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Ohio State: Midwestern Hub of Next-Gen Magnetic Resonance Research

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Left to right: Denis Pelekhov, P. Chris Hammel, Fengyuan Yang, Joseph Heremans, Ezekiel Johnston-Halperin, John Volakis, and Rolando Valdes Aguilar.

Magnetic resonance is one of the most important phenomena in materials and medical research. Its broad range of applications has revolutionized modern technologies, from wireless communication to radar, while saving millions of lives in the medical realms through the early detection of disease.

A team of physicists and engineers at The Ohio State University has now won a $1.071 million award from the National Science Foundation's Major Research Instrumentation program (NSF-MRI) to help advance the study of magnetic resonance technology at the nanoscale level. Over the next three years, they will work to develop and build new equipment capable of discovering novel magnetic resonance phenomena at a very high frequency range up to 330 Ghz. The Institute for Materials Research (IMR) at Ohio State coordinated the group effort that ultimately led to the winning NSF-MRI award.

Department of Physics Professor and IMR Associate Director **Fengyuan Yang**, Principal Investigator (PI) on the project, said the technology they are developing could make Ohio State a center for high-frequency magnetic resonance research across the Midwest. Once constructed, the new instrument will be located inside the university's NanoSystems Laboratory, a facility open to all academic and industrial users.

"This will be the first magnetic resonance spectrometer within this frequency range at a shared user facility in the Midwest," Yang said, "and it will significantly strengthen and expand the investigation of novel fundamental phenomena and the development of paradigm-changing technologies for researchers at Ohio State and from across the region."

The NSF-MRI project team includes Yang, with co-investigators **P. Chris Hammel,** professor of Physics; **John Volakis,** professor of Electrical and Computer Engineering (ECE); **Joseph Heremans**, professor of Mechanical and Aerospace Engineering and Physics; **Rolando Valdes Aguilar**, assistant professor of Physics; **Zeke Johnston-**

Halperin, associate professor of Physics; and **Denis Pelekhov**, director of the NanoSystems Laboratory.

"The team leverages Ohio State's world-leading expertise and infrastructure in magentic resonance research," Yang said.

Hammel is director of the Center for Emergent Materials (CEM) at Ohio State, an NSF-funded MRSEC, which is combining its resources and expertise on the project with that of the ElectroScience Laboratory, directed by Volakis.

More importantly, Yang said, the future research center will help educate future specialists in cutting-edge magentic resonance technology.

“The development of this instrument will offer a rare opportunity to train a large number of postdoctoral researchers, as well as graduate and undergraduate students, to become experts in high frequency magnetic resonance technologies and microwave instrumentation, filling a vital national need,” he said. “This instrument will play an important role in a number of outreach programs at Ohio State to attract and nurture women and underrepresented minority students in scientific research.”

Specifically, the NSF-MRI funding will now go toward developing a broadband, highly sensitive magnetic resonance spectrometer system, providing an indispensable in-house tool for understanding the nature of magnetic excitations, dynamic spin transport and microwave device applications.

Currently, the vast majority of existing magnetic resonance spectrometers are limited to a frequency range of 1–40 GHz. The instrument Ohio State is developing will ultimately help bridge the gap between traditionally important GHz applications (cell phones and radar) with the new frontier of terahertz (1 THz = 1000 Ghz) technologies.

Yang said the instrument will also enable “transformative research” toward building the next-generation of devices, in particular those based on spintronics, by controlling the dynamic behavior of electron spins at very high frequencies.

“It will enable investigations of a wide array of novel materials and structures for a large number of research groups at Ohio State and other institutions in the region,” their research abstract explains. “The MRI team will design and build a series of magnetic resonance cavities with resonant frequencies between 10 and 320 GHz for operation in a cryogenic 14 Tesla superconducting magnet, which offers access to a previously unexplored regime for revealing the underlying mechanisms responsible for the magnonic behavior and dynamically generated spin currents in heterostructures of ferromagnets, antiferromagnets, topological insulators, skyrmions, and nonmagnetic materials.”

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