SR Instrumentation and Beamlines

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Introduction – Fundamentals and Concept

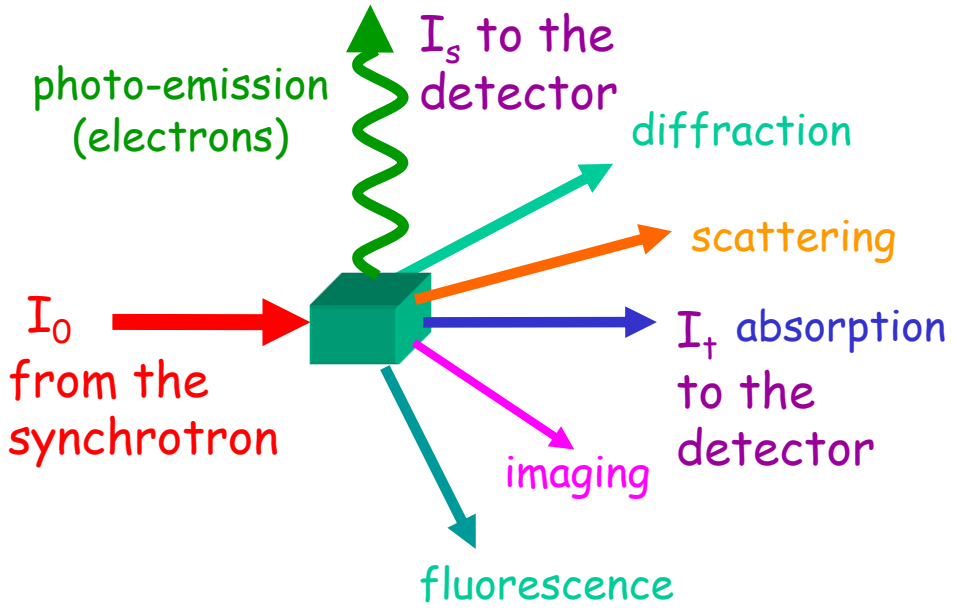
SR Beamline Designs & Instrumentation

- Project timeline, specifications, …
- Main Components - photon sources, optics and end-station(s)
- Detectors and sample environments

Summary

Fundamentals and Concept of SR Beamlines

There are a number of natural processes when light beams interact with materials.



The interactions can tell us about the material details, such as:

- Atomic arrangements
- Electronic structures
- Magnetic and thermal properties
- Chemical characteristics and behaviour
- Others (mechanical, kinetics, etc)

Exploiting the interaction processes SR Instruments or **beamlines** can be bu to study properties and behaviour of materials.

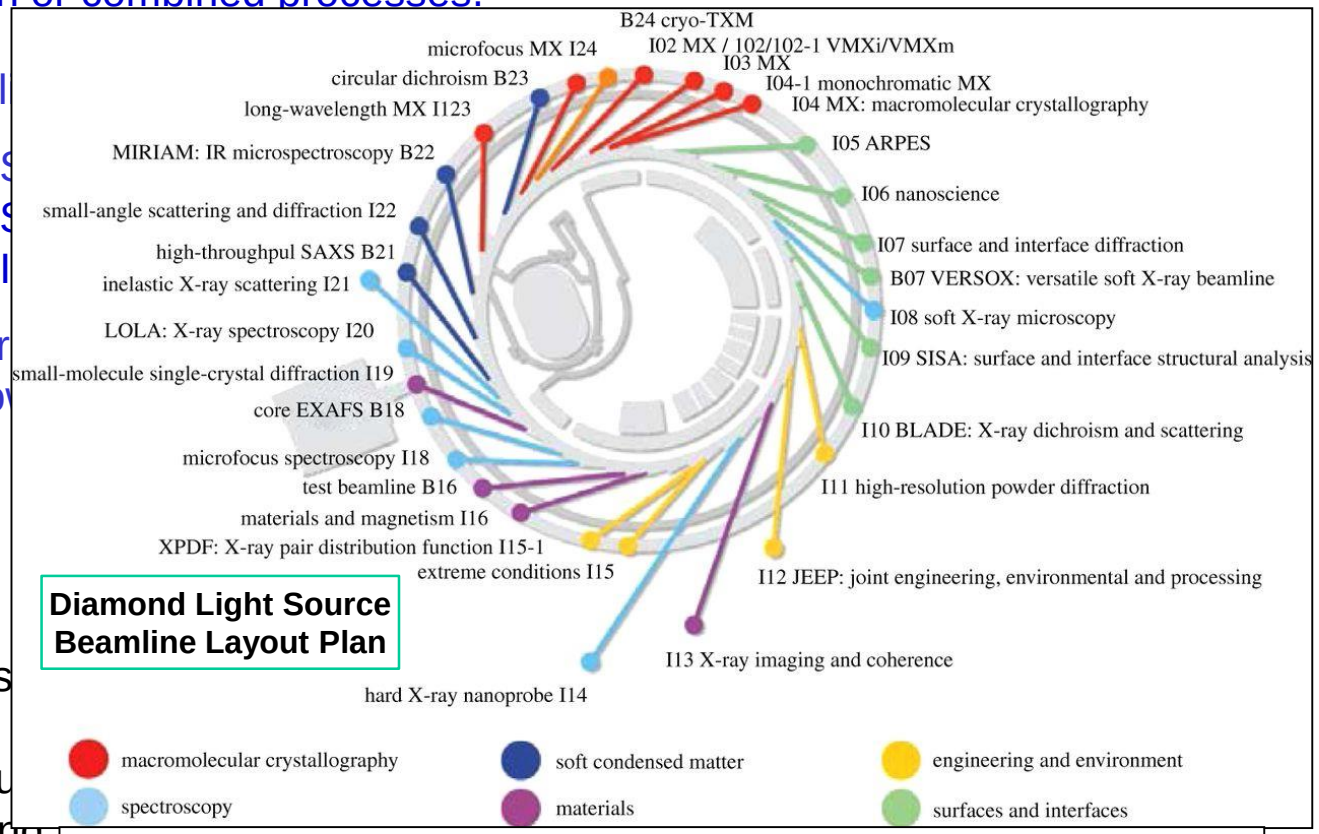
Beamlines of Different Techniques

- The physics (or basic mechanisms) of interaction processes between light and matter are different.
- It is technically not possible or too “compromised” to build one beamline to exploit all the processes.
- Therefore, a suite of beamlines are build in a modern SR facility to exploit each or combined processes.

Beaml

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BLs ar
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Typical beamline layout of a modern SR facility to provide a range of techniques & BLs are cohort by techniques or science disciplines.

Beamlines – concept of project, specifications, layout and design features.

Synchrotron Beamlines are powerful instruments for materials research – New Discoveries and Advancements.

Beamline Project Schedule & Timeline

Beamlines are purposely designed and constructed to control and harnessed the powerful SR light, so these are used to study a vast array of materials.

When building a new beamline, it is therefore important to consider the followings:

- It is a large project requiring considerable resources (capital and manpower).
- Assembly of project team (scientists, design engineers, technicians and others).
- The delivered (when built) is within specifications, time and budget.

Key specifications for μ-focussing XAS beamline

Spatial resolution	2 x 2 μm
Energy range (keV)	2.05 - 20.5
Core energy range (keV)	5 - 15
Energy resolution (Δ E/E)	Si 111: 1.4 x 10^{-4}
Energy stability (eV)	+/- 0.05 per day
Full beam size Flux @ 10 keV at sample (ph/s)	2 x 10^{12}
Beam size at sample (μm) at full flux	7 (H) x 1.8 (V)
Minimum beam size at sample (μm)	2 (H) x 1.8 (V)
Beam divergence at sample (mrad) (FWHM)	3 (H) x 2 (V)
Beam position stability at sample	<1 μm per day

BL project conception

Proposal for the construction of beamline by a user community (research and SR scientists), e.g. a new beamline for Structural and Chemical Analysis (SCA)

Principal techniques

X-ray powder diffraction (XPD):
- High resolution and time-resolved angular dispersive

Absorption spectroscopy:
- XAS, XANES (NEXAFS) and EXAFS

Key Specifications and Requirements	
Photon Source	Undulator (parameters and performance to be specified)
Energy Range (keV)	1.5 - 30
Energy resolution (ΔE/E) at 20 keV	10^{-4}
Energy stability (eV) (or DCM Δθ)	±0.05 (or ±0.25 mdeg) for ms - 24 hr
Beam size at sample (μm)	Min: 2 (v) x 5 (h) Max: 500 (v) x 1000 (h)
Beam divergence at 10 keV (μrad)	20 (v) x 60 (h) or less
Full flux density at sample at 300 mA	10^{13} -10^{14} ph/s/mm^2/0.1%bw at 20 keV
Beam position stability at sample (μm)	1 or less for 24 hr

Specifications of Detectors

X-ray Powder Diffraction
(i) Linear curved PSD
Resolution (Δ2θ) = 0.004°
igh Z sensor (CdTe), 90° aperture
Frame rate = 100 kHz (μs/pattern)
Min and max frames = 1 - 100000
2θ range adjustment: up to 120°
(ii) Area detector (high Z sensor)
Active area = 450x450 mm)
Pixel size = 100x100 μm (or less)
Frame rate = 1 kHz
Min and max frames = 1 – 100000
Sample to detector distance (mm): 100 – 4000

X-ray Absorption
Ion chambers, multi-element Si (low energies) and Ge (high energies) fluorescence detectors with fast DCM mechanic and electronics.
Data acquisition speed: minutes-sec/spectrum (standard) - ms/spectrum (QXAFS)

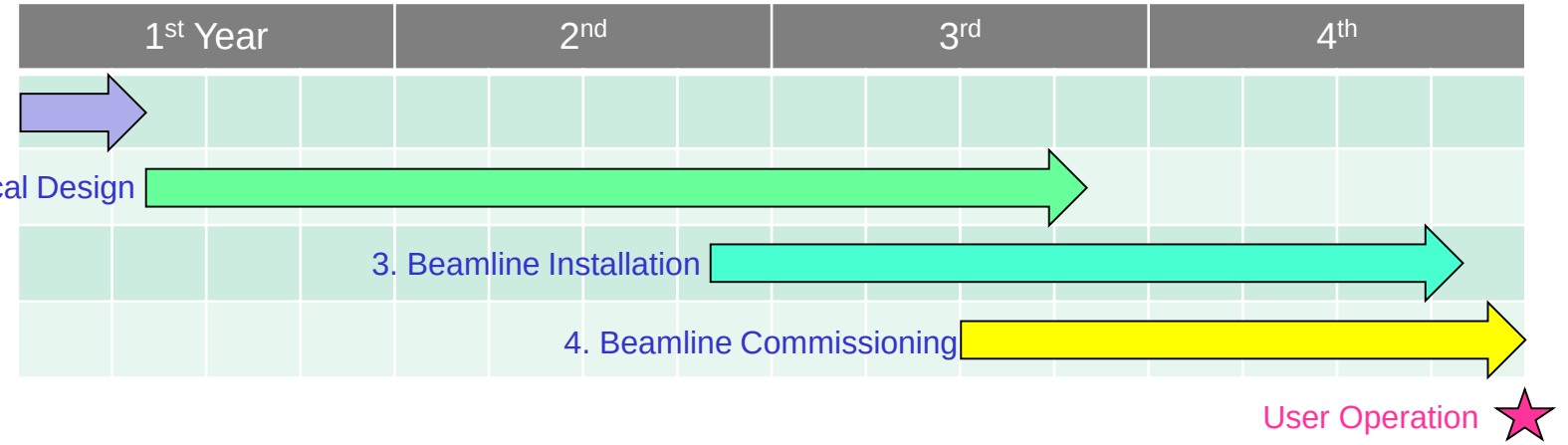
Beamline Project Schedule & Timeline

Proposal & Reviewing Phase

Scientific Committee Reviews & Approval

Workshop(s) to discuss proposed beamline: objectives, main techniques, specifications and documentations, etc

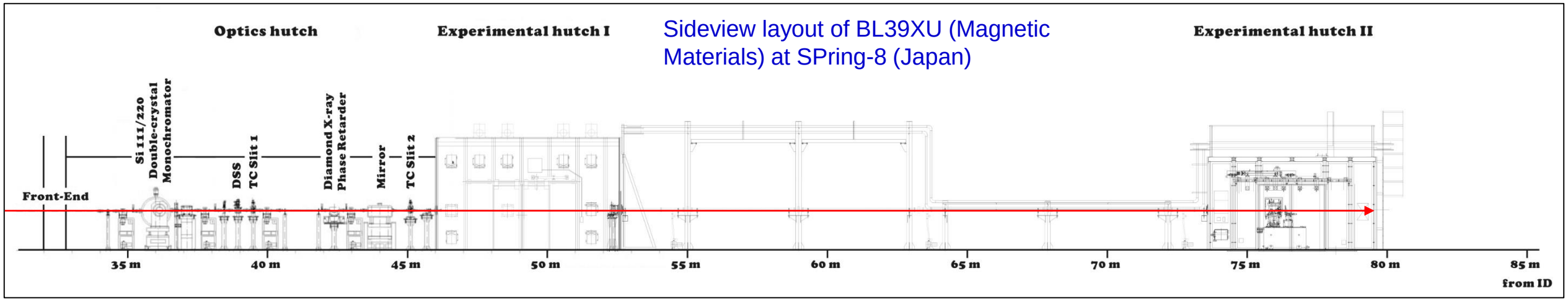
Constructional Timeline and Phases



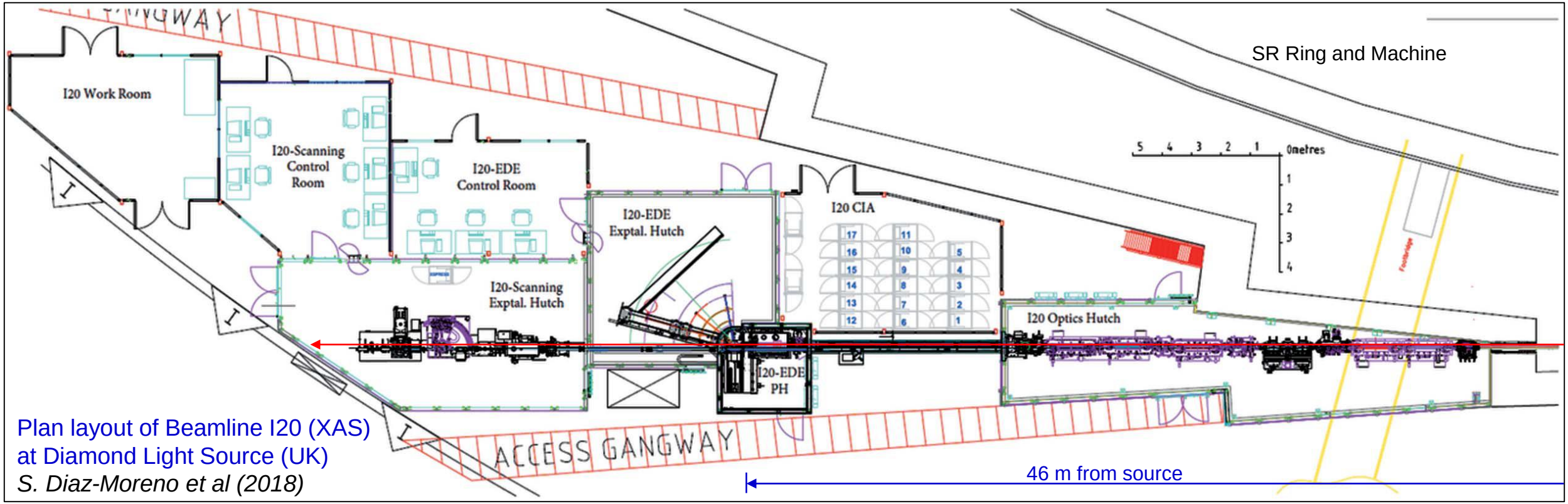
Phase/Stage		Period (months)	Duration (months)
1. Conceptual & Spec		0 – 4	4
2. Technical Design	Detailed design	5 - 10	6
	Spec & Procurements	11 - 34	24
3. BL Installation		22 - 45	24
4. BL Commissioning	Without Beam	30 - 41	12
	With Beam	42 – 47	6
5. User Operation		48 -	-

Beamline Project Milestones:

- Beamline project started
- Conceptual design review (CDR)
- Technical design review (TDR)
- 1st tender/procurement of BL components
- X-ray hutch installation
- Optics/end-station equip on BL
- Detectors and BL ready to take beam
- 1st light in hutches
- BL commissioning start
- 1st user expt.

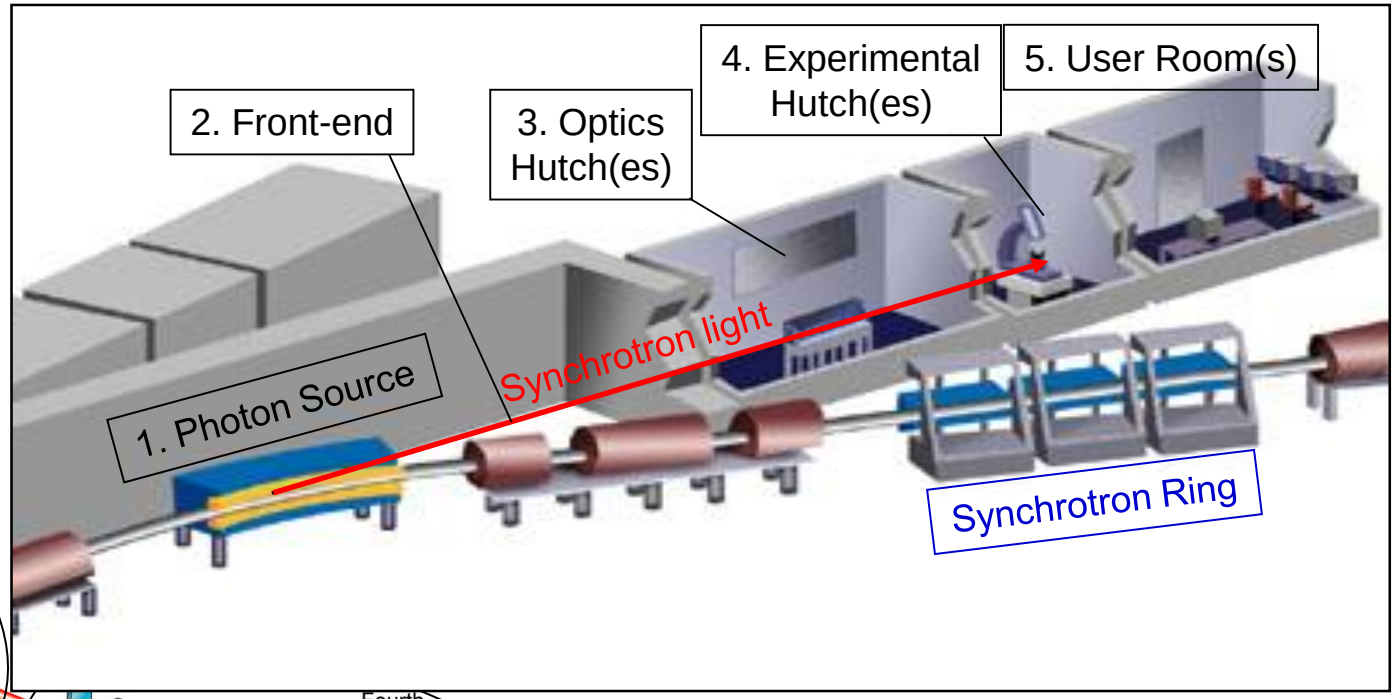


Sideview layout of BL39XU (Magnetic Materials) at SPring-8 (Japan)



Plan layout of Beamline I20 (XAS) at Diamond Light Source (UK)
S. Diaz-Moreno et al (2018)

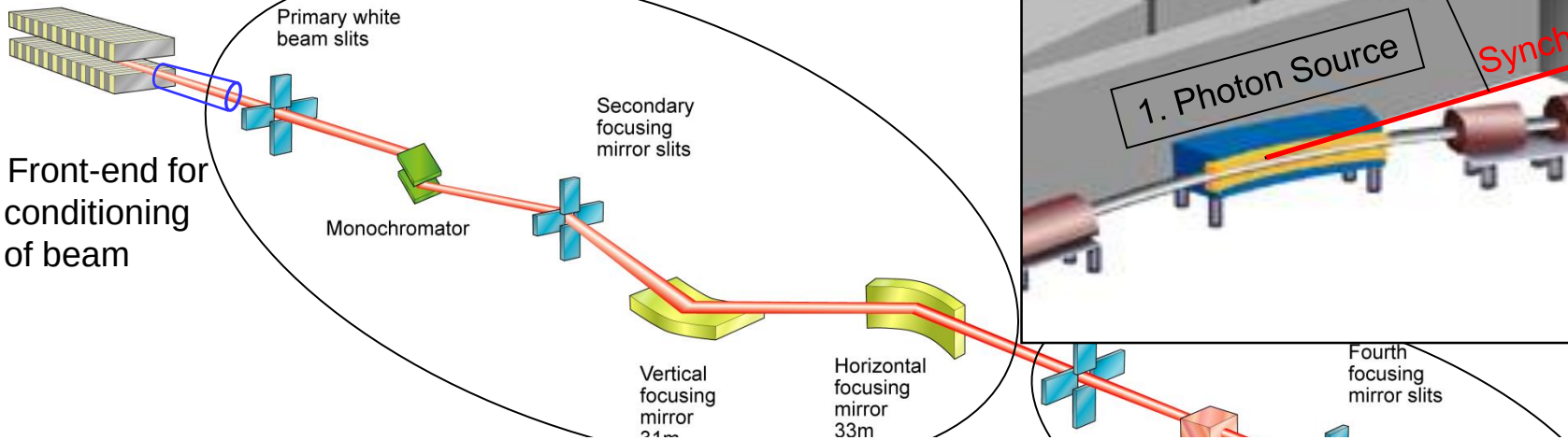
A typical X-ray Beamline Design and Layout

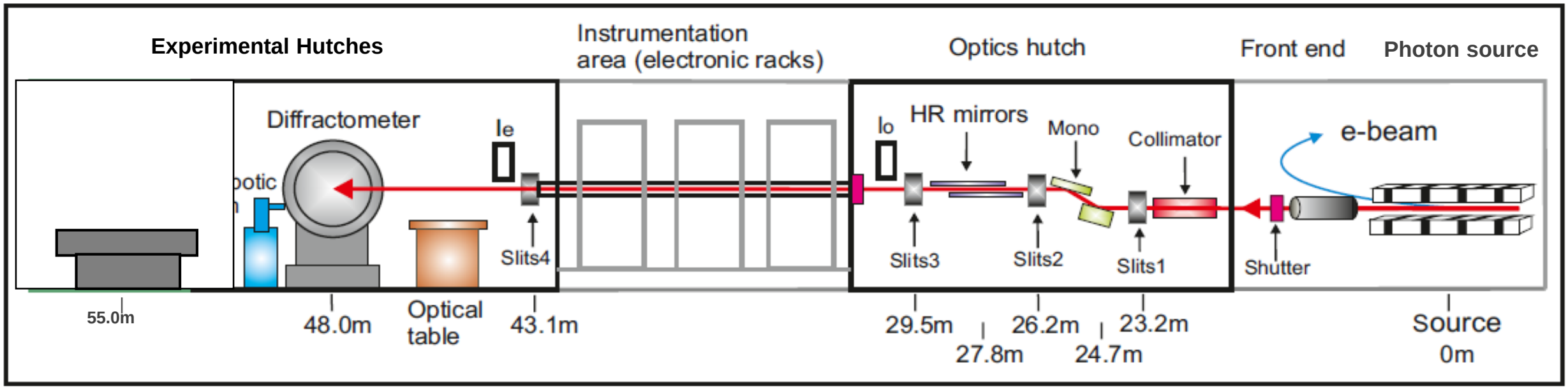


1. Photon source for SR beam production

2. Front-end for conditioning of beam

3. Optics for optimisation of beam



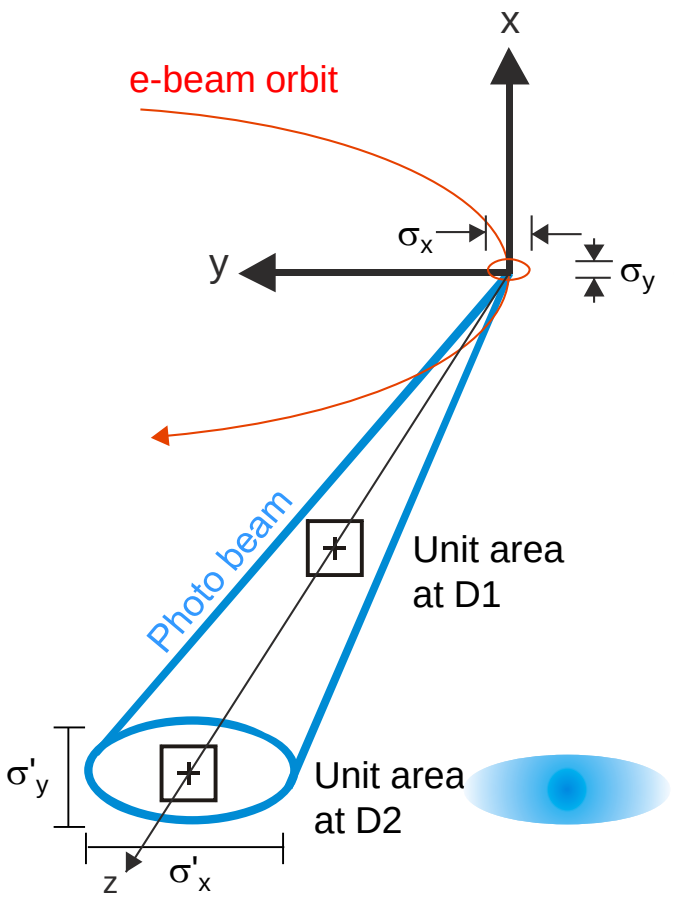


Beamline Main Components

- Photon Sources – production of SR radiation
- Front-end
- Radiation Hutches
- Optical elements
- End-station: instruments for user experiments and accessories.

Emittance

Electrons in the storage ring move in an equilibrium orbit with some amount of fluctuation in space and angle.



The cross section of SR beam can be represented by σ_x (horizontal) and σ_y (vertical); the size distribution of e-beam in x-y plane.

Then the angular distribution (photon beam) can be represented by σ'_x and σ'_y.

Therefore the **emittance** is defined as

$\varepsilon_x = \sigma_x \sigma'_x$ (horizontal emittance)

$\varepsilon_y = \sigma_y \sigma'_y$ (vertical emittance)

Photon Output: Flux, Brightness and Brilliance

Flux (or Flux density) is the number of photons emitted per unit time per unit bandwidth (per unit area) per specified e-current (1, 100, or 200 mA)

$$\frac{d^3N}{dt\, d\lambda\, dA} = \text{photons/s/mm}^2\text{/0.1\%/mA}$$

where dA the photon beam size and $d\lambda$ is 0.1% (universally used). Sometime $d\lambda$=0.01% is used for Si(111) monochromator crystal.

But flux at D1 > D2 (D1 is nearer to the source than D2) due to the spreading of the beam caused by the finite emittance of e-beam. Therefore we must consider the Brightness.

Brightness is the flux per unit solid angle

$$\frac{d^3N}{dt\, d\lambda\, d\Omega\, d\sigma} = \text{photons/s/mrad}^2\text{/0.1\%/mA}$$

Brilliance is the Brightness divided by the size of radiation source (σ) or the electron beam size

$$\frac{d^3N}{dt\, d\lambda\, d\Omega\, d\sigma} = \text{photons/s/mrad}^2\text{/mm}^2\text{/0.1\%/mA}$$

Wave-particle duality

de Broglie equation: $E = h\,\nu$

E = total energy of a particle
h = Planck constant (=6.626068×10^{-34} m^2 kg/s)
ν = frequency of wave (=speed/wavelength λ)

For photons (Infra-red, UV, x-rays, etc.): $E = h\,c/\lambda$

c = speed of light (=2.9979… x10^8 m/s)

In practical units,

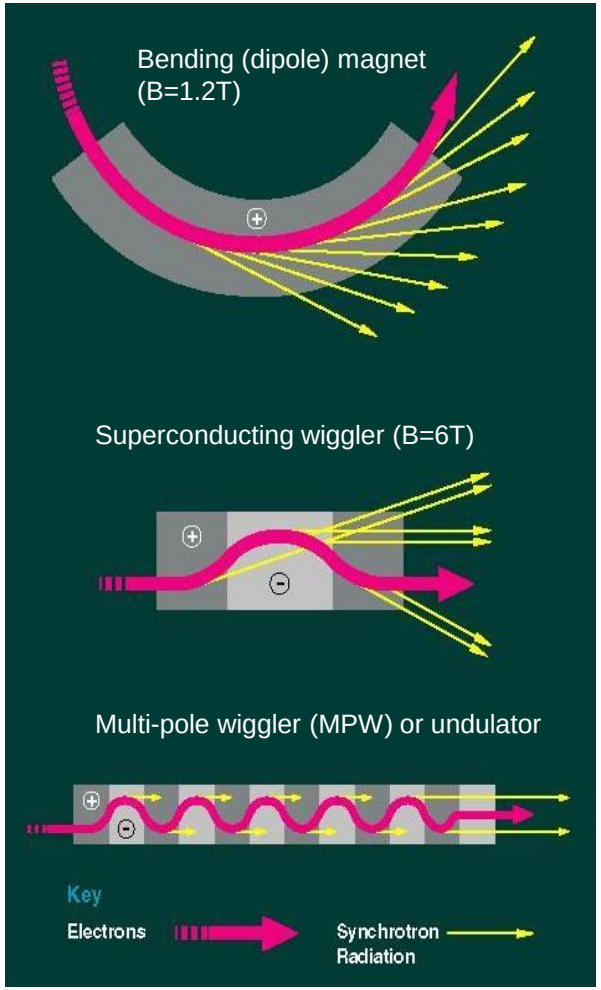
E (keV) = 12.3984/λ (Å) or E (keV) ≈ 12.4/λ (Å)

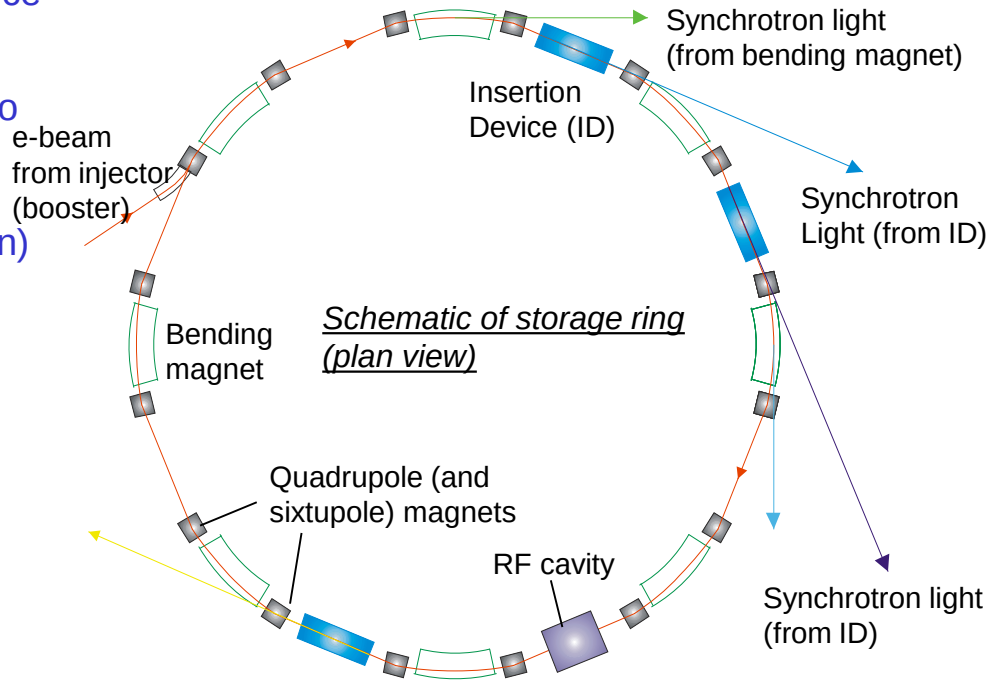
e.g. λ=1 Å → E ≈ 12.4 keV

1 eV = 1.60217646×10^{-19} J, 1 Å = 10^{-10} m

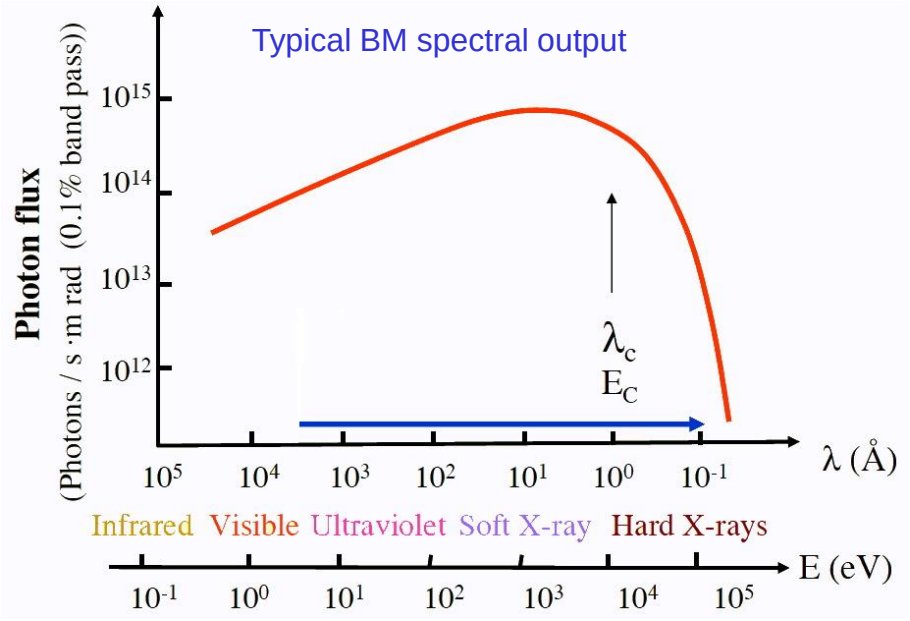
There are a number of ways to produce photons in a SR machine.

Basically, one can broadly divided into three groups:
(1) Bending magnet (intrinsic)
(2) Superconducting wiggler (insertion)
(3) Undulator (insertion)



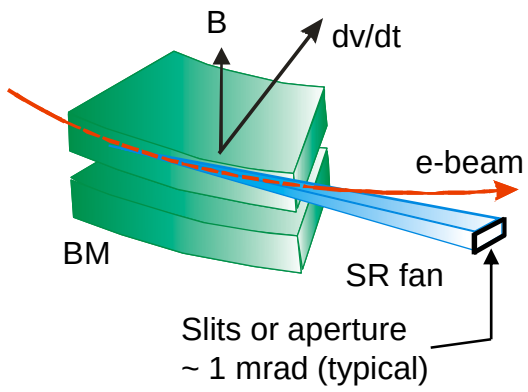


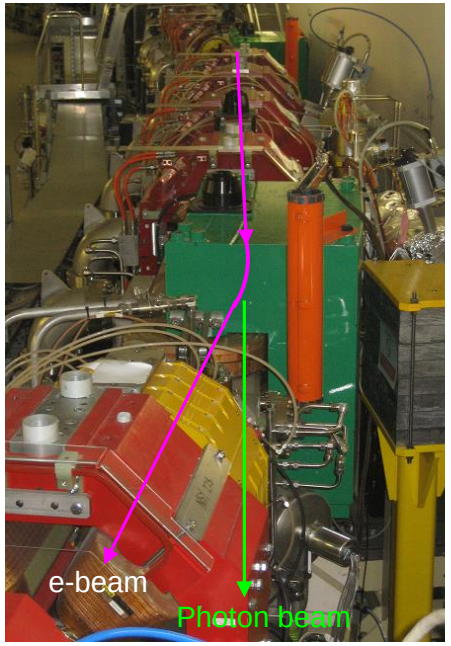
The Characteristics of SR from Bending Magnet

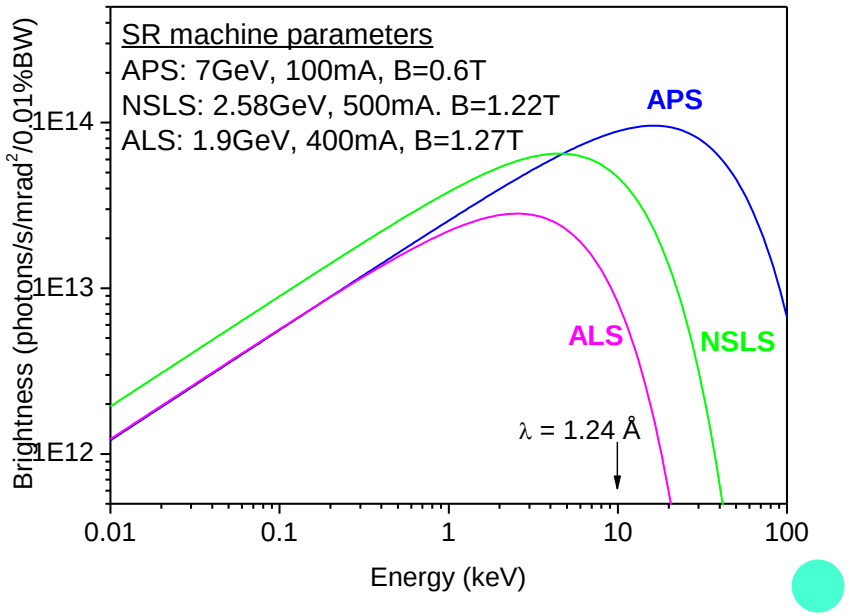


Bending Magnets (BM) – Intrinsic Source

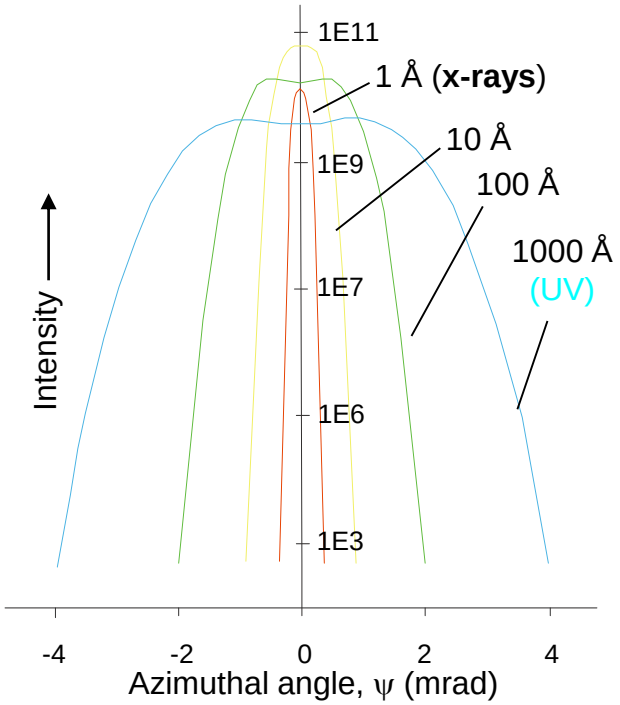
Synchrotron light can be "tapped" straight from BM

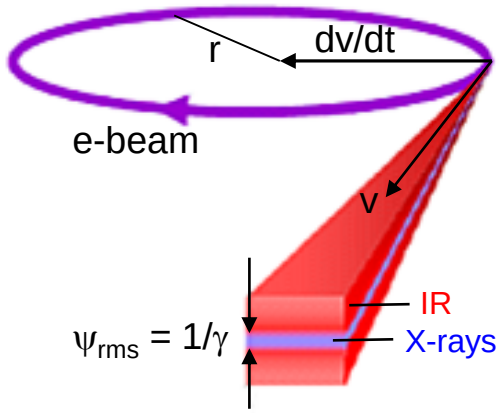






SR angular distribution or spread ($\Delta\psi$) from orbital plane is dependent on the wavelength:



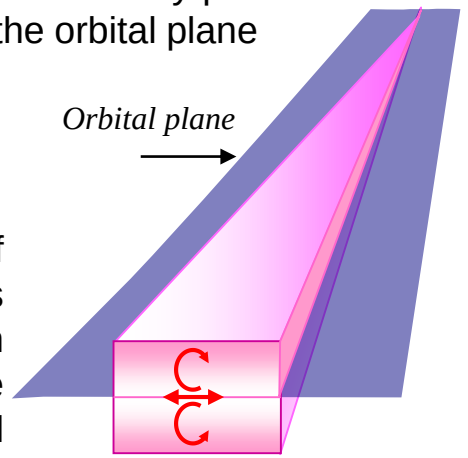


Radiation distribution (schematic)

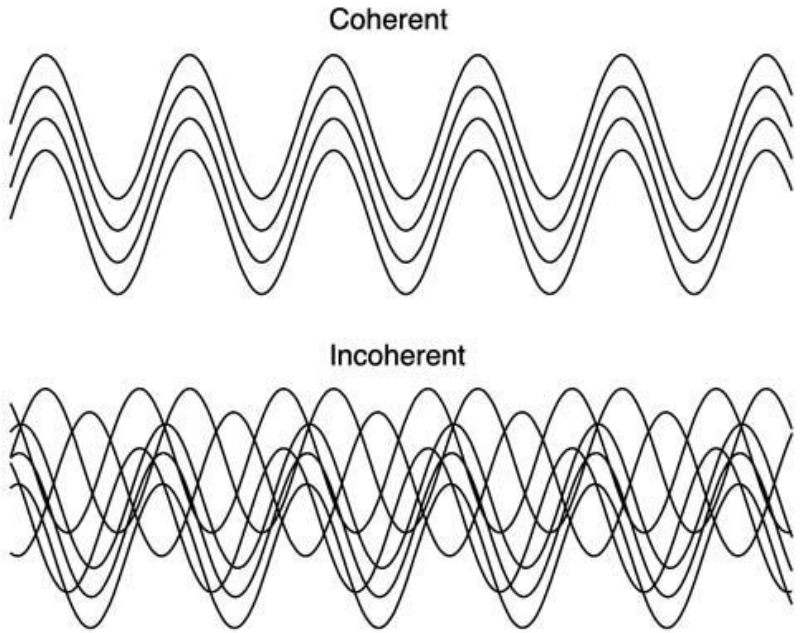
Polarisation of SR

The on-axis synchrotron light is linearly polarized in the orbital plane





Synchrotron light out of the orbital plane has circular components with opposite helicities above and below the horizontal plane.



Coherence length is the prorogation distance from a coherent source to a point where an EM wave maintains a specified degree of coherence. The significance is that interference will be strong within a coherence length of the source, but not beyond it.

Temporal (longitudinal) coherence is a measure of the correlation between the phases of a light wave at different points along the direction of propagation. It tells us how monochromatic a source is.

Longitudinal coherent length, $L_c = \lambda^2/\Delta\lambda$;

Transverse or **spatial** coherent length, L_t

$$L_t = \lambda\, D/\sigma$$

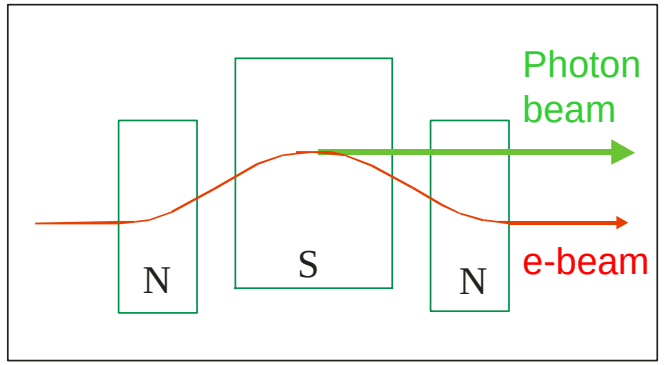
D = source to sample distance, σ = source size

L_t should be bigger than the sample dimensions.

Insertion Devices (ID)

Wiggler or Wavelength shifter

The simplest ID is “wavelength shifter (WS)” or “wiggler”, i.e. with dipole magnets arranged as shown:



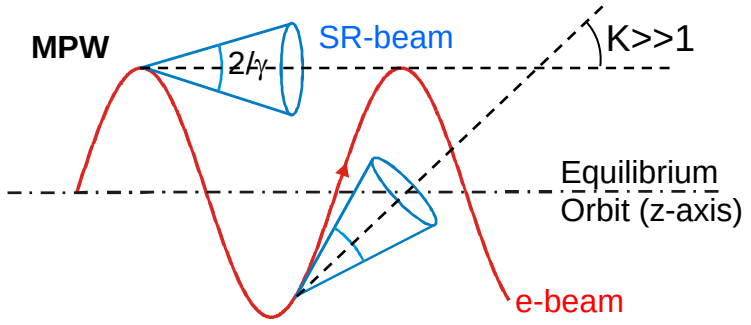
The e-beam receives a “kick” from the high field magnet (superconducting, B ~ 5-6 T). But there is no net displacement of the e-beam. SR emits from the magnet.

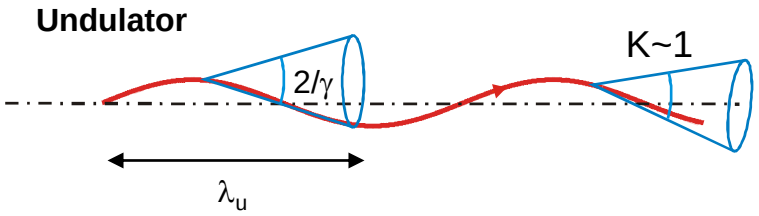
These devices are used to generate hard x-ray in medium energy sources, e.g. E=2.5 GeV, wiggler B-field= 6 T, then λ_c=0.6 Å and compared with the normal BM, λ_c=3.1 Å.

Recently, wigglers are less popular and replaced by multi-pole (MPW) of strong or superconducting magnets (B ≥ 3 T).

Multi-pole wiggler (MPW) and **undulators** have array(s) of dipole magnets or magnetic lattices.

The e-beam is “wiggled or undulated” as it is passing through the B-lattice following a sinusoidal trajectory.





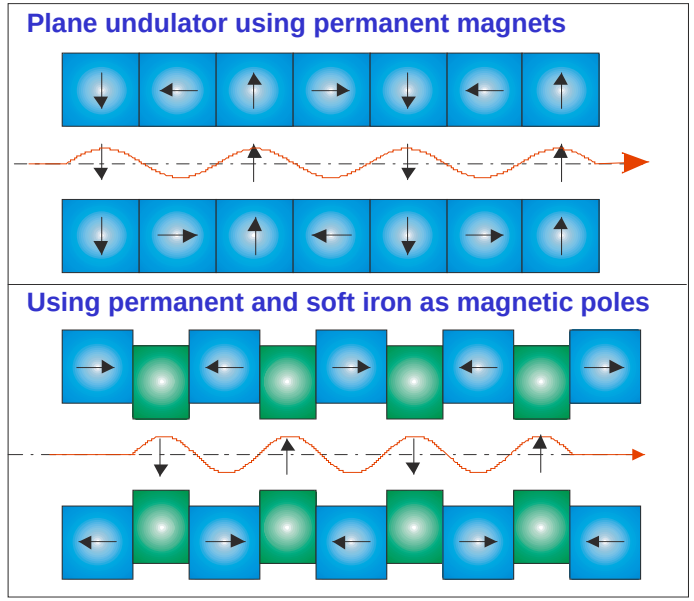
The crucial parameter is known as the K (deflection) parameter given as:

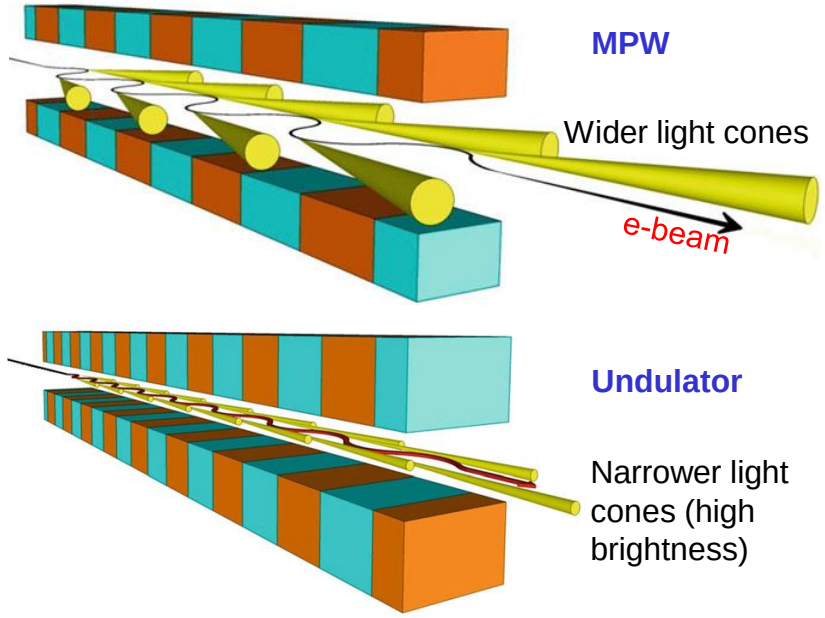
$$K = \frac{B_0 e}{mc}\frac{\lambda_u}{2\pi} = 93.4 B_0 \lambda_u$$

B_0 = peak field (T), λ_u= magnetic period (m)

Radiation opening angle ~ ± γ

The maximum angle an electron can oscillates around the z-axis is K/γ.





Artistic comparison of the SR emission between MPW and undulator (adapted from A. Balerna & S. Mobilio, 2015)

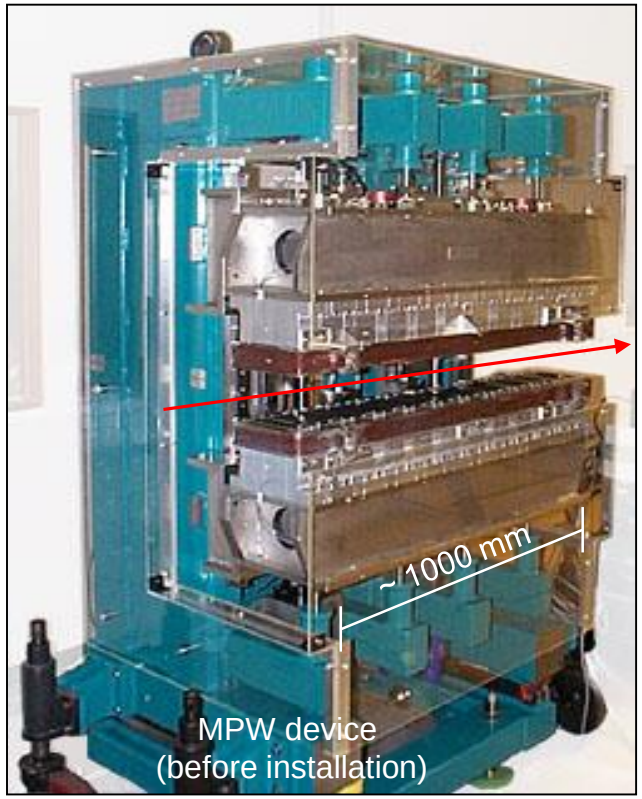
Multi-pole Wiggler

For MPW, K >>1, the radiation “cones” are well spread out, so there are little overlaps from cones produced by different poles.

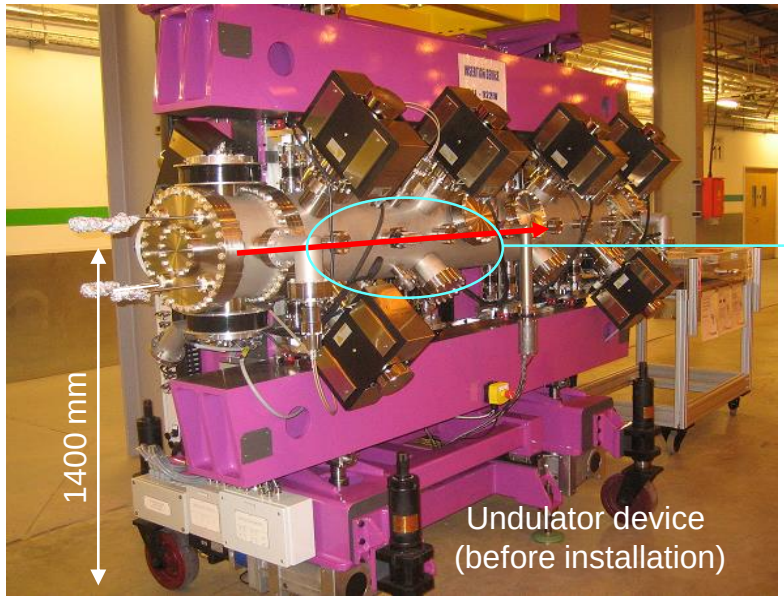
SR can be observed (z-axis or along s) only when electrons move near the top of trajectories.

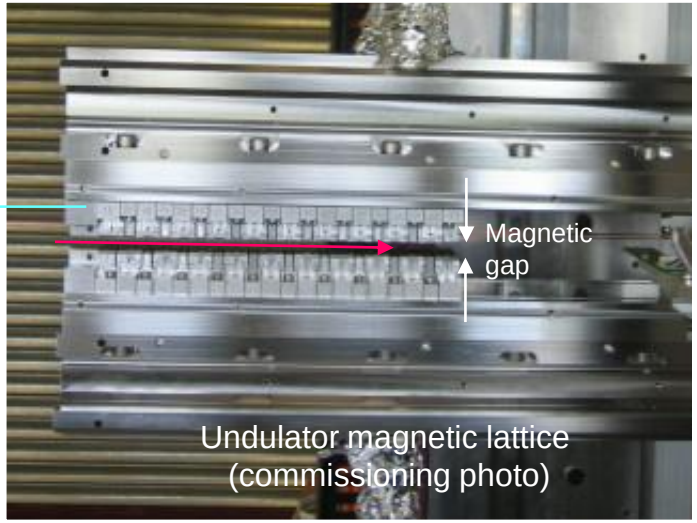
For N number of poles (N ~ 20 - 60), the electrons move N time near the top Therefore, the radiation brightness increases by the N times.

The overall spectrum is shifted to higher energies c.f. bending magnet

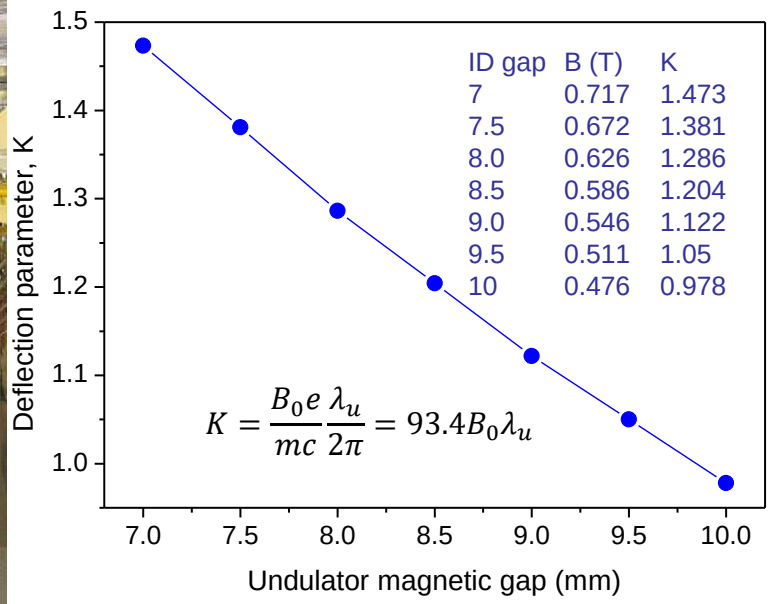


Undulator



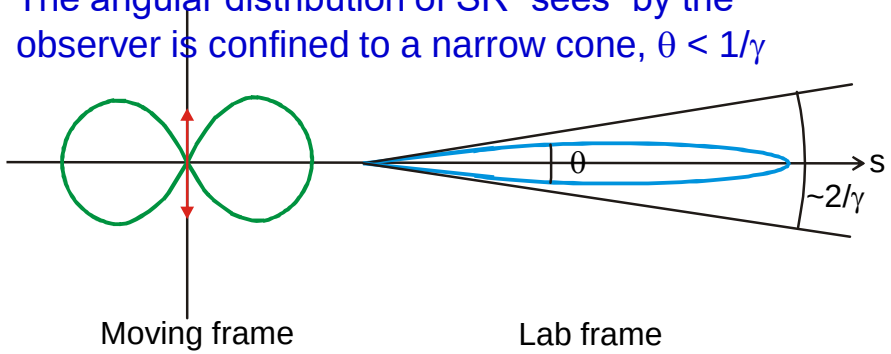




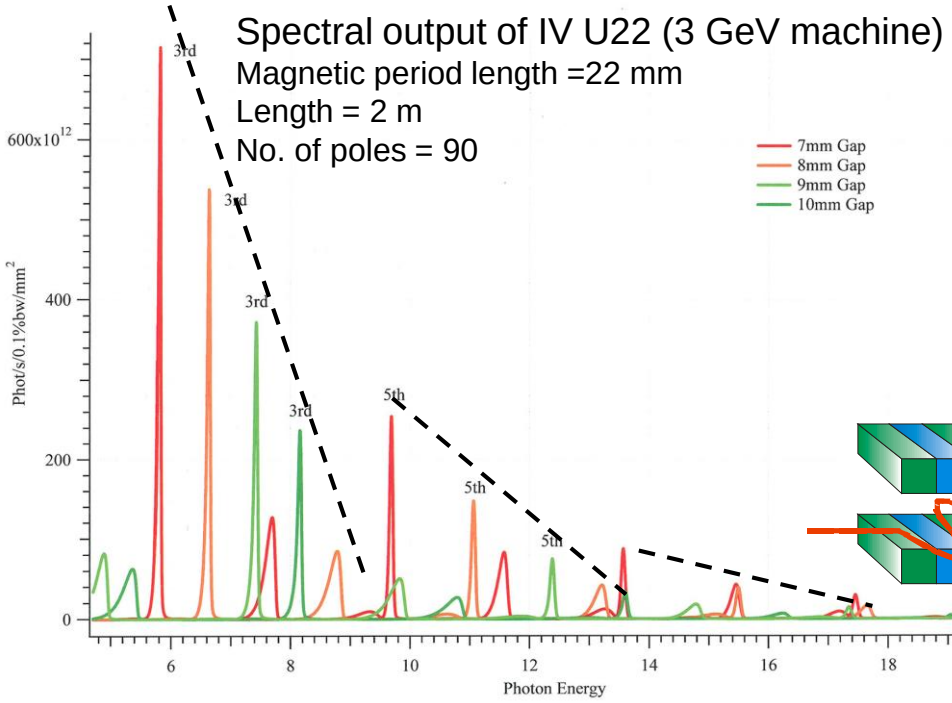


Undulator properties

The angular distribution of SR "sees" by the observer is confined to a narrow cone, $\theta < 1/\gamma$

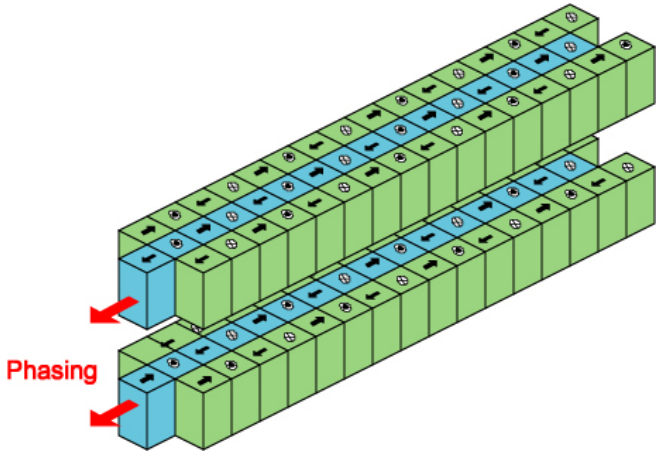


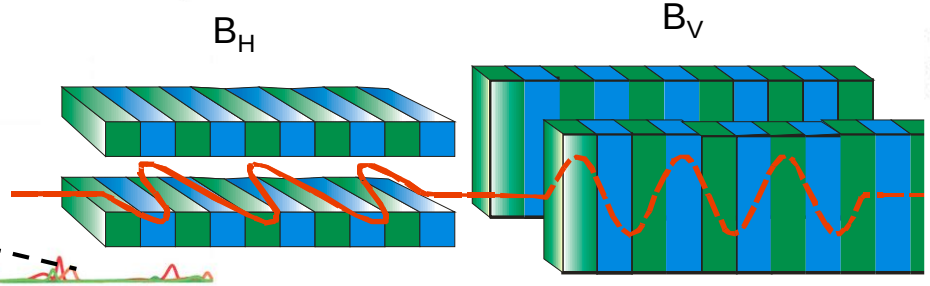
The spectral line width, $\Delta\lambda/\lambda \approx 1/N$
e.g. 100 pole undulator, $\Delta\lambda/\lambda \sim 1\%$ (pink beam)
The central brightness (θ=0) α $N^{2,}$
i.e. undulator $\rightarrow$ high brightness source.

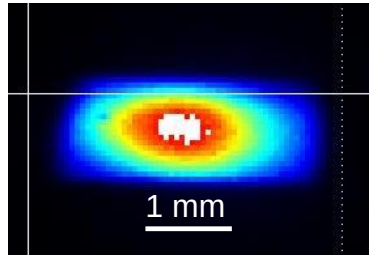


Helical Undulators

There are a number of schemes to produce circularly polarised light; double helix coil, permanent magnets and crossed field undulators



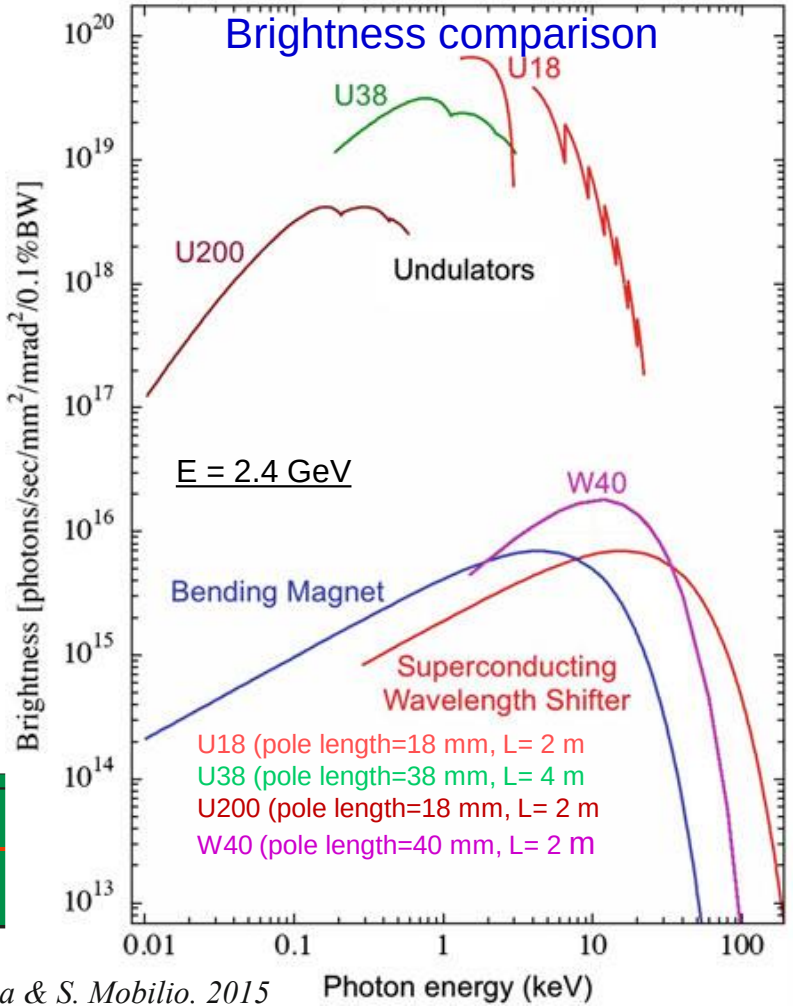




Undulator beam at 48 m from source,
E = 15 keV, Flux ~10^{13} photons/s/0.1%bw

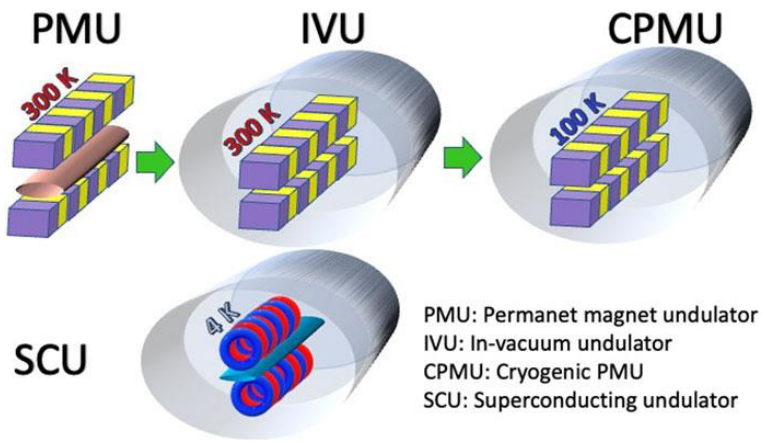


BM beam without focussing optics ~ 120 mm (H) x 7 mm (V)

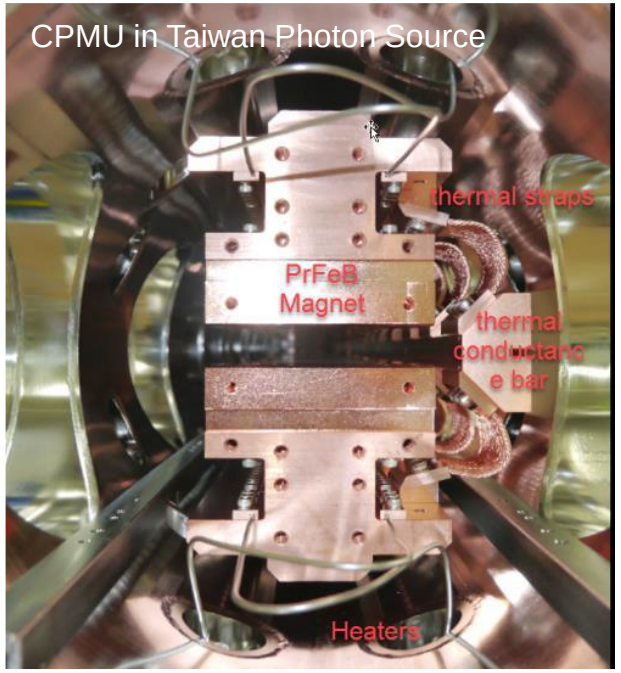


A. Balerna & S. Mobilio. 2015

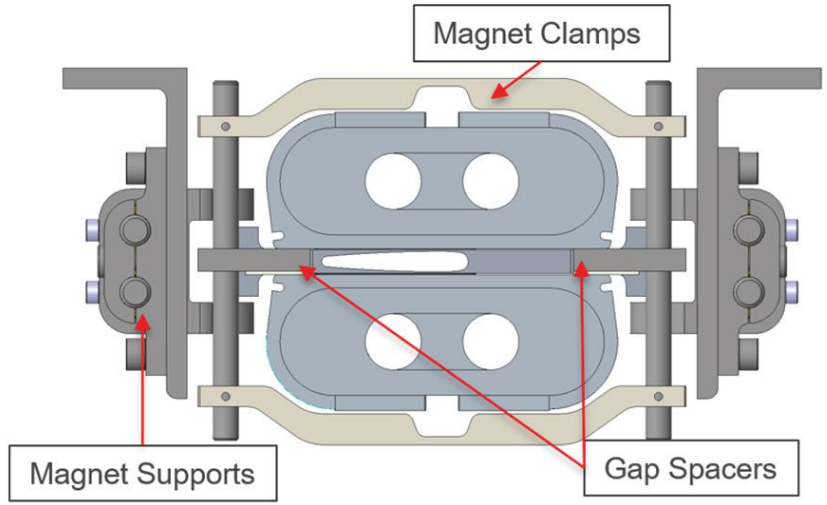
Cryocooled Permanent Magnet (CPMU) and Superconducting Undulators (SCU)



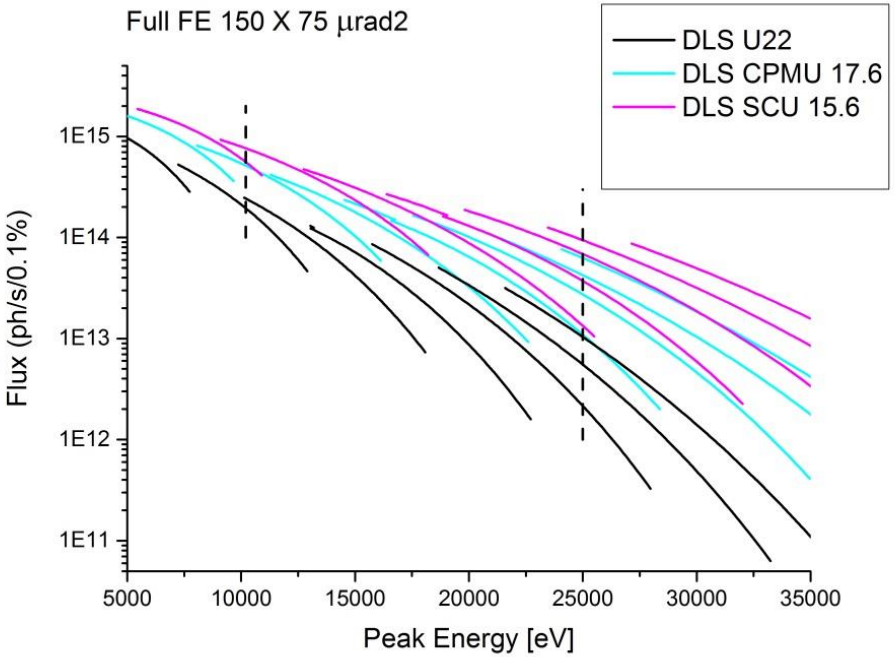
S. Casalbuoni et al. (2023)

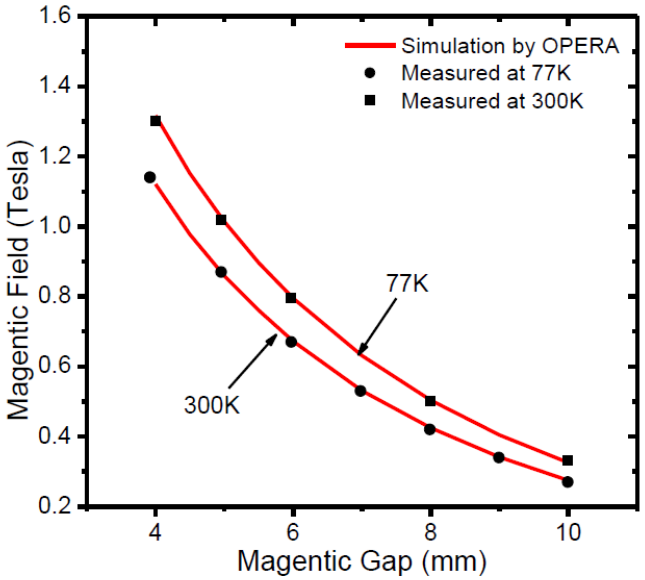


SCU design for Advanced Photon Source (USA)



E. Anliker et al (2021)





J-C. Huang et al (2019)

Front-End – Preconditioning of SR beam

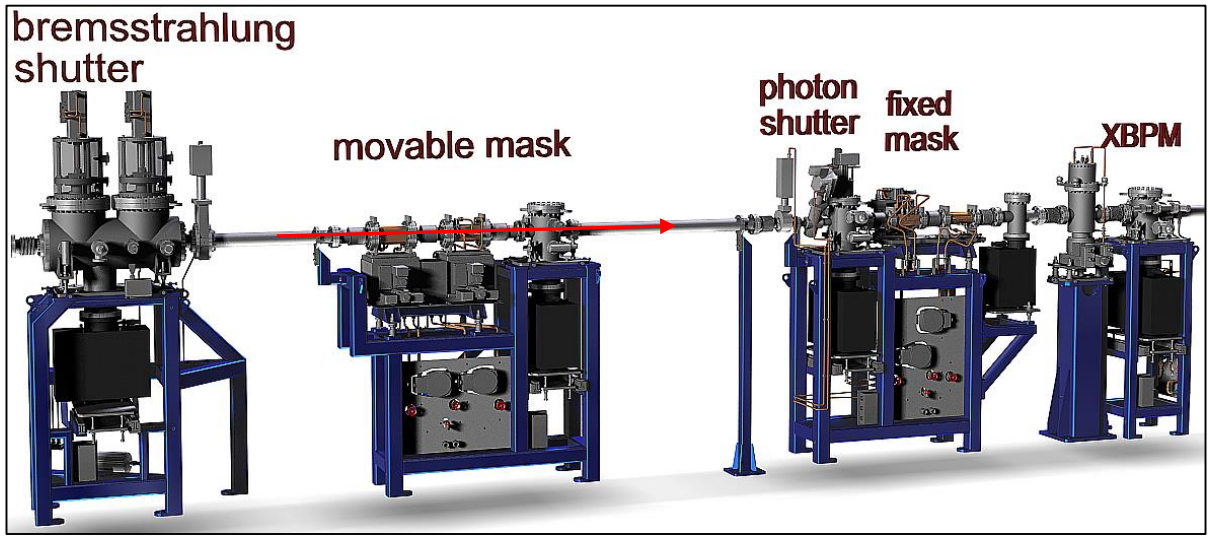
Front-end

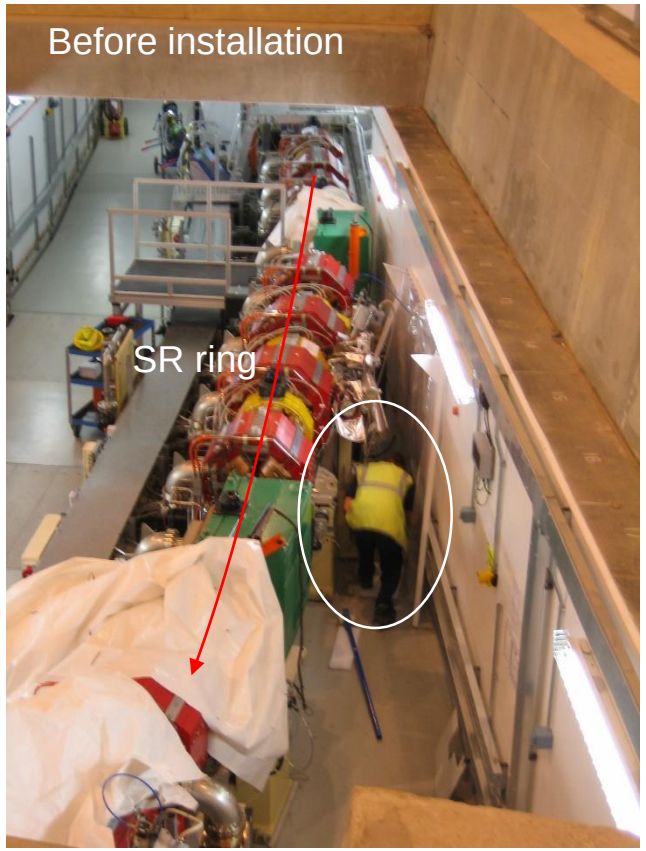
The front end is tangentially connected to the storage ring, channelling and “pre-conditioning” SR beam through the machine wall into the optics hutch.

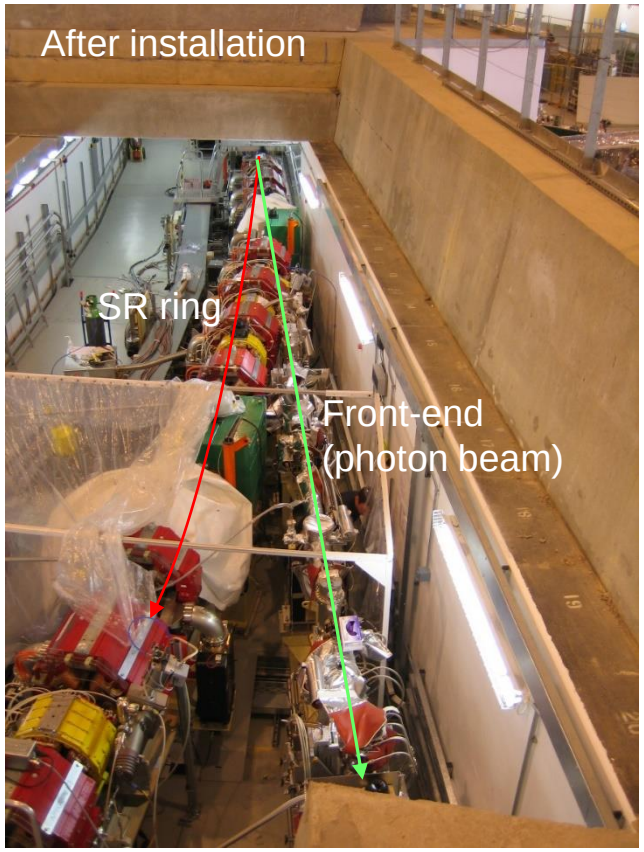
The section is to “pre-condition” the synchrotron beam from the storage ring to pass through to the beamline (masks or apertures)

The main functions of a front end are:

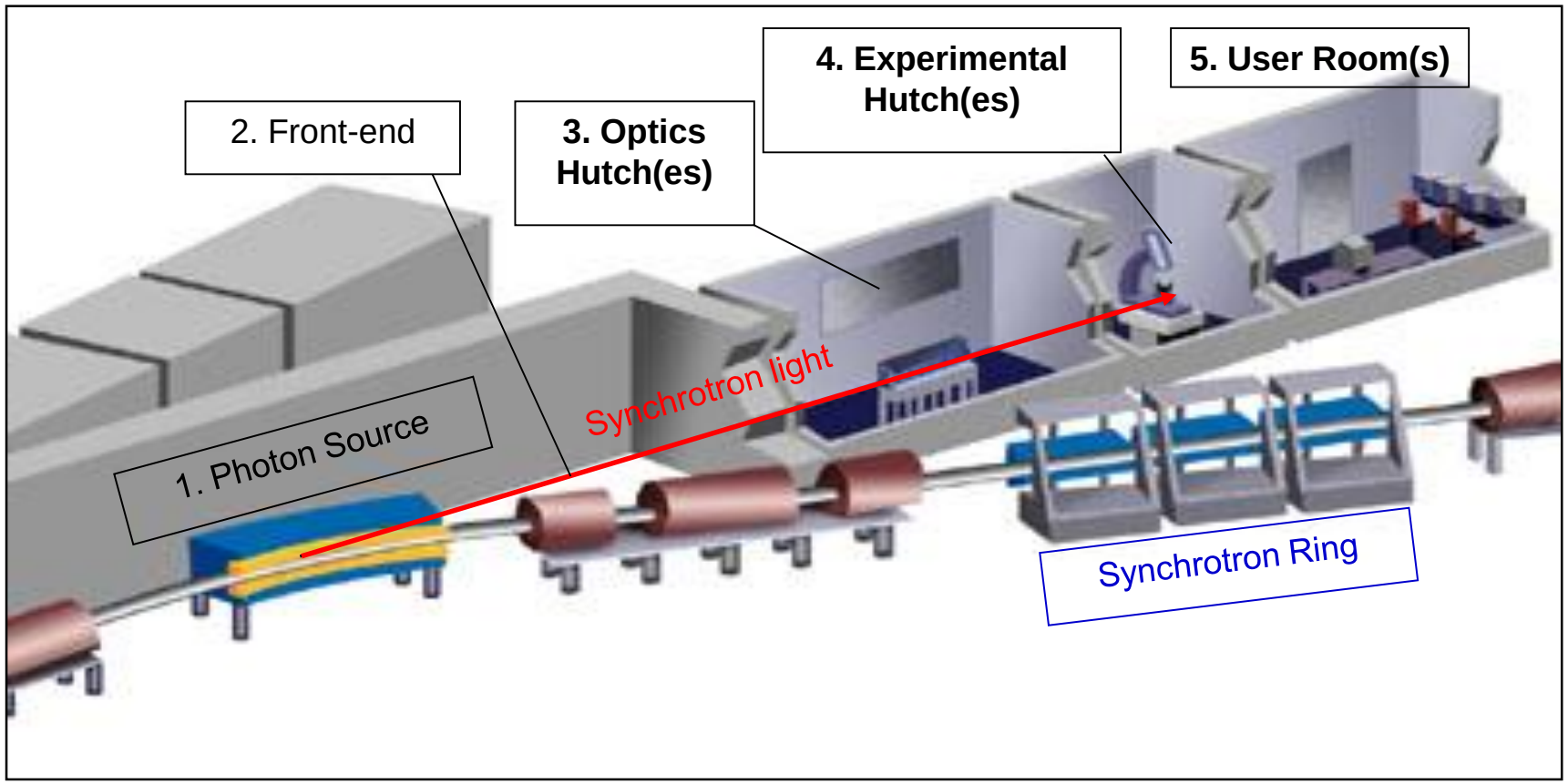
- to collimate the SR beam and to remove as much of the heat as possible from the “raw” beam (water-cooled masks, apertures or slits)
- to monitor the position and intensity of the synchrotron beam using diagnostic components (XPBM).
- to protect the storage ring if there is a vacuum leak in the beamline (sensors, fast vacuum valves).
- to allows safe access into the optics hutch when required (heavy-duty shutters).







Radiation Hutches



Radiation Hutches are built to house:

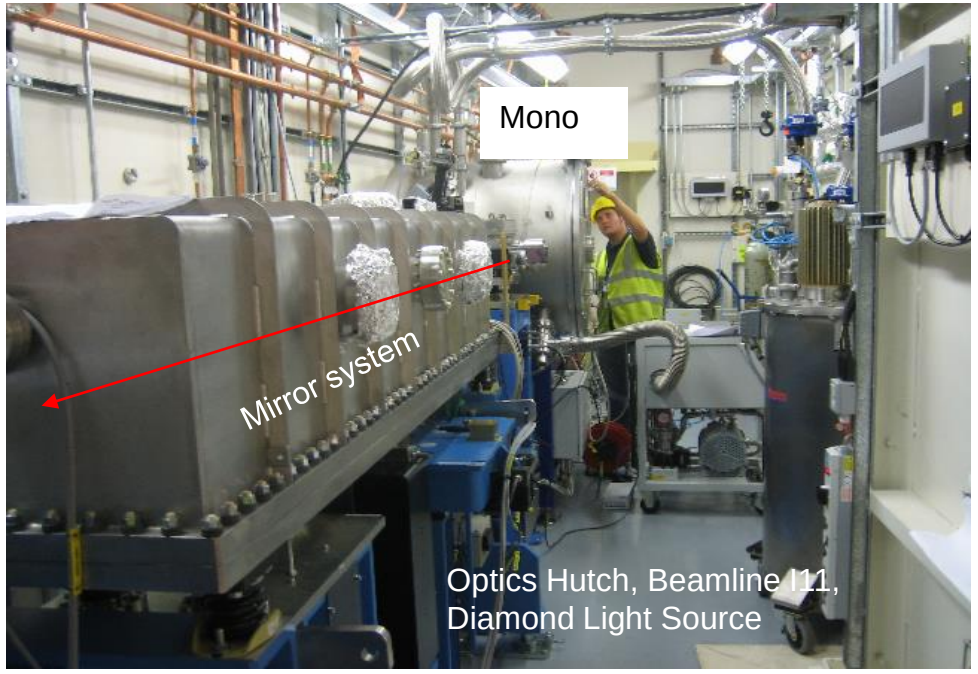
- Optical components or elements for beam optimisation and fine-tuning (collimation, monochromatizating, focussing ..)
- End-station instruments for user experiments

Large and heavily shielded enclosures (lead + stainless steel) are essential for:

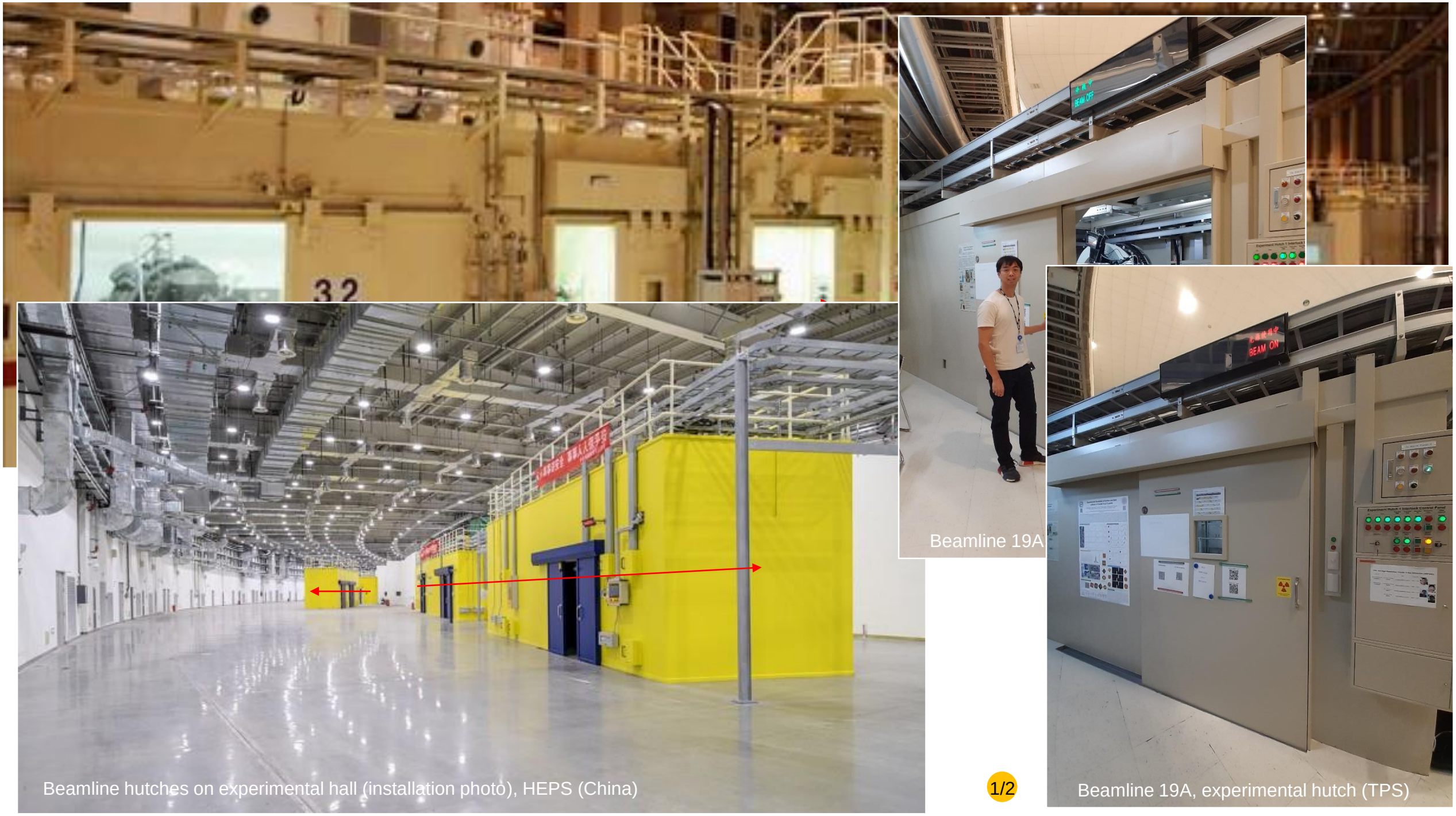
- Safety containments of intense SR beams inside
- Protection of users with beam ON.


X-ray Optics Hutch at Diamond Light Source
(construction photo)


Sirius Synchrotron, Brazil *(photo: CNPEM)*



Optics Hutch, Beamline I11,
Diamond Light Source



Beamline 19A

Beamline hutches on experimental hall (installation photo), HEPS (China)

Beamline 19A, experimental hutch (TPS)

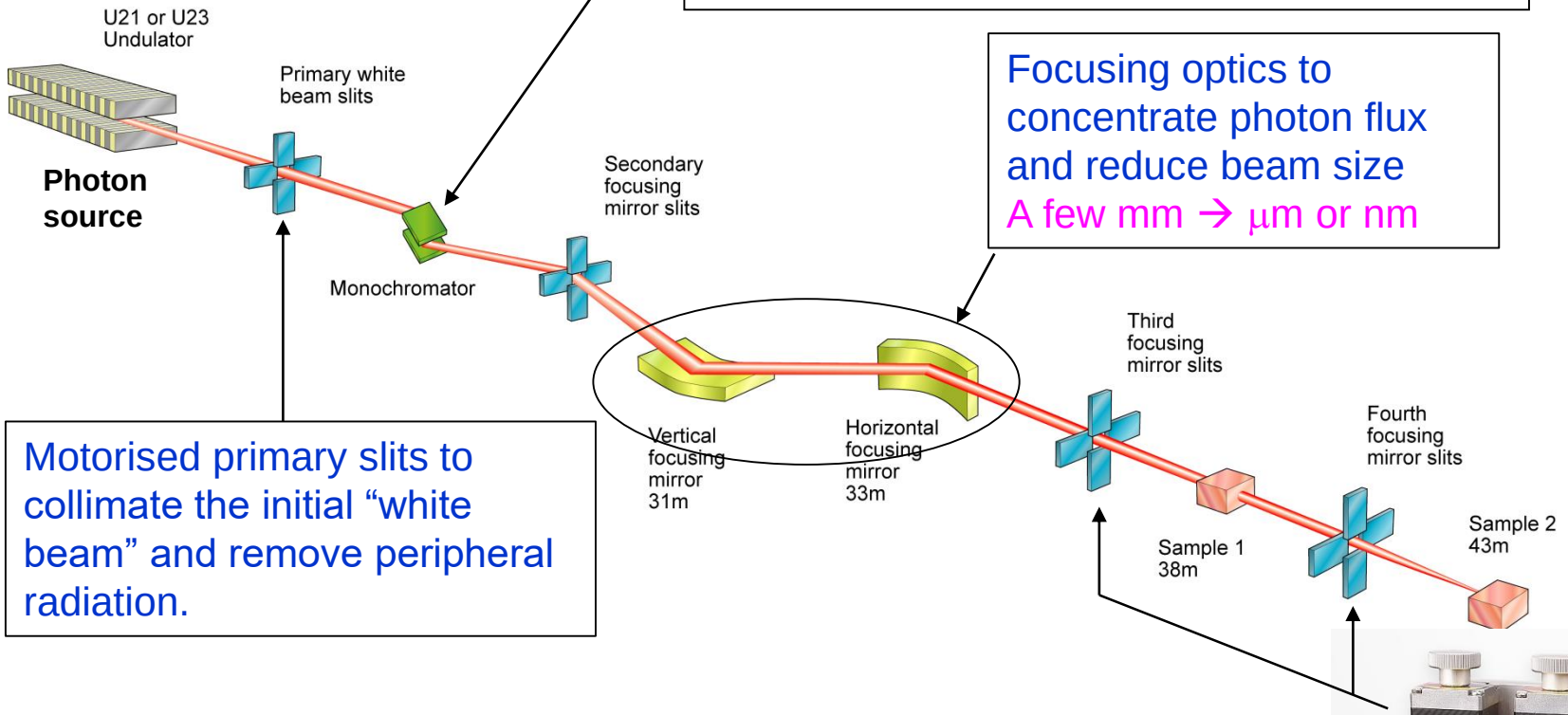
Optics – Optimisation of Beam

Beamline Optics

A typical X-ray beamline

Monochromator

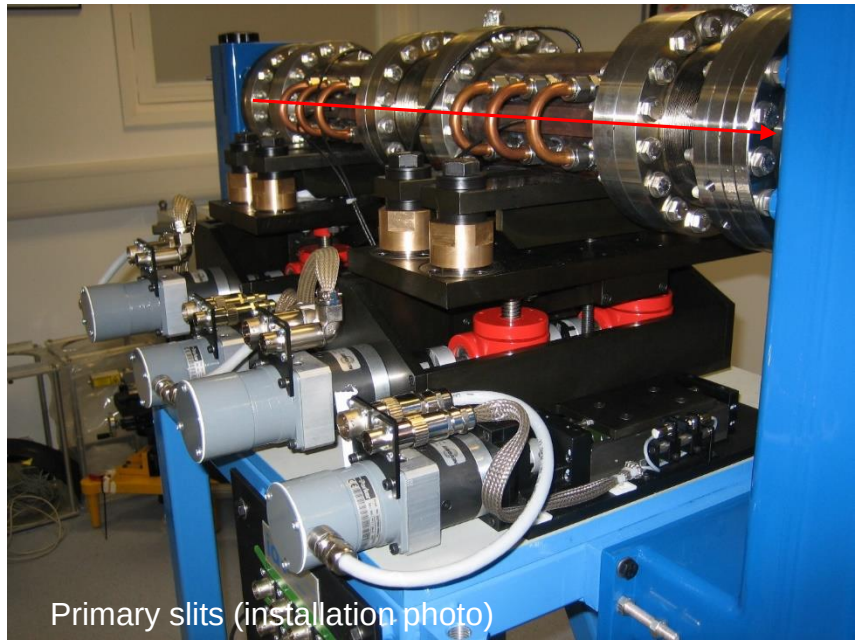
- Polychromatic beam → Monochromatic beam
- Remove beam heat-load



Focusing optics to concentrate photon flux and reduce beam size

A few mm → μm or nm

Motorised primary slits to collimate the initial "white beam" and remove peripheral radiation.



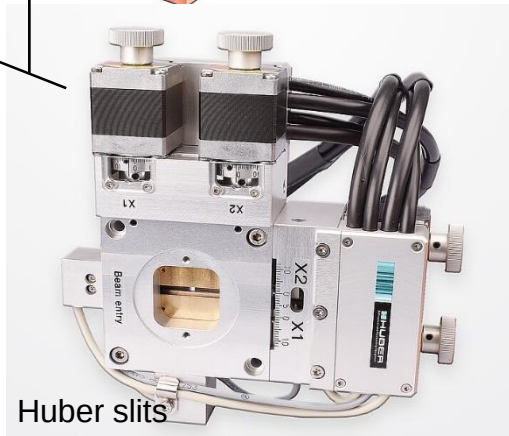
Glidcop apertures with water cooling due to the high heat-load (~ kW).

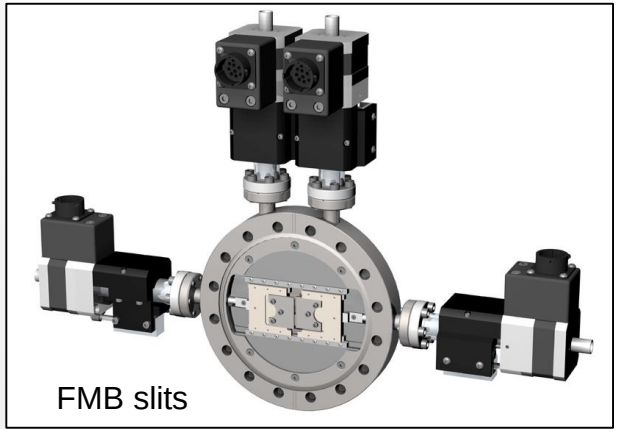
Motorised 2nd, 3rd, … slits to remove scattered radiation and to define beam size.

- Source characteristics
- Crystals or Gratings
- Mirrors
- Harmonic suppression
- Effect of imperfections

Optimise

- Specify - optical layout
  - optics specification
- Predict performance
  - photon flux, resolution, beam size

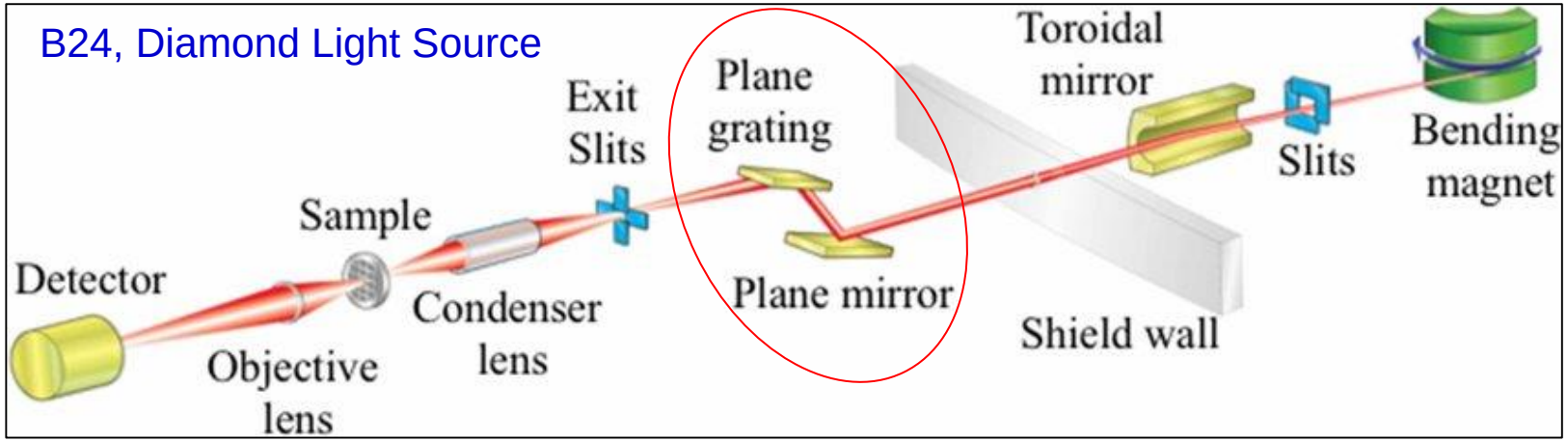




Monochromators

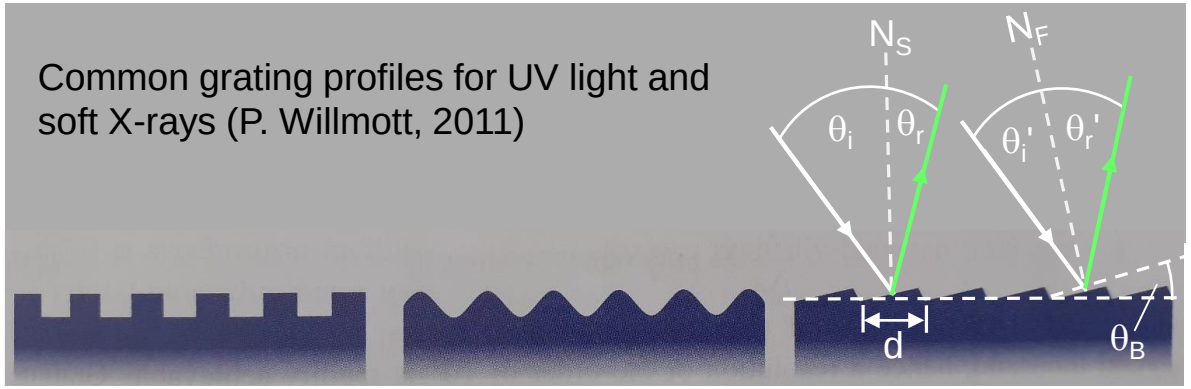
Most SR experiments use a particular wavelength (λ) or discrete energy scanning from the continuous radiation spectrum (white beam).
Exceptions: Laue and energy dispersive diffraction and fluorescence techniques.

Monochromator systems for UV, soft and hard X-rays have been well-developed, but **continuous to develop**.

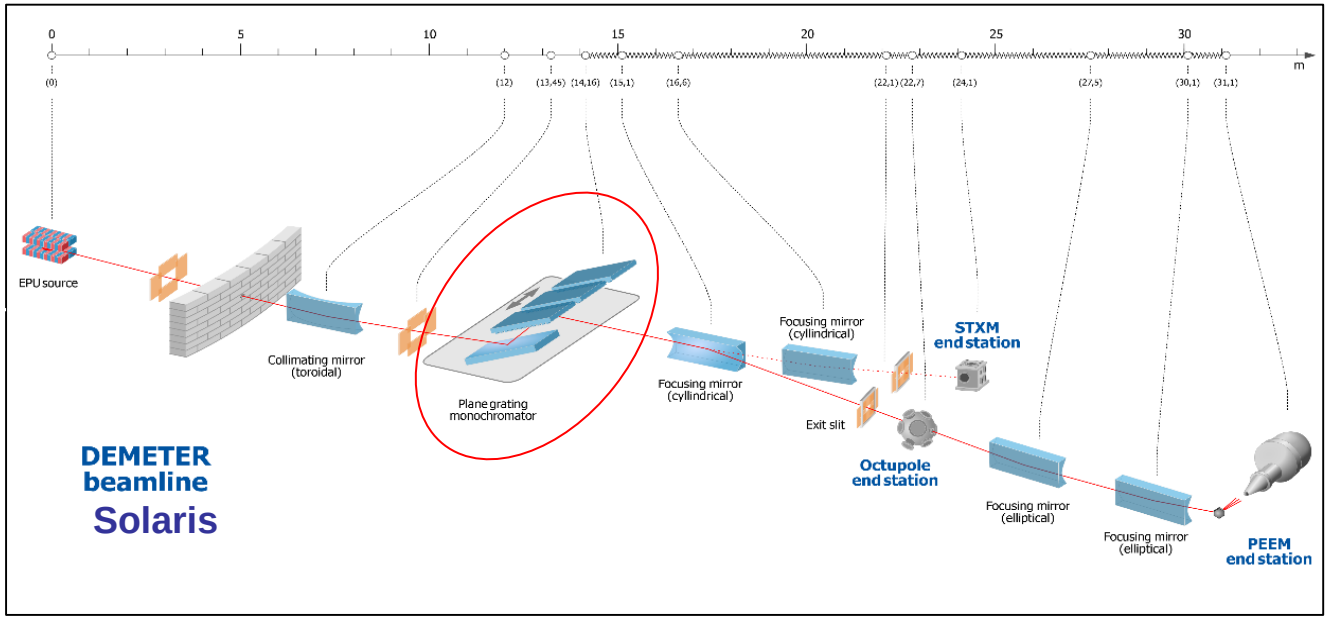


Diffraction Gratings to monochromatize UV light (λ = 100 – 400 nm) and soft X-rays (λ = 1-5 nm)

Common grating profiles for UV light and soft X-rays (P. Willmott, 2011)



Lamellar Sinusoidal Blaze



For blaze grating, $m\lambda = d(\sin\theta_i - \sin\theta_r)$, when $\theta_i' = \theta_r'$

$2d \sin\theta_B = m\lambda$ (θ_B = blaze angle)

If θ_B~10° and grating=1000 grooves/mm → d = 0.001 mm, then
$\lambda = 2d \sin\theta_B = 2x0.001 \cdot \sin(10) = 347.3x10^{-4}$ mm $= 347.3x10^{-6}$ mm
λ = 347.3 nm, since (1 nm = 10^{-6} mm) – This is UV light wavelength!

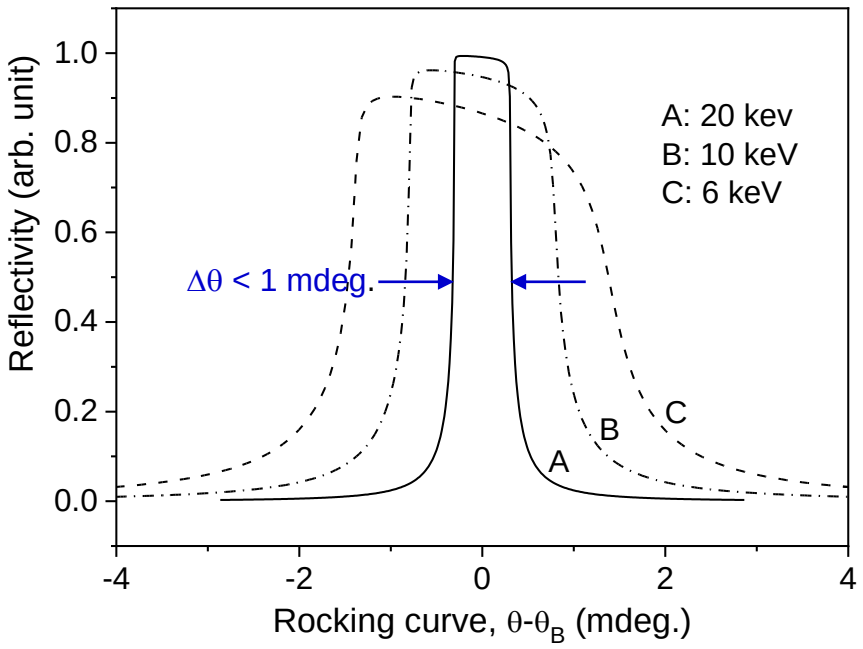
X-rays Monochromator

Single crystal diffraction are used to monochromatize SR according to Bragg's law:

$2d_{hkl}\sin\theta_B = n\lambda \quad (E = 6.199/(d_{hkl}\sin\theta_B))$

λ in Å (1 Å=10^{-10}m=0.1 nm), E in keV and n=1,2, 3 ...

Typically, Si single crystals are used, other materials such as Ge and diamond.

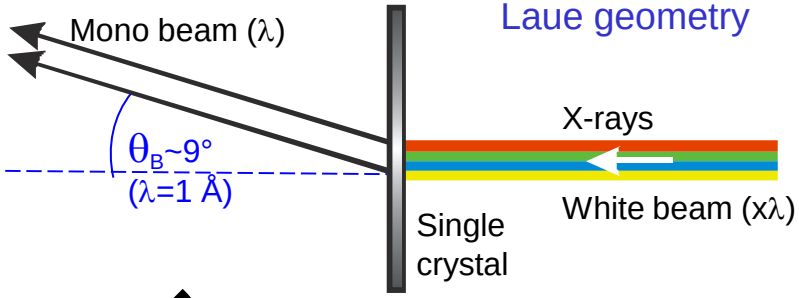


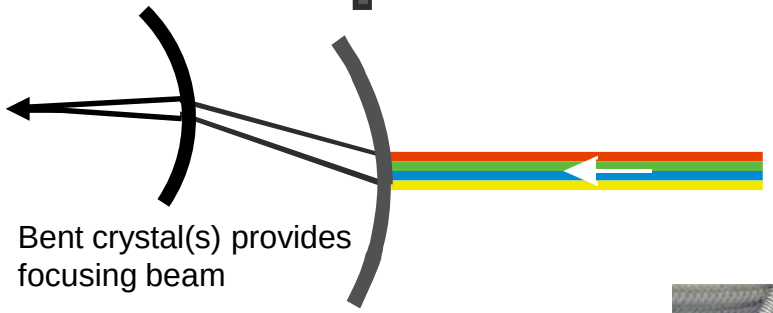
Si(111) rocking curve – measure of the quality of monochromatic beam is

$\Delta\lambda/\lambda = \Delta E/E = \Delta\theta/\tan(\theta)$ **~ 10^{-4}**
As usually specified for Si(111) crystal monochromator

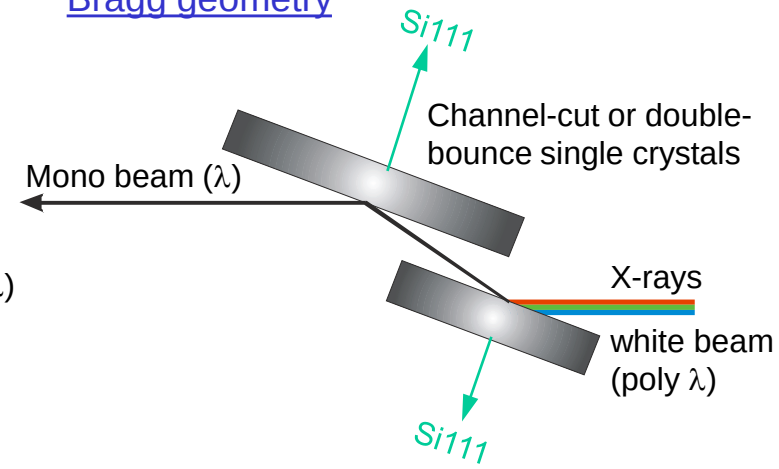
There are a number of schemes and designs:

Laue geometry

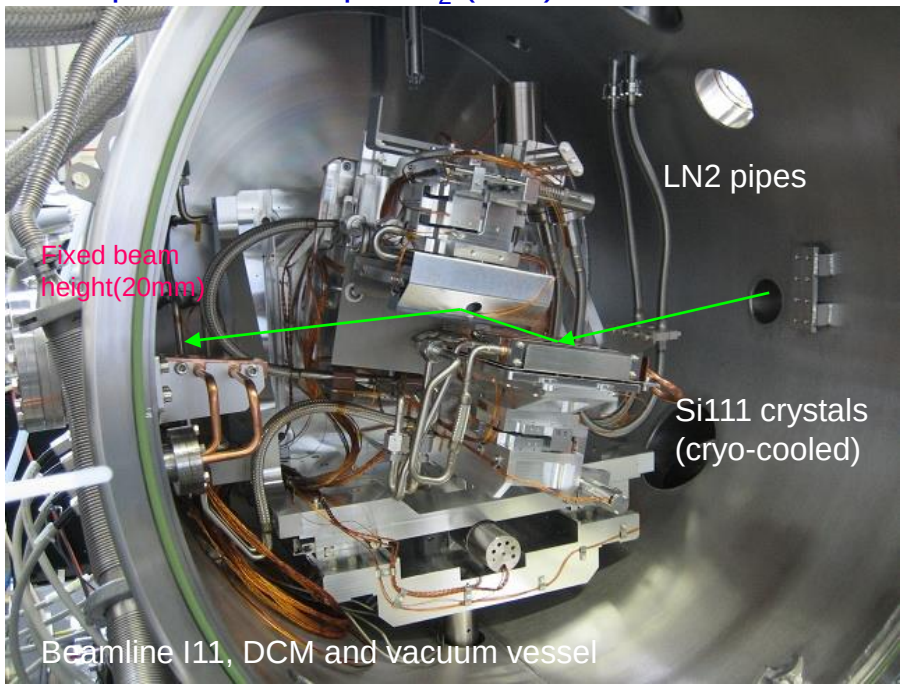


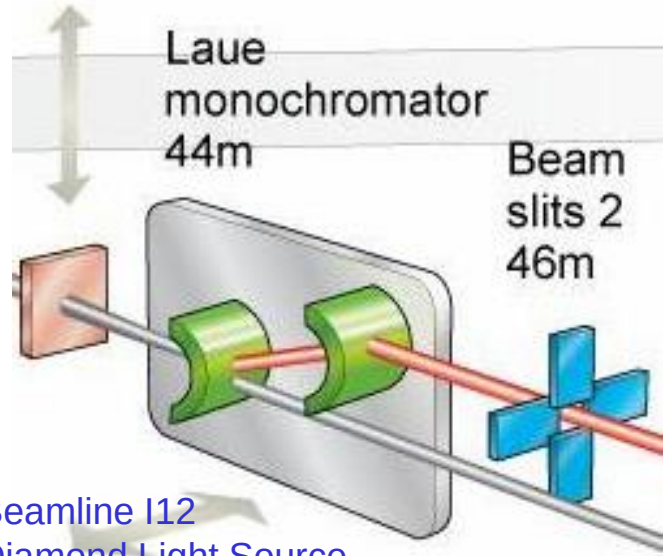


Bragg geometry



Double crystal mono (DCM), cooled by pressurised liquid N_2 (LN2), T ~ 80 K

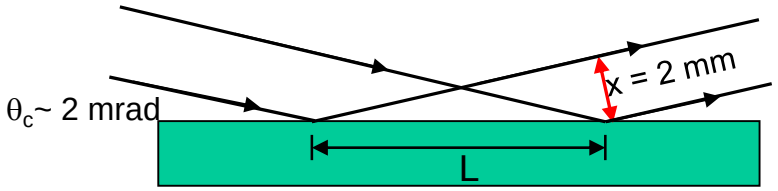




Beamline I12
Diamond Light Source

X-rays Mirror Systems for beam purification, collimation and focussing

X-rays can be reflected from high quality-flat surfaces →



For an incident angle = the critical angle (θ_c) or below → total external reflection.

For most coatings, θ_c ~ a few mrad (< 0.5º), e.g.

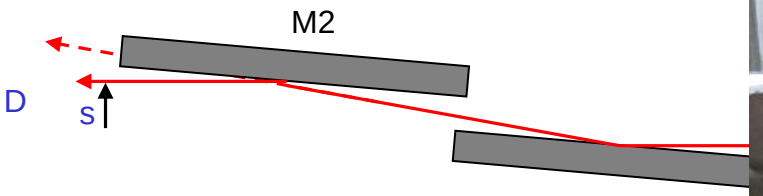
ρ = 2.33 g/cm$_3$ for Si, **θ_c = 2.4 mrad = 0.14º** if one uses a beam with λ =1 Å.

$$\theta_c = x/L$$

$$L = \frac{2}{2x10^{-3}} = 1000 \text{ mm}$$

For x=2 mm (vertical beam size), it requires long (1 m) optics which puts high accuracy requirements on the *surface specifications (slope errors and roughness), positioning and stability*.

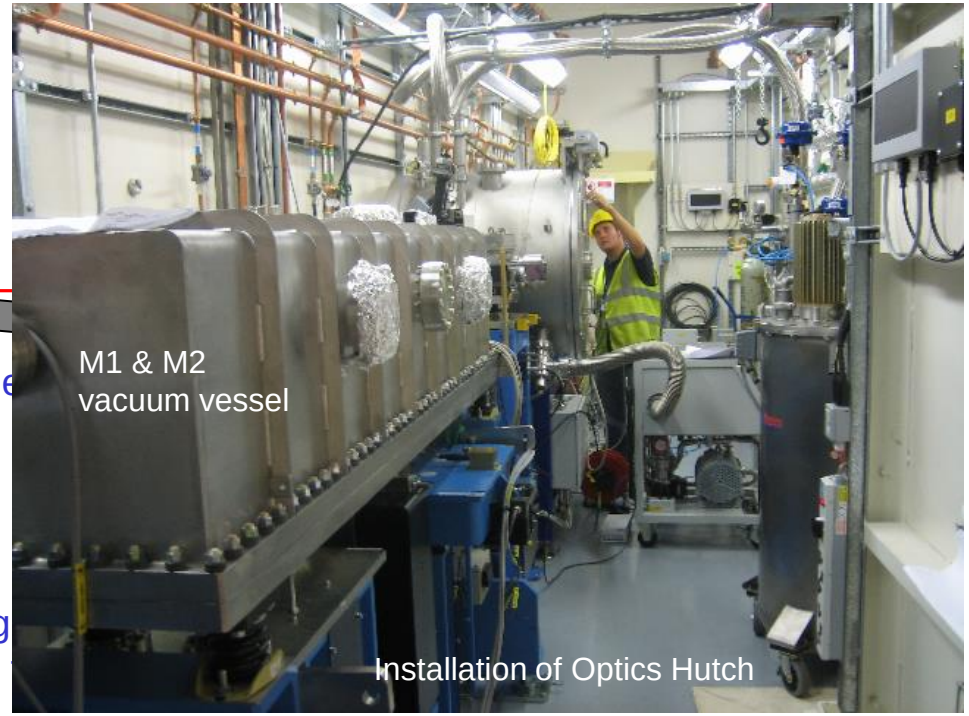
Purification to improve beam quality by harmonic rejection



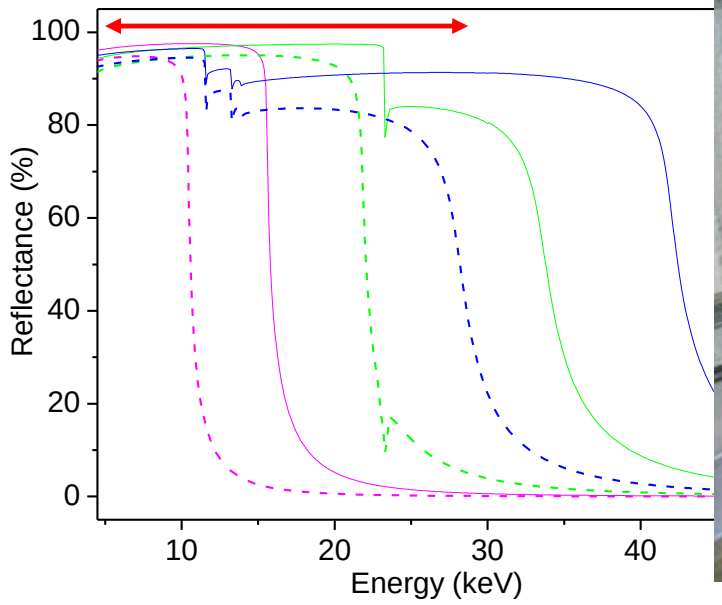
For M1, θ_c = 2.5 mrad (incident angle), defle varies with D.

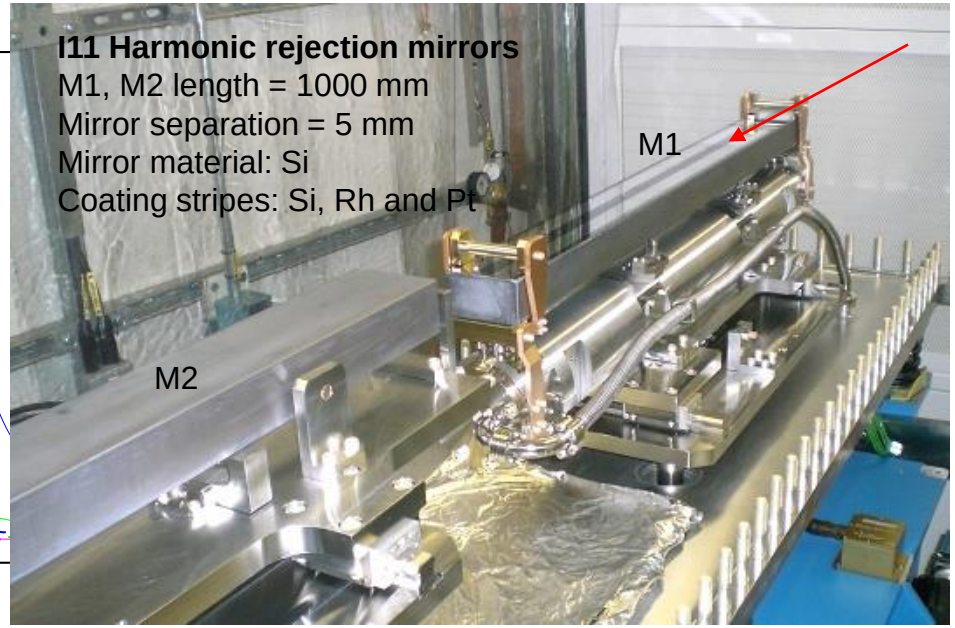
D = 100 mm at 40 m (sample) → large displacement of downstream components.

Bring in M2 to give constant beam exit; orig beam offsets by mirrors' separation, s (~ a



Harmonic rejection





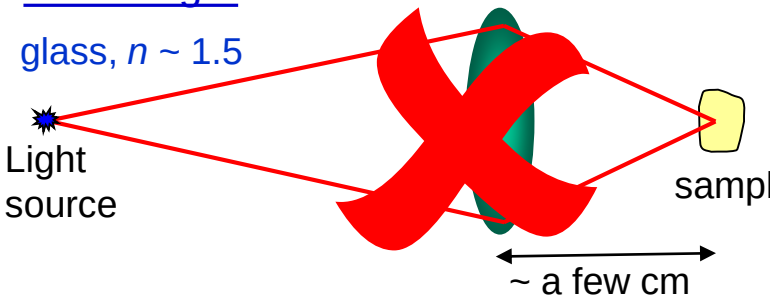
Focussing of X-rays

Focusing X-rays is not easy by refraction as **refractive index**,

$n \leq 1$ (i.e., weakly refracted, but possible!)

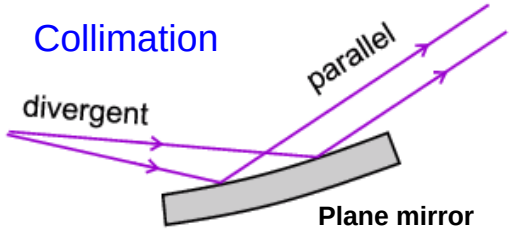
Visible light

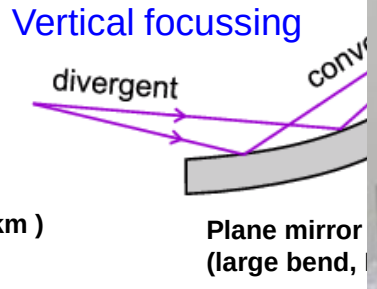
glass, $n \sim 1.5$

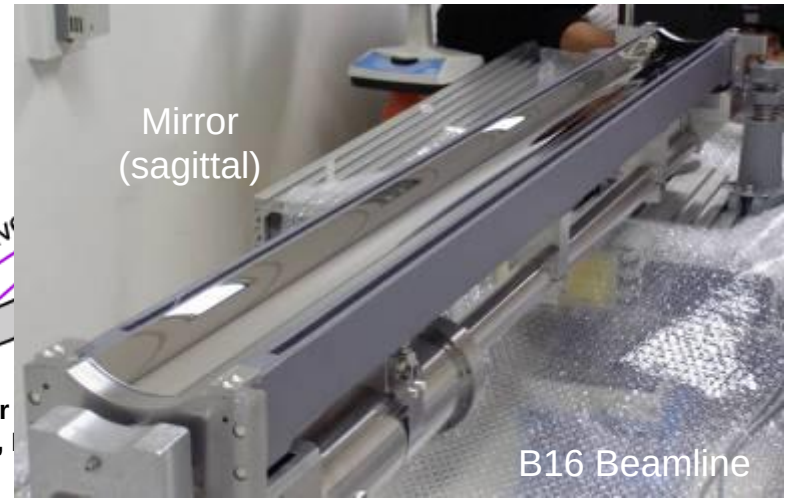


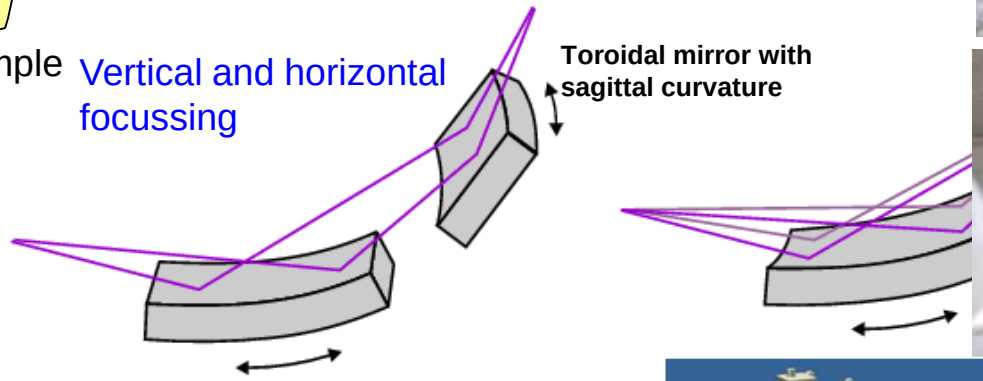
Exploit the reflection of X-ray from high quality surfaces and bending (small).

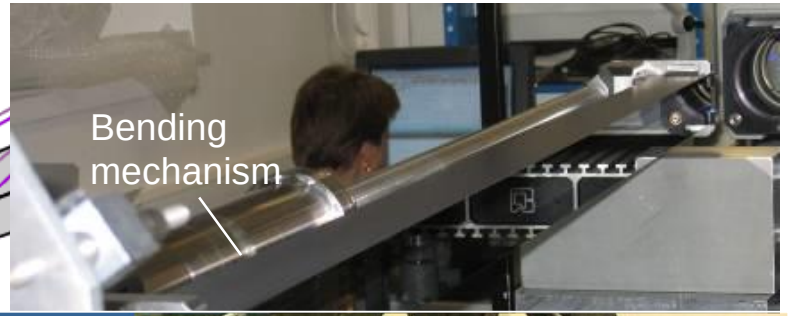
There are a number of configuration:











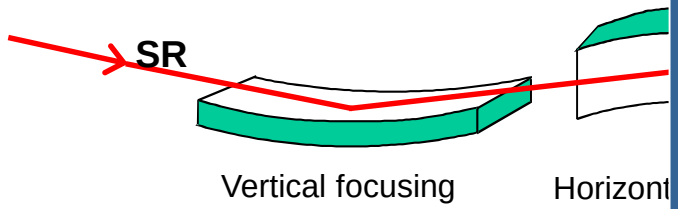
Mirror Equations for bending radius:

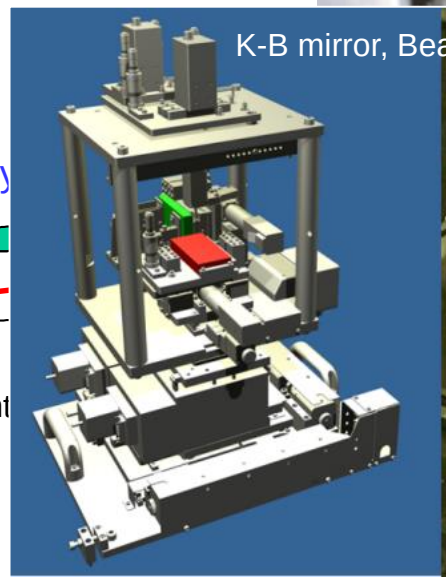
$$R_M = \frac{2}{\sin\theta}\left[\frac{F_1 F_2}{(F_1 + F_2)}\right]$$ For tangential focus $R_M \sim 10$ km

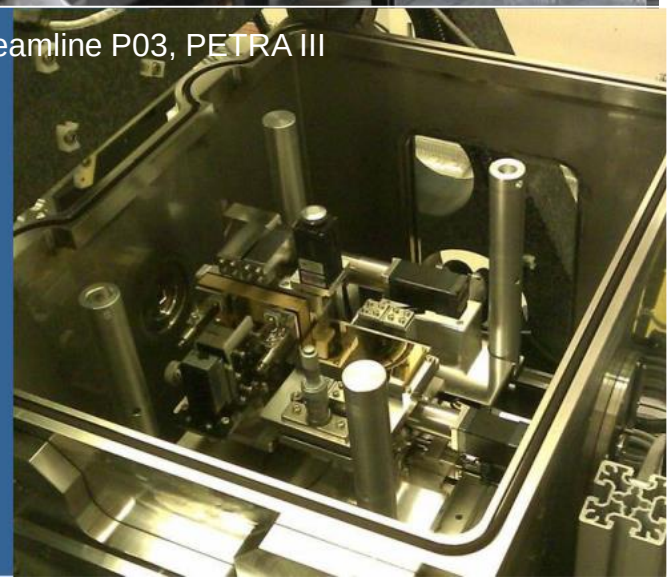
$$R_S = 2\sin\theta\left[\frac{F_1 F_2}{(F_1 + F_2)}\right]$$ For sagittal focus $R_S \sim 6$ cm

$F_1 = F_2 = 25$ m (typical radius for SR beamline)

Kirkpatrick-Baez (KB) geometry







Refractive Optics for focusing X-rays

Refractive index of X-rays:

$n = 1 - \delta + i\beta$

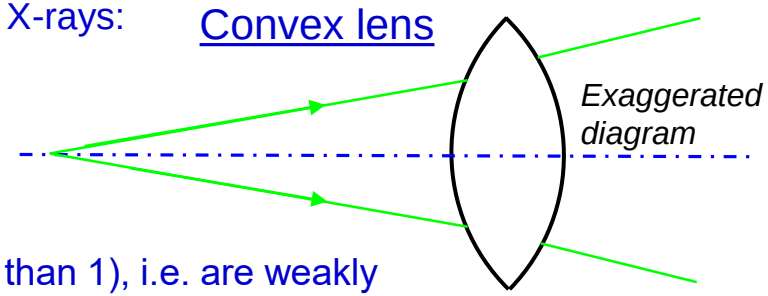
$\delta \sim 10^{-5} - 10^{-6}$

β = absorption

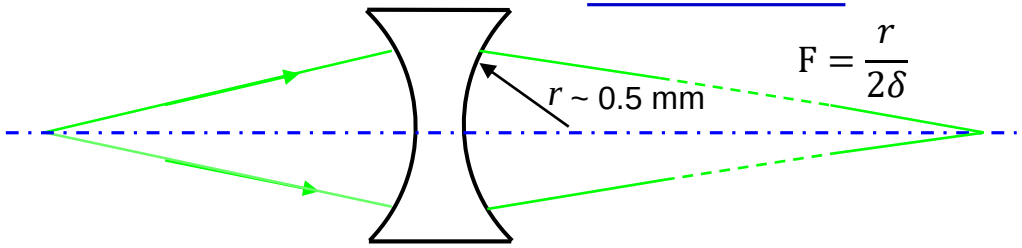
$n \leq 1$ (slightly less than 1), i.e. are weakly refracted and bent away by materials.

Visible light: $n \sim 1.5$ for glass

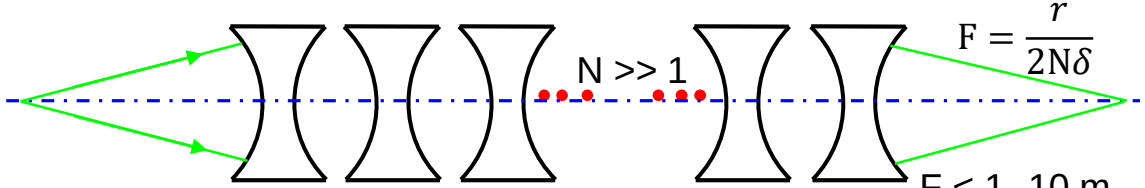
Convex lens



Concave lens

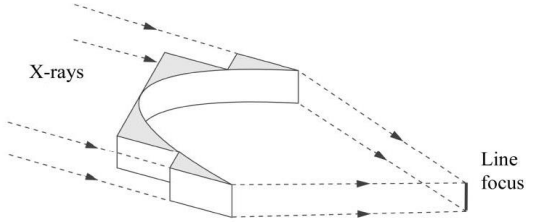


F = 10 -100 m
(not practical)

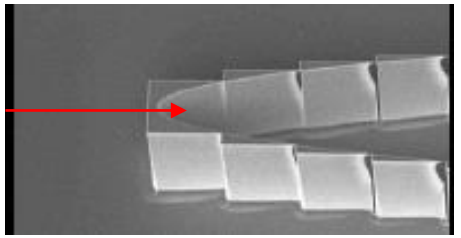


F < 1 -10 m
(practical)

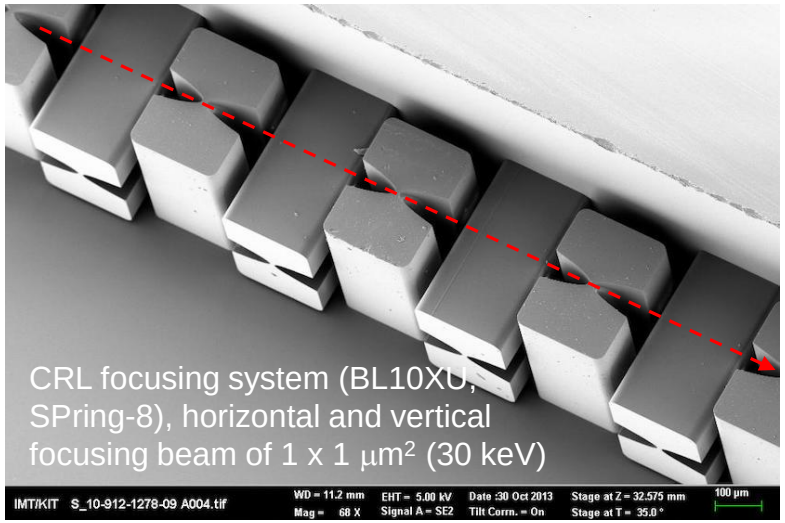
Kinoform lens – Single lens of Si, polyimide, Ni or diamond



kinoform lens, courtesy B Noehammer



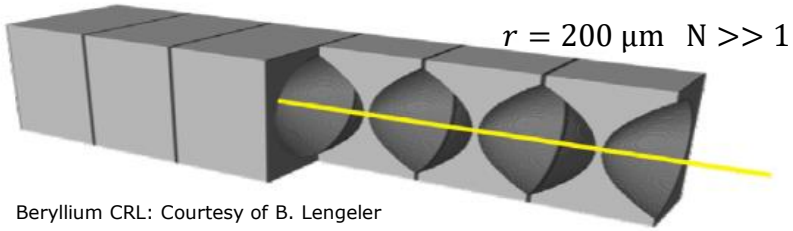
Silicon kinoform lens, courtesy K. Evans-Lutterodt



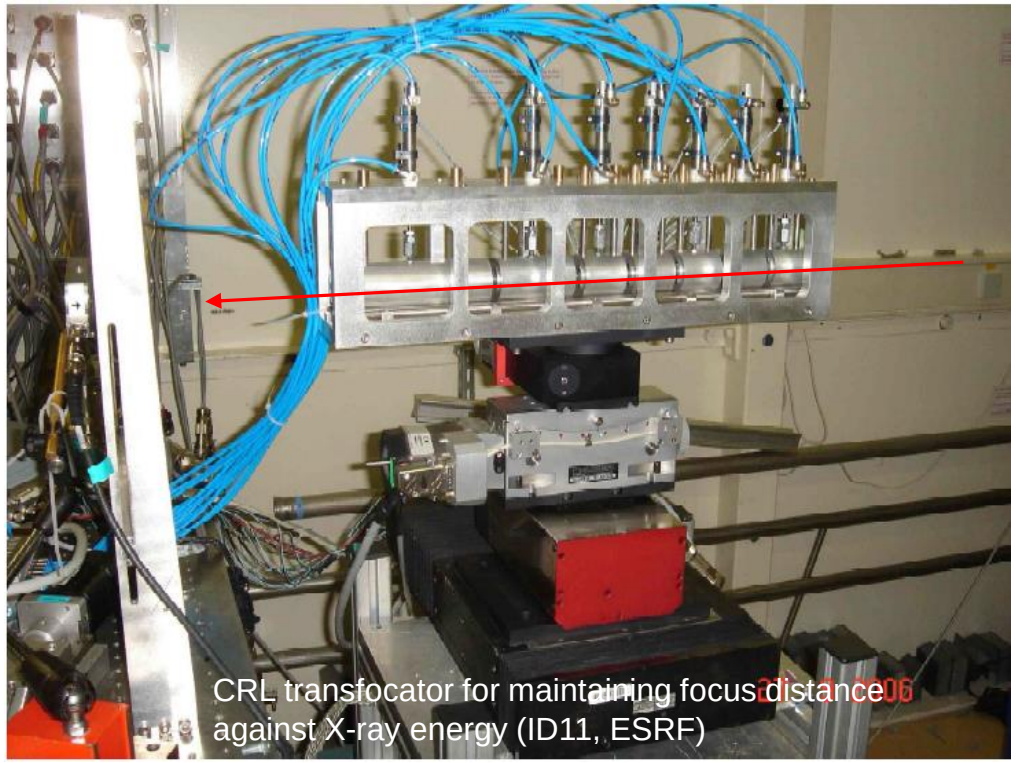
CRL focusing system (BL10XU, SPring-8), horizontal and vertical focusing beam of 1 x 1 μm^2 (30 keV)

Compound Refractive Lenses (CRL)

Focussing can be achieved by stacking N concave single lenses of Be or Al (light metal)



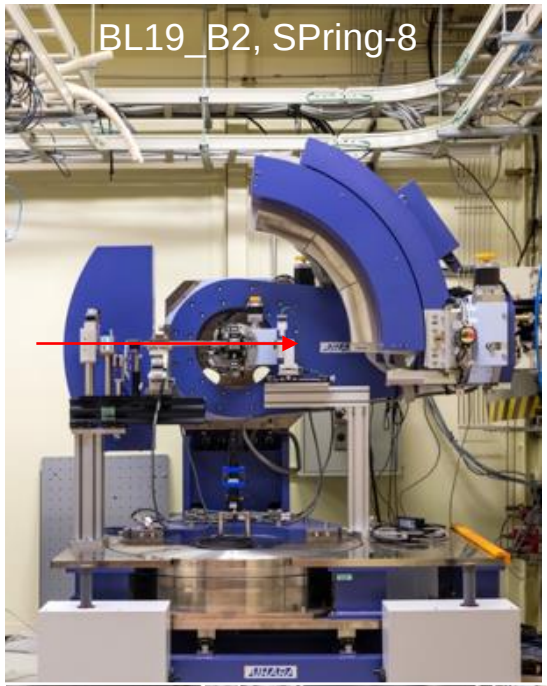
Beryllium CRL: Courtesy of B. Lengeler

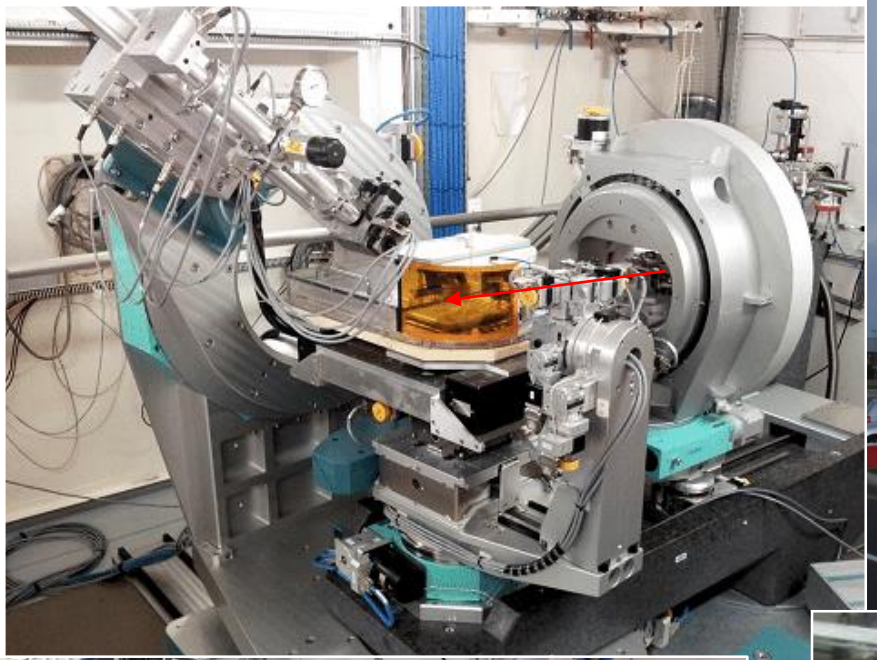


CRL transfocator for maintaining focus distance against X-ray energy (ID11, ESRF)

Experimental Hutch(es) or **End-station(s)** – user experiments

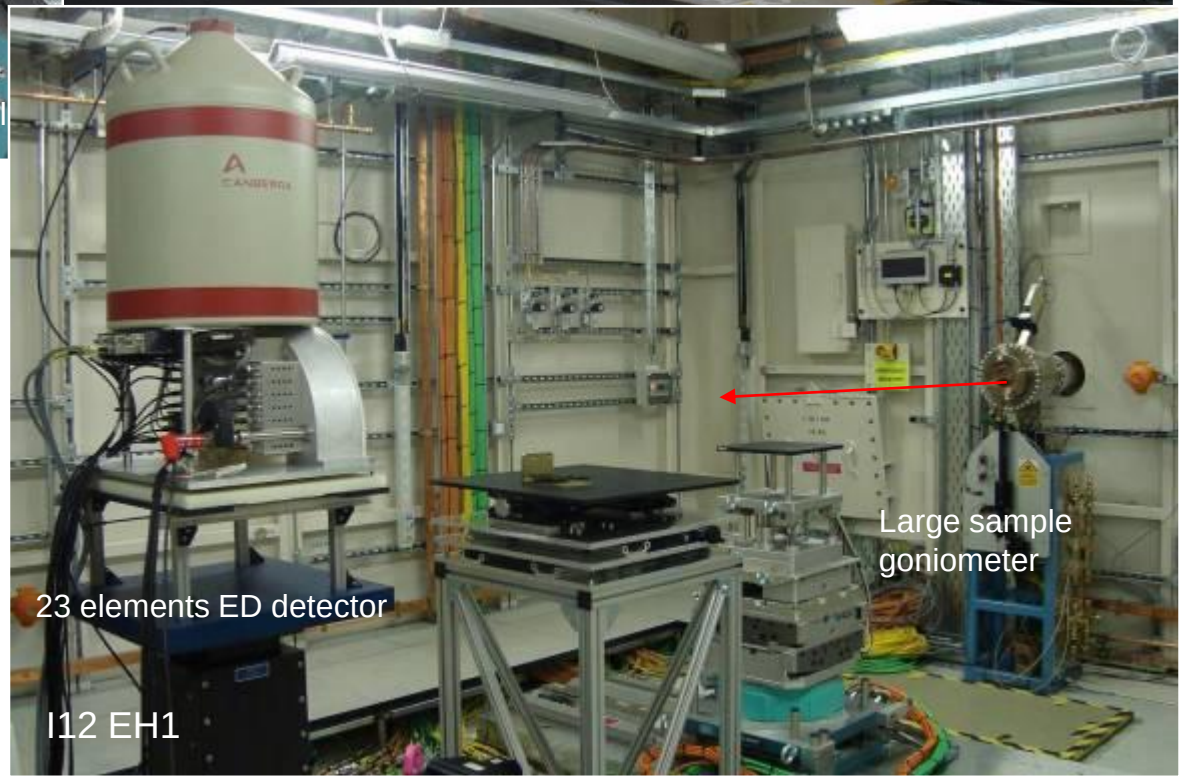
- Beamline with multiple end-stations to facilitate combined techniques
- Present a few examples of photographic demonstration


BL19_B2, SPring-8

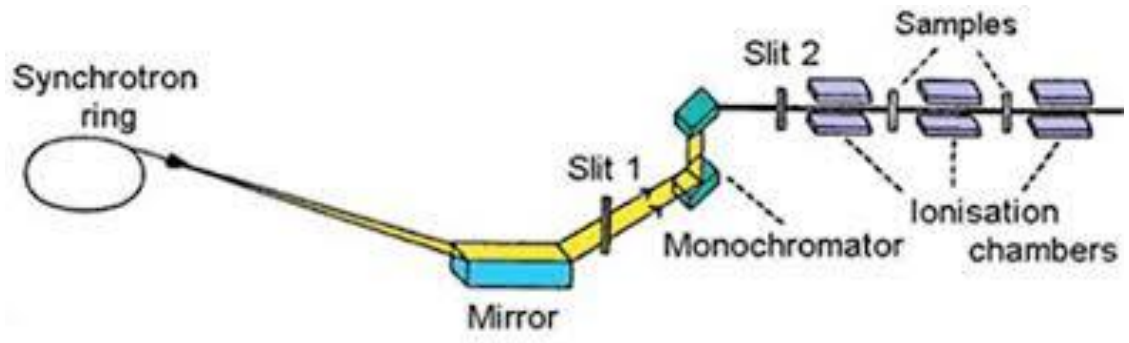




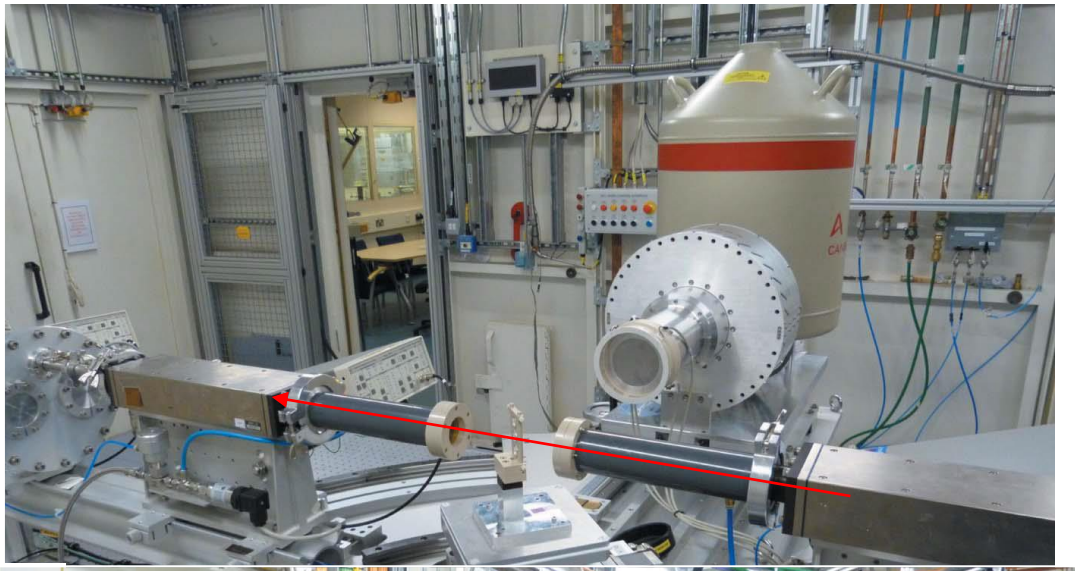

ASWAXS Beamline, ChemMatCARS, APS
Small and wide-angle scattering and diffraction

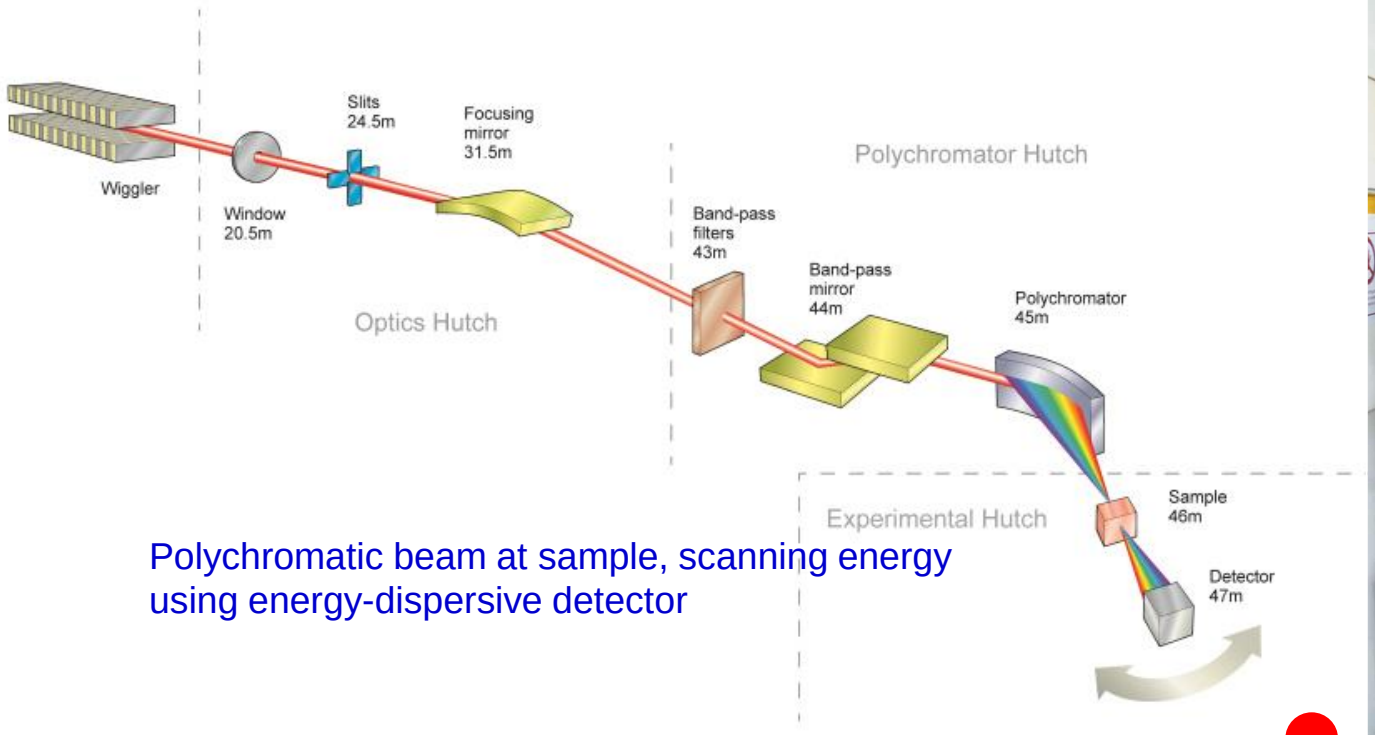

23 elements ED detector
Large sample goniometer
I12 EH1

Spectroscopic beamlines

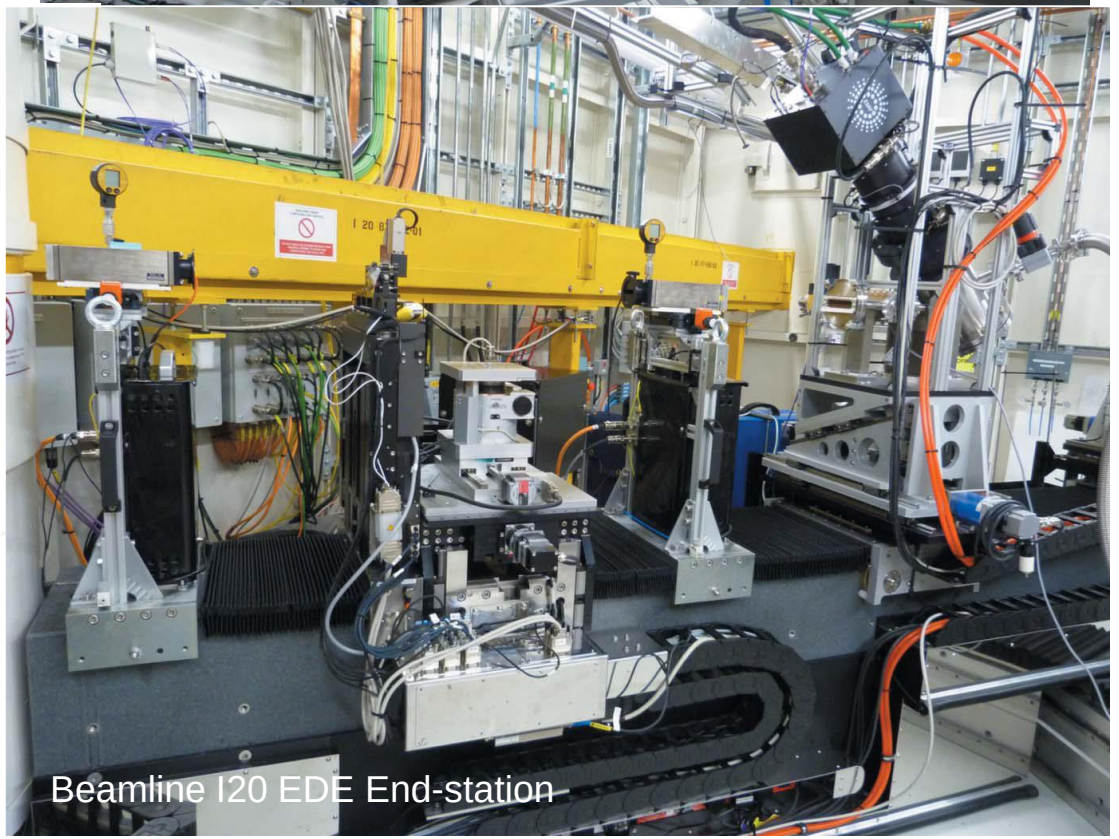


Monochromatic beam at sample, scanning energy using monochromator





Polychromatic beam at sample, scanning energy using energy-dispersive detector



Beamline I20 EDE End-station

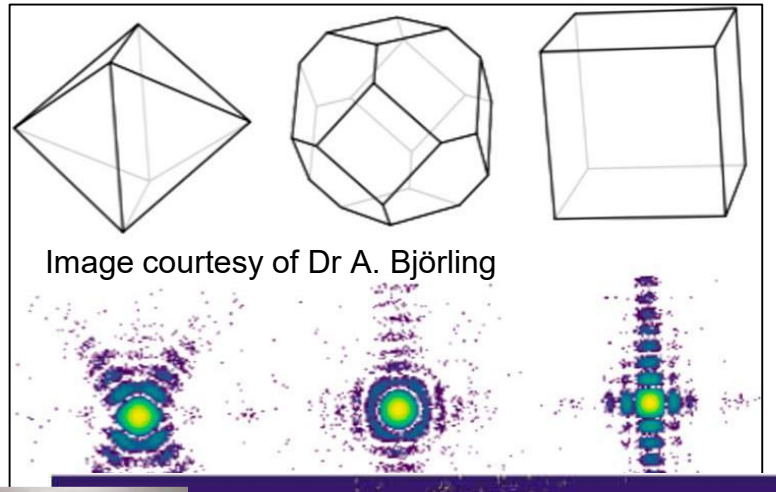
Long Beamlines for X-Ray Imaging and Coherence

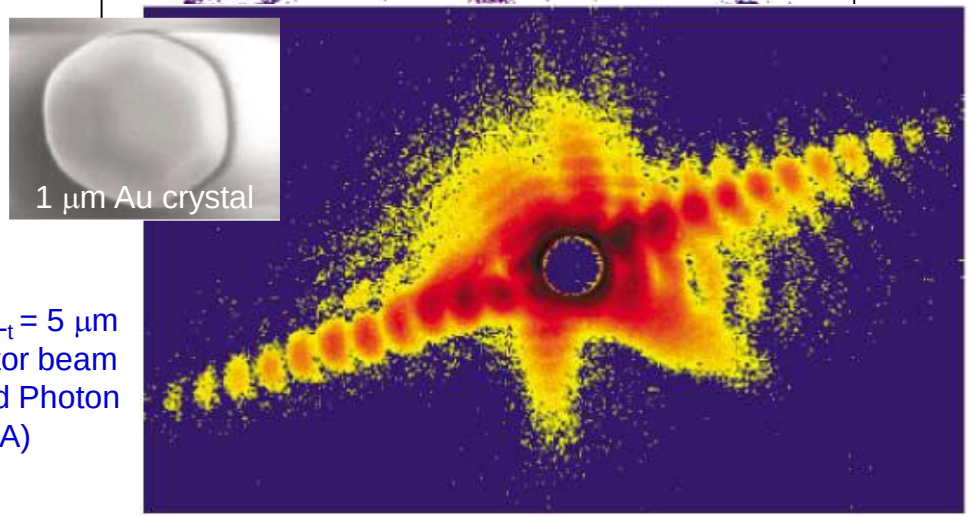
- High spatial resolution X-ray imaging on the micro- and nano-length scale
- Two independent branches: imaging in (i) direct space, (ii) reciprocal space (coherence related experiments).
- Long distance from the source ~ 200 - 1000 m.



Coherent diffraction

Transverse or **spatial** coherent length, $L_t = \lambda D/\sigma$
D = source to sample distance, σ = source size
L_t should be bigger than the sample dimensions



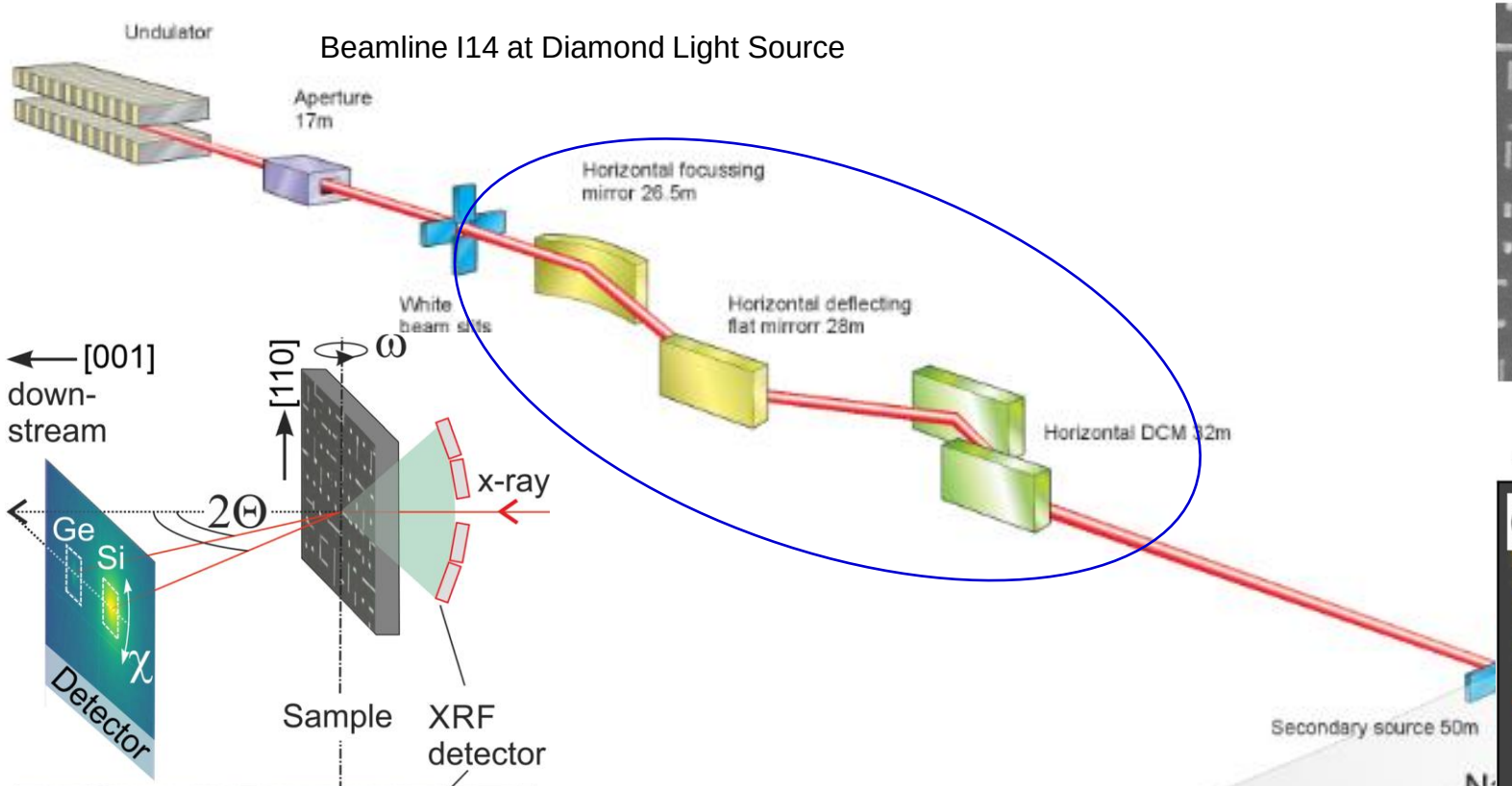


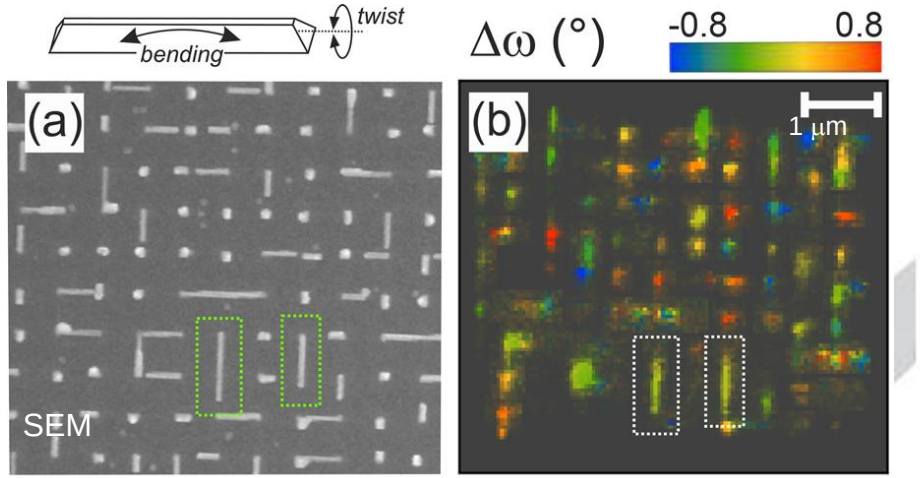
λ= 1.65 Å, L_t = 5 μm and undulator beam at Advanced Photon Source (USA)

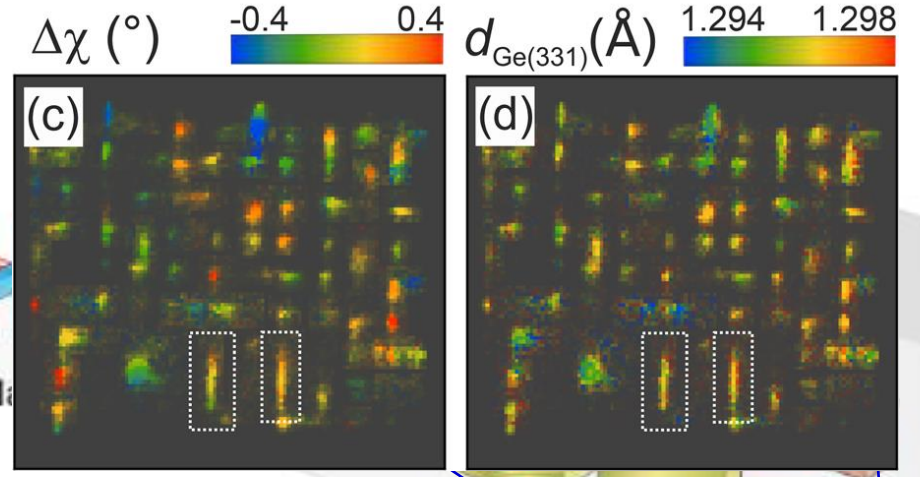
Coherent diffraction pattern of the immediate vicinity of the (111) reflection of a 1 μm gold crystal.
I.K. Robinson et al. (2001), Phys. Rev. Let.

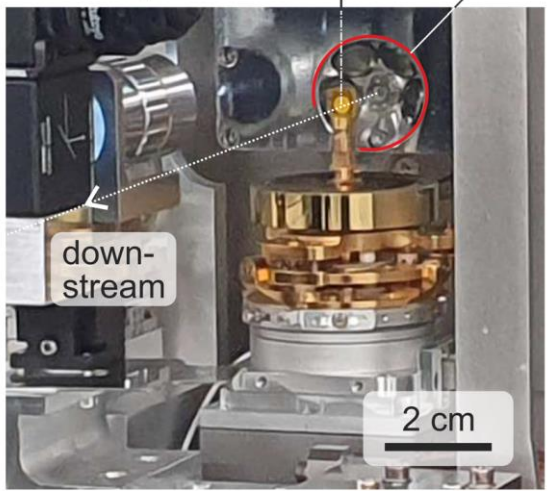
Nanoscience Beamline

Beamline I14 at Diamond Light Source

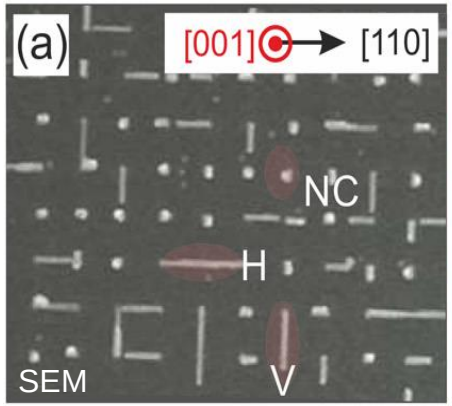


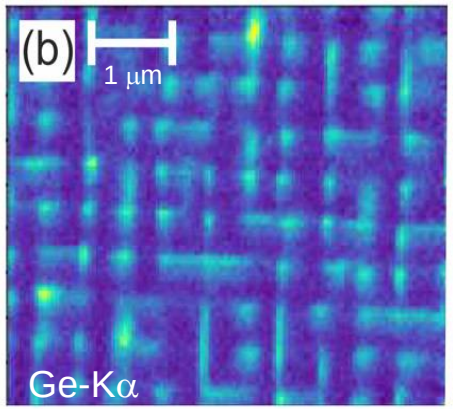


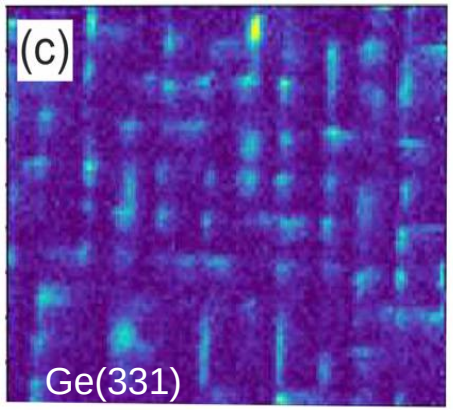


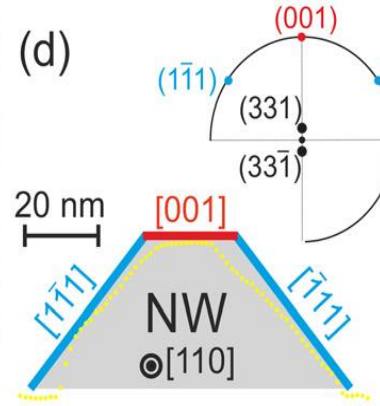


M. Hanke et al (2022), Appl. Phys. Lett.









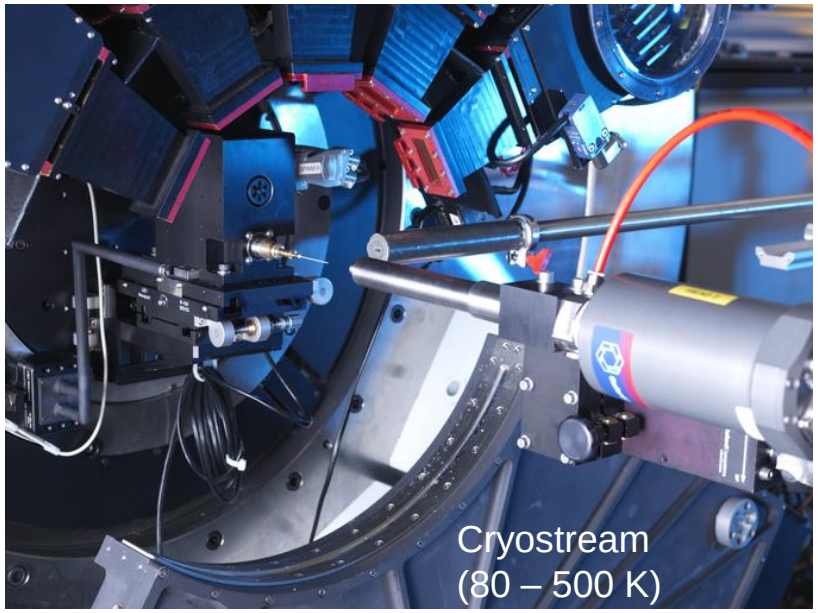
Sample Environments on Beamline
– very important as enhanced capabilities

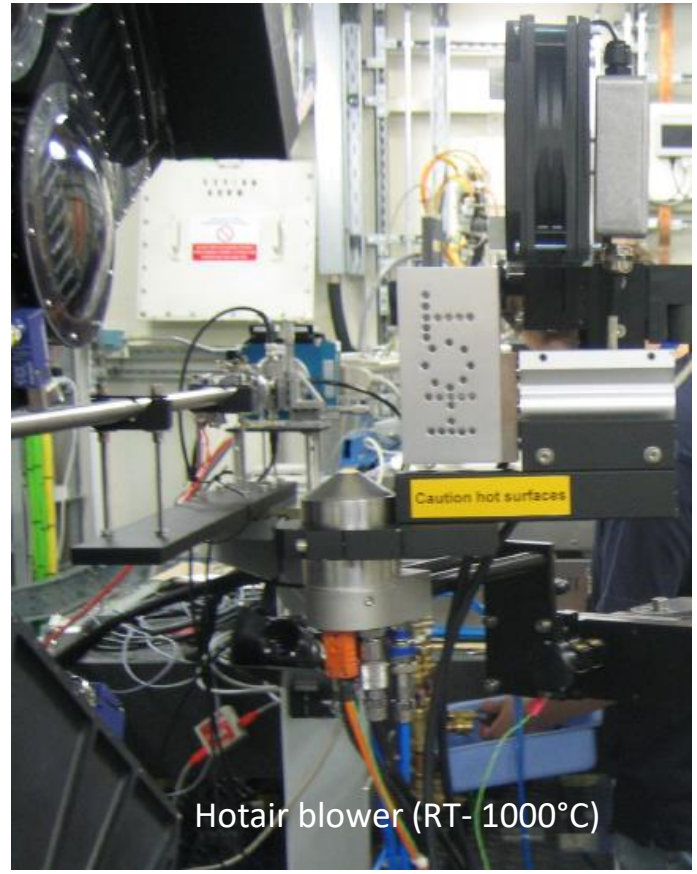
X-ray Detectors

User Control Room/Cabin

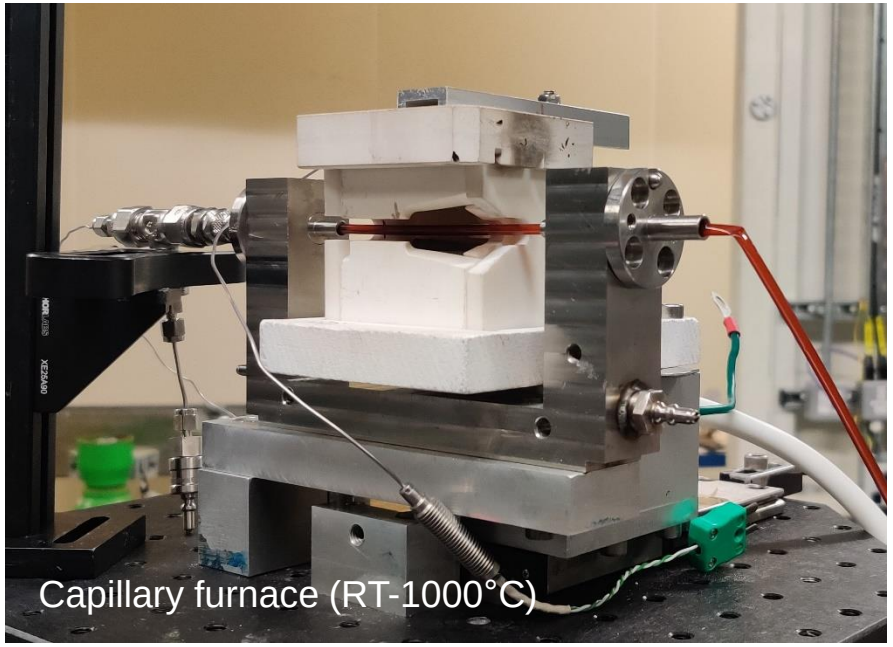
Sample environments and cells – a few examples

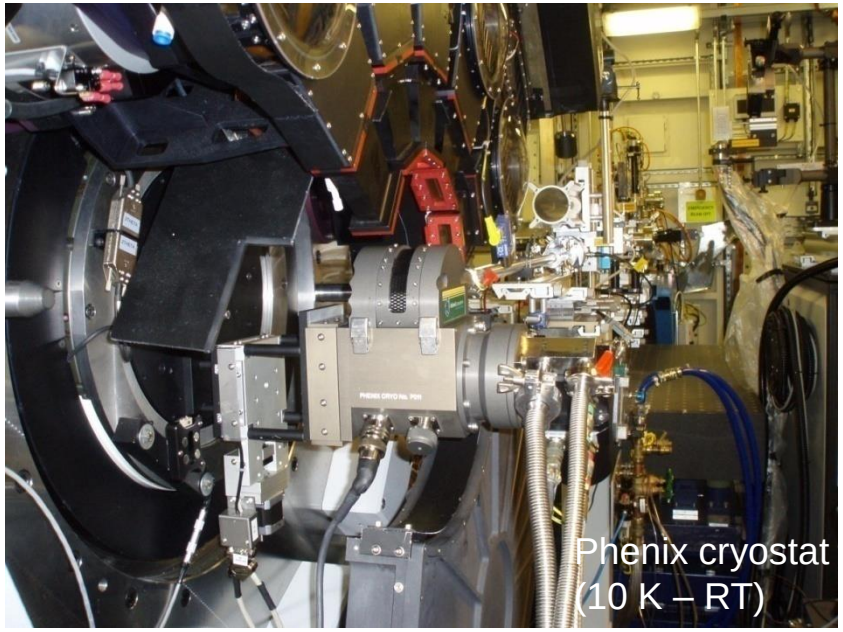
Sample stages	Available
Robotic arm & sample carousel (300 samples)	Yes
Large XYZ table	Yes
Small xyz table	Yes
Tilt and roll stage	Yes
Grazing incident stage (GIXPD)	Yes
Standard sample environments	
Hotair blower (295 – 1273 K)	Yes
LN2 cryostream (80- 500 K)	Yes
Phenix cryostat (11 – 295 K)	Yes
MRI flat-plate furnace (295 – 1700 K)	Yes
Capillary furnace (295 – 1500 K)*	Yes
Cryostat (4 - 295 K)	Comm.
Humidity chamber	Yes

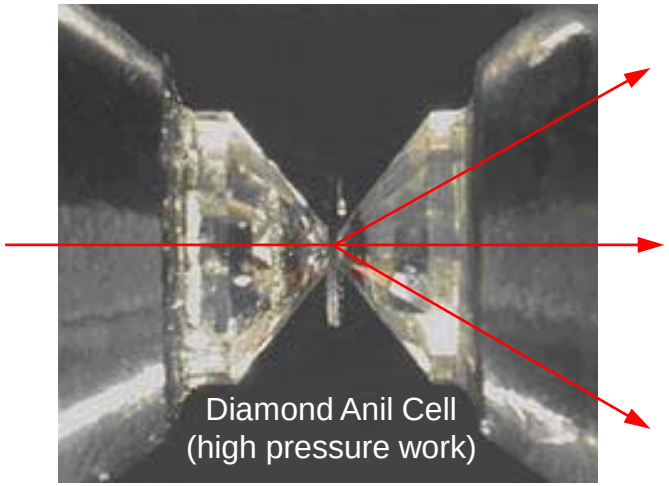

Cryostream
(80 – 500 K)



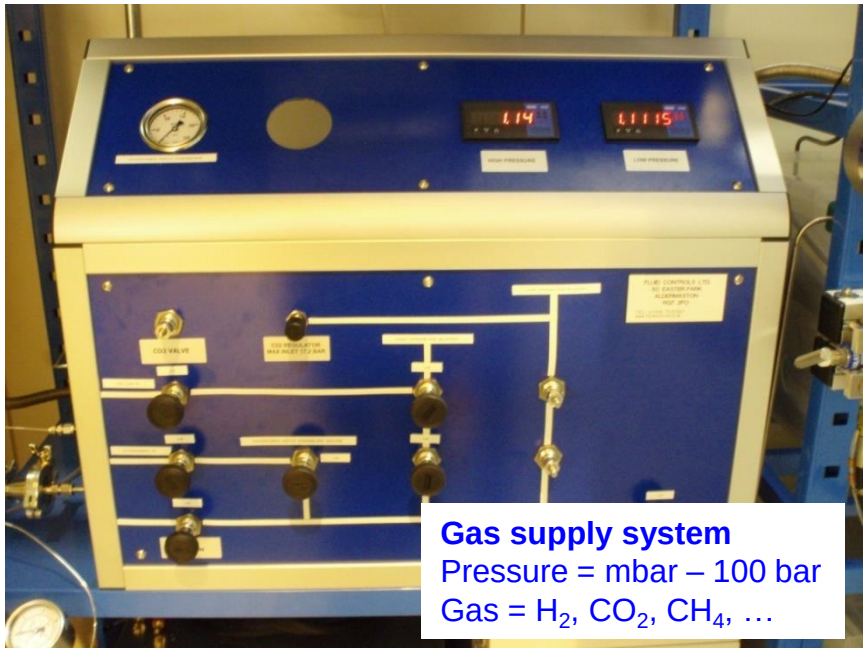
Hotair blower (RT- 1000°C)


Capillary furnace (RT-1000°C)

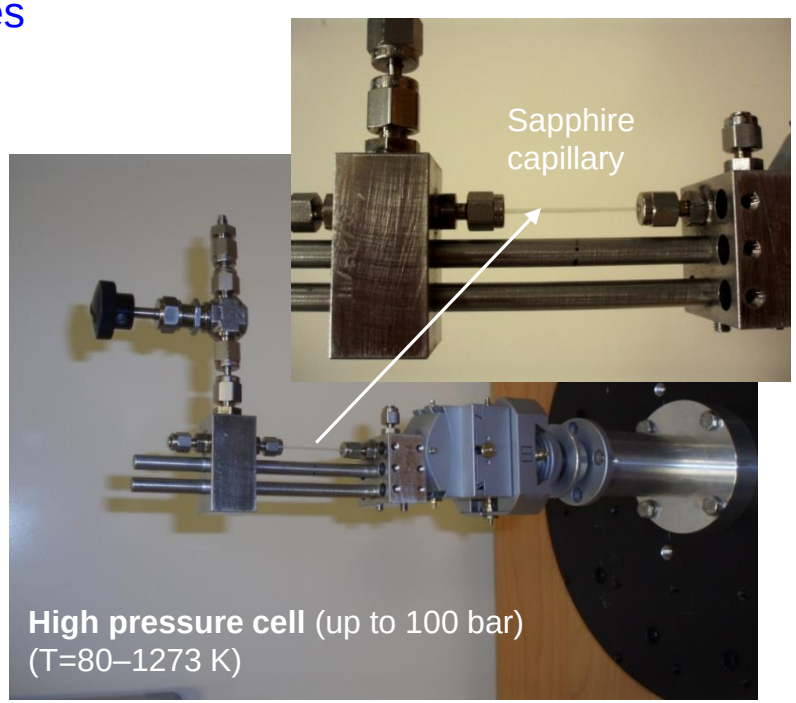

Phenix cryostat
(10 K – RT)


Diamond Anil Cell
(high pressure work)

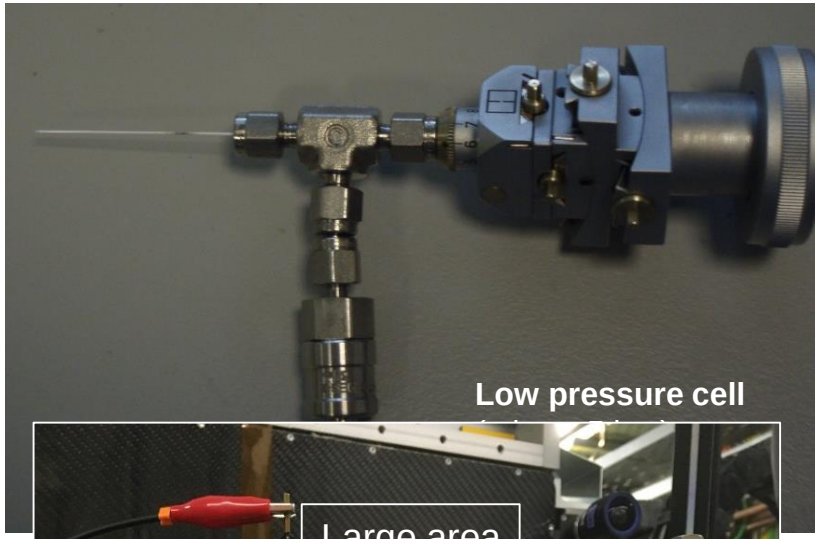
Custom Made Sample Cells – a few examples



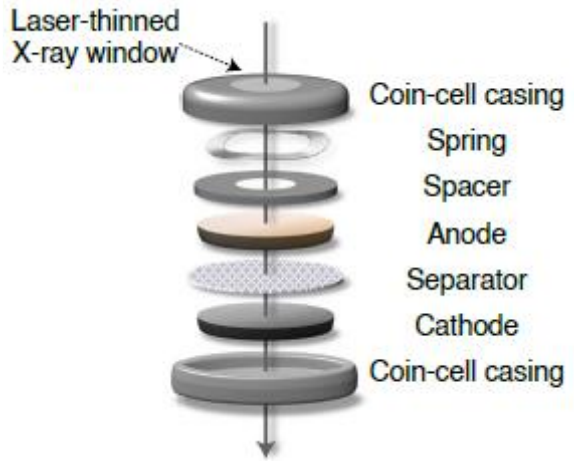
Gas supply system
Pressure = mbar – 100 bar
Gas = H_2, CO_2, CH_4, …



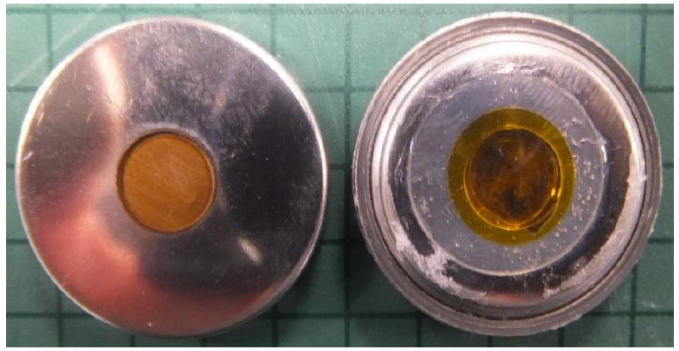
High pressure cell (up to 100 bar)
(T=80–1273 K)



Low pressure cell

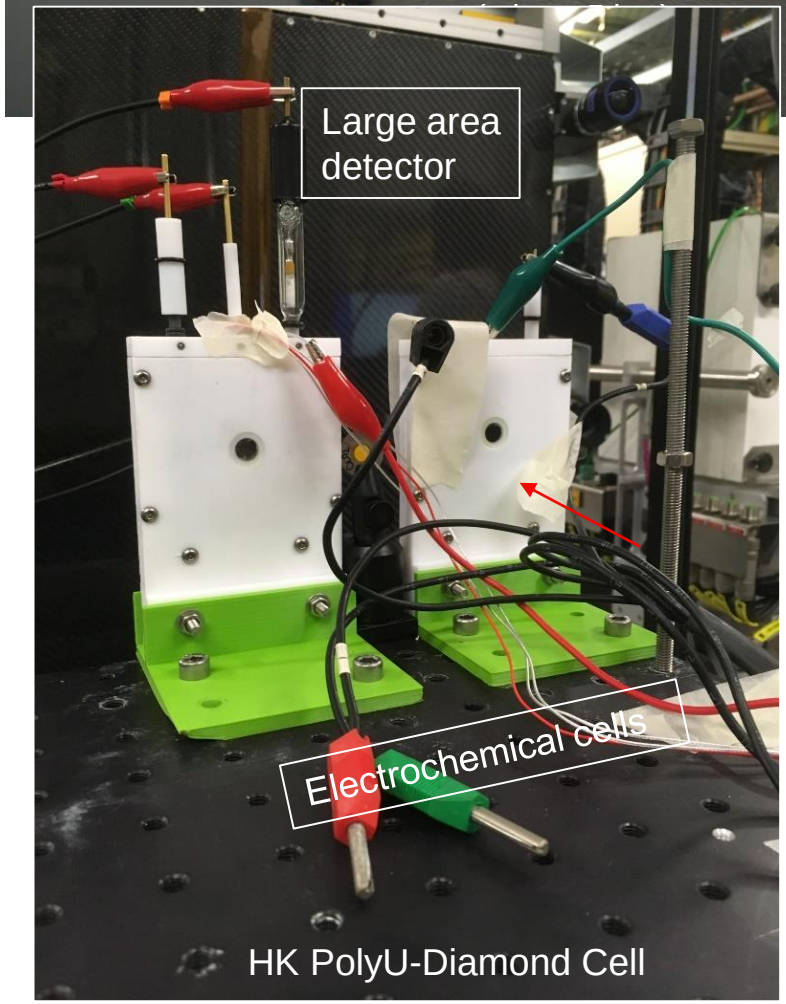


Battery coin cells (CR2032)



Laser thinning: from 300 μm to ~ 50 μm)

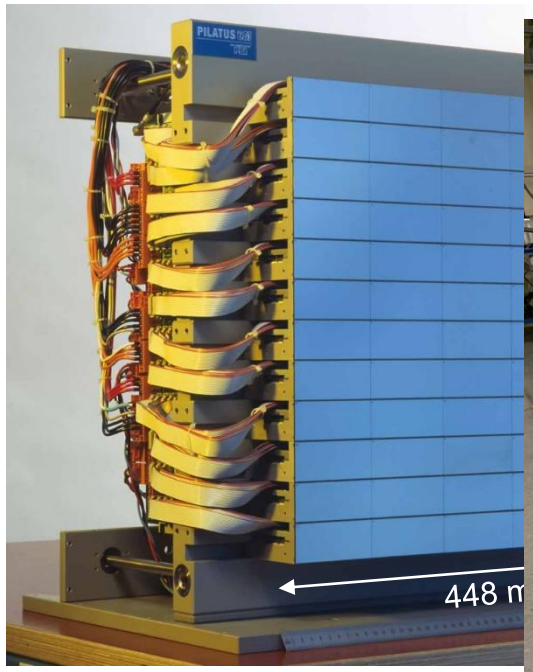
Sapphire + Kap. windows



HK PolyU-Diamond Cell

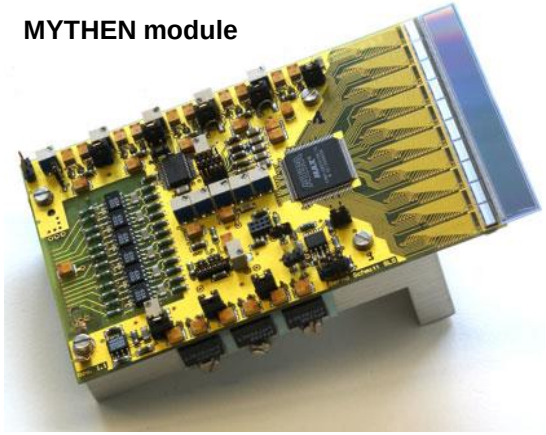
X-ray Detectors

- Highly specialised technology
- Constantly developing in SR facilities and commercial companies
- There are several types of detectors used for X-ray detection.
  (i) Proportional (gas filled)
  (ii) Scintillation
  (iii) Semiconductor
  (iv) Position Sensitive and charge-coupling detector (CCD)
  (v) Others

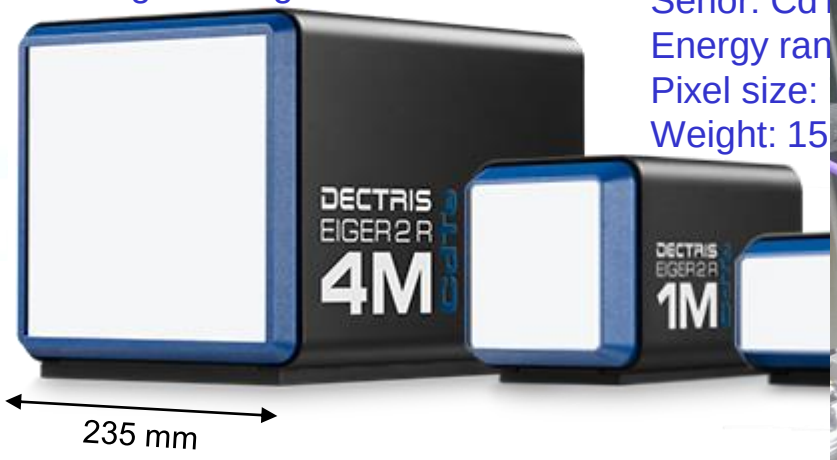




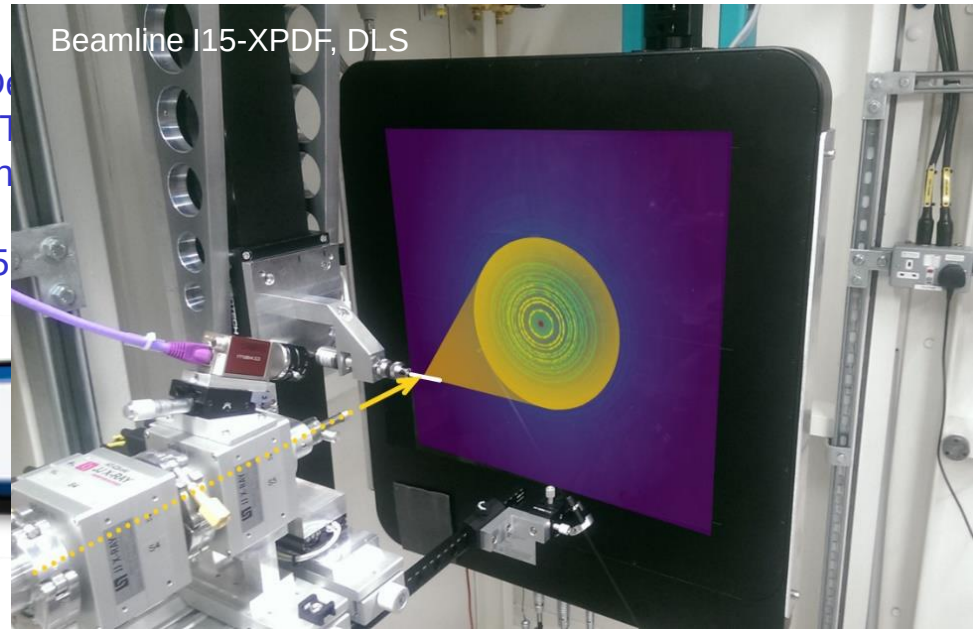
Pilatus 6M Detector System
Senor: Si
Energy range: 4 – 18 keV
Pixel size: 172 x 172 μm^2
Weight: 95 kg



Mythen-2 module (Swiss Ligth Source)
Size: 8mm (width) x 64 mm (length),
Strip size: 50 μm (pitch)
Max count rate: ~5 MHz max rate.
Resolution: $\Delta 2\theta$ ~ **0.004º** (intrinsic) at 700 mm from sample.

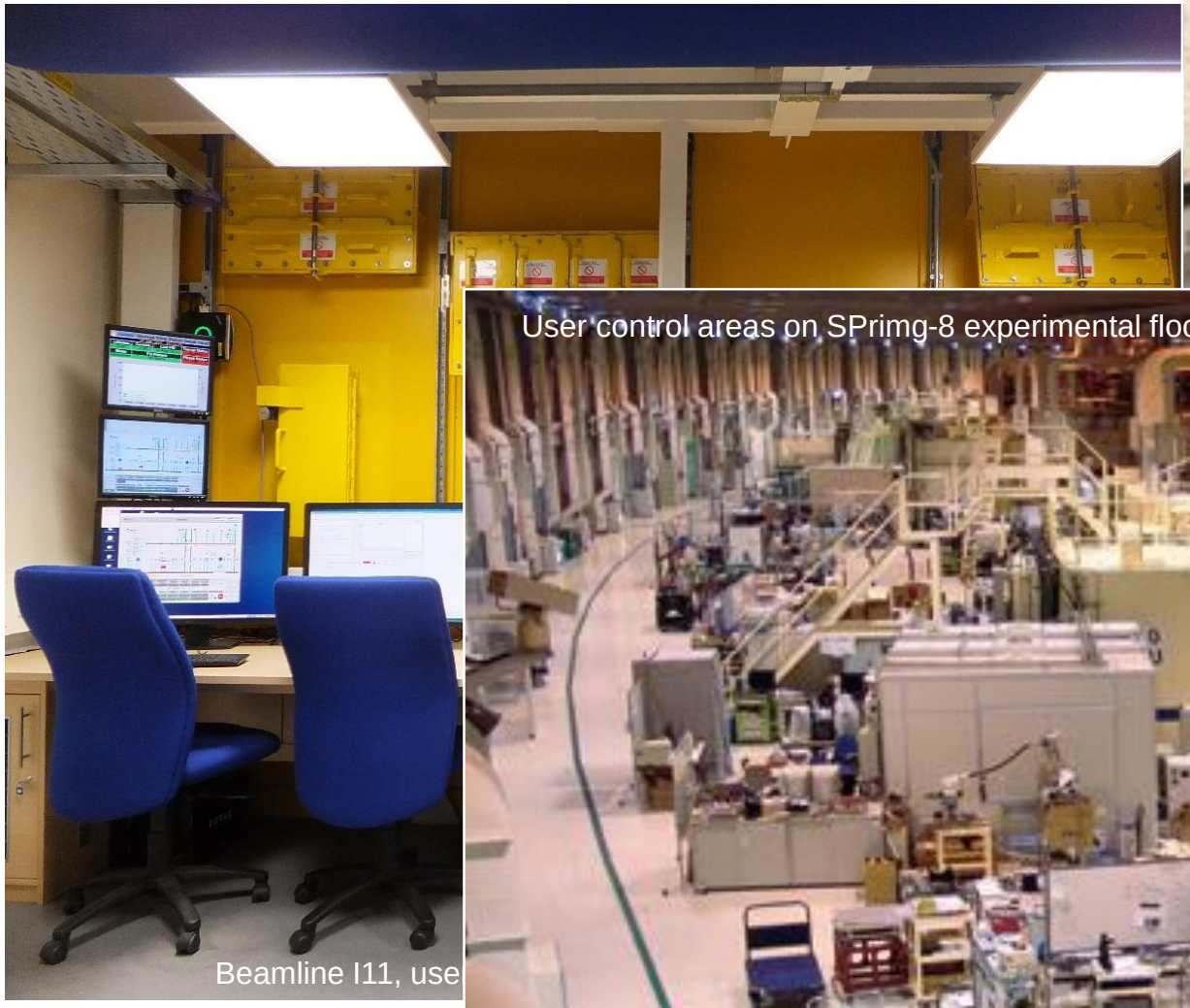


EIGER2 D
Senor: CdT
Energy ran
Pixel size:
Weight: 15



User Control Room(s) or Area





Beamline I11, use

User control areas on SPrimg-8 experimental floor



Synchrotron)

Summary

Introduction –

- Fundamentals and Concept of SR Beamlines
- Different techniques and beamlines

Beamline Designs

- Project, timeline, designed feature and specifications

Beamline major components

- Photon beam sources
- X-ray hutches
- Optical elements (monochromator, mirrors and refractive lenses
- Experimental end-stations (a few examples of instruments)
- Detectors, sample environments and user control rooms

Thank you for your attention.