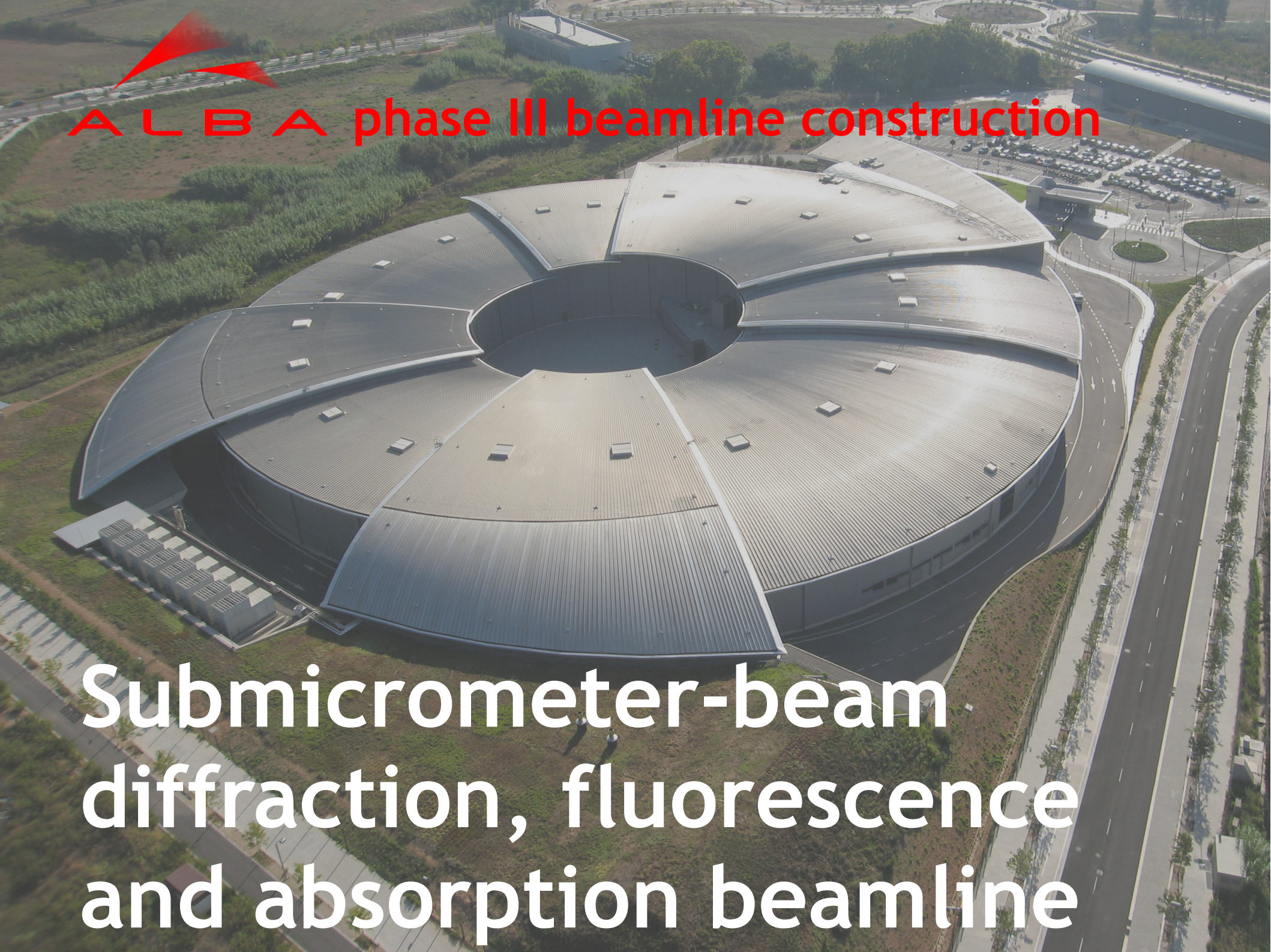




ALBA phase III beamline construction

Submicrometer-beam
diffraction, fluorescence
and absorption beamline

Gema Martínez-Criado

Andrés Cantarero

Mari Cruz García

Fernando Garrido

Julio Pellicer-Porres

Adela Muñoz-Páez

Víctor López-Flores

ESRF (Grenoble, France)

University of Valencia

IEM - CSIC (Madrid)

MNCN - CSIC (Madrid)

University of Valencia

University of Sevilla

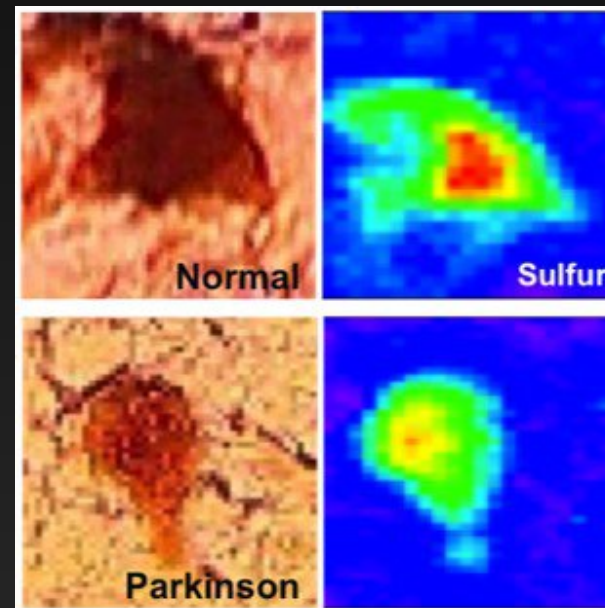
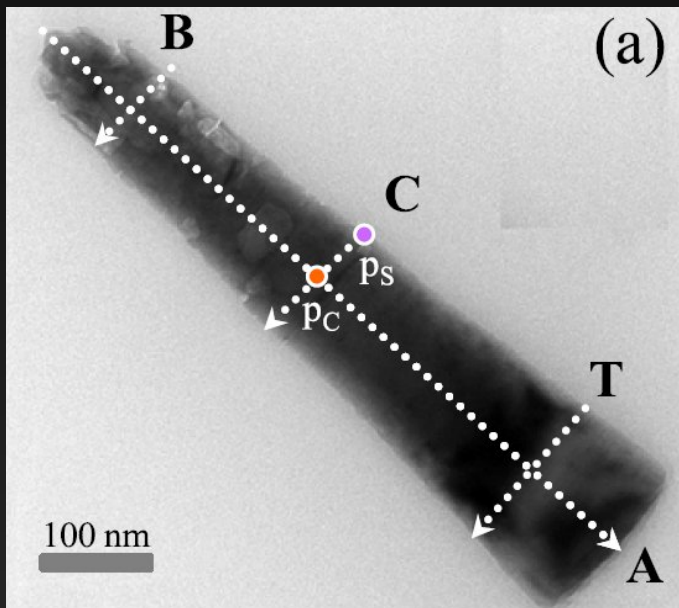
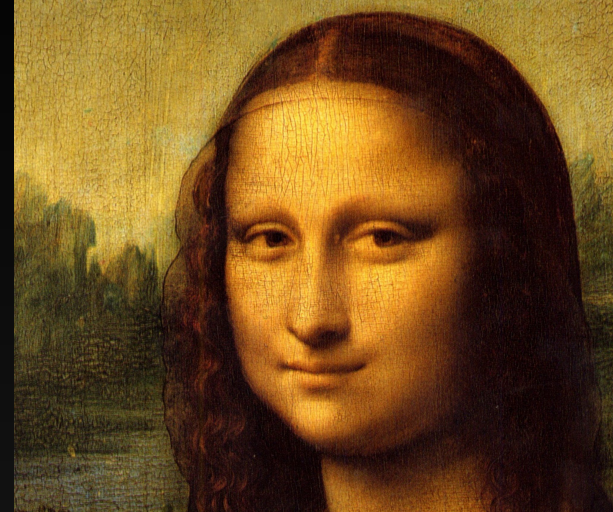
SOLEIL (Paris, France)

Josep Nicolas
Laura Simonelli

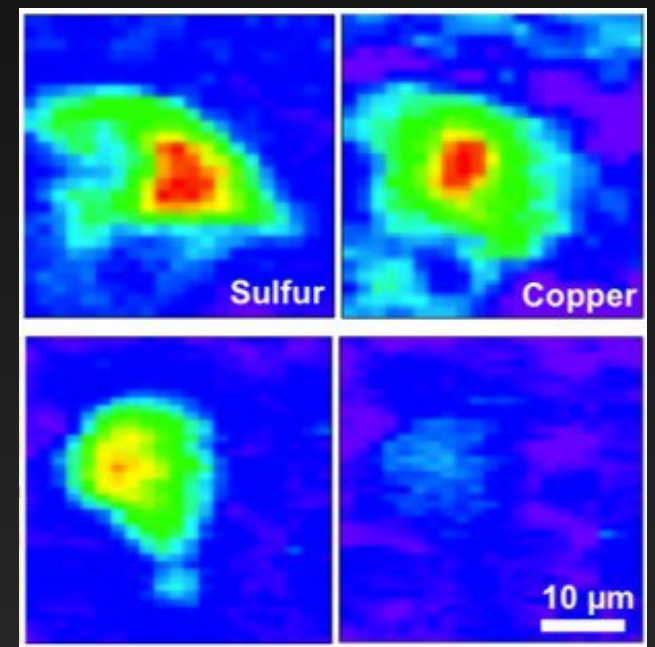
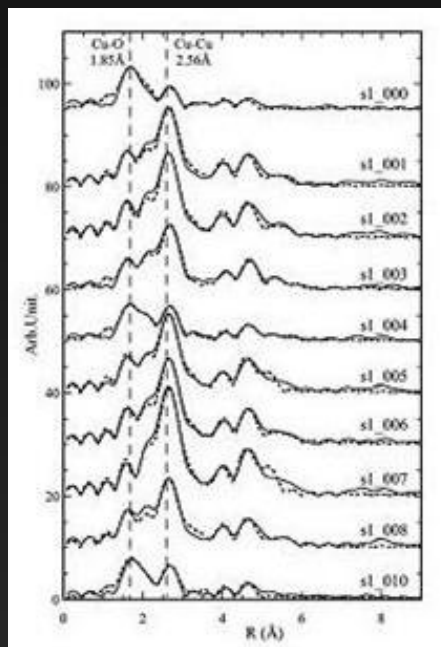
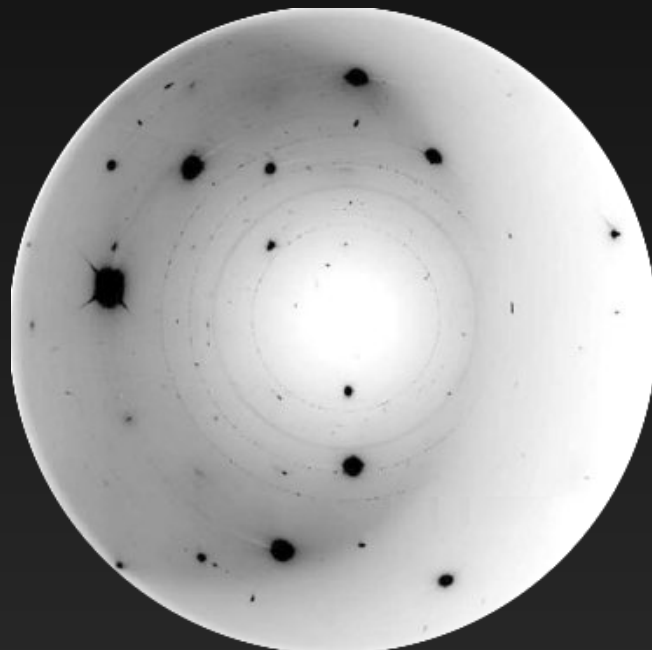
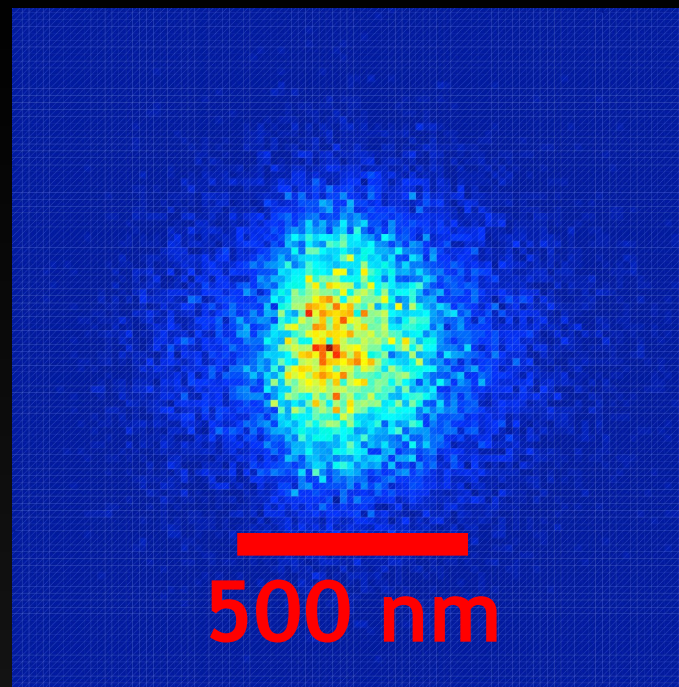
ALBA synchrotron

Heterogeneity

Real samples



Submicrometer-beam diffraction, fluorescence and absorption beamline



Scientific cases



A green rounded square icon featuring a white hammer and a rock.

**Earth and
environment**

A yellow rounded square icon featuring a white silhouette of a woman's head and shoulders.

**Cultural
heritage**

A red rounded square icon featuring a white molecular structure with three nodes and connecting lines.

Materials
Hard / Soft

A blue rounded square icon featuring a white DNA double helix structure.

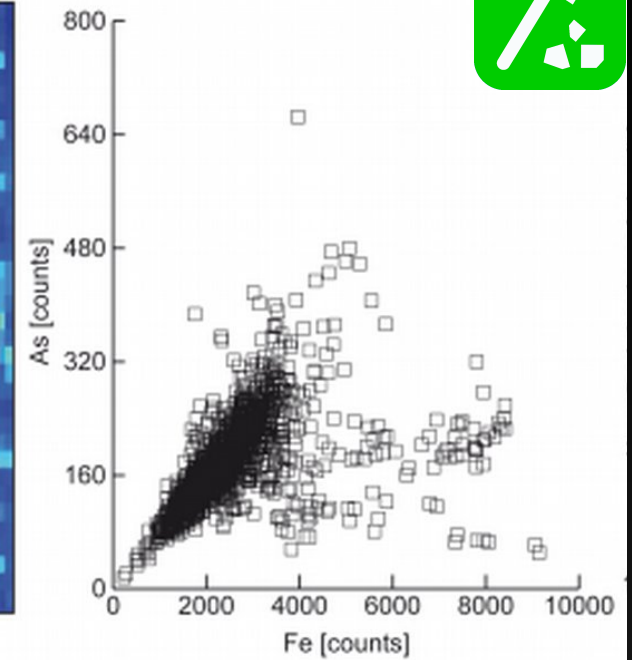
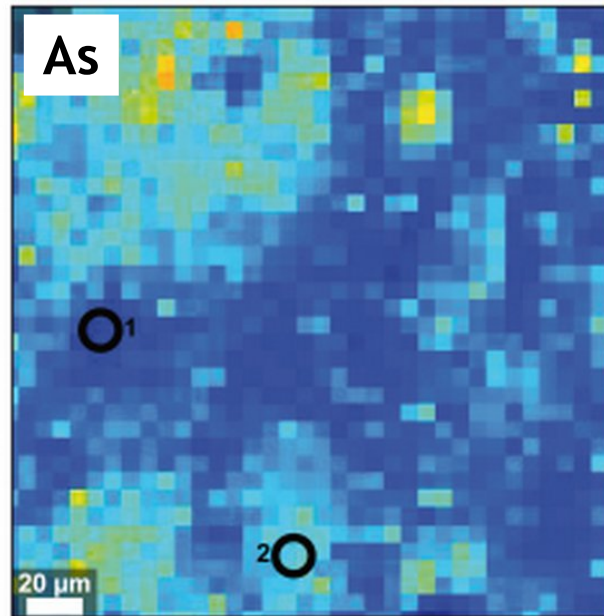
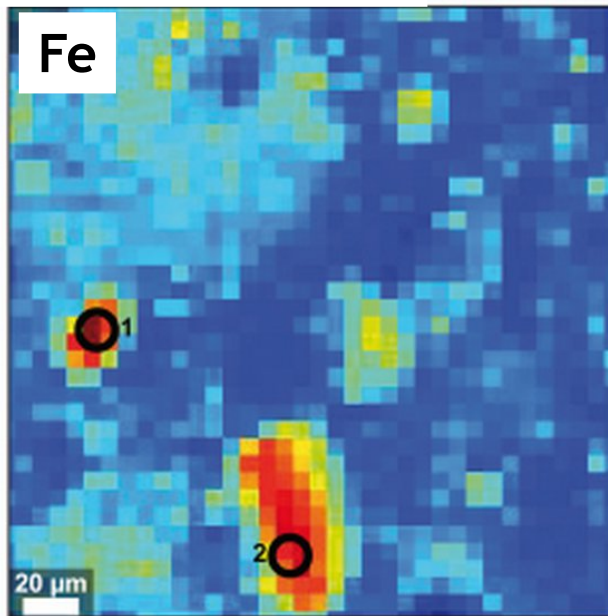
**Bio-medicine/
environment**



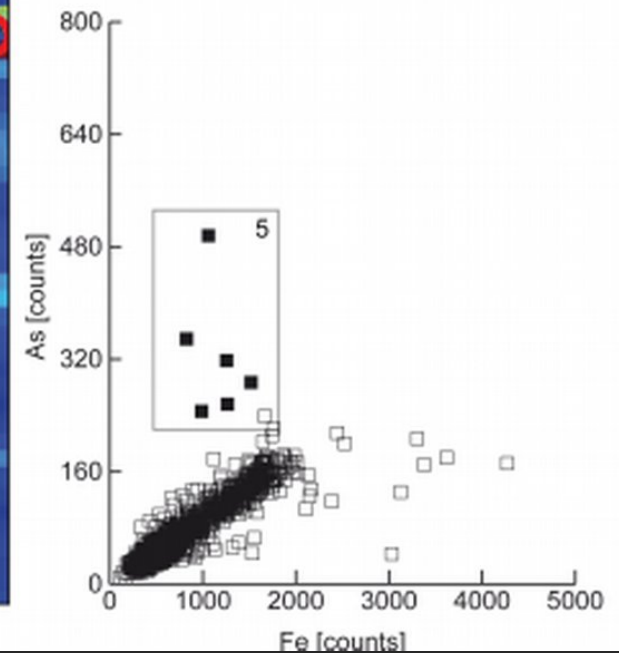
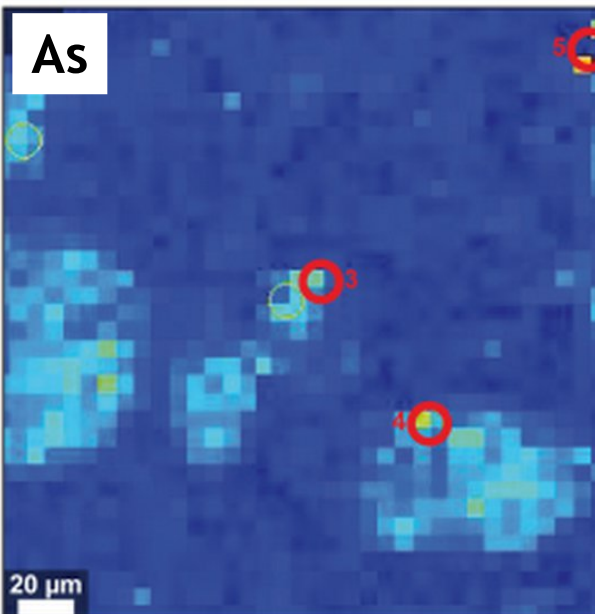
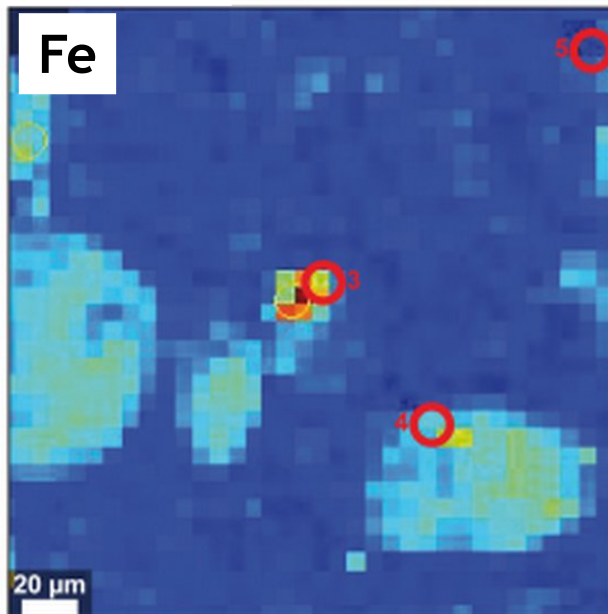
Earth and environment

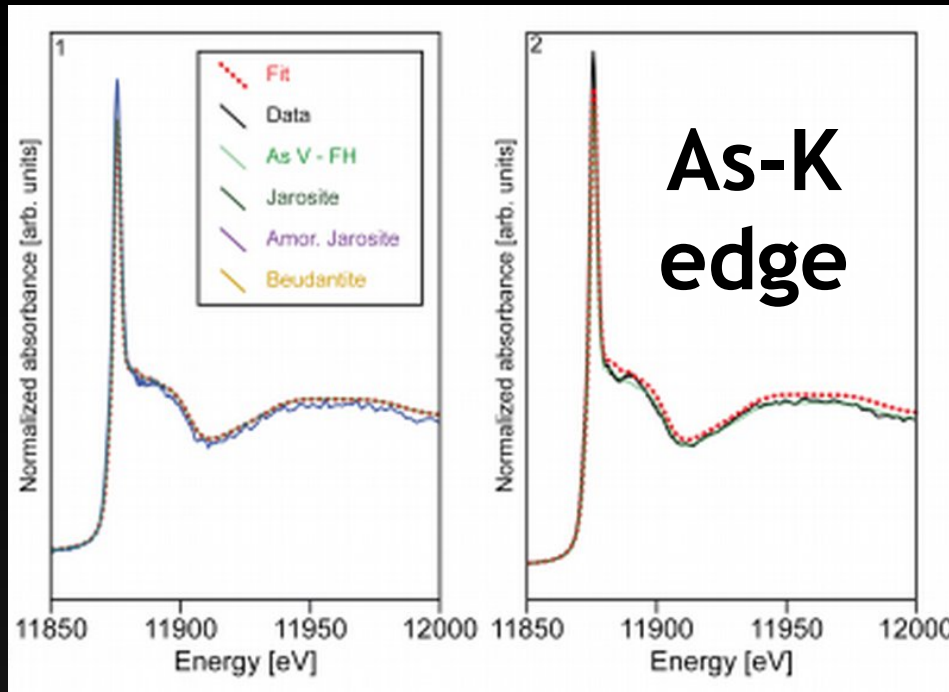
Mineralogy and petrology chemistry
Interface and surface geochemistry
Trace element contamination

Preferential Flow sediment

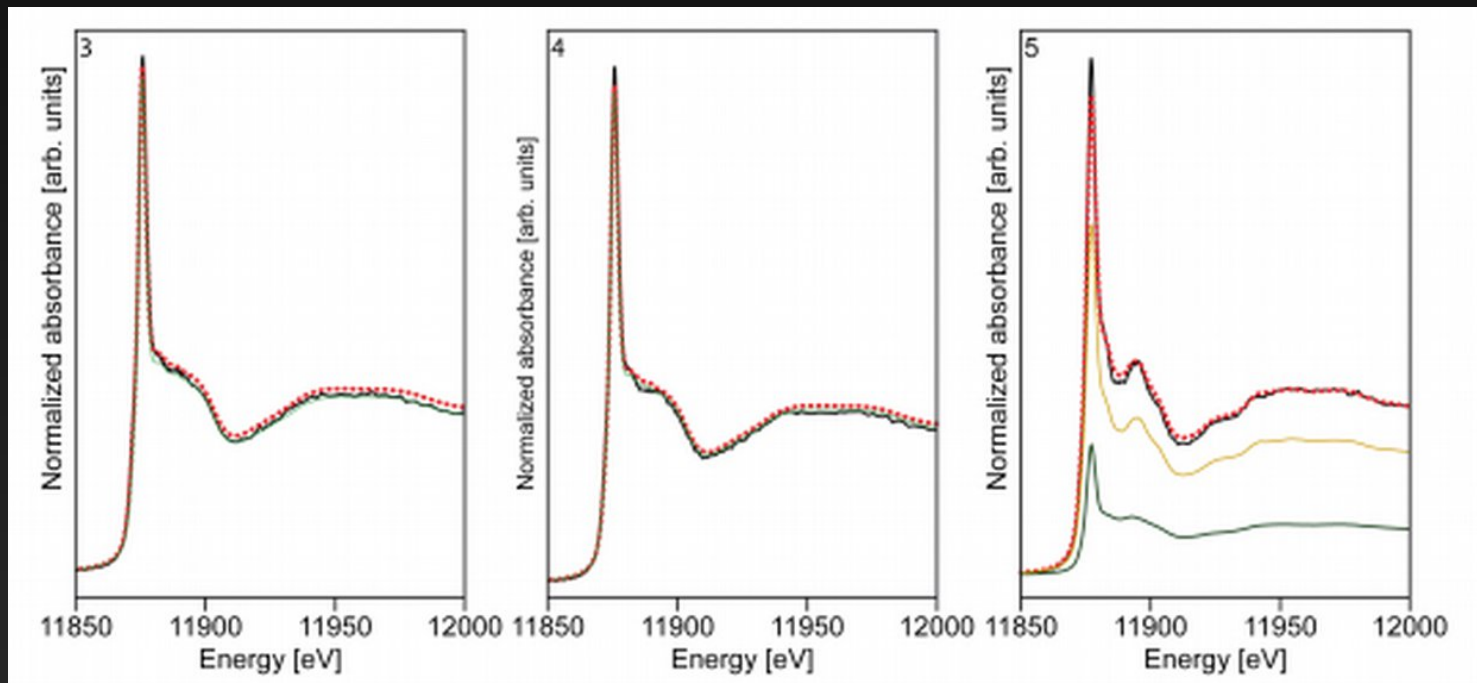


Matrix sediment





As @
ferrihydrite





Earth and environment

High social impact

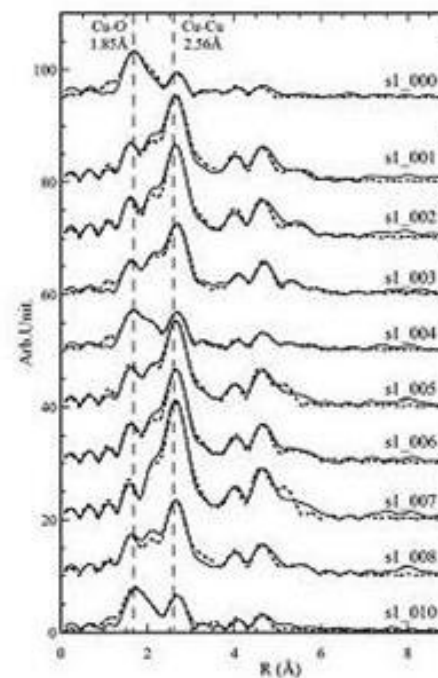
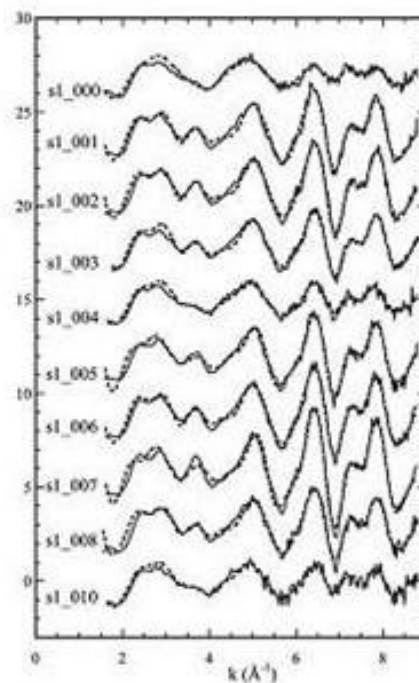
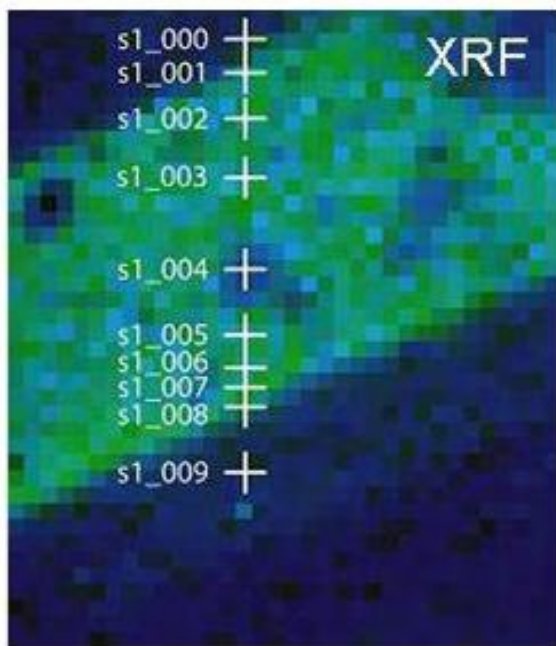
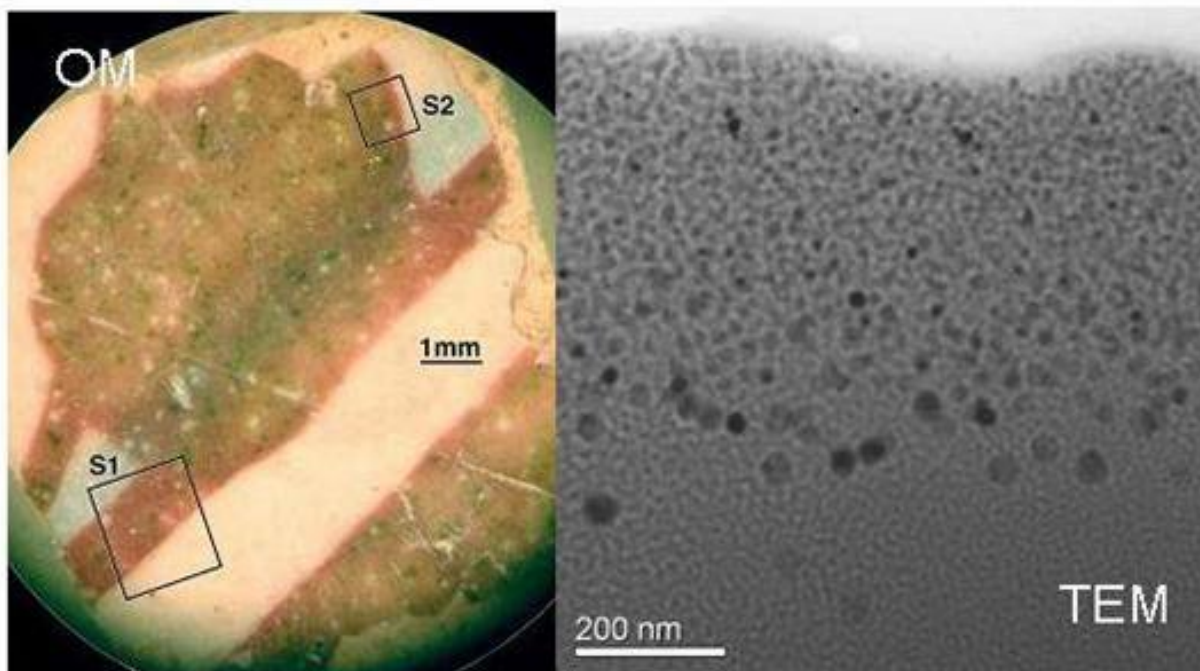


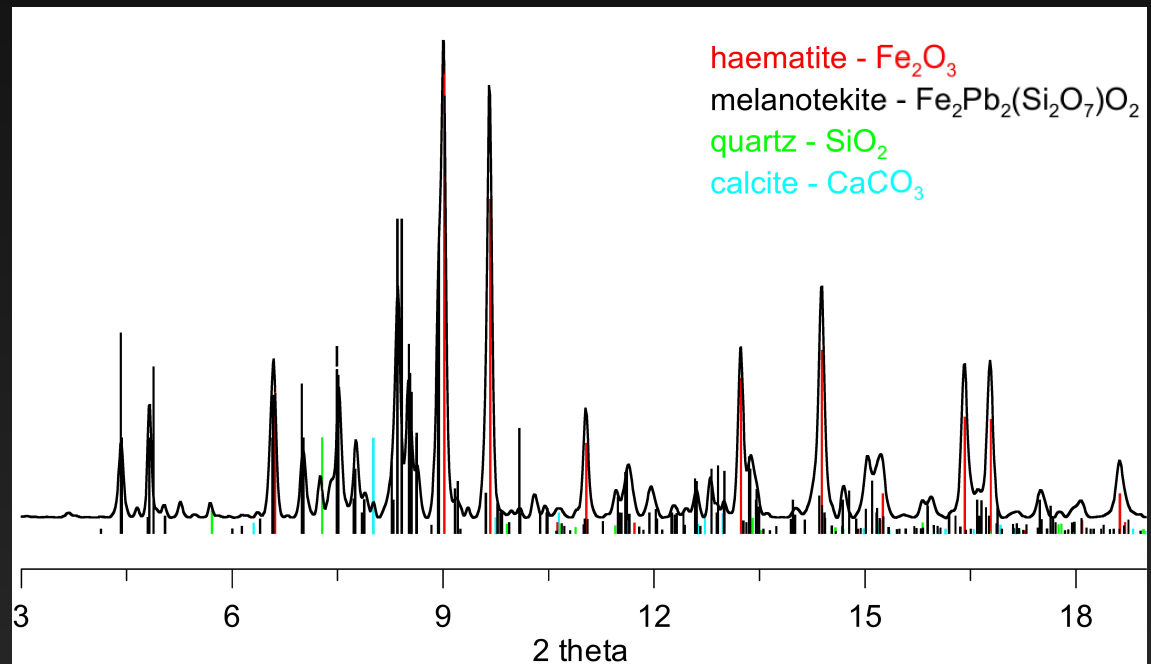
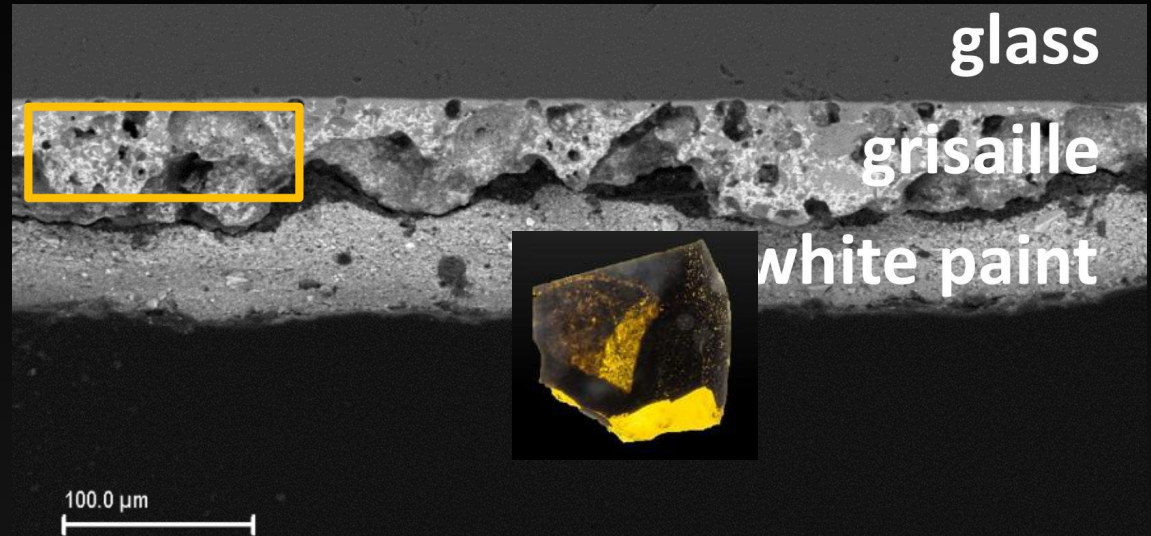
Cultural heritage

Identify components and process (date)
Evaluate alteration (restore)
Non destructive methods



Cu NPs in 13th Cent. “lustre” coating







Cultural heritage

High visibility

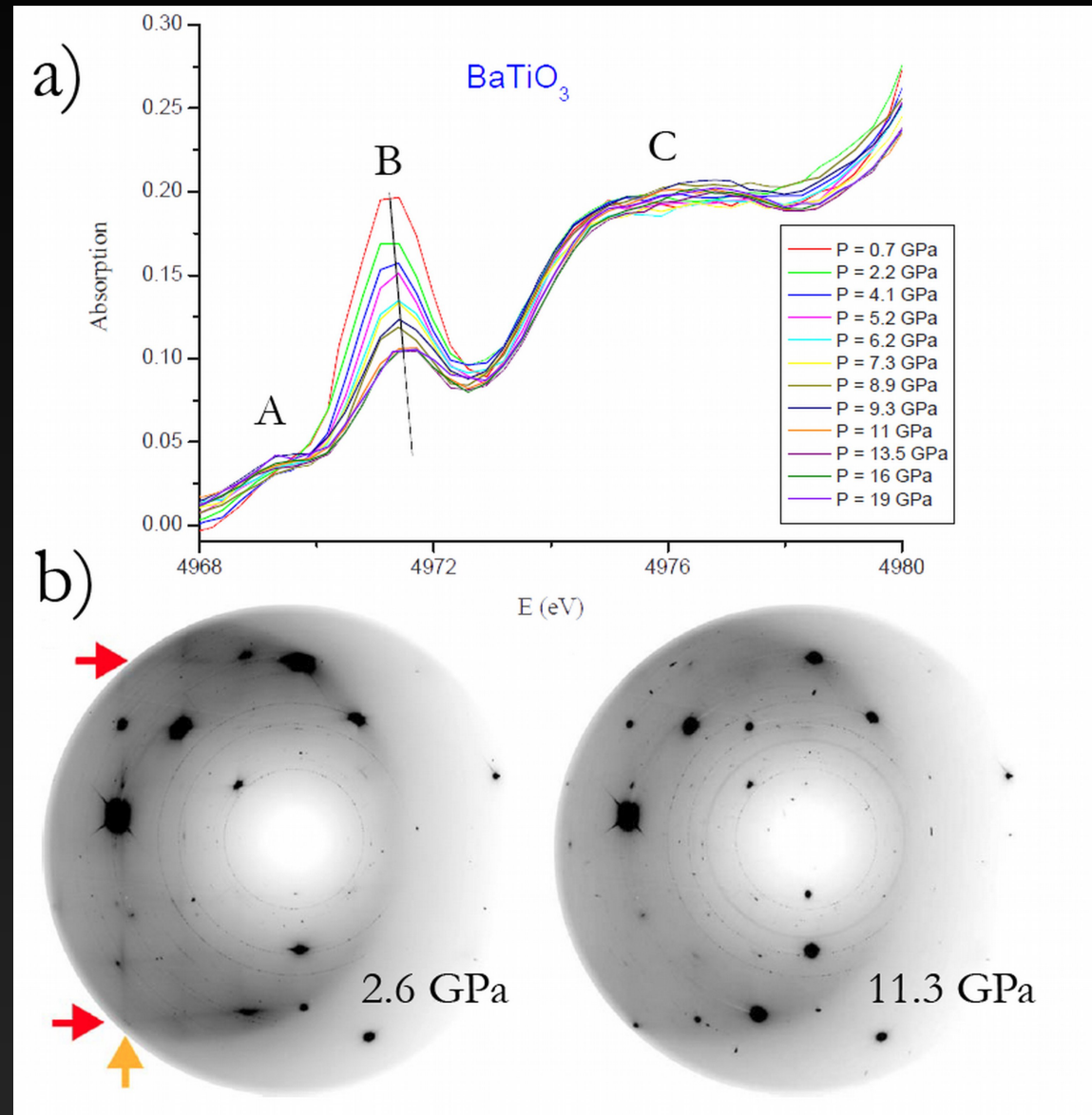
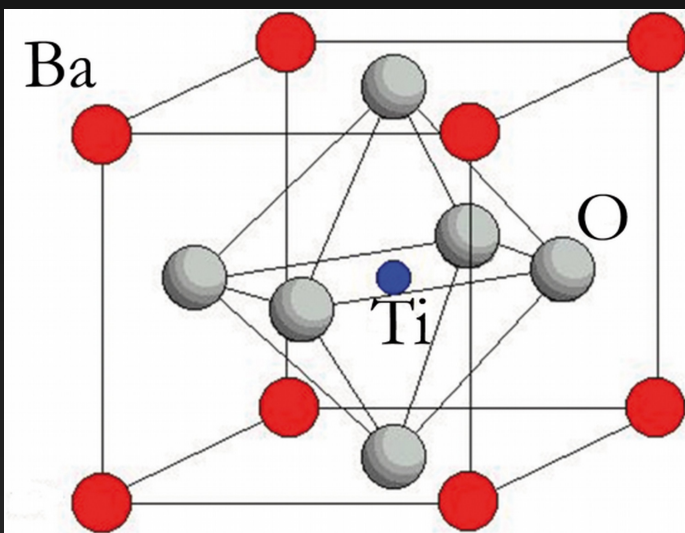
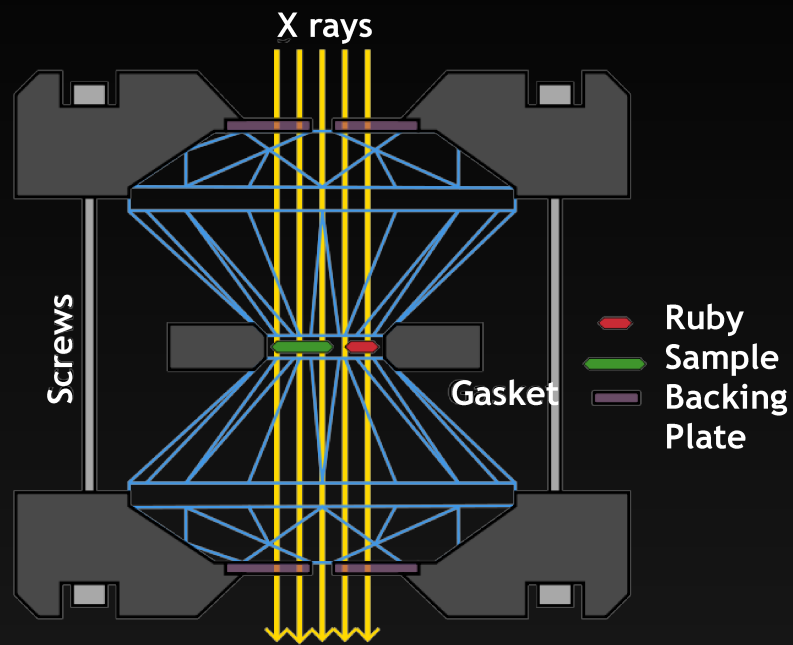


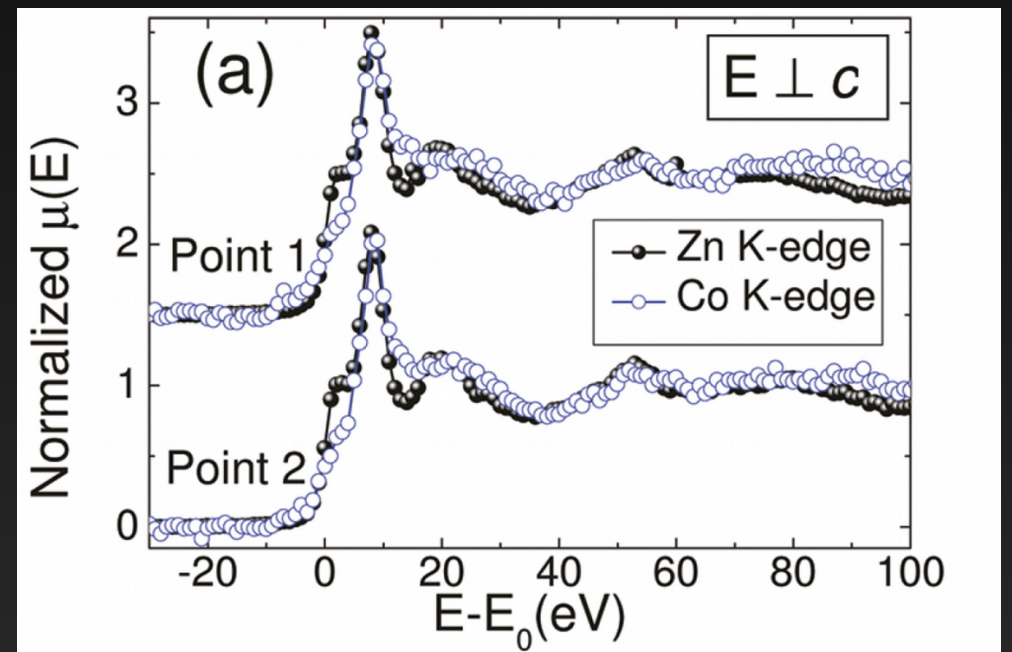
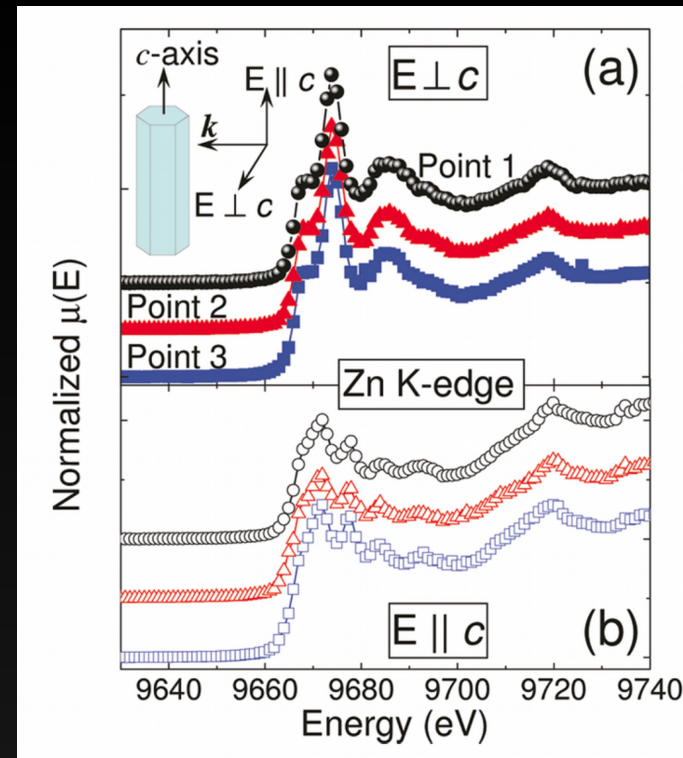
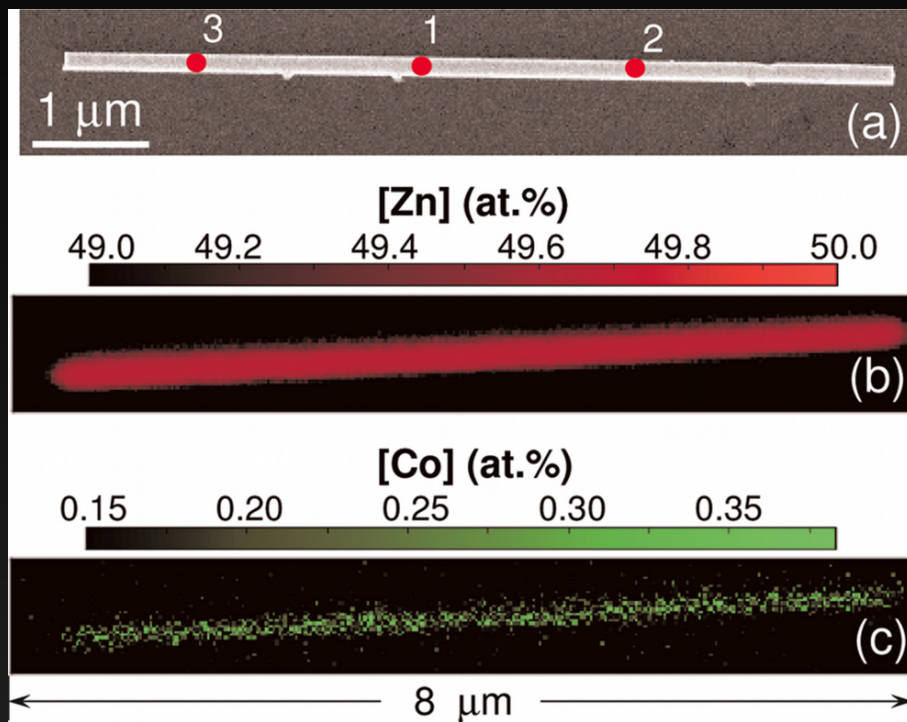
Materials

Characterise new materials
Heterogeneous
Micrometric



Hard condensed matter

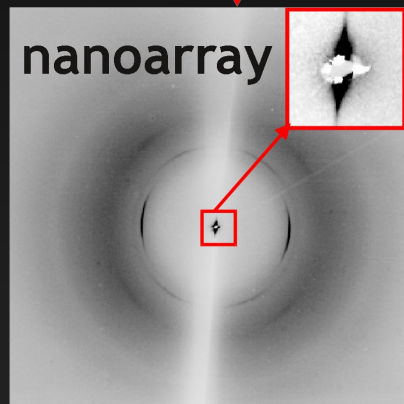
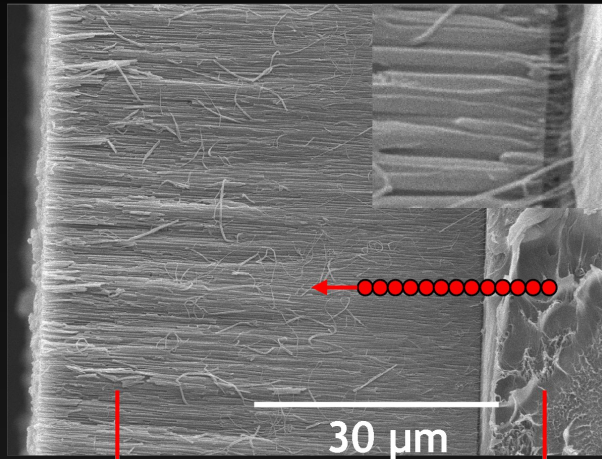
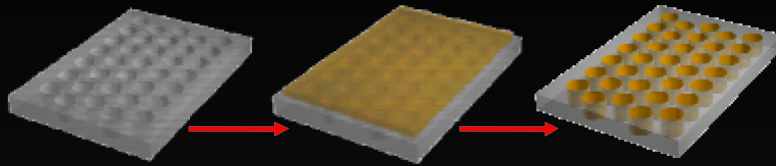




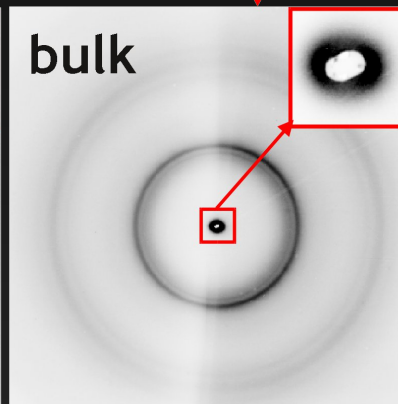


Soft condensed matter

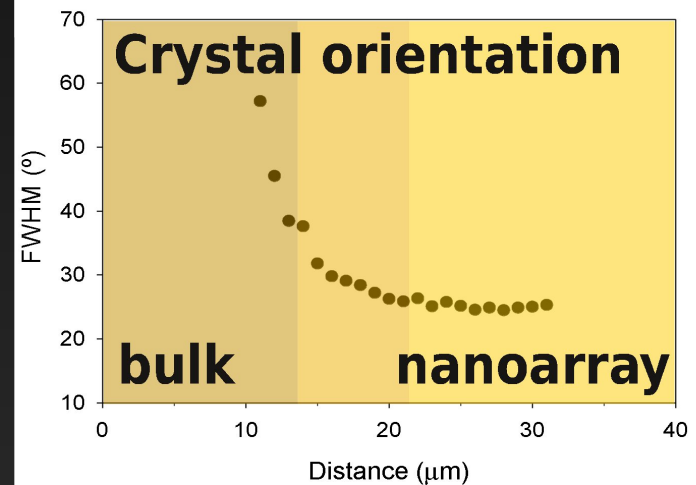
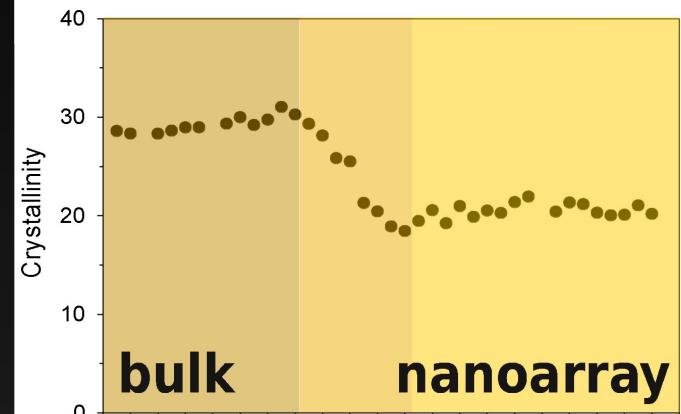
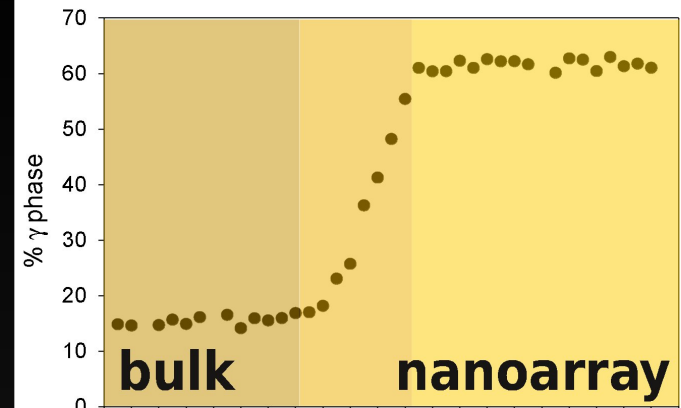
PVDF



**γ form
ferroelectric**



**α form
paraelectric**





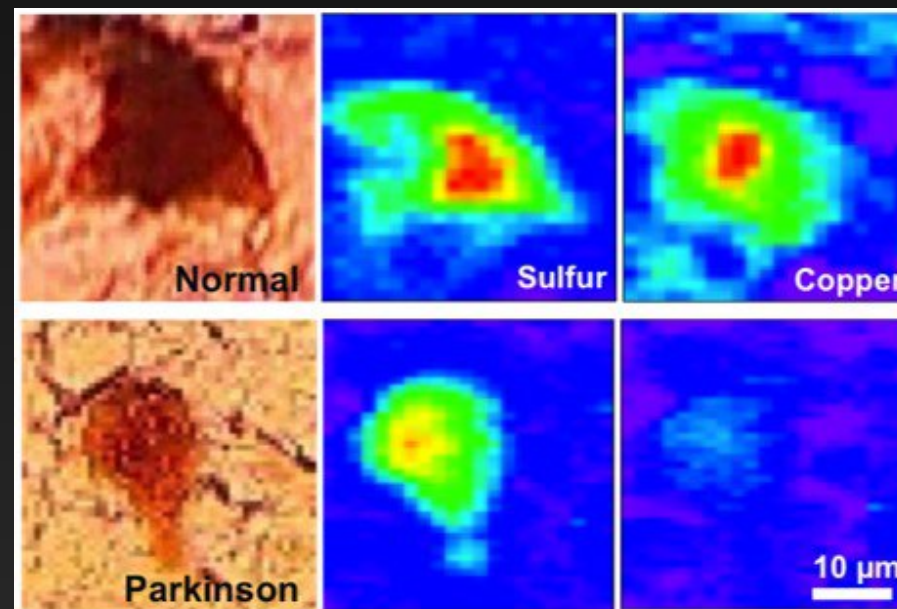
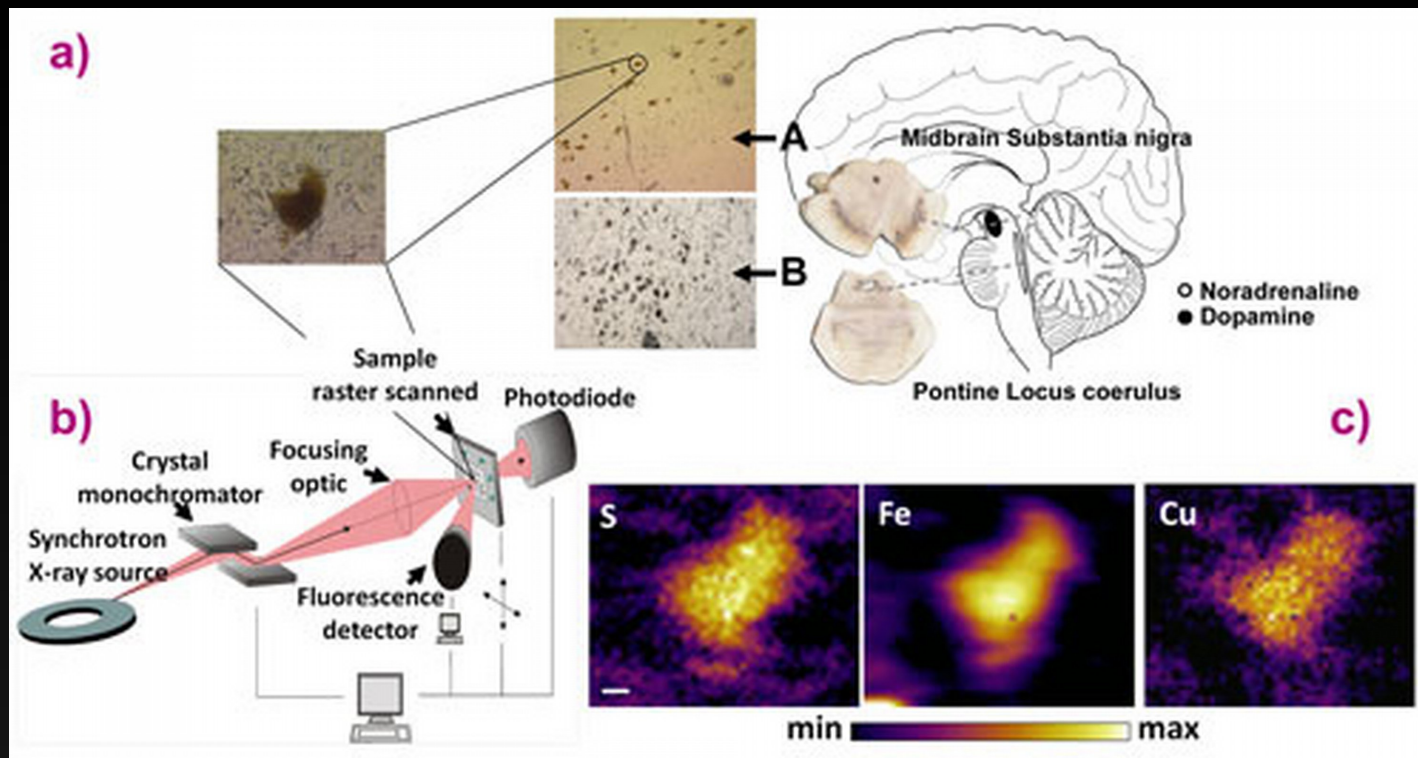
Materials

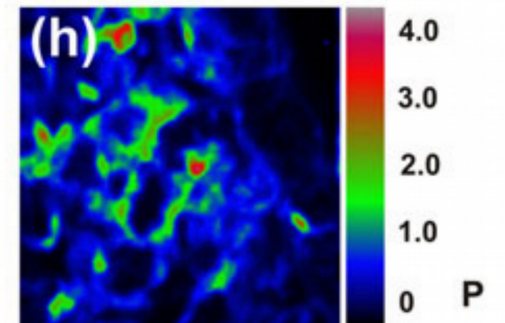
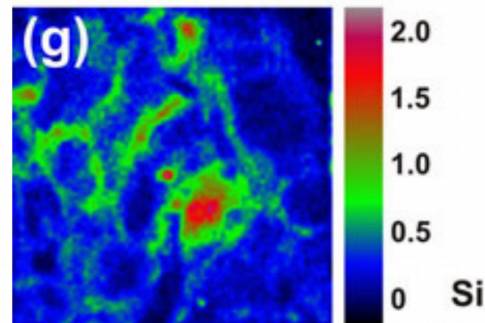
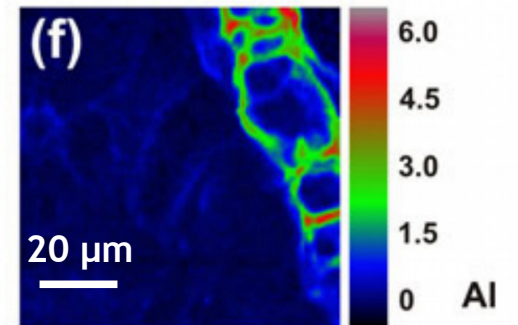
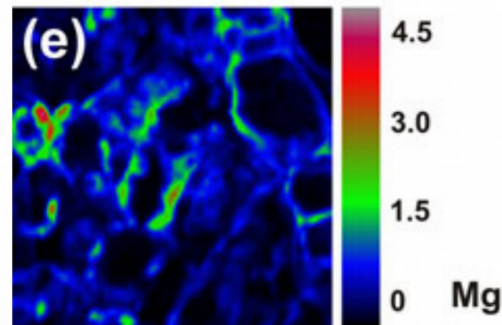
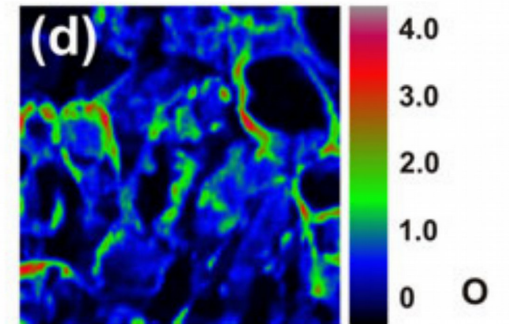
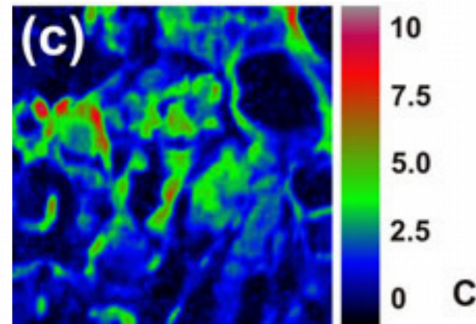
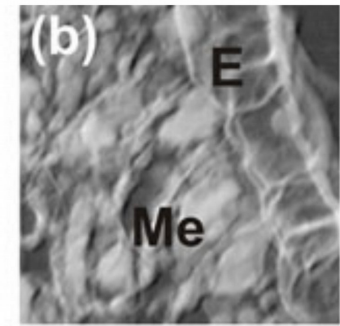
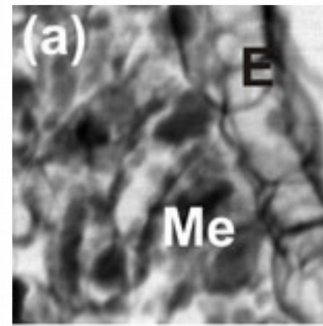
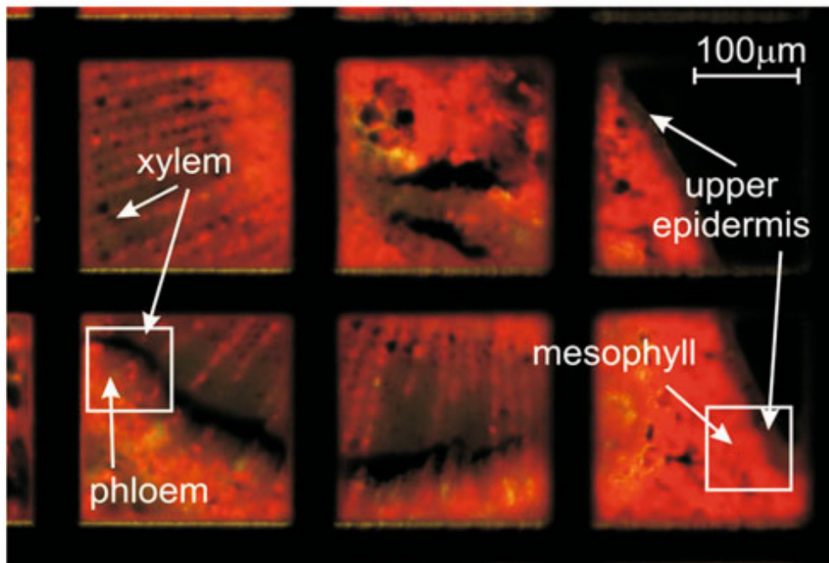
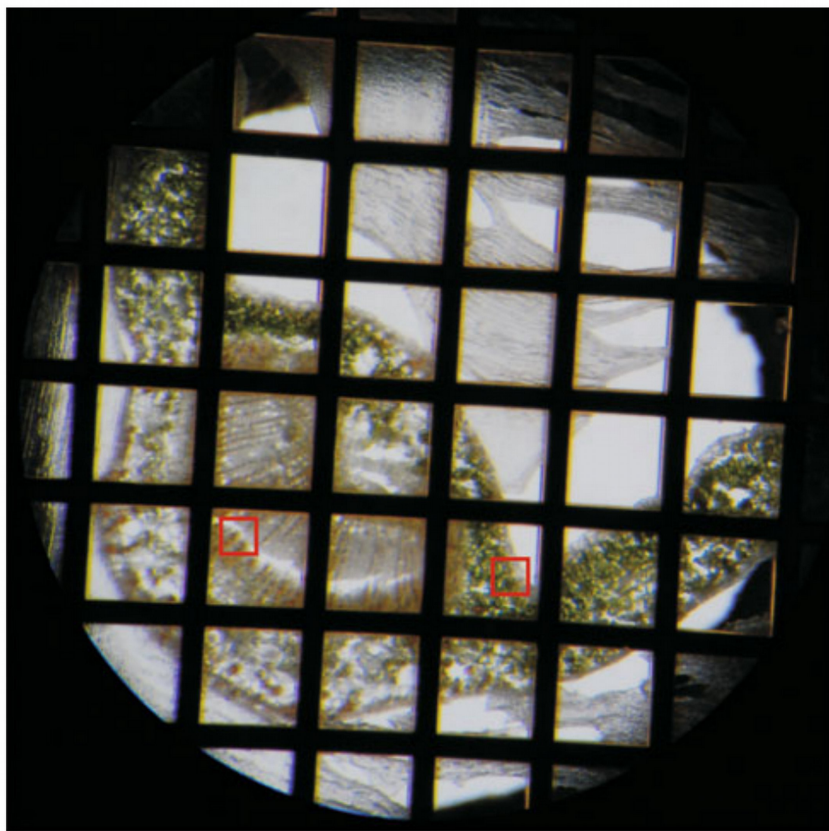
Industrial interest



Bio-medicine and bio-environment

Element mapping in cells
Toxic element accumulation







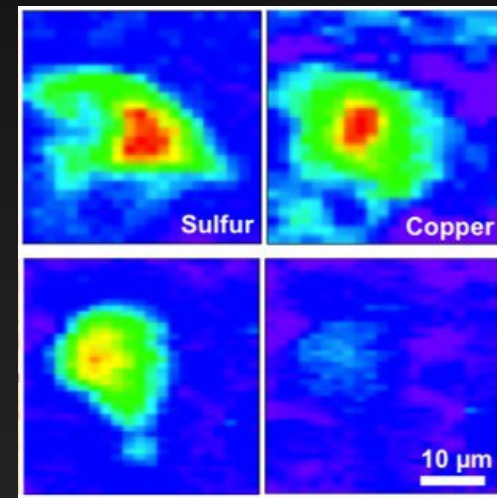
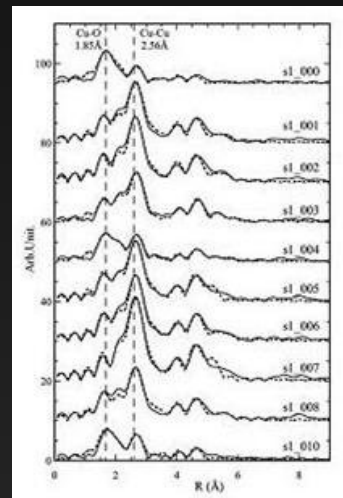
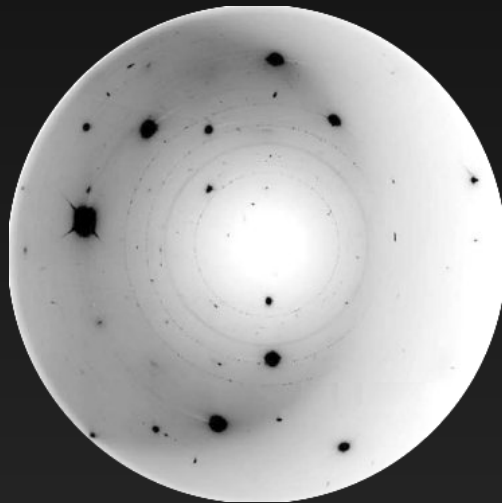
Bio-medicine and bio-environment

High social impact
Industrial interest

Multidisciplinary



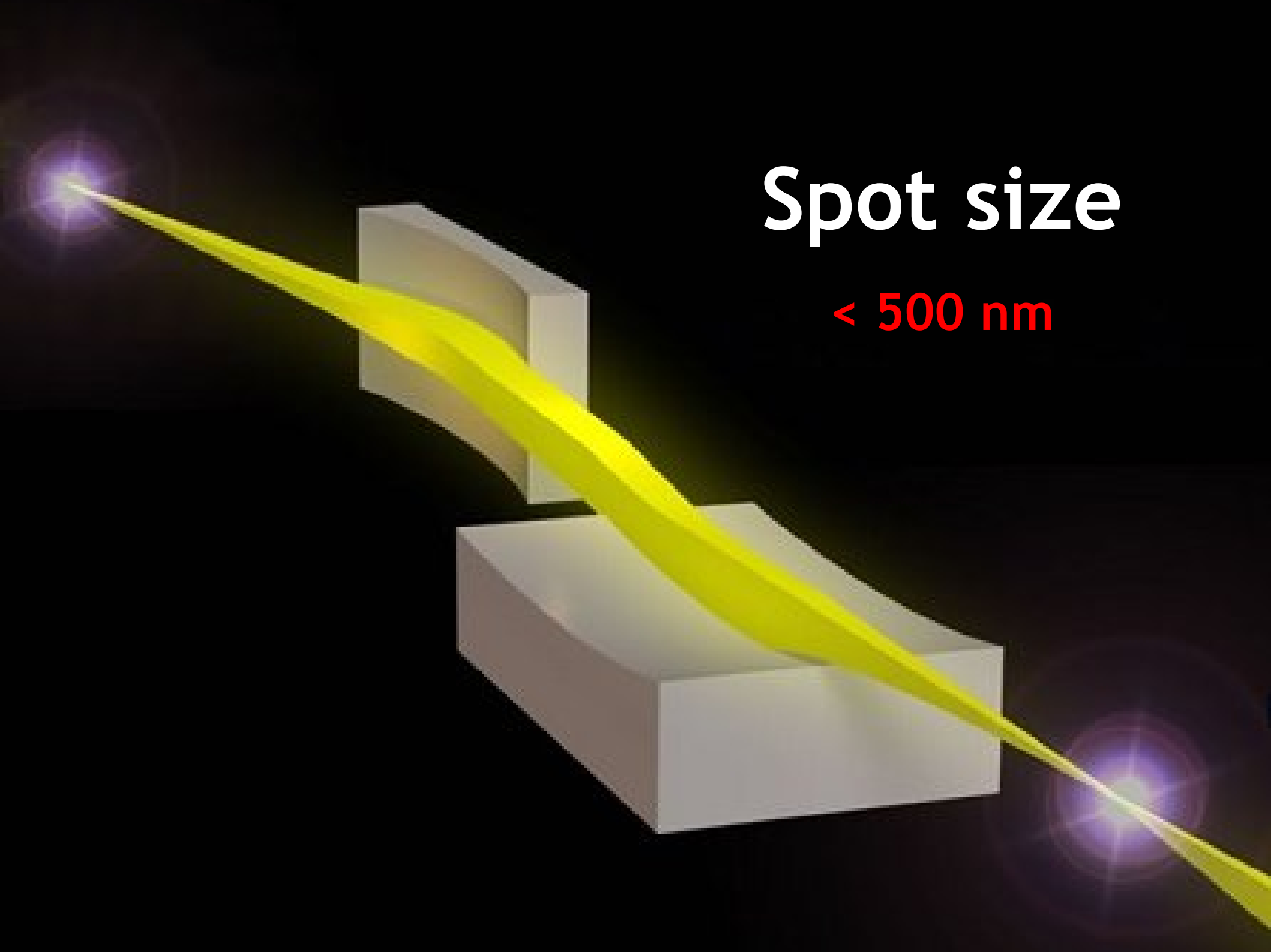
Complementary



Requirements

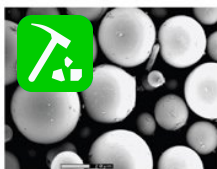
Spot size

< 500 nm

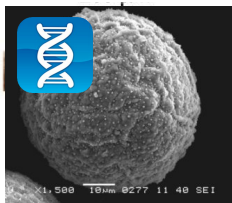




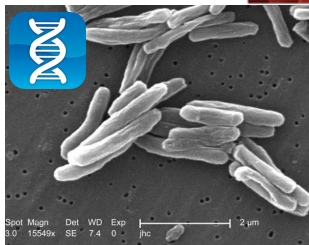
Ant
~ 5 mm



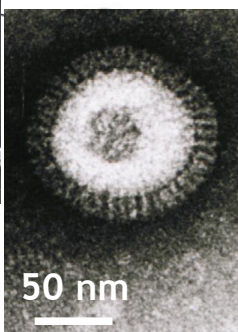
Fly ash
~ 10-20 μm



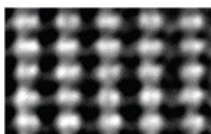
Red blood cells
(~7-8 μm)



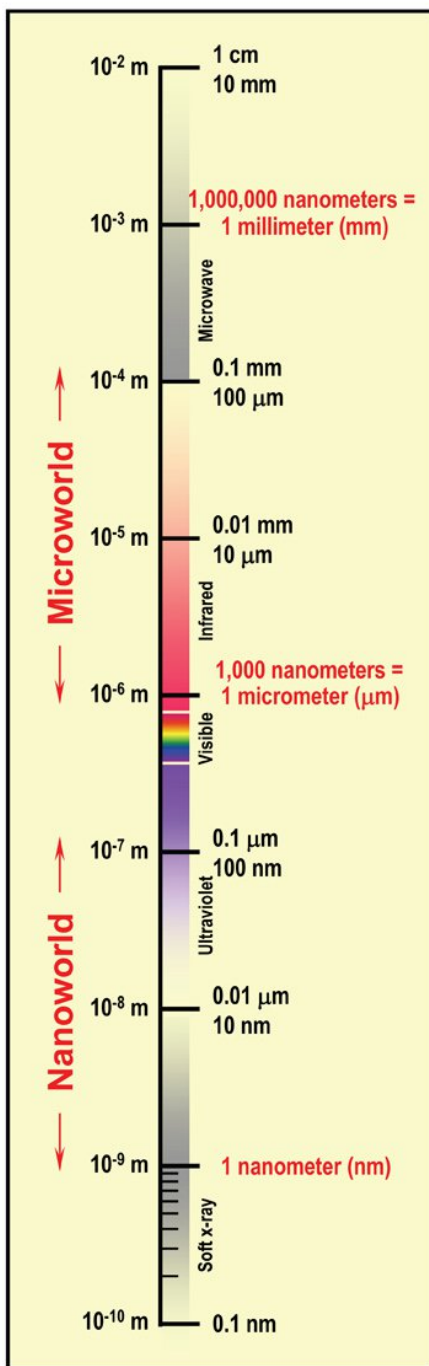
DNA
~2-1/2 nm diameter



50 nm



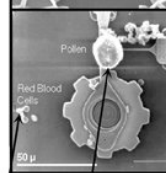
Atoms of silicon
spacing 0.078 nm



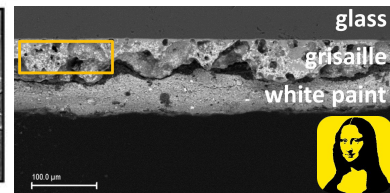
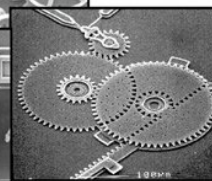
Head of a pin
1-2 mm



MicroElectroMechanical (MEMS) devices
10 -100 μm wide

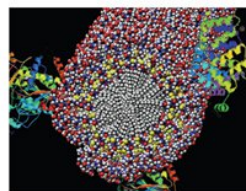


Pollen grain
Red blood cells

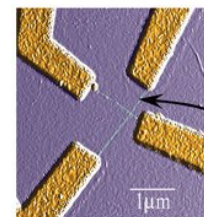


glass
grisaille
white paint

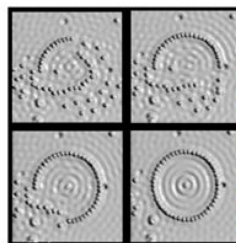
Zone plate x-ray "lens"
Outer ring spacing ~35 nm



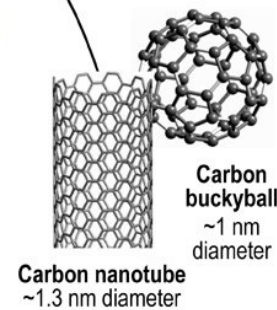
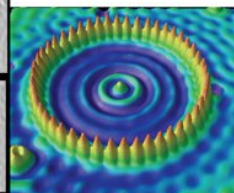
Self-assembled,
Nature-inspired structure
Many 10s of nm



Nanotube electrode



Quantum corral of 48 iron atoms on copper surface
positioned one at a time with an STM tip
Corral diameter 14 nm



Carbon nanotube
~1.3 nm diameter

Carbon buckyball
~1 nm diameter

Spot size

Why not smaller?

Spot size

Limited by budget:

Building extension
Ultra-high stability

Spot size

Flexibility loss

Energy range

2 - 20 keV

2 - 20 keV

H HYDROGEN																	He HELIUM
Li LITHIUM	Be BERYLLIUM											B BORON	C CARBON	N NITROGEN	O OXYGEN	F FLUORINE	Ne NEON
Na SODIUM	Mg MAGNESIUM											Al ALUMINIUM	Si SILICON	P PHOSPHORUS	S SULFUR	Cl CHLORINE	Ar ARGON
K POTASSIUM	Ca CALCIUM	Sc SCANDIUM	Ti TITANIUM	V VANADIUM	Cr CHROMIUM	Mn MANGANESE	Fe IRON	Co COBALT	Ni NICKEL	Cu COPPER	Zn ZINC	Ga GALLIUM	Ge GERMANIUM	As ARSENIC	Se SELENIUM	Br BROMINE	Kr KRYPTON
Rb RUBIDIUM	Sr STRONTIUM	Y YTTRIUM	Zr ZIRCONIUM	Nb NIOBIUM	Mo MOLYBDENUM	Tc TECHNETIUM	Ru RUTHENIUM	Rh RHODIUM	Pd PALLADIUM	Ag SILVER	Cd CADMIUM	In INDIUM	Sn TIN	Sb ANTIMONY	Te TELLURIUM	I IODINE	Xe XENON
Cs CAESIUM	Ba BARIUM	Lu LUTETIUM	Hf HAFNIUM	Ta TANTALUM	W TUNGSTEN	Re RHENIUM	Os OSMIUM	Ir IRIDIUM	Pt PLATINUM	Au GOLD	Hg MERCURY	Tl Thallium	Pb LEAD	Bi BISMUTH	Po POLONIUM	At ASTATINE	Rn RADON
Fr FRANCIUM	Ra RADIUM	Lr LAWRENCIUM	Rf RUTHERFORDIUM	Db DUBNIUM	Sg SEABORGIUM	Bh BOHRIUM	Hs HASSIUM	Mt MEITNERIUM	Ds DARMSTADIUM	Rg ROENTGENIUM	Cn COPERNICIUM	Uut UNUNTRIUM	Uuq UNUNQUADIUM	Uup UNUNPENTIUM	Uuh UNUNHEXIUM	Uus UNUNSEPTIUM	Uuo UNUNOCTIUM
		La LANTHANUM	Ce CERIUM	Pr PRASEODYMIUM	Nd NEODYMIUM	Pm PROMETHIUM	Sm SAMARIUM	Eu EUROPIUM	Gd GADOLINIUM	Tb TERBIUM	Dy DYSPROSIUM	Ho HOLMIUM	Er ERBIUM	Tm THULIUM	Yb YTTERBIUM		
		Ac ACTINIUM	Th THORIUM	Pa PROTACTINIUM	U URANIUM	Np NEPTUNIUM	Pu PLUTONIUM	Am AMERICIUM	Cm CURIUM	Bk BERKELIUM	Cf CALIFORNIUM	Es EINSTEINIUM	Fm FERMIUM	Md MENDELEVIUM	No NOBELIUM		

2 - 20 keV

H HYDROGEN																	He HELIUM				
Li LITHIUM	Be BERYLLIUM															B BORON	C CARBON	N NITROGEN	O OXYGEN	F FLUORINE	Ne NEON
Na SODIUM	Mg MAGNESIUM															Al ALUMINIUM	Si SILICON	P PHOSPHORUS	S SULFUR	Cl CHLORINE	Ar ARGON
K POTASSIUM	Ca CALCIUM	Sc SCANDIUM	Ti TITANIUM	V VANADIUM	Cr CHROMIUM	Mn MANGANESE	Fe IRON	Co COBALT	Ni NICKEL	Cu COPPER	Zn ZINC	Ga GALLIUM	Ge GERMANIUM	As ARSENIC	Se SELENIUM	Br BROMINE	Kr KRYPTON				
Rb RUBIDIUM	Sr STRONTIUM	Y YTTRIUM	Zr ZIRCONIUM	Nb NIOBIUM	Mo MOLYBDENUM	Tc TECHNETIUM	Ru RUTHENIUM	Rh RHODIUM	Pd PALLADIUM	Ag SILVER	Cd CADMIUM	In INDIUM	Sn TIN	Sb ANTIMONY	Te TELLURIUM	I IODINE	Xe XENON				
Cs CAESIUM	Ba BARIUM	Lu LUTETIUM	Hf HAFNIUM	Ta TANTALUM	W TUNGSTEN	Re RHENIUM	Os OSMIUM	Ir IRIDIUM	Pt PLATINUM	Au GOLD	Hg MERCURY	Tl Thallium	Pb LEAD	Bi BISMUTH	Po POLONIUM	At ASTATINE	Rn RADON				
Fr FRANCIUM	Ra RADIUM	Lr LAWRENCIUM	Rf RUTHERFORDIUM	Db DUBNIUM	Sg SEABORGIUM	Bh BOHRIUM	Hs HASSIUM	Mt MEITNERIUM	Ds DARMSTADTIUM	Rg ROENTGENIUM	Cn COPERNICIUM	Uut UNUNTRIUM	Uuq UNUNQUADIUM	Uup UNUNPENTIUM	Uuh UNUNHEXIUM	Uus UNUNSEPTIUM	Uuo UNUNOCTIUM				
		La LANTHANUM	Ce CERIUM	Pr PRASEODYMIUM	Nd NEODYMIUM	Pm PROMETHIUM	Sm SAMARIUM	Eu EUROPIUM	Gd GADOLINIUM	Tb TERBIUM	Dy DYSPROSIUM	Ho HOLMIUM	Er ERBIUM	Tm THULIUM	Yb YTTERBIUM						
		Ac ACTINIUM	Th THORIUM	Pa PROTACTINIUM	U URANIUM	Np NEPTUNIUM	Pu PLUTONIUM	Am AMERICIUM	Cm CURIUM	Bk BERKELIUM	Cf CALIFORNIUM	Es EINSTEINIUM	Fm FERMIUM	Md MENDELEVIUM	No NOBELIUM						

2 - 20 keV

P to Nb (K-edges)

2 - 20 keV

H HYDROGEN																	He HELIUM						
Li LITHIUM	Be BERYLLIUM																	B BORON	C CARBON	N NITROGEN	O OXYGEN	F FLUORINE	Ne NEON
Na SODIUM	Mg MAGNESIUM																	Al ALUMINIUM	Si SILICON	P PHOSPHORUS	S SULFUR	Cl CHLORINE	Ar ARGON
K POTASSIUM	Ca CALCIUM	Sc SCANDIUM	Ti TITANIUM	V VANADIUM	Cr CHROMIUM	Mn MANGANESE	Fe IRON	Co COBALT	Ni NICKEL	Cu COPPER	Zn ZINC	Ga GALLIUM	Ge GERMANIUM	As ARSENIC	Se SELENIUM	Br BROMINE	Kr KRYPTON						
Rb RUBIDIUM	Sr STRONTIUM	Y YTTRIUM	Zr ZIRCONIUM	Nb NIOBIUM	Mo MOLYBDENUM	Tc TECHNETIUM	Ru RUTHENIUM	Rh RHODIUM	Pd PALLADIUM	Ag SILVER	Cd CADMIUM	In INDIUM	Sn TIN	Sb ANTIMONY	Te TELLURIUM	I IODINE	Xe XENON						
Cs CAESIUM	Ba BARIUM	Lu LUTETIUM	Hf HAFNIUM	Ta TANTALUM	W TUNGSTEN	Re RHENIUM	Os OSMIUM	Ir IRIDIUM	Pt PLATINUM	Au GOLD	Hg MERCURY	Tl Thallium	Pb LEAD	Bi BISMUTH	Po POLONIUM	At ASTATINE	Rn RADON						
Fr FRANCIUM	Ra RADIUM	Lr LAWRENCIUM	Rf RUTHERFORDIUM	Db DUBNIUM	Sg SEABORGIUM	Bh BOHRIUM	Hs HASSIUM	Mt MEITNERIUM	Ds DARMSTADIUM	Rg ROENTGENIUM	Cn COPERNICIUM	Uut UNUNTRIUM	Uuq UNUNQUADIUM	Uup UNUNPENTIUM	Uuh UNUNHEXIUM	Uus UNUNSEPTIUM	Uuo UNUNOCTIUM						
		La LANTHANUM	Ce CERIUM	Pr PRASEODYMIUM	Nd NEODYMIUM	Pm PROMETHIUM	Sm SAMARIUM	Eu EUROPIUM	Gd GADOLINIUM	Tb TERBIUM	Dy DYSPROSIUM	Ho HOLMIUM	Er ERBIUM	Tm THULIUM	Yb YTTERBIUM								
		Ac ACTINIUM	Th THORIUM	Pa PROTACTINIUM	U URANIUM	Np NEPTUNIUM	Pu PLUTONIUM	Am AMERICIUM	Cm CURIUM	Bk BERKELIUM	Cf CALIFORNIUM	Es EINSTEINIUM	Fm FERMIUM	Md MENDELEVIUM	No NOBELIUM								

P to Nb (K-edges)

Y to U (L_3 edges)

XRD, SAXS, WAXS

Crystal and nanostructure

Sub-ppm XRF

Elemental composition

XAS

Oxidation states, local structure

Mapping

Fast	→	radiation damage
Precise	→	sub- μm steps
Robust	→	stability
Versatile	→	sample environment

Sample environment

Vacuum

Low temperature

High temperature

Reactive environment

High pressure

...

Simultaneous measurements

Techniques synergy

Technical design

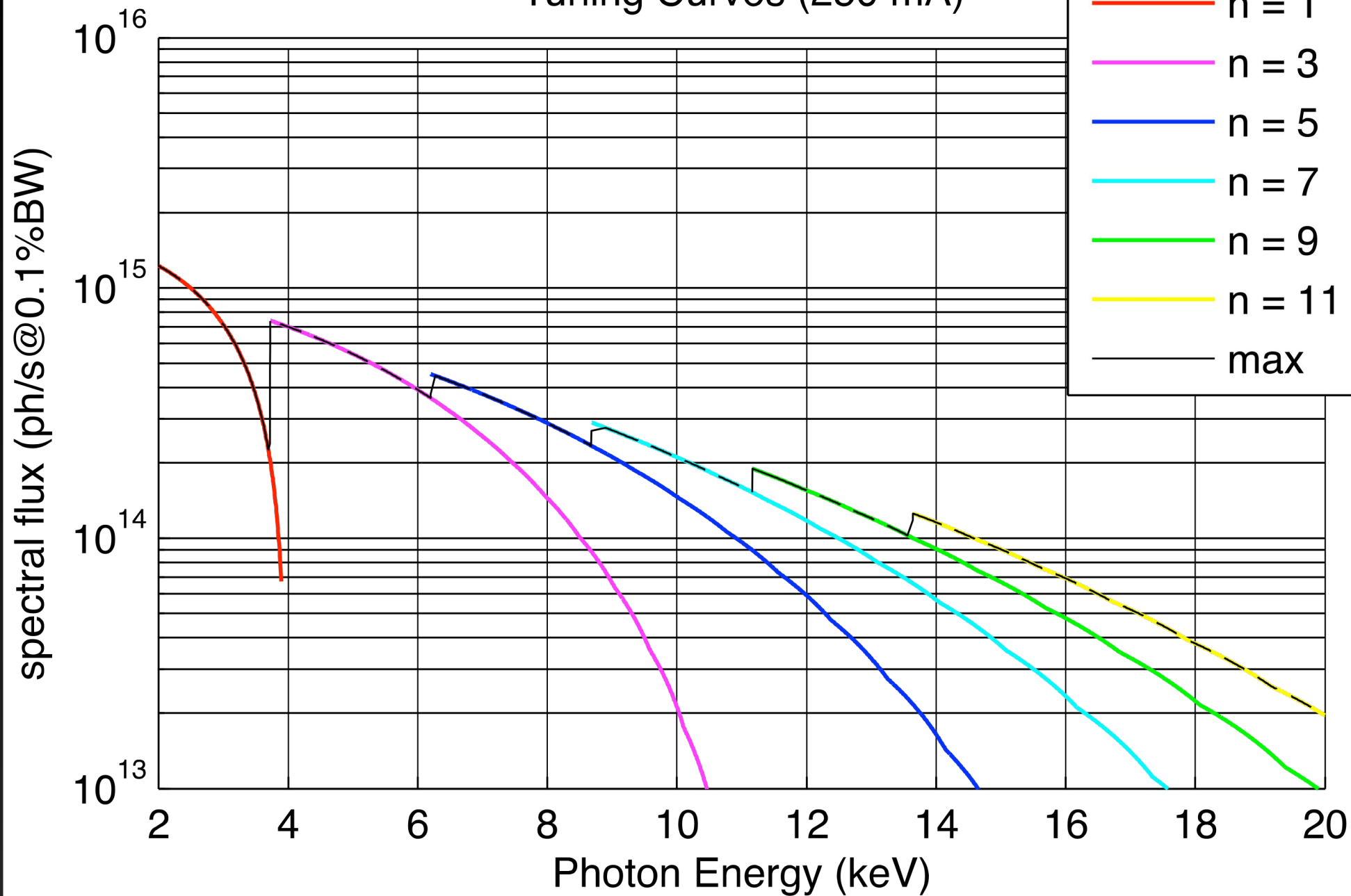
Undulator

In-vacuum, cryo-cooled, hybrid magnet

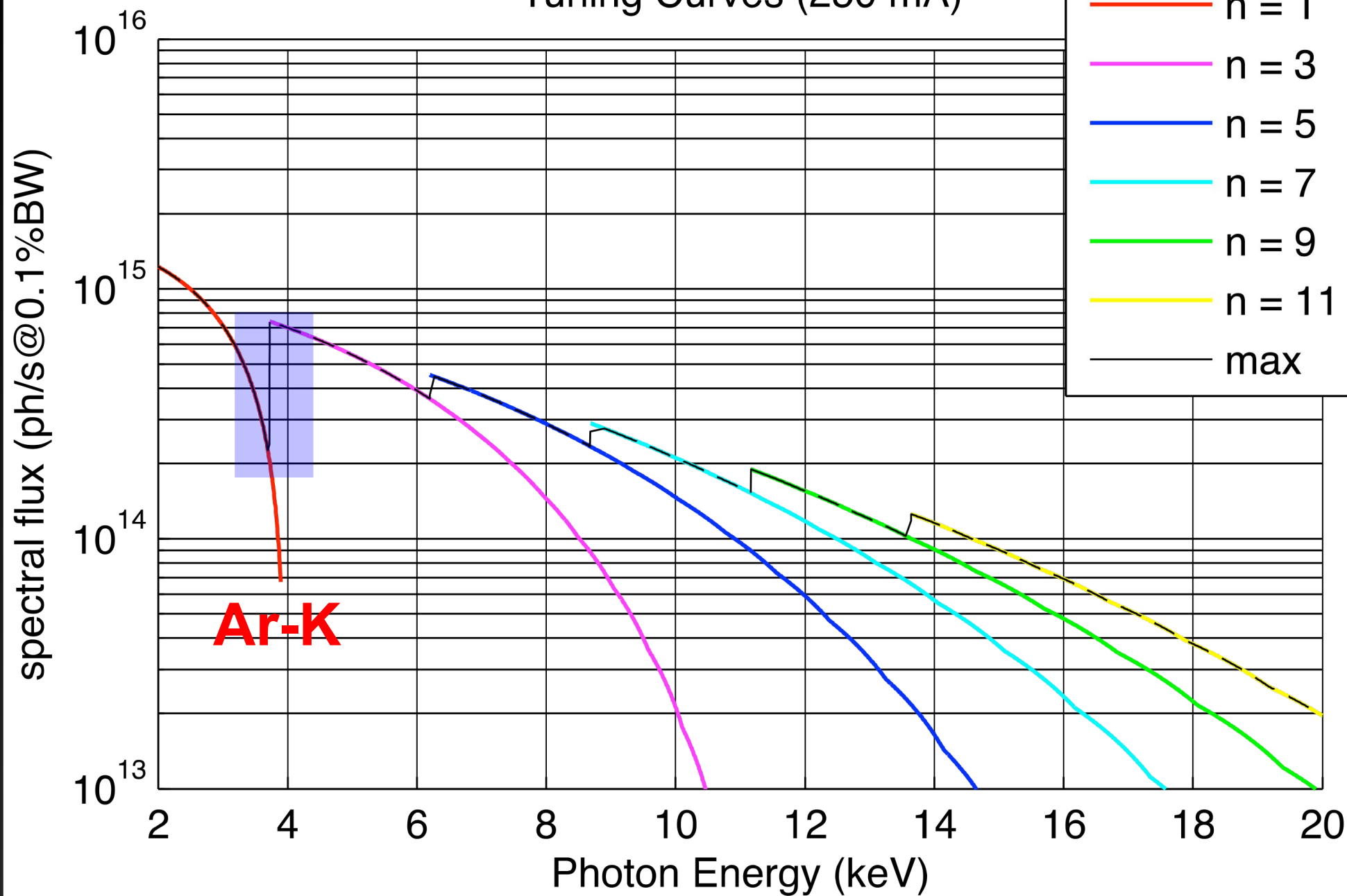
Undulator

Period	21.5 mm
Length	2.0 m
Max K_y	2.15
Min Gap	4.8 mm

Tuning Curves (250 mA)



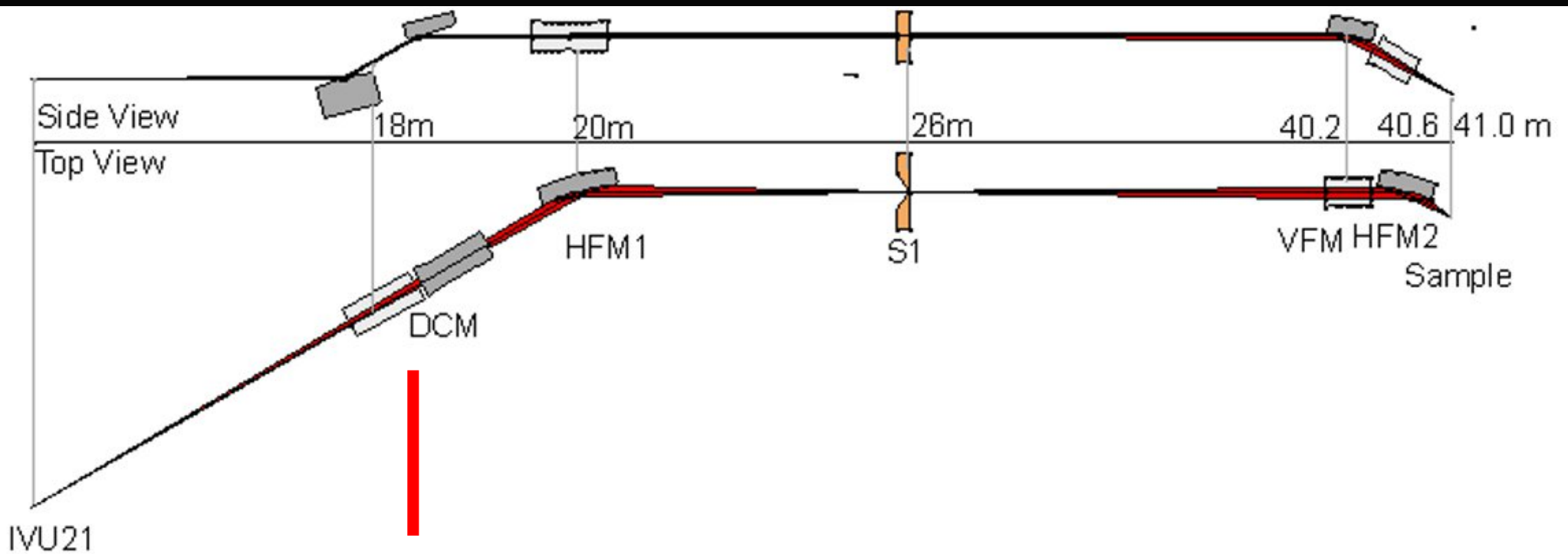
Tuning Curves (250 mA)



Undulator

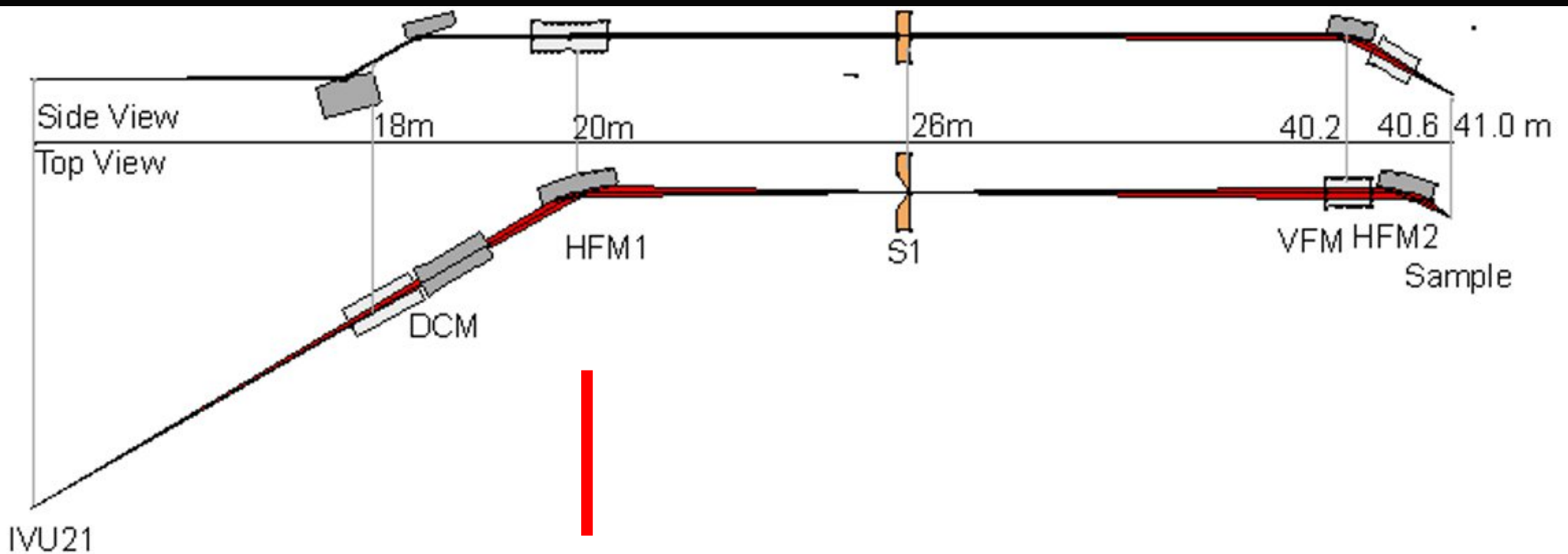
Low- β straight section

Optics



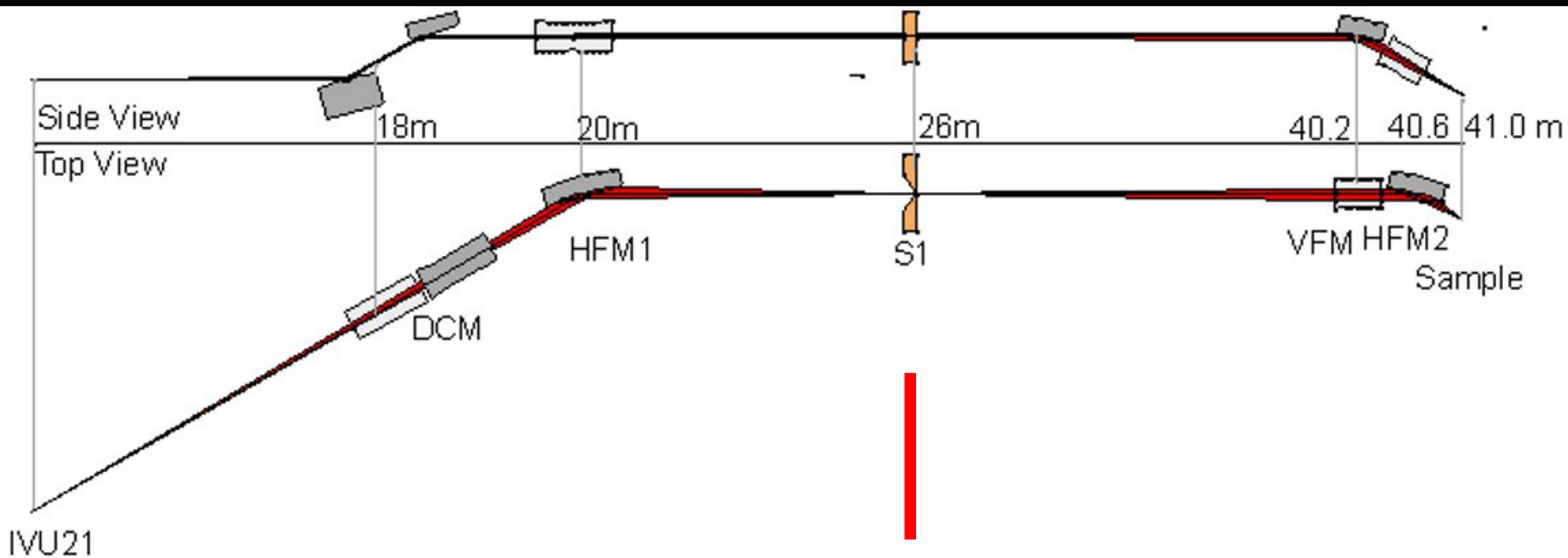
**Double-crystal
monochromator**

**Monochromatic
or pink beam**



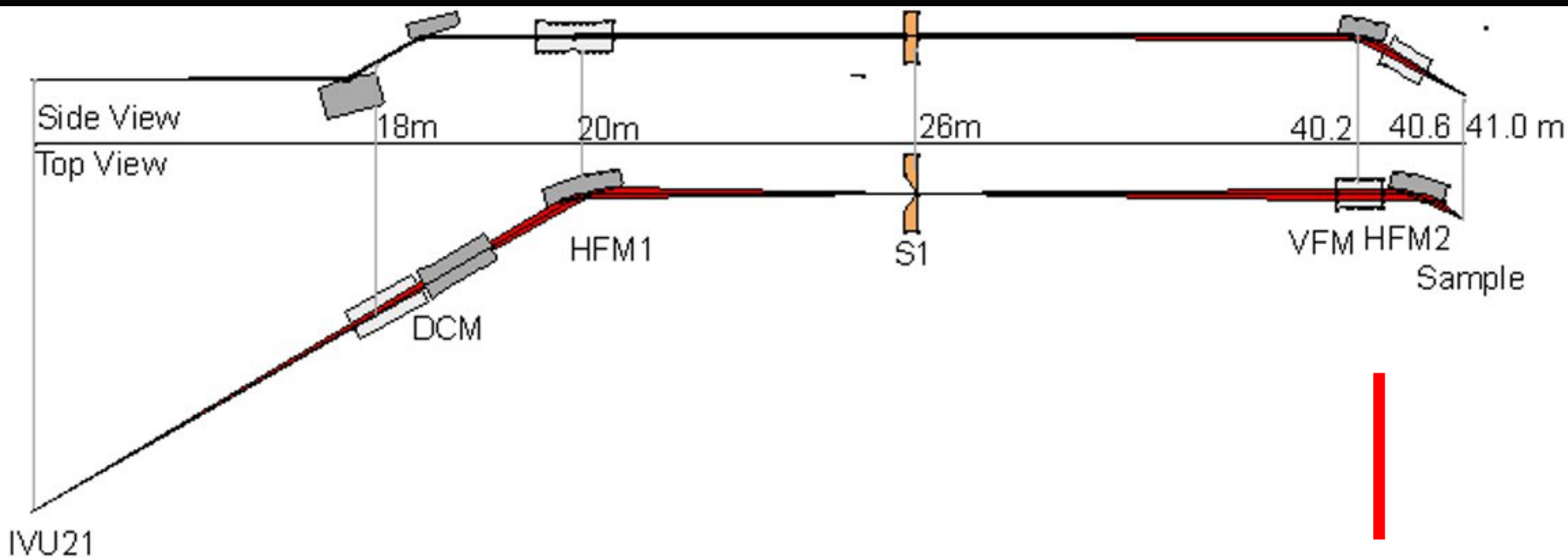
**1st horizontal
focussing mirror**

**First focus
Harmonic rejection (Si, Rh, Ir stripes)**



Slits

Secondary source

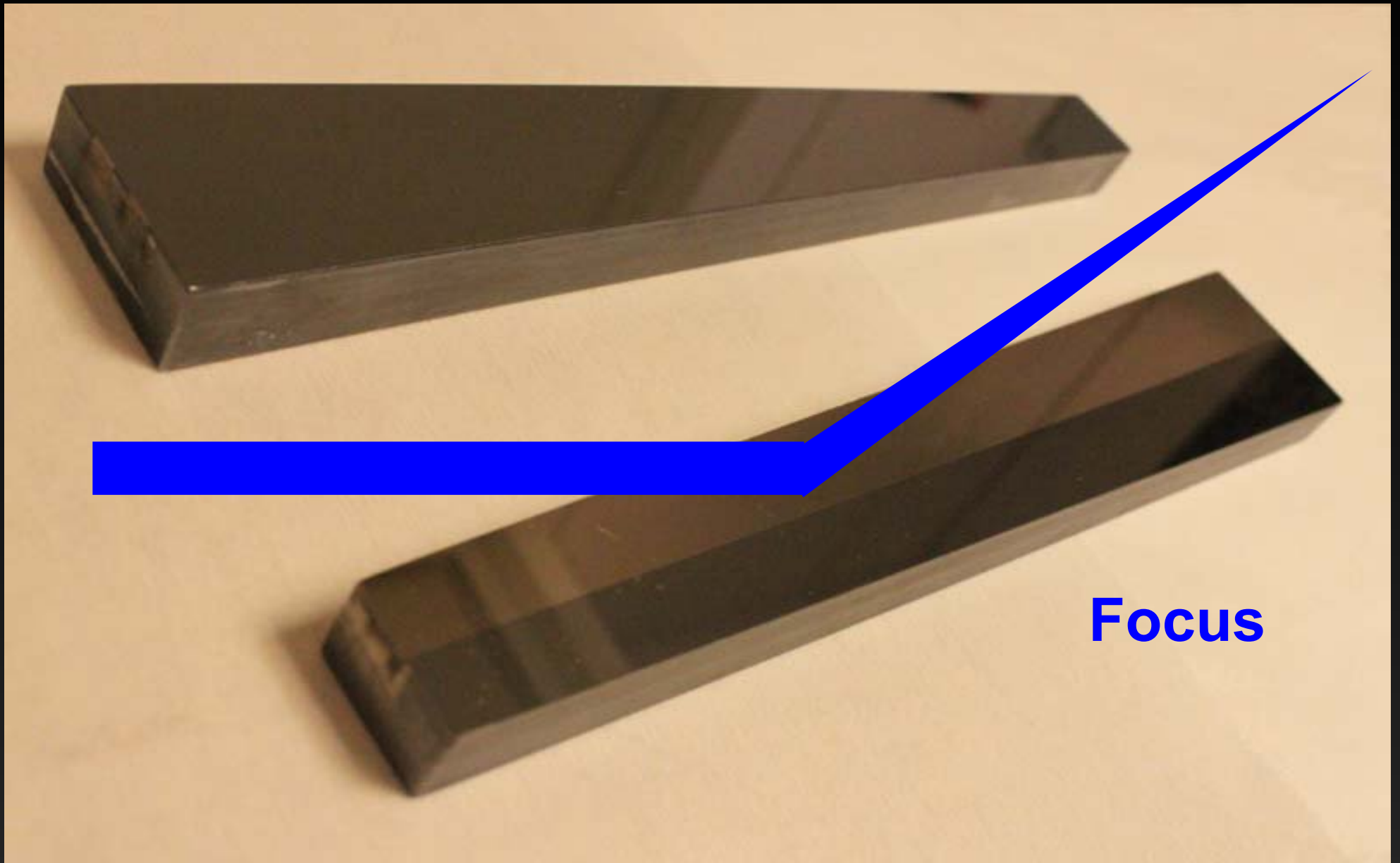


**Sample focus
and pink beam**

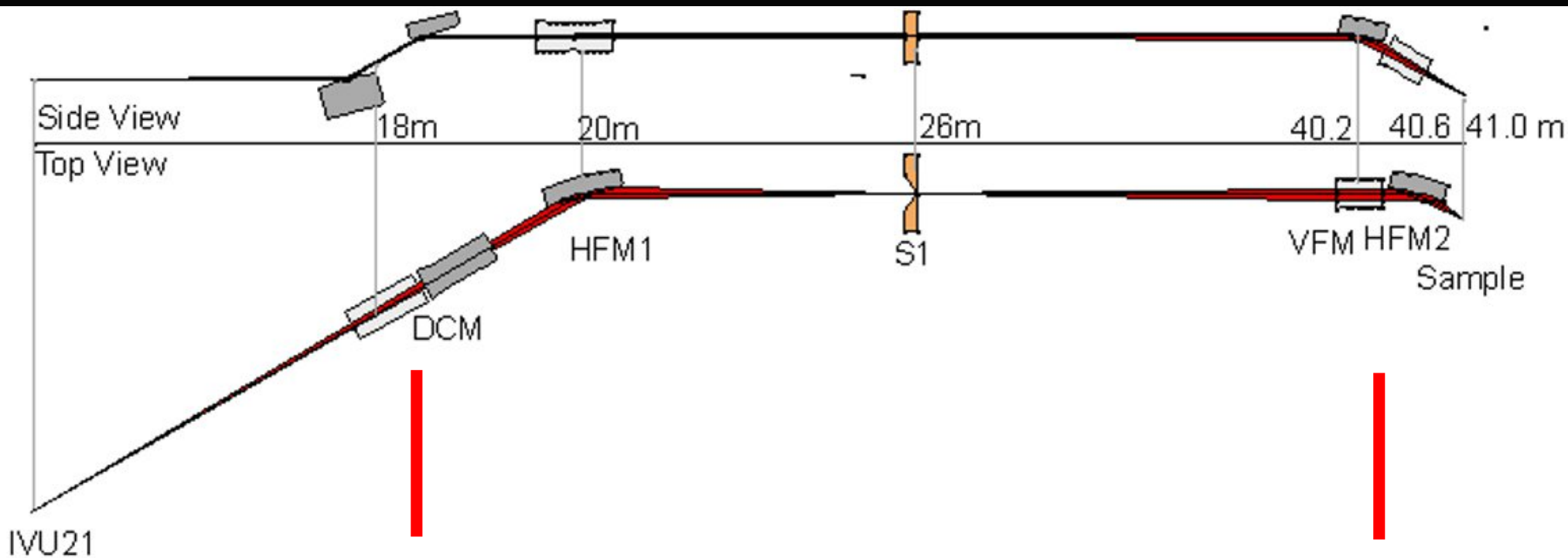
**Kirkpatrick-
Baez
focussing
mirrors**







Focus

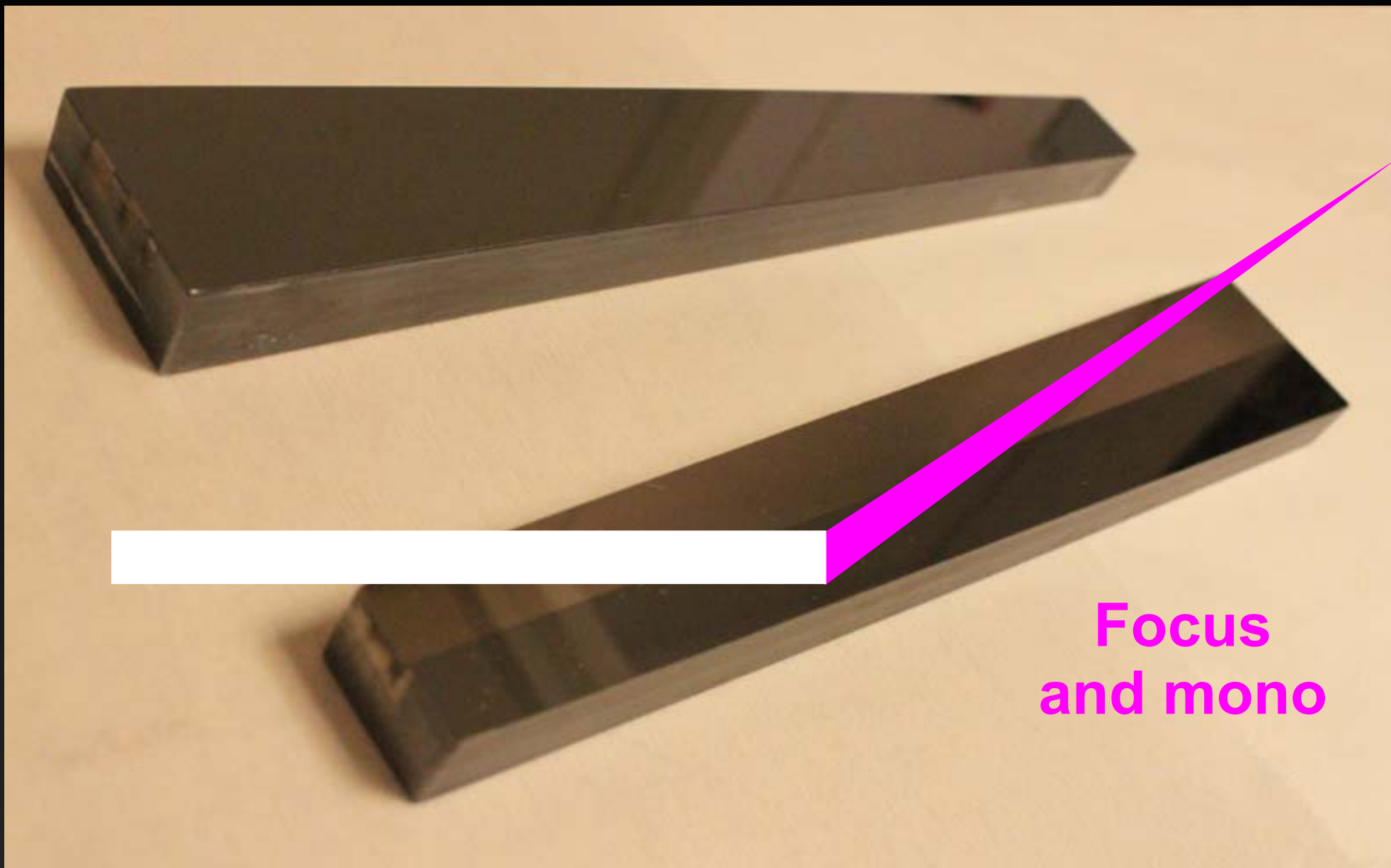


Mono in

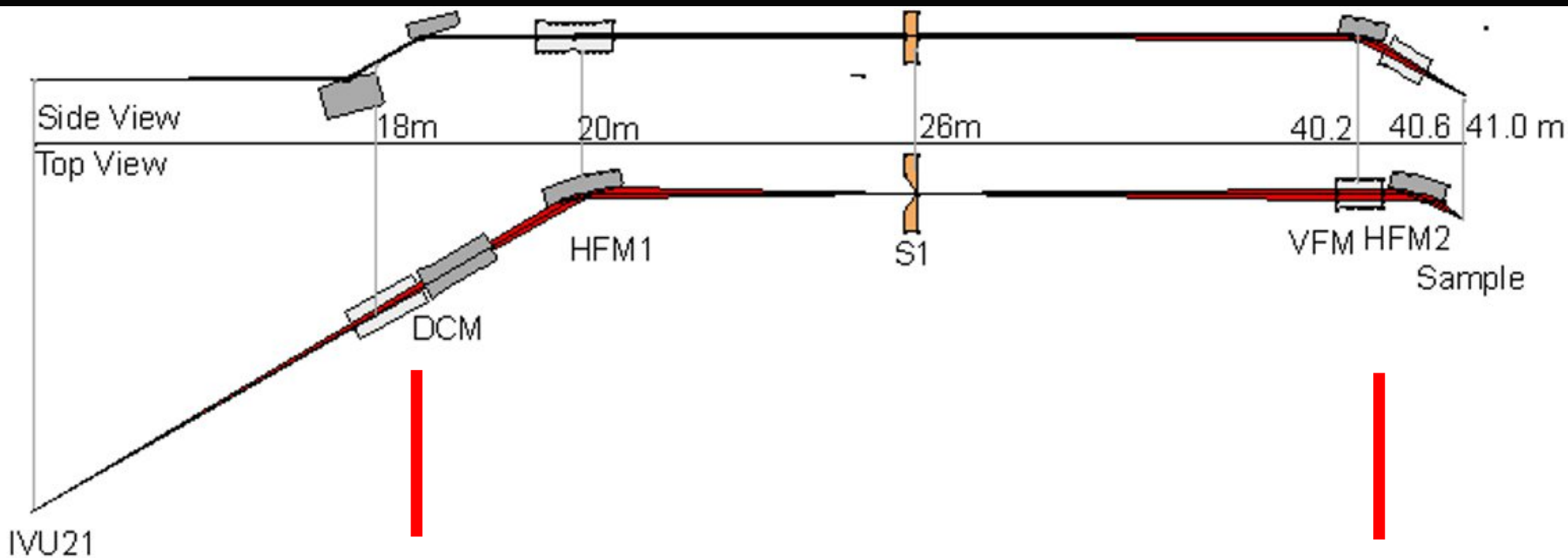
**KB
Single layer
coating**

Spectroscopy mode





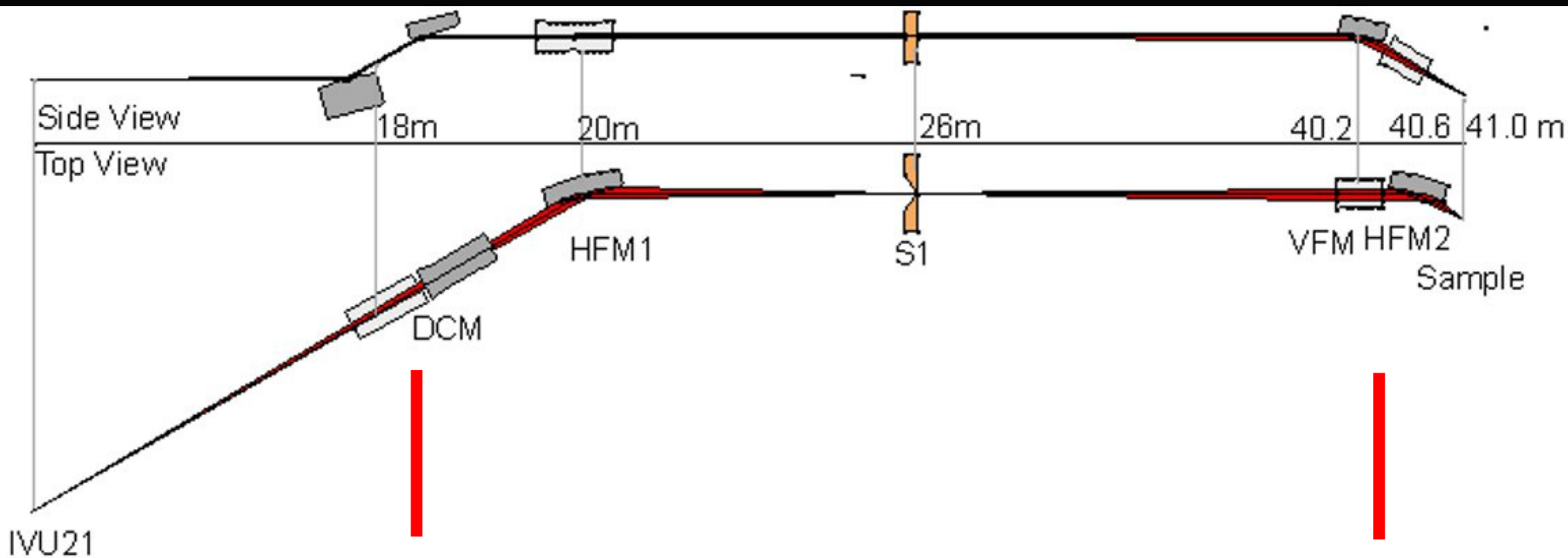
Focus
and mono



Mono out

**KB
Multilayer
coating**

**Diffraction mode
alternative 1**



**Mono
multilayer**

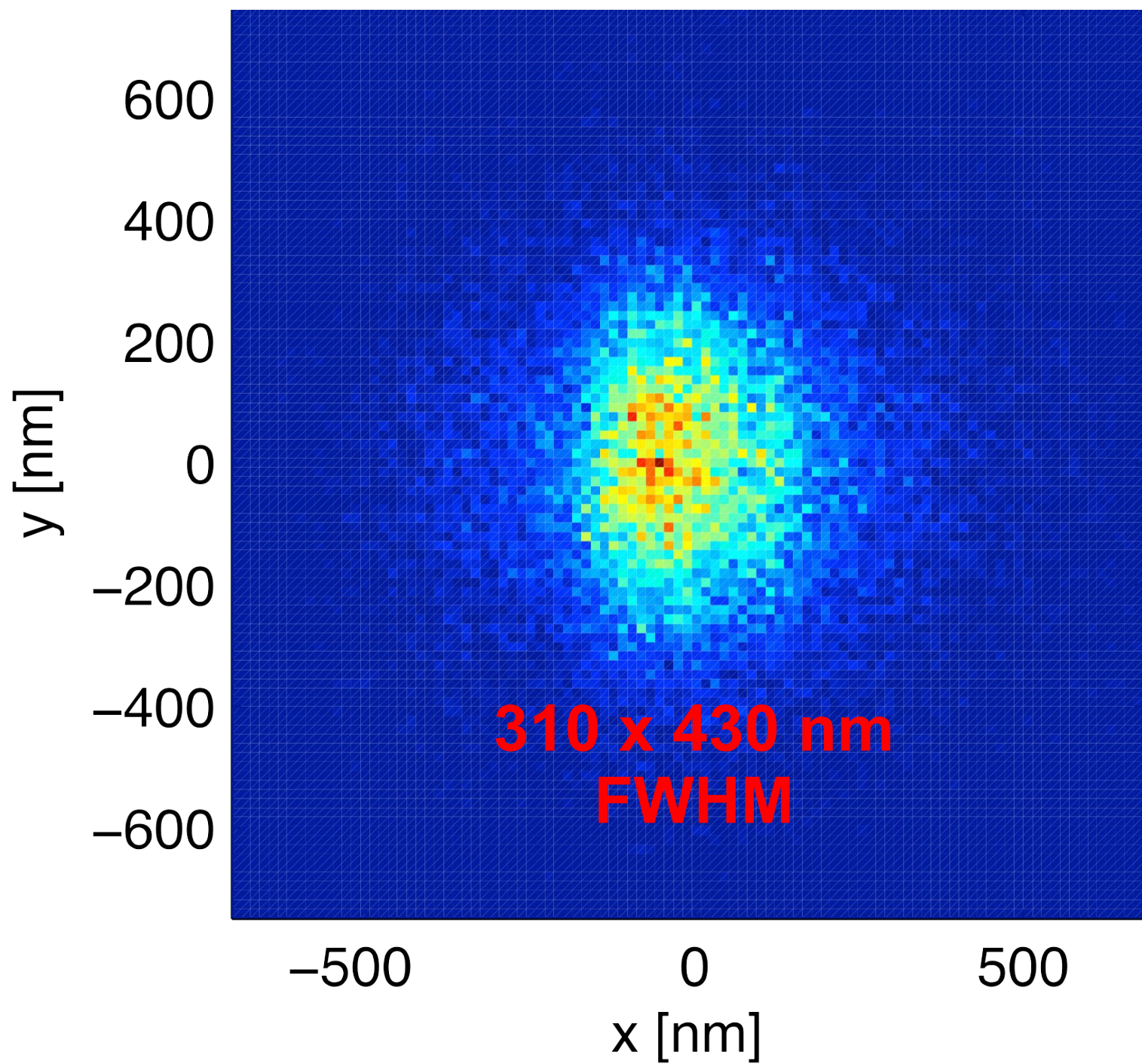
**KB
Single layer
coating**

**Diffraction mode
alternative 2**

No mono vs. multilayer mono

More flux
No DCM

“White” beam
Extra cooling
Beamline align



Detectors

XAS

ionization chambers



Sub-ppm and fast XRF

Multielement Silicon Drift Detector



XRD, SAXS, WAXS

Large area CCD camera



SAXS, WAXS

Same CCD camera + Small beamstop

SAXS, WAXS

KB divergence → < 30 nm

Mapping

Piezo stage

Heavy table

Controlled environment

Sample environment

Vacuum or He chamber

Cryostat

Furnace

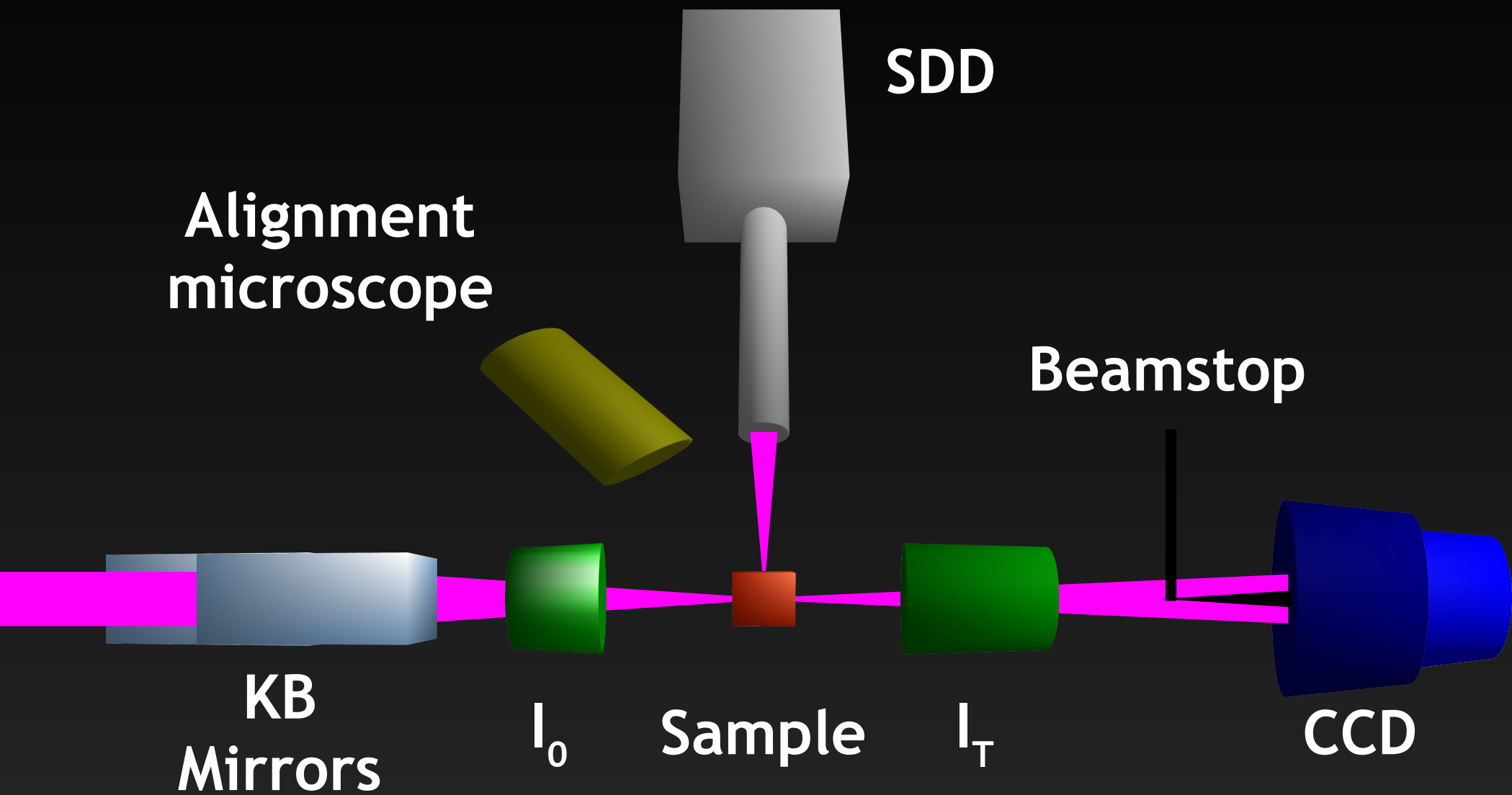
Reaction cell

High-pressure cell

...

Simultaneous measurements

Techniques synergy



Cost

~ 6500 k€

Major Item	k€	Comment
Undulator+frontend	950	Hybrid magnet in-vacuum undulator
Lead optical hutch	300	Dimensions: 10 m long, 2.5 m wide, 3.4 m high
OH services	250	Control cabins cabling, electricity, fluids
Lead experim. hutch	250	Dimensions: 10 m long, 4.5 m wide, 4 m high
EH services	600	Cabling, air conditioning, electricity, fluids
Instruments hutches	400	Shutters, collimators, BPMs, filters, slits, cryocooler,
Tubes and shielding	250	Transport of pink beam
Vacuum equipment	200	Vacuum pumps and gauges
HF mirror	350	High quality cooled and coated crystal + motorization
Monochromators	900	Fast scanning and coherence preservation
Table	60	Granite support and motorization
Focusing optics	250	High quality KB mirrors system
Sample stage	120	XYZ, encoders, piezo-scanner
Detectors	600	SSD, CCD, ion chambers
Control electronics	300	Motors and general control electronics
Support laboratory	60	Visible light microscope for sample alignment
Network	60	Plugs, 10 Gbe clients
Subtotal	5900	
Contingencies	590	10% of subtotal
Total estimate	6490	

Major Item	k€	Comment
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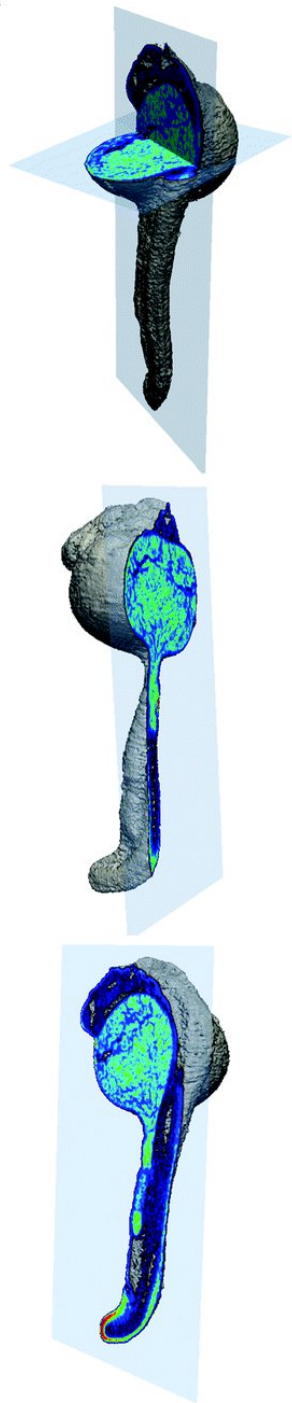
Future

Imaging techniques

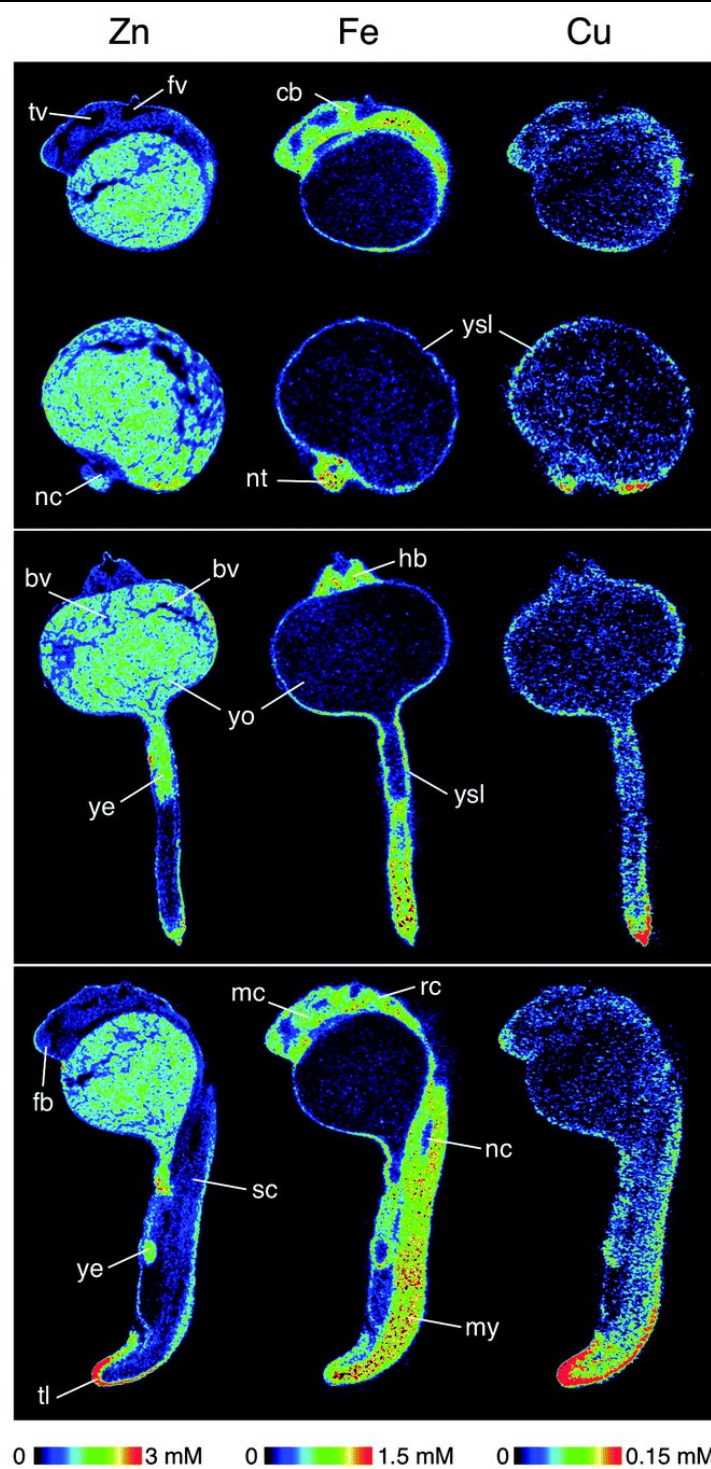
3D XRF tomography

Tomography rotary stage

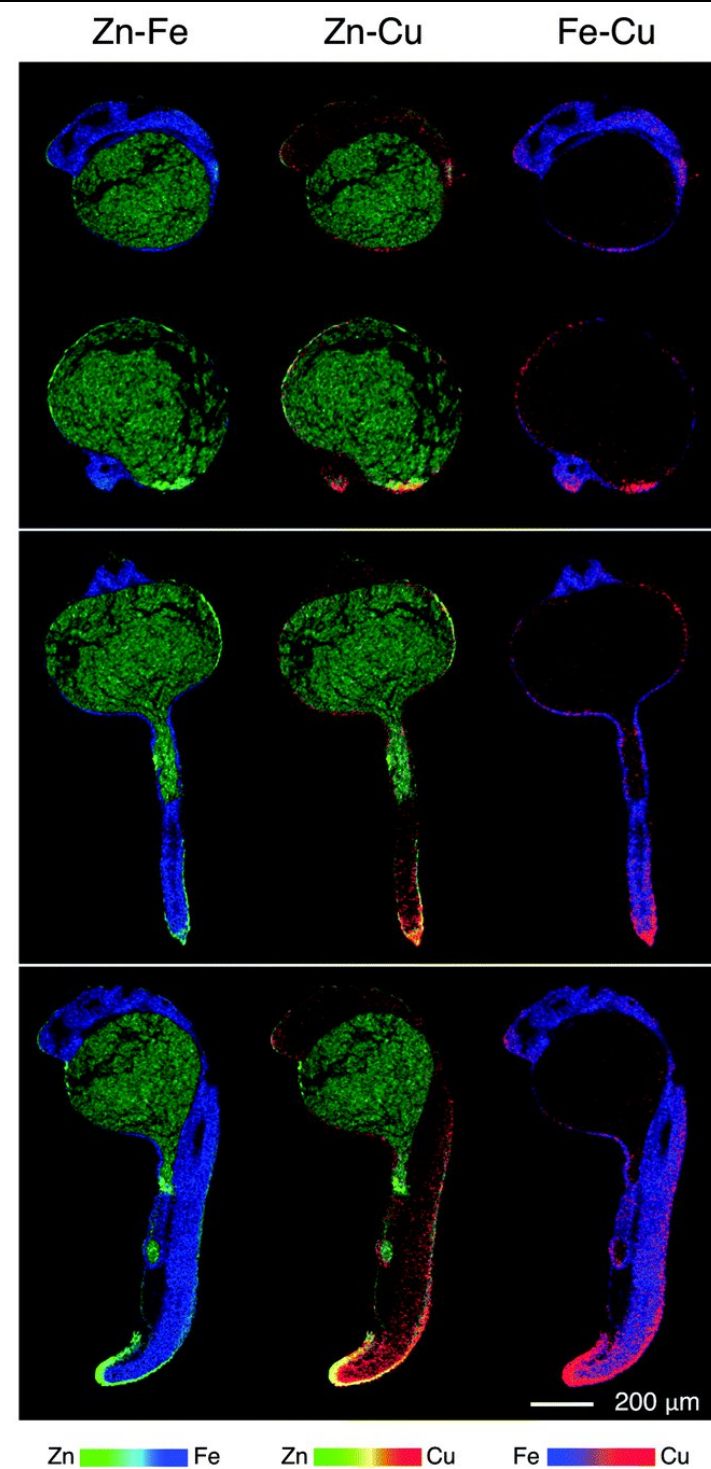
A



B

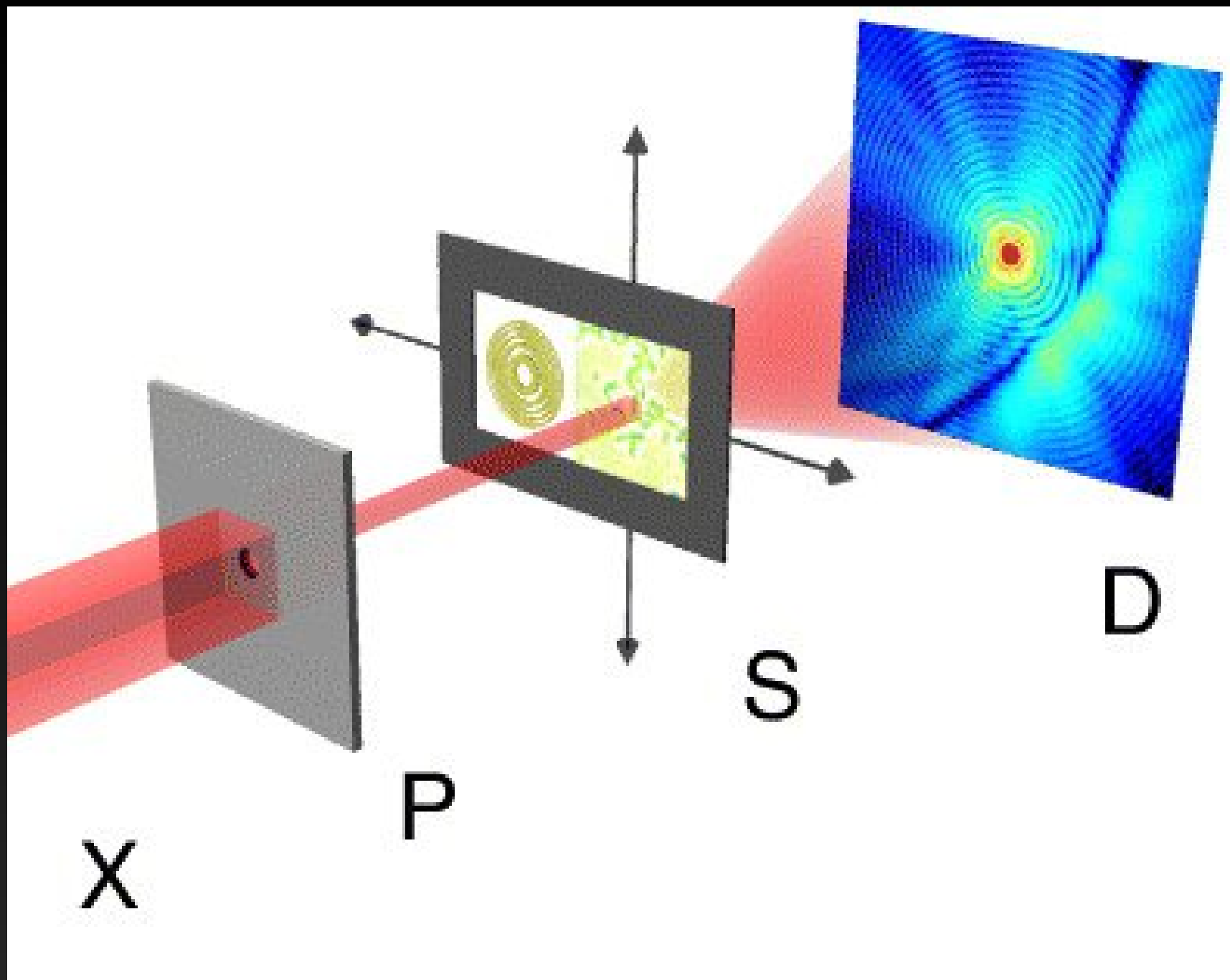


C



Ptychography

Beam coherence
Software development
< 100 nm image resolution

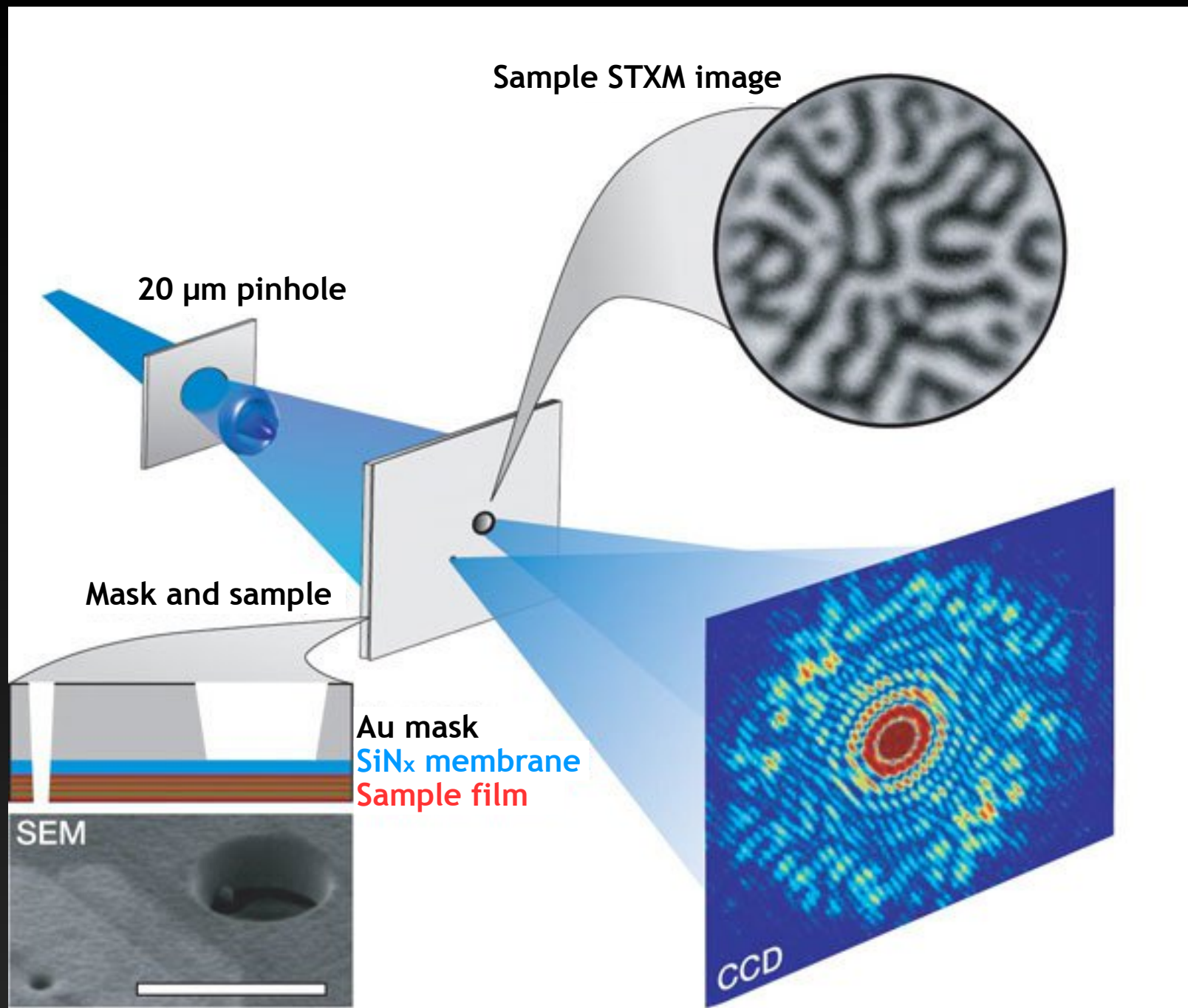


Fourier transform holography

Beam coherence

Sample preparation (mask + pinhole)

< 100 nm image resolution



Scientific developments

Nanofocus beamlines

Technical risks

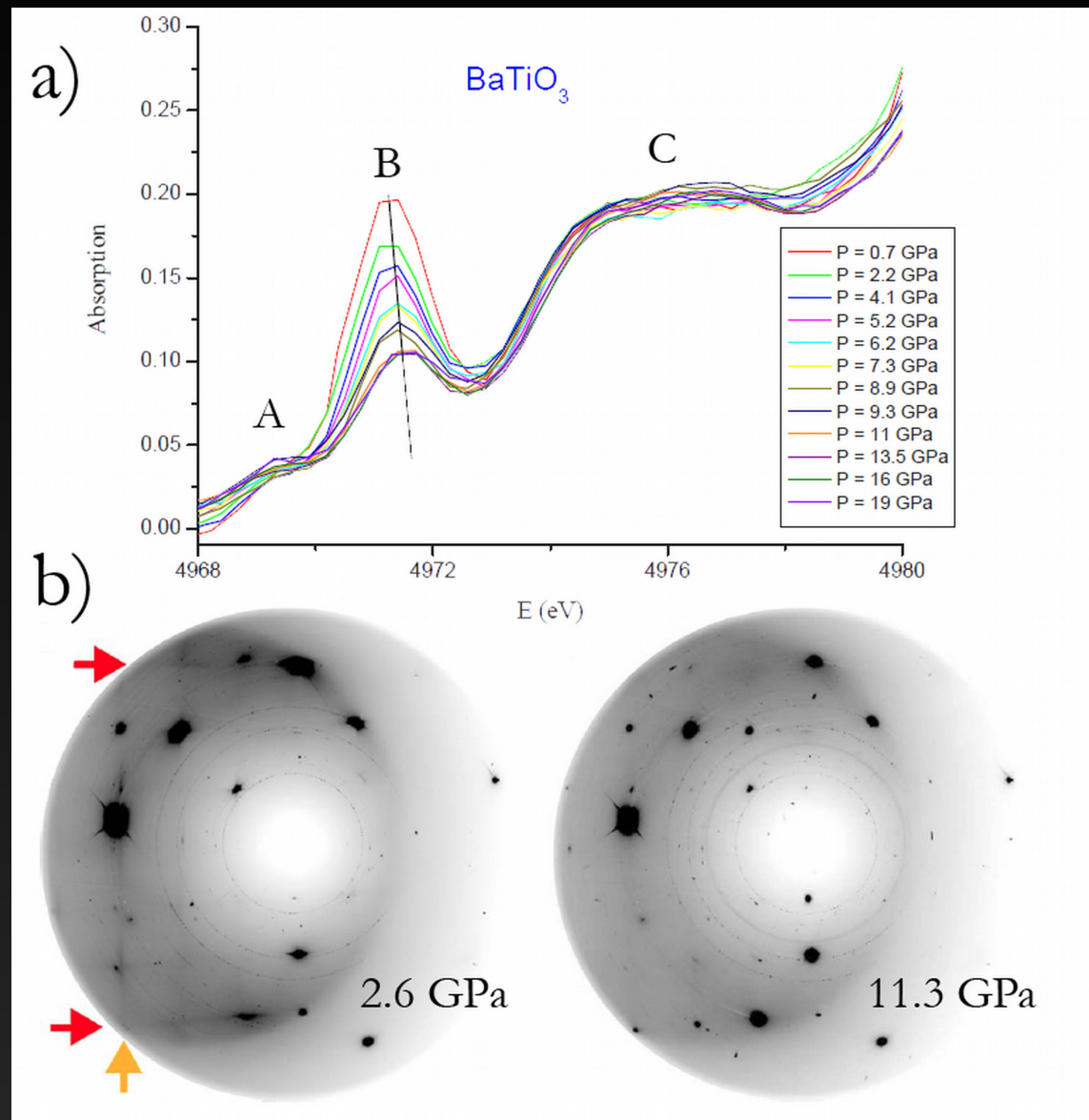
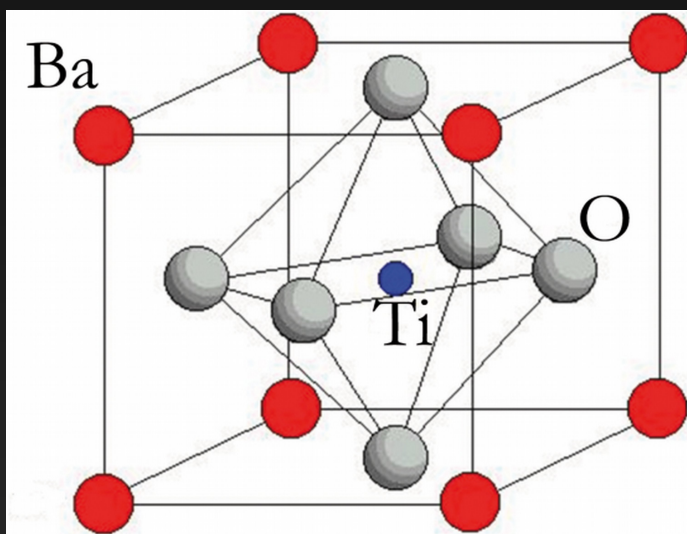
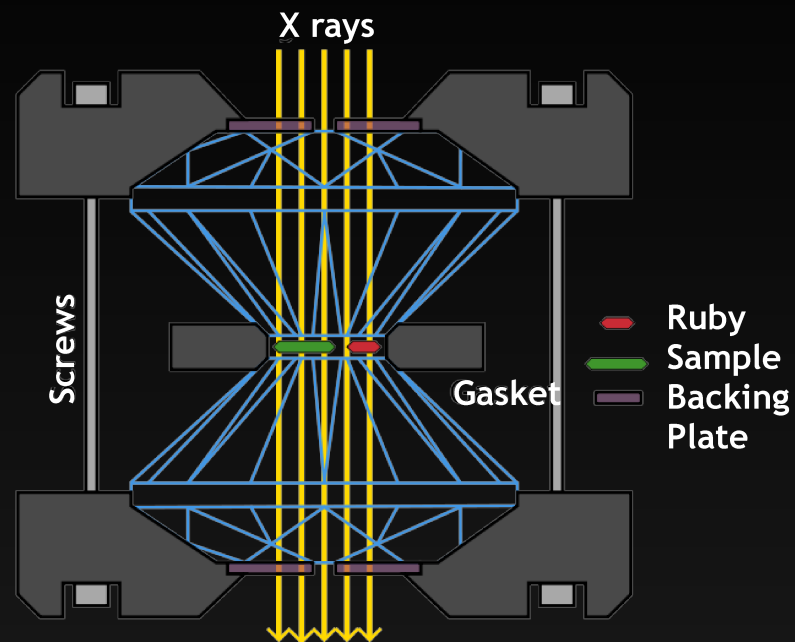
Optical components

Detectors

Beamline stability components

Academic experiment

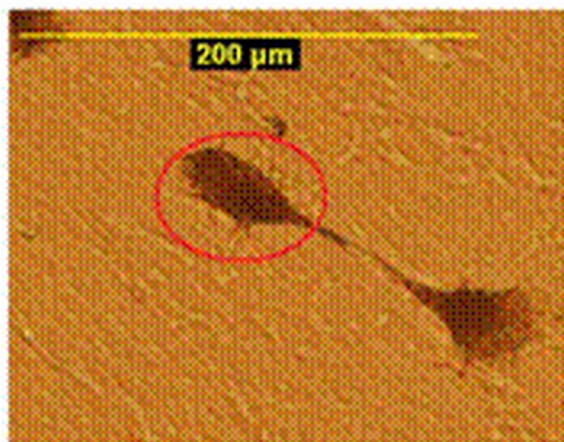
Very high pressure



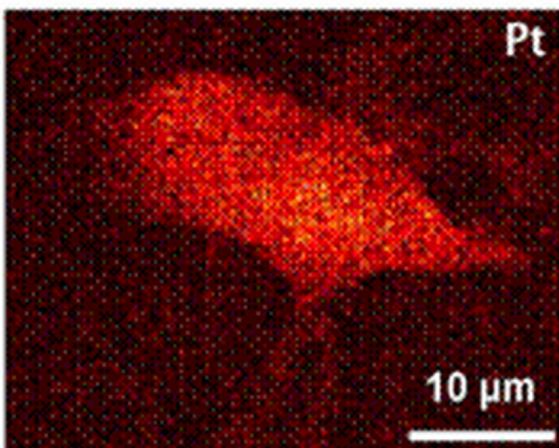
Industrial experiment

Pharmaceutical company, in vitro experiment
Distribution of new drug inside cell

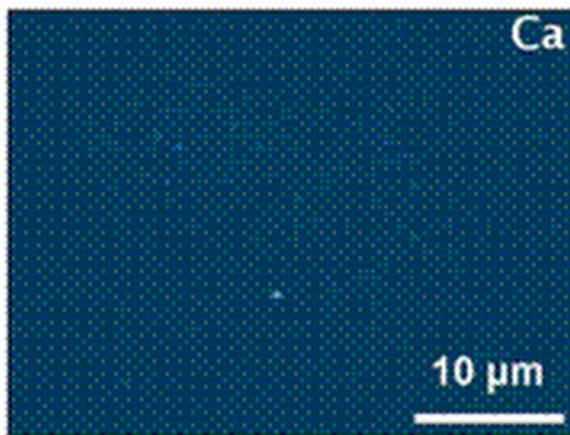
(A)



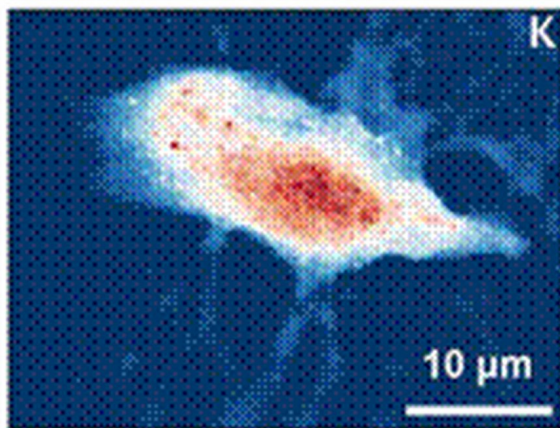
(B)



(C)



(D)



European leadership

Multitechnique study of low-Z elements

2 - 20 keV

H HYDROGEN																	He HELIUM						
Li LITHIUM	Be BERYLLIUM																	B BORON	C CARBON	N NITROGEN	O OXYGEN	F FLUORINE	Ne NEON
Na SODIUM	Mg MAGNESIUM																	Al ALUMINIUM	Si SILICON	P PHOSPHORUS	S SULFUR	Cl CHLORINE	Ar ARGON
K POTASSIUM	Ca CALCIUM	Sc SCANDIUM	Ti TITANIUM	V VANADIUM	Cr CHROMIUM	Mn MANGANESE	Fe IRON	Co COBALT	Ni NICKEL	Cu COPPER	Zn ZINC	Ga GALLIUM	Ge GERMANIUM	As ARSENIC	Se SELENIUM	Br BROMINE	Kr KRYPTON						
Rb RUBIDIUM	Sr STRONTIUM	Y YTTRIUM	Zr ZIRCONIUM	Nb NIOBIUM	Mo MOLYBDENUM	Tc TECHNETIUM	Ru RUTHENIUM	Rh RHODIUM	Pd PALLADIUM	Ag SILVER	Cd CADMIUM	In INDIUM	Sn TIN	Sb ANTIMONY	Te TELLURIUM	I IODINE	Xe XENON						
Cs CAESIUM	Ba BARIUM	Lu LUTETIUM	Hf HAFNIUM	Ta TANTALUM	W TUNGSTEN	Re RHENIUM	Os OSMIUM	Ir IRIDIUM	Pt PLATINUM	Au GOLD	Hg MERCURY	Tl Thallium	Pb LEAD	Bi BISMUTH	Po POLONIUM	At ASTATINE	Rn RADON						
Fr FRANCIUM	Ra RADIUM	Lr LAWRENCIUM	Rf RUTHERFORDIUM	Db DUBNIUM	Sg SEABORGIUM	Bh BOHRIUM	Hs HASSIUM	Mt MEITNERIUM	Ds DARMSTADTIUM	Rg ROENTGENIUM	Cn COPERNICIUM	Uut UNUNTRIUM	Uuq UNUNQUADIUM	Uup UNUNPENTIUM	Uuh UNUNHEXIUM	Uus UNUNSEPTIUM	Uuo UNUNOCTIUM						
		La LANTHANUM	Ce CERIUM	Pr PRASEODYMIUM	Nd NEODYMIUM	Pm PROMETHIUM	Sm SAMARIUM	Eu EUROPIUM	Gd GADOLINIUM	Tb TERBIUM	Dy DYSPROSIUM	Ho HOLMIUM	Er ERBIUM	Tm THULIUM	Yb YTTERBIUM								
		Ac ACTINIUM	Th THORIUM	Pa PROTACTINIUM	U URANIUM	Np NEPTUNIUM	Pu PLUTONIUM	Am AMERICIUM	Cm CURIUM	Bk BERKELIUM	Cf CALIFORNIUM	Es EINSTEINIUM	Fm FERMIUM	Md MENDELEVIUM	No NOBELIUM								

P to Nb (K-edges)

Y to U (L_3 edges)

Multitechnique, low Z

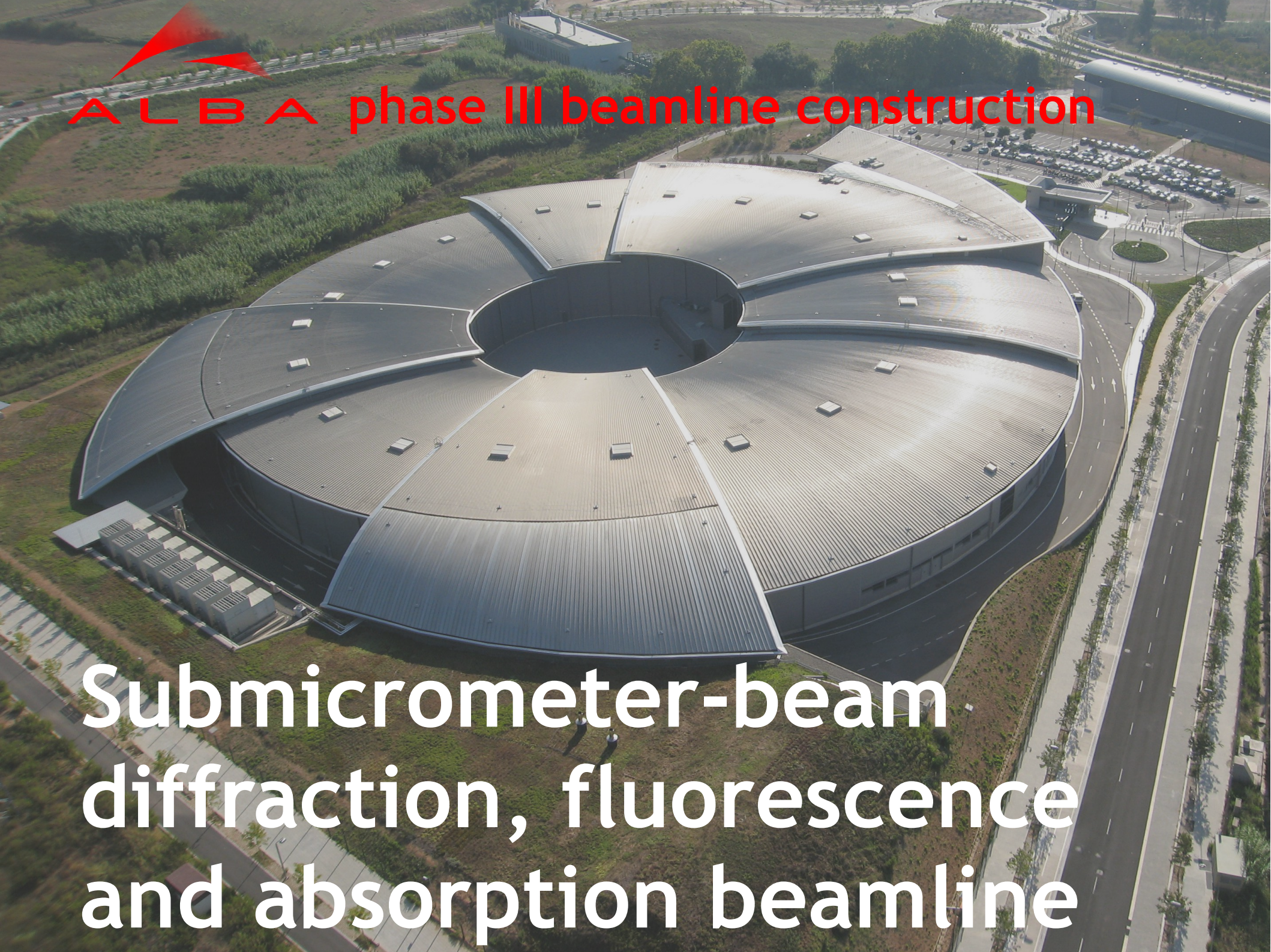
**Life and earth sciences
(and interaction between them)**

Conclusions

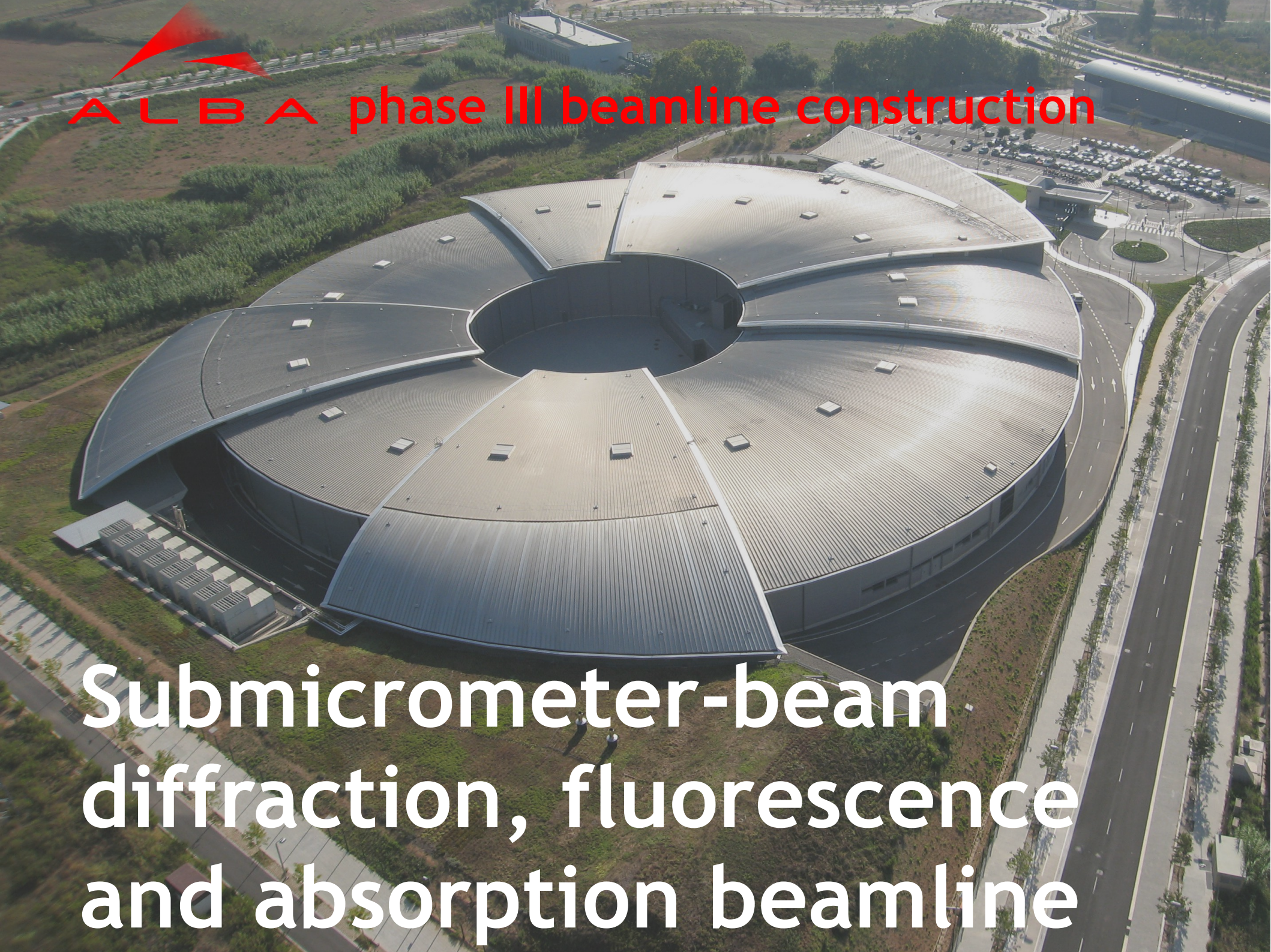
Synchrotron
Complementary
Heterogeneous
Multidisciplinary
X-ray
Fluorescence
Spectroscopy
Absorption
Beamline
ALBA
Sub-micrometer
Diffraction
Hard Matter
European
Cultural Heritage
Research
Techniques
Monochromator
Ion Chamber
XANES
2-20 keV
Materials
Crystal
Polymers
Drugs
Local
Mapping
Phase
XRF
Microprobe
SDD
Resolution
XRD
EXAFS
High Pressure
Bio-medical
Soft Matter
Sample
Study
WAXS
SAXS
Earth and Environmental
Industry
Element
Geology
Soil Conditions
Energy
Speciation
Science
Composition
Structure
Metal
Imaging
Cell
Mirror



ALBA phase III beamline construction



Submicrometer-beam
diffraction, fluorescence
and absorption beamline



ALBA phase III beamline construction

Submicrometer-beam
diffraction, fluorescence
and absorption beamline