The African Lightsource Project

Recent Progress Towards an African Light Source

Prosper Ngabonziza

Louisiana State University (LSU)-USA/ Rwanda

African Light Source Foundation

New Directions in Theoretical Physics

Edinburgh, January 11th, 2023

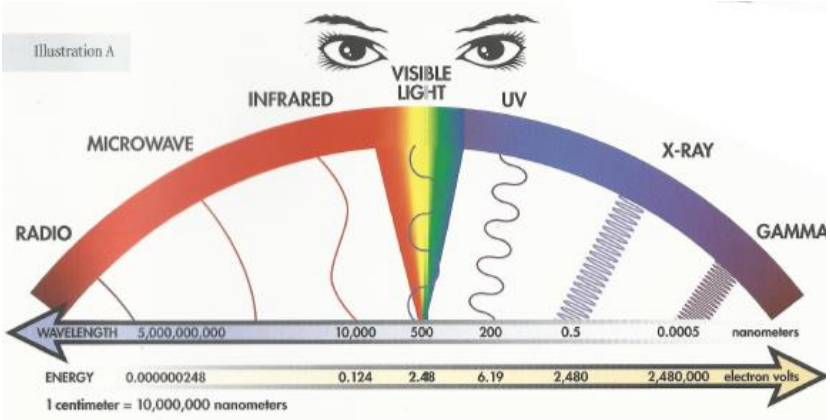
The African Lightsource Project

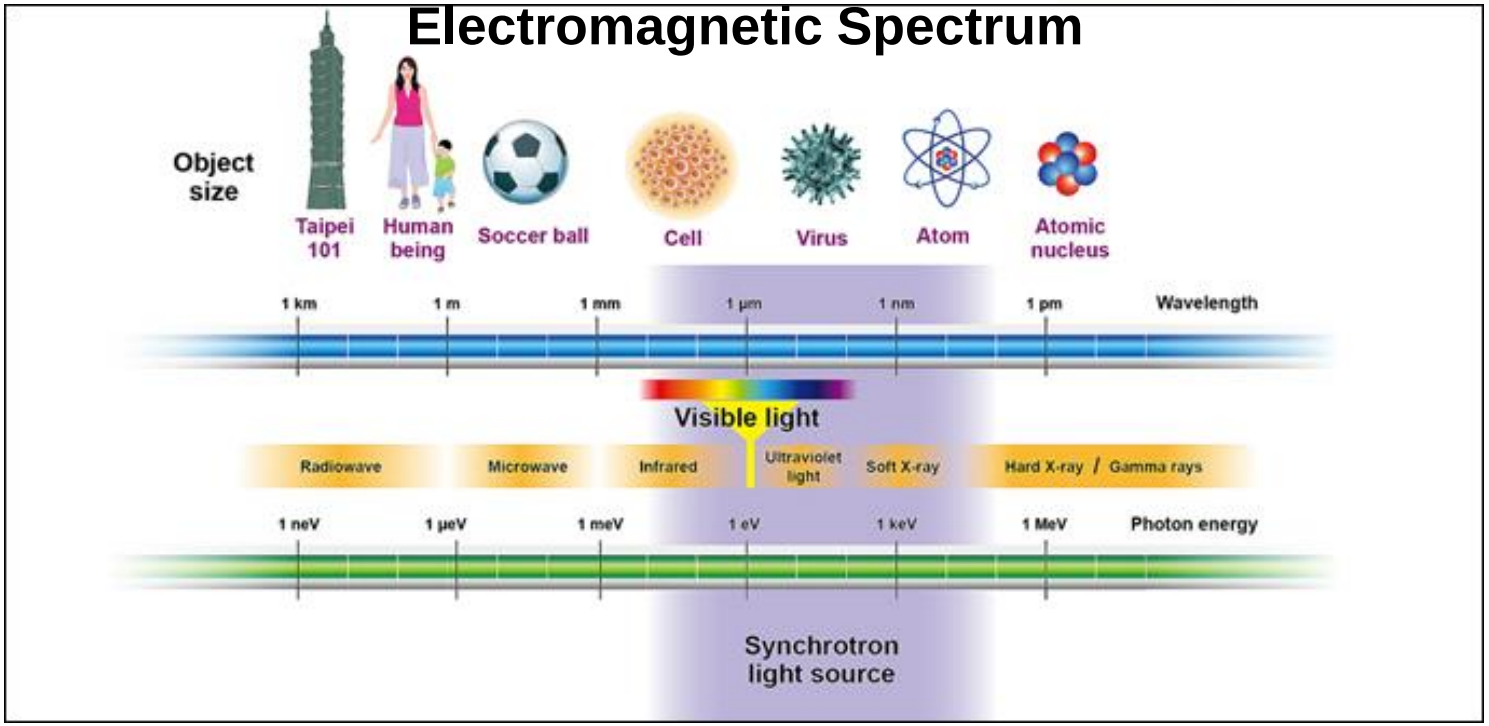
What is a Synchrotron light source and how does it work?

In science and technology:

the word **Light** applies generally to

Electromagnetic Radiation





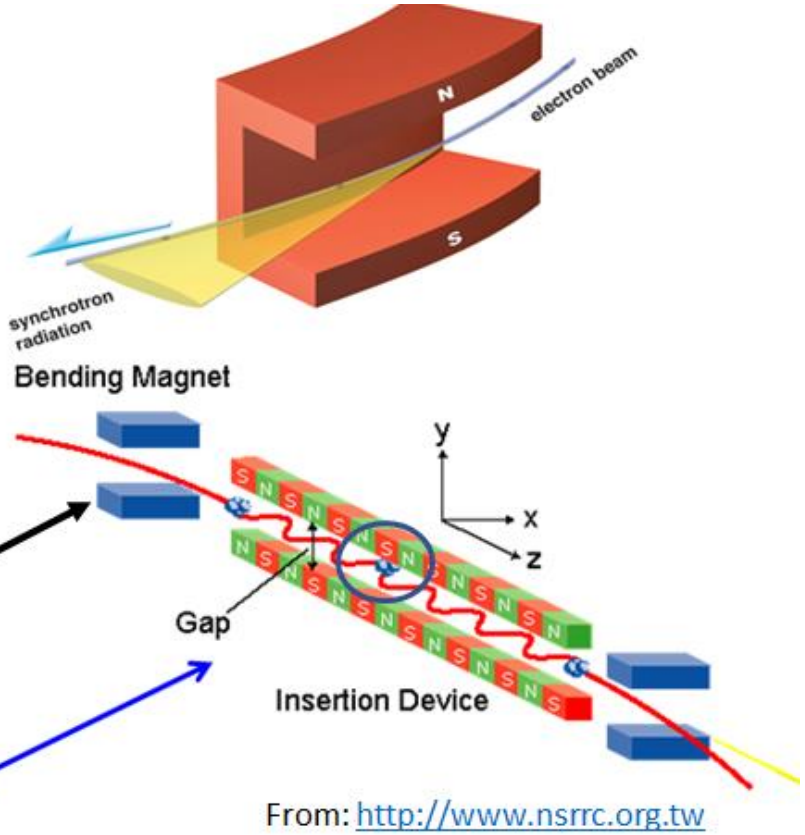
Available at: http://www.nsrrc.org.tw/english/lightsource.aspx

What is a Synchrotron light source and how does it work?

- A **Synchrotron light source** is **electromagnetic radiation** emitted when charged particles (electrons) are subject to an acceleration perpendicular to their velocity, using **magnetic fields**.

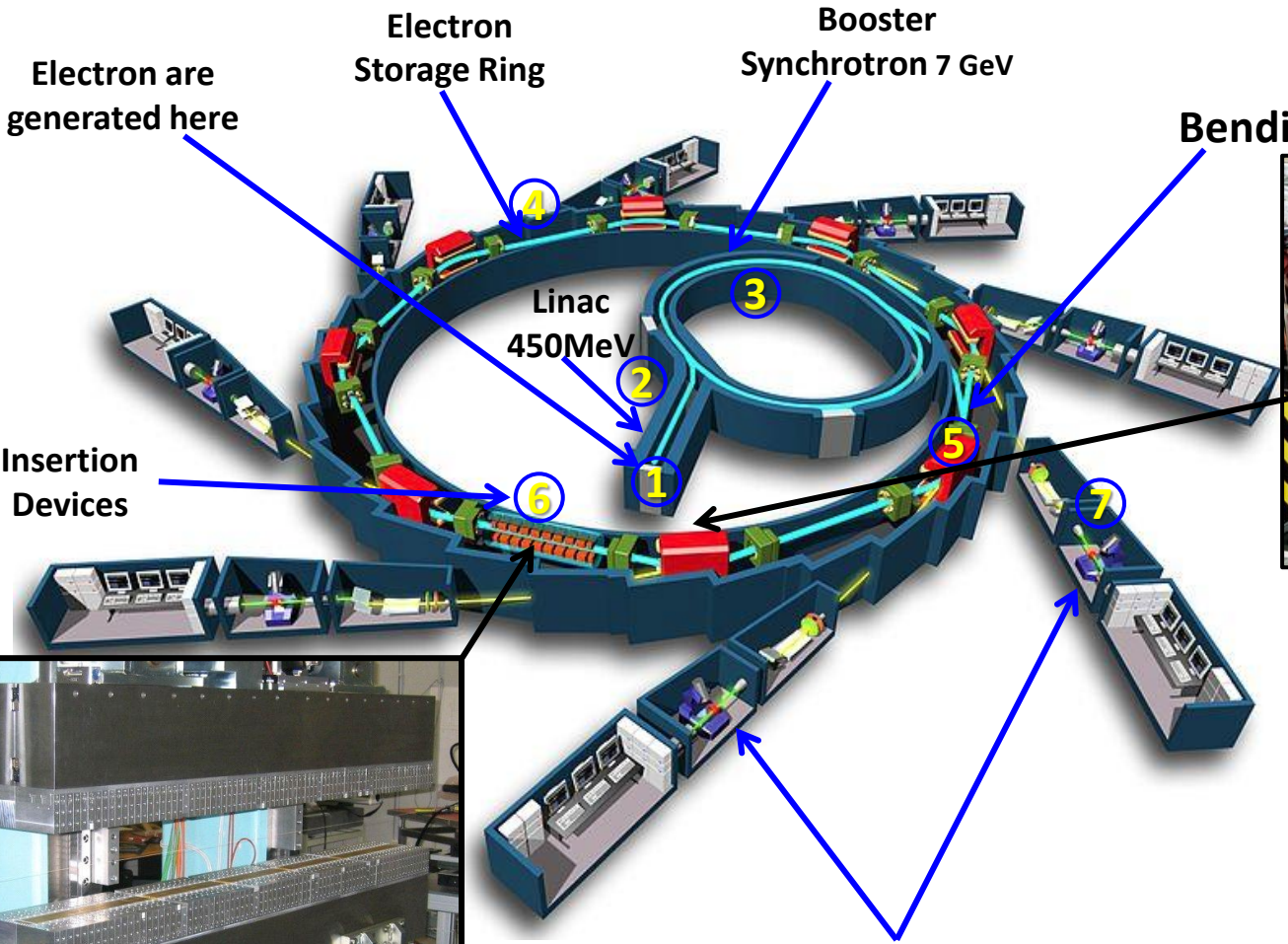
- Specially designed magnets or arrangements of magnets produce radiation with specific, desired properties.

- Magnet configurations include simple **bending magnets** or arrays of magnets called **undulators** and **wigglers**.

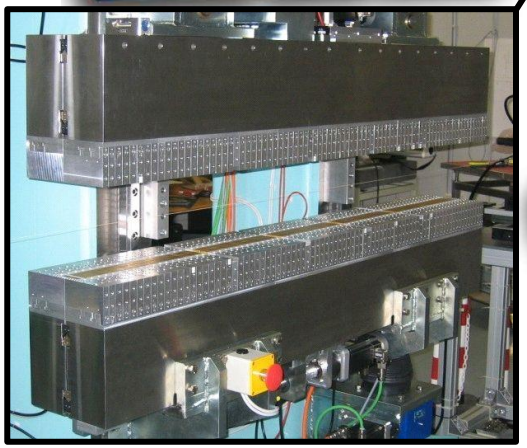


From: http://www.nsrrc.org.tw

Layout of Synchrotron light sources



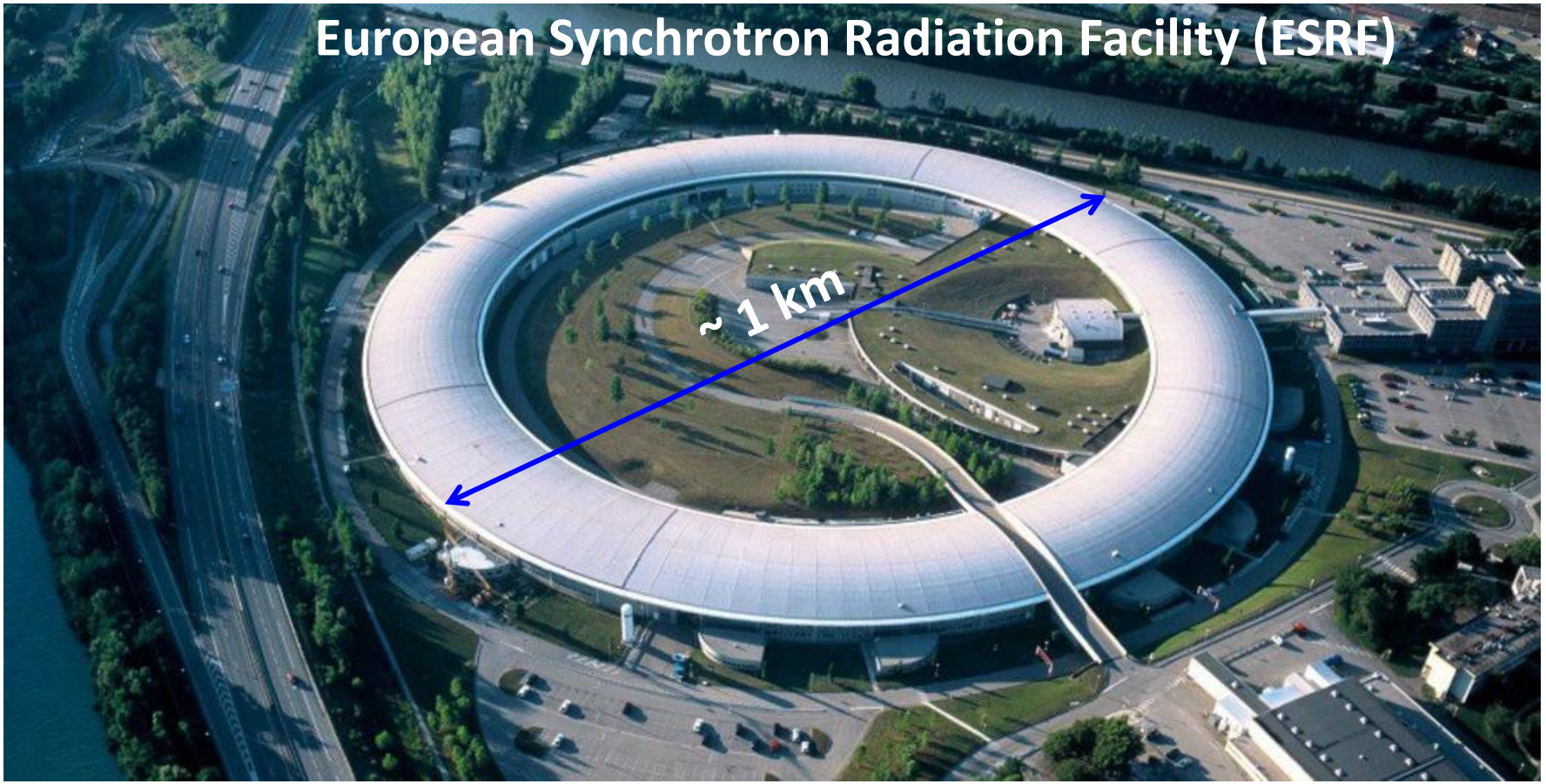
Bending magnets



Undulators and Wigglers

Beamlines & Instruments

Layout of Synchrotron light sources



From: http://www.esrf.eu/

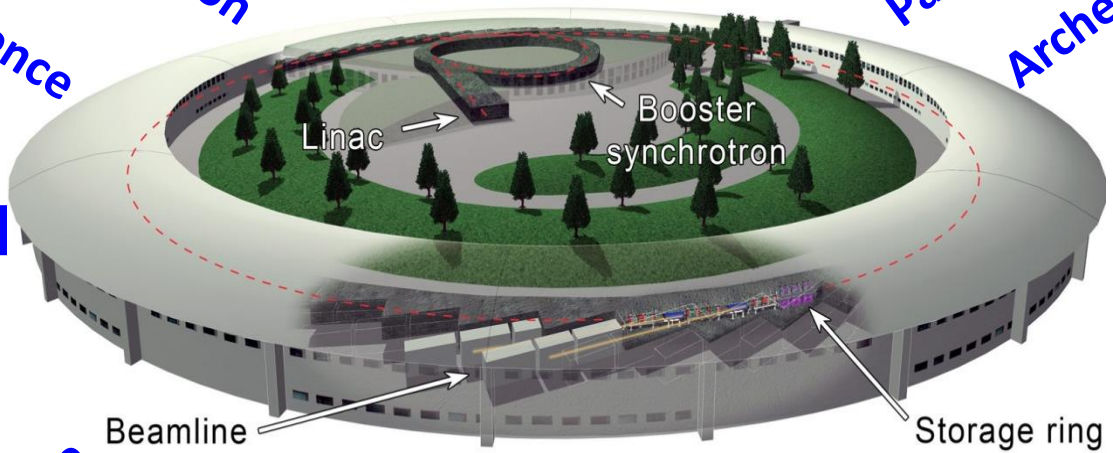
Layout of Synchrotron light sources

https://www.lsu.edu/camd/

The African Lightsource Project

Why an African Synchrotron Lightsource ?

- **Scientific Discoveries**
- **Industrial Innovations**
- **Social economic Impacts**
- **Capacity Building**



Environmental Science
Agriculture
Oil Exploration
Forensic Science
Cultural Heritage
Paleontology
Archeology
Biomedicine
Nanotechnology
Engineering
Physics
Chemistry
Crystallographic Sciences
Material Sciences

The African Lightsource Project

Why an African Synchrotron Lightsource ?

2016: ~50 synchrotrons in the world, mostly in "developed" countries

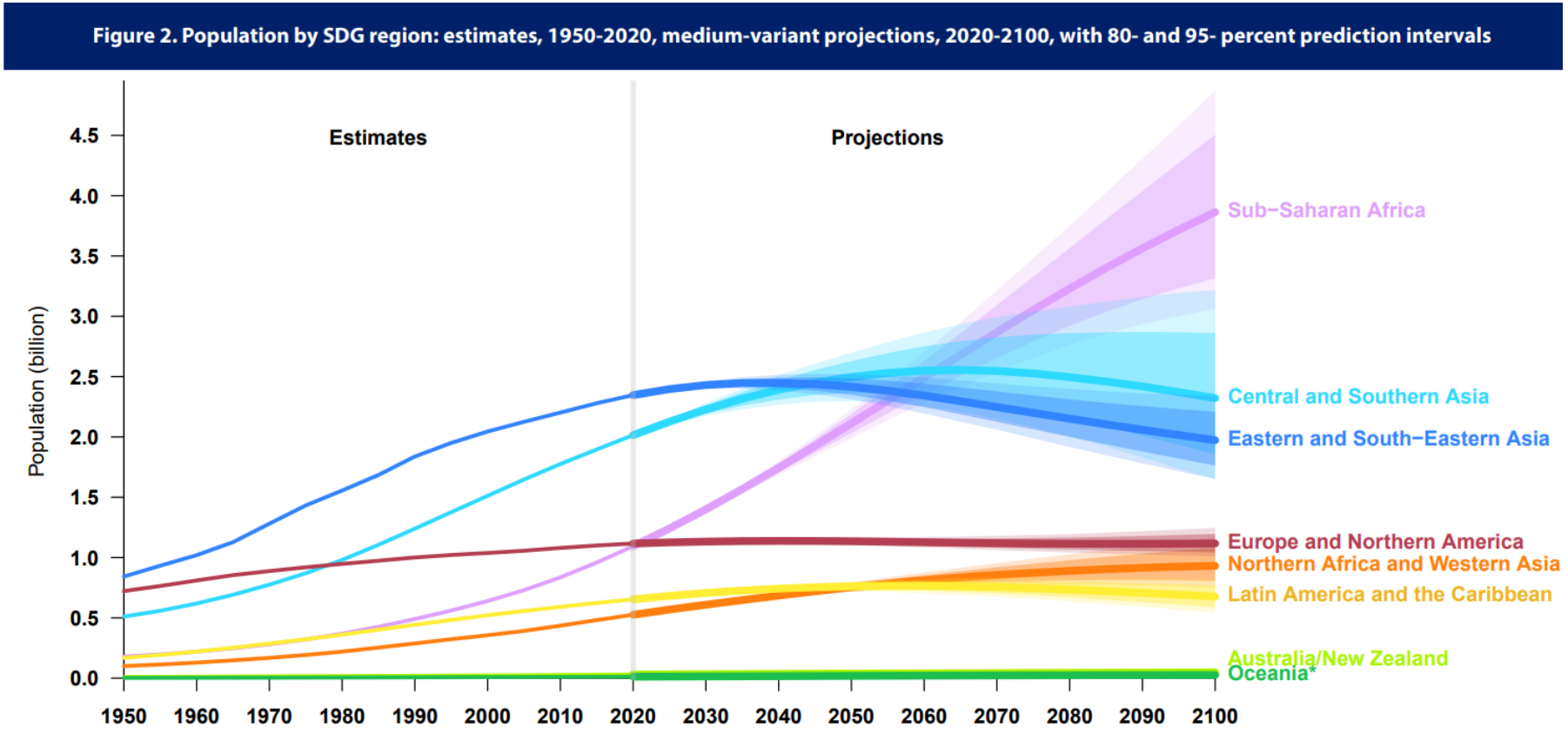
Adapted from "AfLS Roadmap", C. Biscari, 2016

- Science for Peace and uniting countries together (e.g. SESAME, CERN, ESRF)
- Return of the African Science Diaspora - new opportunities for young excellent scientists
- For African countries to take control of their destinies and become major players in the international community

Africa is the only habitable continent without a lightsource.

- Being part of a bigger cause
- Connecting (fundamental) science to different challenge of our Society

Why an African Synchrotron Lightsource ?



An African lightsource will contribute in the:

- Capacity building and growth of spin-off companies for technological development and innovation,
- Generation of employment opportunities for qualified African youth

The African Lightsource Project

Why an African Synchrotron Lightsource ?

The AfLS will promote advanced capacity building, innovation, industrial linkages, industrial research, competitive industry, big data, 4IR technologies, and localisation of manufacturing skills. This will drive growth and new sustainable jobs.

The AfLS will promote world-leading research in agriculture. The literature has many examples of AdLS focus on food security by plant, soil and food scientists. This is based on the capacity of the AdLS for 5D imaging in terms of sensitivity to chemical and biological characterisation, 3D spatial form, and also time sequences, including in response to various stimuli.

The AfLS will be the premier instrument to tackle the disease burden of Africa. The drug discovery for the medical interventions for HIV/AIDS was driven by high resolution atomic level viral structures obtained mostly at AdLSs, allowing drug targets to be identified. A similar process is underway for the SARS-Cov-2 and other viruses.

The AfLS will promote the public understanding of science, attract new young minds, especially girls. It will be a repository and a dissemination hub for all levels of educational material. It will be a premier site for advanced human capacity building. The research outputs will be visually palatable and easily understood.

The AfLS will abound with modern role models for both women and men in science. Most AdLSs concentrate on increasing diversity, based on gender, ethnicity, geographical representation, amongst others.

The AfLS will be a premier facility for environmental research. The infrared beamlines will allow molecular imaging at unprecedented bio-sensitivity. Advanced spectroscopy, such as XAFS and XANES, are techniques that allow the study of chemistries and materials in the field at unprecedented sensitivity, complete with imaging.

Renewable energy studies will be well represented, including new photovoltaic materials, novel batteries, novel catalysts for fuel cells, and detailed chemical studies of the reactions involved, both those that are to be promoted and those that represent adverse pathways that need remediation.

The site for the AfLS will require a large space that soon will become populated with a mega-scale science and industry park. This is due to the technology transfer and innovation associated with AdLSs.

Ultimately, there will be a high demand for Industrial users to perform proprietary commercial research, where IP protection, rather than publications, will be the output. This will have a premium charge. There also will be industry-relevant research, which will be published as usual in open academic collaborations. In all cases, there will be innovation, leading to new industrial capacity.

The ethos of AdLSs is diversity, tolerance, and the global nature of science and science diplomacy. True education reduces endemic prejudice and promotes the culture of Ubuntu

The research on the environment, clean water and sanitation, renewable energies, will promote and enable sustainable lifestyles and development.

As above, the research on the environment, clean water and sanitation, renewable energies, promotes and enables sustainable lifestyles and development.

The multidisciplinary capacity of research at AdLSs includes research into the understanding of climate, including the interaction between bio-systems and the fluids around them, trace element chemistries as they affect precipitation, and other physical, chemical and biological processes. All scientific aspects can be addressed at unprecedented levels of accuracy in these studies.

Once again, the multidisciplinary capacity of research at AdLSs will include research into other physical, chemical and biological processes relevant to water based life.

Once again, the multidisciplinary capacity of research at AdLS light sources will includes research into other physical, chemical and biological processes relevant to land- based life.

AdLSs are usually globally used and globally relevant infrastructures. The ethos of AdLSs is diversity, tolerance, and the global nature of science, science diplomacy.

Major large-scale globally relevant infrastructures for research and innovation are unavoidably catalysts that spark networks, collaborations and partnerships that enable such concentration of equipment at such scale and innovation. The partnerships occur at government level and are evident at all other levels, most especially the user levels.

Informative chart illustrating how an African Light Source will address all 17 United Nations Sustainable Development Goals (UN SDGs), which are an urgent call for action by all countries.

The African Lightsource Project

Preparing Africa for the Forthcoming African Synchrotron Lightsource

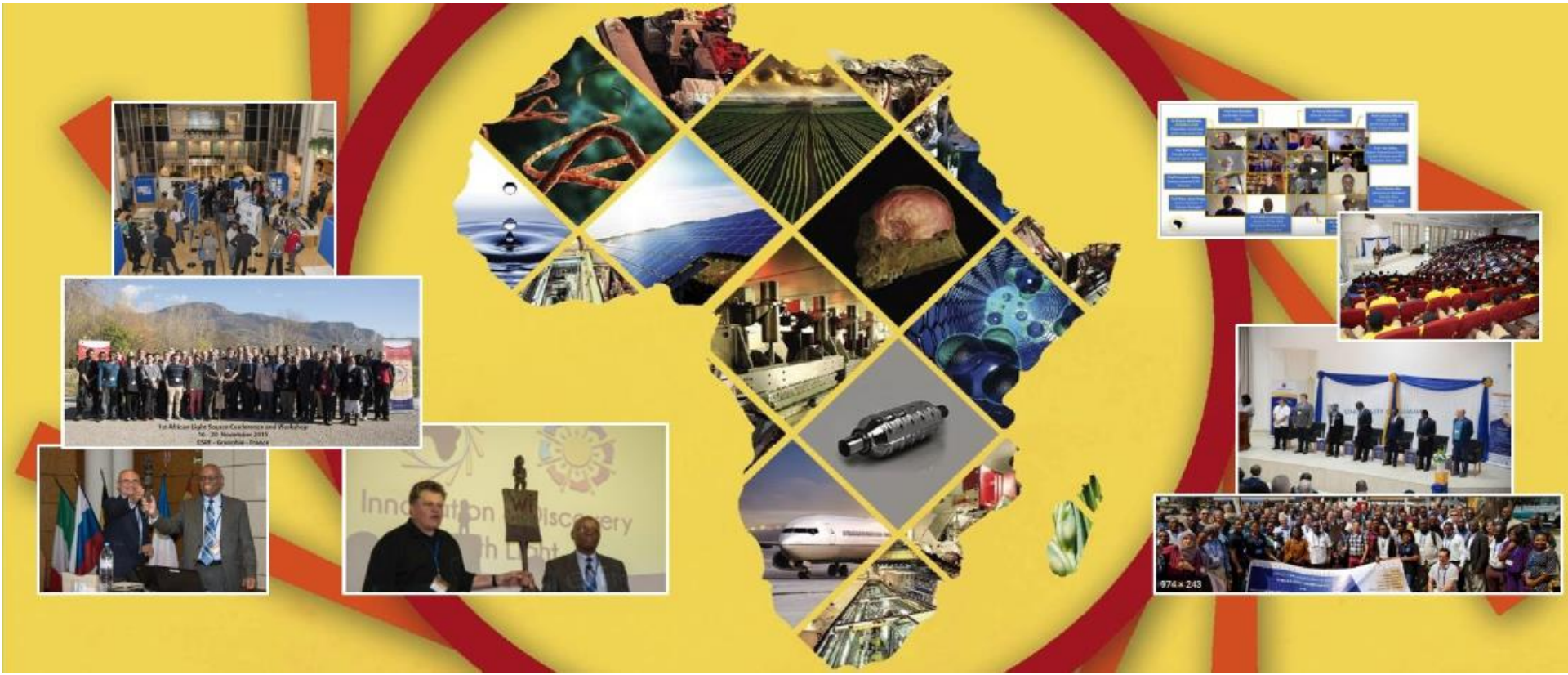
The AfLS Conference & Workshop Series

Central starting point:

- Training and networking,
- Building user community in Africa,
- Extending activities and sharing opportunities

The African Lightsource Project

Preparing Africa for the Forthcoming African Synchrotron Lightsource



The African Lightsource Project

Preparing Africa for the Forthcoming African Synchrotron Lightsource

The AfLS Conference & Workshop Series

- ✓ 1st African Light Source Conference and workshop (AfLS1) November/ 2015 at ESRF, Grenoble, France
- ✓ The conference had an assessment and an outcomes phases

The African Lightsource Project

Preparing Africa for the Forthcoming African Synchrotron Lightsource

The 2nd African Light Source Conference (AfLS2)

&

Pan African Conference on Crystallography (PCCR2)

28 Jan – 2 Feb 2019 in Accra, Ghana

The African Lightsource Project

Preparing Africa for the Forthcoming African Synchrotron Lightsource

- ✓ The AfLS2020 developed more the Pan-African and socio-political aspects of AfLS project
- ✓ Strengthen the AfLS motivation case

The African Lightsource Project

nature reviews physics

Explore content ⌄ About the journal ⌄ Publish with us ⌄

nature › nature reviews physics › comment › article

Comment | Published: 19 October 2022

Building a brighter future for Africa with the African Light Source

Marcus C. Newton ✉, Simon H. Connell, Edward P. Mitchell, Sekazi K. Mtingwa, Prosper Ngabonziza, Lawrence Norris, Tshepo Ntsoane & Daouda A. K. Traore

Nature Reviews Physics (2022) | Cite this article

617 Accesses | 18 Altmetric | Metrics

https://www.nature.com/articles/s42254-022-00534-3#citeas

PROSPER NGABONZIZA

The Need for an African Lightsource

22 October 2019 | doi:10.5281/zenodo.3515004 | No Comments

Setting up new infrastructures would play an important role in preventing best-trained African researchers from emigrating. The physicist Prosper Ngabonziza states that having a synchrotron light source would be very beneficial for the continent as a whole.

https://elephantinthelab.org/the-need-for-an-african-lightsource/

AfLS: Conceptual Design Report (CDR)
Coming out in 2023

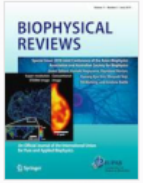
The African Review of Physics
formerly published as The African Physical Review

The African Review of Physics (2018) **13**: 0019

Proceedings of the first African Conference on Fundamental Physics and Applications 2018, Namibia.
Guest Editors: K. A. Assamagan, M. Backes, D. Charlton, S. Muanza , D. Sahu, and D. Singh

The African Light Source Project

http://lamp.ictp.it/index.php/aphysrev/article/view/1610/586



Biophysical Reviews
pp 1–9 | Cite as

Towards an African Light Source

Authors Authors and affiliations

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6682199/

The African Lightsource Project

Visit us at : http://www.africanlightsource.org

AfLS Executive Committee

SIMON CONNELL (CHAIR)

University of Johannesburg, South Africa
shconnell@uj.ac.za

PROSPER NGABONZIZA (DEPUTY CHAIR)

Max Planck Institute, Germany and Rwanda
p.ngabonziza@fkf.mpg.de

SEHAM K. ABDEL-AAL

Cairo University and Egypt Nanotechnology Center
seham@sci.cu.edu.eg

SAPHINA BIIRA

Busitema University, Uganda
bsaphina@yahoo.co.uk

GIHAN KAMEL

SESAME (Jordan) and Helwan University (Egypt)
gihan.kamel@sesame.org.jo

NKEM KHUMBAH

University of Michigan and Cameroon, also STEM-Africa Initiative, Cameroon
nkhumbah@umich.edu

SENDJA BRIDINETTE

University of Yaounde I, Cameroon
sbridine@yahoo.fr

RICHARD CATLOW

Royal Society, UK
Richard.Catlow@royalsociety.org

THIERRY D'ALMEIDA

CEA France, X-TechLab
kemthal@yahoo.fr
Thierry.dalmeida@cea.fr

TABBETHA DOBBINS

Rowan University, USA
Dobbins@rowan.edu

THANDEKA MOYO GWETE

National Institute for Communicable Diseases (NICD) SA
thandekam@nicd.ac.za

SEKAZI MTINGWA

TriSEED Consultants, USA
sekazi.mtingwa@gmail.com

BRIAN MASARA

SA Institute of Physics and Zimbabwe
brian.masara@saip.org.za

EDWARD MITCHELL

European Synchrotron Research Foundation
mitchell@esrf.fr

MARCUS NEWTON

University of Southampton, UK
M.C.Newton@soton.ac.uk

LAWRENCE NORRIS

Arlington Science and Technology Alliance
lnorris@arlingtonscience.org

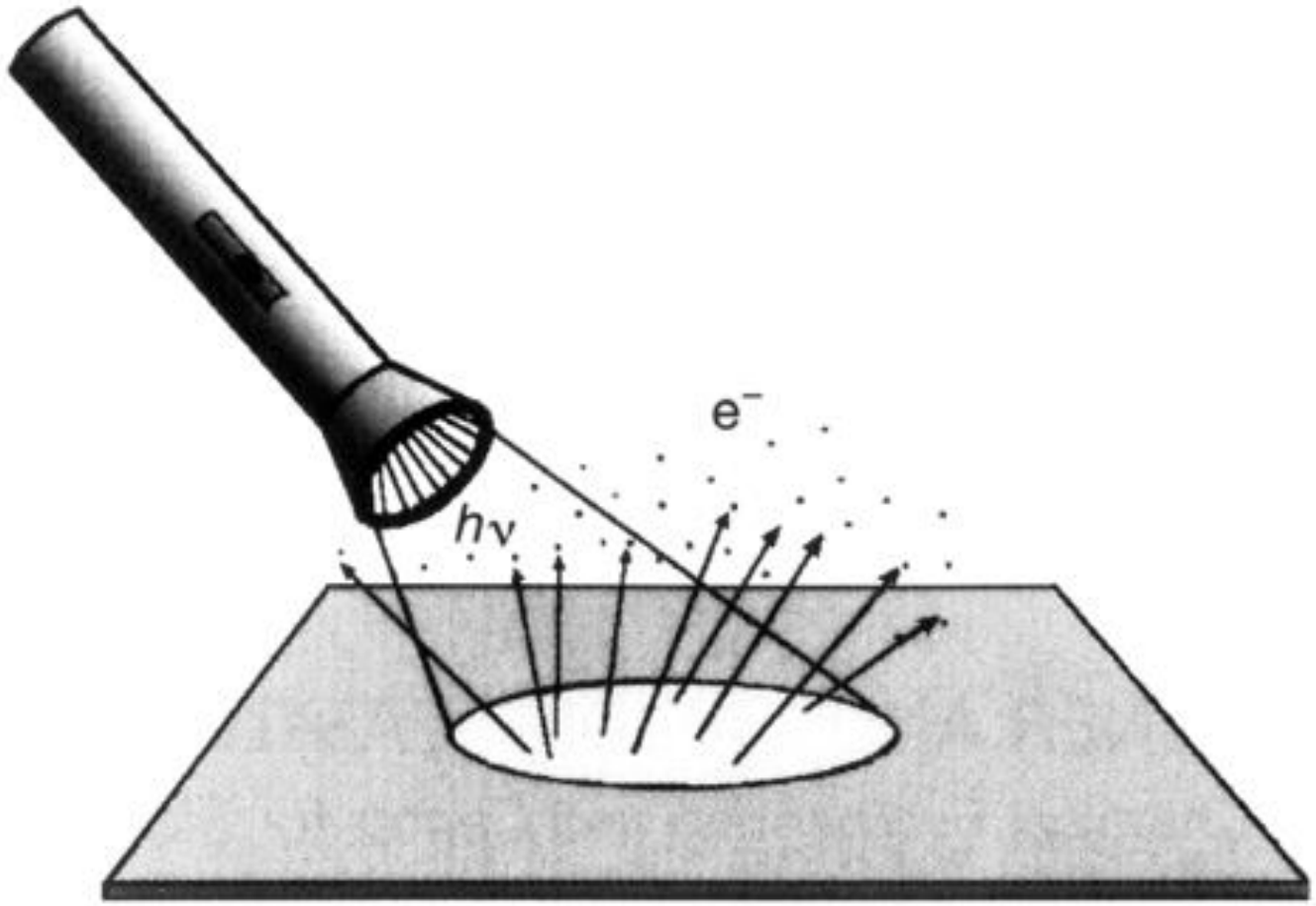
AHMADOU WAGUE

UCAD, Senegal
ahmadou.wague@ucad.edu.sn

Applications in Condensed Matter Physics
&
Materials Science

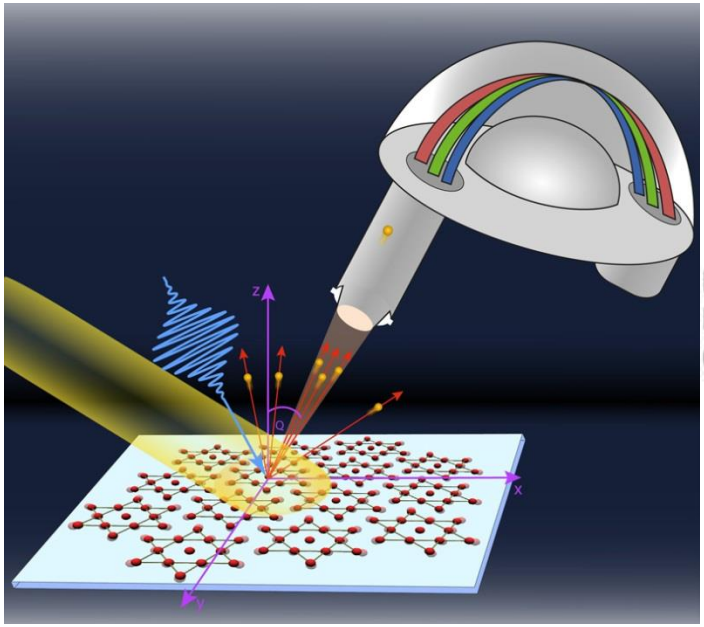
Which particular experimental technique?

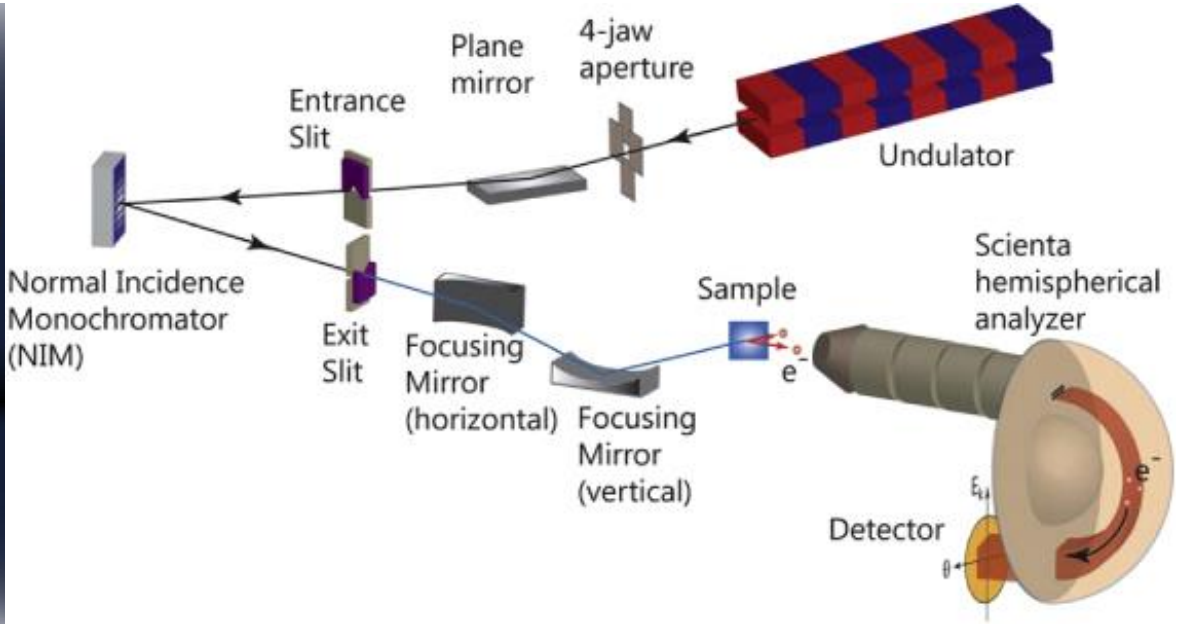
Angle Resolved Photoemission Spectroscopy (ARPES)



Which particular experimental technique?

Angle Resolved Photoemission Spectroscopy (ARPES)





1. **The kinetic energy and momentum of these electrons are measured by use of an appropriate instrument;**

2. **The data measured reflect the electronic properties of the material;**

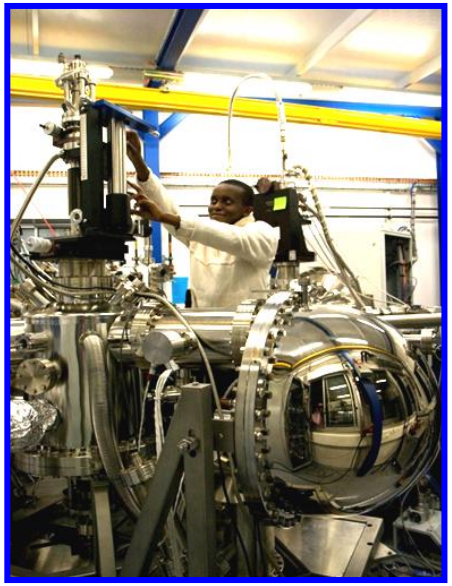
3. **ARPES: measures electronic excitations in solid → band structure.**

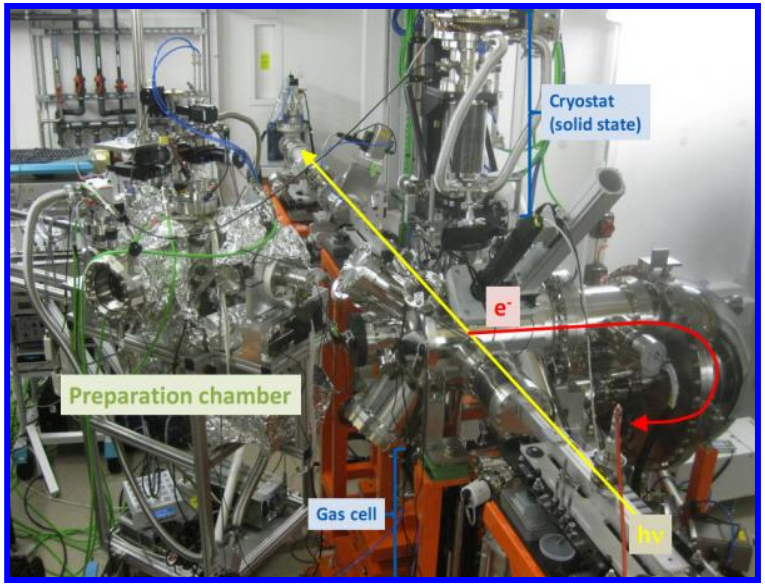
From: http://qcmd.mpsd.mpg.de/index.php/tARPES.html

Applications in Materials and Condensed Matter Physics

At which Synchrotron Light Source?

ARPES Experiments at Soleil Synchrotron (France)

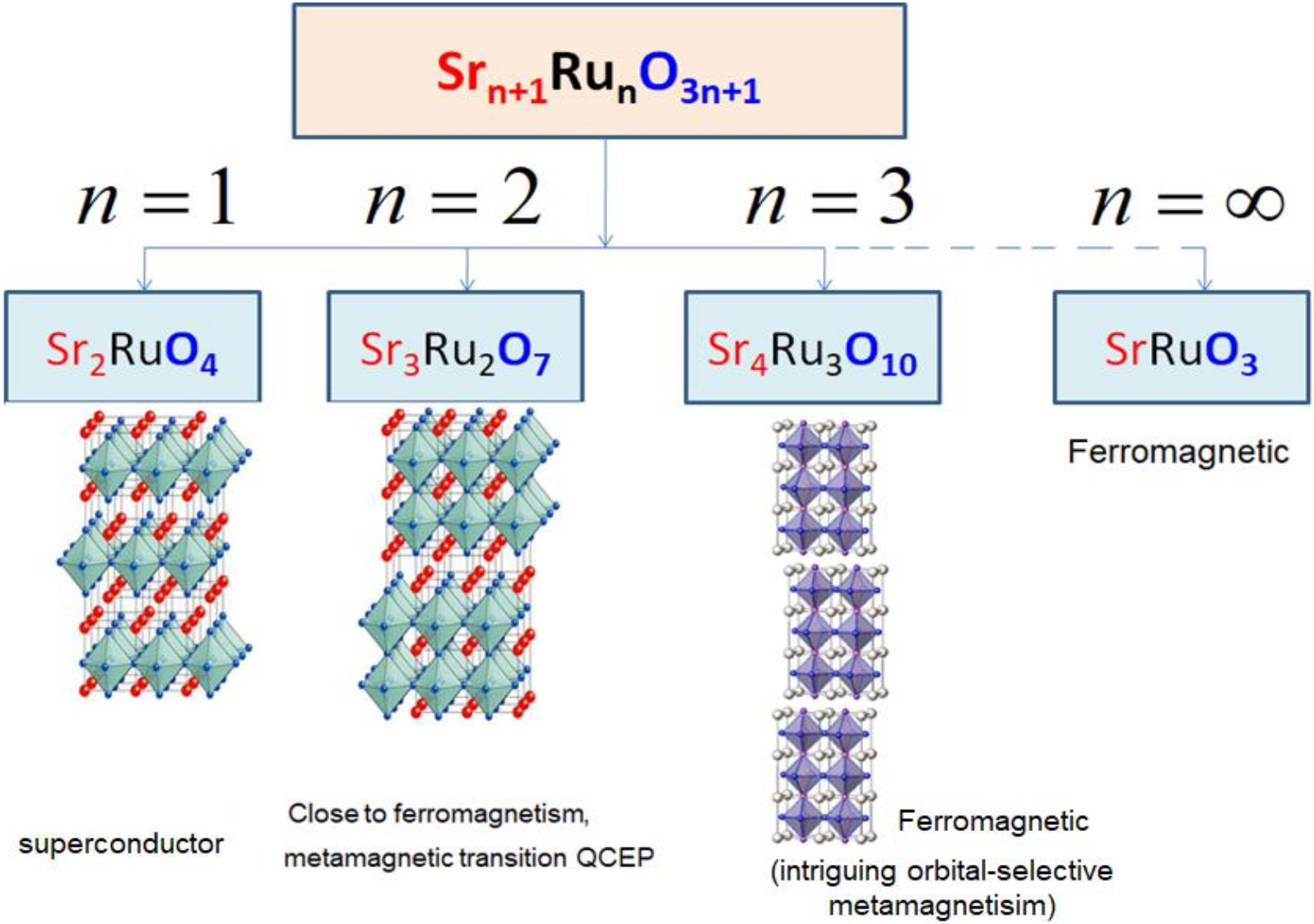




- Photon energy range: 8 - 1500 eV,
- Measurement temperature of 5 K;
- Ultra-high vacuum conditions (~ 5×10^{-10} mbar)

From: https://www.synchrotron-soleil.fr/fr/lignes-de-lumiere/cassiopee

Distinct Collective Ground State Properties in $Sr_{n+1}Ru_nO_{3n+1}$

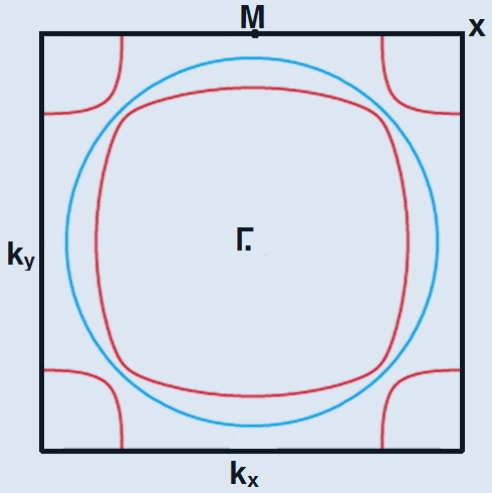


K. Ishida *et al*., Nature **396** (1998) S. A Grigera *et al*., Science **294 ,** 329 (2001) Y. J. Jo *et al.,* Phys. Rev. B **75**, 0944413 (2007) Koster, G. *et al*. , Rev. Mod. Phys. **84**, 253 (2012)

Electronic Band Structure of $Sr_{n+1}Ru_nO_{3n+1}$ (*n=1, 2, 3*) Systems

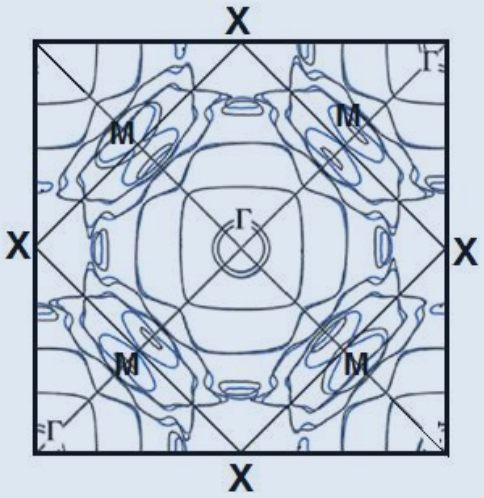
Band structure calculations

Sr_2RuO_4



Haverkort *et al.*,
Phys. Rev. Let. **101,** 026406 (2008)

$Sr_3Ru_2O_7$



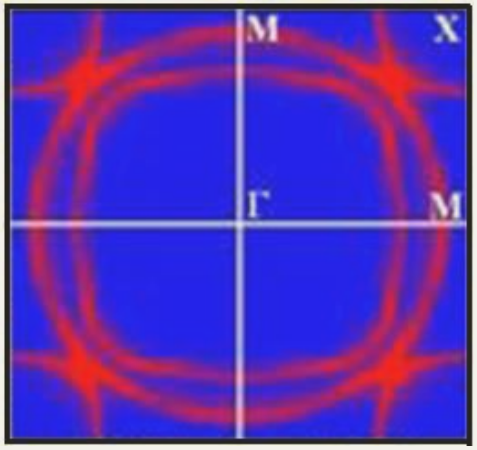
Tamai, *et al*.
Phys. Rev. Let. **101**, 026407 (2008)

$Sr_4Ru_3O_{10}$

?

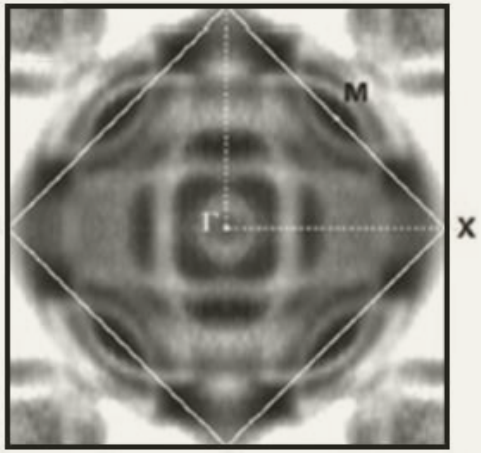
ARPES experiments

Sr_2RuO_4



Damascelli, *et al*.
Phys. Rev. Let. **85**, 5194 (2000)

$Sr_3Ru_2O_7$



Tamai, *et al*.
Phys. Rev. Let. **101**, 026407 (2008)

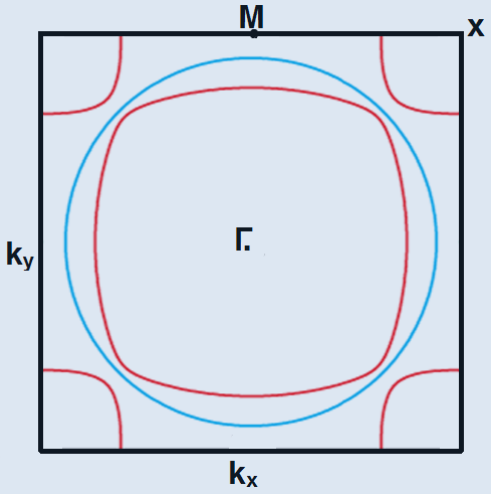
$Sr_4Ru_3O_{10}$

?

Electronic Band Structure of $Sr_{n+1}Ru_nO_{3n+1}$ (*n=1, 2, 3*) Systems

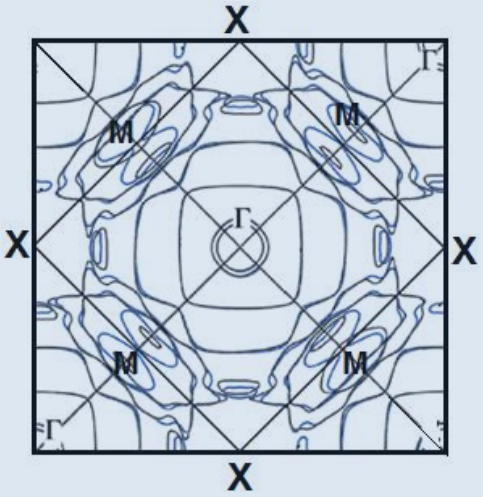
Band structure calculations

Sr_2RuO_4



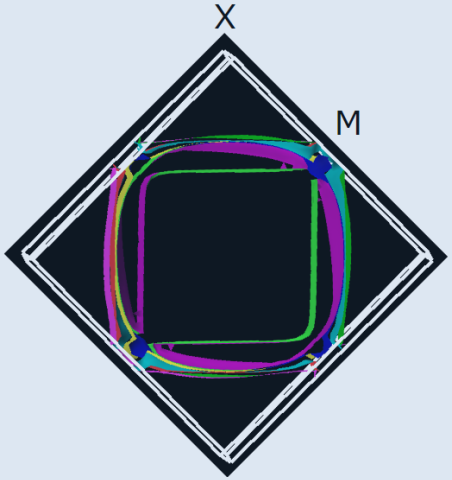
Haverkort *et al.*,
Phys. Rev. Let. **101,** 026406 (2008)

$Sr_3Ru_2O_7$



Tamai, *et al*.
Phys. Rev. Let. **101**, 026407 (2008)

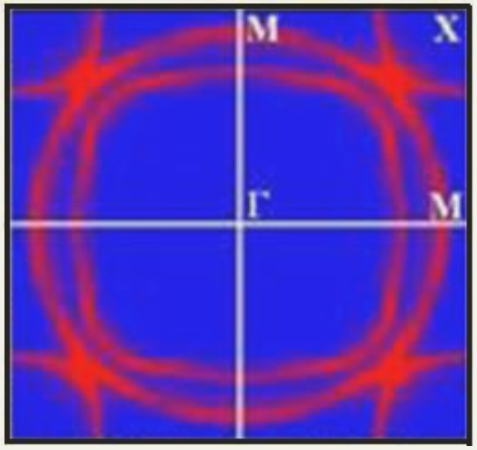
$Sr_4Ru_3O_{10}$



G. Gebreyesus, P. Ngabonziza,
R. Martin *et al*., Phys. Rev. B (2022)

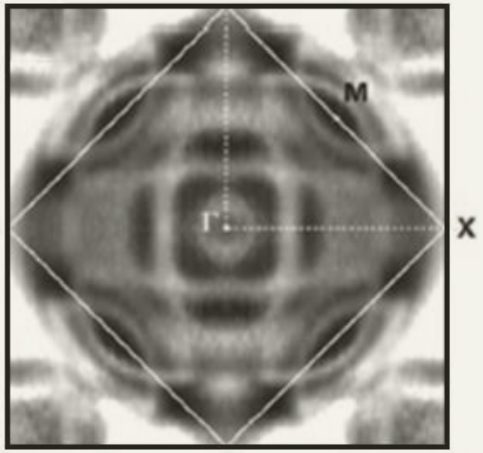
ARPES experiments

Sr_2RuO_4



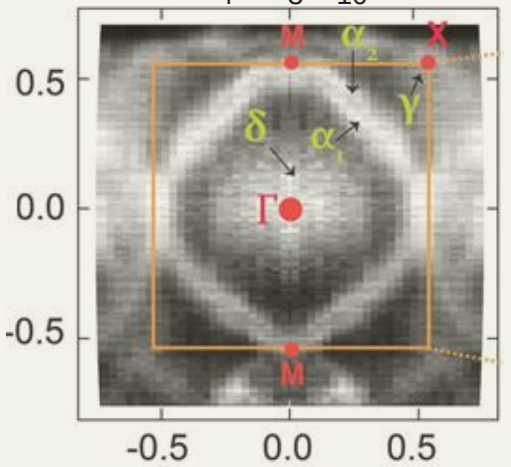
Damascelli, *et al*.
Phys. Rev. Let. **85**, 5194 (2000)

$Sr_3Ru_2O_7$



Tamai, *et al*.
Phys. Rev. Let. **101**, 026407 (2008)

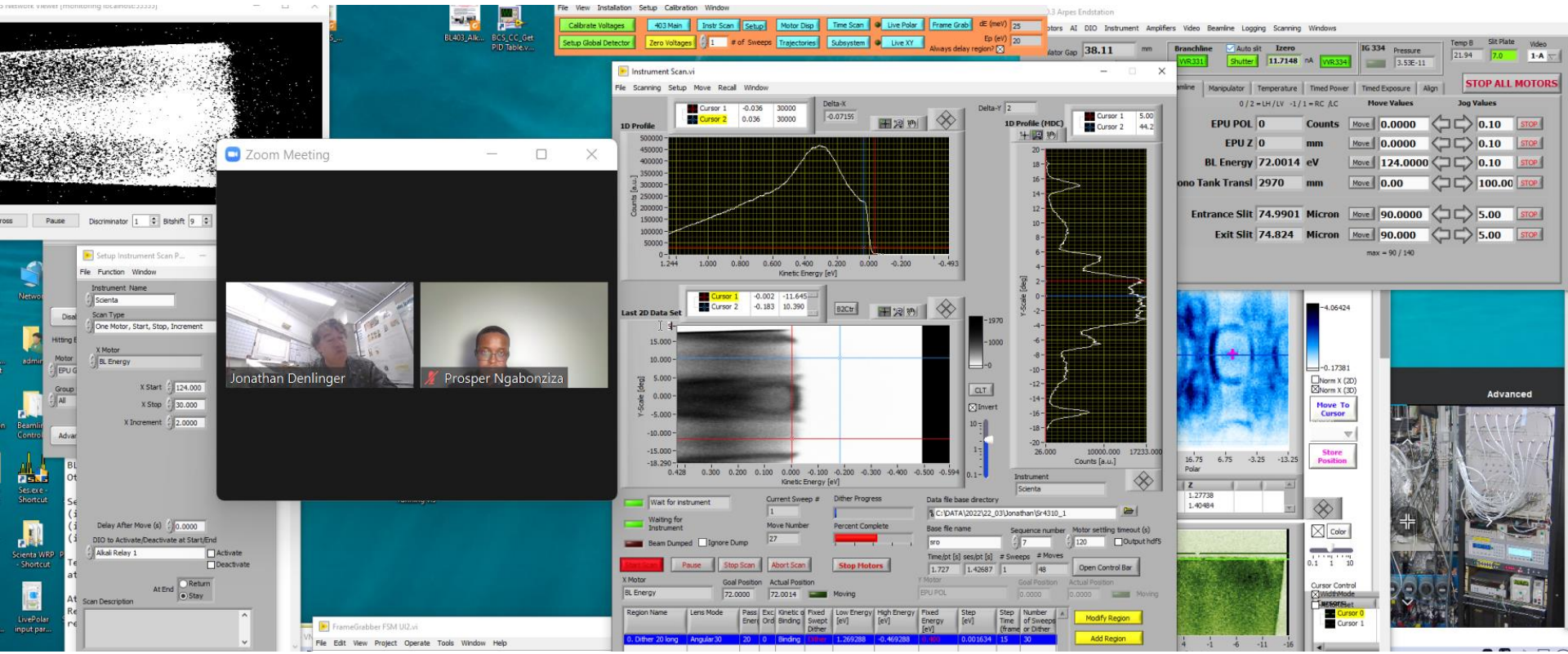
$Sr_4Ru_3O_{10}$



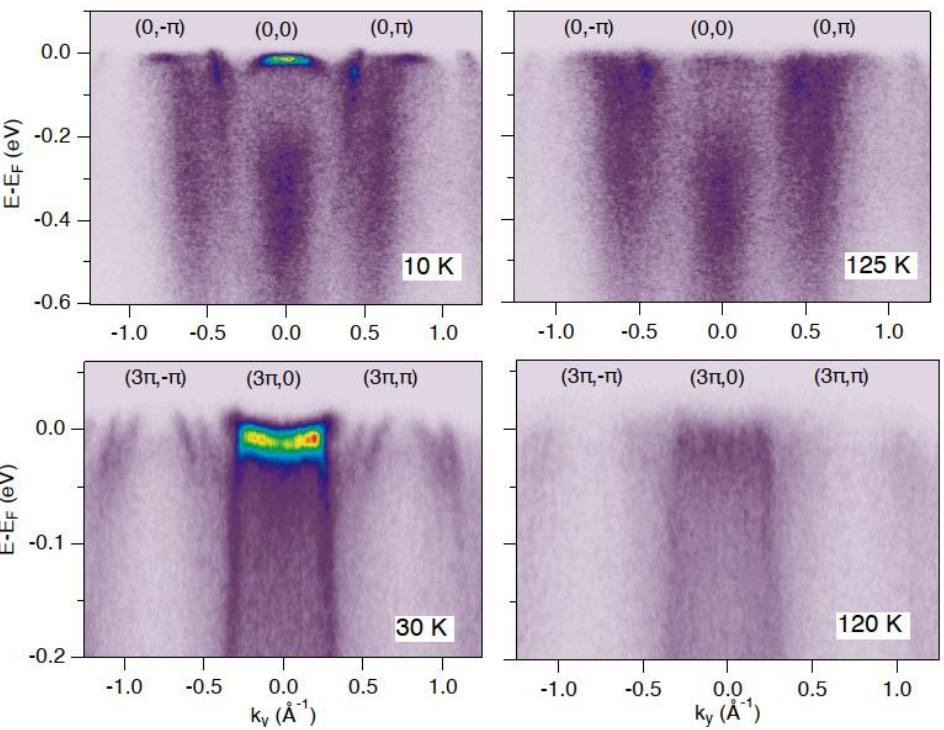
P. Ngabonziza *et al*.,
Sci. Rep. **10**, 21062 (2020)

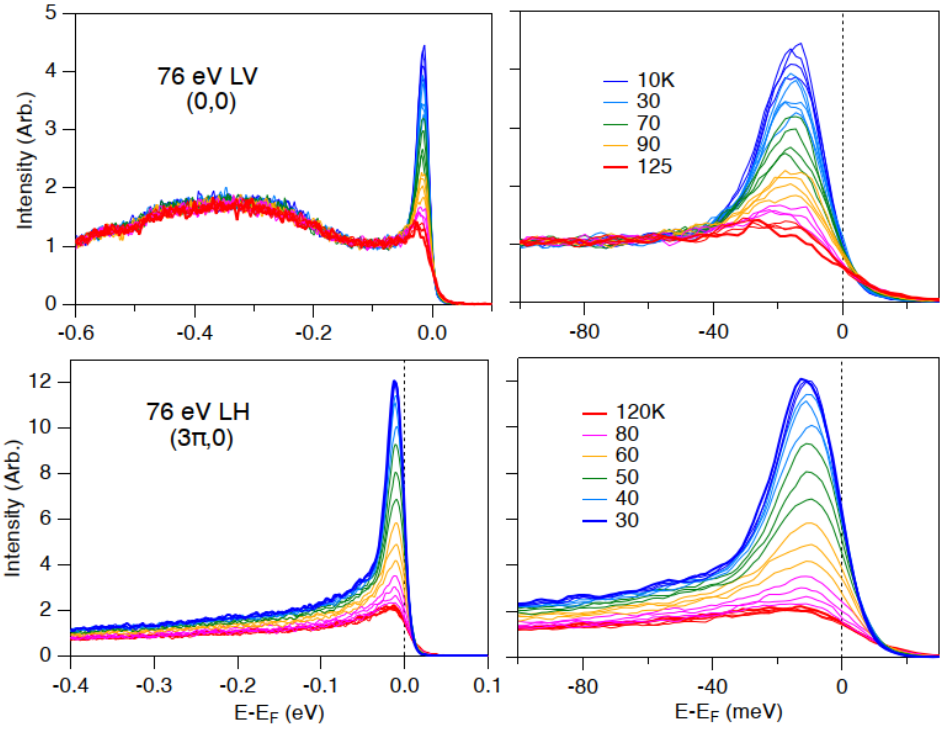
T-dependent and Spin-ARPES Study of $Sr_4Ru_3O_{10}$

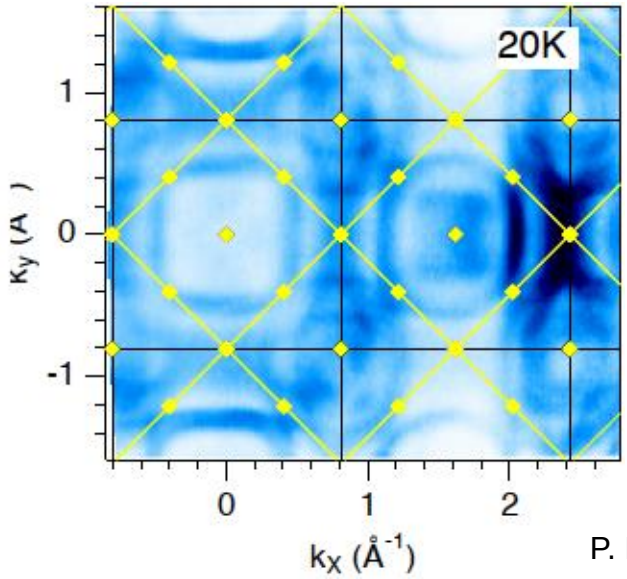
Synchrotron-based ARPES and Spin-ARPES at ALS, Lawrence Berkeley lab

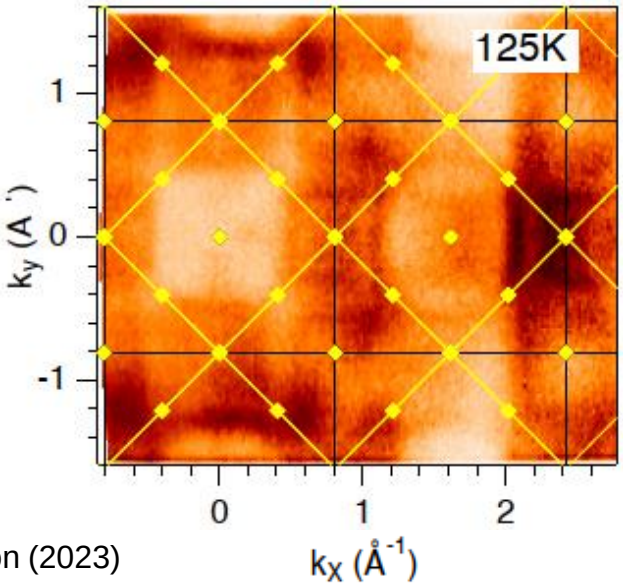


T-dependent and Spin-ARPES Study of $Sr_4Ru_3O_{10}$









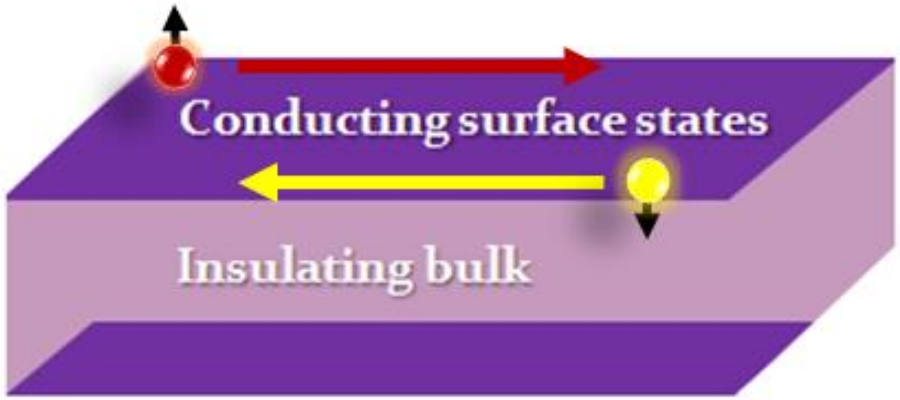
P. Ngabonziza *et al.*, in submission (2023)

Applications in Materials and Condensed Matter Physics

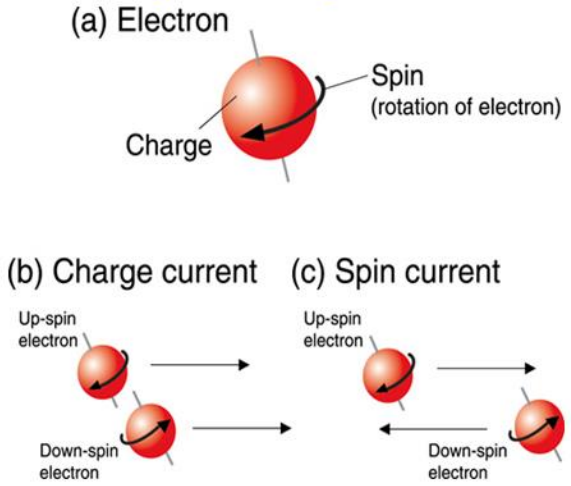
Topological quantum materials: Promising material for quantum technology

Topological Insulator (Bi_2Te_3):

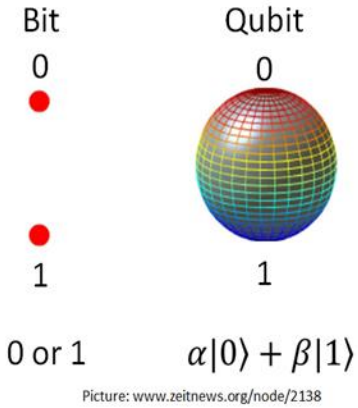
Both insulating and conducting

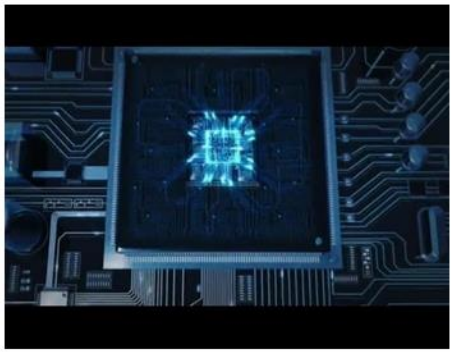


Spintronics: spin transport electronics



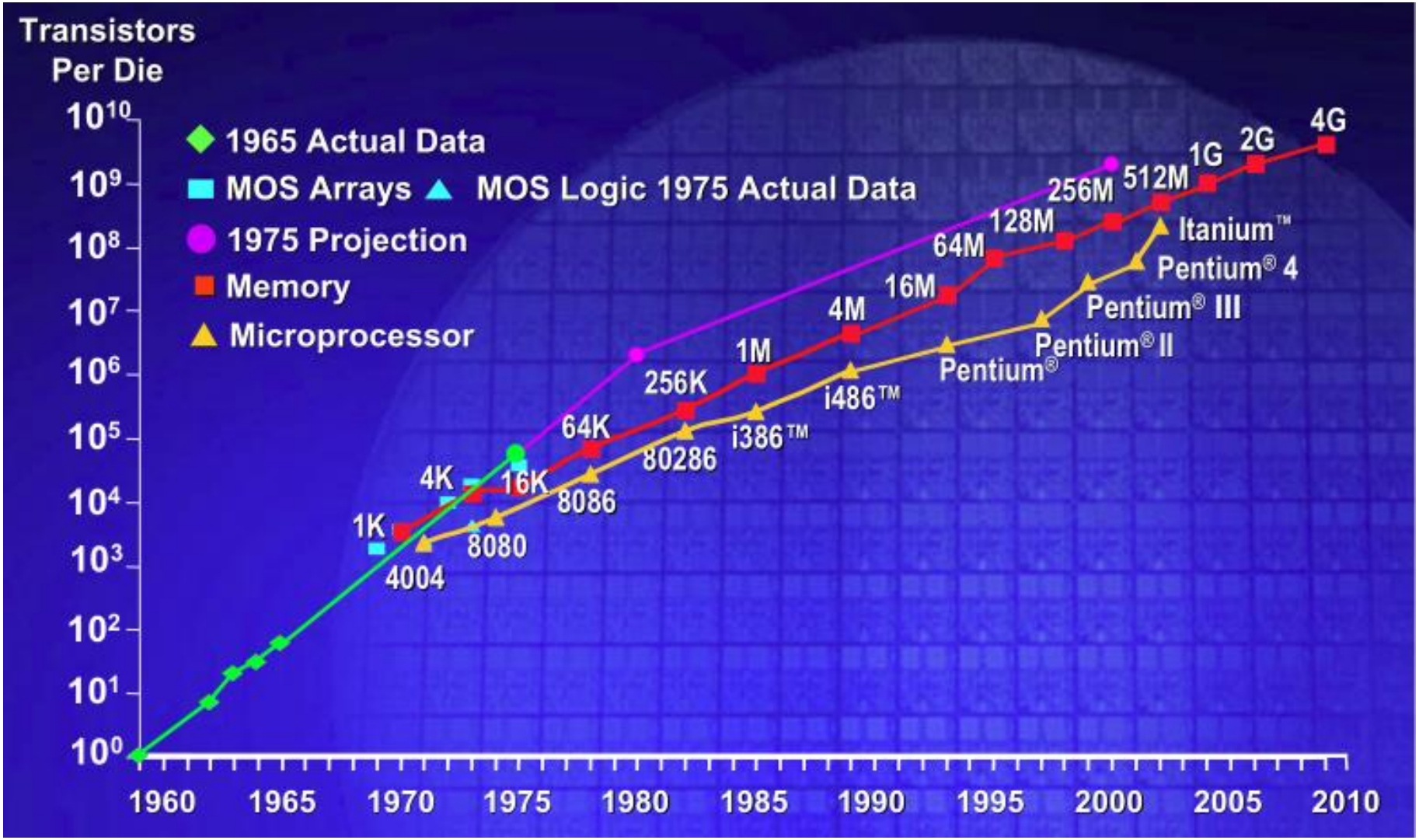
Quantum computation



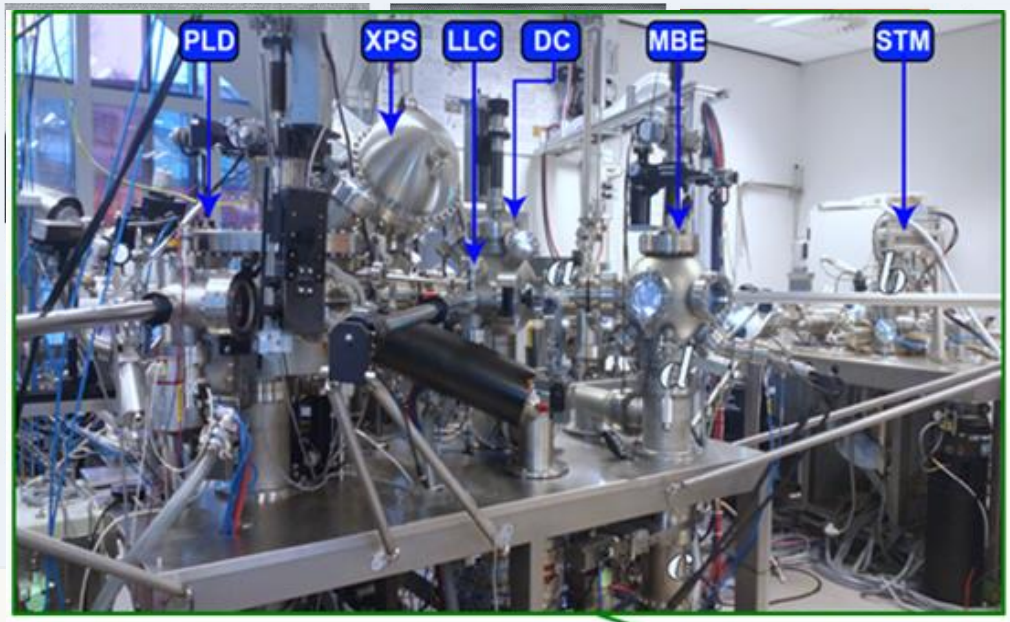


Applications in Materials and Condensed Matter Physics

Topological quantum materials: **Promising material for quantum technology**



MBE Grown Bulk Insulating Bi_2Te_3 Thin Films & Quantum Transport Properties

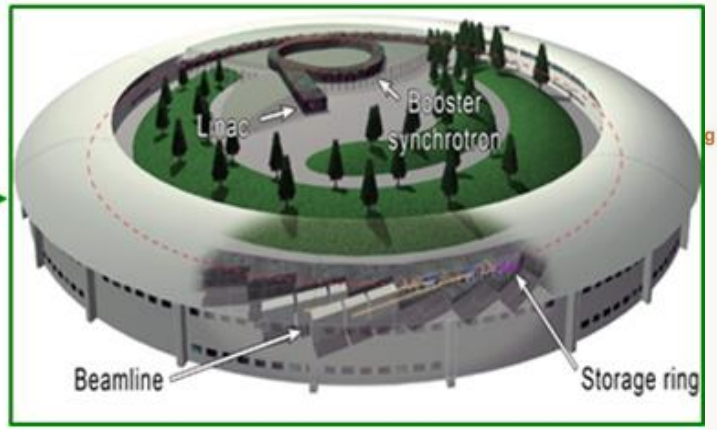


LT STM/STS

ARPES

Device fabrication

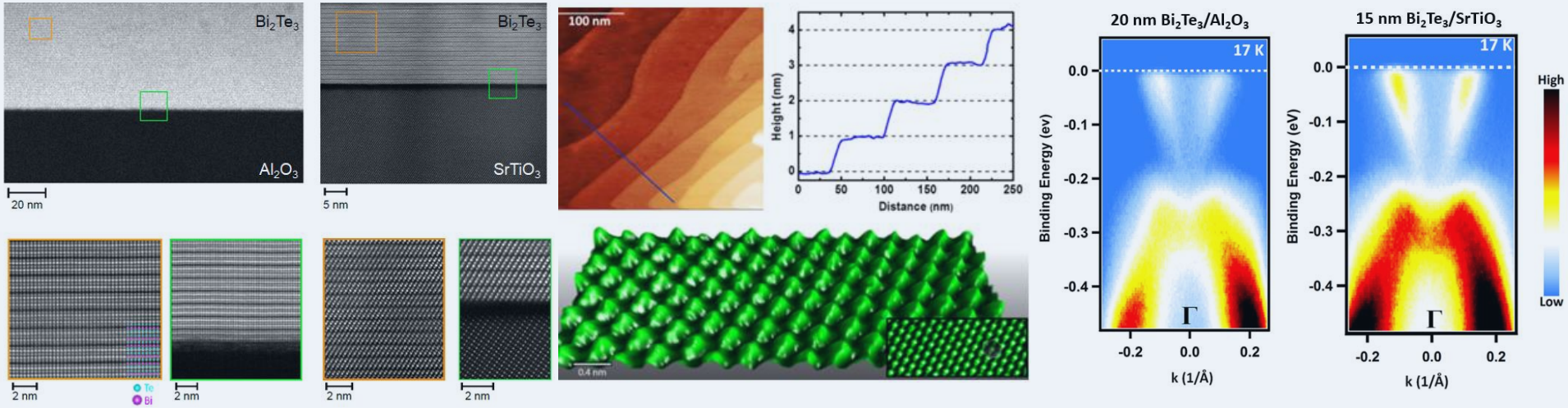
UVH conditions



Synchrotron Light Sources

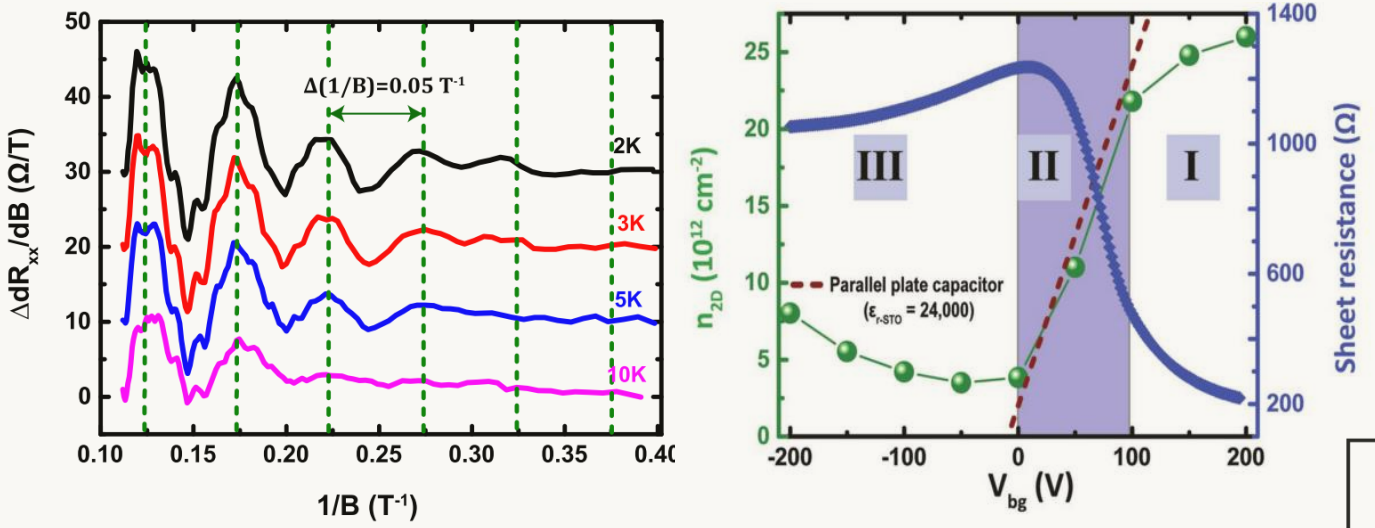
P. Ngabonziza *et al.*, Book Chapter in Springer Book Series (2018)

MBE Grown Bulk Insulating Bi_2Te_3 Thin Films & Quantum Transport Properties



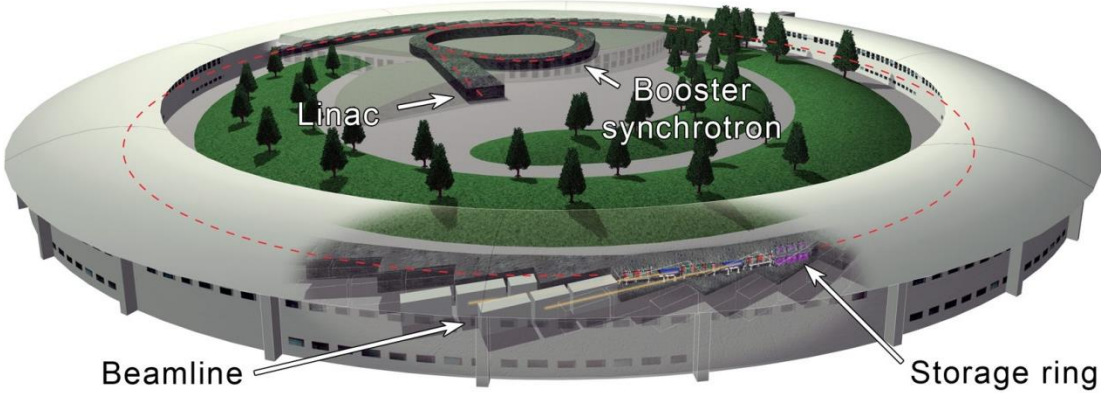
P. Ngabonziza *et al*., Phys. Rev. Mater. **2**, 044204 (2018)

P. Ngabonziza *et al*., Phys. Rev. B **92**, 035405 (2015)

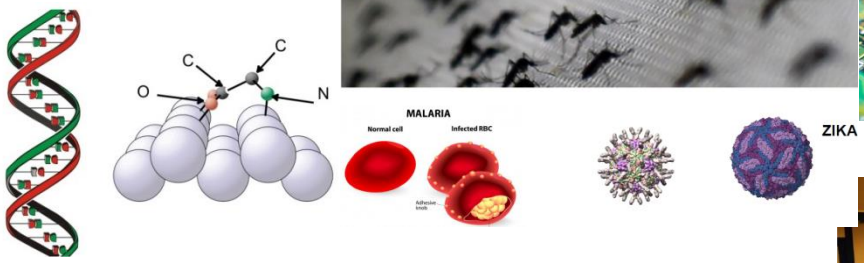


P. Ngabonziza *et al*., Adv. Electron. Mater. **2**, 1600157 (2016)

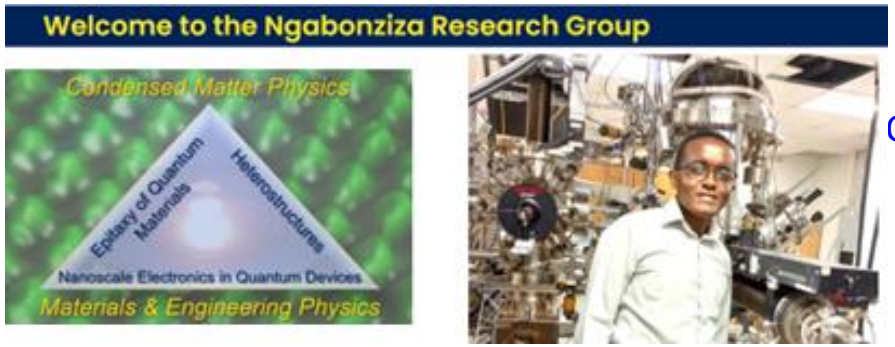
In Summary…



- Revolutionized basic and applied research in many scientific and technological disciplines.



- Diverse applications:
  - Health and Pharmaceuticals
  - Medical applications,
  - Agriculture and environmental,
  - Improve the quality of University education/research



Quantum Heterostructures and Device Physics Lab @ LSU

https://quantummaterialsanddevicelab.com/