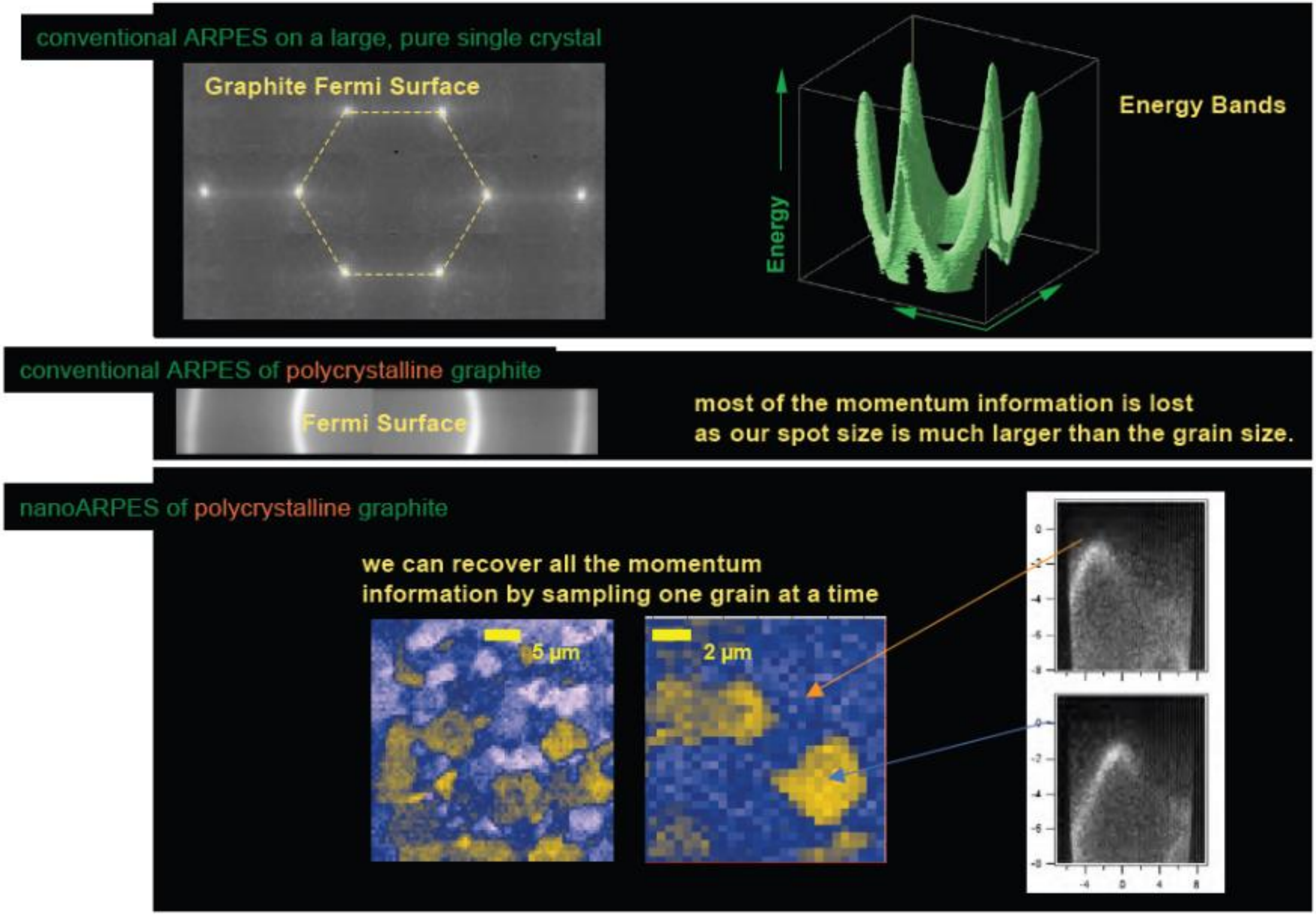


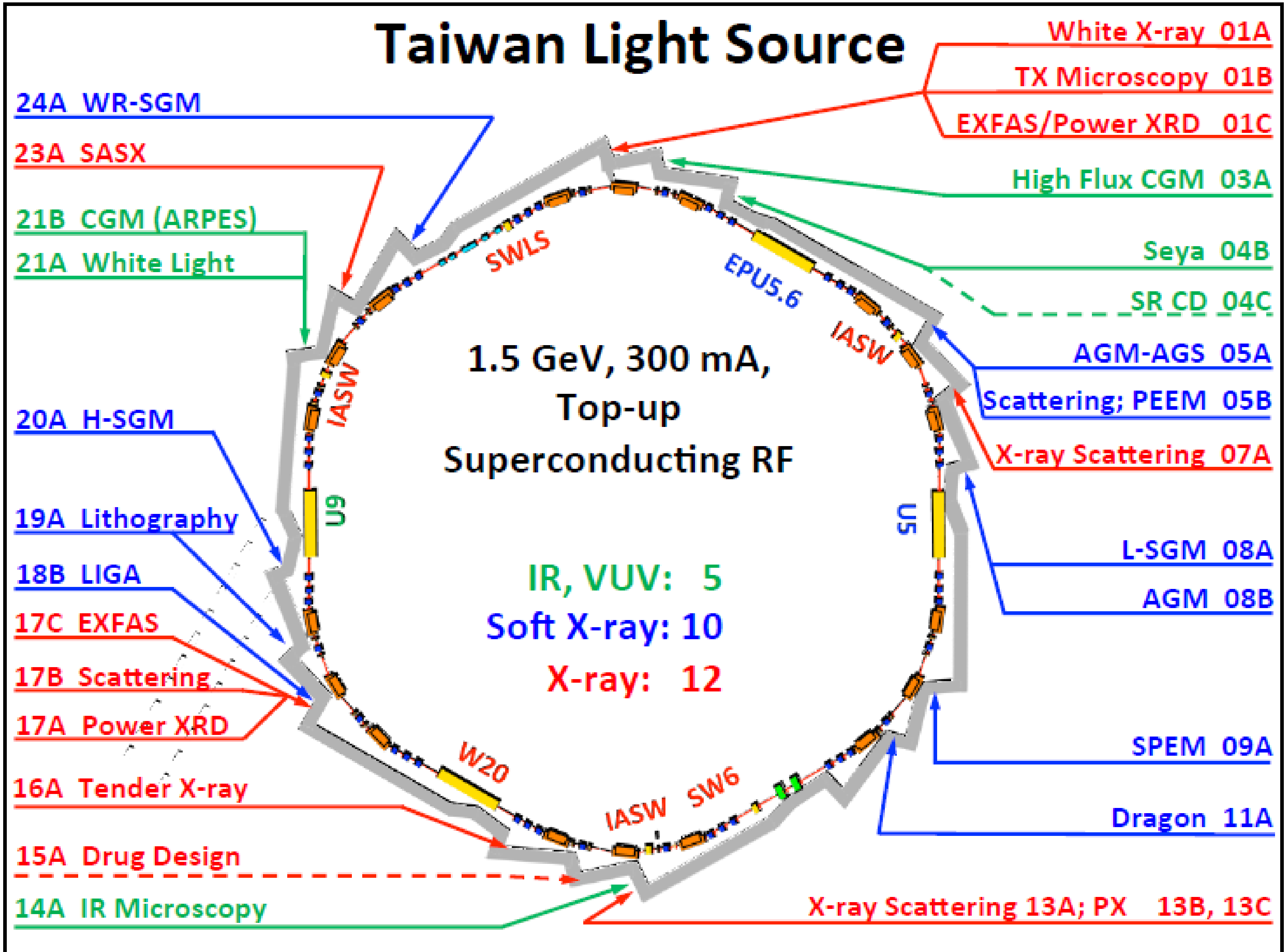


新型態同步輻射顯微術簡介

Spatially resolved ARPES




conventional ARPES on a large, pure single crystal
Graphite Fermi Surface
Energy
Energy Bands
conventional ARPES of polycrystalline graphite
Fermi Surface
most of the momentum information is lost
as our spot size is much larger than the grain size.
nanoARPES of polycrystalline graphite
we can recover all the momentum
information by sampling one grain at a time
5 µm
2 µm

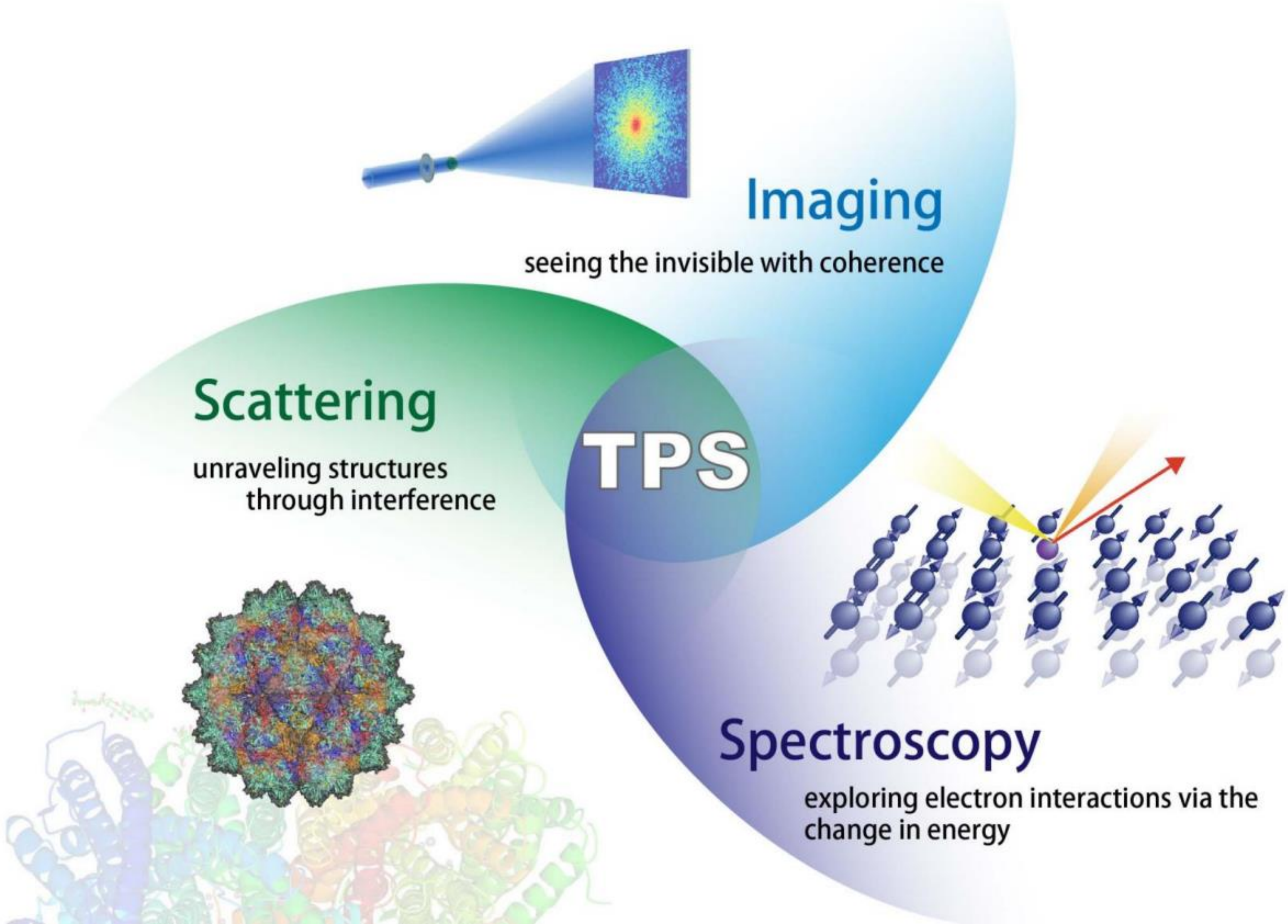


國家同步輻射研究中心
National Synchrotron Radiation Research Center

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

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

TPS provides opportunities for scientists to reveal electrons, spins, and lattices, covering a wide range of applications.

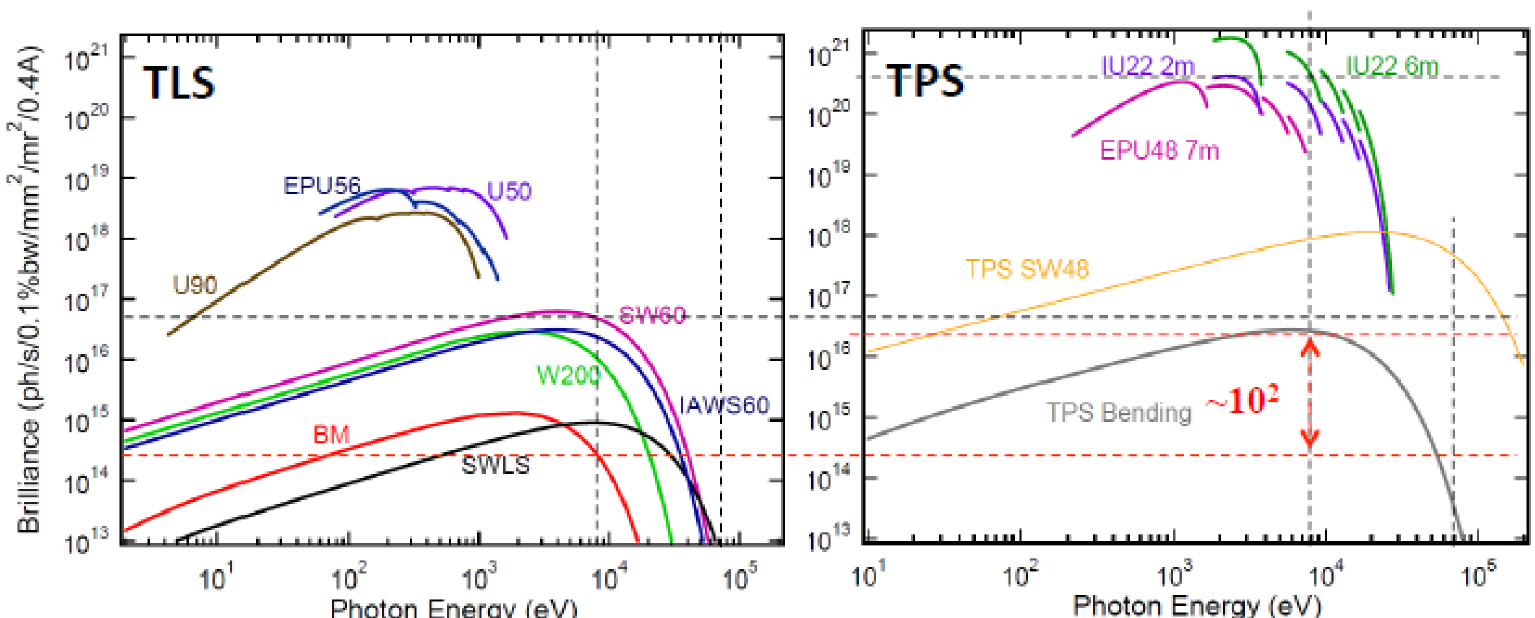


Comparison of Brilliance between TLS and TPS

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.



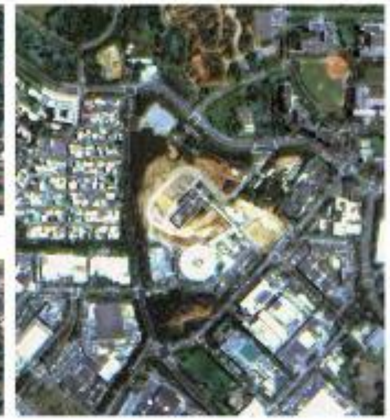
15

中心現址衛星圖
(太空中心提供)

Groundbreaking
2010-02-07

2010-02-10

2010-05-21



2010-08-04

2011-02-05

2011-09-27

2012-05-14

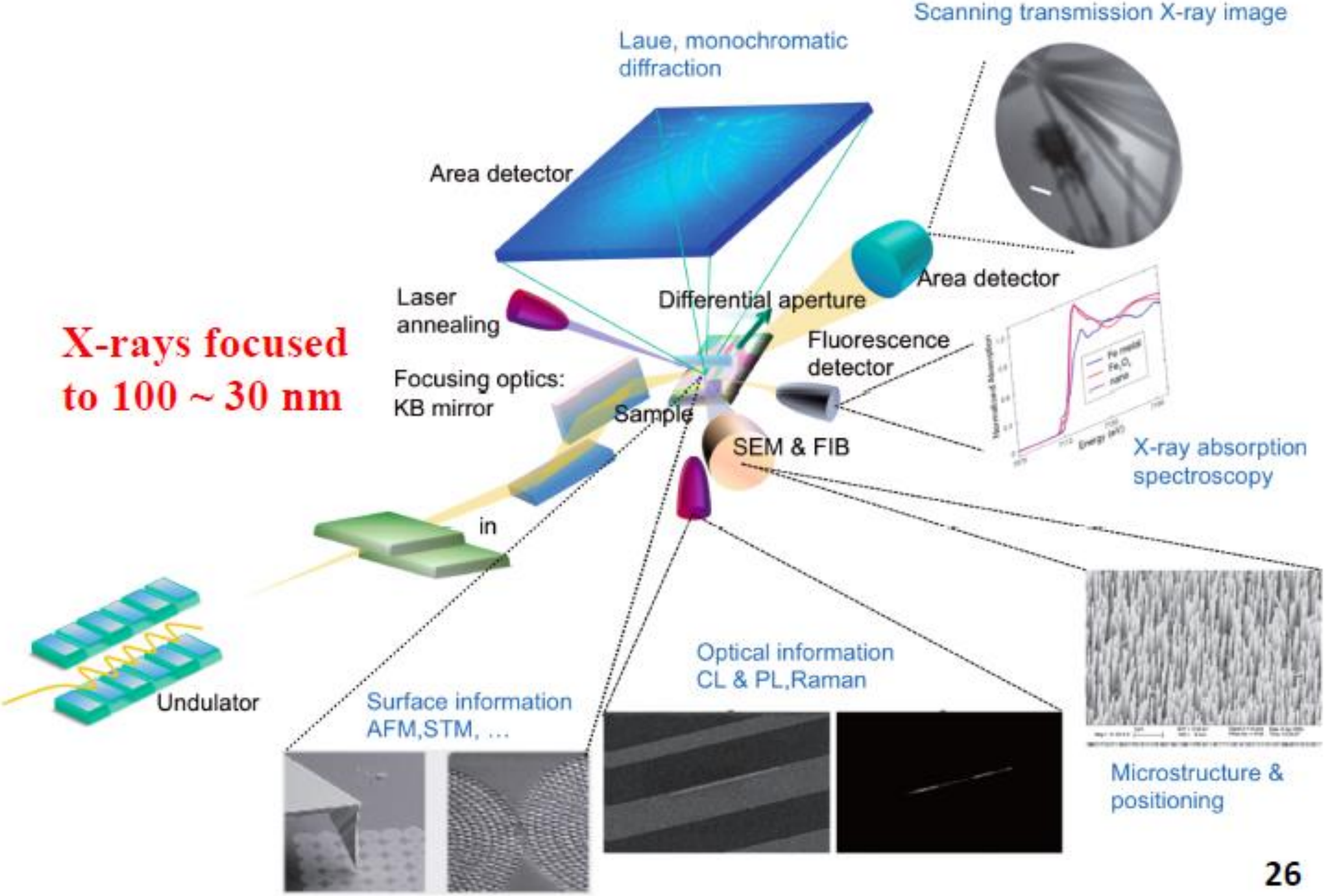
2013-01-16

Civil Construction of TPS

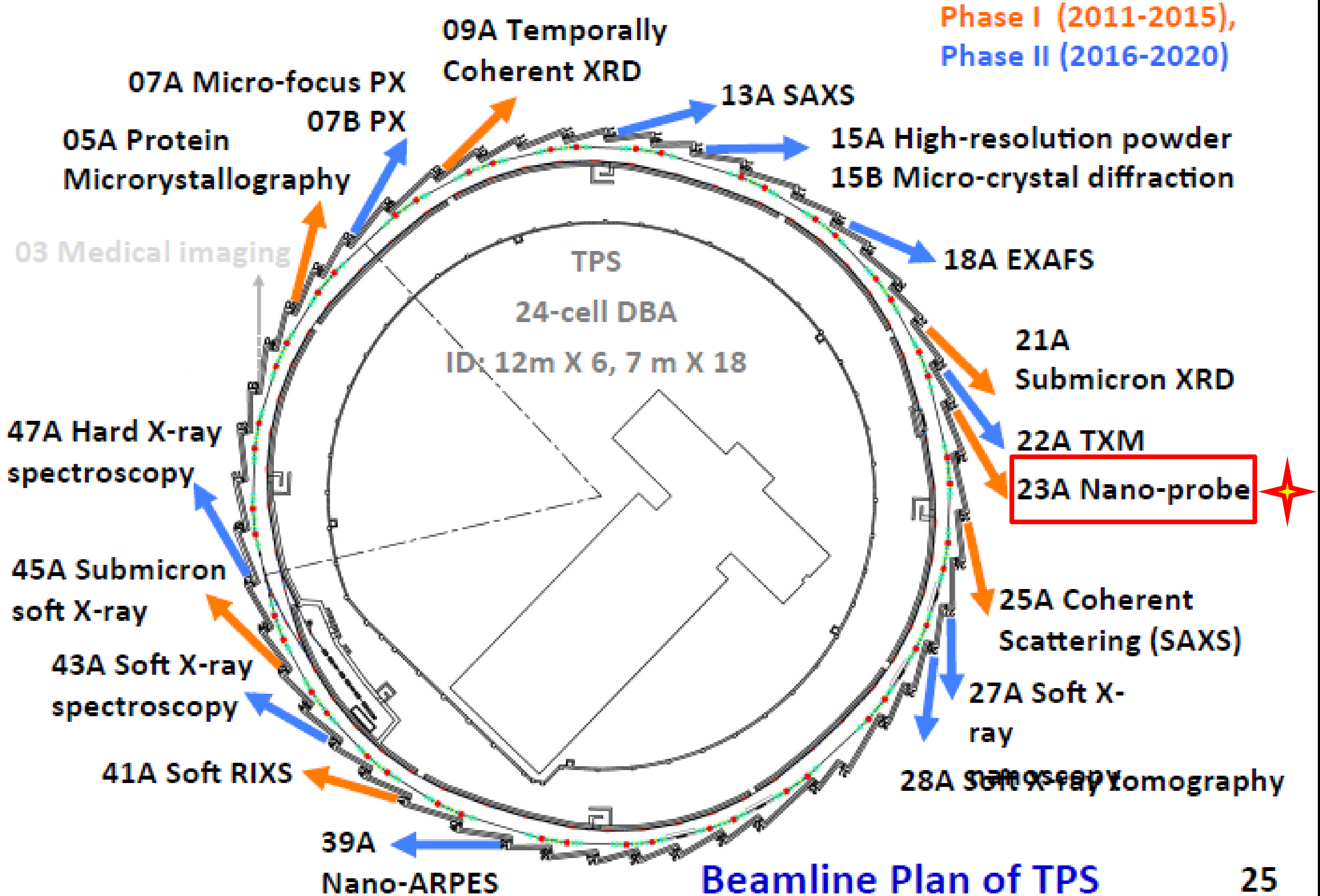
Taiwan Photon Source (TPS)

TPS will brighten the future of scientific discovery.

X-rays focused to 100 ~ 30 nm



The user operation of the TPS will begin in 2015.



Beamline Plan of TPS

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

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

2015年是台灣光子源值得紀念的一年


The first synchrotron light from TPS (December 31, 2014)

104年第一季:
儲存電流達到100毫安培
(室溫RF共振腔 (Petra))

↓

104年第二季及第三季:
安裝2台超導RF共振腔
(KEKB) & 10台插件磁鐵

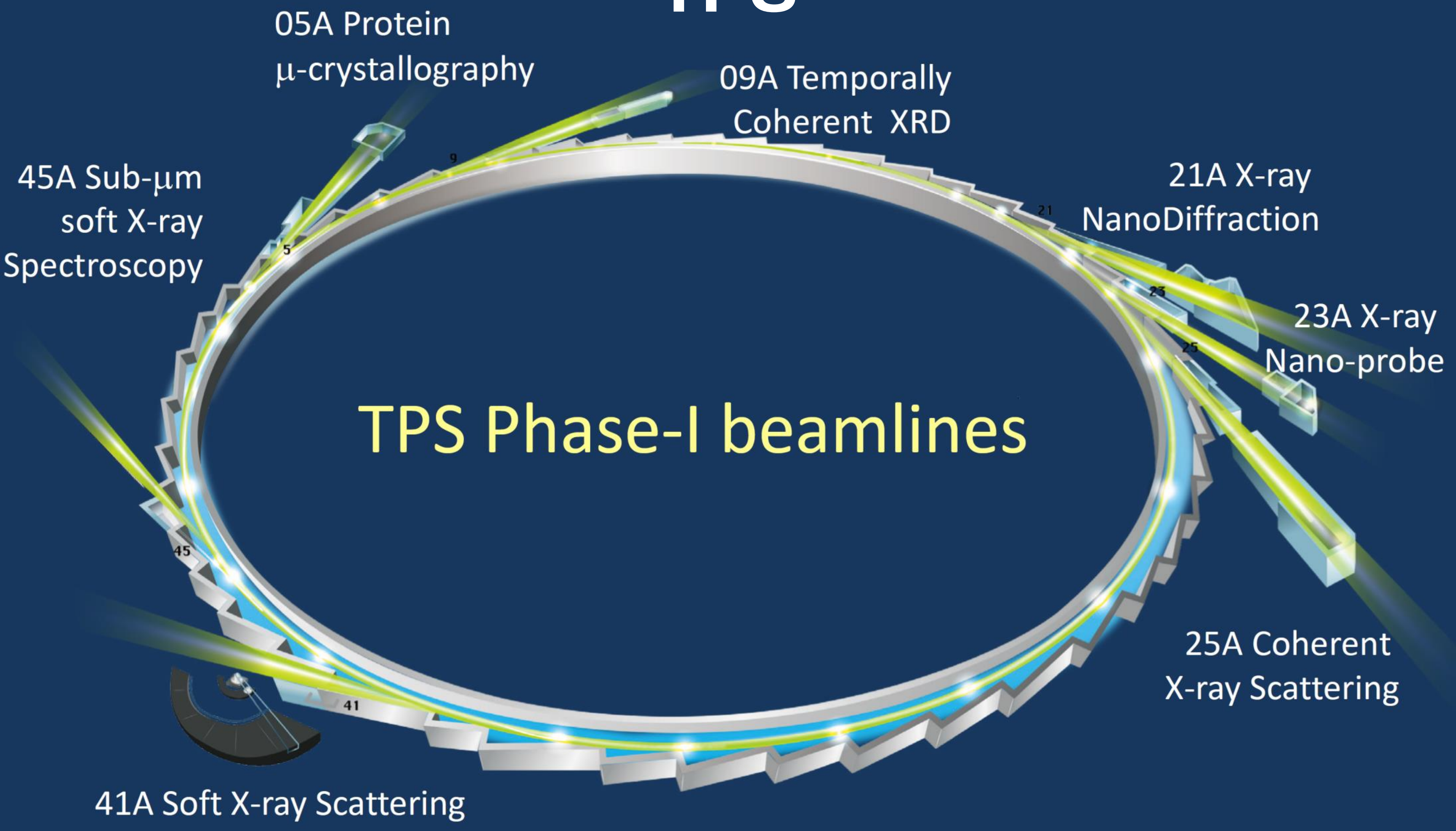
↓

104年第四季:
TPS & 第一期7條光束線
試車

Outline

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

Nanoprobe project is in the first phase 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：$< 2\times10^{-4}$ with Si(111) crystals
- Beam size：$\sim$ 40 nm at 10 keV (H $\times$ 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)

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

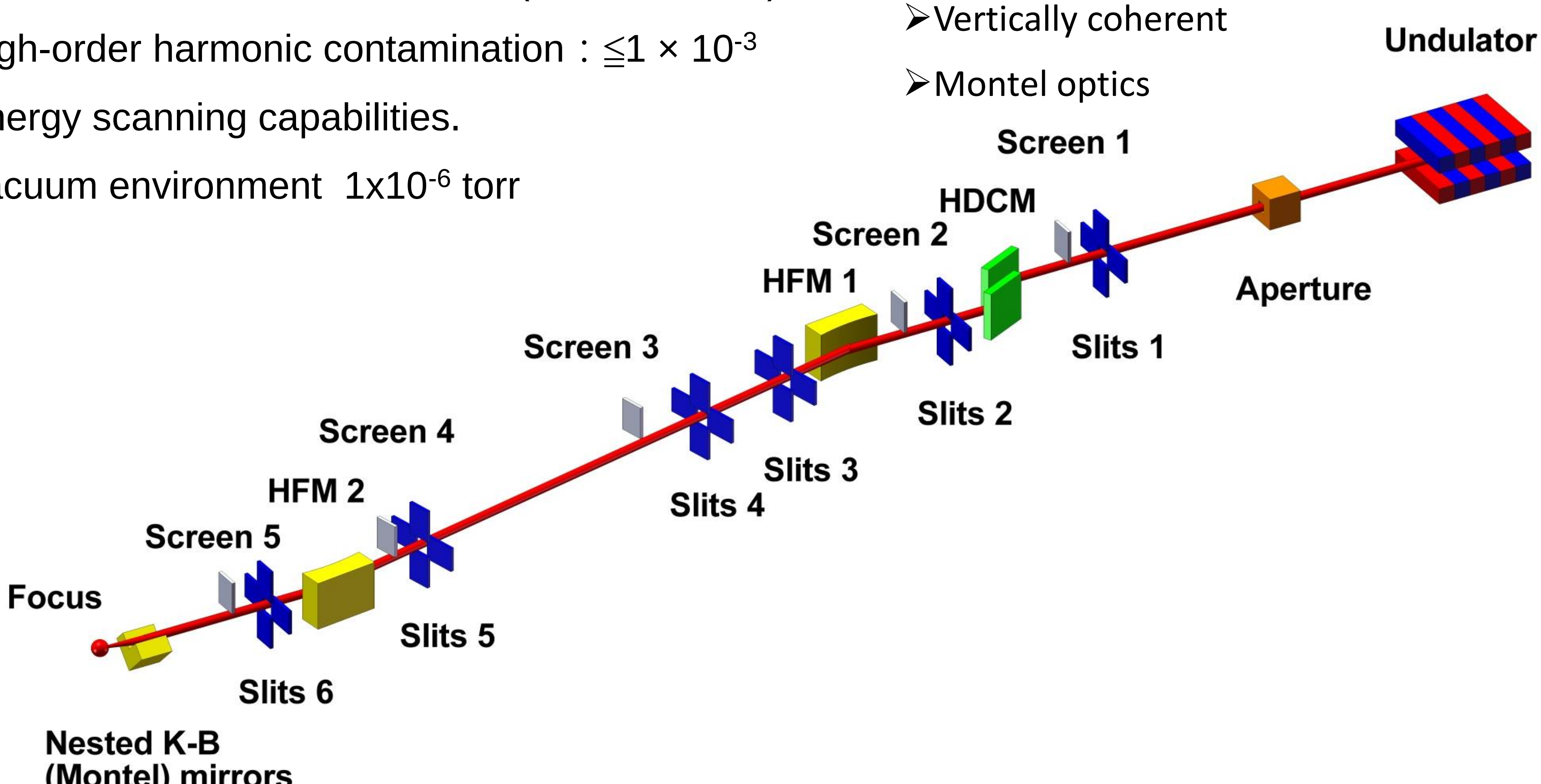
Optical Layout

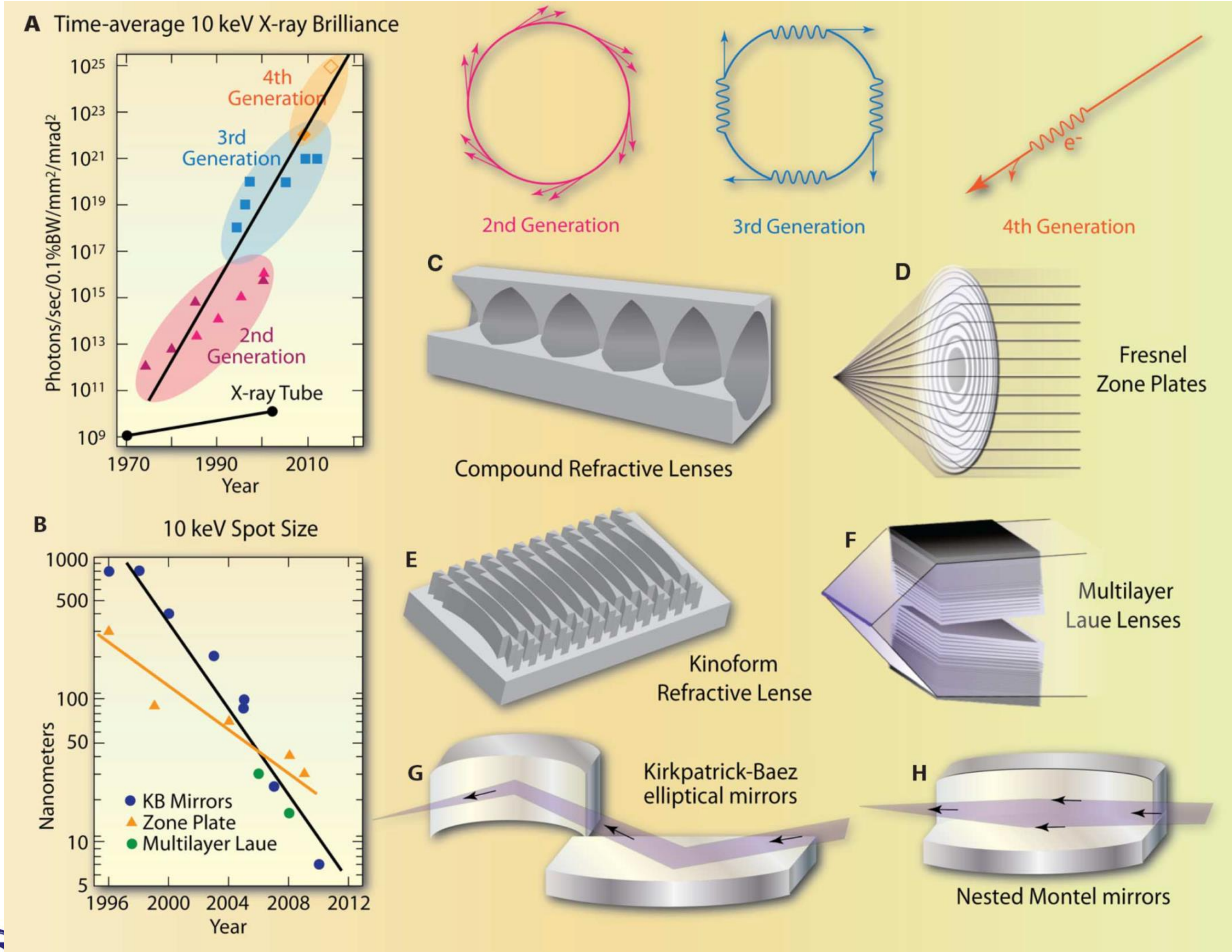
Expected Beamline performance

- Energy range : 4 - 15 kev
- Photon flux : 10^{10} ~10^{11} photons/sec
- Energy resolution : < 2×10^{-4} with Si(111) crystals
- Beam size : ~ 40 nm at 10 keV (H × V, FWHM)
- High-order harmonic contamination : $\leqq 1 \times 10^{-3}$
- Energy scanning capabilities.
- Vacuum environment $1\text{x}10^{-6}$ torr

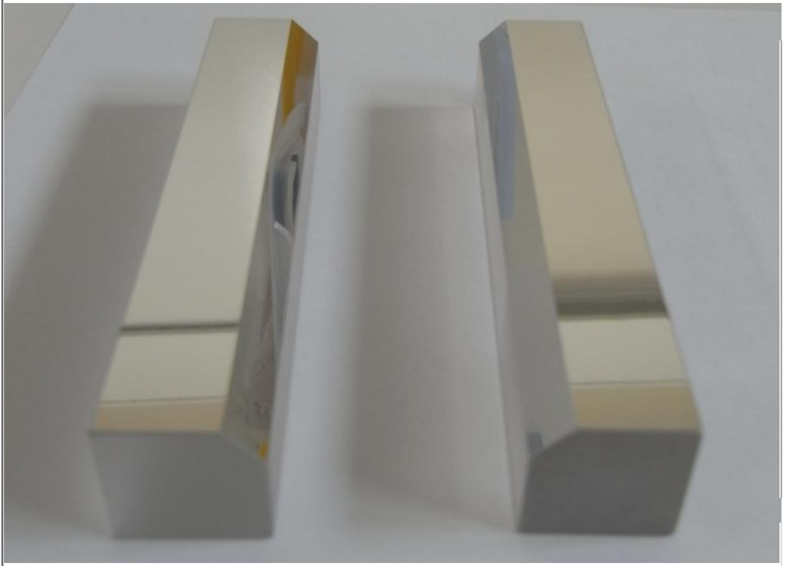
Features

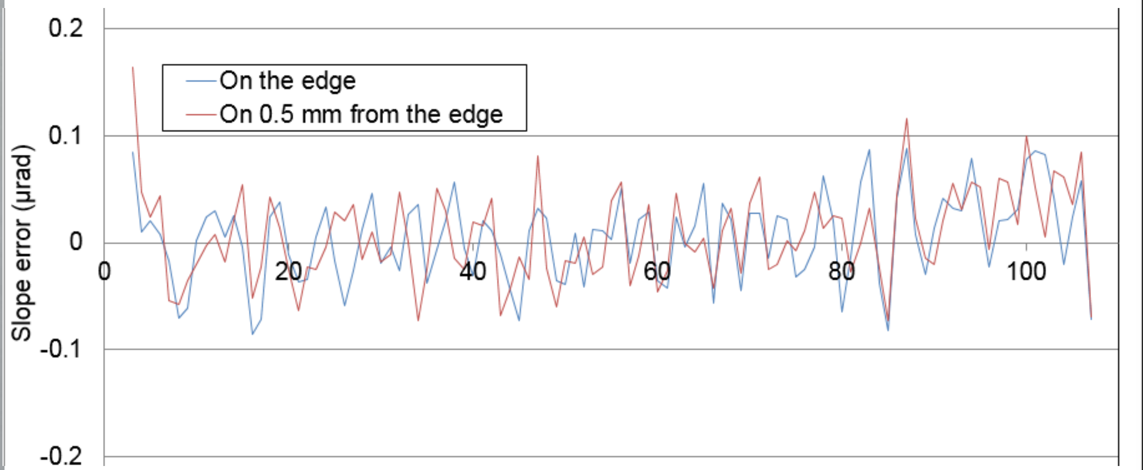
- 2-stage Horizontal focusing
- Horizontal DCM
- Short in length (<70 m)
- Windowless
- Vertically coherent
- Montel optics

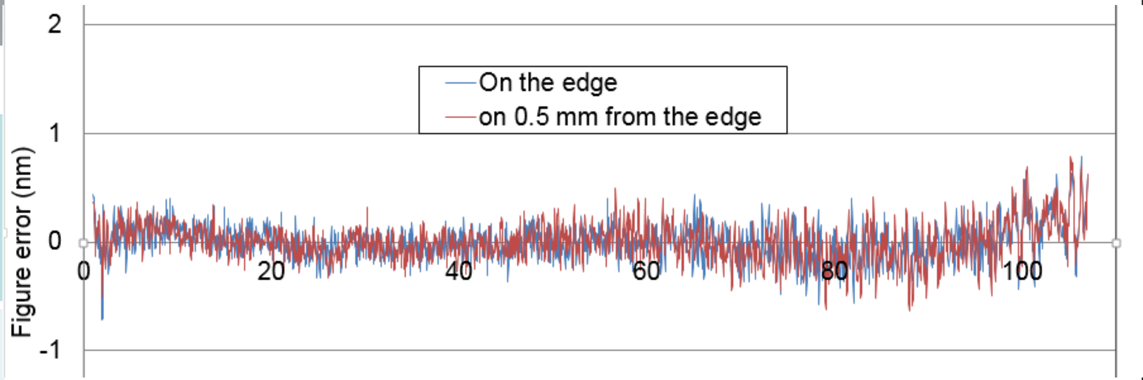



A Time-average 10 keV X-ray Brilliance
Photons/sec/0.1%BW/mm²/mrad²
4th Generation
3rd Generation
2nd Generation
X-ray Tube
Year
B 10 keV Spot Size
Nanometers
KB Mirrors
Zone Plate
Multilayer Laue
Year
2nd Generation
3rd Generation
4th Generation
e-
C
Compound Refractive Lenses
D
Fresnel Zone Plates
E
Kinoform Refractive Lense
F
Multilayer Laue Lenses
G
Kirkpatrick-Baez elliptical mirrors
H
Nested Montel mirrors

1. nano-optics: Montel mirrors







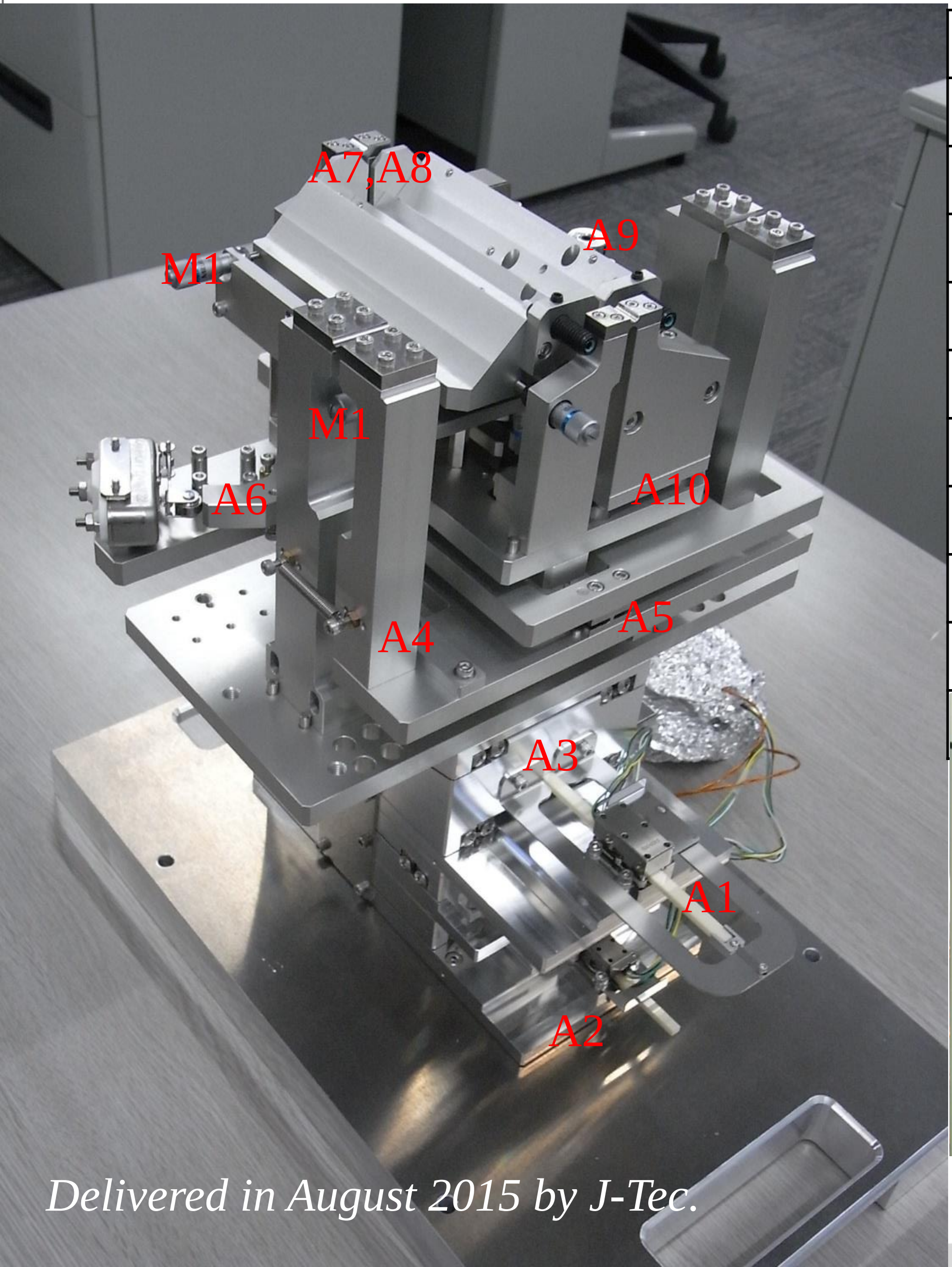
	Slope error RMS	Roughness (nm) RMS
Mirror 1	0.042 (μrad)	0.135 (nm)
Mirror 2	0.039 (μrad)	0.142 (nm)

No crack at edge is observed by Optical microscope

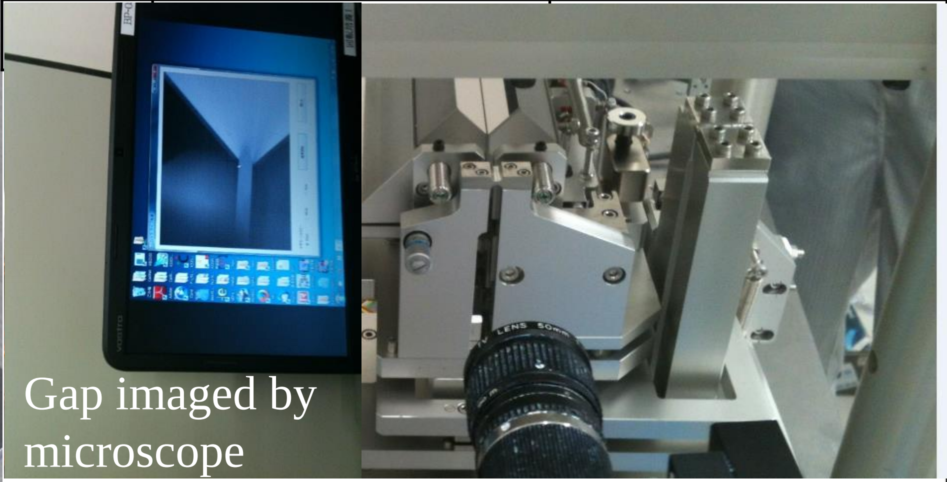
國家同步輻射研究中心
National Synchrotron Radiation Research Center

Delivered in June 2015 by J-Tec

Mirror holders



A1	X	Optical encoder
A2	Y	Optical encoder
A3	Z	Optical encoder
A4	Pitch	Laser interferometer
A5	Roll	Laser interferometer
A6	Yaw	Laser interferometer
A7	Top-Y	Pre-aligned
A8	Top-Z	Pre-aligned
A9	Top-Pitch (X)	Pre-aligned
A10	Top-Roll (Y)	Pre-aligned

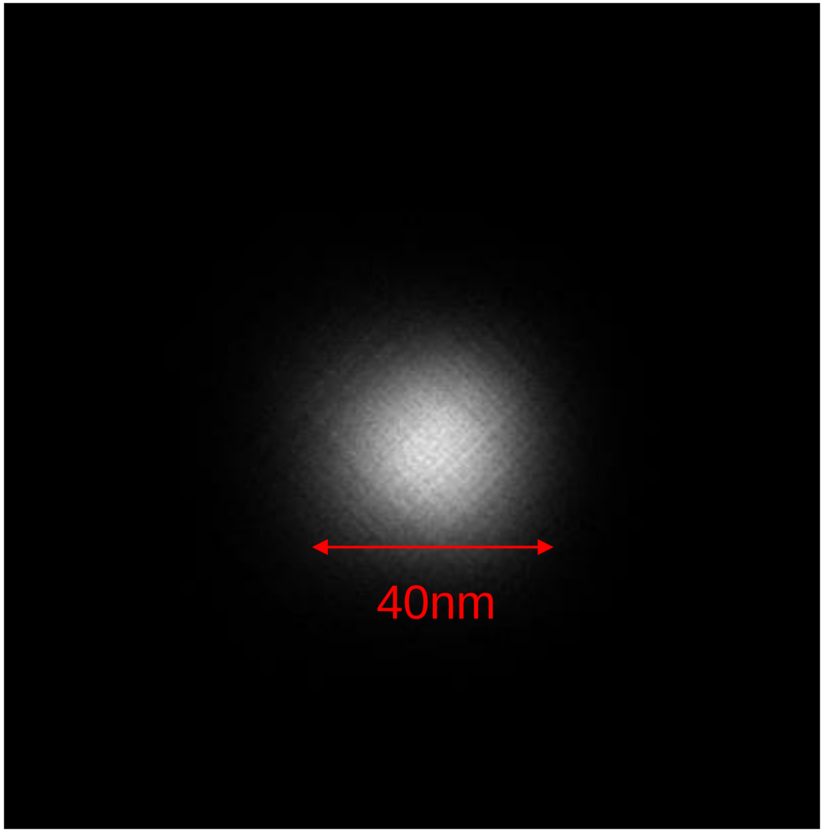


Montel Mirrors in the holder

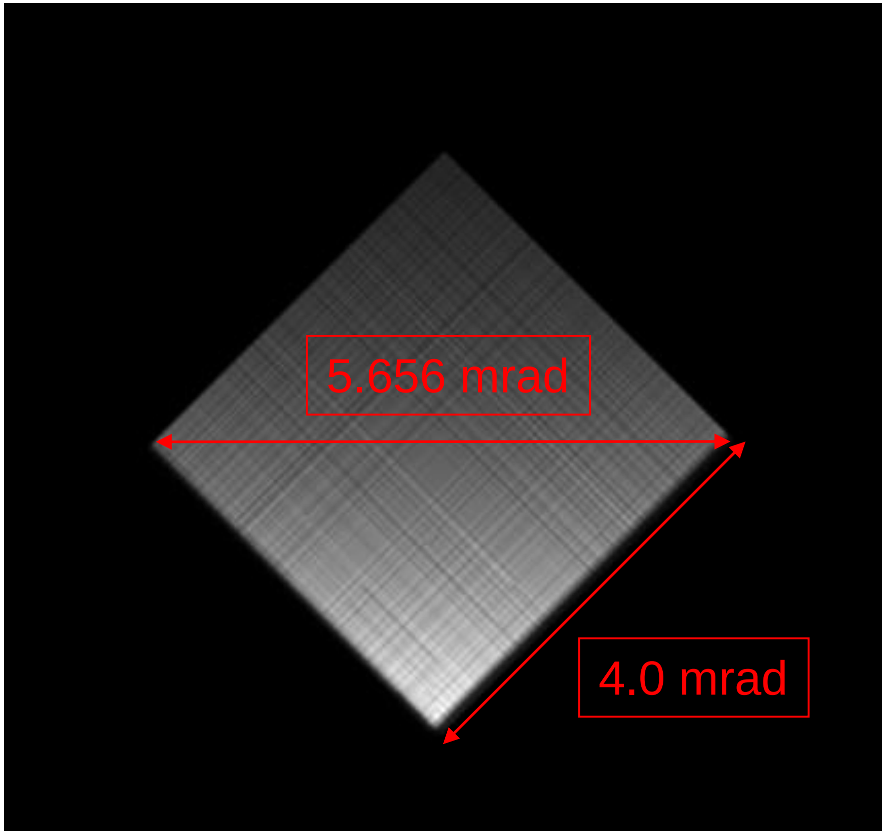
Simulation of Focus Spot

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	25nm x 25nm,



Simulated
Focus spot size

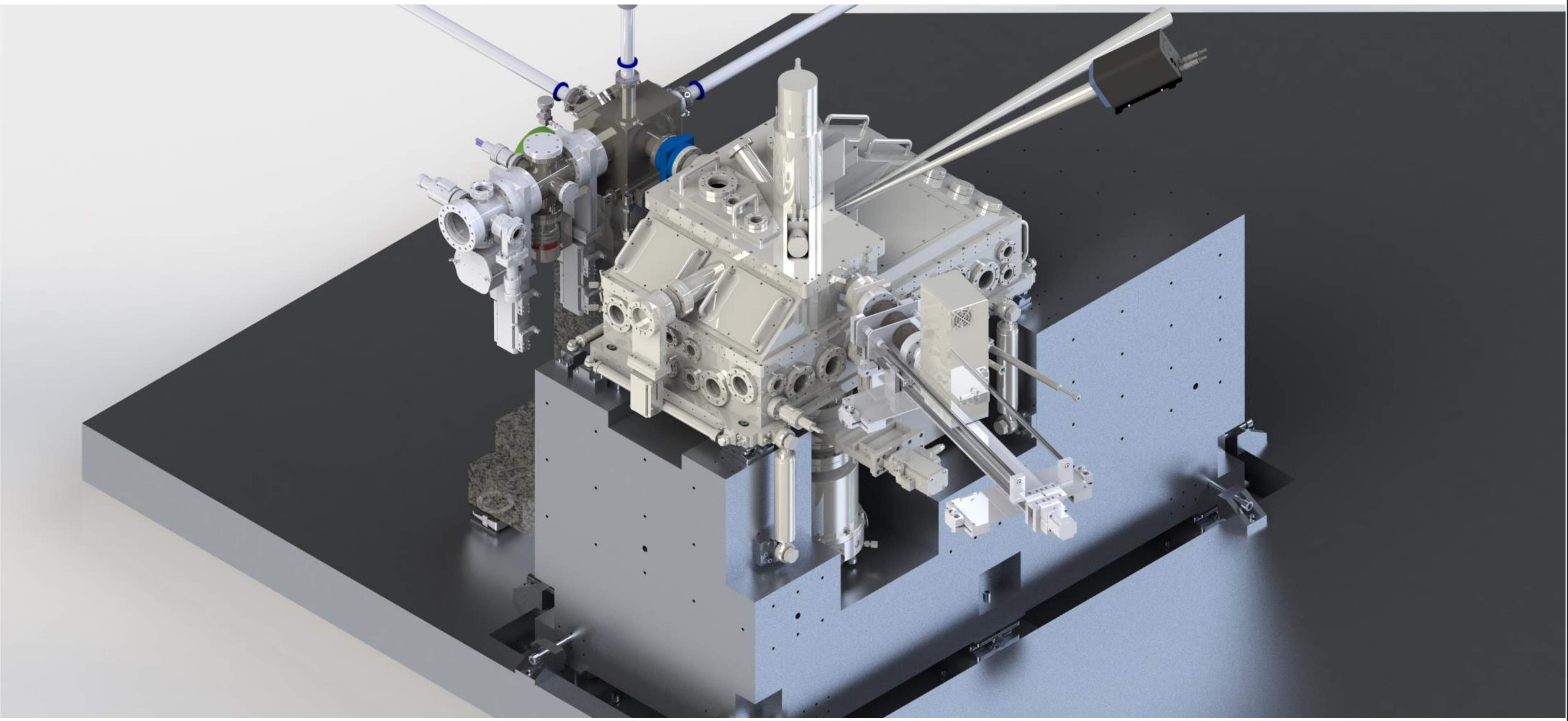


Simulated
Divergence

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

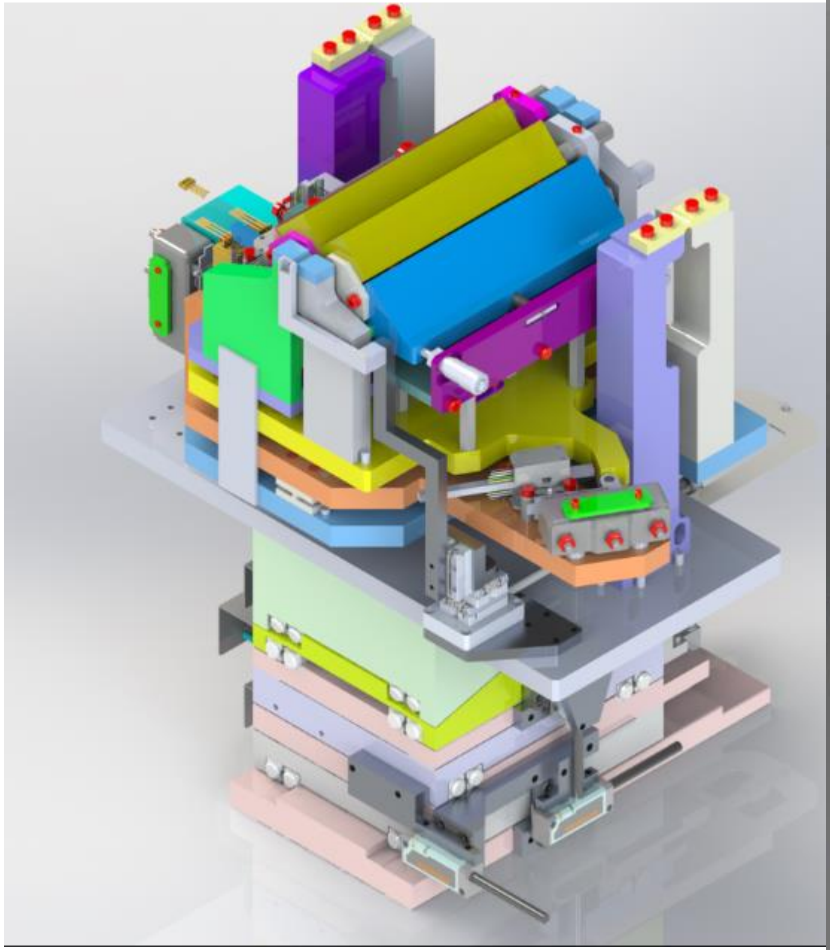
By Gung-Chian Yin

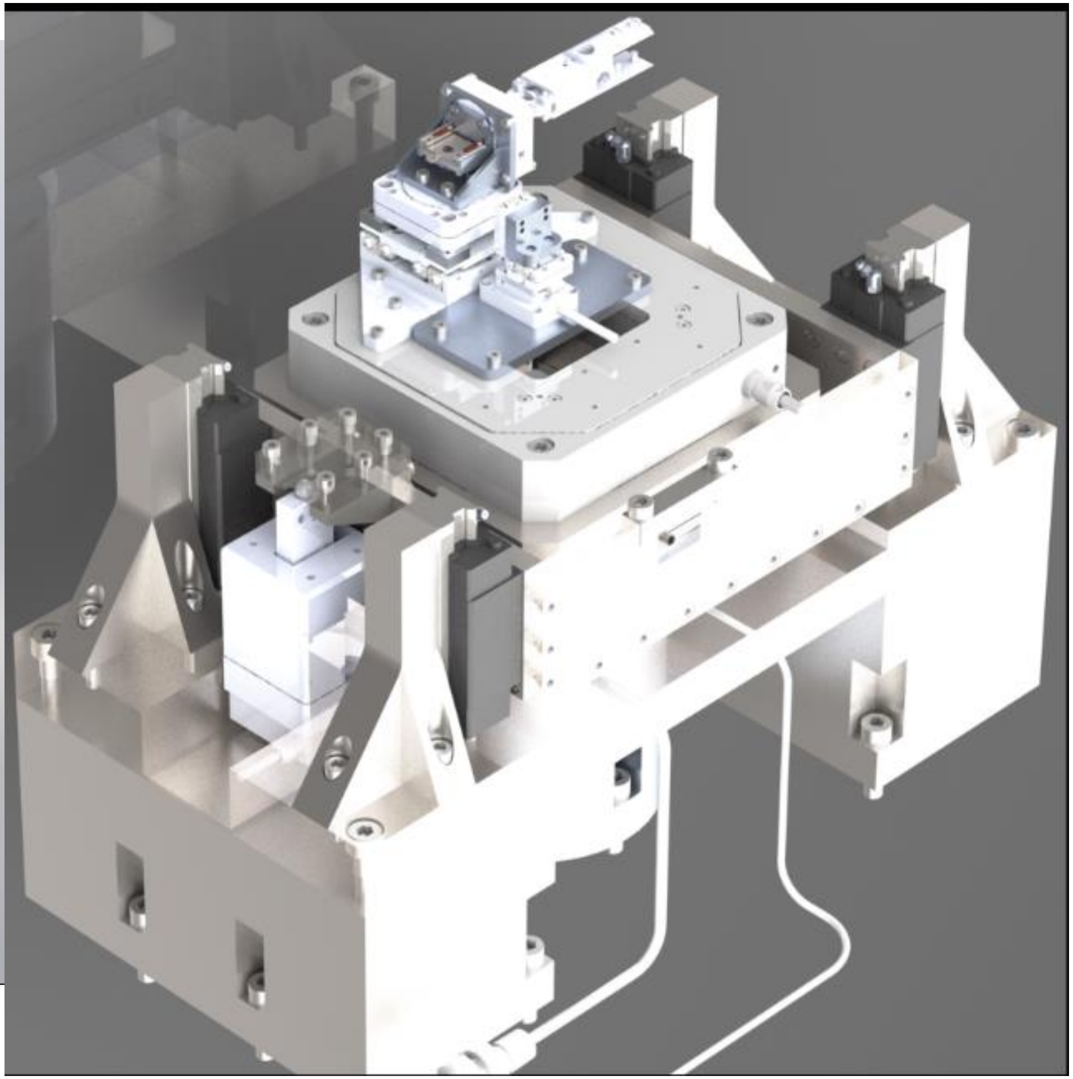
Experimental Station

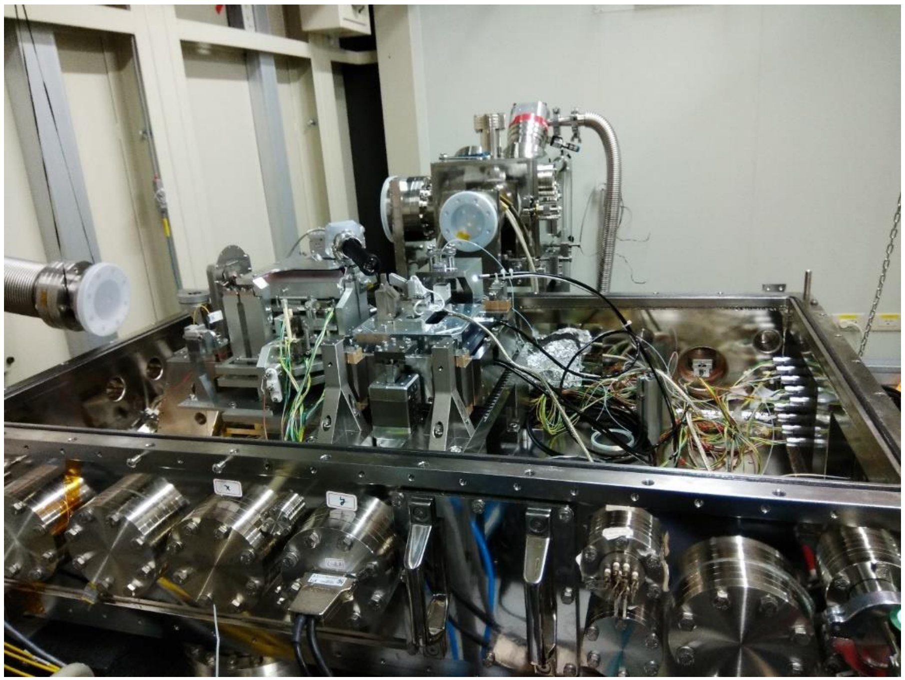


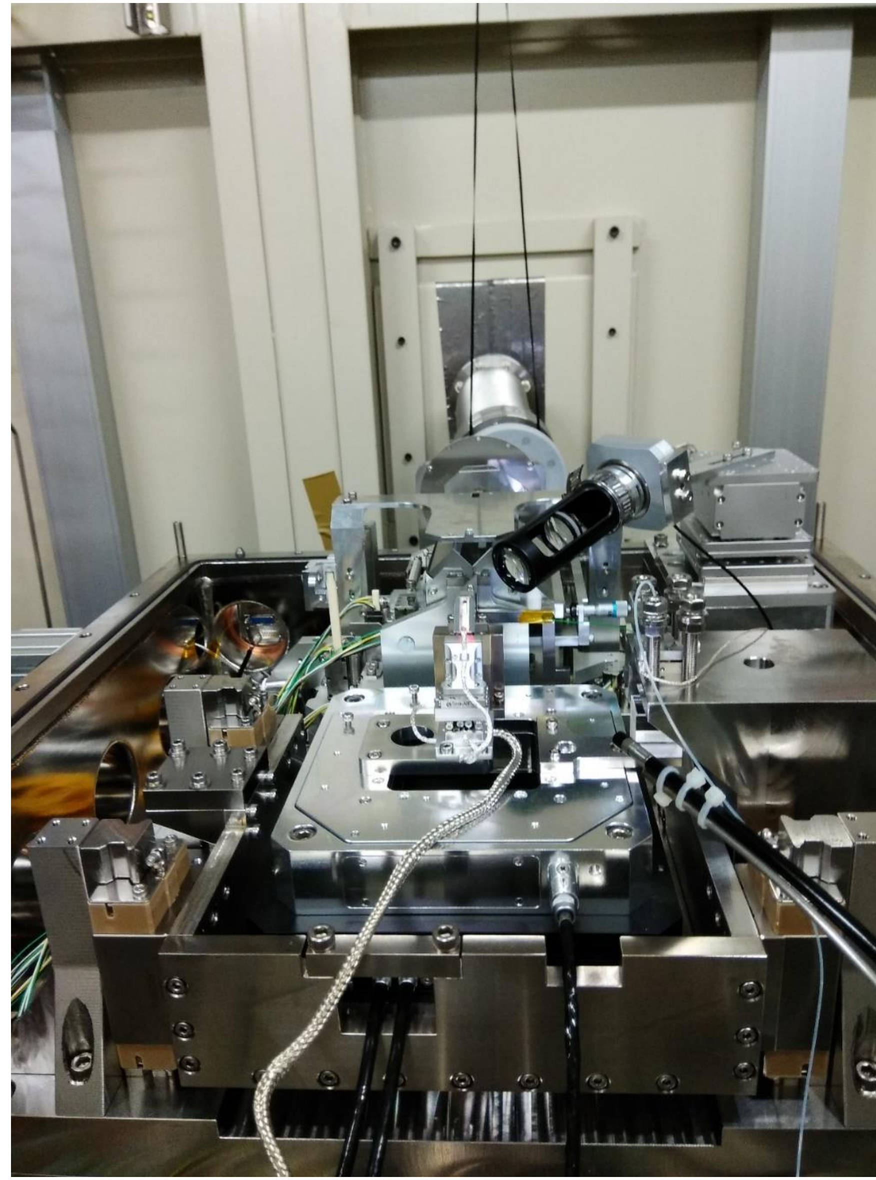
國家同步輻射研究中心
National Synchrotron Radiation Research Center

Experimental Station



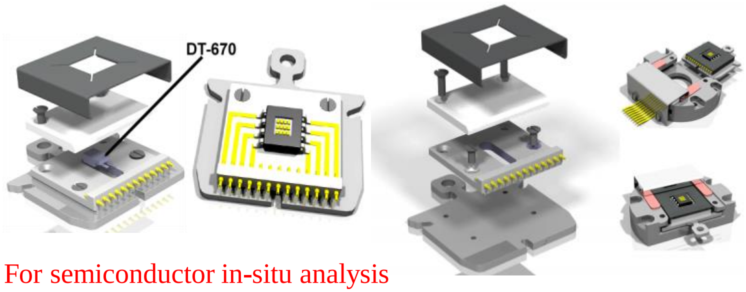




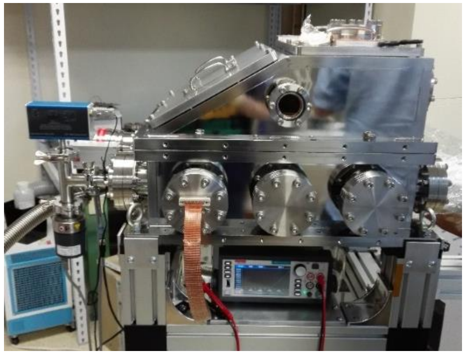


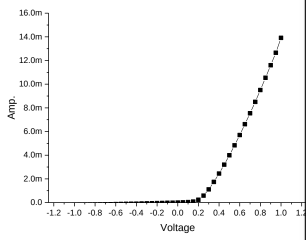
Sample environment and Preparation Chamber

Sample Holder with 13 electrical contacts



For semiconductor in-situ analysis

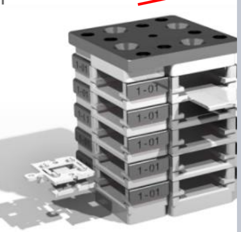


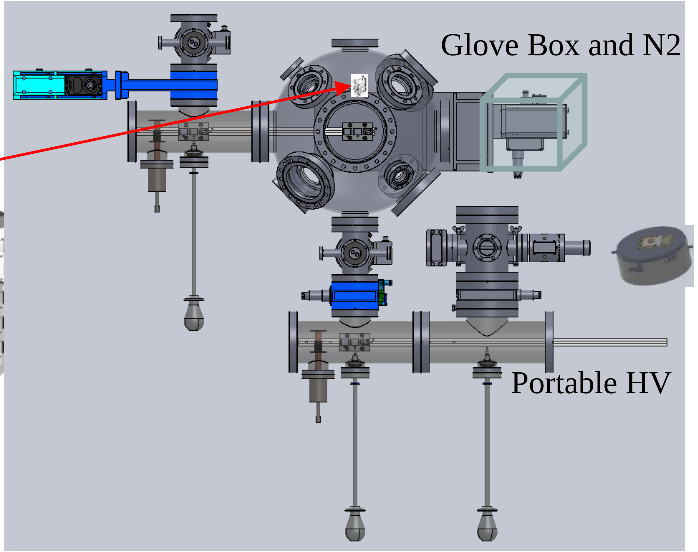


To main Chamber

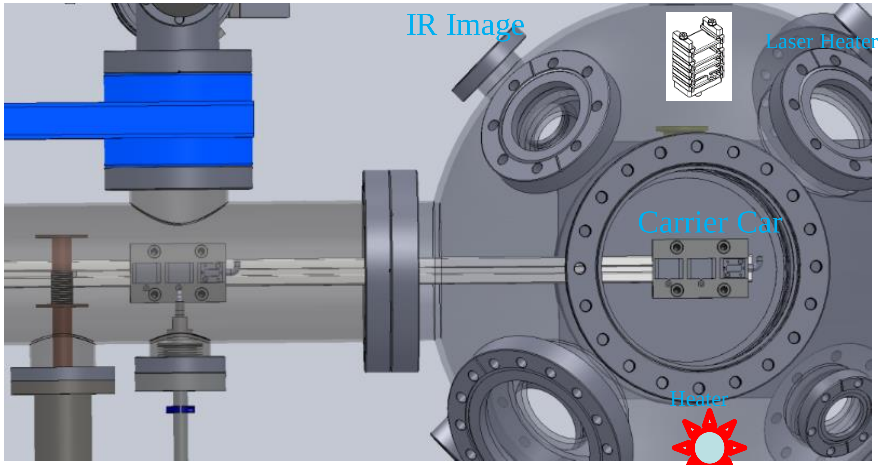
Glove Box and N2 Purge

5*4=20
Pieces





Stack of Receptacles



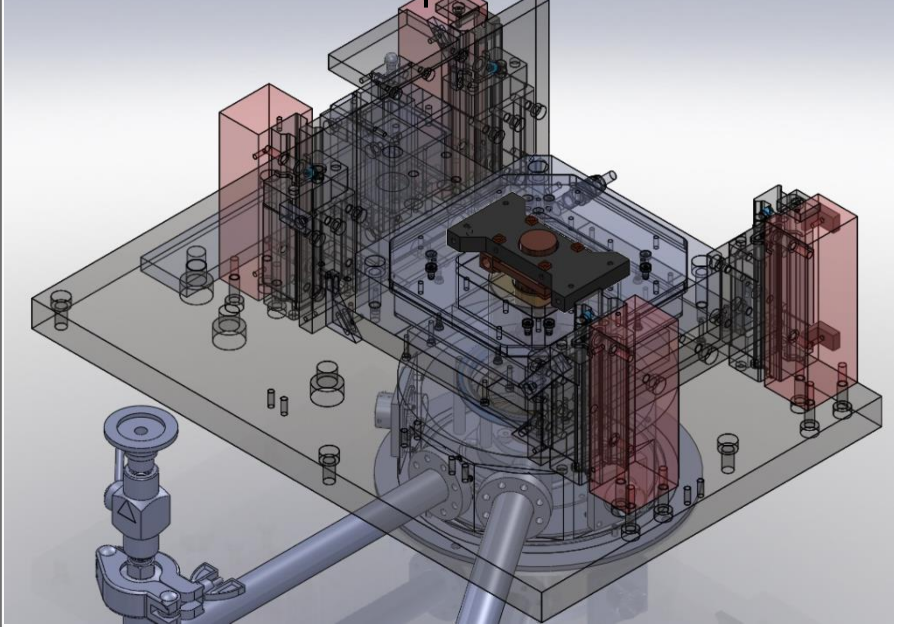
Ion Gun and O_2 Plasma

Conduit of Reaction Gas + MFC (O_2, H_2 ...)

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

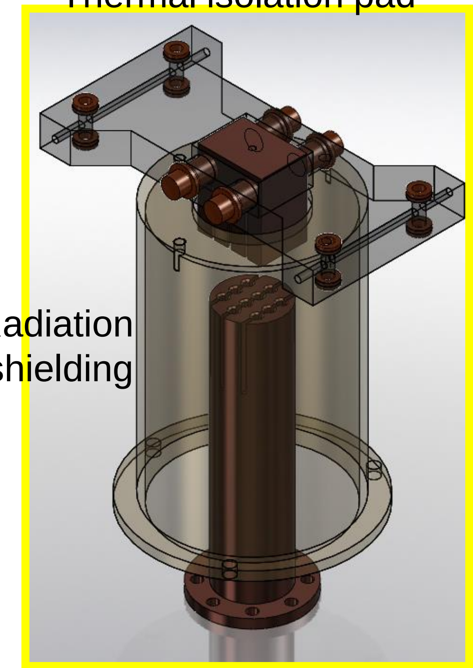
The Design of the L-He Cooling System

- JANIS ST-500 He cryo-stage
- Estimated temperature~ 10K

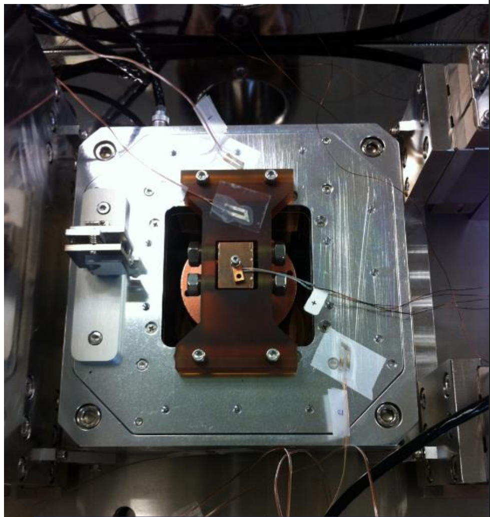


Thermal isolation pad

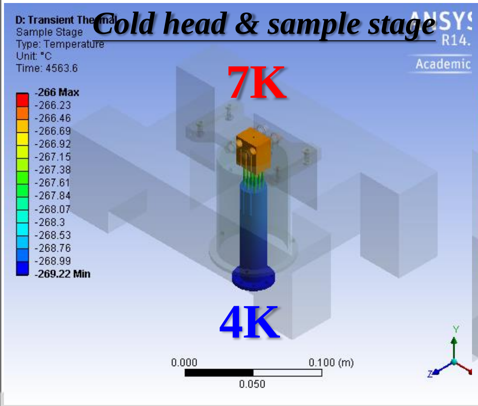
Radiation shielding

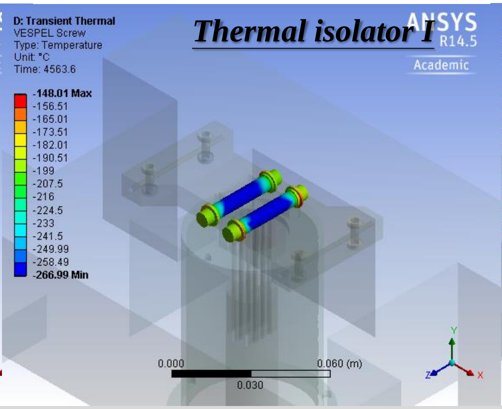


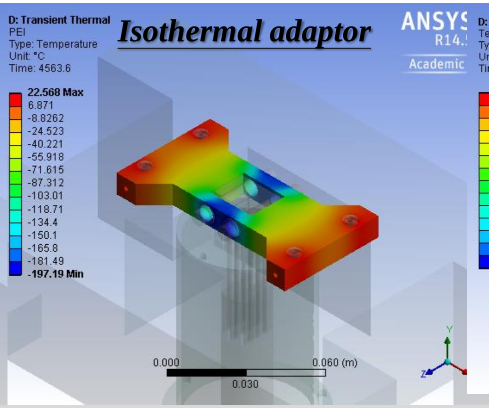
Cooling head

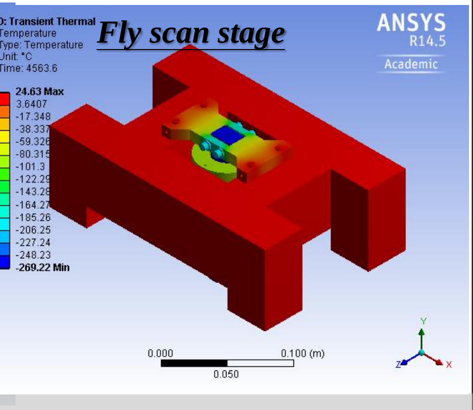


➔FEM simulation results

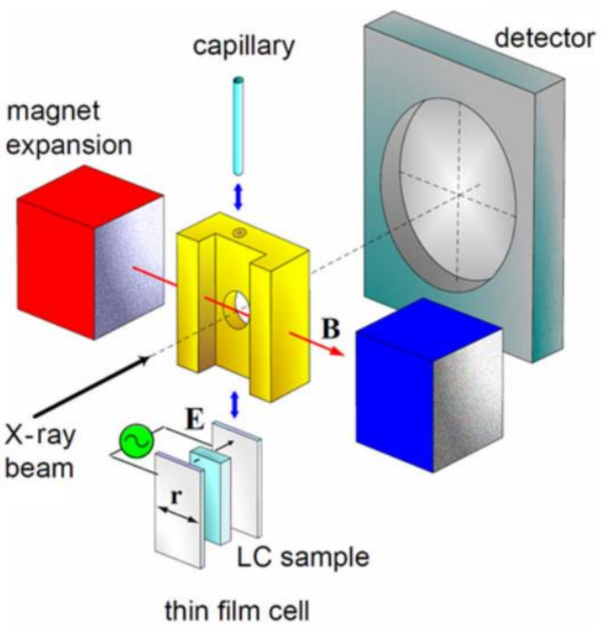


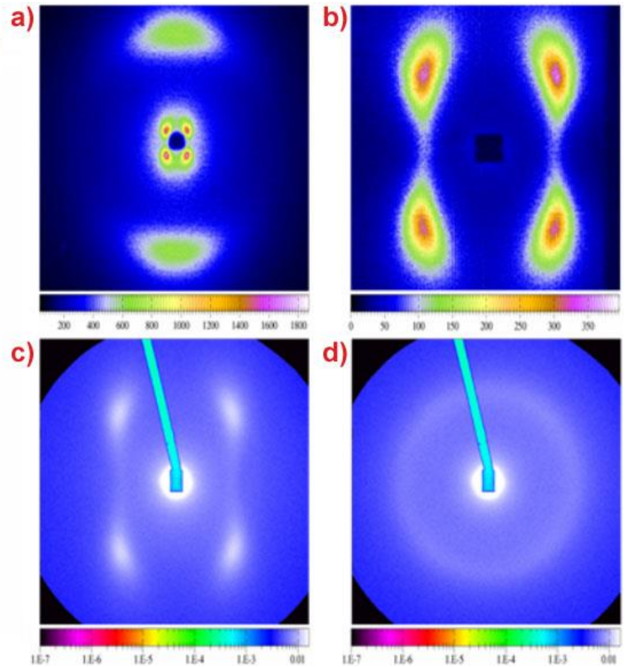


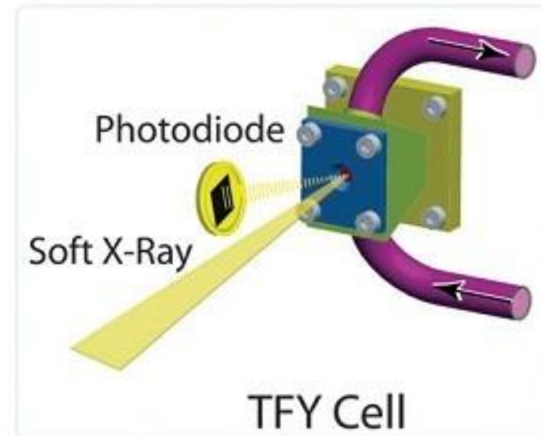


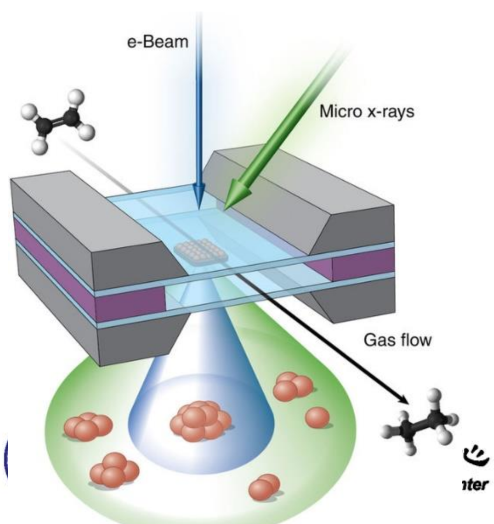


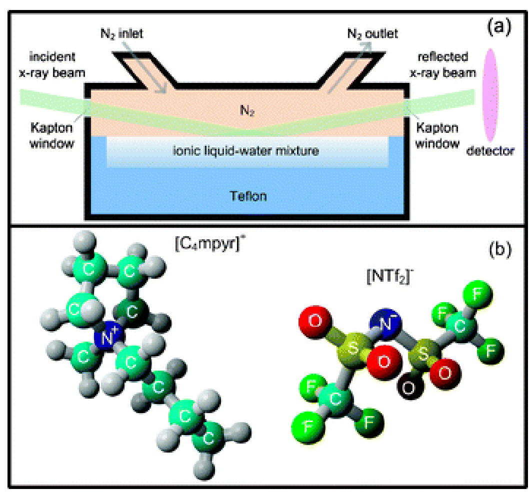
In-Situ Gas and Liquid Cell

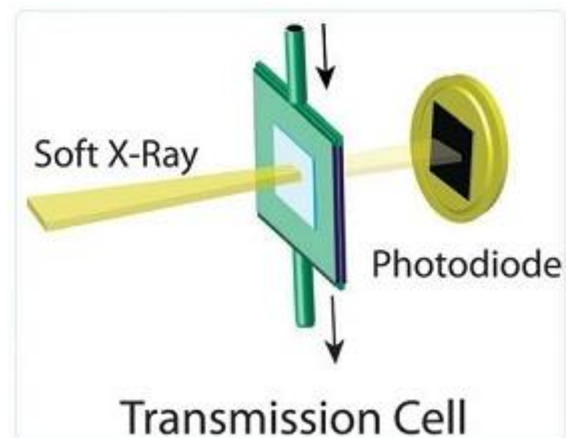


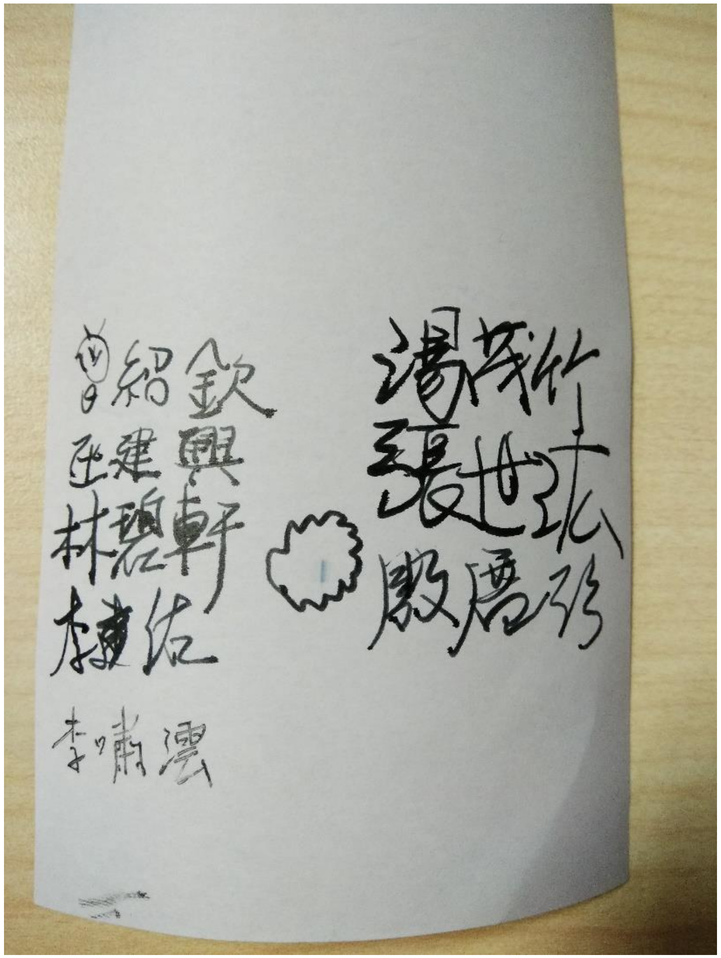


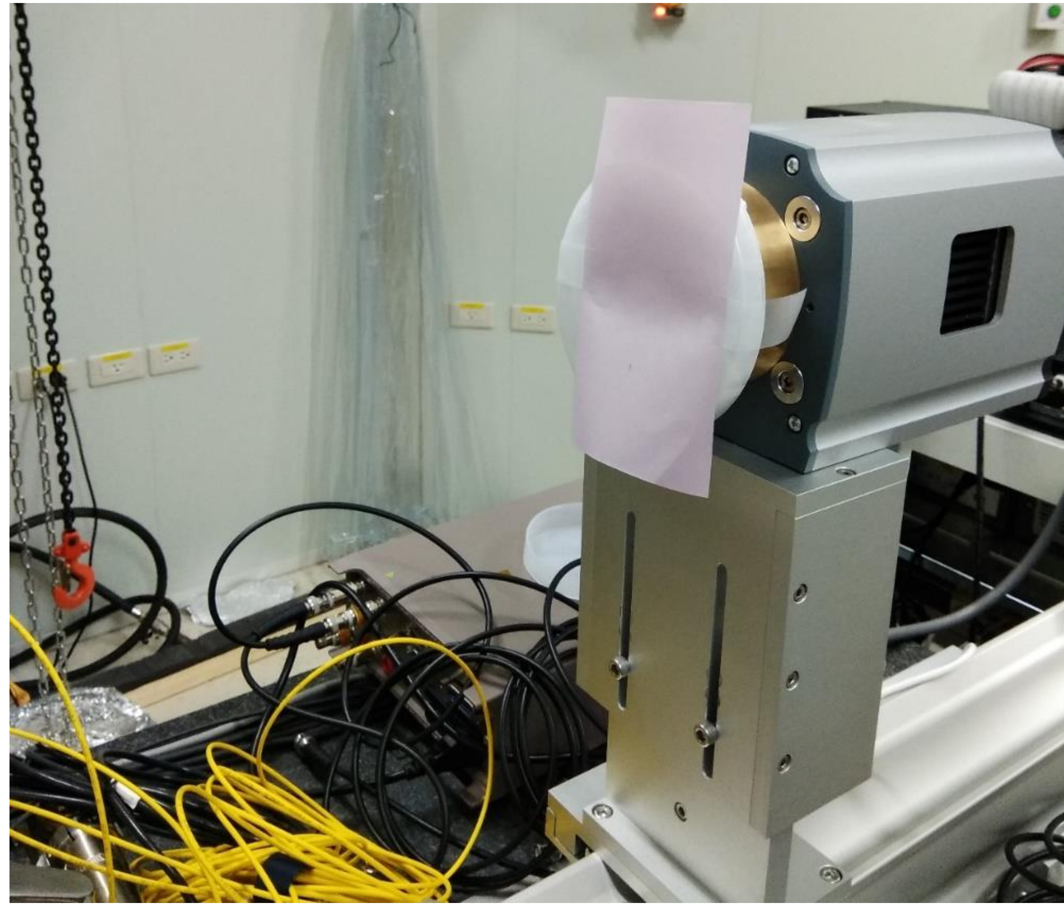


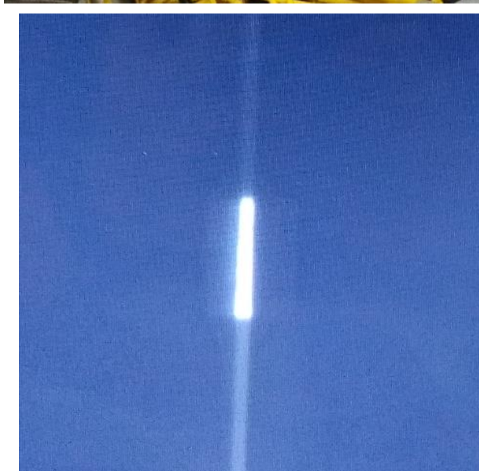


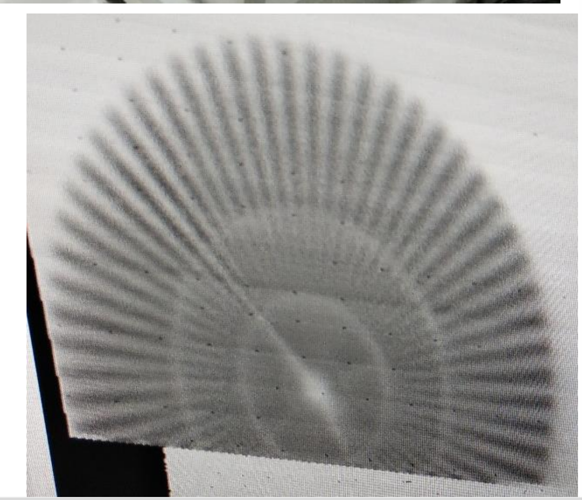












國家同步輻射研究中心
National Synchrotron Radiation Research Center

nano-XRF (x-ray fluorescence)

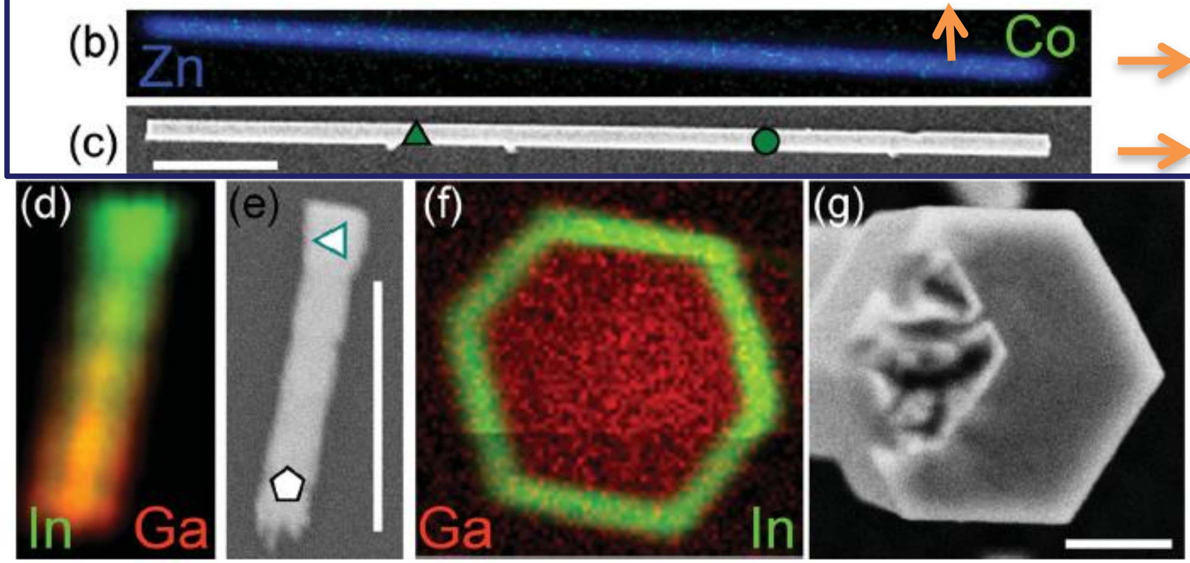
Element-specific nano-imaging

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

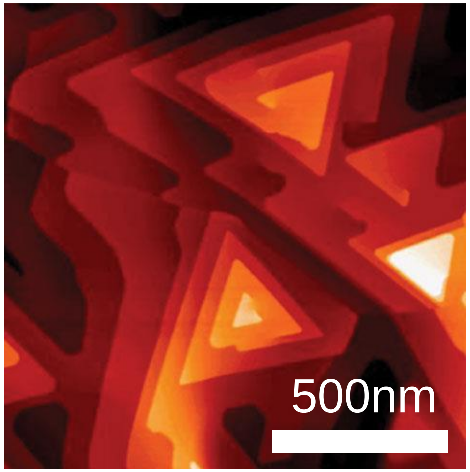
- Distribution
- Short structure order
- Elemental composition

- ➢ 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



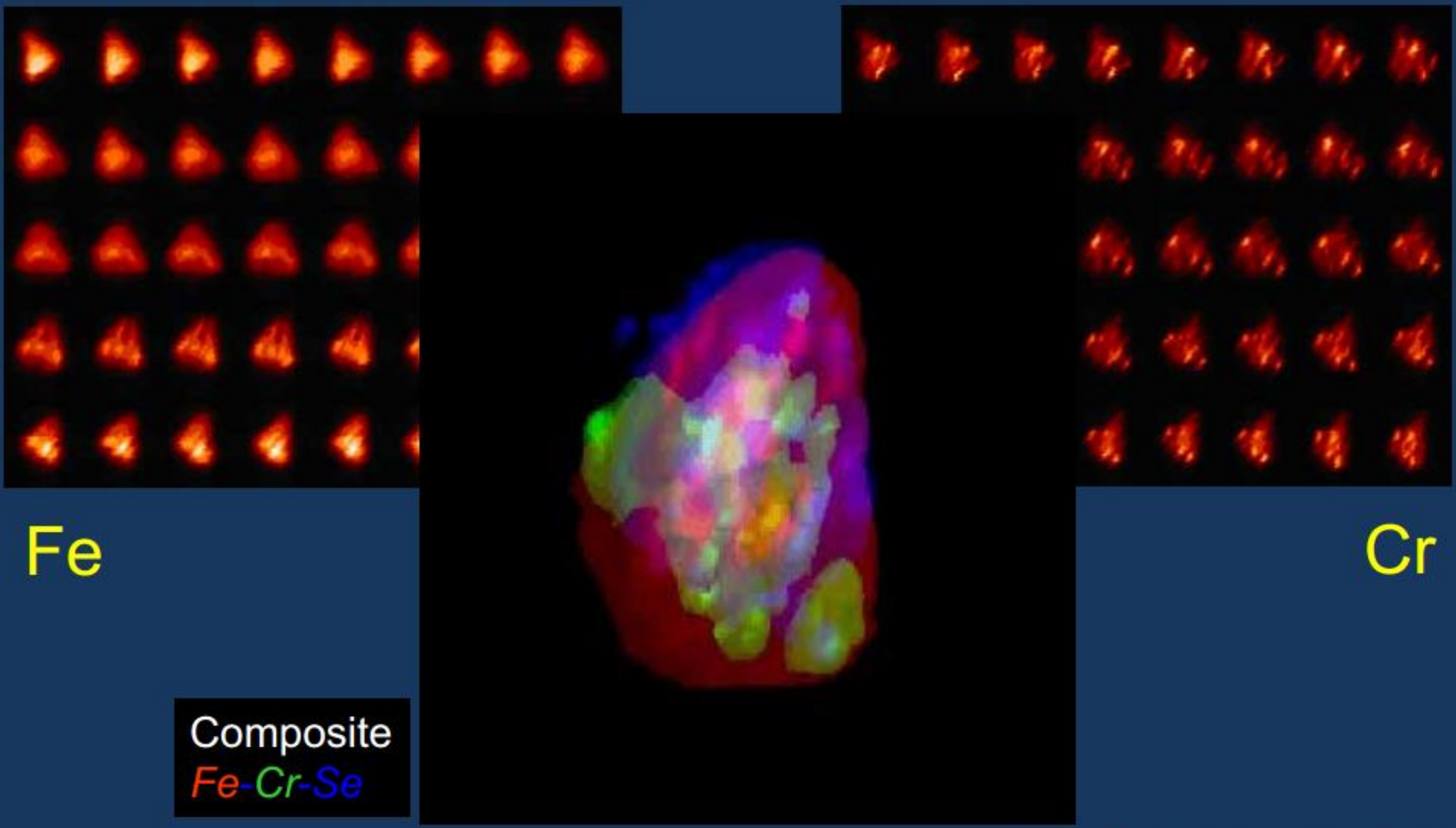
Doping method:
Ion implantation
and thermal annealing
→ Elemental map of XRF
→ SEM



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

High resolution XRF tomography

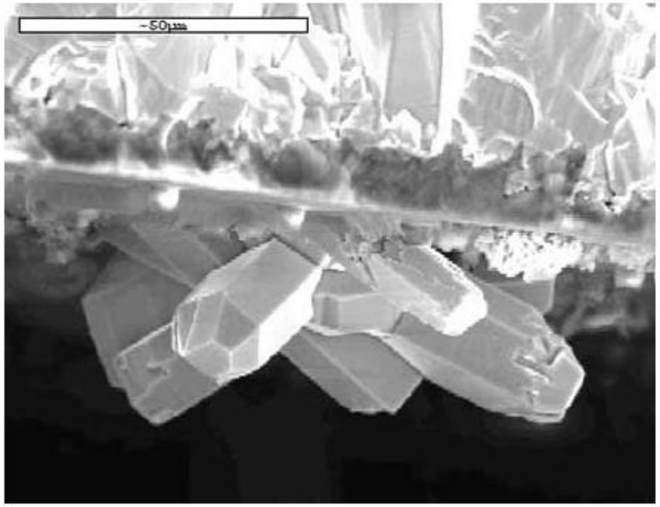
Pixel size: 100 nm, sample rotation 0-180° (4.5° / image)



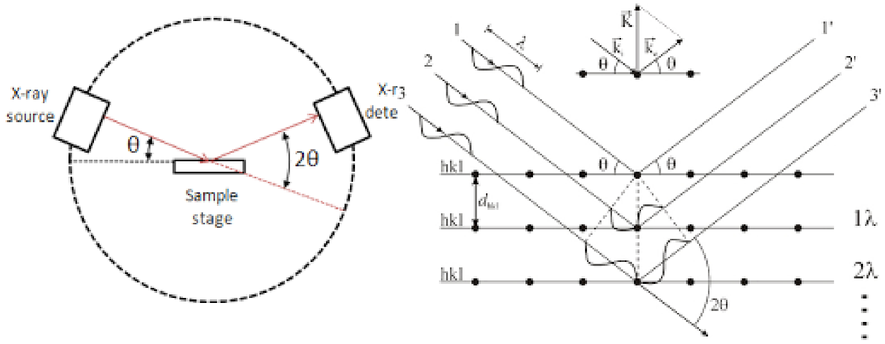
Silversmit *et al., Anal. Chem.* 81 (2009)

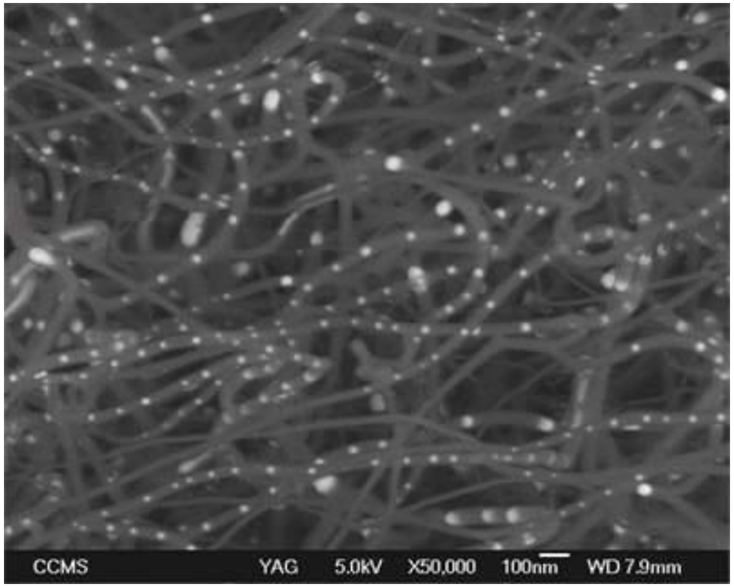
nano-XRD (x-ray Diffraction)

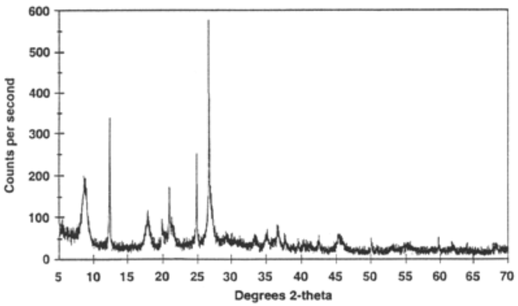
nano-Crystalline



Carbon

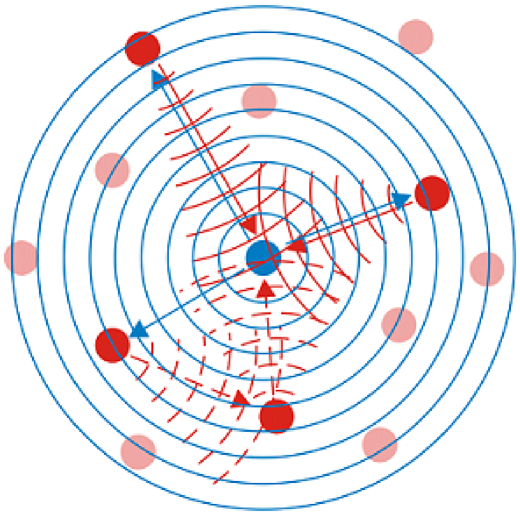


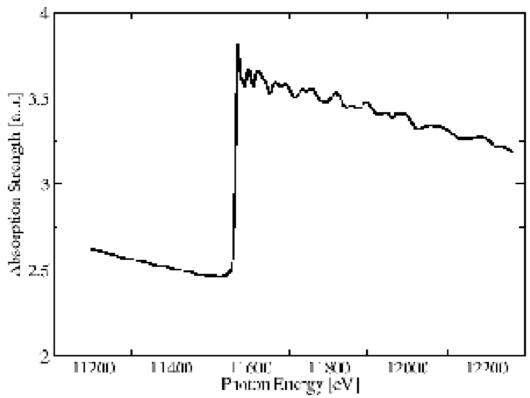


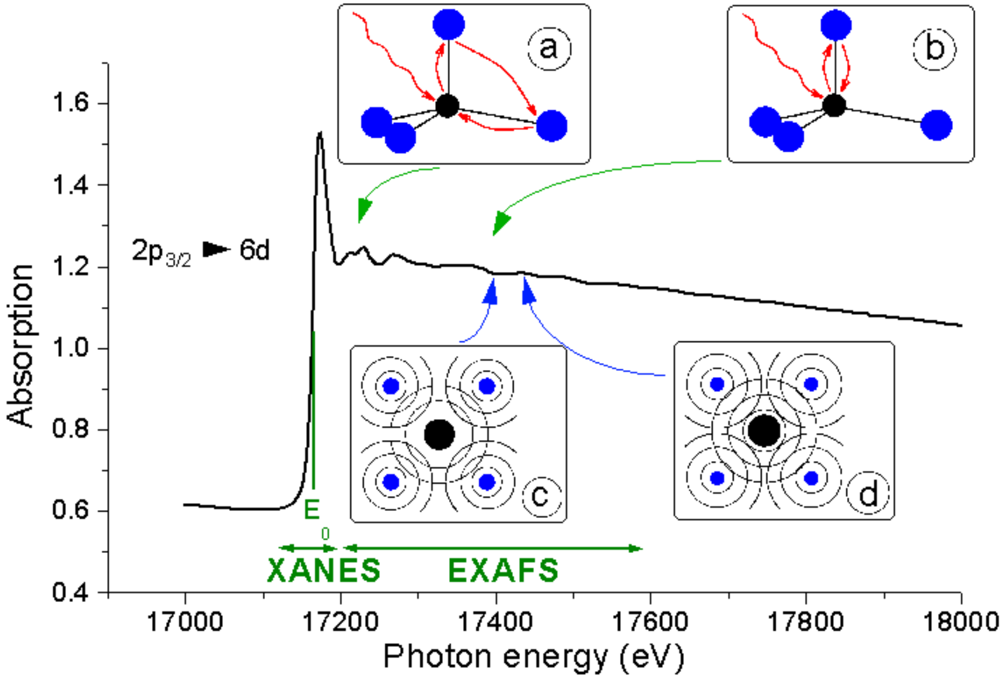


nano-XAFS (x-ray absorption fine structures)

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

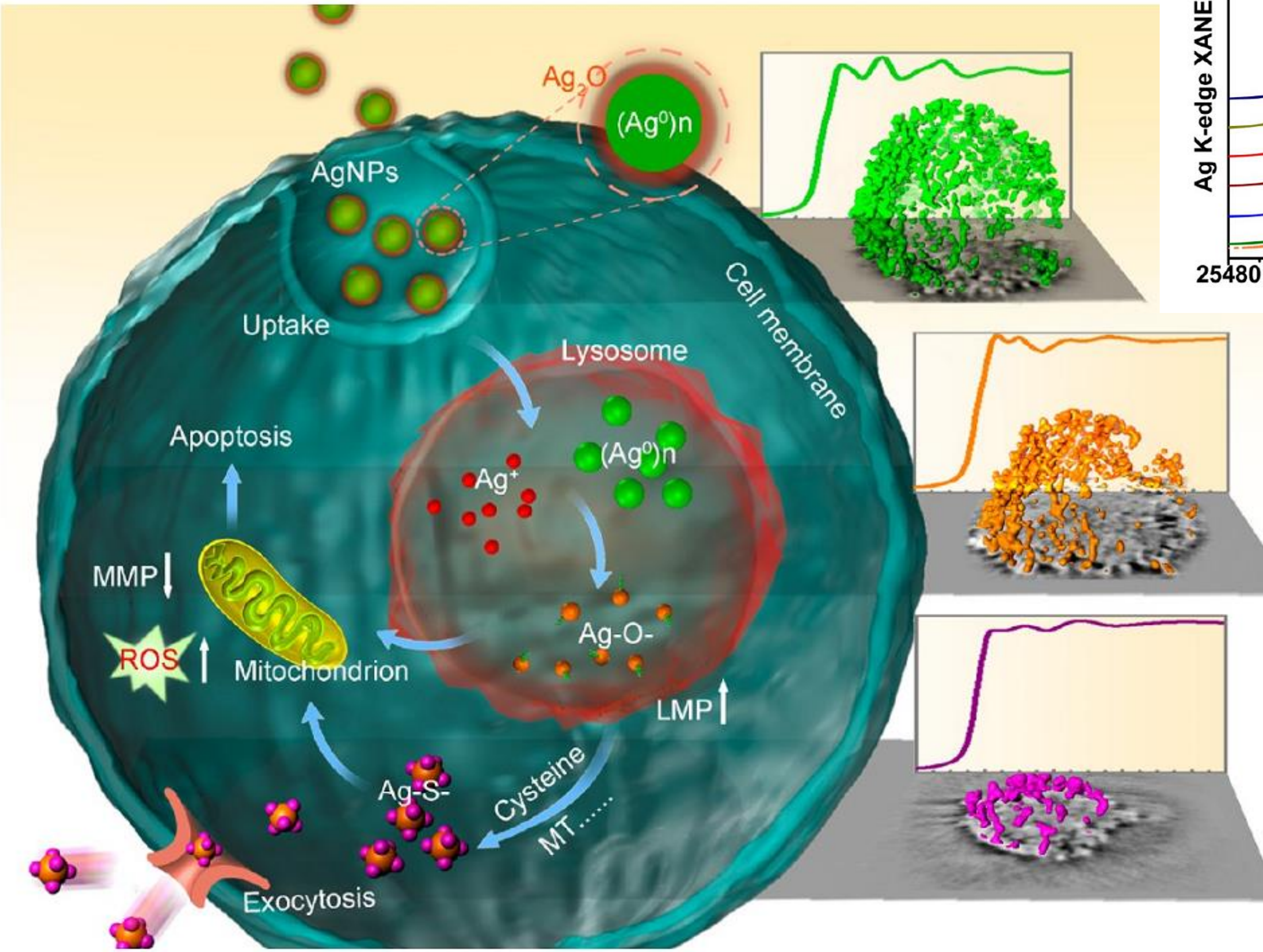


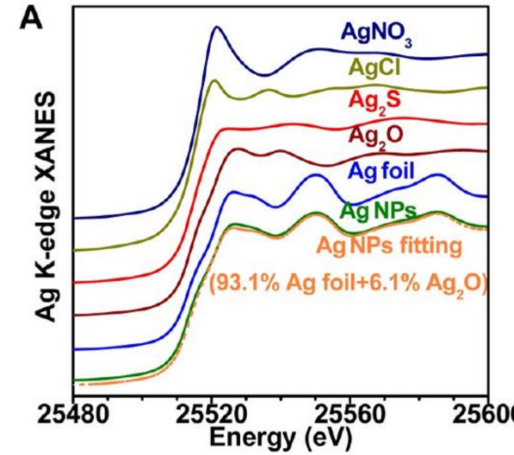




國家同步輻射研究中心
National Synchrotron Radiation Research Center

nano-XAFS

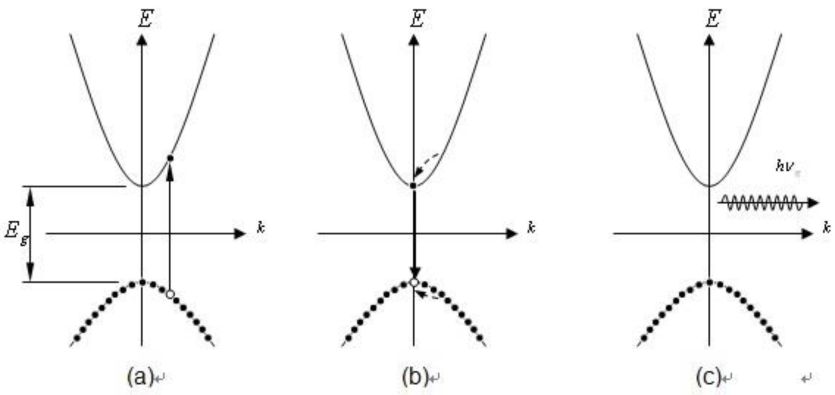


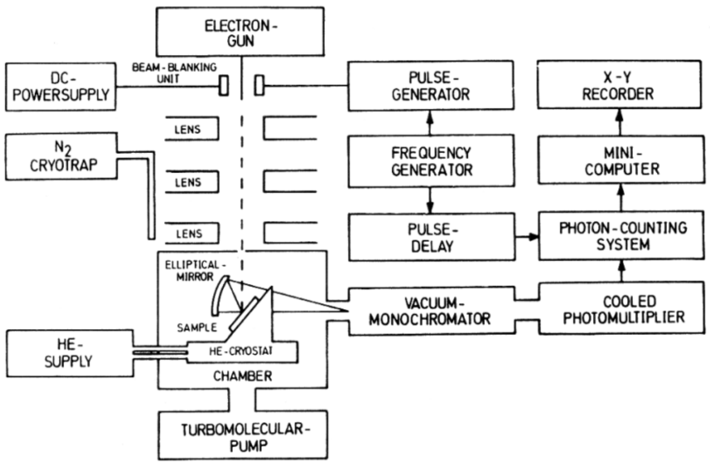


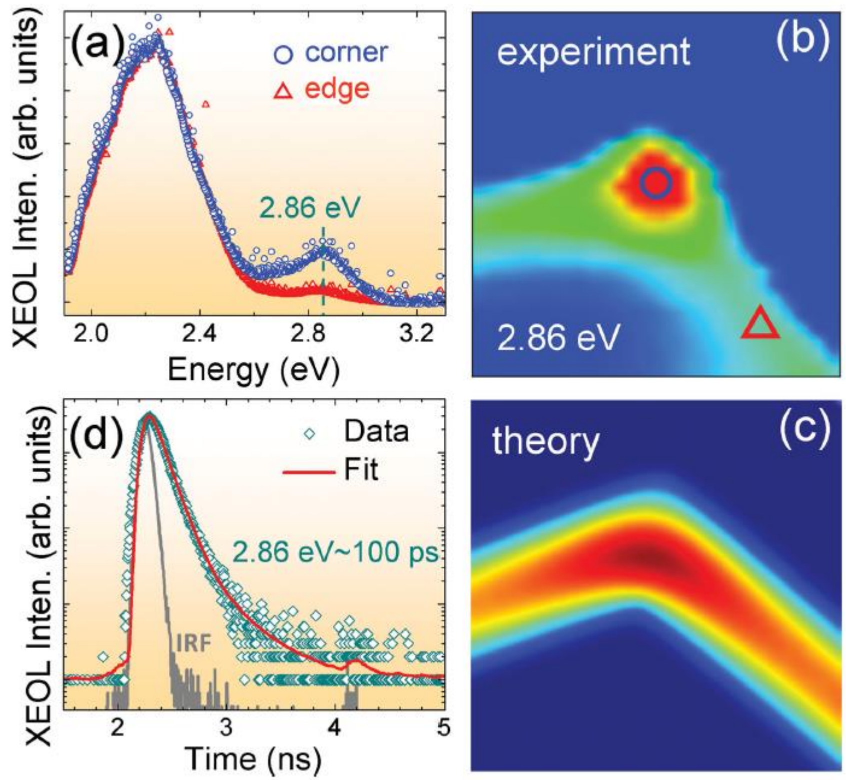
ACS NANO Vol 9, 6, 6532–6547 (2015)

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

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







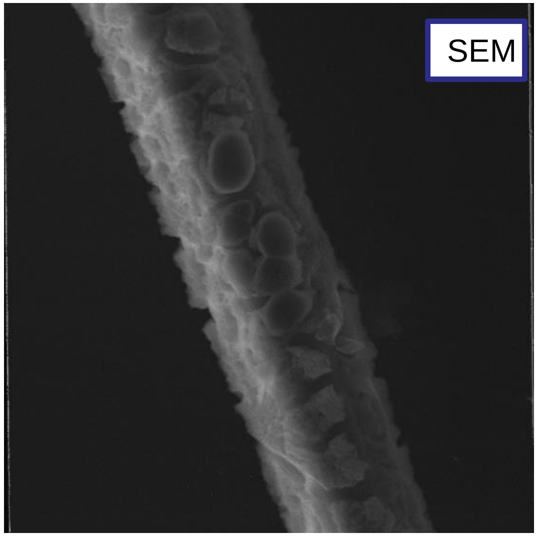
XEOL: 1.nano-area

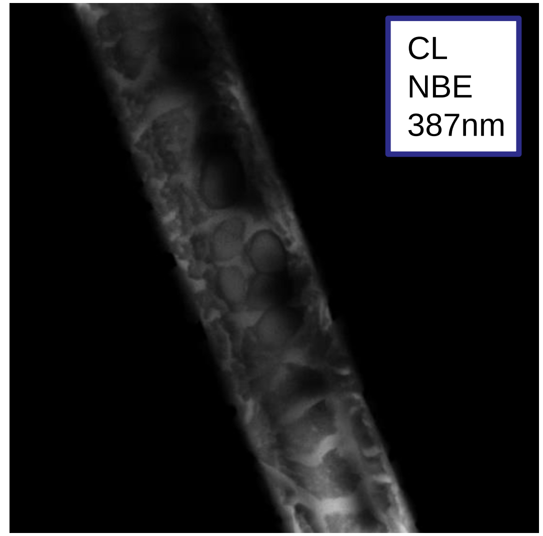
2.multi-layer, buried layer

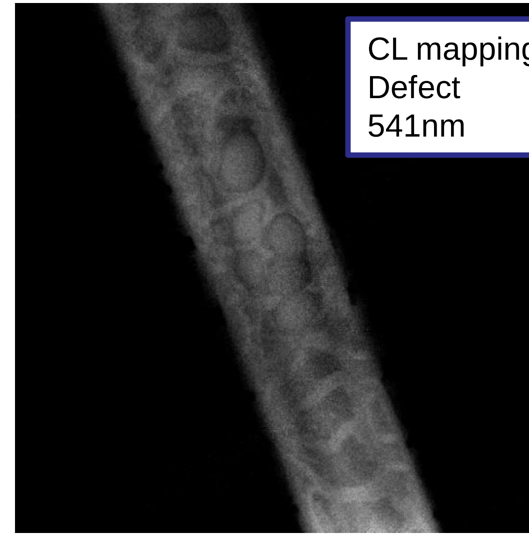
Doping species, Band gap, Defect band, Charge transport

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

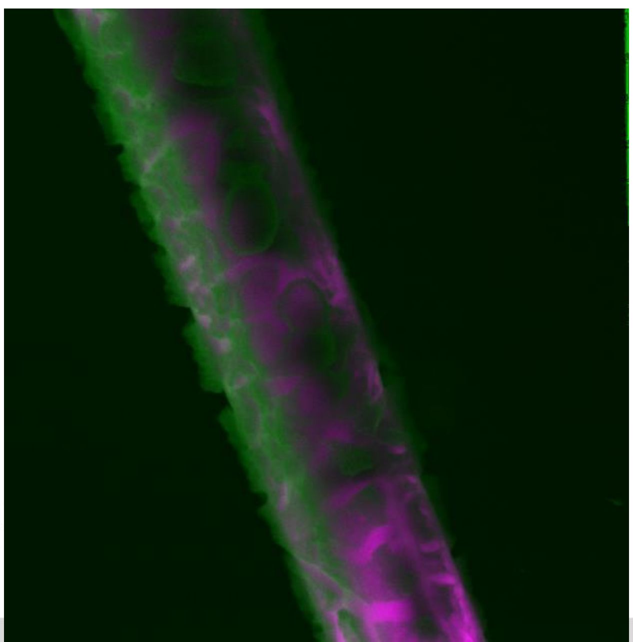
ZnO microwire
SEM and CL mapping

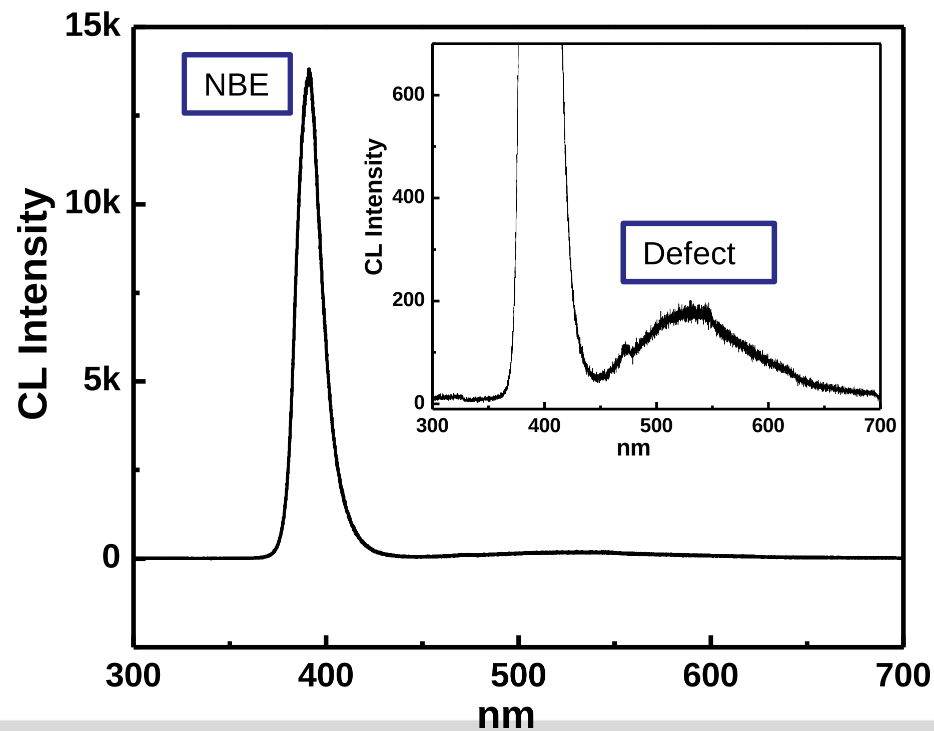




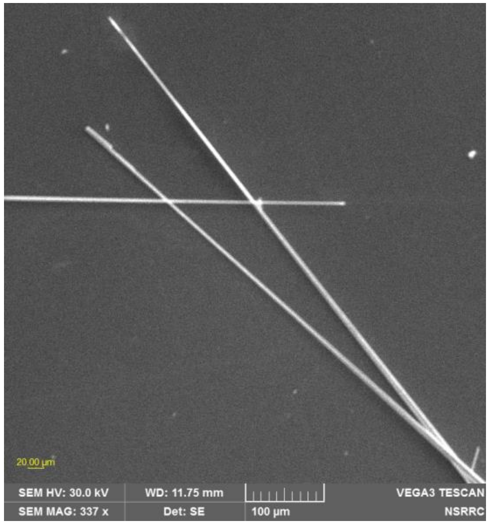


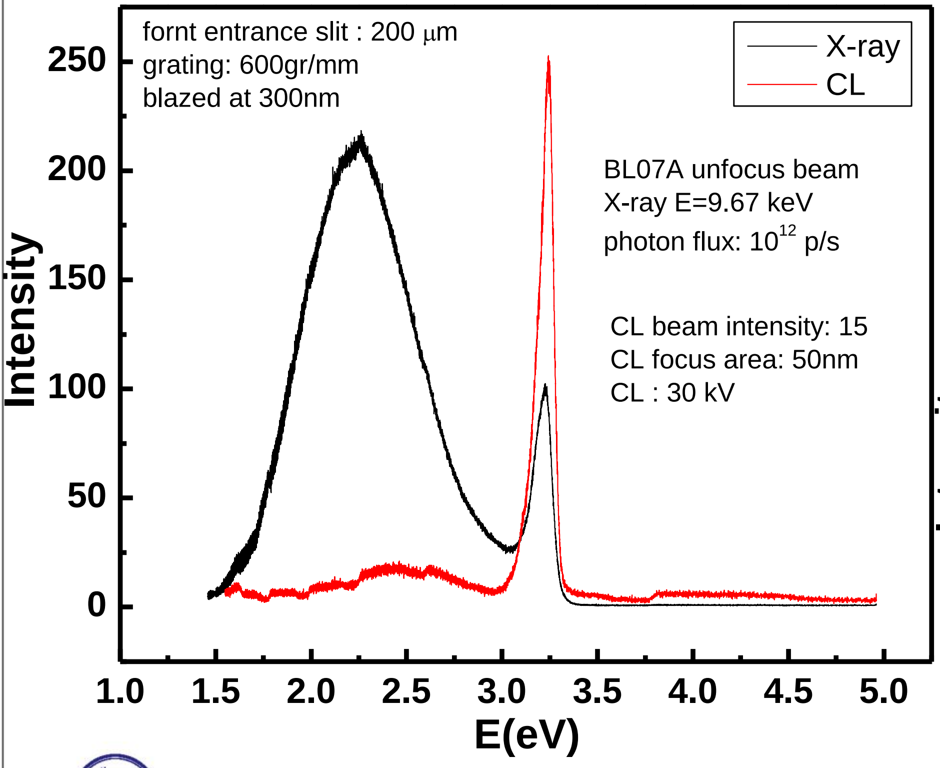
40 µm x 40 µm



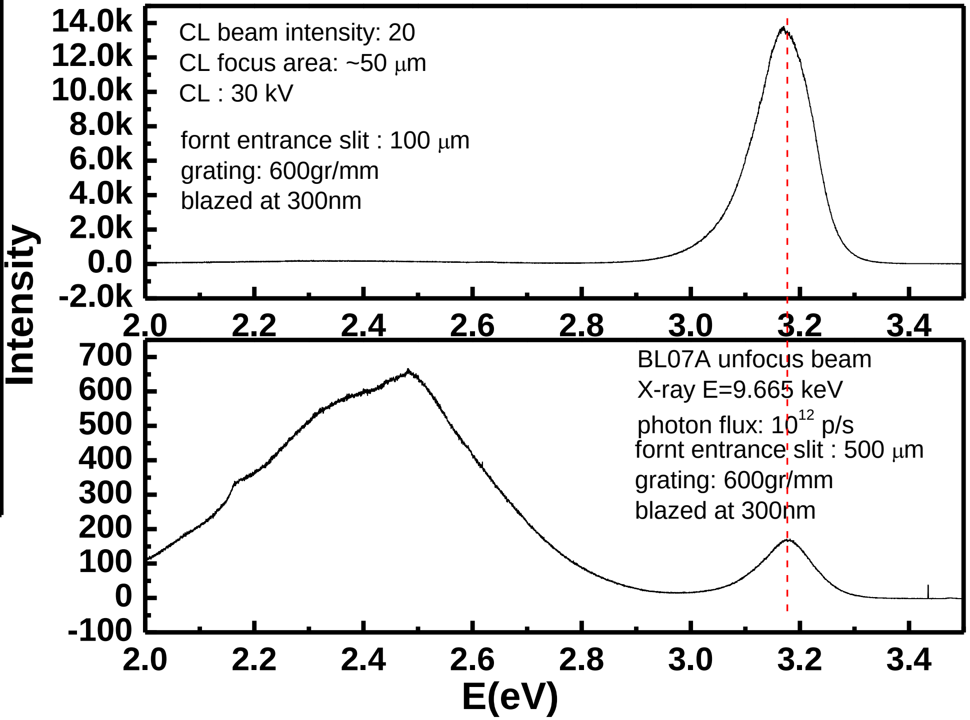


O-polar ZnO wafer



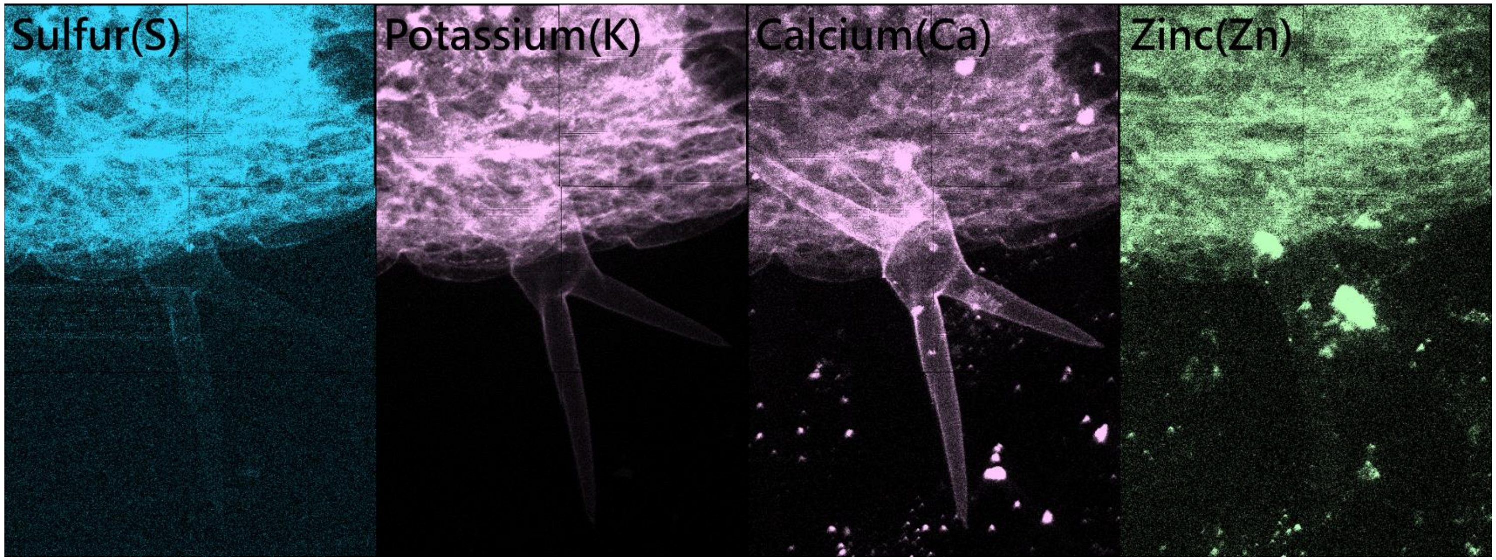


ZnO single microwire

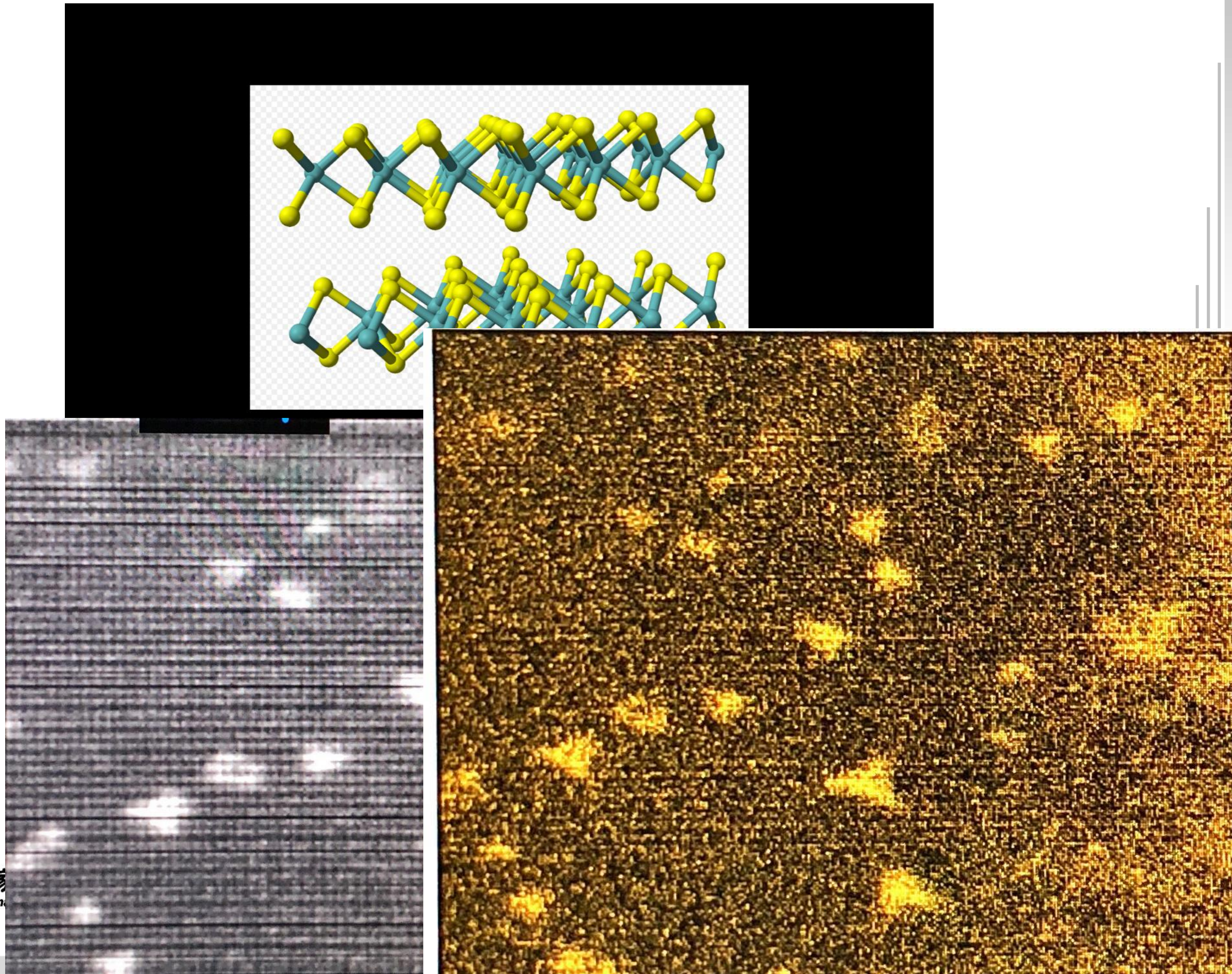


國家同步輻射研究中心
National Synchrotron Radiation Research Center

nano-XRF testing

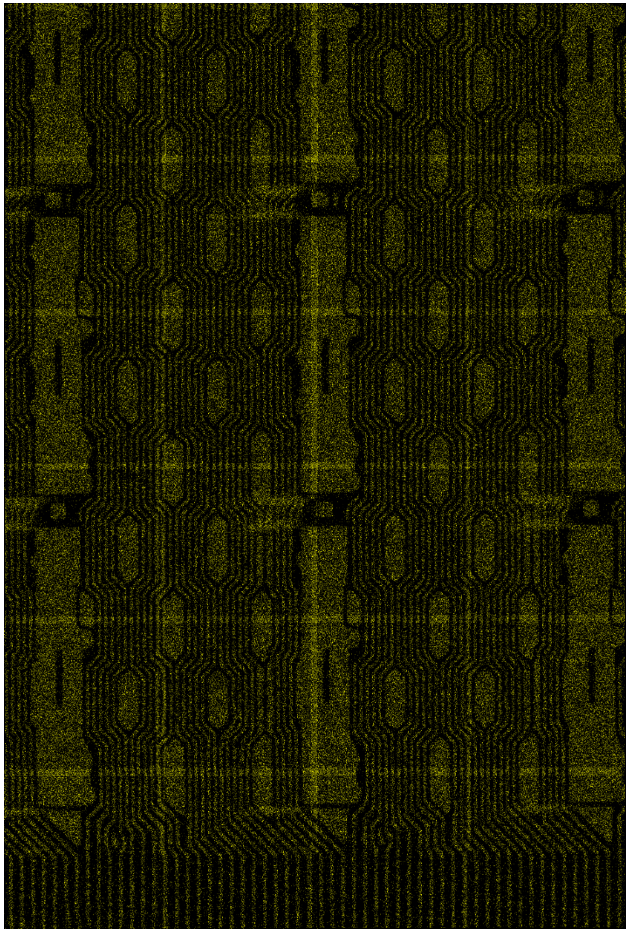


nano-XRF testing

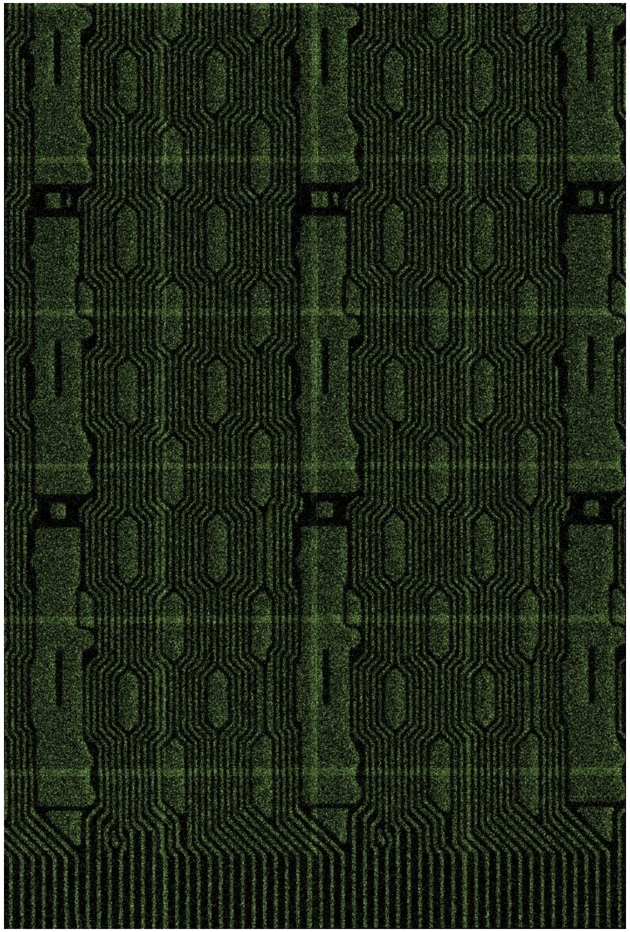


nano-XRF testing

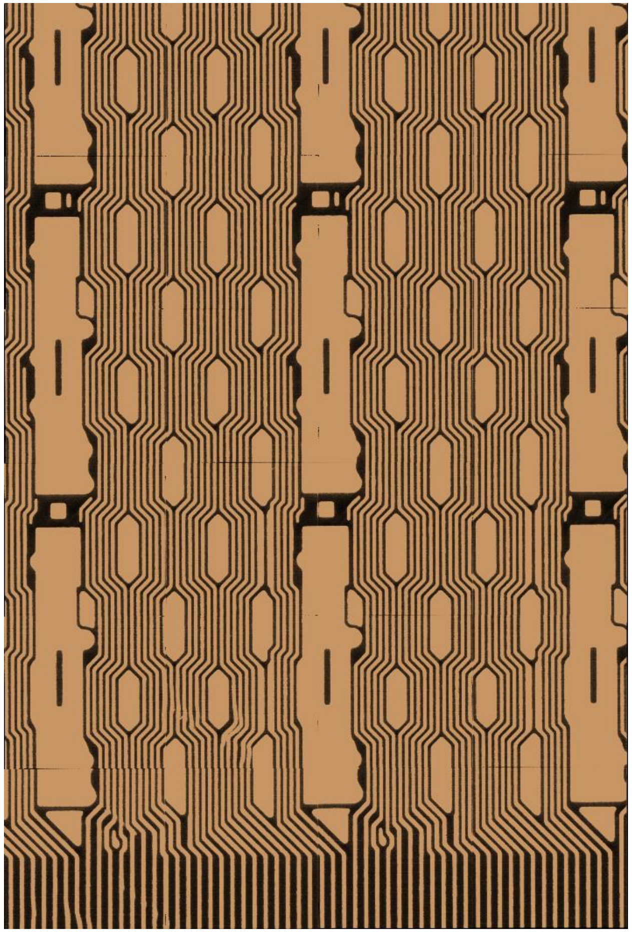
1780eV_Silicon(Si)



4510eV_Titanium (Ti)

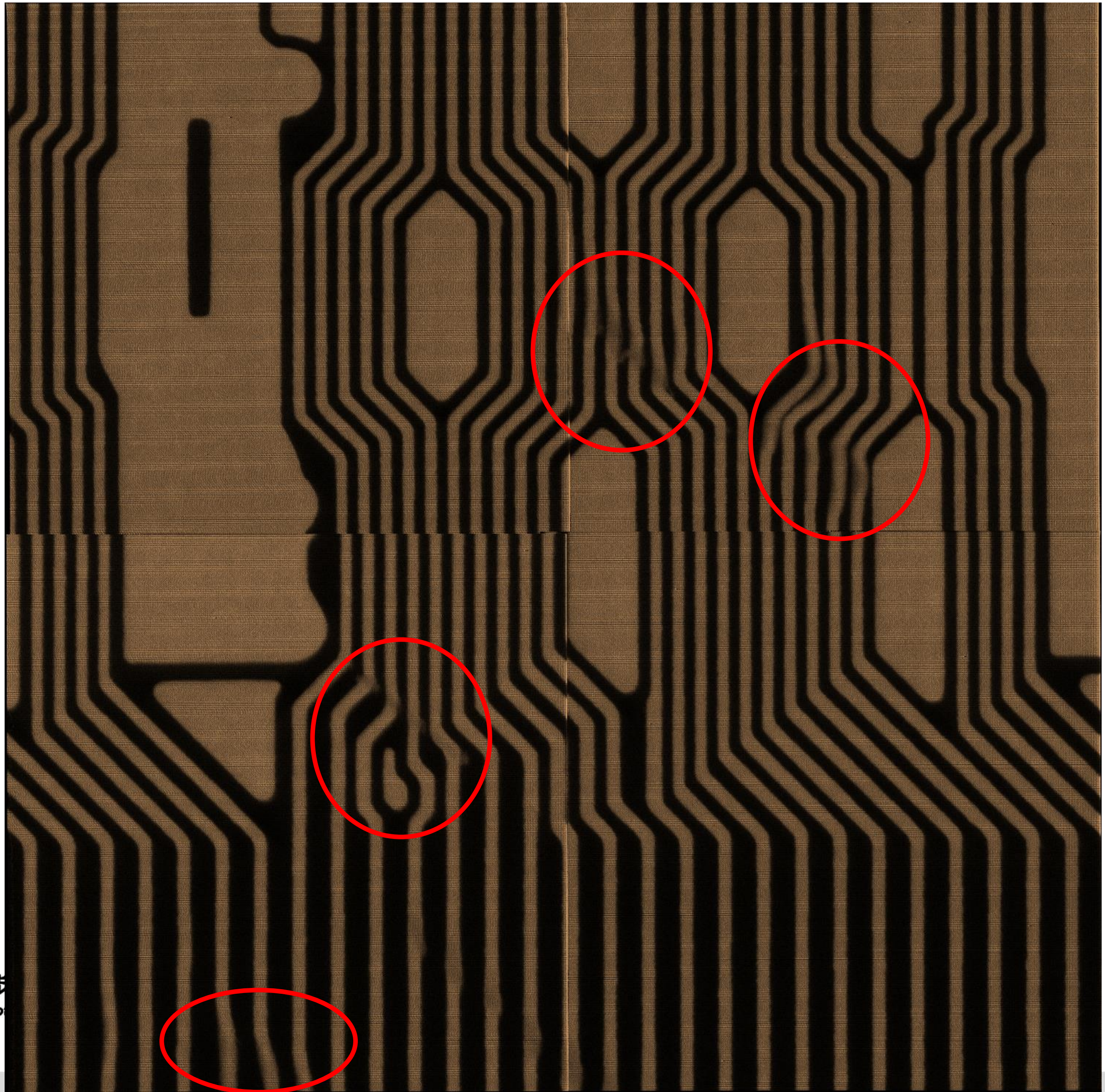


8040eV_Copper (Cu)



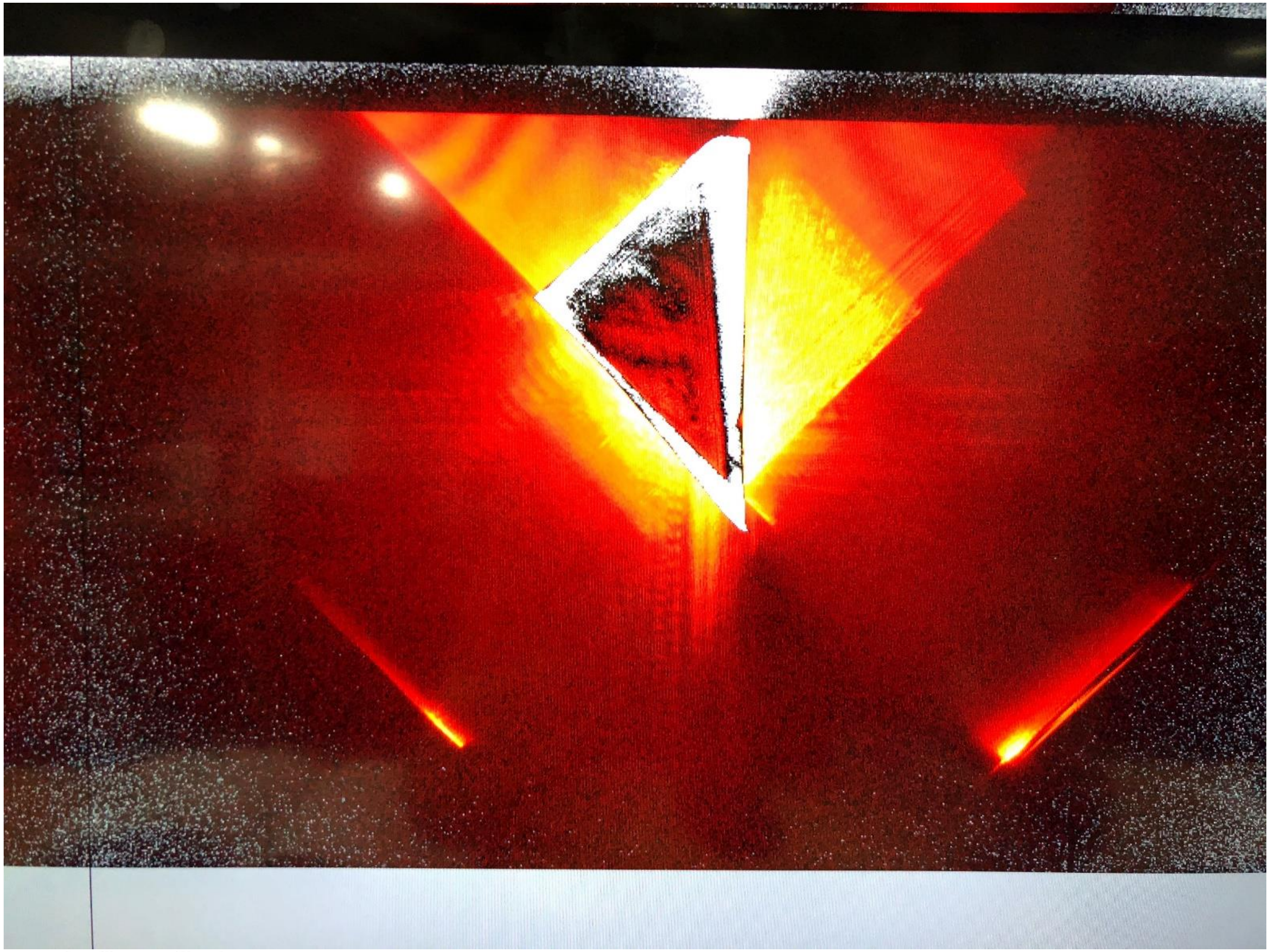
國家同步輻射研究中心
National Synchrotron Radiation Research Center

Defect (Cu)



Ptychograpgy Testing

For strain measurement

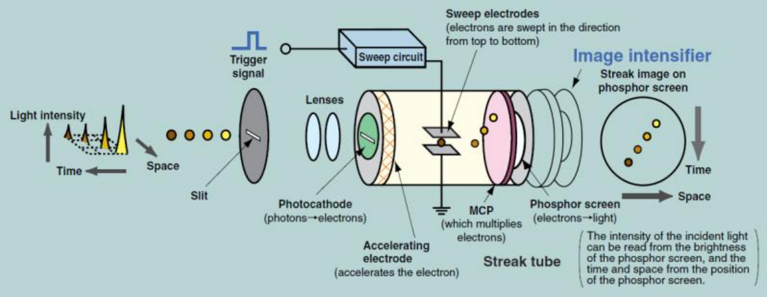


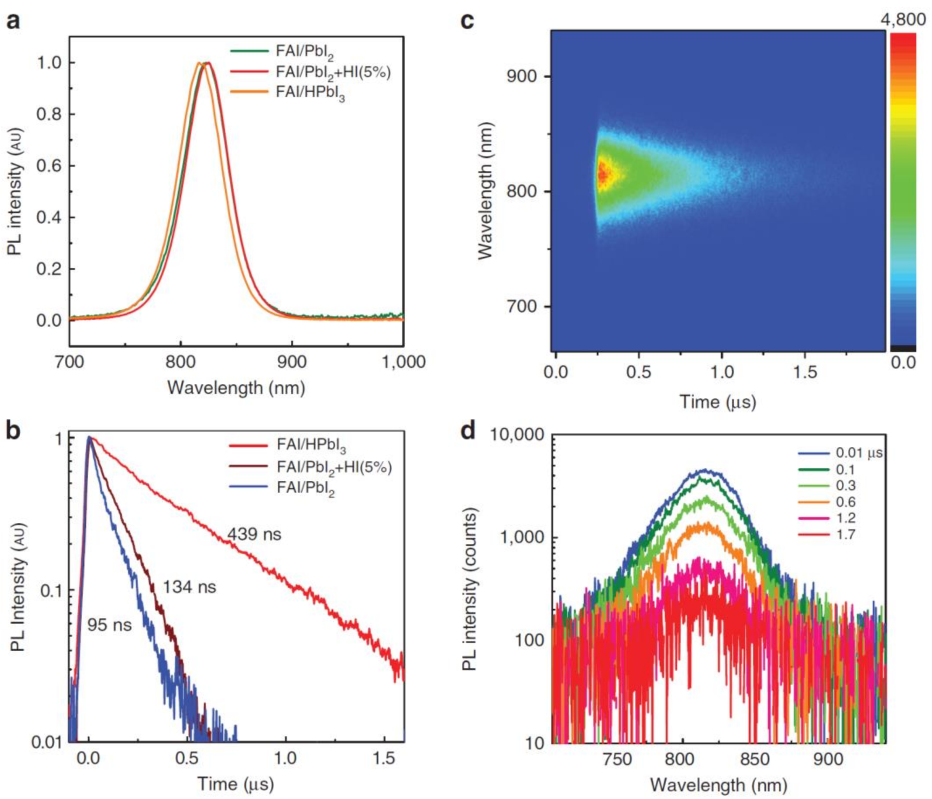
國家同步輻射研究中心
National Synchrotron Radiation Research Center

Time-Resolved X-ray Excited Optical Luminescence (TR-XEOL)

Photoexcitation dynamics in solution-processed formamidinium lead iodide perovskite thin films for solar cell applications

Hong-Hua Fang[1], Feng Wang[2], Sampson Adjokatse[1], Ni Zhao[2], Jacky Even[3] and Maria Antonietta Loi[1]





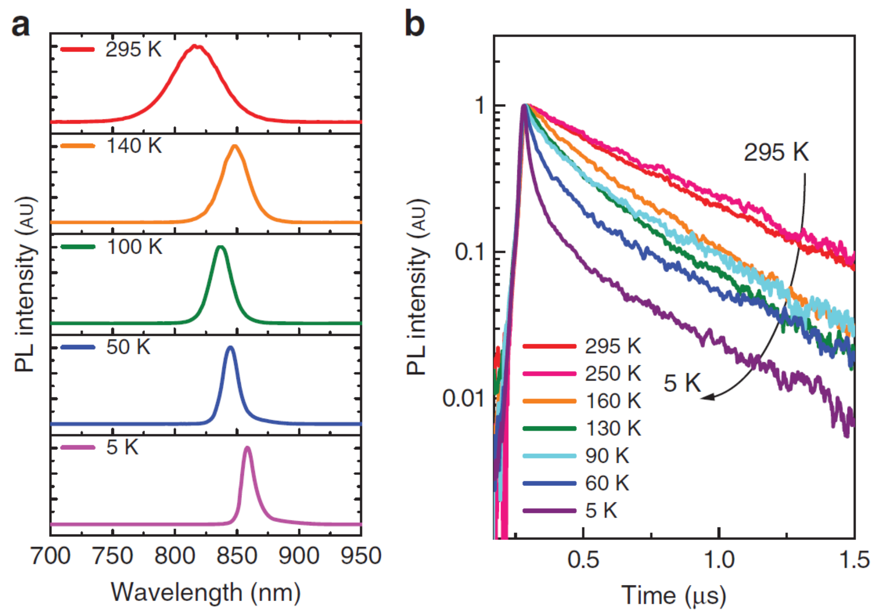


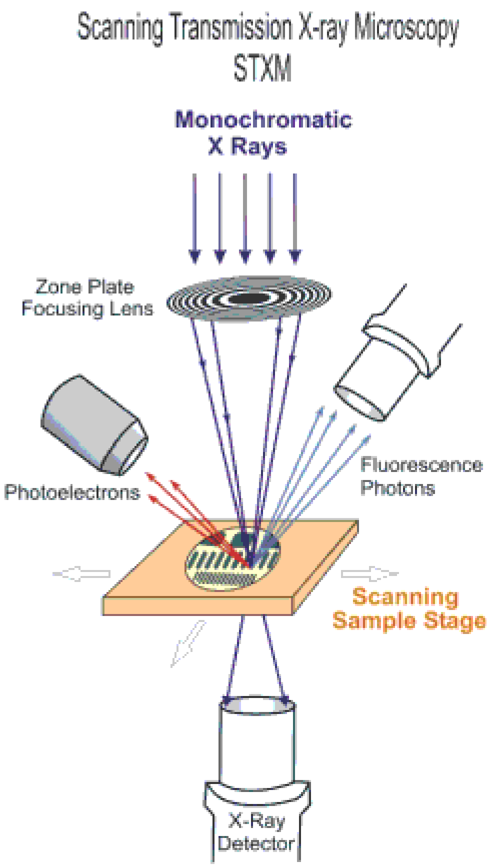
Figure 4 (**a**) PL spectra and (**b**) TRPL decay kinetics after photo-excitation with an excitation power density of 1.4 µJ cm^{-2} at representative temperatures.

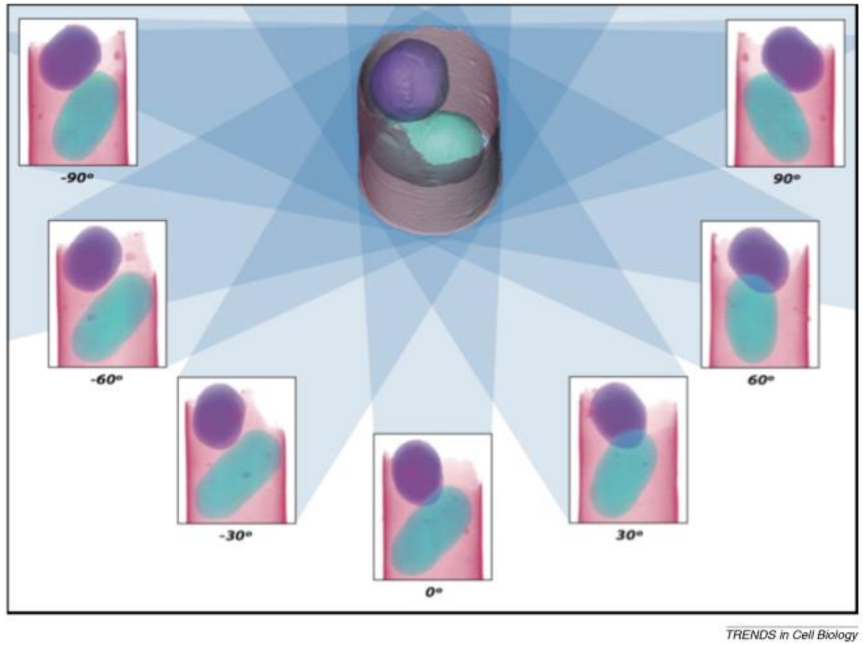
Light: Science & Applications (2016) 5, e16056; doi:10.1038/lsa.2016.56

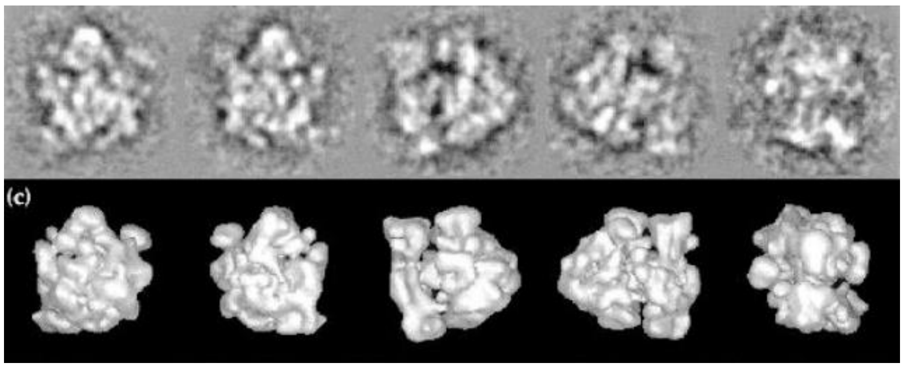
www.nature.com/lsa

nano-PXM (projection x-ray microscopy)

– Absorption and phase contrast x-ray images



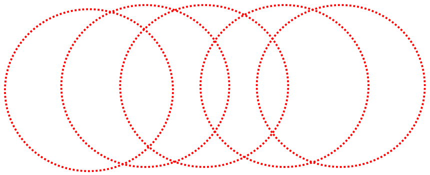




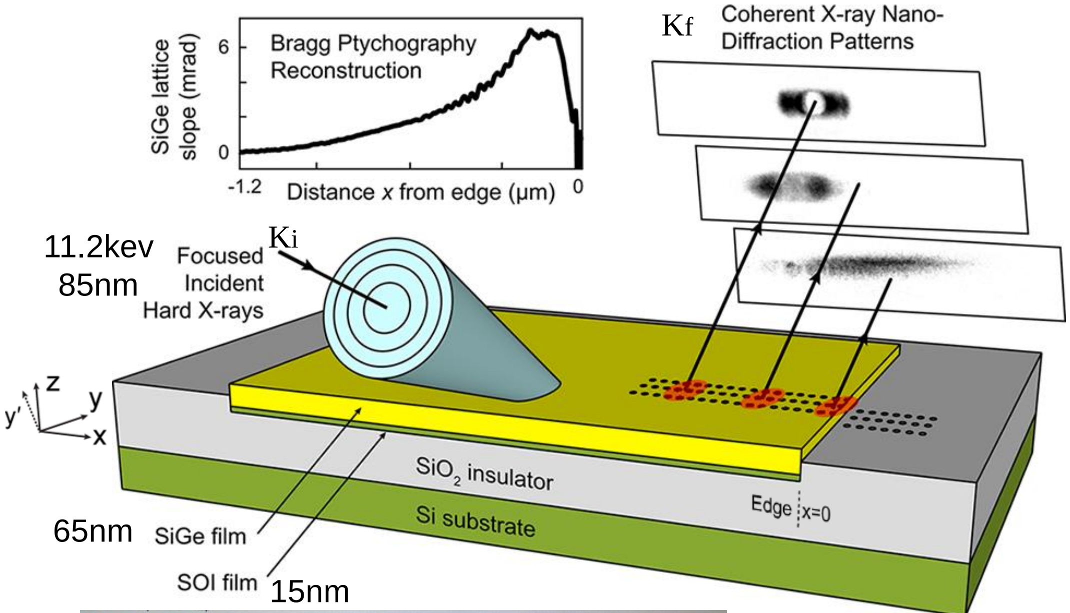
國家同步輻射研究中心
National Synchrotron Radiation Research Center

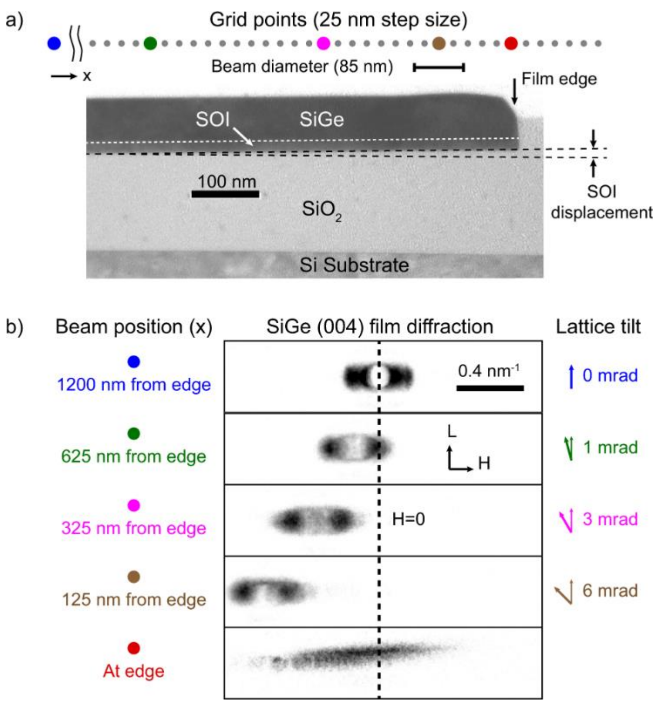
Adv. Mater. **2014**,
DOI: 10.1002/adma.201304345

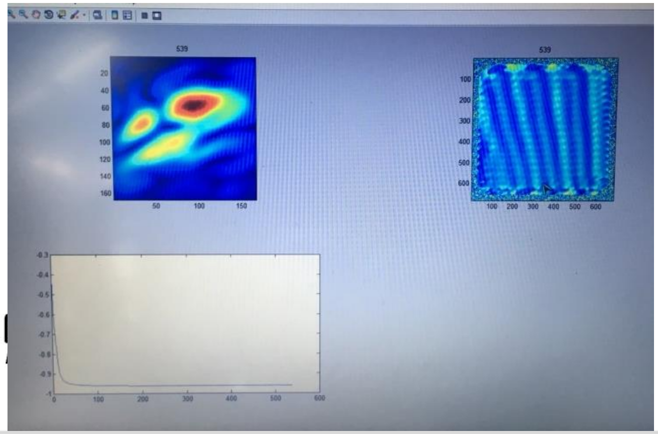
X-ray Bragg projection ptychography from thin film heterostructures



70% spatial overlap





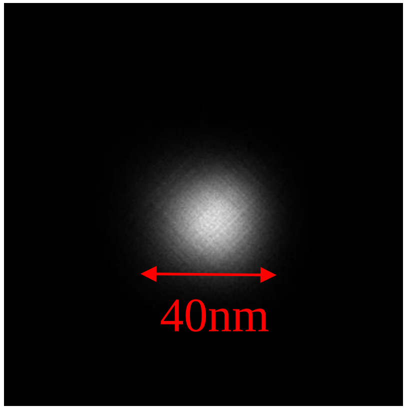


M. V. Holt *et al*, Phys. Rev. Lett. 112, 165502 (2014)

Summary

X-ray methods at 23A of TPS

- nano-XRF (x-ray fluorescence)
  - Element-specific nanoimaging
- nano-XRD (x-ray diffraction)
  - Nano-Crystalline
- 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
- nano-CXDI (coherent x-ray diffraction imaging)
- Bragg-ptychograpgy
  - strain dynamics in nano-devices



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

Applications

Solid state physics

- Strongly correlated electron systems

YbAl3, YbInCu4, YbCu2Si2

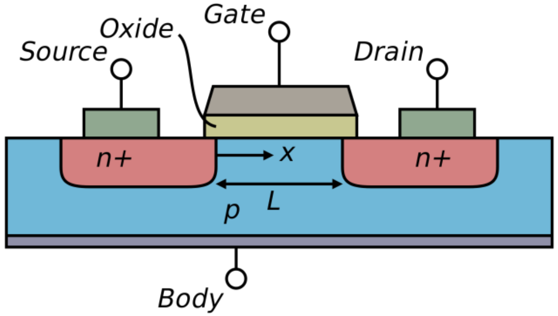
La1-xSrxMnO3 (LSMO)

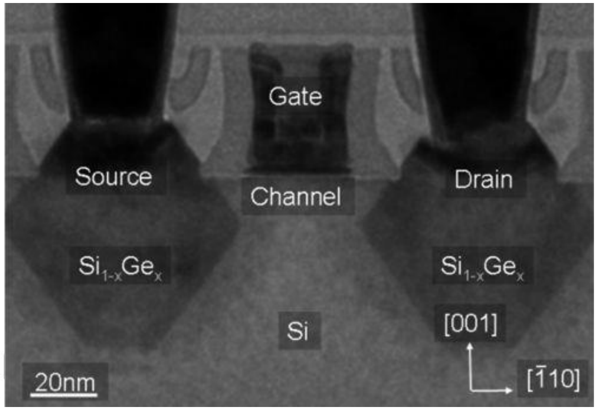
- Spintronics

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

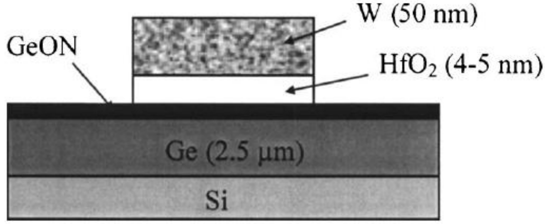
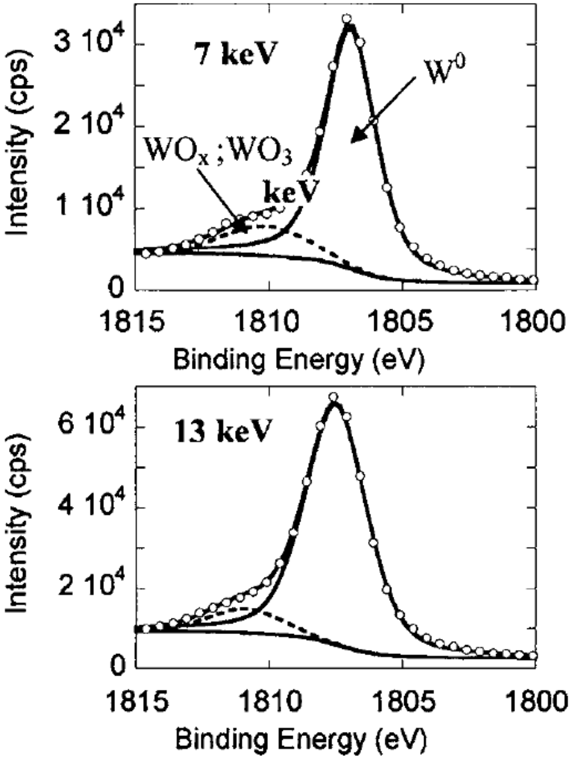


FIG. 1. Diagram of the $W/HfO_2/GeON/Ge$ stack.

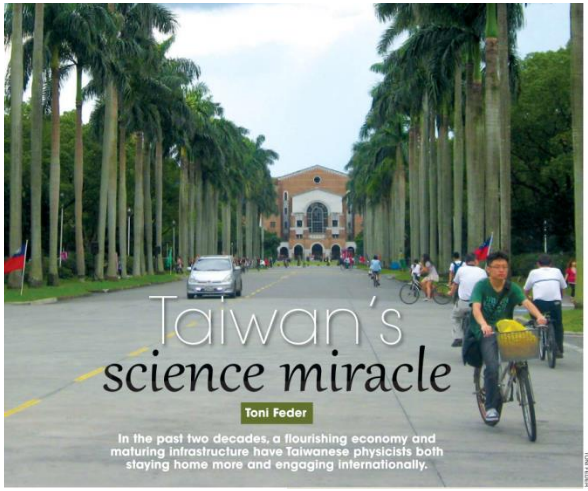


房價

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

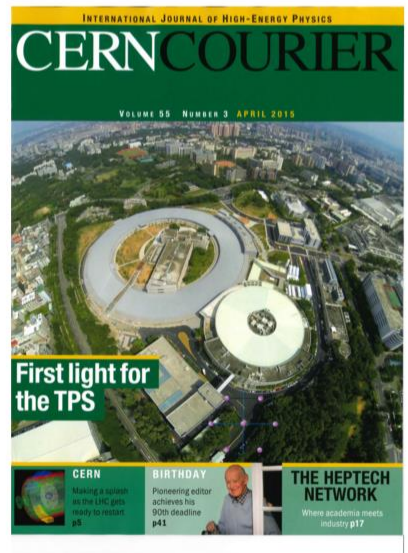
國家同步輻射研究中心
National Synchrotron Radiation Research Center



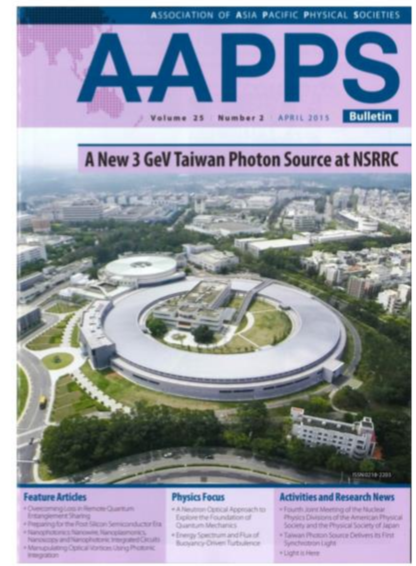
March 2014 Physics Today

「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

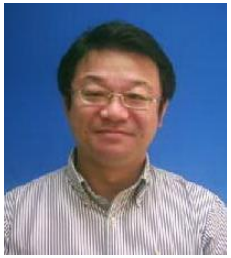
X-ray Nanoprobe Construction Team

Project Leader: Prof. J. Raynien Kwo (NTHU)

Construction Team

Leader

Mau-Tsu Tang



Beamline-

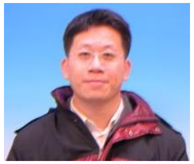
Shih-Hung Chang and Beamline Group

Endstation-

Gung-Chian Yin, optical design and overall system integration.

Bo-Yi Chen, Mechanical engineer.

Chien-Yu Lee, Electronic engineer.



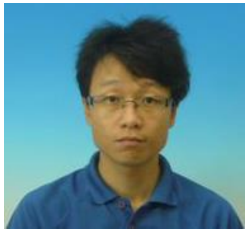
Huang-Yeh Chen, Mechanical design and experiment assistant.

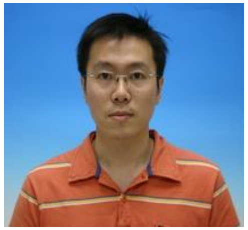
Jian-Xing Wu, Software programmer, GUI and control panel design.

Beamline Scientist and Manager-

Shao-Chin Tseng, Sample preparation, experiment design

Bi-Hsuan Lin, Experiment design, XEOL, XRD.





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


Thanks for your attentions