Collaboration reveals interplay between charge order and superconductivity at nanoscale

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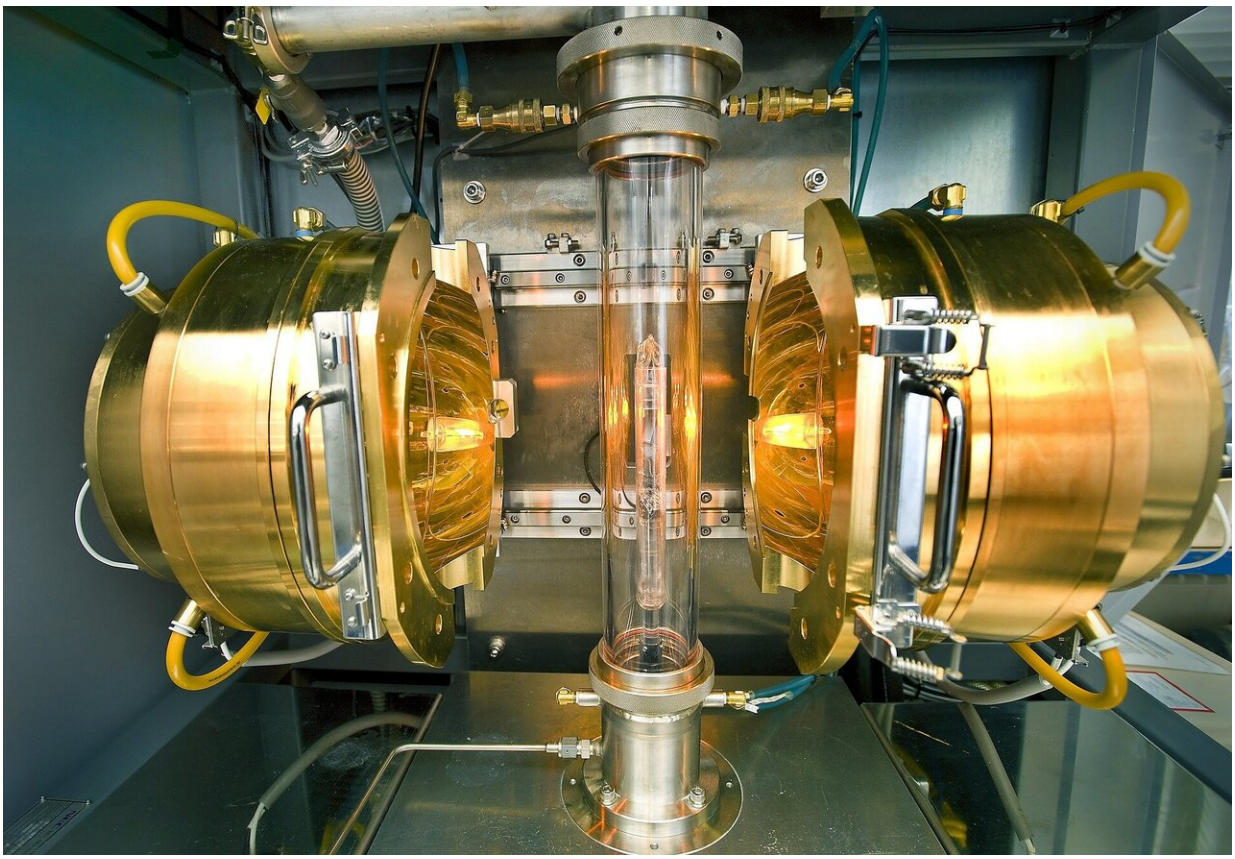

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High temperature superconductivity is something of a holy grail for

researchers studying quantum materials. Superconductors, which conduct electricity without dissipating energy, promise to revolutionize our energy and telecommunication power systems. However, superconductors typically work at extremely low temperatures, requiring elaborate freezers or expensive coolants. For this reason, scientist have been relentlessly working on understanding the fundamental mechanisms at the base of high-temperature superconductivity with the ultimate goal to design and engineer new quantum materials superconducting close to room temperature.

Fabio Boschini, Professor at the Institut national de la recherche scientifique (INRS), and North American scientists studied the dynamics of the superconductor yttrium barium copper oxide (YBCO), which offers superconductivity at higher-than-normal temperatures, via time-resolved resonant X-ray scattering at the Linac Coherent Light Source (LCLS) free-electron laser, SLAC (US). The research was published on May 19 in *Science*. In this new study, researchers have been able to track how charge density waves in YBCO react to a sudden "quenching" of the superconductivity, induced by an intense laser pulse.

"We are learning that charge density waves—self-organized electrons behaving like ripples in water—and superconductivity are interacting at the nanoscale on ultrafast timescales. There is a very deep connection between superconductivity emergence and charge density waves," says Fabio Boschini, co-investigator on this project and affiliate investigator at the Stewart Blusson Quantum Matter Institute (Blusson QMI).

"Up until a few years ago, researchers underestimated the importance of the dynamics inside these materials," said Giacomo Coslovich, lead investigator and Staff Scientist at the SLAC National Accelerator Laboratory in California. "Until this collaboration came together, we really didn't have the tools to assess the charge density wave dynamics in these materials. The opportunity to look at the evolution of charge order

is only possible thanks to teams like ours sharing resources, and by the use of a free-electron laser to offer new insight into the dynamical properties of matter."

Owing to a better picture of the dynamical interactions underlying high-temperature superconductors, the researchers are optimistic that they can work with theoretical physicists to develop a framework for a more nuanced understanding of how high-temperature superconductivity emerges.

Collaboration is key

The present work came about from a collaboration of researchers from several leading research centers and beamlines. "We began running our first experiments at the end of 2015 with the first characterization of the material at the Canadian Light Source, says Boschini. Over time, the project came to involve many Blusson QMI researchers, such as MengXing Na who I mentored and introduced to this work. She was integral to the data analysis."

"This work is meaningful for a number of reasons, but it also really showcases the importance of forming long-lasting, meaningful collaborations and relationships," said Na. "Some projects take a really long time, and it's a credit to Giacomo's leadership and perseverance that we got here."

The project has linked at least three generations of scientists, following some as they progressed through their postdoctoral careers and into faculty positions. The researchers are excited to expand upon this work, by using light as an optical knob to control the on-off state of superconductivity.

More information: S. Wandel et al, Enhanced charge density wave

coherence in a light-quenched, high-temperature superconductor, *Science* (2022). DOI: 10.1126/science.abd7213

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