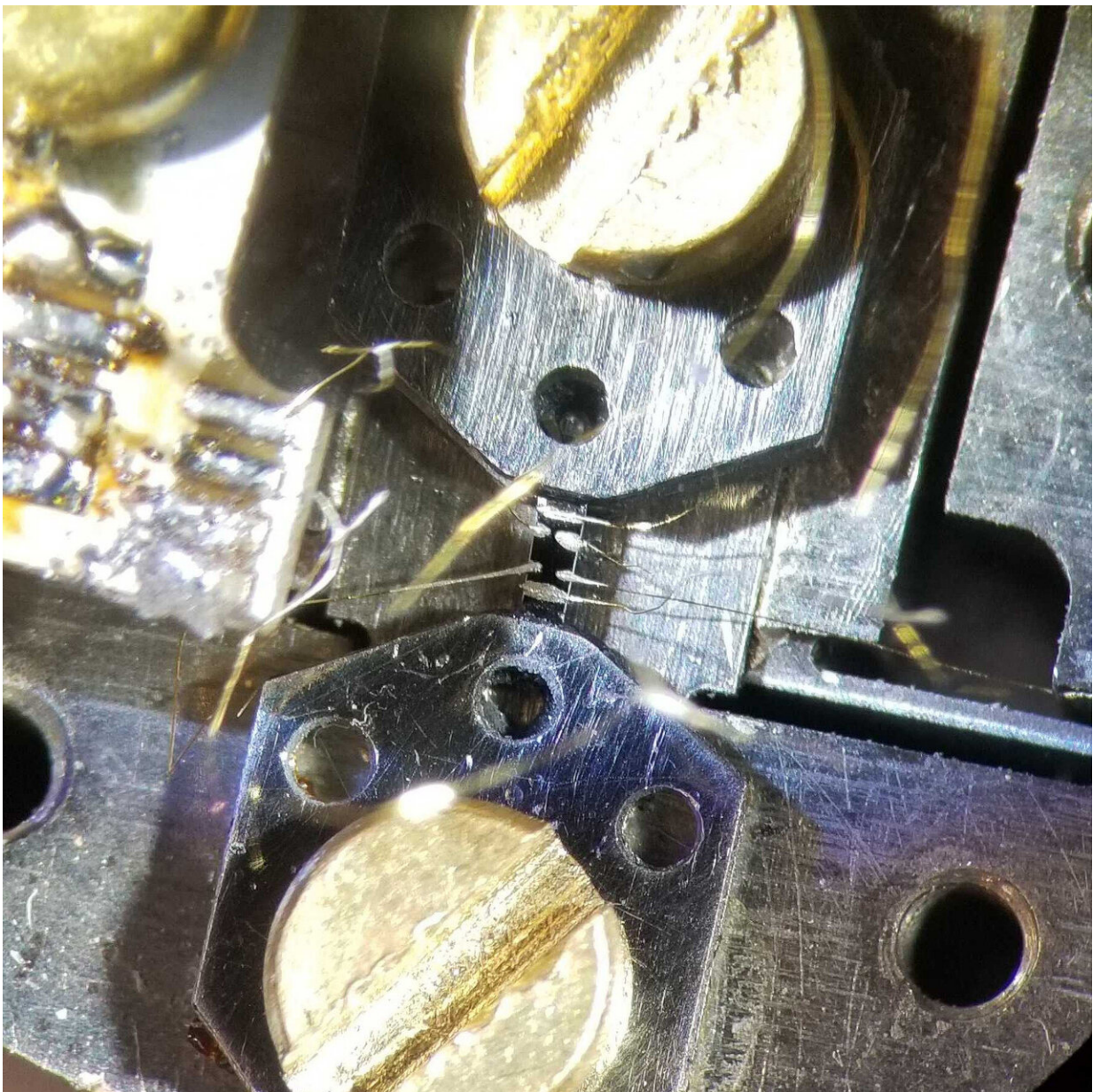


Study investigates enhancements in the superconductivity of electronic nematic systems

January 22 2020, by Ingrid Fadelli



Strain cell used to stretch the crystal while measuring electrical resistivity in-situ in order to probe the electronic nematic order as a function of strain, temperature, magnetic field and chemical composition. Credit: Eckberg et al.

High-temperature superconductors, materials that become superconducting at unusually high temperatures, are key components of a variety of technological tools, including MRI machines and particle accelerators. Recently, physicists have observed that the two families of known high-temperature superconductors—copper- and iron-based compounds—both exhibit a unique phenomenon in which electronic degrees of freedom can break the overall crystal rotational symmetry and form what is known as the electronic nematic phase.

Akin to the liquid crystal phase, the spontaneous breaking of symmetries by electrons is understandable, except for the fact that electrons are not molecules with irregular shapes. In addition, electrons tend to be involved in other properties such as magnetism, so understanding the role of "nematicity" can be quite challenging, since it is often found in coexistence with other orders such as magnetism.

Physicists at the University of Maryland and the University of Illinois-Urbana Champaign, in collaboration with theorists at the University of Minnesota, have recently carried out a study aimed at better understanding the electronic nematic phase in different [high-temperature superconductors](#). Their [paper](#), [published in Nature Physics](#), is based on ideas and observations that they gathered over several years of research.

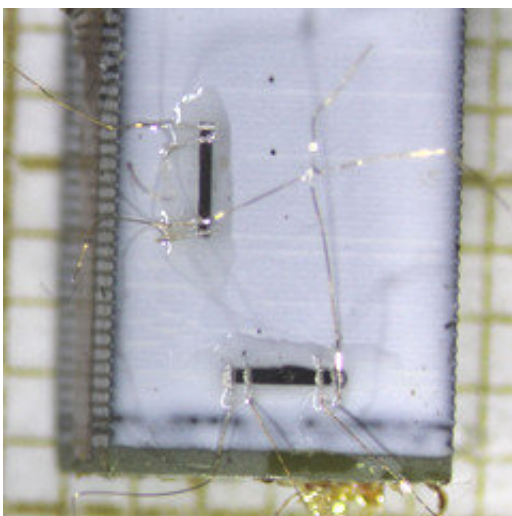
The same team of researchers started investigating iron-based superconductors approximately 10 years ago. They have since published

numerous papers focusing specifically on the electronic nematic phase.

"Some iron superconductors with the same crystal structure arrangement as $\text{Ba}_{1-x}\text{Sr}_x\text{Ni}_2\text{As}_2$ are known to 'collapse' at low temperatures," Dr. Johnpierre Paglione, the lead researcher of the study, told Phys.org.

"Intrigued by this observation, we started looking for the same collapsing effect in the nickel-based system by studying its crystal structure at low temperatures. While doing this, we discovered that a completely different phase transition happens, called charge ordering."

In their recent study, the researchers set out to determine whether the charge order that they had previously observed in nickel-based superconductors is also accompanied by the nematic phase. They specifically studied the material $\text{Ba}_{1-x}\text{Sr}_x\text{Ni}_2\text{As}_2$, which has a structure similar to that of iron-based superconductors.



Elastoresistivity setup- two identical crystals mounted on a piezoelectric device that stretches each of them while measuring the resistivity. In the experiment carried out by the researchers, the strain is applied both parallel and perpendicular to the electrical measurement and the comparison of the two allows for extracting the nematic response (normally zero in common metals). Credit: Eckberg et al.

"We knew that in both 'end-member' compounds BaNi_2As_2 and SrNi_2As_2 , superconductivity exists at very low temperatures (below 1 Kelvin) and we were very intrigued that it appeared very similar in character in both systems, even if BaNi_2As_2 has all this crazy physics happening and SrNi_2As_2 is basically a lemon," Paglione explained. "We thus set about to make alloys of the two, mixing barium and strontium in a systematic way to go from one end to the other in a continuous way."

Interestingly, Paglione and his colleagues observed that when their alloys were somewhere between the barium and strontium compounds (at around 70%Sr) their charge order was completely killed (i.e., suppressed to absolute zero temperature), while their nematic fluctuation signatures remained strong. They also found that at the peak of these fluctuations the material's superconductivity was amplified by a factor of six (i.e., the transition temperature was pumped up from 0.6 K to 3.5 K).

This observation is difficult to explain using conventional theories and of superconductivity and other approaches. They thus concluded that it must be a result of nematic fluctuations.

"Our study has important implications, because we know the tuning knob to do this, and there is no pesky magnetism to complicate the theoretical interpretation, so our interpretation provides a pathway toward fine-tuning materials to get high temperature superconductivity," Dr. Paglione said.

Overall, Paglione and his colleagues observed a direct relationship between enhanced pairing and nematic fluctuations in the model system they examined. In the future, the insight gathered in their study could inform future studies investigating the role of nematicity in strengthening superconductivity.

"We are currently focusing on the hot zone around 70%Sr to see how finely we can tune things using other knobs in the lab, such as pressure and strain," Dr. Paglione said. "At the same time we are searching for other materials that show similar properties and therefore may be artificially tuned to become [superconductors](#) as well, hopefully near room [temperature](#)."

More information: Chris Eckberg et al. Sixfold enhancement of superconductivity in a tunable electronic nematic system, *Nature Physics* (2019). [DOI: 10.1038/s41567-019-0736-9](https://doi.org/10.1038/s41567-019-0736-9)

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