

# IXS2022

The 12<sup>th</sup> International Conference on Inelastic X-ray Scattering

**Opening Remarks**  
**Andrew Harrison, Diamond Light Source**

Monday 22<sup>nd</sup> August 2022



# IXS2022 – the long and winding road

- IXS International Conference series started in Krakow in 1992, covering Compton Scattering and non-resonant inelastic hard X-ray scattering, with soft X-ray resonant scattering introduced about 10 years ago and now the dominant subject
- Diamond originally bid to host the IXS conference in 2013 – and the first time for the UK - led by Ke-Jin Zhou
- Originally planned to be held in 2021, but due to the pandemic it was decided to postpone to 2022 to ensure in-person participation
- This week we welcome 120 delegates from 14 different countries
- Two thirds of the audience have travelled from Europe and further abroad to be here – thank you !

# Auspicious timing: 75 years of synchrotron radiation

## Radiation from Electrons in a Synchrotron

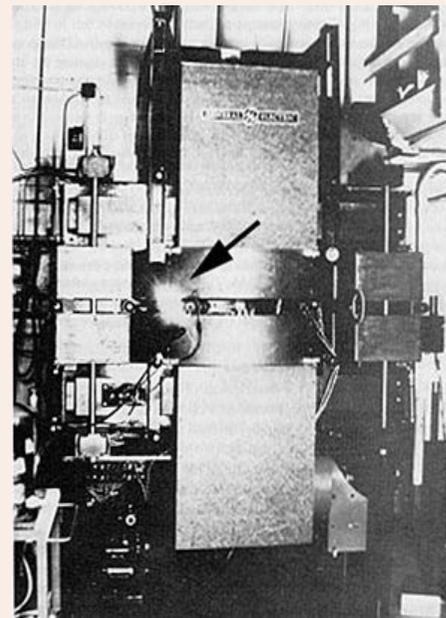
F. R. ELDER, A. M. GUREWITSCH, R. V. LANGMUIR,  
AND H. C. POLLOCK  
Research Laboratory, General Electric Company,  
Schenectady, New York  
May 7, 1947

HIGH energy electrons which are subjected to large accelerations normal to their velocity should radiate electromagnetic energy.<sup>1-4</sup> The radiation from electrons in a betatron or synchrotron should be emitted in a narrow cone tangent to the electron orbit, and its spectrum should extend into the visible region. This radiation has now been observed visually in the General Electric 70-Mev synchrotron.<sup>5</sup> This machine has an electron orbit radius of 29.3 cm and a peak magnetic field of 8100 gauss. The radiation is seen as a small spot of brilliant white light by an observer looking into the vacuum tube tangent to the orbit and toward the approaching electrons. The light is quite bright when the x-ray output of the machine at 70 Mev is 50 roentgens per minute at one meter from the target and can still be observed in daylight at outputs as low as 0.1 roentgen.

The synchrotron x-ray beam is obtained by turning off the r-f accelerating resonator and permitting subsequent changes in the field of the magnet to change the electron orbit radius so as to contract or expand the beam to suitable targets. If the electrons are contracted to a target at successively higher energies, the intensity of the light radiation is observed to increase rapidly with electron energy. If, however, the electrons are kept in the beam past the

peak of the magnetic field and then expanded to a target, the intensity of the radiated light appears to be independent of the energy at which the electrons are removed from the beam. This is to be expected, for in a given machine the radiation is proportional to the fourth power of the electron energy. The light radiation is not observed if the beam is contracted before its energy is about 30 Mev. When the electron beam has been accelerated to the peak of the magnetic field and then decelerated to low energy, a rough measurement of the phase angle over which the light was visible gave a value of 90-100 degrees. The light was viewed through a slotted disk rotating at synchronous speed.

If the r-f resonator is turned off a short time before the peak of the magnetic field, the electron beam slowly contracts to a radius just larger than that of the interior



target and then expands as the magnetic field decreases. In this case, the observer no longer sees a single point of light but a short line with extension in the plane of the orbit.

The light emitted from the beam is polarized with the electric vector parallel to the plane of the electron orbit. It disappears as the observer rotates a piece of Polaroid before the eye through ninety degrees. An investigation of the spectral distribution of the energy is in progress and will be reported.

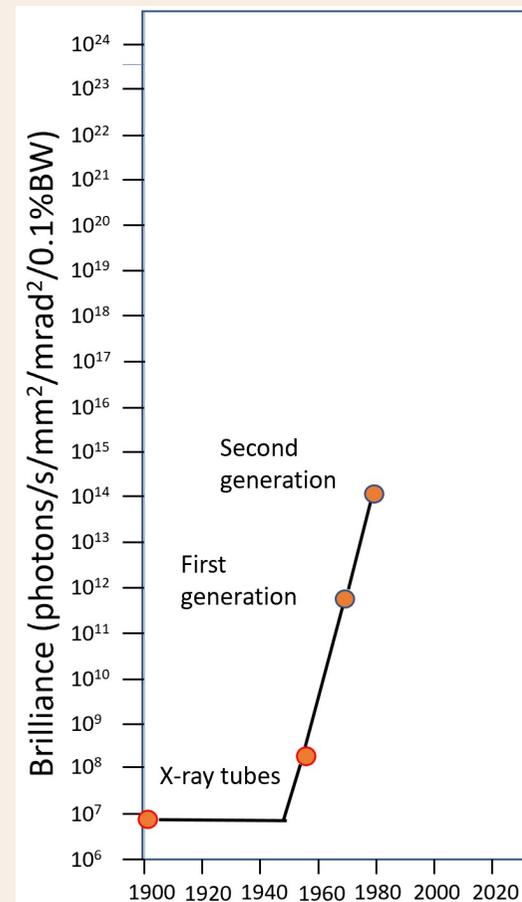
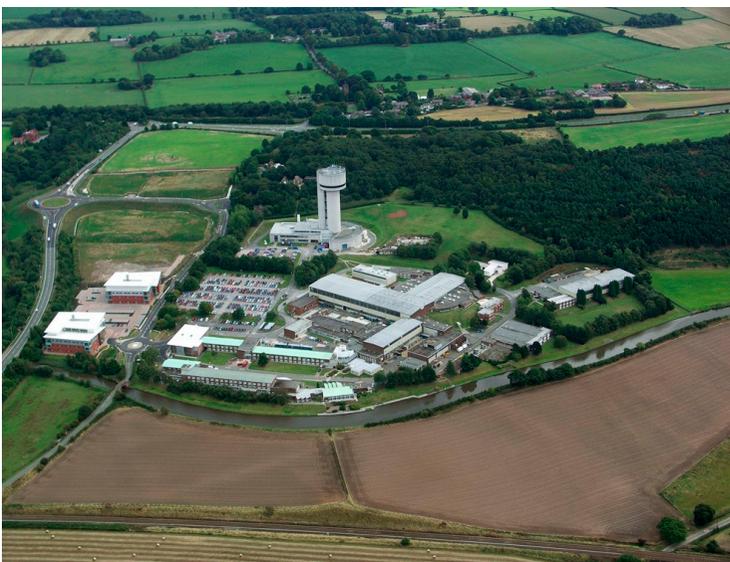
This work has been supported by the Office of Naval Research under contract N5ori-178.

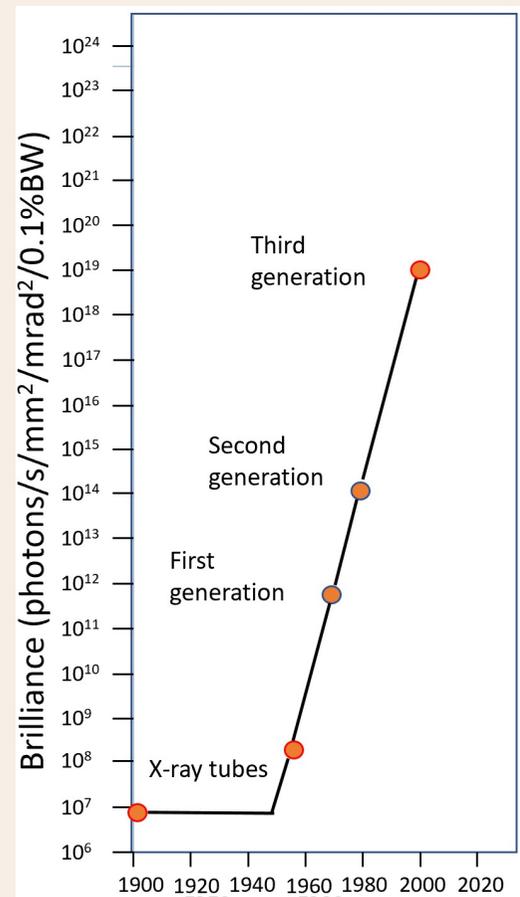
- <sup>1</sup> D. Iwanenko and I. Pomeranchuk, *Phys. Rev.* **65**, 343 (1944).
- <sup>2</sup> J. P. Blewett, *Phys. Rev.* **69**, 87 (1946).
- <sup>3</sup> L. I. Schiff, *Rev. Sci. Inst.* **17**, 6 (1946).
- <sup>4</sup> J. S. Schwinger, *Phys. Rev.* **70**, 798 (1946).
- <sup>5</sup> H. C. Pollock *et al.*, *Phys. Rev.* **70**, 798 (1946).

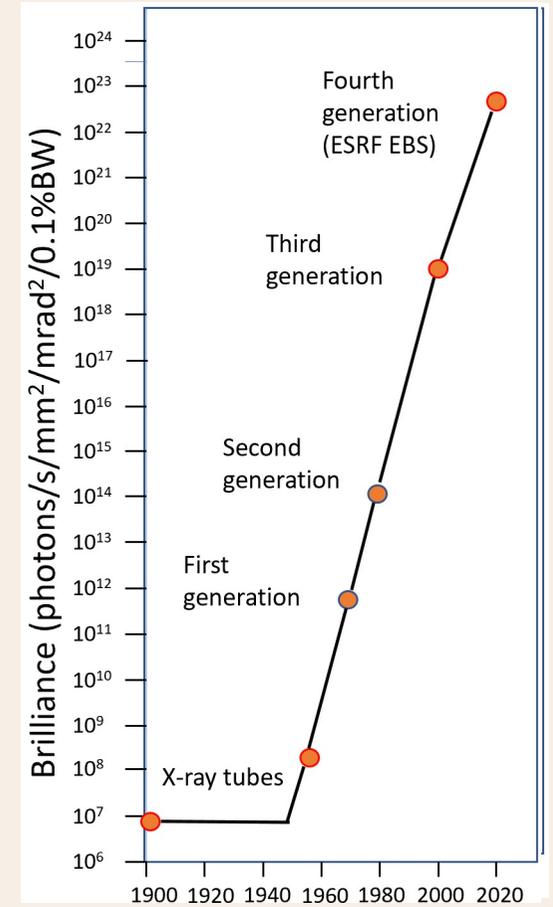
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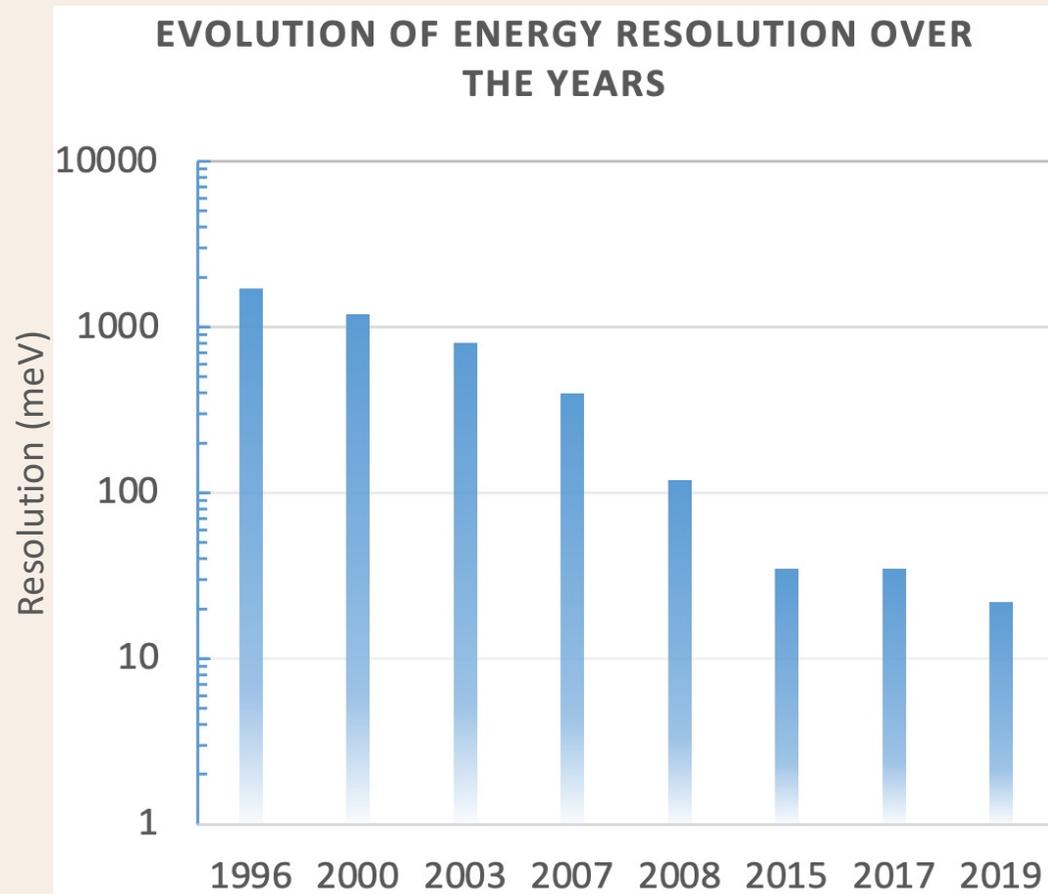




# Impossible measurements....

"When a crystal is irradiated with X-rays, the processes of photoelectric absorption and fluorescence are no doubt accompanied by absorption and emission of phonons. The energy changes involved are however so large compared with phonon energies that information about phonon spectrum of the crystal cannot be obtained in this way. The same is true for Compton scattering."<sup>1</sup> W.Cochran, 1966.

# Impossible measurements...become possible

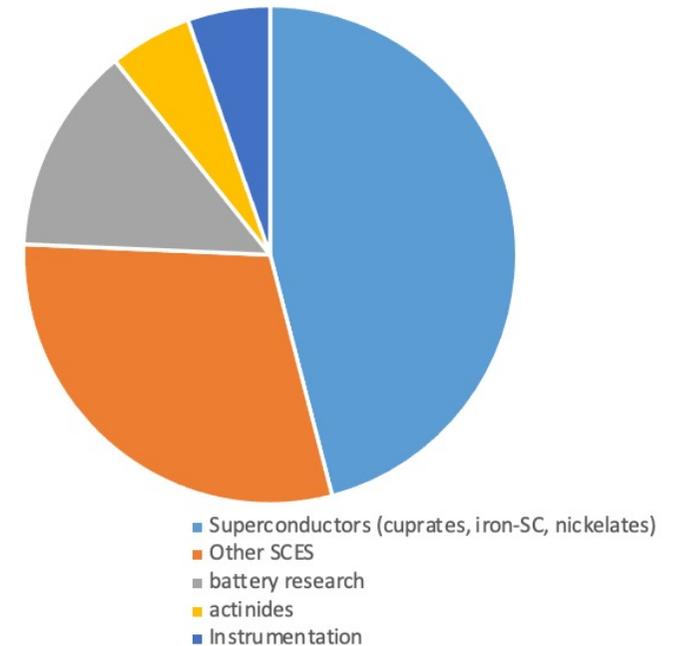




# Broadening reach of science

- Quantum Materials I, II and III
- Functional Materials
- Energy and Catalytic Materials
- Time Domain Spectroscopy
- Novel Instruments and Methods
- Soft Extreme Conditions

Research topics of Publications

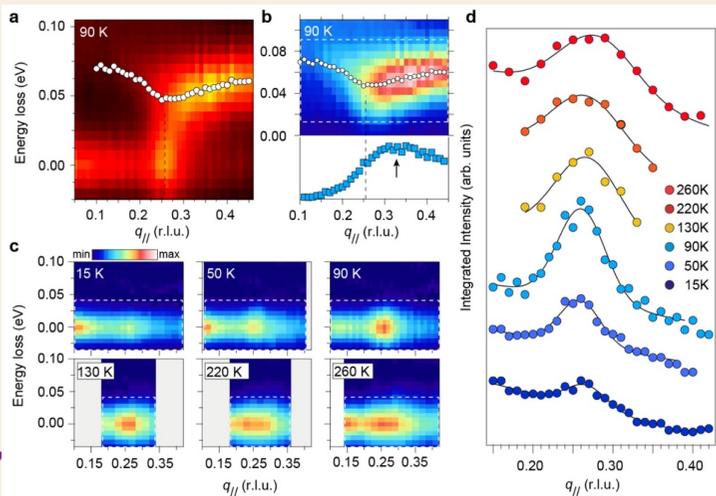


# Melting of charge order by quantum fluctuations in cuprates

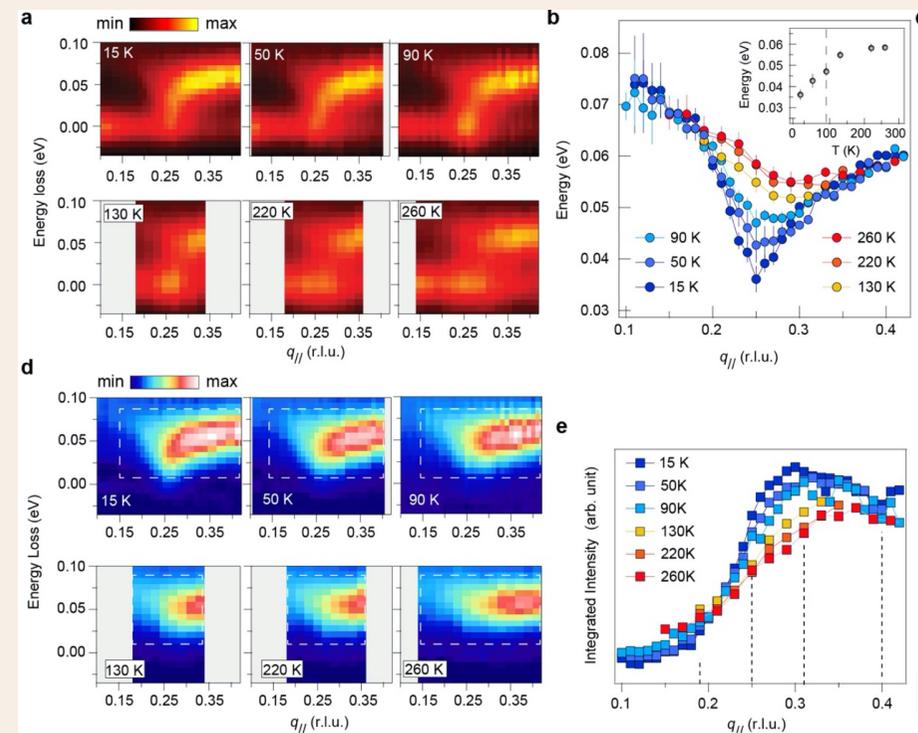
nature physics LETTERS  
<https://doi.org/10.1038/s41567-020-0993-7>  
 Check for updates

## Spectroscopic fingerprint of charge order melting driven by quantum fluctuations in a cuprate

W. S. Lee<sup>1</sup>, Ke-Jin Zhou<sup>2</sup>, M. Hepting<sup>1</sup>, J. Li<sup>2</sup>, A. Nag<sup>2</sup>, A. C. Walters<sup>2</sup>, M. Garcia-Fernandez<sup>2</sup>, H. C. Roberts<sup>2</sup>, M. Hashimoto<sup>3</sup>, H. Lu<sup>4</sup>, B. Nosarzewski<sup>4</sup>, D. Song<sup>5</sup>, H. Eisaki<sup>5</sup>, Z. X. Shen<sup>1,6</sup>, B. Moritz<sup>1</sup>, J. Zaanen<sup>7</sup> and T. P. Devereaux<sup>1,6</sup>



## Quantum fluctuation associated with charge order in Bi2212 cuprate superconductors



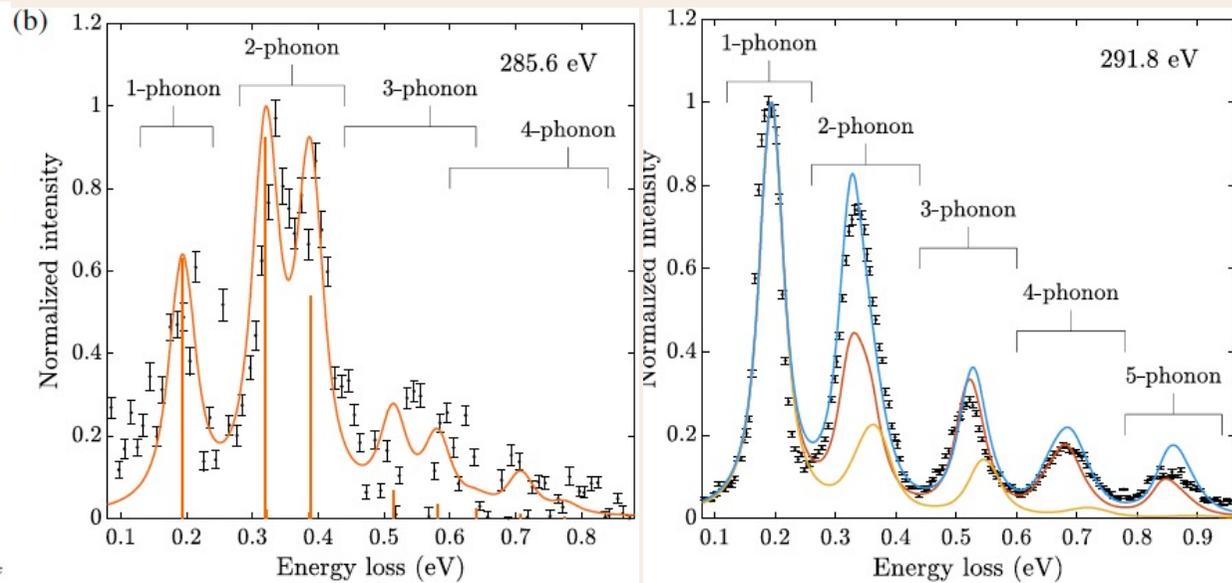
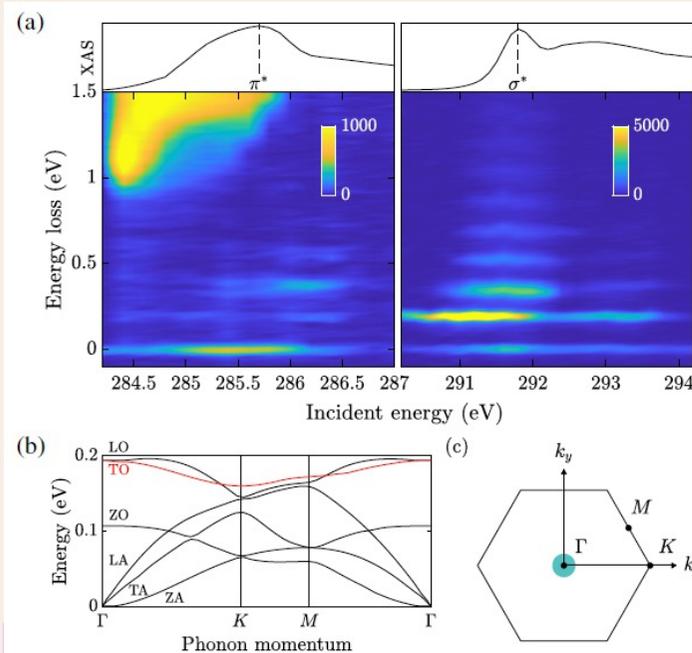
# Electron-phonon interactions in graphite

Energy tuned to probe phonon interactions with specific energy states: C  $\sigma$  and  $\pi$

PHYSICAL REVIEW X 11, 041052 (2021)

## Probing Electron-Phonon Interactions Away from the Fermi Level with Resonant Inelastic X-Ray Scattering

C. D. Dashwood<sup>1,\*</sup>, A. Geondzhian,<sup>2,3,‡</sup> J. G. Vale,<sup>1</sup> A. C. Pakpour-Tabrizi,<sup>4</sup> C. A. Howard<sup>1</sup>, Q. Faure,<sup>1</sup> L. S. I. Veiga,<sup>1</sup> D. Meyers,<sup>5,6</sup> S. G. Chiuzbăian<sup>7,8</sup>, A. Nicolaou,<sup>7</sup> N. Jaouen<sup>7</sup>, R. B. Jackman<sup>4</sup>, A. Nag<sup>9</sup>, M. García-Fernández,<sup>9</sup> Ke-Jin Zhou,<sup>9</sup> A. C. Walters<sup>9</sup>, K. Gilmore,<sup>5,10,11</sup> D. F. McMorrow,<sup>1</sup> and M. P. M. Dean<sup>5,†</sup>



# Performance of energy materials

502 | Nature | Vol 577 | 23 January 2020

## Superstructure control of first-cycle voltage hysteresis in oxygen-redox cathodes

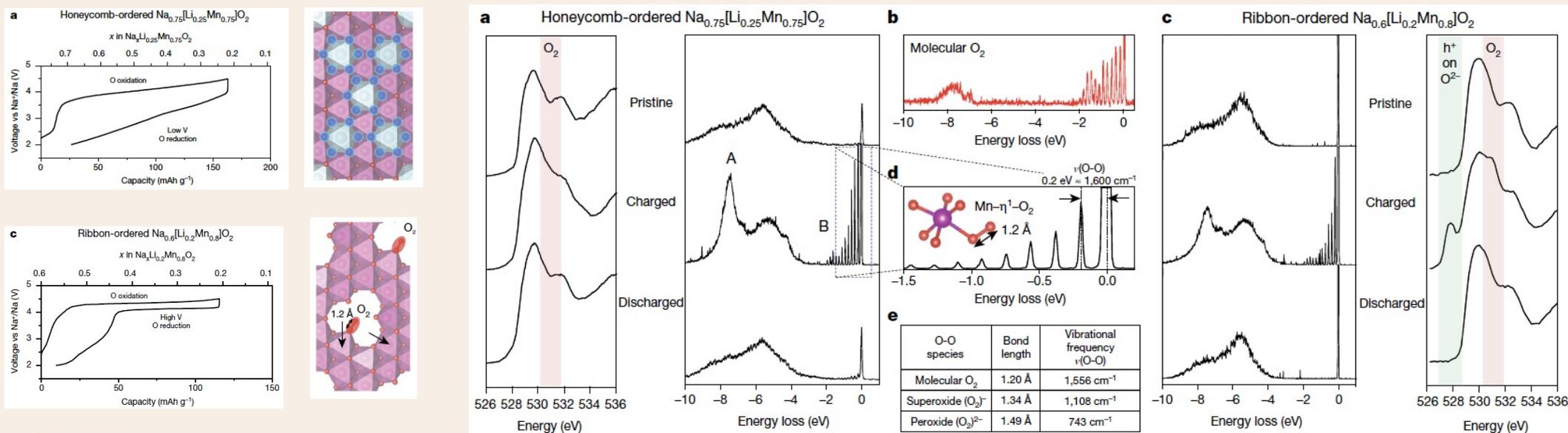
### Oxygen-redox cathodes – Na<sup>+</sup>-rich batteries and formation of molecular oxygen species

<https://doi.org/10.1038/s41586-019-1854-3>

Robert A. House<sup>1</sup>, Urmimala Maltra<sup>1,8</sup>, Miguel A. Pérez-Osorio<sup>1,8</sup>, Juan G. Lozano<sup>1,2</sup>, Liyu Jin<sup>1</sup>, James W. Somerville<sup>1</sup>, Laurent C. Duda<sup>2</sup>, Abhishek Nag<sup>4</sup>, Andrew Walters<sup>4</sup>, Ke-Jin Zhou<sup>4</sup>, Matthew R. Roberts<sup>5</sup> & Peter G. Bruce<sup>1,5,6,7\*</sup>

Received: 12 February 2019

Accepted: 1 October 2019



# Challenges and opportunities

- Lower the energy resolution below 10 meV (at 1 KeV with reasonable photon flux) – requiring super high quality optics, yet more precise and stable engineering solutions and perhaps completely new optical concepts
- Extend availability of time-resolved RIXS, building on pioneers such Heisenberg RIXS at XFEL, Furka at SwissFEL, qRIXS at LCLS-II, RIXS at SHINE...
- Increased automation all the way from sample handling to data processing, particularly important for non-expert users
- Complementary theoretical modelling

# Bringing techniques together



# Strength in numbers



**LEAPS Technology Pillars**

LEAPS Lead partners:

	ALBA	DESY	DIAMOND	ELETTRA	ESRF	EUROPEAN XFEL	FELIX	HZB	IKM	INM	ISF	MAX-IV	PSI	PTB	SORLITE	SORL	Implication level
<b>Detectors</b>																	High Medium Low
Ultra-high continuous frame rate imager (> 10 <sup>3</sup> frames per second with >10 <sup>3</sup> pixels)																	
Small pixel imager (< 10 micron pixels, with > 10 <sup>6</sup> pixels)																	
Large format and high flux energy resolving imagers (≥ 500 cm <sup>2</sup> , DE/E < 0.04)																	
Soft X-ray imager (50 – 2000 eV photon range)																	
Tender X-ray imager (500 – 5000 eV photon range)																	
High-speed multi-element spectroscopy detector (> 100 elements, >10 <sup>6</sup> cps/element)																	
Common Toolbox (back end electronics and interface with computing system)																	
<b>X-ray Optics</b>																	
Reflective Optics																	
Refractive Optics																	
Diffraction Optics																	
Optomechanics, nanopositioning and thermal management																	
Simulation and modeling																	
At-wavelength metrology and test facilities																	
<b>Sample Environment</b>																	
Nanopositioning																	
High throughput sample environment equipment																	
Extreme conditions																	
In-situ / operando sample environment equipment																	
Time dependent experiments																	
Standards for sample environment: control, data & metadata																	
<b>Photon Diagnostics</b>																	
Intensity monitors for EUV, Soft and Hard X-rays																	
Beam position monitors																	
Pulse length measurements																	
Polarization measurements																	
Energy spectrometers																	
Wavefront sensing																	
Automation for 24/7 operation of online diagnostics																	
Machine learning approaches to automatically optimize and stabilize the machine as well as the beam transport																	
Bunch purity measurements																	
<b>Photon Sources</b>																	
High field small aperture magnets and related vacuum technology																	
High brilliance electron beam production and control																	
Specialized laser systems for electron beam production, FEL seeding and plasma acceleration																	
RF acceleration systems																	
Advanced instrumentation for beam control and beam diagnosis																	
Joint R&D on compact plasma accelerator for photon science (context: EU design study EuPRAXIA)																	
<b>Information Technology</b>																	
Governance, Education and Training																	
Open Data Policy for Open Science																	
High Speed Data Acquisition																	
Data Analysis and Reduction																	
Federated Data Catalogue																	
Generalization of the use of Cloud Services																	

# Thank you

- 9 plenary speakers
  - 41 invited speakers
  - 8 sponsors:
    - Brookhaven National Laboratory
    - Bestec
    - CINEL
    - DECTRIS
    - ExPaNDS
    - FMB Oxford
    - Lightsources.org
    - JTEC Corporation
  - 14 contributing speakers
  - 33 poster presenters
  - 52 members that make up the:
    - Local Organising Committee
    - International Steering Committee
    - International Programme Committee
  - IXS2019 hosts Brookhaven National Laboratory for their guidance and support throughout the planning
- We hope you enjoy the conference!**

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