Imagining X-ray science in 2050

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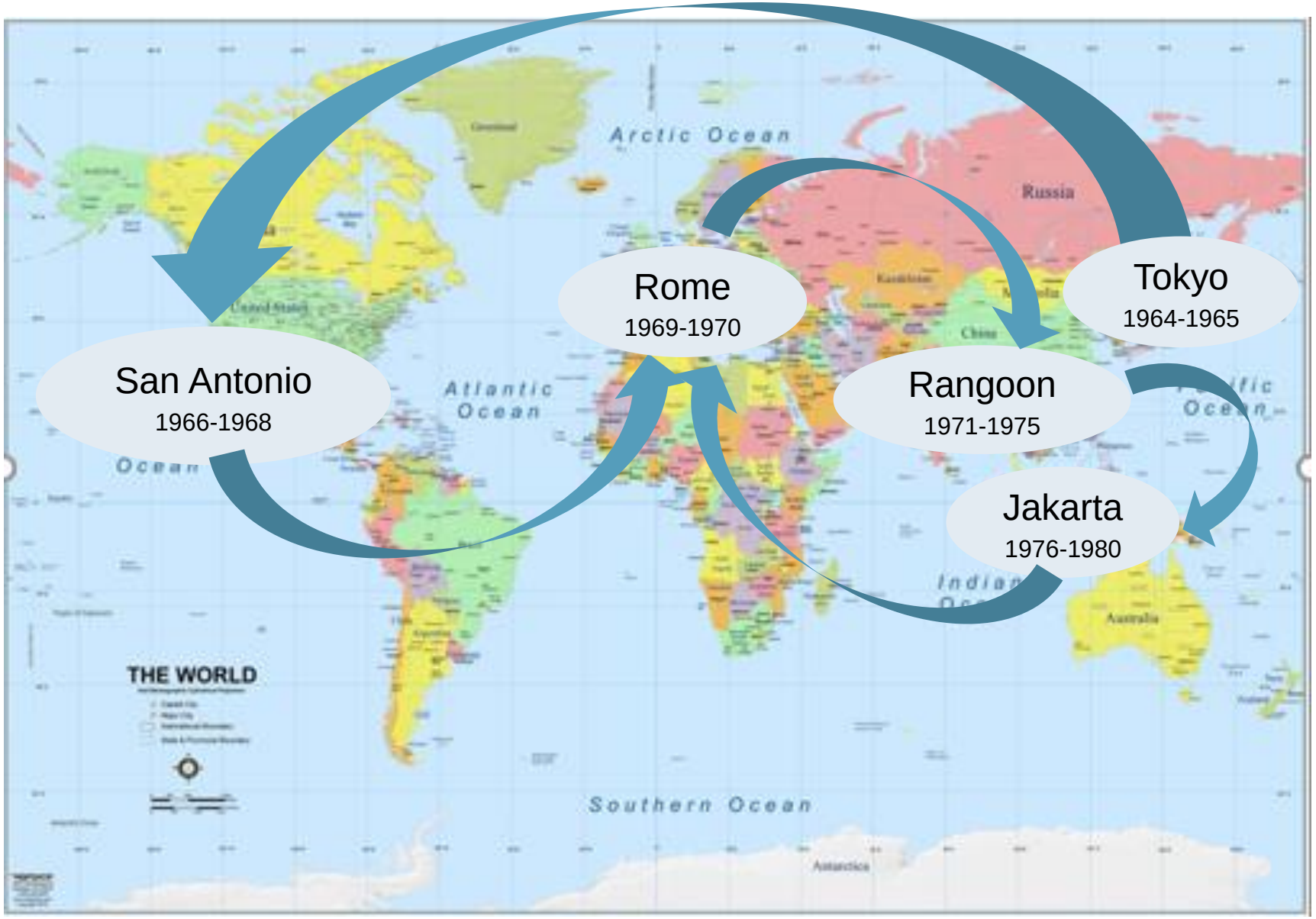
The Innova XN Plenary Event
ESRF, 6-7 July 2022

Sakura 桜


Arctic Ocean
Russia
Rome
1969-1970
Tokyo
1964-1965
San Antonio
1966-1968
Atlantic Ocean
Rangoon
1971-1975
Jakarta
1976-1980
THE WORLD
Southern Ocean
Australia

- **2019** • Scientific Director @ EuXFEL
- **2015** • Head of Matter at Extremes Group @ESRF
- **2012** • Head of Electronic Structure and Magnetism Group @ESRF
- **2000** • Permanent appointment
- **1997** • Beamline Responsible @ESRF
- **1993** • Beamline Scientist @ESRF
- **1990** • Post Doc @INFN

Hamburg

Grenoble
1993-2019

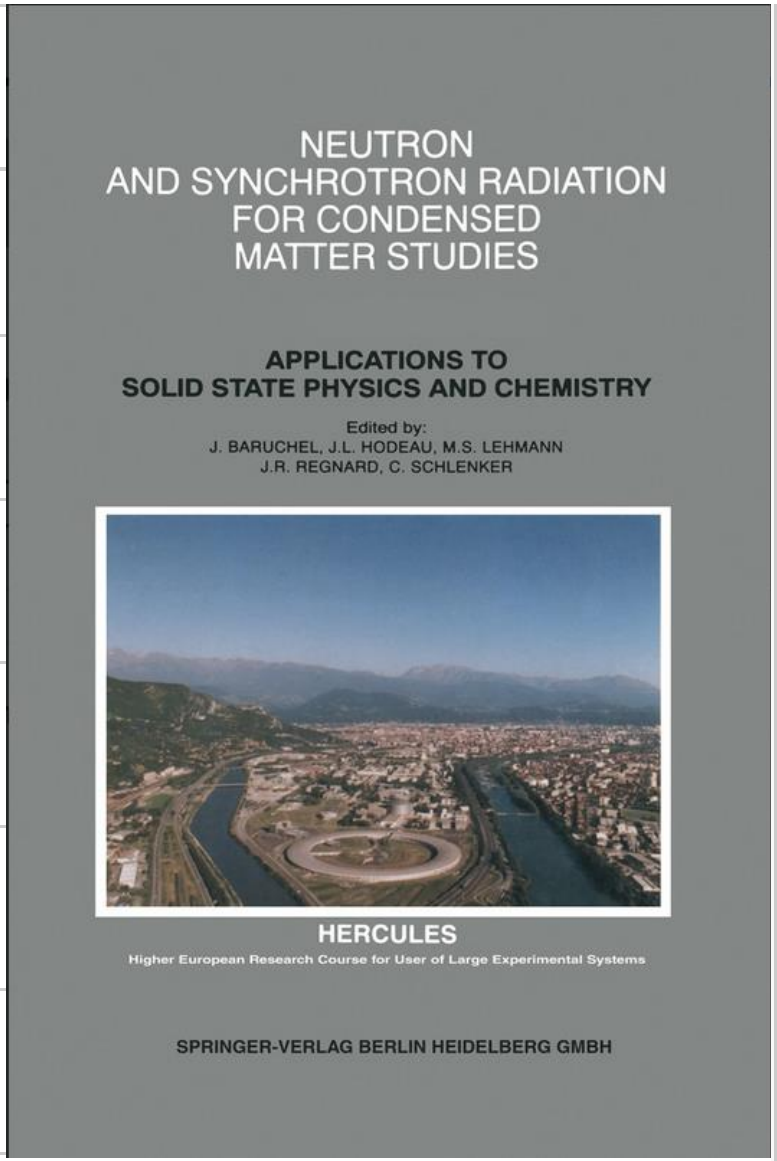
Rome
1981-1992

Looking back 30 yrs …..

- No 3rd generation synchrotron sources …
  - **No exploitation of coherence properties of SR**
  - **The dawn of time-resolved, in-situ, operando studies**

- X-ray Free Electron Lasers not invented yet…
  - **Motions of electrons, atoms, molecules in time-domain observed only indirectly (optical lasers)**

ESRF construction site, 1990



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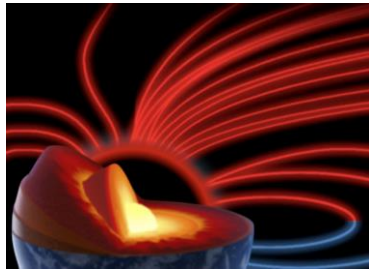
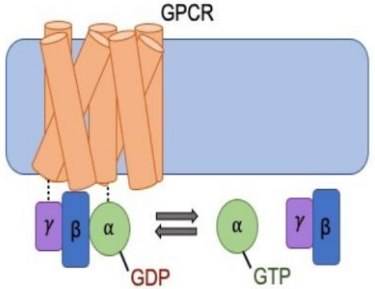
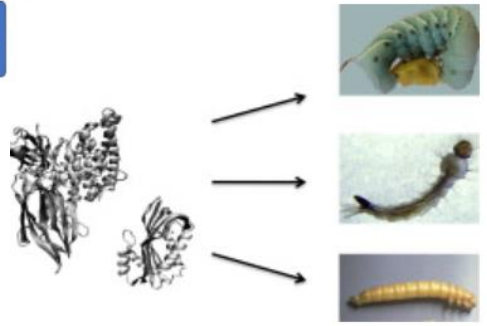
Trends 1

The development of X-ray user facilities, providing access to a large community of multidisciplinary scientists, has been a determinant in solving scientific and societal problems over the ~ 50 yrs, and this will continue for many decades and even centuries to come.



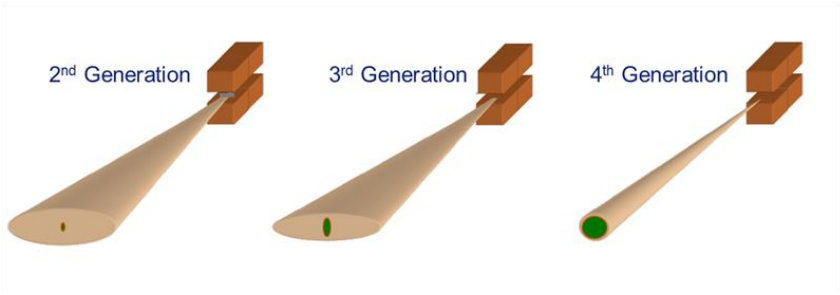


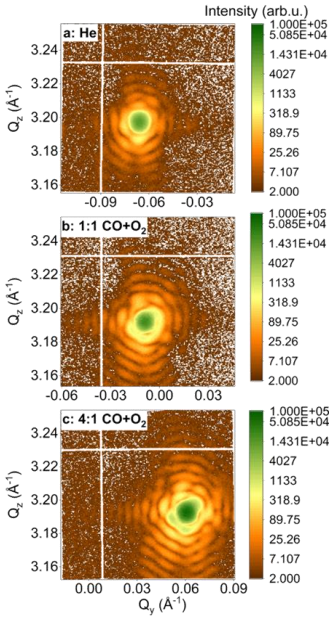


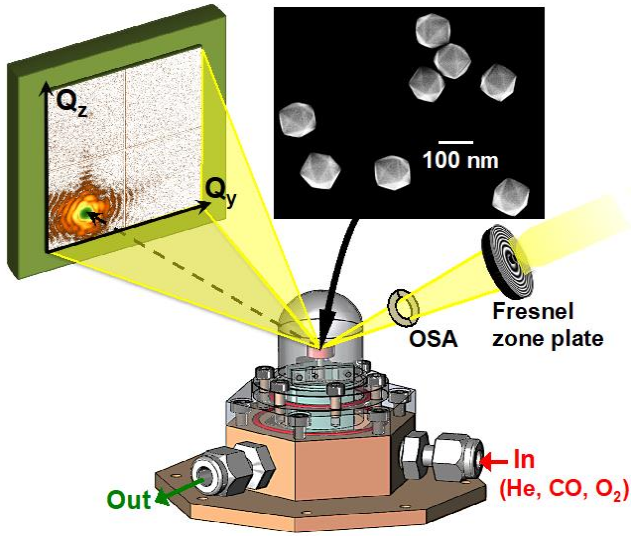
- ***water purification***
- ***geophysical processes of our planet***
- ***fundamental processes important for human health***
- ***designing heterostructures for future nano-optoelectronics***
- ***more efficient bacterial insecticides for agriculture and medicine***
- ***promising candidates for future high-density magnetic data storage media***
- ***new materials for greener and more sustainable energy solutions and improved energy efficiency***

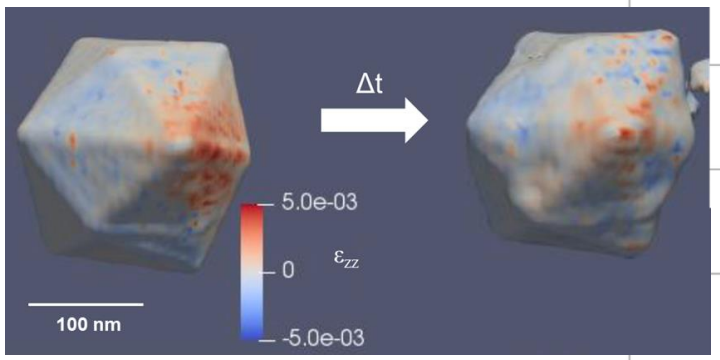
Trends 2

Step increase in brightness and coherence with MBA is an enabler for applying 3D microscopy with nanometer spatial resolution as a routine analytical tool, using dedicated sample environments for *in situ* and *operando* studies, in a broad range of research fields, with time resolution as a fourth dimension.

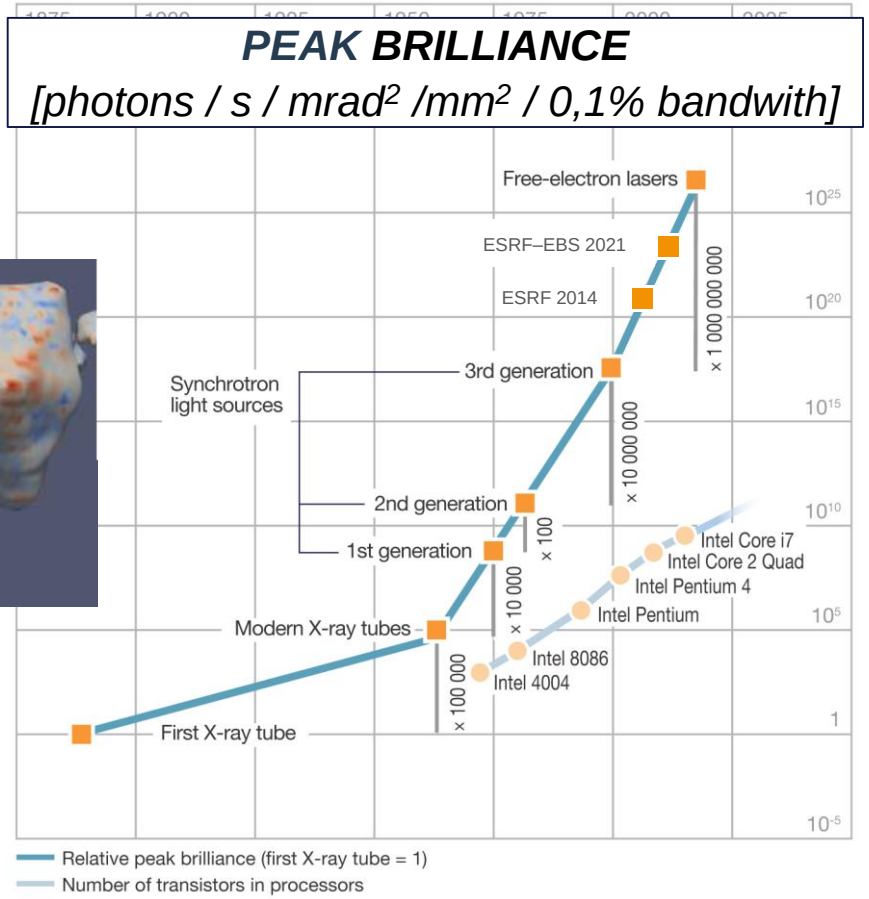






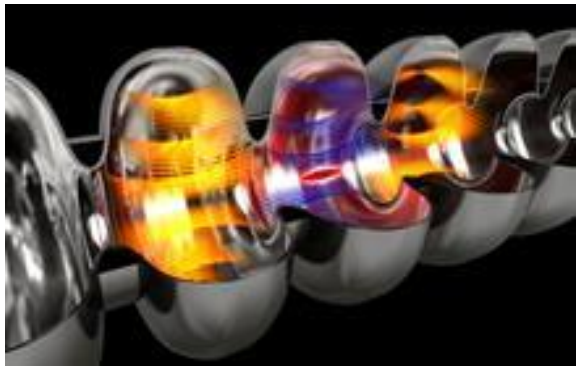


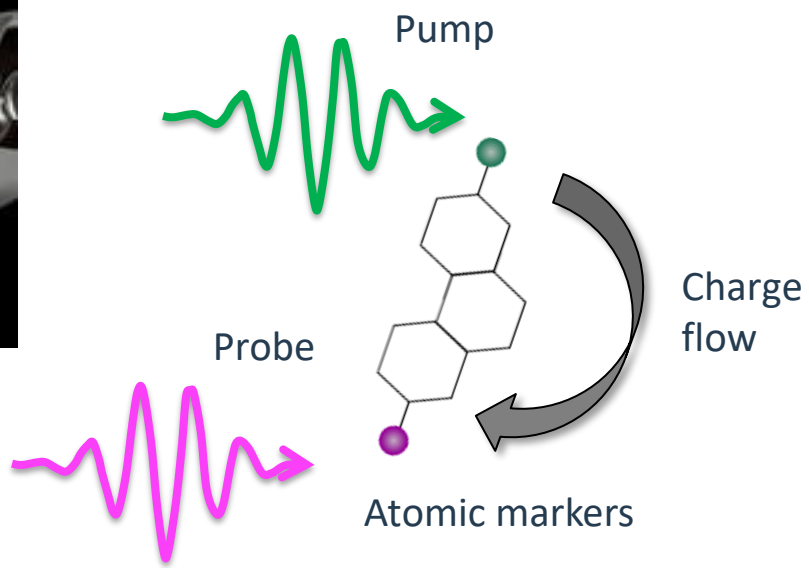
J. Carnis & **M.I. Richard**

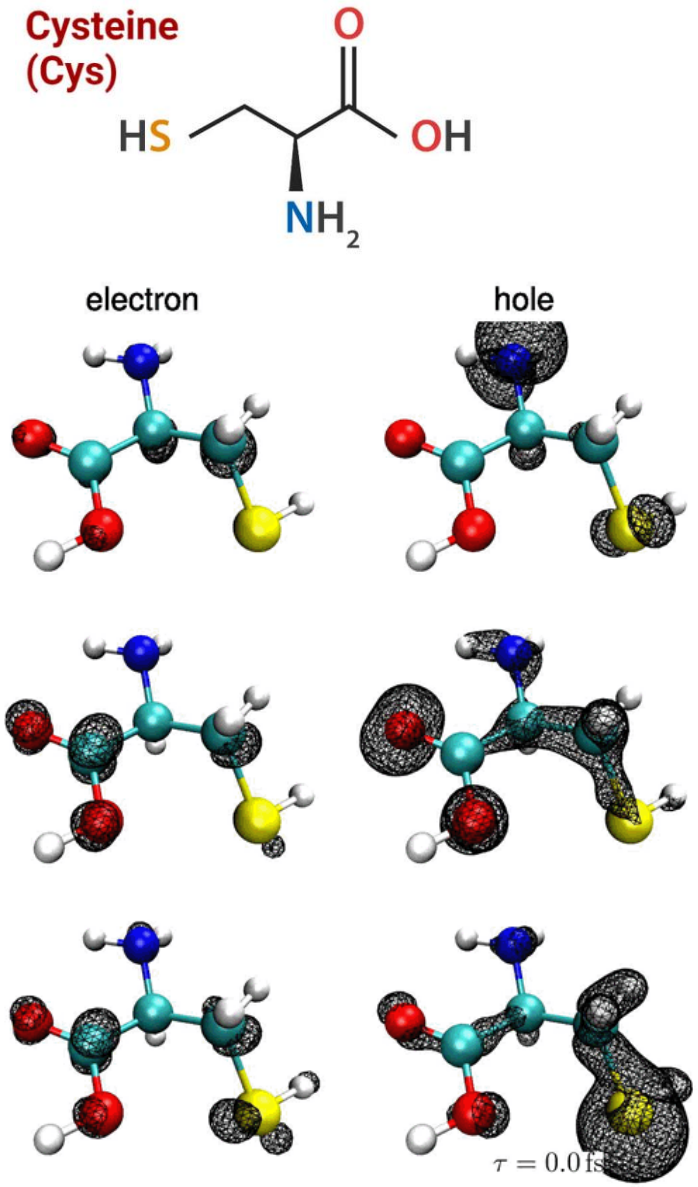


Trends 3

We are well on track towards fully coherent and controllable XFEL pulses that will enable filming atomic scale movements of electrons and ions at the relevant timescales (attoseconds), visualizing rapid electronic structure changes, for example during a chemical reaction, a phase transition of a material, or a magnetic recording.







Simulation courtesy of Yu Yhang , S. Mukamel et al.

Opportunities and Challenges

- Growing scientific community, expansion of research fields
- Remote access: facilities become more open, accessible and inclusive
  - **A new era in access to SR and XFEL radiation based research**
- Large scale facilities will
  - **strengthen their role as places of inter- and multi-disciplinary work, intrinsically fostering brain circulation and cooperation**
  - **advance international integration, inclusion, and training of researchers who are not able to travel**
- Data Deluge & Data Science Technology
- How to develop cost-effective, green facilities?
- Machine Learning & Artificial Intelligence

2050 is yours to create!