ESRF | The European Synchrotron

Welcome to the *CREMLIN* WP2 Workshop

Funding and Joint Research Programme at the Megascience Facilities

Harald Reichert – reichert@esrf.fr

HISTORY OF THE ESRF

- **1975** **Idea for a European third-generation synchrotron source**

- **1988** **Signature between the governments of 12 Member States.**

13 years pre-history
27 years success story

- **1992** **First electron beam in the storage ring. Commissioning phase.**
- **1994** **User operations with 15 beamlines**
- **1998** **40 beamlines**
- **2008** **Upgrade Programme Phase I (2009-2015)**
- **2014** **Upgrade Programme Phase II (2015-2022)**

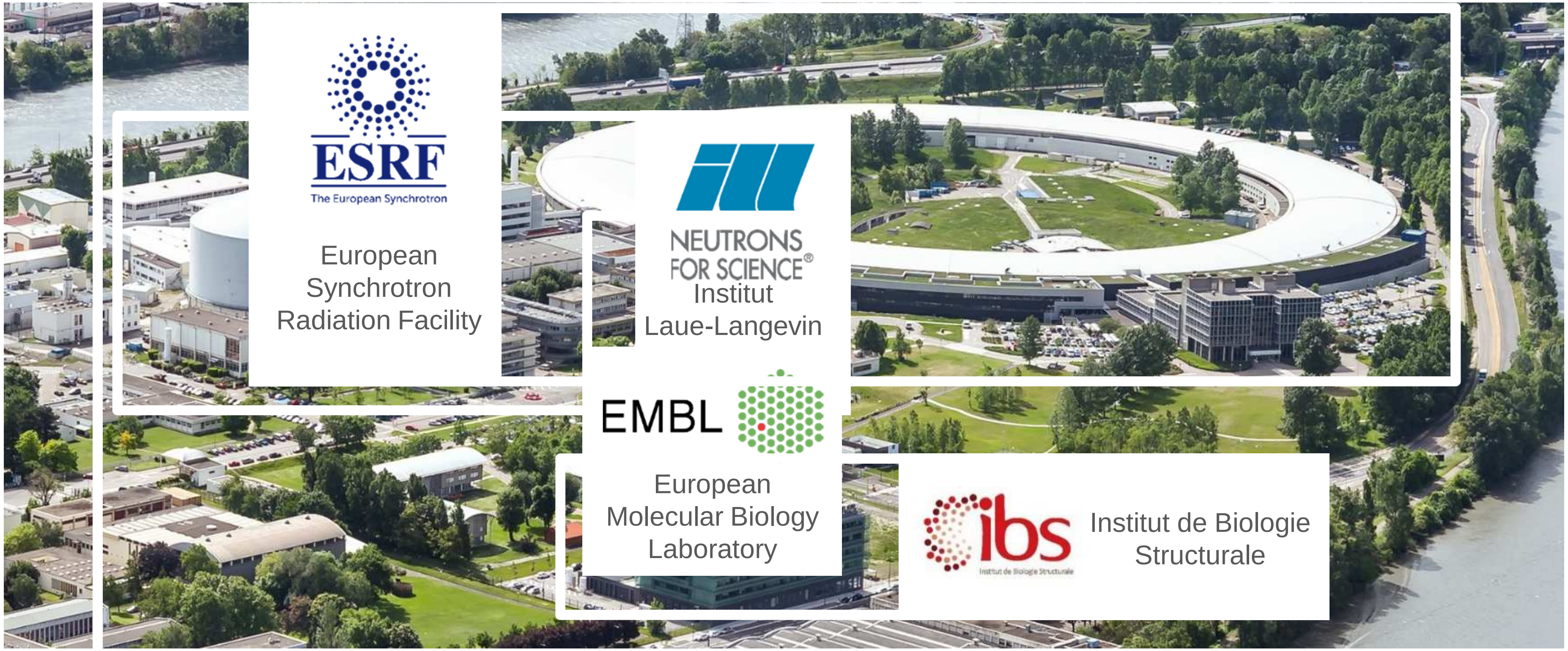
Fundamental and applied studies on materials and living matter

Many industrial partners

Observing, characterising and understanding the structure of matter

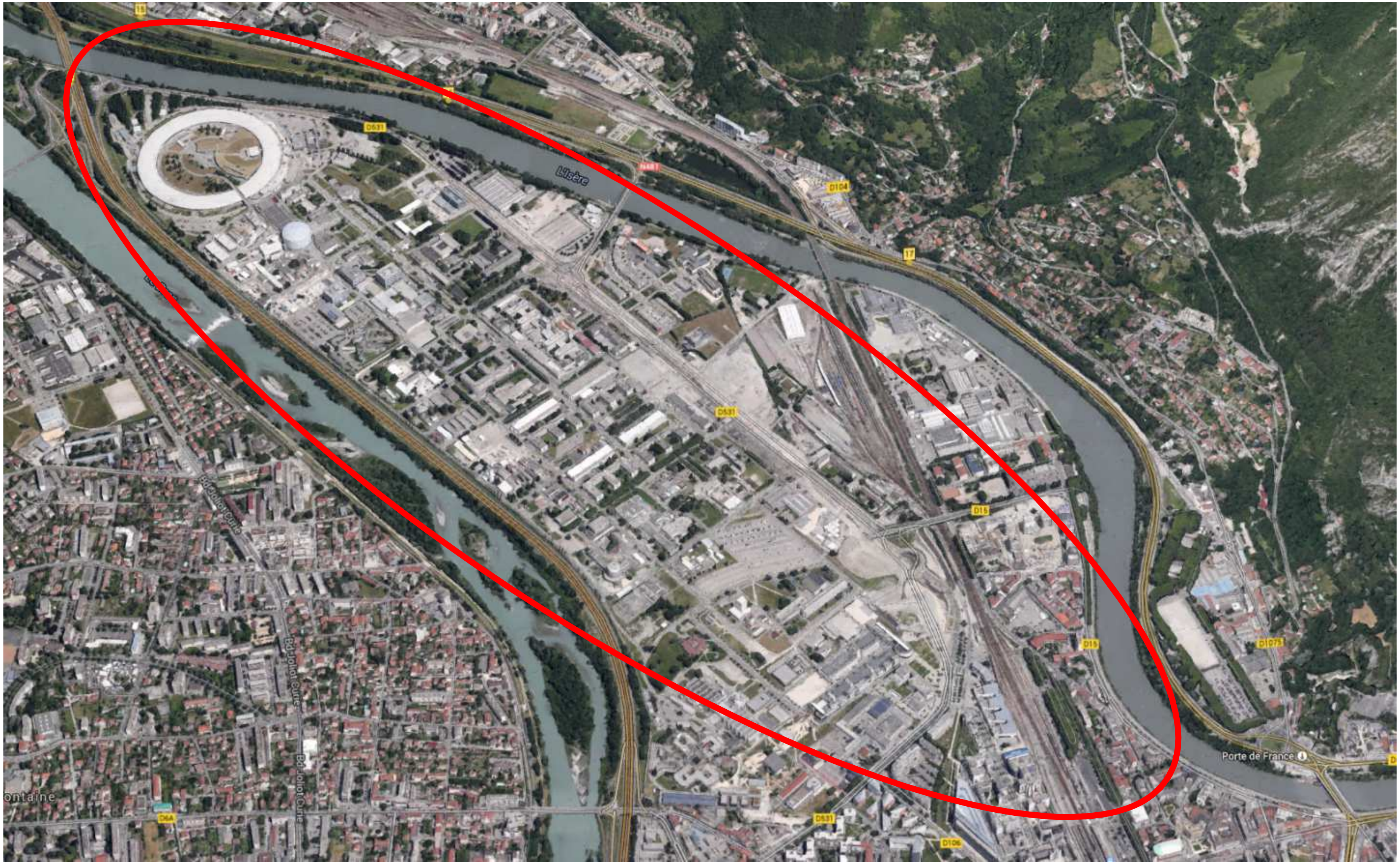
ArcelorMittal
TOTAL
MERCK
Medivi
Johnson Matthey
Bayer HealthCare
Bayer Schering Pharma
novo nordisk
TOYOTA CENTRAL R&D LABS., INC.
syngenta
L'ORÉAL RECHERCHE
Sareum
Schneider Electric
GALDERMA R & D
CORNING
NERVIANO MEDICAL SCIENCES
numericalrod
Unilever
sanofi aventis
astex therapeutics
ucb
Rhodia
AREVA
Vernalis
gsk GlaxoSmithKline
AstraZeneca

A UNIQUE SITE FOR RESEARCH AND INNOVATION



european photon & neutron science campus

AROUND ESRF - THE "PRESQU'ÎLE SCIENTIFIQUE"



THE ESRF AND ITS NEIGHBOURS

Large scale European laboratories

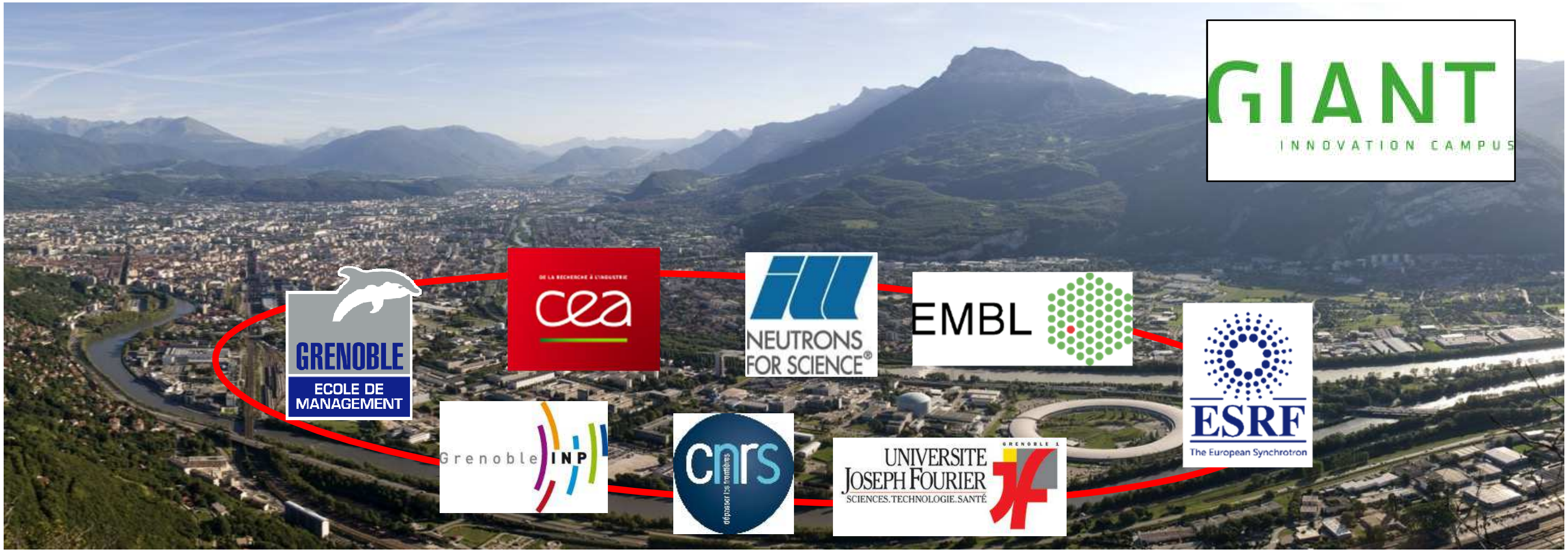
Academic partners

Research organisations

Local Authorities

At the heart of a global innovation campus

Concentrating research, innovation and higher education in one location



Communauté UNIVERSITÉ Grenoble Alpes

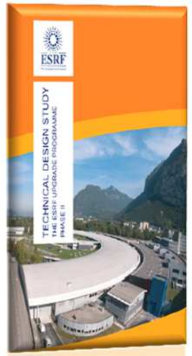
- F. Sette, member of the CA of the COMUE
- Scientific and pedagogical partnerships

TRAINING AND EDUCATION

- Hercules courses since more than 20 years
- PhD programme with ESRF funding for 30 positions (many of them co-funded)
- Trainee programme (up to 6 month in science and technology, funded by ESRF)
- Sandwich courses (2-year courses alternating at the ESRF and in school)
- ESRF-ILL International summer student summer programme (1 month, 20 places)
- Synchrotron @ School (a day of immersion in science for school kids, ~ 850 participants in 2016)

ESRF UPGRADE PROGRAMME

Purple Book
January 2008



Orange Book
January 2015

ESRF UPGRADE PHASE I
164 M€ (2009-2015):
ESFRI ROADMAP 2006-2016
ESFRI LANDMARK (2016)

- 19 new beamlines, many specialised on *nano*-beam science
- Upgrade and renewal of facilities and support laboratories

ESFRI

European Commission

ESRF-EBS
Extremely Brilliant Source
150 M€ (2015-2022)
ESFRI LANDMARK (2016)

revolutionary design
for a new generation of synchrotron
source storage rings

Phase I

19 upgraded or deeply refurbished BLs

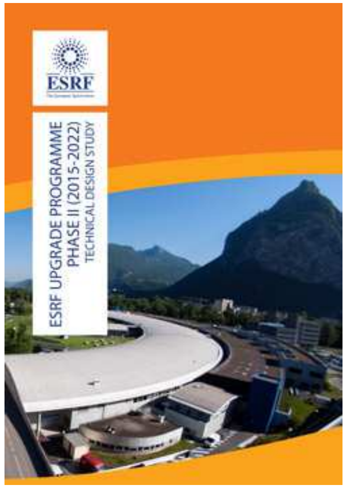
Accelerator and source upgrade

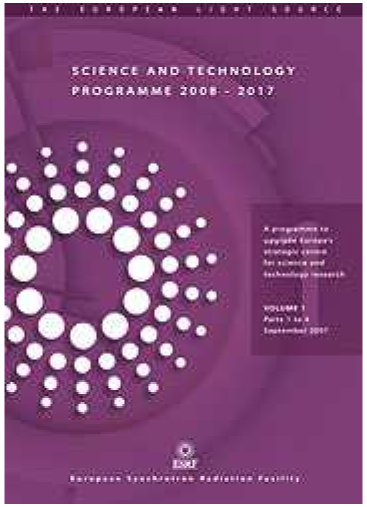
Construction programme

2009

2015

Orange Book
January 2015





Purple Book
2008

2015

2022

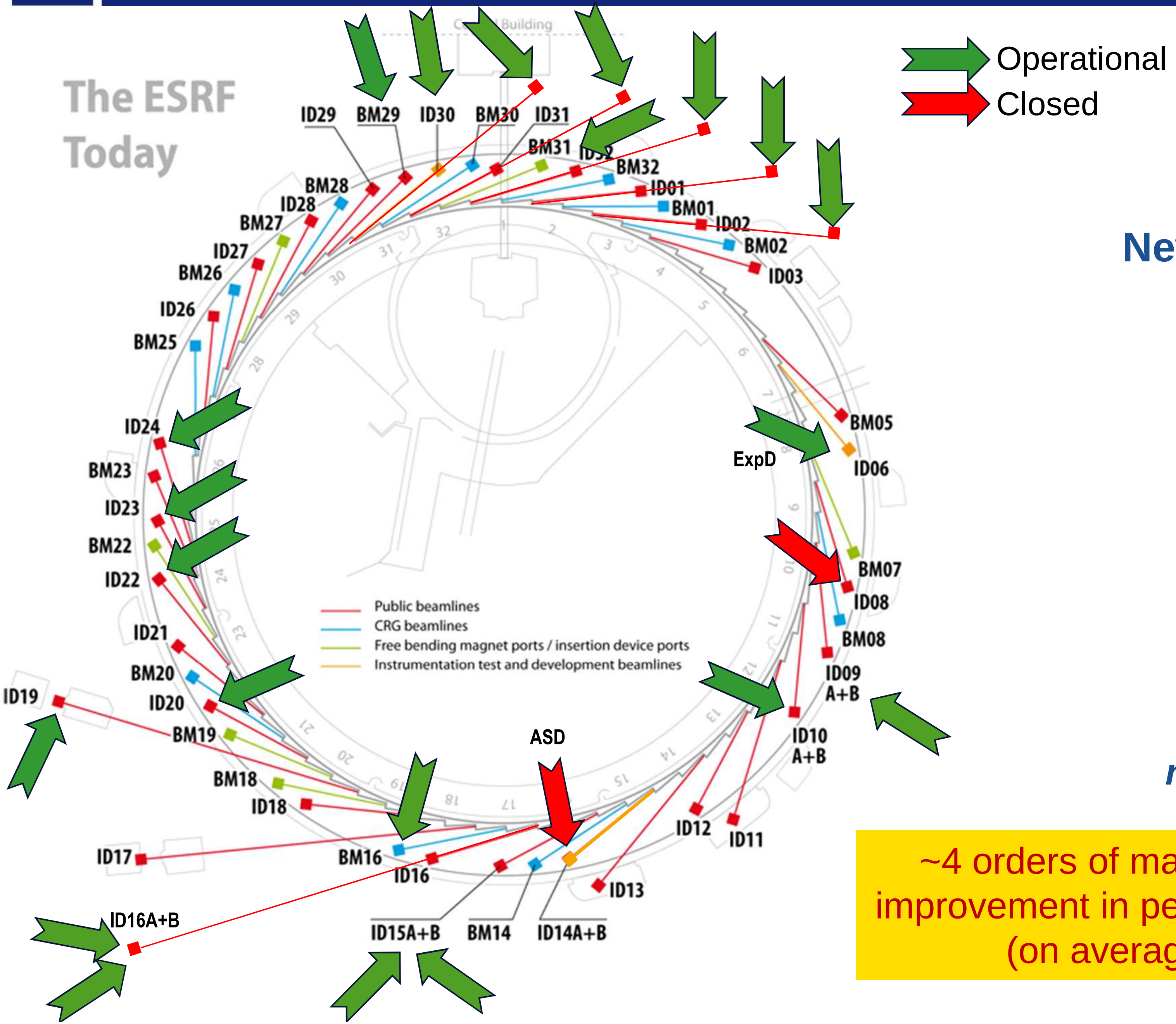
Phase II

New storage ring

4 new BLs

Technology program

UP PHASE I 2016: NEW BEAMLINE PORTFOLIO



Beamline portfolio

New Beamlines 2009 - 2015

Imaging
Diffraction
Spectroscopy

Fundamental Research

Energy
Life Science
***nano*-Materials**

~4 orders of magnitude improvement in performance! (on average)

LIMITATIONS OF TODAY'S SYNCHROTRON RADIATION SOURCES

Today limitations in
• Brightness (~95% loss in nanobeams)
• Coherence (0.2% at 10 keV)

Increase in brightness / coherence

- Smaller source size
- Larger working distance for given beam size
- Resolution beyond the limits of beam size
- Higher time resolution

Increase in flux and flux density

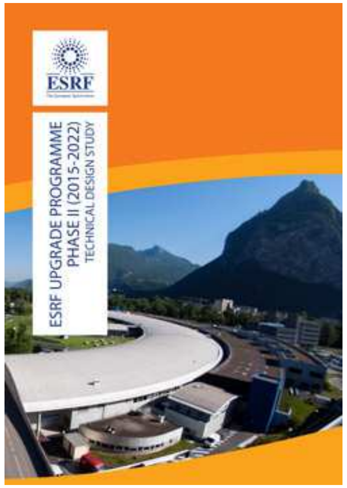
- Higher time resolution

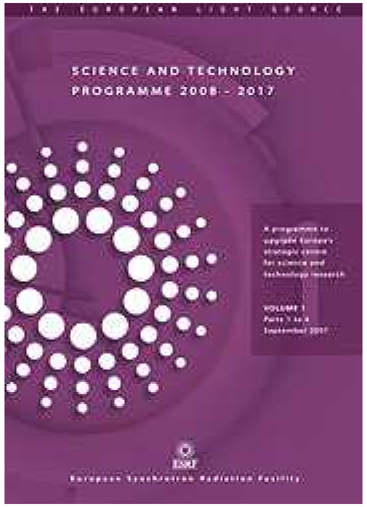
Phase I

19 upgraded or deeply refurbished BLs
Accelerator and source upgrade
Construction programme

2009 — 2015

Orange Book
January 2015





Purple Book
2008

2015 — 2022

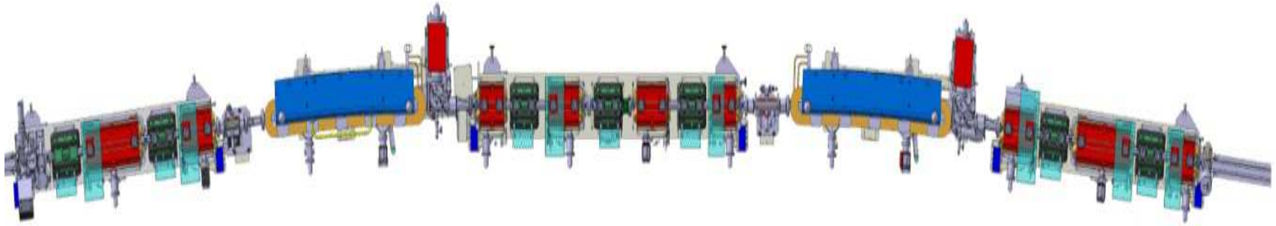
Phase II

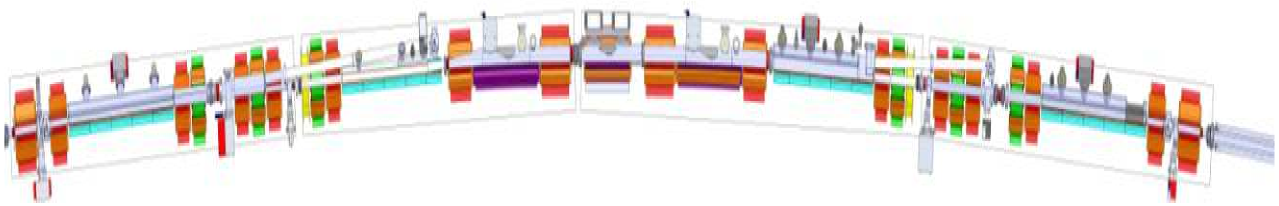
New storage ring
4 new BLs
Technology programme

The 844m storage ring hosts 32 identical arcs

Each Arc is composed by a well defined sequence of Magnets, Vacuum Components (vacuum vessel, vacuum pumps etc), sensors (diagnostic) etc.

Present ESRF arc layout: $\varepsilon_x = 4$ nm·rad



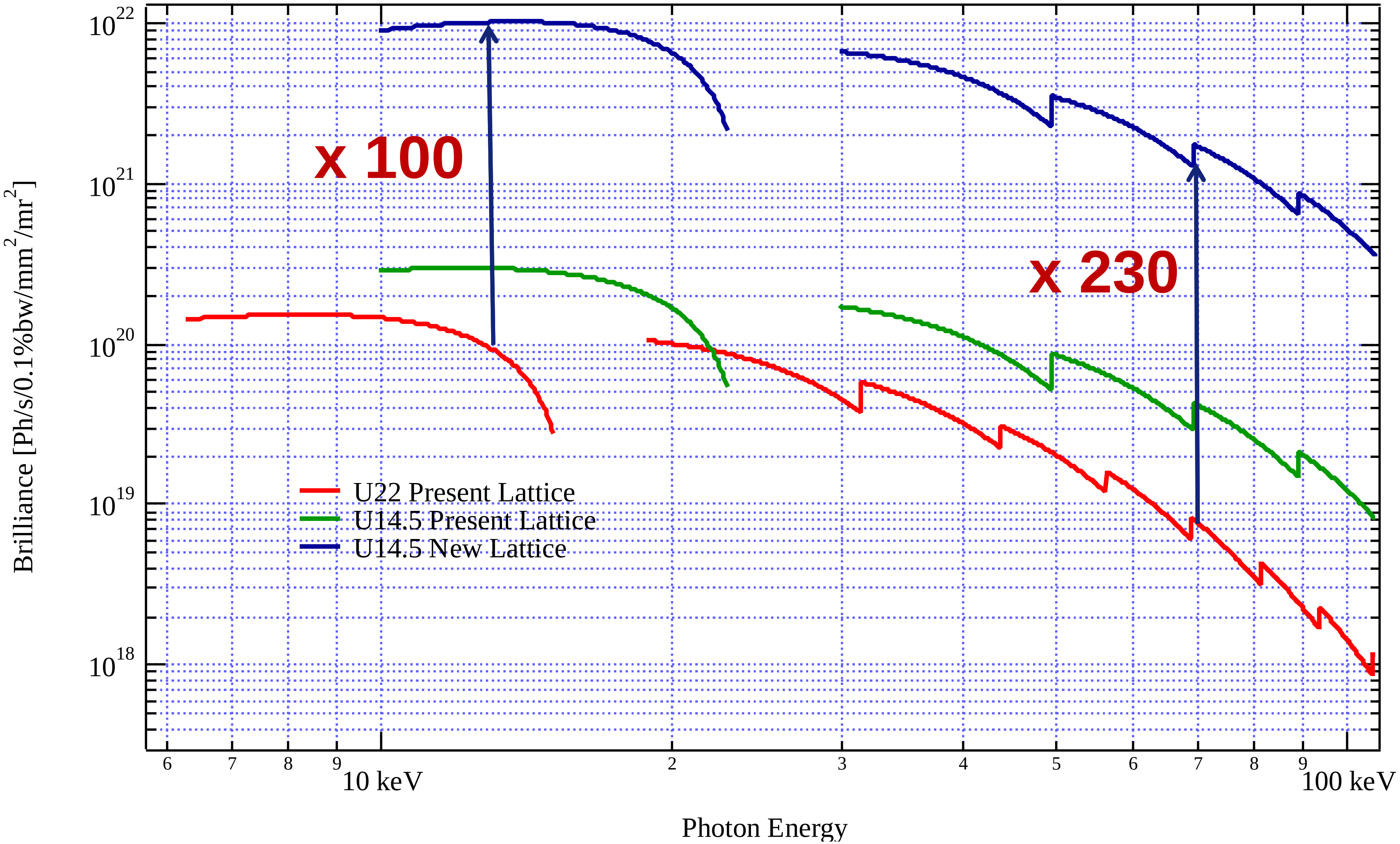


New low emittance layout: $\varepsilon_x = 0.135$ nm·rad

$\varepsilon_x \sim 0.100$ nm·rad with radiation damping by insertion devices

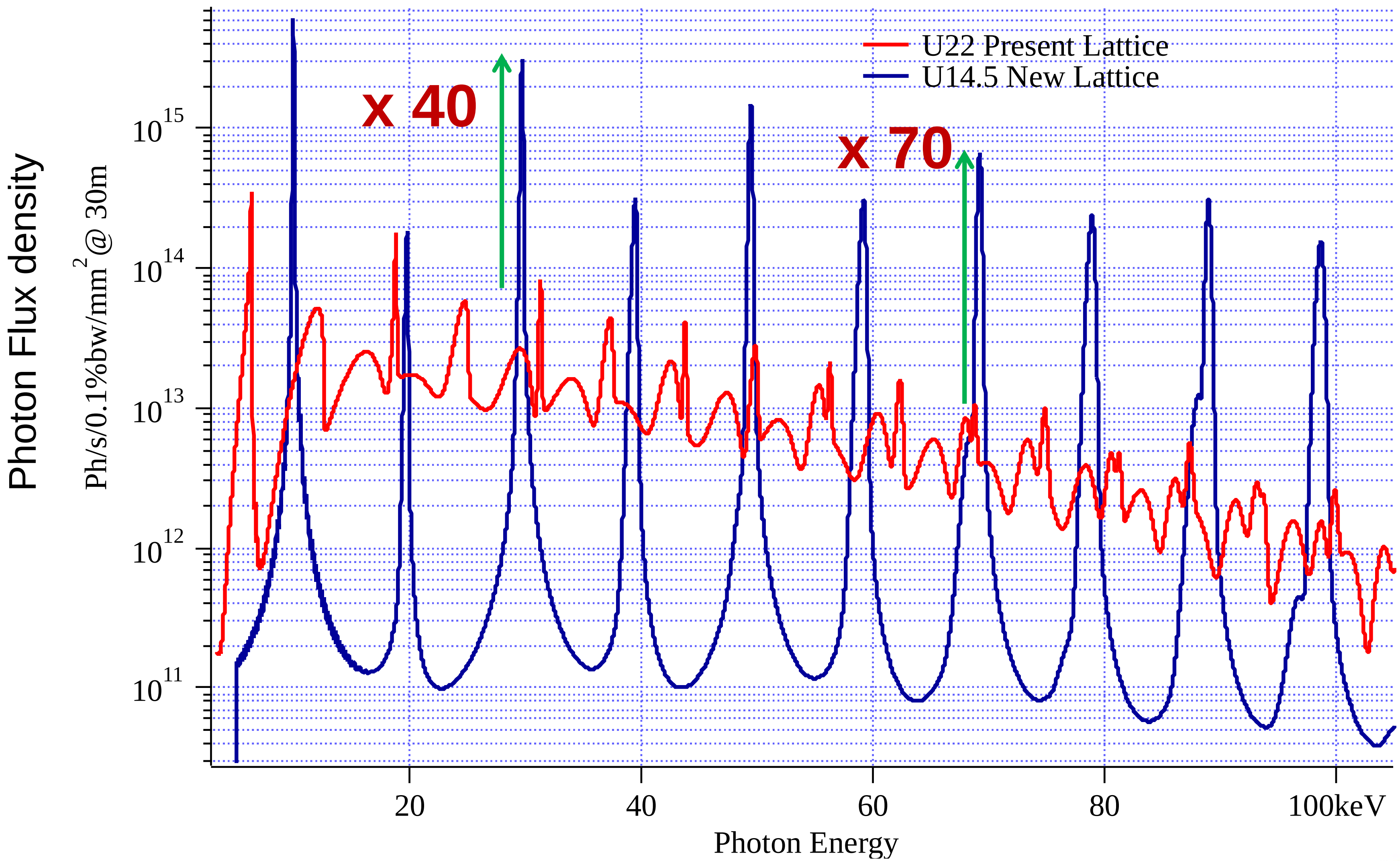
2 M IVUS & CPMUS

IVUN22 min. gap 6 mm, K_{max}=1.7
CPMU14.5 min. gap 4 mm, K_{max}=1.7



2 M IVUS & CPMUS

IVUN22 min. gap 6 mm, K_{max}=1.7
CPMU14.5 min. gap 4 mm, K_{max}=1.7



Science Programme

CDRs FOR UPGRADE BEAMLINE SELECTION

1. Beamline for coherence applications
2. Beamline for hard X-ray diffraction microscope
3. High throughput large field phase-contrast tomography beamline
4. Surface science beamline
5. High-flux nano-XRD beamline for science under extreme conditions
6. Facility for dynamic compression studies
7. High brilliance XAS beamline
8. Serial crystallography beamline

- Conceptual Design Report (CDRs)
  - Science case
  - Project indicators
  - Technical description
  - Budget estimation

ESRF EBS PROGRAMME

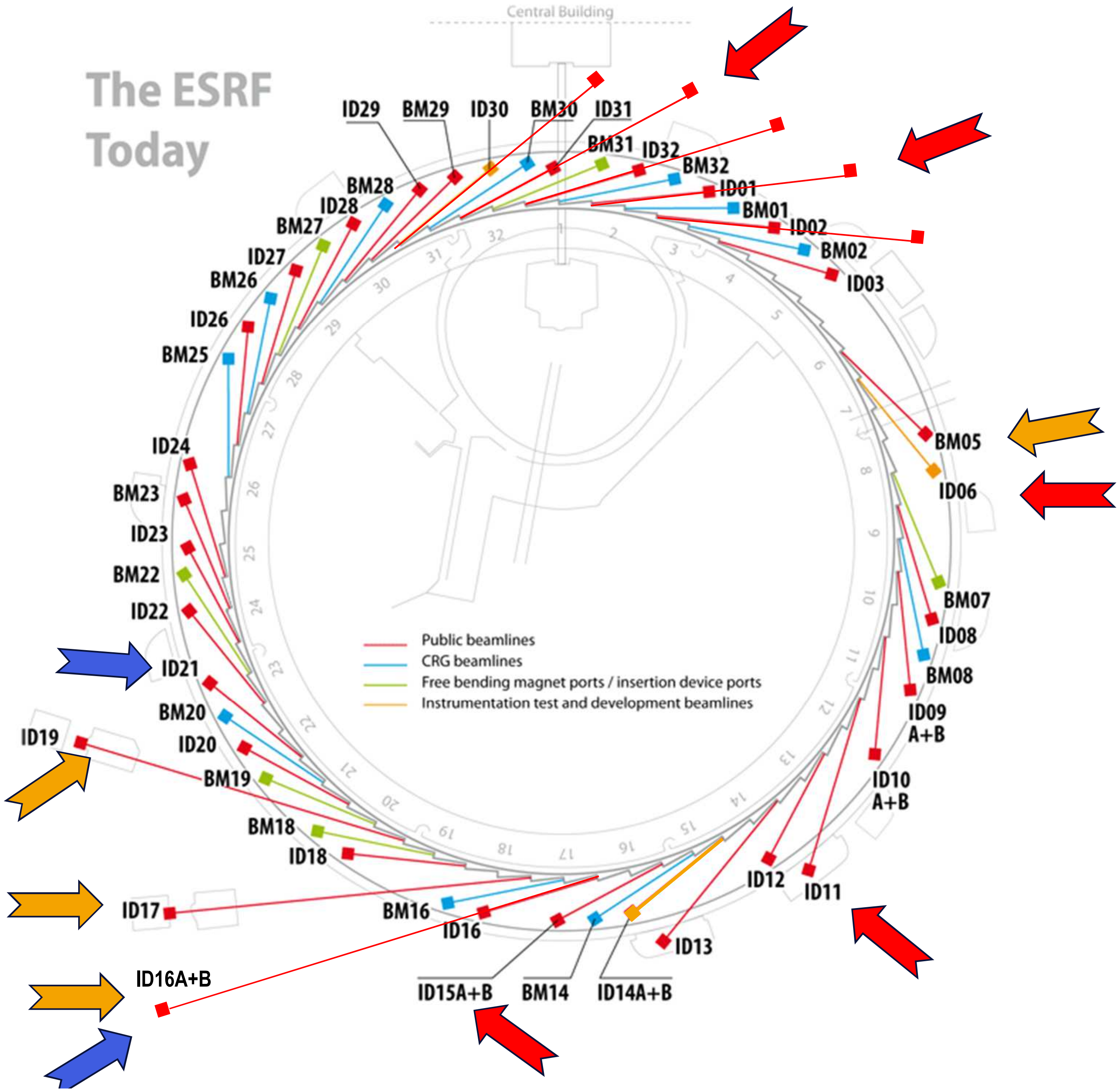
CONCEPTUAL DESIGN REPORT
UPBL

Name of Project:	

ESRF Spokesperson for project	
ExpD Group(s) affiliated with the project	
Scientific field(s)	
Proposed destination in the EXPH	
Proposed time scale for realisation of the project	
Executive summary	
Cost estimate (k€)	
Members of the expert working Group	- - - - -

Document created on:	XX/XX/2014
Updated on:	XX/XX/2014

IMAGING @ ESRF



Beamline portfolio

Energy range spans from 2 keV to 350 keV

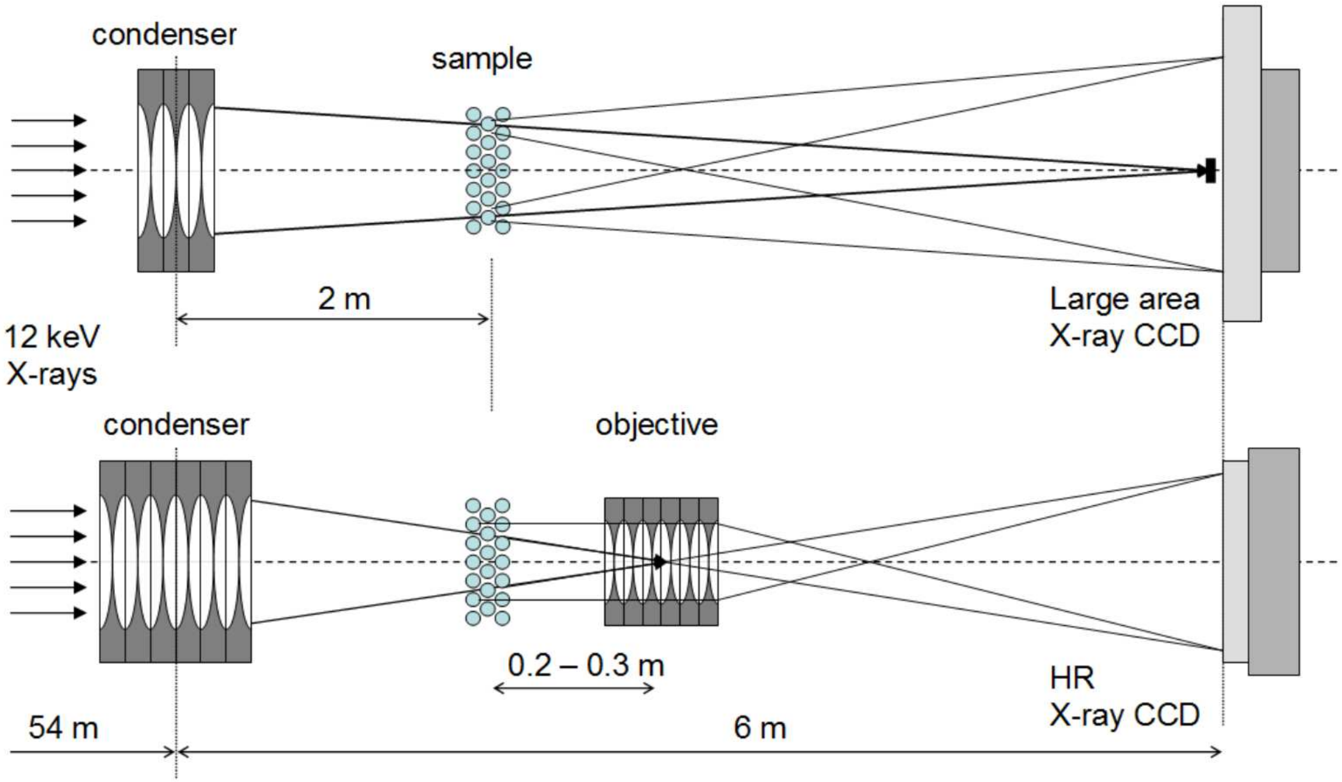
beam size cm – mm – mm – nm

Imaging
Crystallography
Scattering
Spectroscopy

The European Synchrotron | ESRF

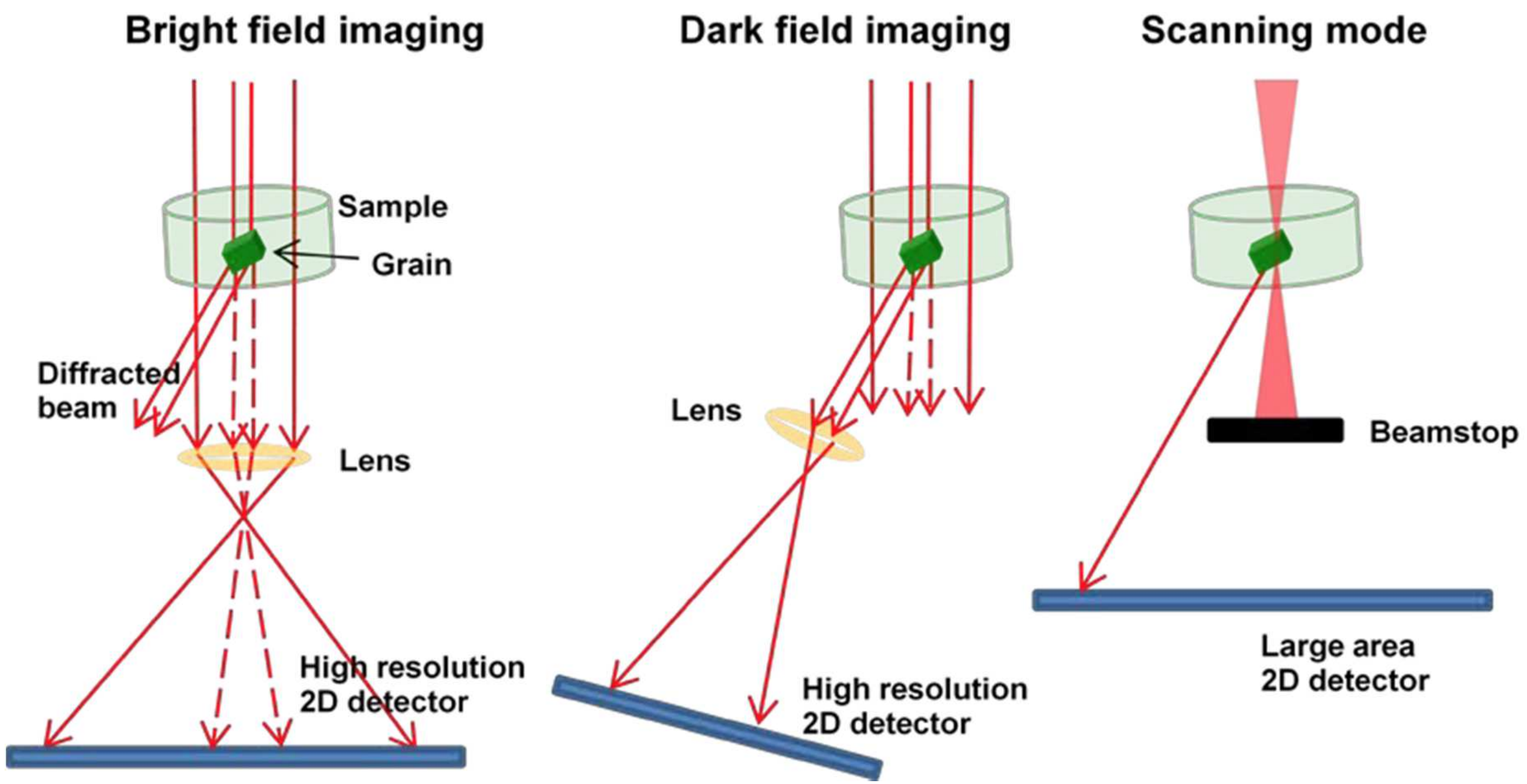
BRIGHT FIELD IMAGING - SAXS MICROSCOPY

- **reciprocal space (top) and direct space (bottom) modes of operation**
- **3D self-assembled systems,
  e.g. bio-minerals, photonic crystals, colloidal systems**
- **at the borderline between bright field and dark field microscopy**



A. Bosak et al., “A new tool for mesoscopic materials,” *Adv. Mat.* 22, 3256 (2010)

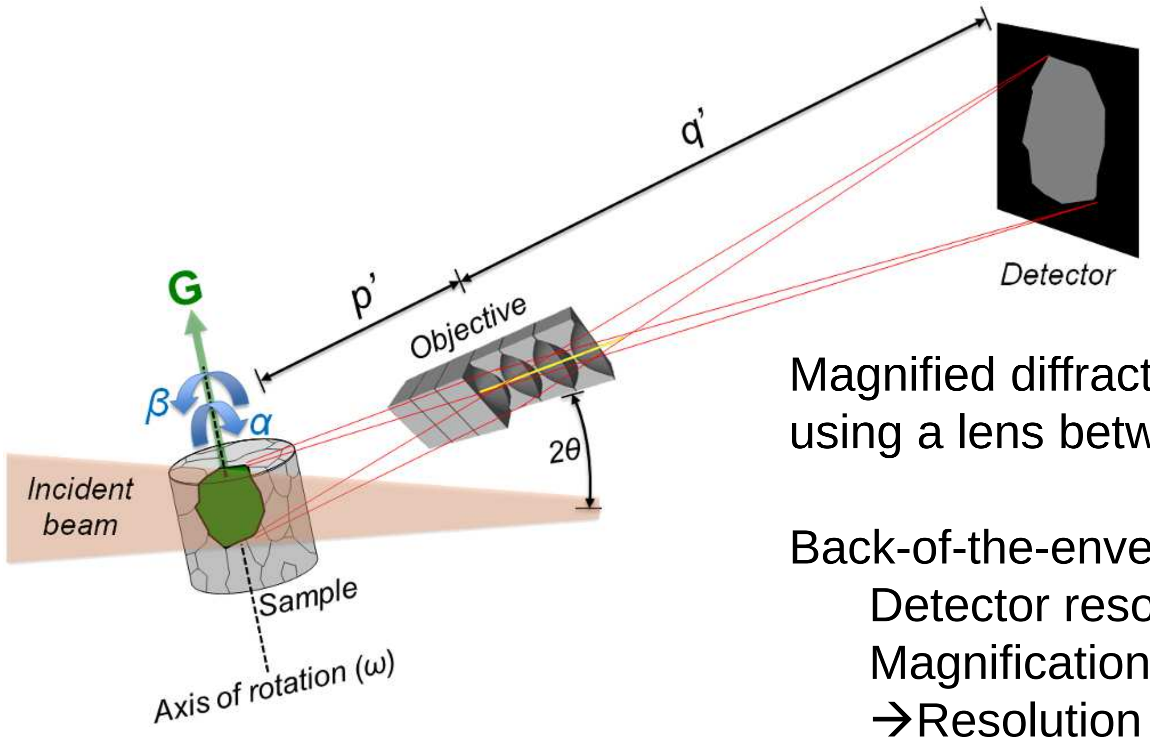
Diffraction based Transmission X-ray Microscopy



Optics < 15 keV : zone plates 10 nm

> 15 keV : compound refractive lenses 100 nm => 20 nm

Hard x-ray microscopy project:
Full field imaging using a lens between sample and detector



Magnified diffraction topography/topo-tomo using a lens between sample and detector

Back-of-the-envelope:

Detector resolution 1 µm

Magnification 10x

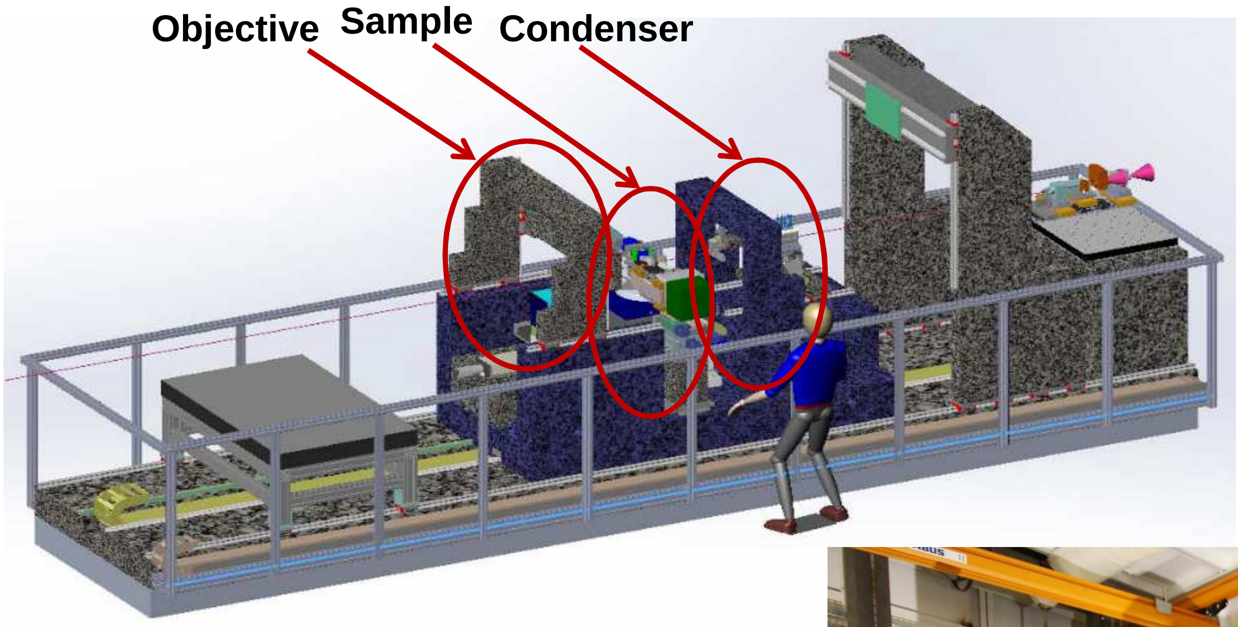
→Resolution at the sample 100 nm.

Advantages:

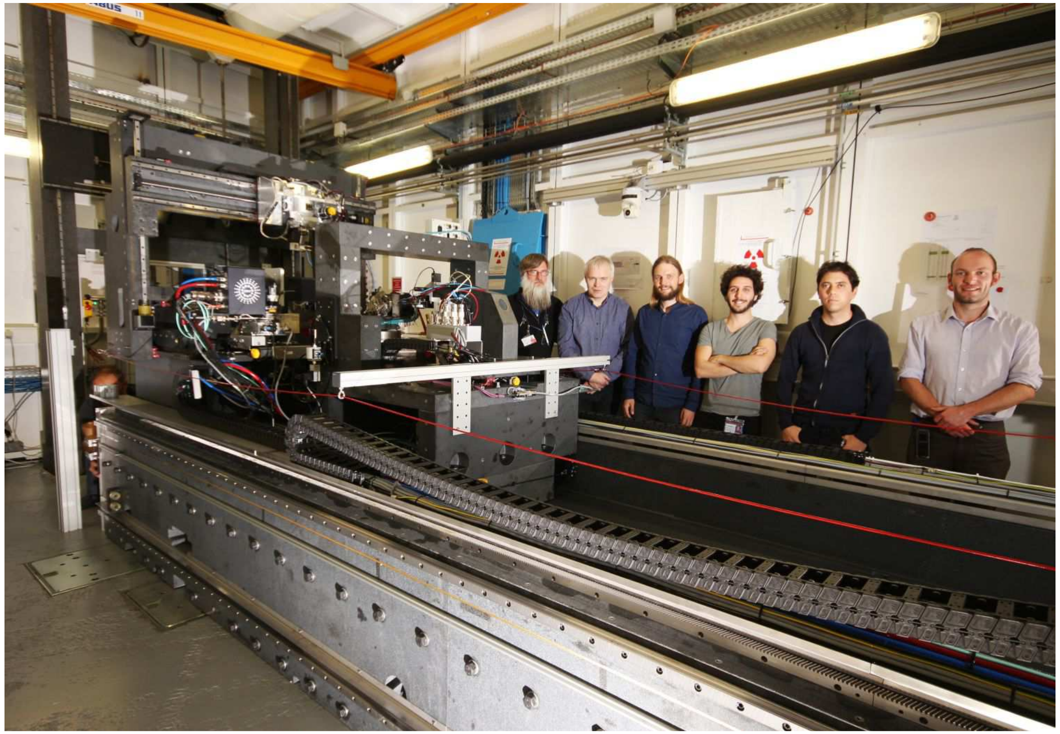
- Full field method,
- High spatial and angular resolution,
- Diffraction

Collaboration with DTU (H. Poulsen)

THE HXDM INSTRUMENT



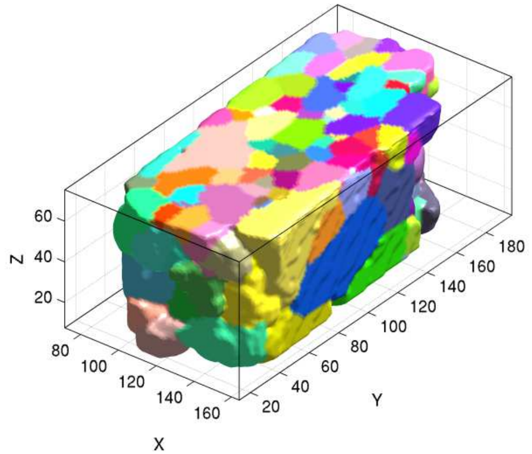
CDR-2 Beamline for
Hard X-ray Diffraction Microscopy
(fully optimised BL layout)

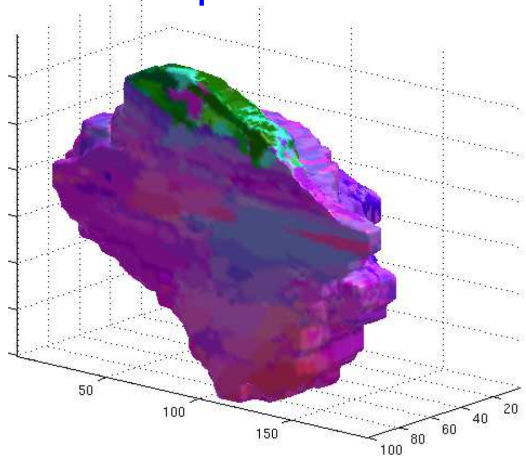


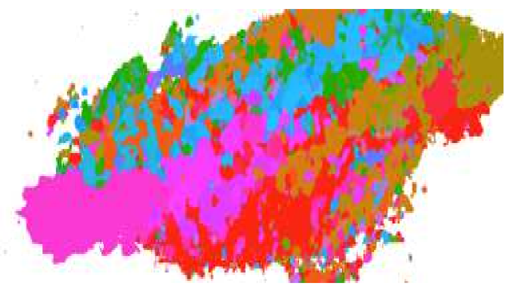
Funded by ESRF and ERC
(H. Poulsen, DTU)

Hard X-ray microscopy: multiscale structural mapping

3D Orientation mapping of Al1050 sample deformed 6%:







Grain mapping

Zoom on one grain

Zoom on sub-grains

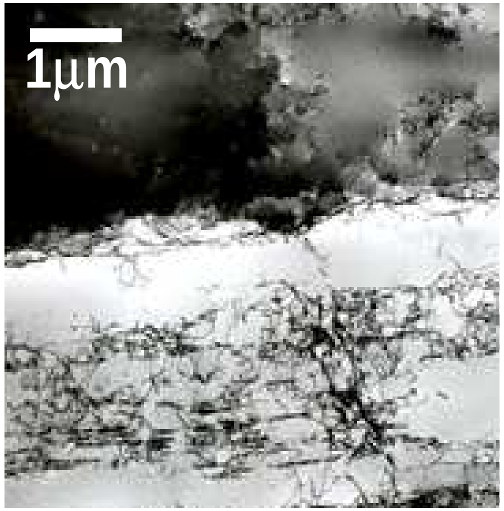
2 µm	200 nm	200 nm
0.5 deg	0.15 deg	0.02 deg

Collaboration with DTU
H. Poulsen

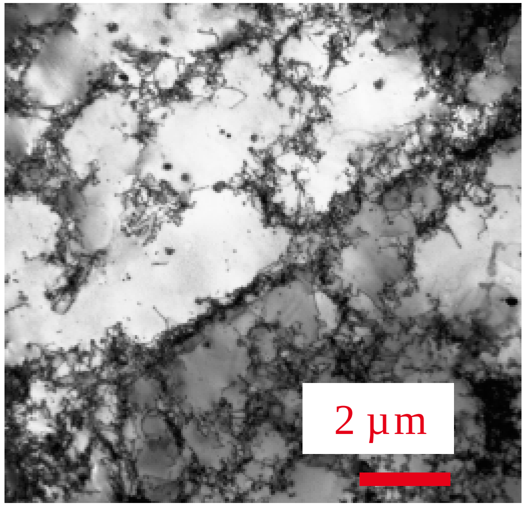
H. Simons et al. Nat. Comm. (2015)

Dislocation structures

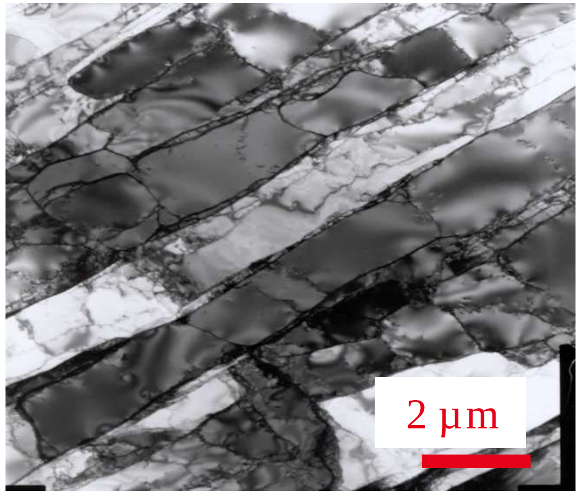
0.3%



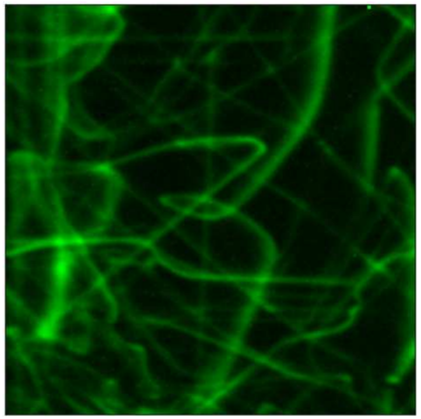
2%



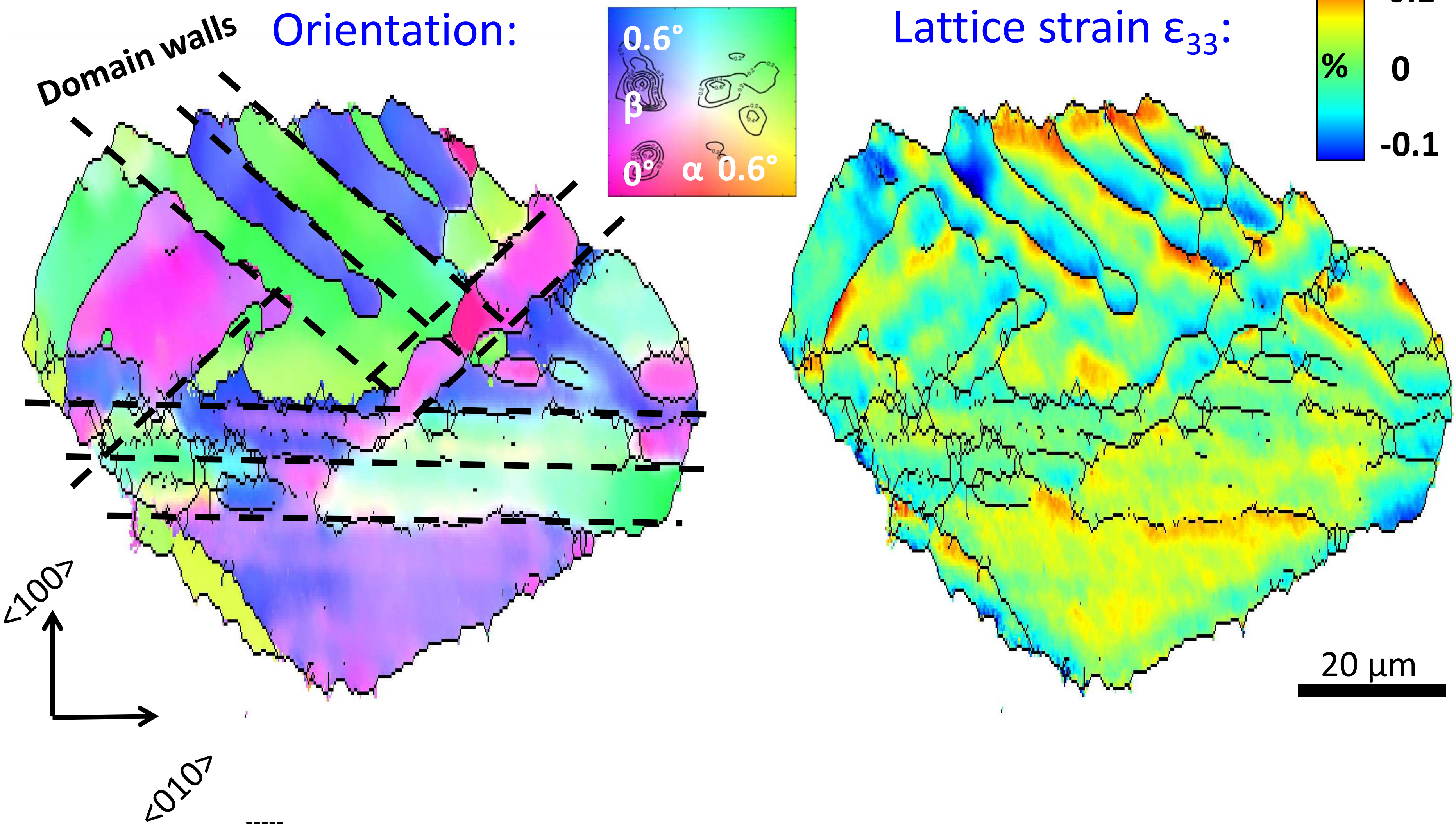
50%



Diffraction Microscopy:

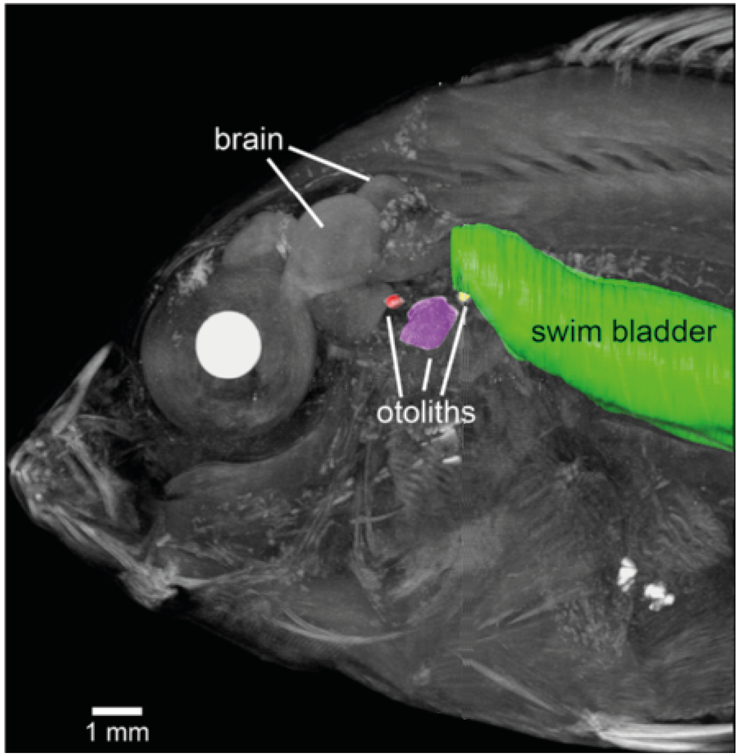


Domains in $BaTiO_3$

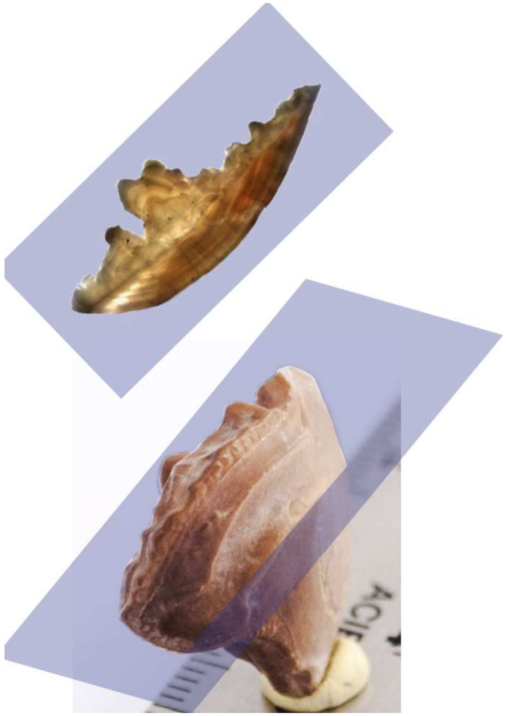


H. Simons, M. Majkut, S. Schmidt, A.C. Jakobsen, H.F. Poulsen, F. Stöhr, A.B. Haugen, C. Detlefs, J.E. Daniels, D. Damjanovic, *Submitted* (2017)

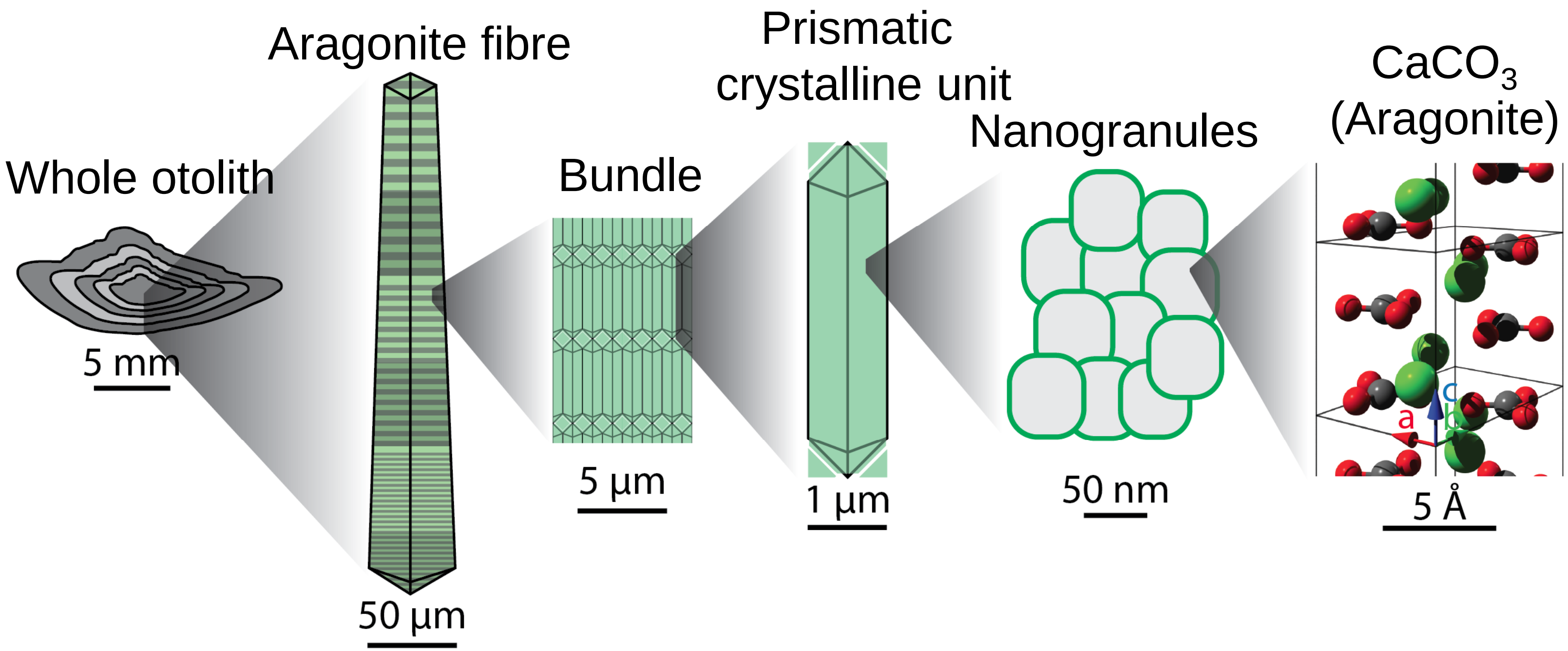
- **Ordered structure from nanoscale to macro-scale – crystal texture**
- **Biological control over structures**
- **Material properties optimized for function**
- **Shell, coral, bone, teeth, pearls, otoliths….**



Schulz-Mirbach et al., *BMC Biol.* (2013)

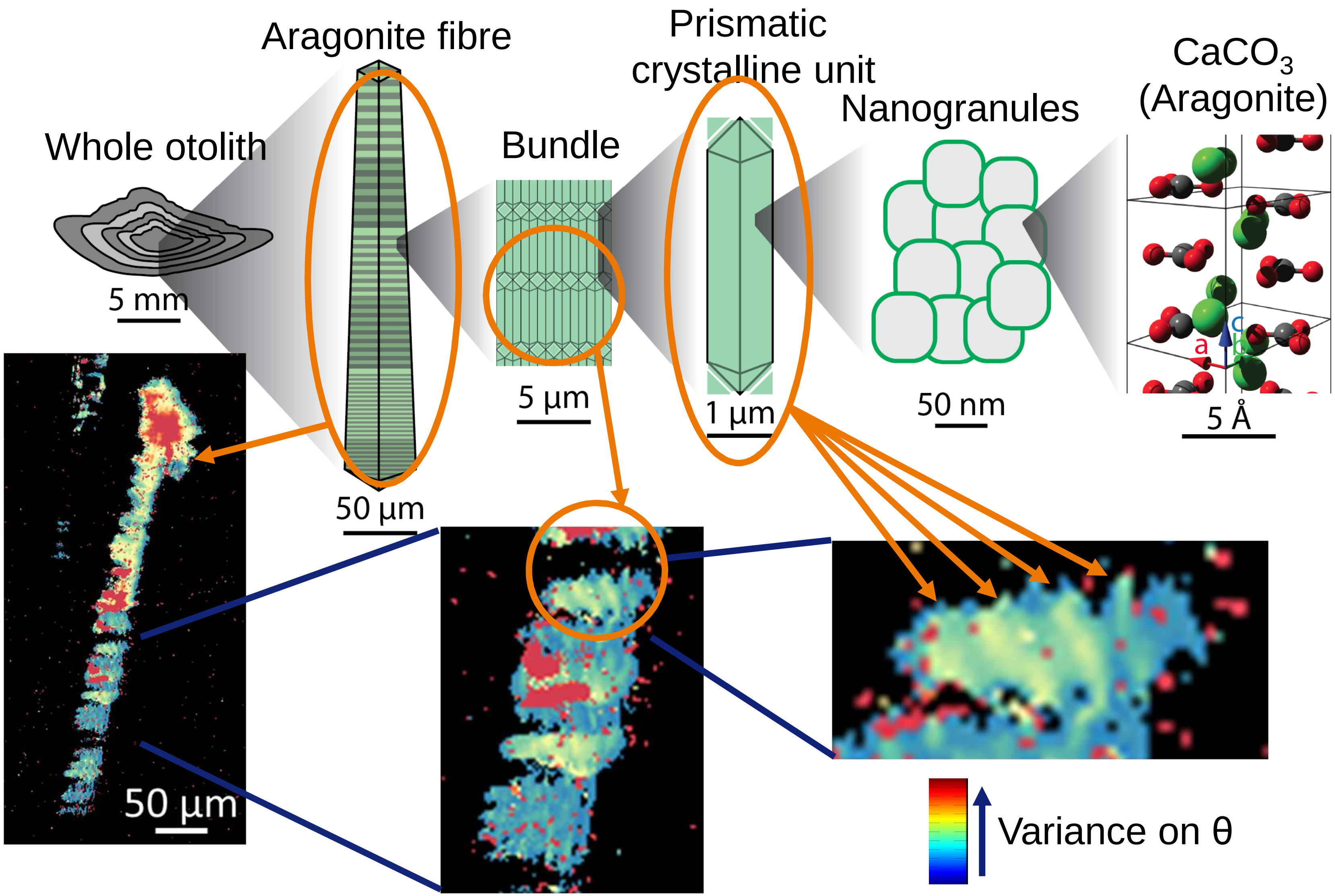


FISH OTOLITH ULTRASTRUCTURE…



Phil K. Cook. (unpublished)

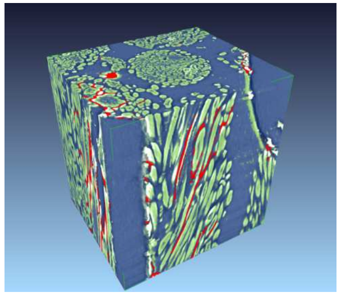
FISH OTOLITH ULTRASTRUCTURE… SEEN BY HXDM

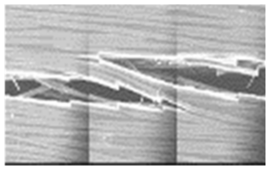


Phil K. Cook. (unpublished)

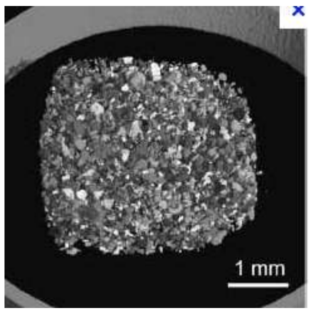
HXDM – MATERIALS & MULTISCALE STUDIES

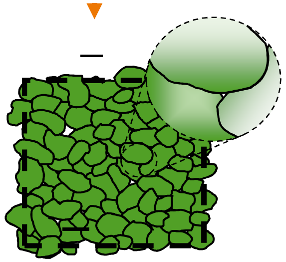
Composites for wind



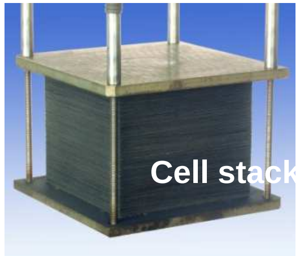


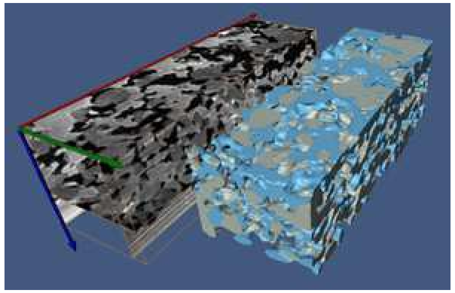
Batteries

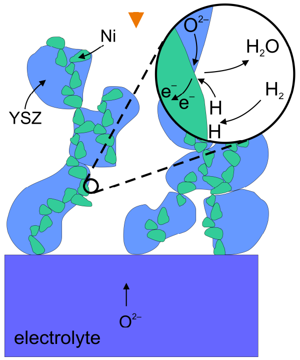




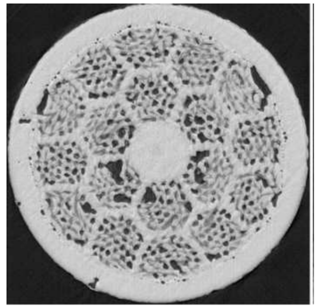
Fuel cells

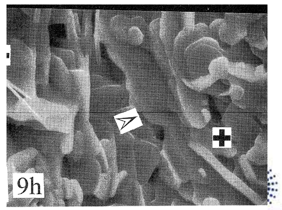






Superconducting cables





THANK YOU FOR YOUR ATTENTION!