

# Title:

**The Road To LAAMP: Unveiling the Crystal and local Structure of doped-BSCCO High-Temperature Superconductors using XRD, and EXAFS/XRF Beam Line at SESAME Synchrotron.**



The Abdus Salam  
International Centre  
for Theoretical Physics



## Dr. Mustafa Shalaby

Assistant Prof. –NCRRT-Egyptian Atomic Energy Authority



School on Synchrotron Light Sources and their Applications

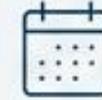
# Outline

- General Remarks
- Our Research points
- The Road TO LAAAMP



# Egyptian Atomic Energy Authority: Pioneering National Vision for Peaceful Nuclear Research

The Egyptian Atomic energy Authority (EAEA) has been the leading national body for research and development in basic and applied peaceful nuclear science since **1955**.



Established in **1955**



Second in Africa to build a nuclear reactor



Member of **IAEA** and key international organizations

The EAEA's main facility is strategically located at Inshas, 60 km from Cairo.



# A National Infrastructure for Scientific Advancement

EAEA's research centers and reactors are the engines of Egypt's nuclear capabilities.



## Nuclear Research Center (NRC)

Mandate: The main research facility at Inshas, the heart of EAEA's scientific inquiry.



## Hot Laboratory and Waste Management Center (HLWMC)

Mandate: Responsible for critical radioactive material handling and processing.



## National Centre for Radiation Research and Technology (NCRRT)

Mandate: Focused on translating research into practical radiation applications for industry and medicine.



## National Centre for Nuclear Safety and Radiation Control (NCNSRC)

Mandate: The national authority for regulatory oversight and ensuring the highest safety standards.

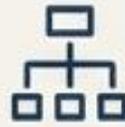


# The National Centre for Radiation Research and Technology (NCRRT)

Promoting research and development using ionizing radiation since 1972.



- **Establishment:** Founded in 1972 with a specific focus on ionizing radiation applications.



- **Structure:** Comprised of 3 Main divisions housing twelve specialized departments.



- **Core Facilities:** Includes central laboratories for advanced research, industrial radiation processing facilities, and technical and agricultural service sectors.

# A Bridge of Applications: From Ionizing Radiation to Synchrotron Science



## Medical

Sterilization of medical equipment and supplies.



## Food

Food irradiation for safety and preservation.



## Industrial

Material processing and modification.



## Environmental

Environmental studies and applications.

*“The expertise developed at NCRRT in manipulating radiation for material, medical, and industrial benefit provides a strong foundation for advancing research with synchrotron light sources.”*

# A Trusted Partner in Global and Regional Science

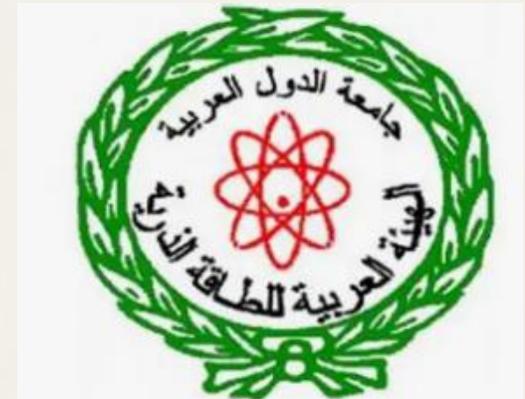
NCRRT's work is built on a network of key international collaborations.



**IAEA** - International Atomic Energy Agency



**AFRA** - African Regional Cooperative Agreement



**AAEA** - Arab Atomic Energy Agency

# The Solid State Physics and Functional Materials Group



Polymers/Irradiation effects



High-Tc Superconductors



Thermoelectricity



Energy Storage



## Publications and Activity:

**21**

Publications in Q1 and Q2 journals in 2025

**2**

CERIC accepted proposals in 2025

**2**

SESAME accepted proposal in 2025

**1**

RIANNA accepted proposal for four experiments in 2026

# Our Research is Strengthened by Collaborations with Leading International Institutions



# □ Our Research points



## RESEARCH

# Enhanced the Structural, Dielectric Constants, and Linear/Non-linear Optical Properties of PVB/Gd<sub>2</sub>O<sub>3</sub> Nanocomposites for Flexible Optoelectronics

Amani Alruwaili<sup>1</sup> · Mohammed O. Alziyadi<sup>2</sup> · Soraya Abdelhaleem<sup>3</sup> · M. S. Shalaby<sup>4</sup> · A. Z. Mahmoud<sup>5,6</sup>

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**Table 2** Parameters of optical of PVB-Gd<sub>2</sub>O<sub>3</sub> nanocomposites

Sample	$E_g \pm 0.05$ (eV)	$E_U$ (eV)
PVB	5.14	0.714
PVB+0.5% Gd <sub>2</sub> O <sub>3</sub>	5.01	0.815
PVB+1% Gd <sub>2</sub> O <sub>3</sub>	4.88	1.059
PVB+2% Gd <sub>2</sub> O <sub>3</sub>	4.65	1.209
PVB+3% Gd <sub>2</sub> O <sub>3</sub>	4.48	1.725

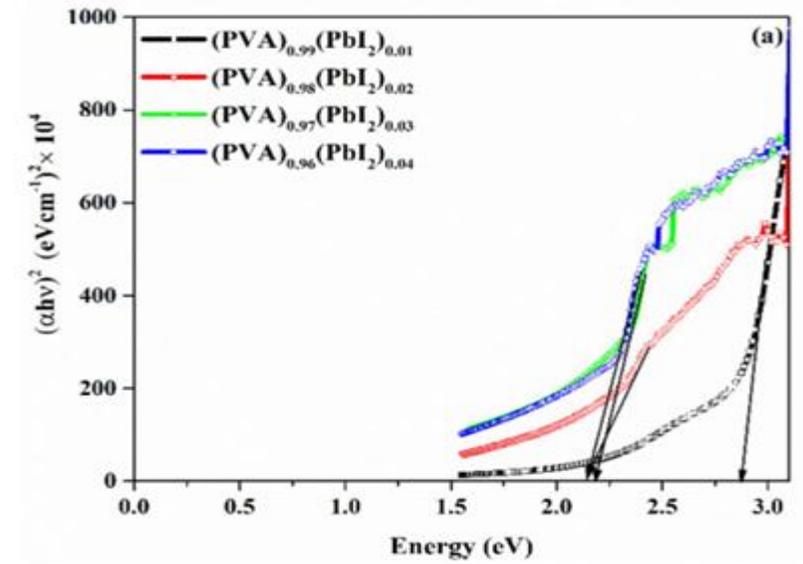


## Effect of Pbl<sub>2</sub> concentrations on structural, thermal, optical, and radiation shielding properties of PVA/Pbl<sub>2</sub> nanocomposites

Mohammed O. Alziyadi<sup>1</sup>, Amani Alruwaili<sup>2</sup>, M. Rashad<sup>3</sup>, Soraya Abdelhaleem<sup>4</sup>, Asma Alkabsh<sup>5</sup>, and M. S. Shalaby<sup>6,\*</sup>

<sup>1</sup> Department of Physics, College of Science and Humanities–Shaqra, Shaqra University, Riyadh, Saudi Arabia

<sup>2</sup> Department of Physics, College of Science, Northern Border University, Arar, Saudi Arabia



# Thermoelectric materials

Discover Applied Sciences

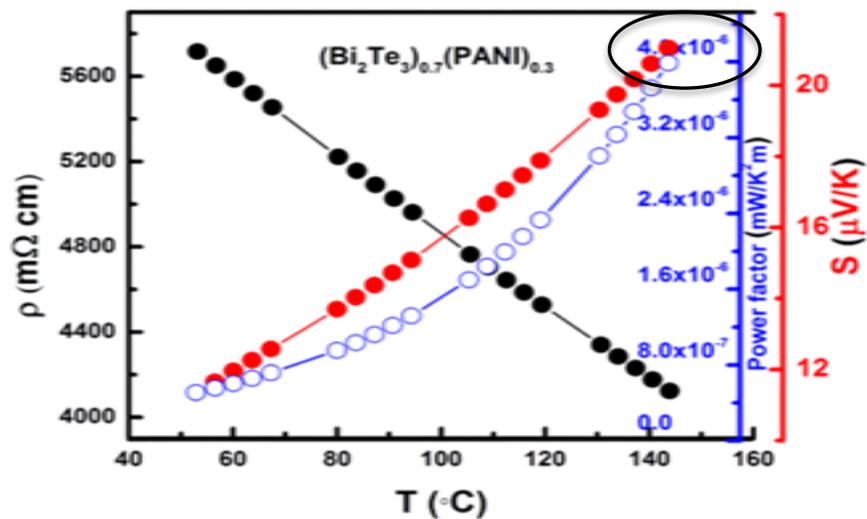
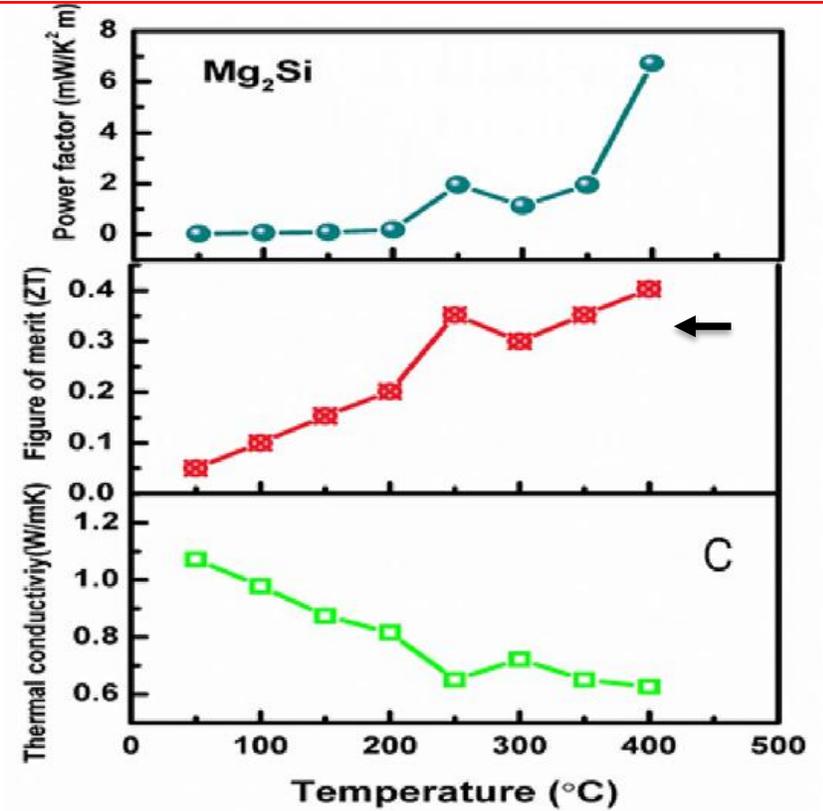
Research

## Gamma-irradiation induced synthesis of Ag-decorated $Mg_2Si$ : ion beam analysis investigation for enhanced thermoelectric performance

M. S. Shalaby<sup>1</sup> · Manale Noun<sup>2</sup> · Soraya Abdelhaleem<sup>3</sup> · M. I. A. Abdel Maksoud<sup>3</sup>

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$$ZT = S^2 \sigma T / k$$



Synthetic Metals 285 (2022) 117025



Contents lists available at ScienceDirect

Synthetic Metals

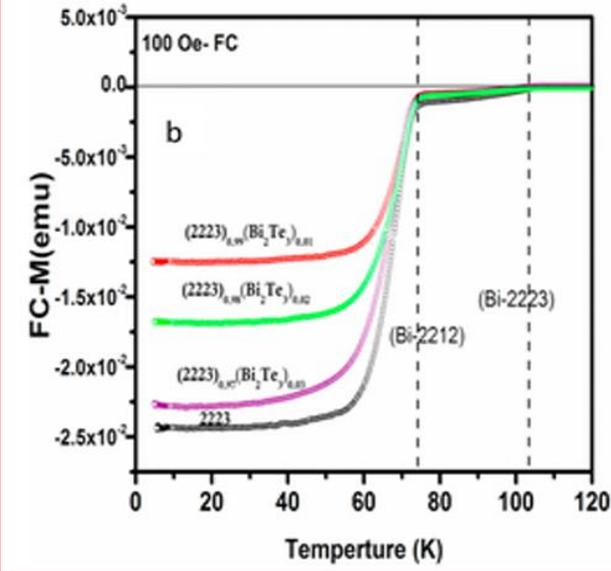
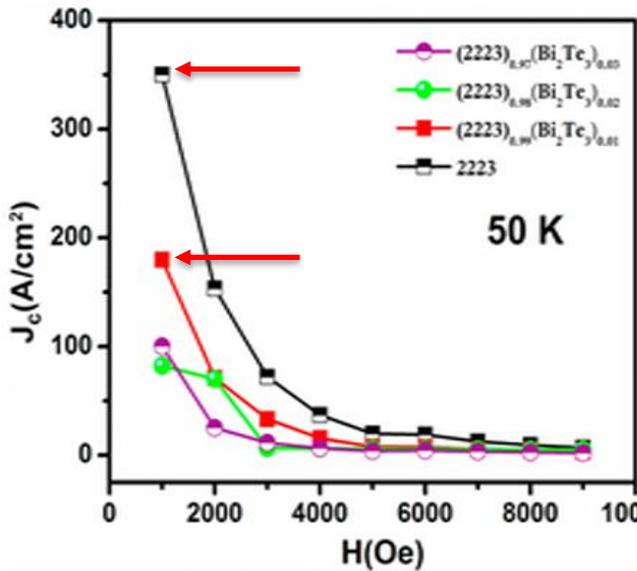
journal homepage: [www.elsevier.com/locate/synmet](http://www.elsevier.com/locate/synmet)



$(Bi_2Te_3)_{1-x}(PANI)_x$  compositions- synthesis, structural, spectroscopic characterization with enhanced thermoelectric performance

M.S. Shalaby<sup>a,1,\*</sup>, Soraya Abdelhaleem<sup>b,2</sup>, A. Sotelo<sup>c,3</sup>

# High T<sub>c</sub>-Superconductors



Ceramics International xxx (xxxx) 1–13



ELSEVIER

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Ceramics International

journal homepage: [www.elsevier.com/locate/ceramint](http://www.elsevier.com/locate/ceramint)



The impact of the addition of Bi<sub>2</sub>Te<sub>3</sub> nanoparticles on the structural and the magnetic properties of the Bi-2223 high-T<sub>c</sub> superconductor

M.S. Shalaby<sup>a,\*</sup>, Mai Hussein Hamed<sup>b,c</sup>, N.M. Yousif<sup>a</sup>, H.M. Hashem<sup>c</sup>

Physica B 697 (2025) 416704

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Physica B: Condensed Matter

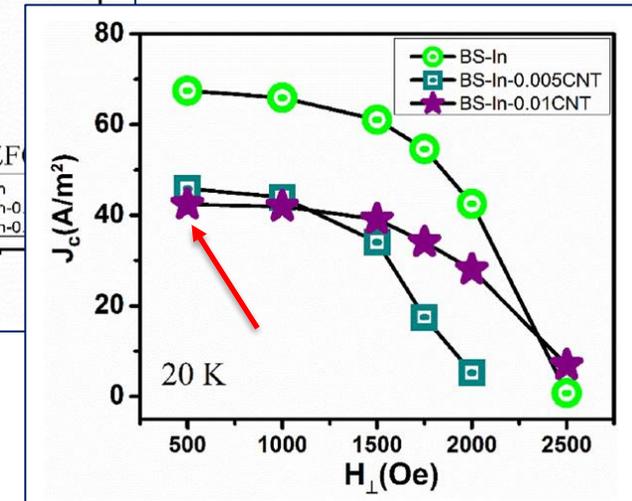
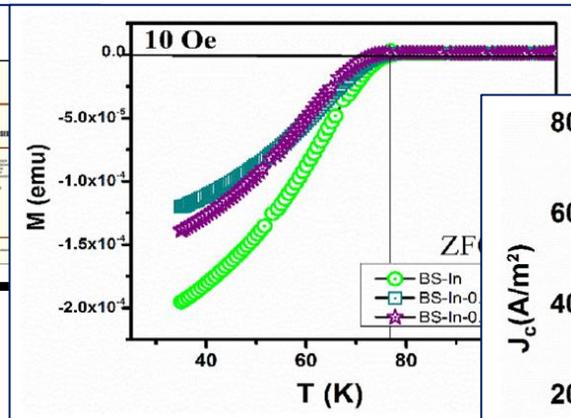
journal homepage: [www.elsevier.com/locate/physb](http://www.elsevier.com/locate/physb)



ELSEVIER

Impact of carbon nanotubes on superconducting properties and ferromagnetism of indium-doped Bi-2212 superconductors: Critical current density enhancement

Soraya Abdelhaleem<sup>a</sup>, Manale Noun<sup>b</sup>, Nashwa M. Yousif<sup>c</sup>, Mustafa Saeed Shalaby<sup>c,\*</sup>



**The Road To**



# Connecting National Expertise to the Global Scientific Frontier

## What is LAAAMP?

LAAAMP stands for **L**ight sources for **A**frica, the **A**mericas, **A**sia and **M**iddle **E**ast **P**roject.

### Key Project Details,

- **Funding:** Supported by a €300K grant from the International Science Council (ISC).
- **Genesis:** A joint IUPAP-IUCr project active since 2016.
- **Leadership:** The Abdus Salam ICTP joined as a lead institution in 2020.



# The Core Objectives of the LAAAMP Initiative

LAAAMP is designed to create a self-sustaining ecosystem for advanced scientific research in the region.

## Key Objectives

- ✓ Develop deep expertise in synchrotron techniques.
- ✓ Support new research applications across a wide range of disciplines.
- ✓ Enhance and strengthen regional scientific collaboration.
- ✓ Train the next generation of researchers in advanced synchrotron methods.

This school is a direct manifestation of LAAAMP's mission—to train the next generation of researchers.

For more information, visit:  
<https://laaamp.iucr.org/>



# LAAAMP

Lightsources for Africa, the Americas, Asia, Middle East and Pacific



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

## Africa

**Simon Connell** (*Chair*) Univ. of Johannesburg, South Africa  
**Djamel Bradai** UST Houari Boumediene, Algeria  
**Jean-Pierre Ezin** Université d'Abomey-Calabi, Benin  
**Claude Lecomte** Chair of IUCr Crystallography in Africa initiative  
**Ernie Malamud** Fermilab, University of Nevada, USA  
**Brian Masara** SA Inst of Physics, Zimbabwe  
**Genito Maure** Universidade Eduardo Mondlane, Mozambique  
**Prosper Ngabonziza** Dept Solid State Quantum Electronics, Rwanda  
**Ahmadou Wague** University of Cheikh Anta Diop, Senegal

## Mexico

**Matías Moreno** (*Chair*) Universidad Nacional Autónoma de México  
**Abel Moreno Cárcamo** Coordinator of the Red de Usuarios de Luz Sincrotrón (RedTULS) and Instituto de Química, UNAM  
**Mayra Cuellar** Universidad de Guanajuato  
**José Reyes Gasga** President of the Sociedad Mexicana de Cristalografía and Instituto de Física, UNAM  
**José Ignacio Jiménez** Universidad Nacional Autónoma de México  
**Tomás Viveros** Universidad Autónoma Metropolitana-Iztapalapa

## Caribbean

**Carlos Cabrera** (*Chair*) University of Puerto Rico at Río Piedras  
**Fidel Antonio Castro Smirnov** Advisor to the President of the University of Informatics Sciences, Cuba  
**Noel Blackburn** Brookhaven National Laboratory, USA  
**Eric Sheppard** Hampton University, USA

## SE Asia

**Supagorn Rugmai** (*Chair*) Head of Research Facility, Synchrotron Light Research Institute (SLRI), Thailand  
**Gwo-Huei Luo** President of Asia-Oceania Forum on Synchrotron Radiation Research (AOFSTR) and Director, National Synchrotron Radiation Research Center (NSRRC), Taiwan  
**Chia-Hung Hsu** Secretary General and Staff Scientist, NSRRC, Taiwan  
**Pinit Kidkhunthod** Assistant Chief of Research Facility Division of SLRI, Thailand  
**Michael James** Head of Science, Australian Synchrotron

## Central Asia

**Davron Matrasulov** (*Chair*) Head of Laboratory for Advanced Studies, Turin Polytechnic University in Tashkent, Uzbekistan  
Members to be appointed

## Middle East

**Kirsi Lorentz** (*Chair*) The Cyprus Institute, Nicosia, Cyprus  
**Roy Beck-Barkai** Tel-Aviv University, Israel  
**Musa Mutlu Can** Istanbul University, Turkey  
**Ahmed Farghaly** National Research Center, Cairo, Egypt  
**Jamal Ghabboun** Bethlehem University, Palestine  
**Hanan Saladeh** University of Jordan, Amman

## Pacific Islands

**Sekazi K. Mtingwa** (*Acting Chair*) TriSEED Consultants, USA  
Chair and Members to be appointed

### *Eligibility*

**Faculty** members at universities in Africa, the Caribbean, Mexico, SE Asia, Middle East and Pacific region. Interested in using AdLSs to further one's research and training endeavors. Previous experience with using AdLSs is limited to a year or less. Ability to spend 2 months as a full-time visitor in residence at an AdLS that is a *LAAAMP* collaborative partner.

**Student** registered as full-time Ph.D. student and supervised by the Faculty member.

### *Categories*

**Continuing** and **New** applications are considered.

### *Financial Support*

*LAAAMP* provides ca **2,000 Euros per person** to cover transportation and (partially) accommodation costs. The remainder of accommodation and subsistence should be negotiated with the host AdLS and other sources of support.

### *Deliverables*

[\*\*\*https://laaamp.iucr.org/calls\*\*\*](https://laaamp.iucr.org/calls)

- ✓ All publications resulting from the visits must acknowledge the support provided by IUPAP-IUCr-ICTP *LAAAMP* initiative.
- ✓ 3-page report that evaluates the non-scientific aspects of the visit, including positive experiences as well as ways that the visit could be enhanced in the future.

**The Road To**



**STEP 1**

# SESAME is the Beacon for Science in the Middle East



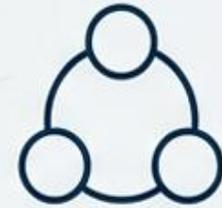
## What it is

SESAME (Synchrotron-light for Experimental Science and Applications in the Middle East) is a state-of-the-art X-ray and Infrared characterisation facility.



## Its Mission

To foster scientific excellence and build a culture of international cooperation in the region.



## Its Model

An international collaboration model with member countries, including Egypt, serving as a hub for the region's top scientific talent.

# A Closer Look: Beamlines & Applications.

## Six Beamlines are in Operation

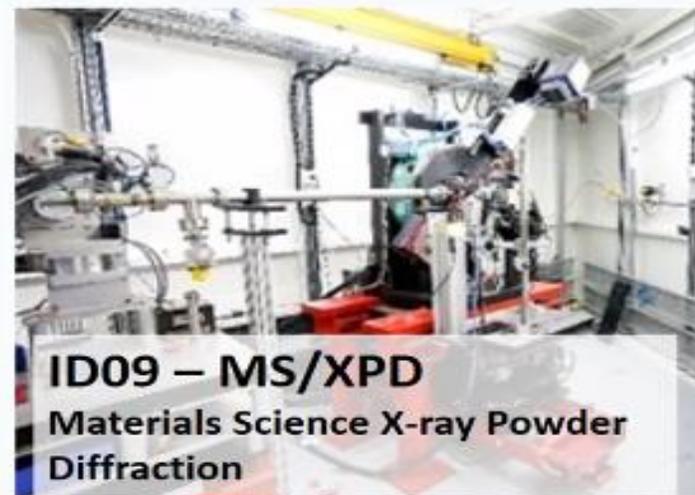
**BM02 – IR**  
Infrared Spectromicroscopy



**BM08 – XAFS/XRF**  
X-ray Absorption Fine Structure  
X-ray Fluorescence Spectroscopy



**ID09 – MS/XPD**  
Materials Science X-ray Powder  
Diffraction



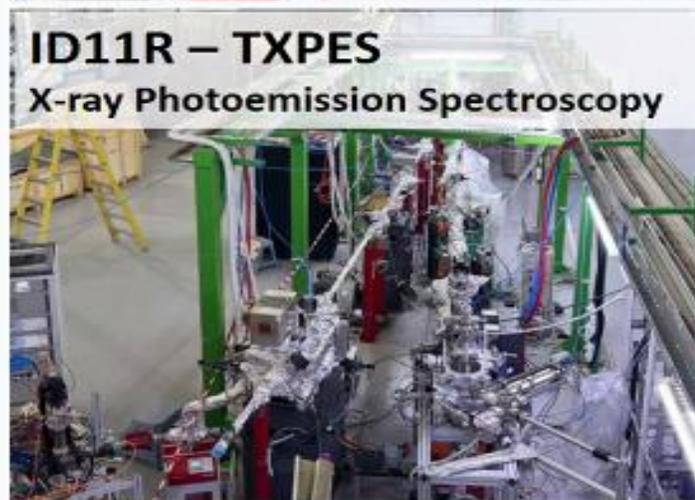
**ID10 – BEATS**  
X-ray Tomography



**ID11L – HESEB**  
Soft X-ray Absorption Spectroscopy



**ID11R – TXPES**  
X-ray Photoemission Spectroscopy



## The 5 Steps to Your Invitation Letter



### Step 1: Prepare Your Proposal

Develop your scientific case and experimental plan.



### Step 2: Select the Beamline

Choose the instrument best suited for your research goals.



### Step 3: Contact the Beamline Scientist

Crucial step: Engage with the expert staff for guidance.



### Step 4: Align Your Proposal

Refine your plan based on the scientist's suggestions and technical feedback.



### Step 5: Get Your Invitation Letter

The final confirmation for your experiment at SESAME.

**The Road To**



**STEP 2**

# A Focused Opportunity: The LAAAMP Program.

## The Plan for LAAAMP

For qualifying researchers, the LAAAMP program offers a specialized track for engagement with SESAME. This section outlines the requirements to participate.



<https://laaamp.iucr.org/calls>

# Are You a Candidate for LAAAMP?



You must be a **Faculty member** and have a **Student**.  
*Emphasizes the program's mentorship and training component.*



You must have an **Invitation** from a **beamline scientist**.  
*Connects back to the general application process, showing this is a prerequisite.*



You must provide **Proof** for previous experience with **Synchrotron Radiation**.  
*Indicates this may be for returning researchers or those in a specific network.*

**If you meet these criteria, you are ready for LAAAMP Applications.**

**The Road To**

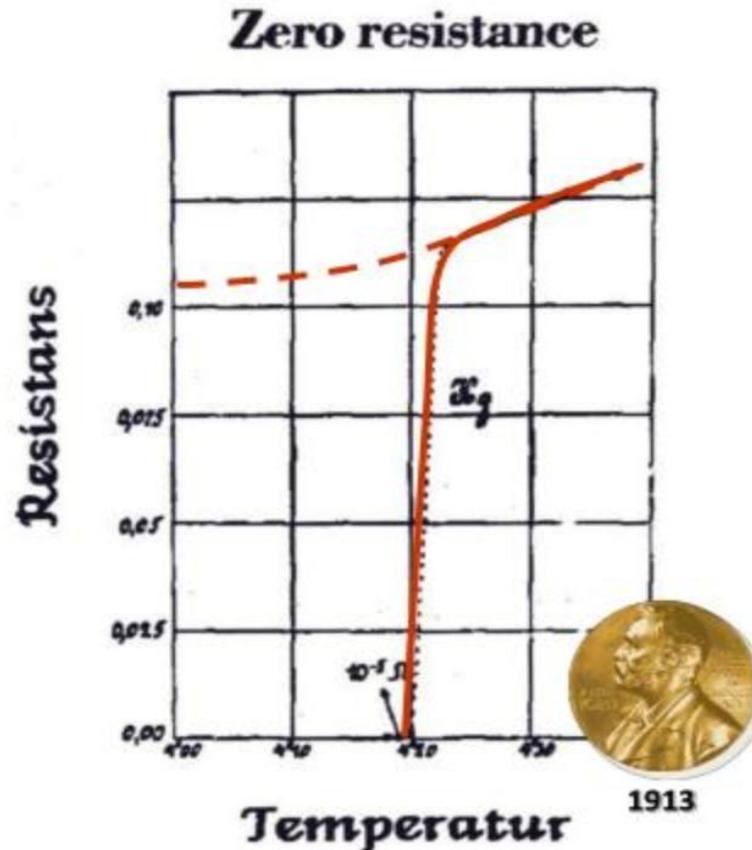


**STEP 3**

**Superconductivity:** is the phenomenon where certain materials, when cooled below a critical temperature, conduct electricity with *zero resistance* and expel magnetic fields (the Meissner effect).



- Discovered by **Kamerlingh Onnes** in 1911 during first low temperature measurements to liquefy helium
- Whilst measuring the resistivity of “pure” Hg he noticed that the electrical resistance dropped to zero at 4.2K
- In 1912 he found that the resistive state is restored in a magnetic field or at high transport currents



“Superconductivity is perhaps the most remarkable property in the universe” David Pines

# Superconductors

✧

material	$T_c, K$	$H_c, Oe$	year
Al	1.2	105	1933
In	3.4	280	
Sn	3.7	305	
Pb	7.2	803	1913
Nb	9.2	2060	1930

pure metals

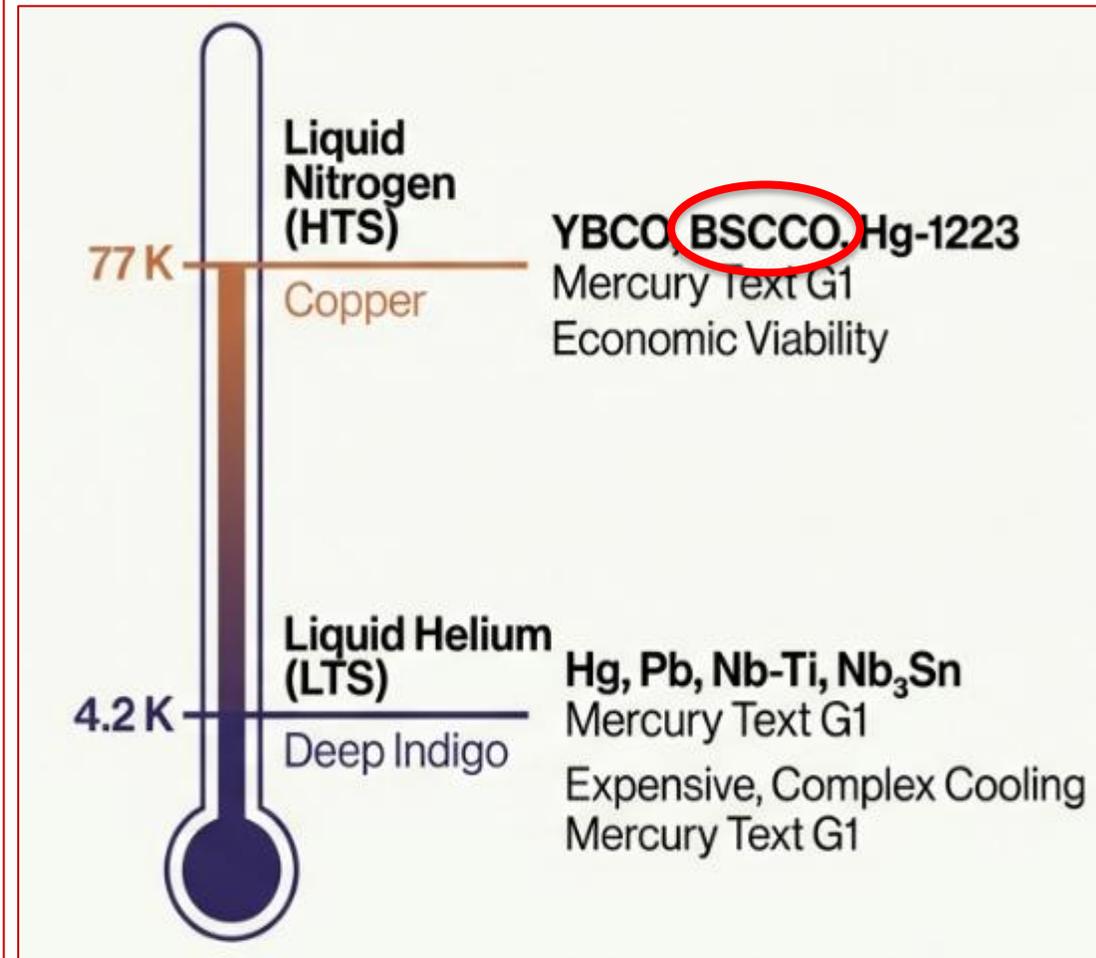
alloys

material	$T_c, K$	$H_c, Oe$	year
NbN	15	$1.4 \cdot 10^5$	1940
Nb <sub>3</sub> Ge	23	$3.7 \cdot 10^5$	1971

ceramics

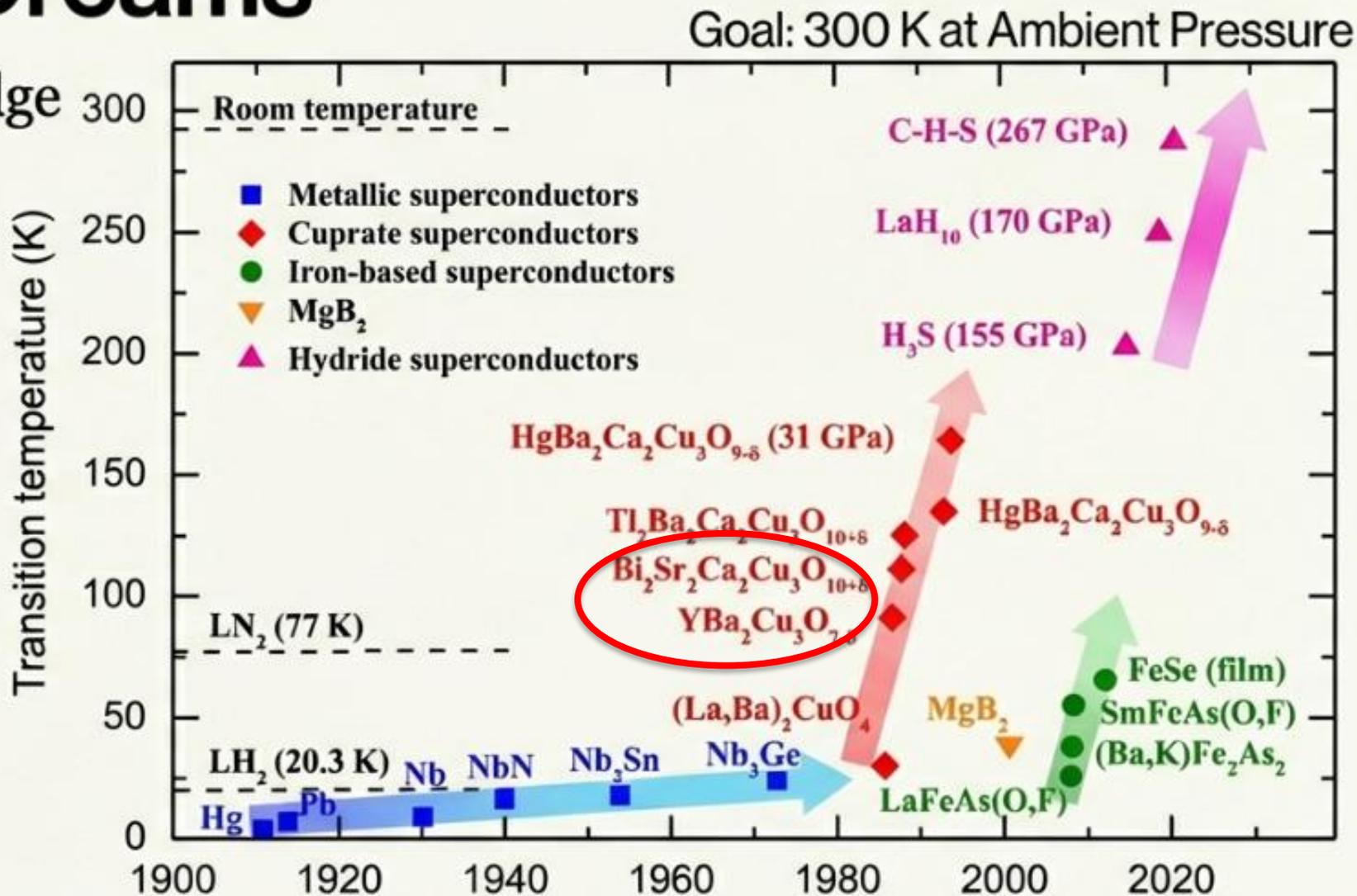
material	$T_c, K$	year
La <sub>1.85</sub> Ba <sub>0.15</sub> CuO <sub>4</sub>	35	1986
YBa <sub>2</sub> Cu <sub>3</sub> O <sub>7</sub>	93	1987
Bi <sub>2</sub> Sr <sub>2</sub> CaCu <sub>2</sub> O <sub>8+x</sub>	94	1988
Ta <sub>2</sub> Ba <sub>2</sub> Ca <sub>2</sub> Cu <sub>3</sub> O <sub>10+x</sub>	125	1988
HgBa <sub>2</sub> Ca <sub>2</sub> Cu <sub>3</sub> O <sub>8+x</sub>	150*	1993

\* under pressure



# The Future: Designing Room Temperature Dreams

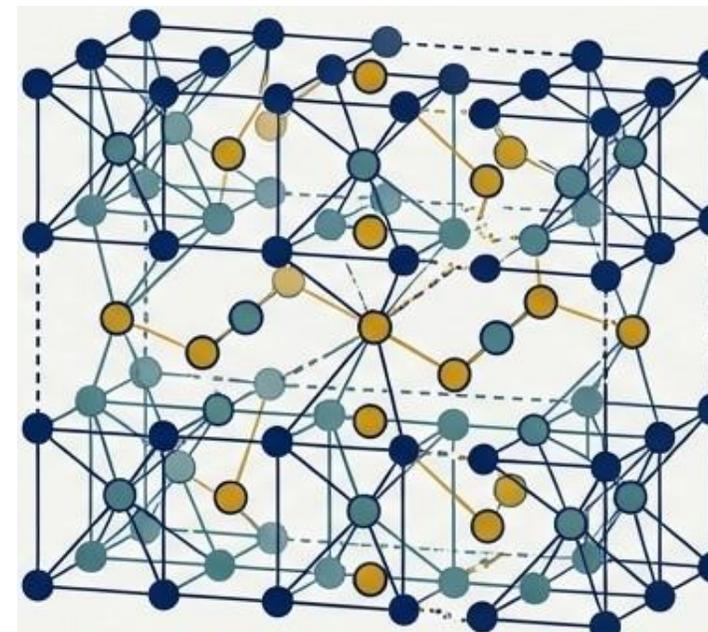
Guided by the Double-Bridge theory, we are optimizing material parameters to push  $T_c$  higher, aiming for the ultimate goal: Room Temperature Superconductivity.







## The Performance Bottleneck



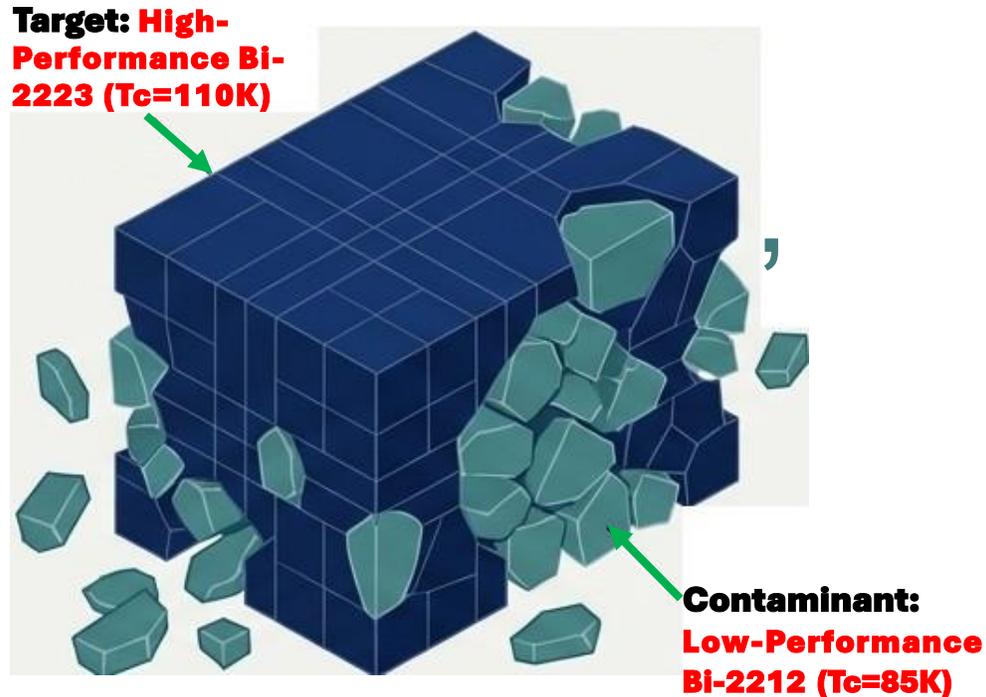
- **Bi-Sr-Ca-Cu-O (BSCCO)** is a leading candidate for HTSC applications, with a high **critical temperature ( $T_c$ )** of 110K for its Bi-2223 phase.

- However, its **real-world performance** is severely limited by strong variations in critical temperature ( $T_c$ ) and critical current density ( $J_c$ ).

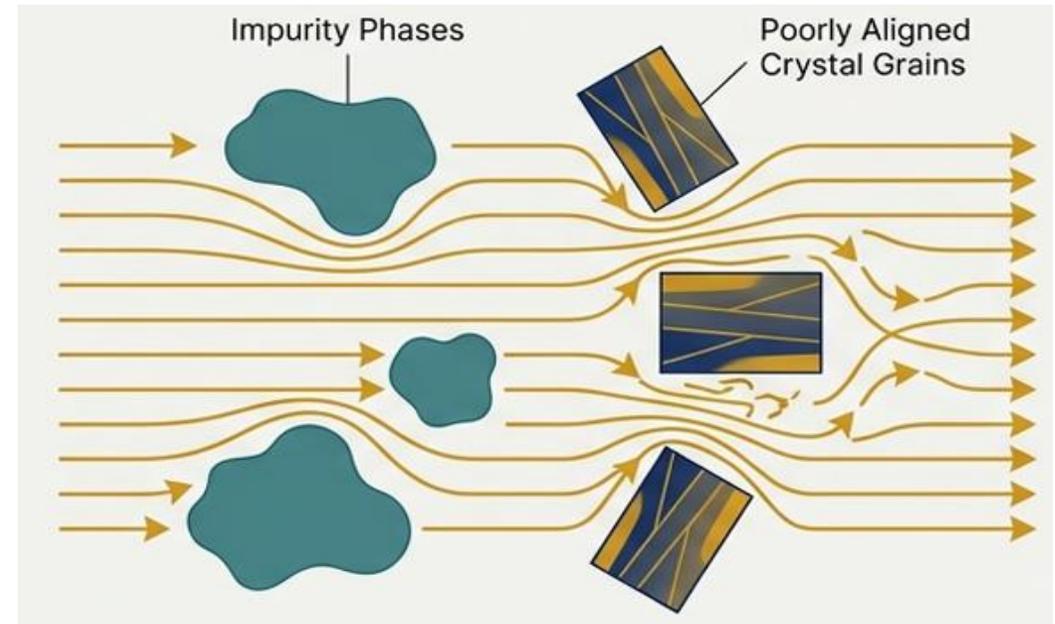
- A complex, **one-dimensional incommensurate lattice** modulation (ILM) that makes its properties highly unpredictable and difficult to optimize.

# □ The Twin Challenges: Phase Purity and Current Density

## The Phase Purity Problem



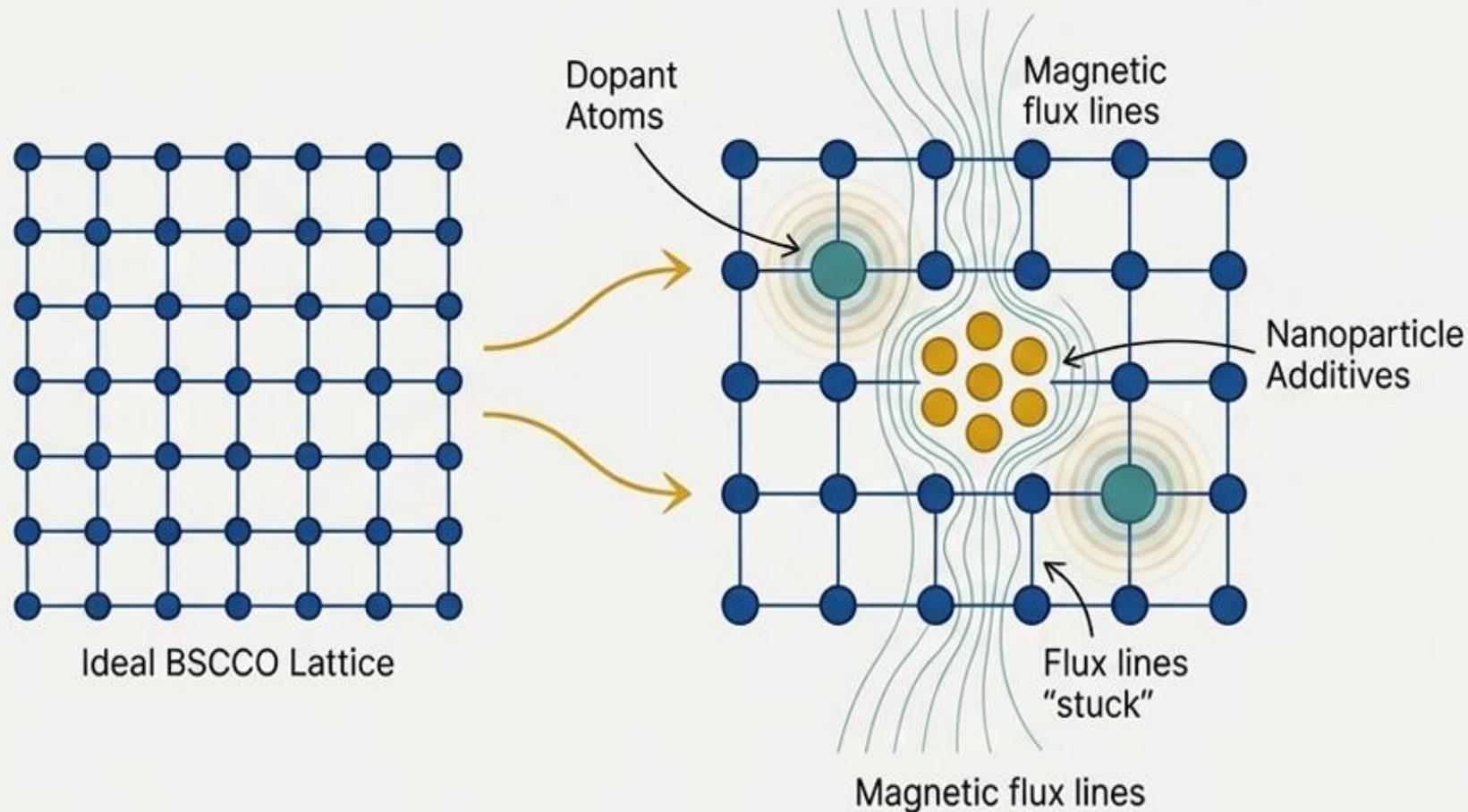
## The Current Density ( $J_c$ ) Problem



Achieving enhanced superconducting performance requires solving two fundamental problems:

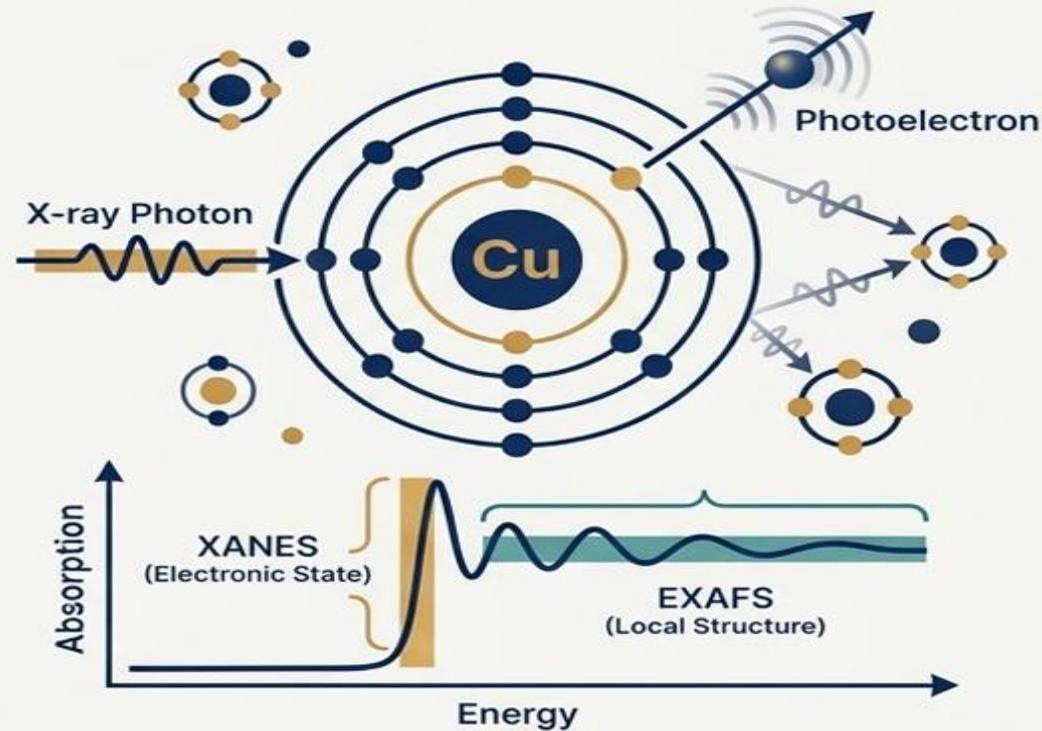
- 1. Maximizing the Bi-2223 Phase:** Synthesizing the pure high- $T_c$  phase is notoriously difficult due to the incommensurate structure.
- 2. Improving Critical Current ( $J_c$ ):** This requires decreasing impurity phases that block current and improving crystal orientation uniformity.

# Engineering the Lattice: A Strategy of Dopants and Nanoparticles



- A powerful strategy for engineering BSCCO properties is the introduction of dopants and nanoparticle additives.
- **Mechanism:** Selectively replacing atoms (doping) or adding nanoparticles creates defects that act as "pinning centers," which anchor magnetic flux lines and enhance the critical current density ( $J_c$ ).
- **Challenge:** The effect of these additions is highly sensitive and complex. We know *that* it works, but not precisely *how* it works at the atomic level.

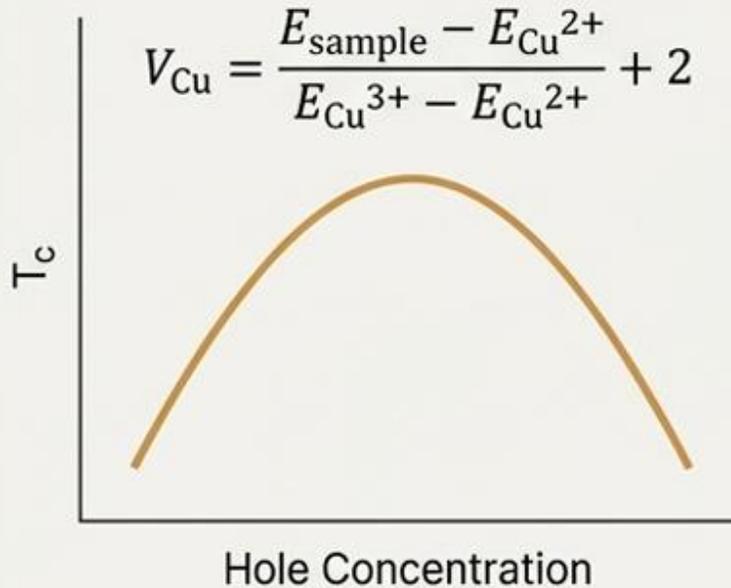
# X-ray Absorption Fine Structure (XAFS): The Probe to See Inside the Black Box



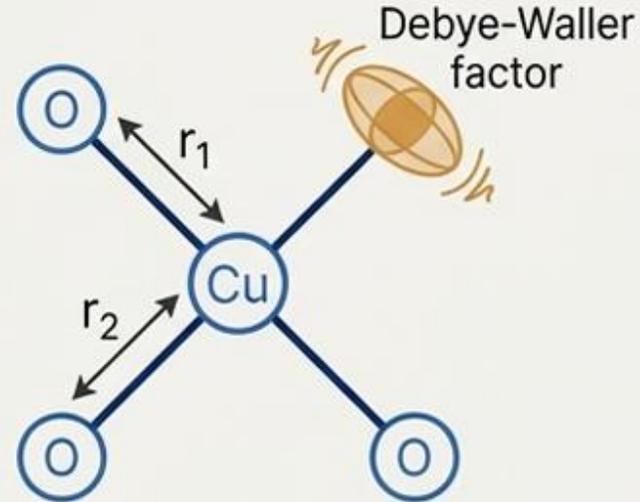
- To understand the effect of dopants, we need a technique that is element-specific and sensitive to the **local atomic and electronic structure**. Synchrotron-based XAFS is the ideal tool. It provides two critical pieces of information:
  - ❖ **XANES (X-ray Absorption Near Edge Structure)**: Reveals the oxidation state (e.g.,  $\text{Cu}^{2+}/\text{Cu}^{3+}$  ratio) and electronic configuration.
  - ❖ **EXAFS (Extended X-ray Absorption Fine Structure)**: Quantifies local structural parameters: bond distances, coordination numbers, and atomic disorder (Debye-Waller factors).

# Quantifying the Key Drivers of Superconductivity with XAFS

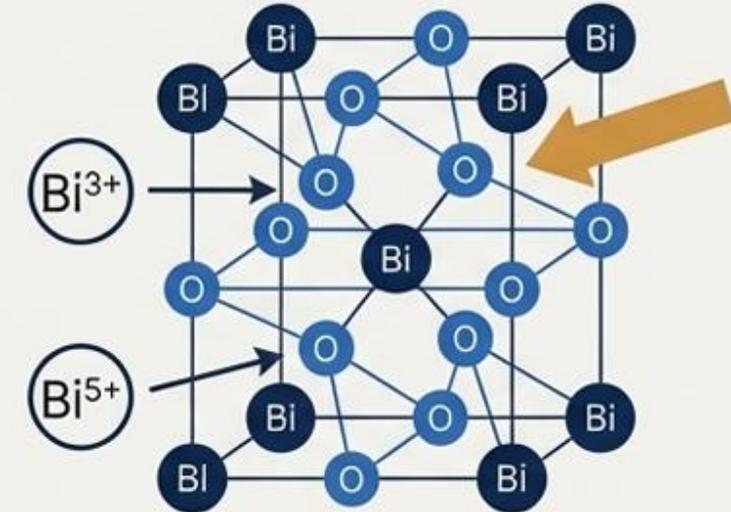
## Cu Oxidation State & Hole Concentration



## Local Structural Distortions



## Dopant & Oxygen Stoichiometry



□ Cu K-edge XANES directly quantifies the  $Cu^{2+}/Cu^{3+}$  ratio, which determines the hole carrier concentration—the primary governor of  $T_c$  and  $J_c$ .

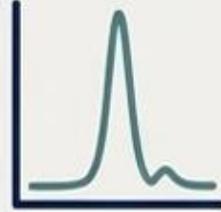
□ EXAFS measures dopant-induced changes to bond lengths and the Mean-Square Relative Displacement (MSRD), revealing how structural strain impacts the  $CuO_2$  planes.

□ Bi L3-edge XANES can investigate the oxidation states of Bi ( $Bi^{3+}/Bi^{5+}$ ), providing crucial information on oxygen content, which directly controls hole doping.

## □ The Unique Capabilities of the SESAME (BM08) Beamline are Essential for This Work

### High Energy Resolution

Crucial for resolving subtle pre-edge features in Cu K-edge XANES, which are directly related to  $\text{Cu}^{2+}/\text{Cu}^{3+}$  ratios and hole concentration in doped BSCCO.



SESAME



### High Flux & Tunability

The high photon flux is necessary to obtain high-quality data on dilute dopant elements (e.g., Mo, Zn) with low concentrations, which is impossible with lab-based sources.



### Elemental Specificity (XAFS & XRF)

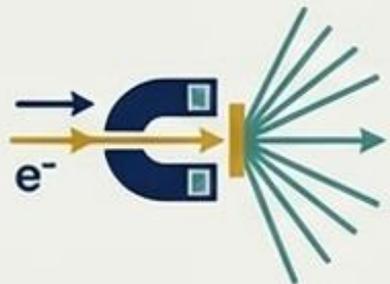
BM08's ability to probe the local environment around *specific* elements (Cu, Bi, dopants) is the core of this proposal. The complementary XRF capability is ideal for analyzing complex, layered materials like BSCCO.

**The combination of high resolution, flux, and elemental specificity at the BM08 beamline makes SESAME uniquely suited to achieve the scientific objectives of this study.**

# □ Experimental Protocol and Measurement Strategy



**Sample Preparation:** Pelletize powder samples with PVP binder.



**Beamline Setup:** Measurements at BM08-XAFS/XRF. Calibrate energy using metal foils.



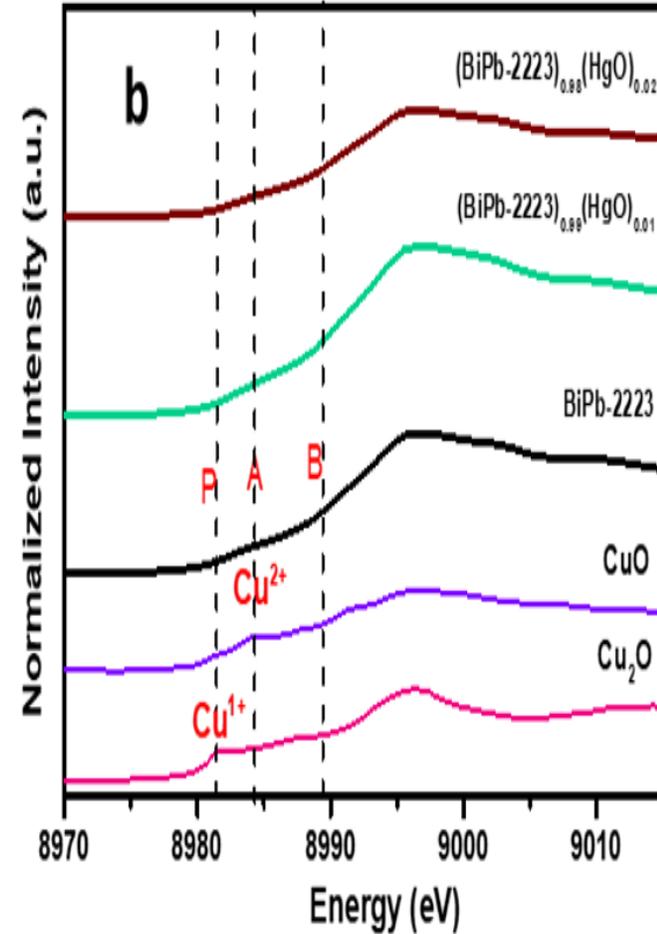
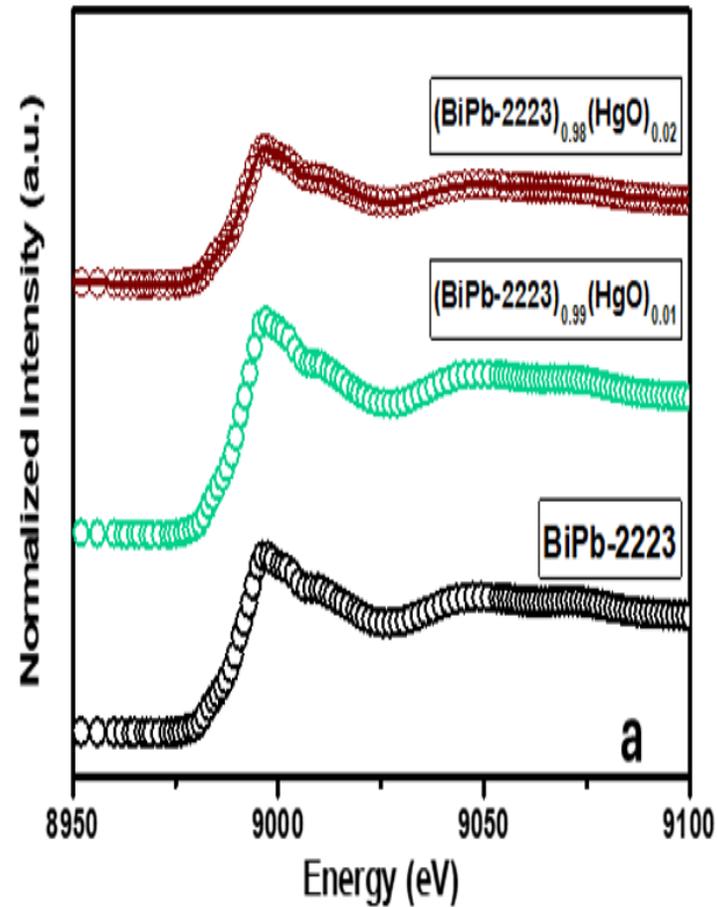
**Data Acquisition:** Collect EXAFS & XANES spectra at Room Temp & 100 K.



**Data Analysis:** Process and analyze spectra using Athena and Artemis software.



# Our Preliminary XAFS Data from the SESAME BM08 Beamline



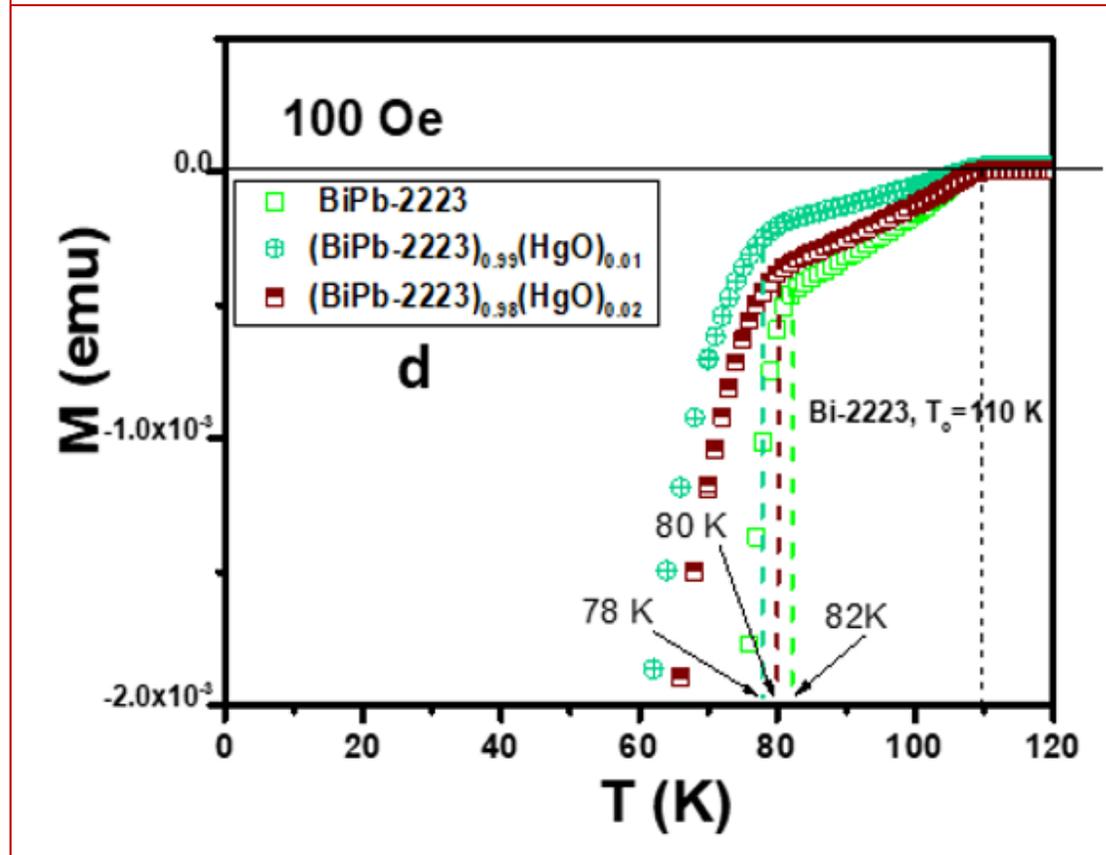
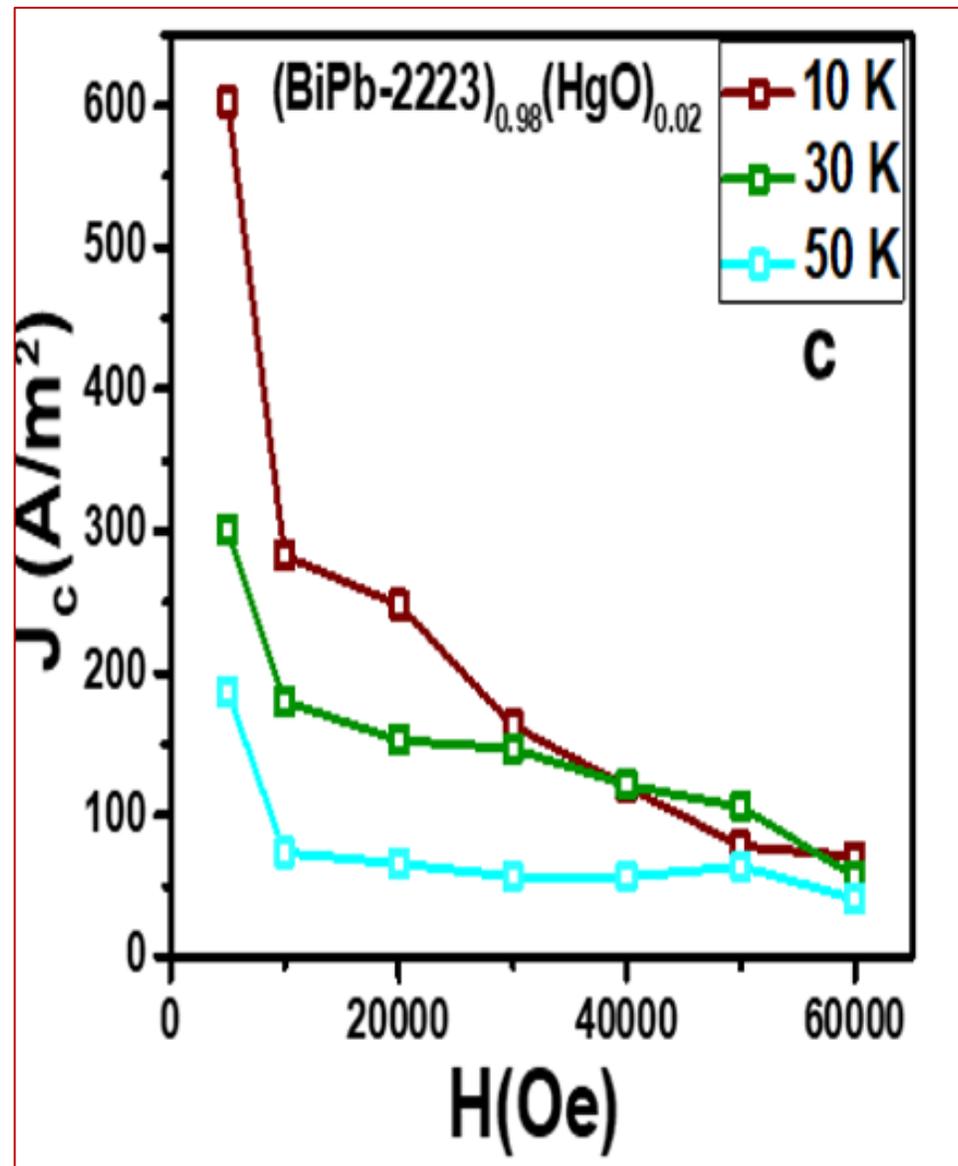
Data collected from the BM08 XAFS/XRF beamline @ SESAME on a related BSCCO system (our work, under review).

These results demonstrate our capability to:

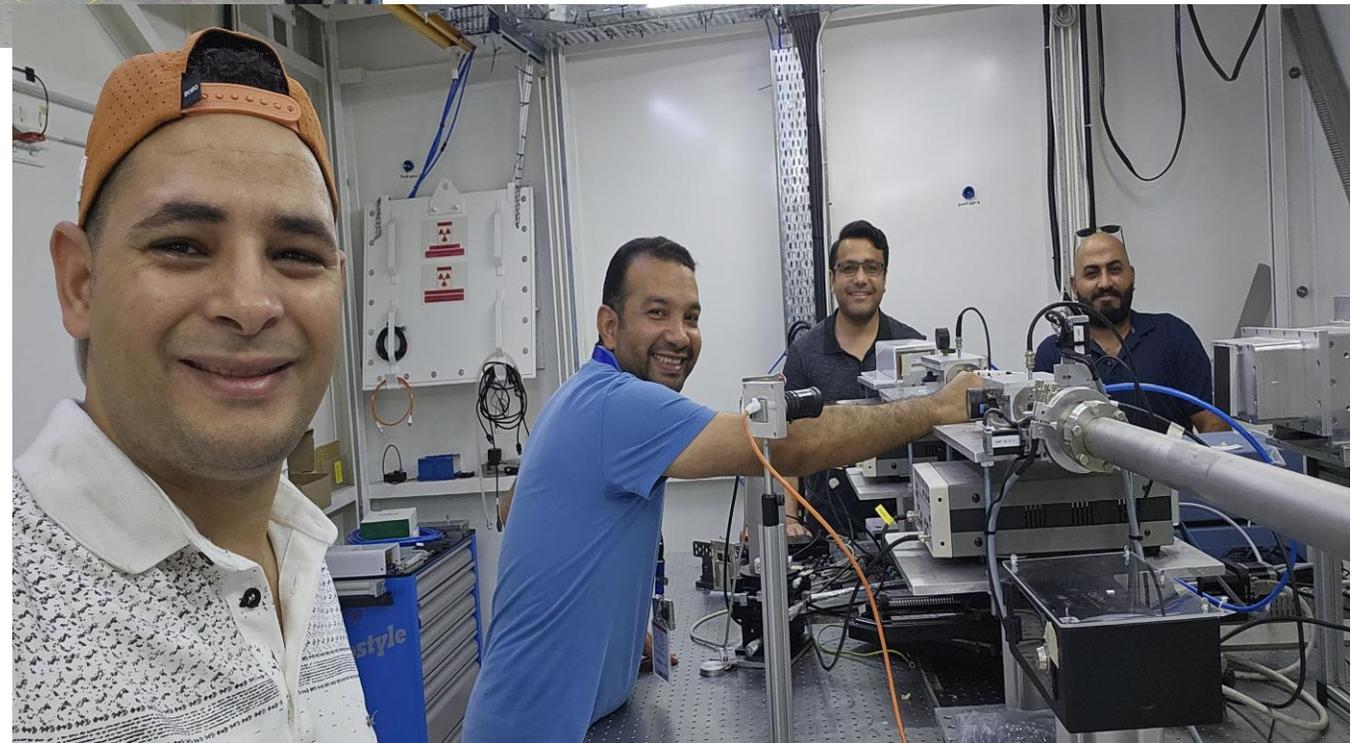
- Acquire high-quality XANES/EXAFS spectra on complex BSCCO materials.
- Distinguish subtle spectral changes due to nanoparticle additives.
- Analyze the data to extract local structural information (radial distributions).

This preliminary work validates our proposed methodology and de-risks the experiment.

Figure (3): a) Normalized Cu K- edge XANES spectra, b) Cu K- edge XANES spectra in comparison with CuO and Cu<sub>2</sub>O



Critical current density ( $J_c$ ) as a function of applied magnetic field ( $H$ ) and M-T measurements for  $(\text{BiPb-2223})_{1-x}(\text{HgO})_x$ , where  $x=0.0, 0.01$  and  $0.02$  nanocomposites at 10, 30, and 50 K.





Thank You!