MSU collaborative research leads to new supercomputing technologies

As you're updating your cover photo on Facebook, or plotting out your next trip using Google Maps or purchasing something on Amazon, probably the last thing on your mind is how much computer memory and energy you're using as you're accessing these massive computing installations. But it's uppermost on the minds of scientists and researchers who work in the energy field.

"Supercomputers consume enormous amounts of power in exchange for their computational abilities," said Norman Birge, a professor in Michigan State University's Department of Physics and Astronomy.

According to the Natural Resources Defense Council, data centers are one of the largest and fastest growing consumers of electricity in the United States. In 2013, U.S. data centers consumed an estimated 91 billion kilowatt-hours of electricity and are on track to reach 140 billion kilowatt-hours by 2020.

When the Intelligence Advanced Research Projects Activity (IARPA) organization projected what larger-scale computers might look like in the future, it seemed they would become almost energy prohibitive. It became evident that new computer technology would need to display much more energy efficiency than current technologies in order to reduce world electricity use.

In a research project funded through IARPA, Birge and several MSU researchers, as well as scientists from Northrop Grumman Systems Corporation, recently developed a superconducting magnetic memory element that has greatly reduced heat generation and power consumption compared to conventional alternatives.

"This novel scalable memory element can be controllably switched into two distinct phase states to act as the 1's and 0's of computer language," said Birge, co-author of a paper that was recently published in *Nature Physics*. "Memory like this is an essential piece in work toward developing a fully superconducting computer."

This paper is the first demonstration that using these types of devices for computer memory is actually feasible.

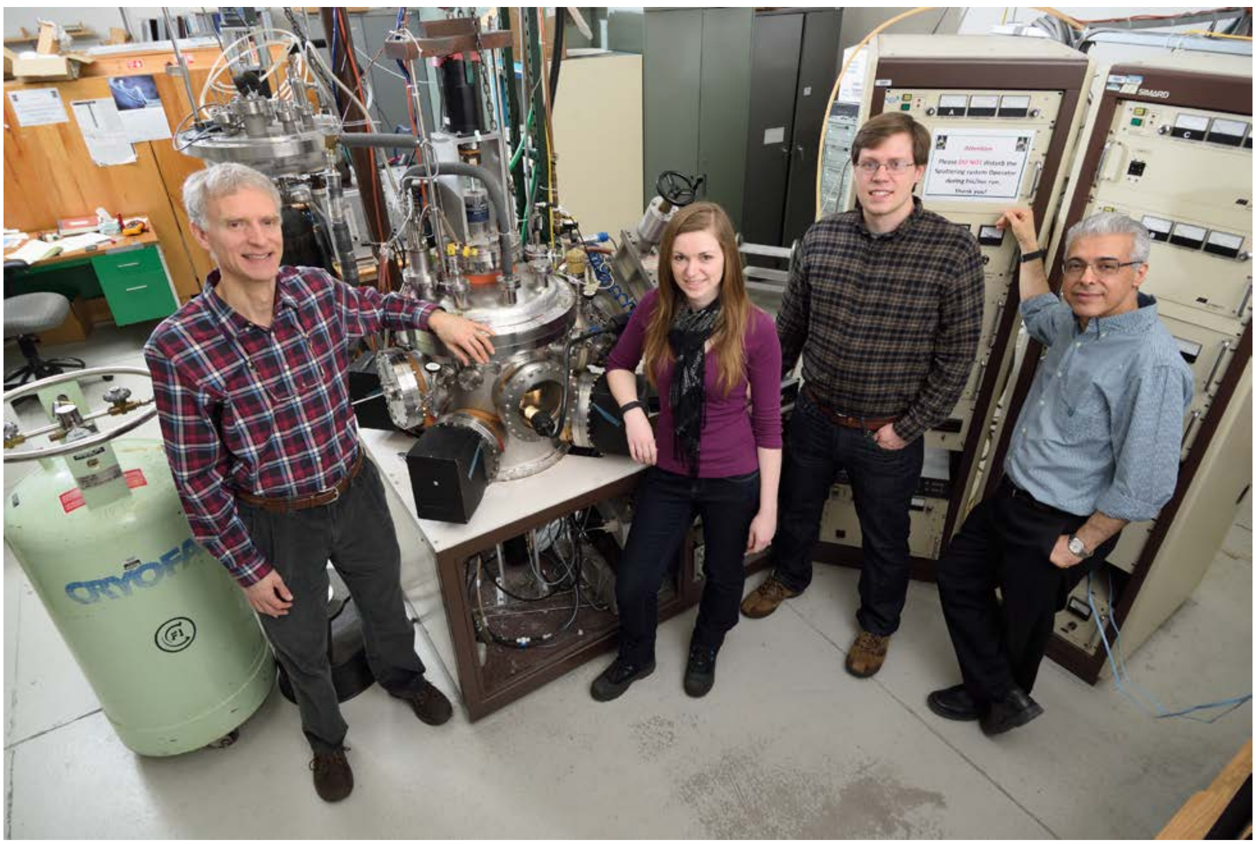
"One of the major impediments to superconducting computing technology had been the lack of an efficient memory that took advantage of the superconducting state," said Eric C. Gingrich, a physicist at Northrop Grumman who was the lead student on this project while he was a student at MSU. "This project has demonstrated experimentally a solution to that problem, and brings the technology one step closer to being realized."

"I was originally drawn to Dr. Birge's research group because of this project's combination of rich and interesting physics with the potential for real-world applications," said Bethany Niedzielski, a physics Ph.D. student who aided in fabrication and completed all measurements of the devices featured in the paper. "We are not only able to probe these complicated systems to verify theoretical predictions, but we are able to manipulate them into functional memory bits."

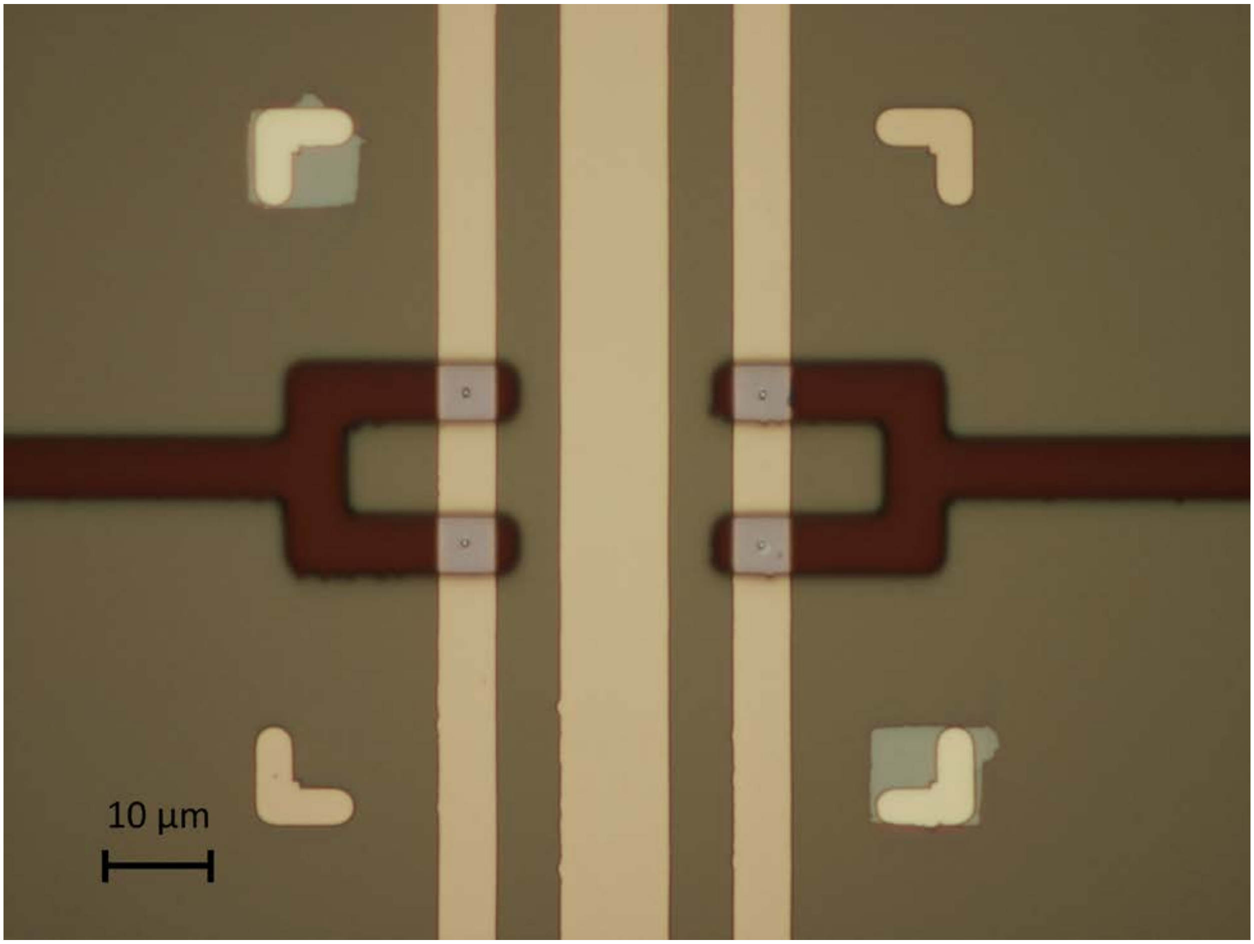
IARPA hopes the superconducting circuits developed based on this new magnetic memory element will use 10,000 times less power than conventional semiconductor circuits, so that after the cooling is taken into account, the final efficiency will be 100 times less power for the superconducting supercomputer.

“For most of my career, I’ve been working on things that are very interesting to the fundamental physicist, but they’re a little bit esoteric,” Birge said. “Now, I’m working on a project that could have an impact on a much broader scale in society. It’s the first time in my career that I’ve worked on something that potentially has a practical application. That’s quite thrilling!”

Additional MSU researchers contributing to this project are Joseph A. Glick, Yixing Wang, Reza Loloee and William P. Pratt, Jr. Don Miller, a scientist at Northrop Grumman, also contributed.



[GROUP PHOTO – CAPTION]
Pictured is the high-vacuum sputtering system used to deposit the superconducting and ferromagnetic materials that form the basis of the Josephson junction samples used in the experiment. The deposition system was designed by William Pratt, Jr., physics and astronomy professor, in the 1980s; its capabilities have been expanded extensively over the intervening years by Reza Loloee, Ph.D., scientific instrument facilities coordinator in MSU’s Department of Physics and Astronomy. Shown are *(left to right)* Professor Norman Birge, graduate students Bethany Niedzielski and Joseph Glick, and Loloee.



[PHOTO OF SAMPLE – CAPTION]

This optical microscope image shows two SQUIDs (Superconducting QUantum Interference Devices), each one consisting of two micron-sized Josephson junctions and a loop of superconducting material. The central wire between the two SQUIDs is used to introduce magnetic flux into the loops. The image shows a sample during the fabrication process in the Keck Microfabrication Facility at MSU, after patterning was performed using optical and electron-beam lithography.