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Emergent Quantum Materials and Technologies

ABDELGHANI LARAOUI

Department of Mechanical & Materials Engineering, University of Nebraska-Lincoln

Studying Nanoscale Magnetic Phenomena in Magnetic Thin Films Using Diamond Magnetic Microscopy

ABSTRACT

Magnetic microscopy based on diamond nitrogen vacancy (NV) quantum sensors has become a versatile tool to detect magnetic fields in magnetic materials with a unique combination of spatial resolution and magnetic sensitivity [1-4]. In this seminar, I will present two examples of using NV magnetic microscopy in both confocal microscopy (CFM) and scanning probe microscopy (SPM) geometries to study nanoscale magnetic phenomena in different materials.

First, I will discuss recent NV-CFM measurements of spin-wave transport in ferrimagnetic insulator thulium iron garnet (TmIG) thin films. Spin waves (SWs) are dynamic magnetic excitations of magnetically ordered systems. They can be generated by injecting current or microwave and are being explored for magnon spintronics, low-energy logical operations, and as quantum buses. NV magnetometry allows probing of SWs at the sub-micrometer scale, seen by the amplification of the local microwave magnetic field due to the coupling of NV spins with the stray-field produced by the SWs. By monitoring the NV optically detected magnetic resonance contrast, we map SWs in TmIG thin films (thickness of 34 nm) and measure their amplitude, decay length (~ 50 mm), and SW wavelength in the range of 0.6 - 2 mm that depends strongly on the amplitude of the applied magnetic field [5].

Then, I will discuss NV-SPM measurements of skyrmions in CoxPt1-x gradient single-crystal films (thickness 10 -30 nm), where stoichiometric coefficient x is engineered to vary continuously from the top surface to the bottom interface. Skyrmions are topological spin textures in magnetic systems where strong spin orbit coupling and broken inversion symmetry lead to Dzyaloshinskii-Moriya interaction (DMI). We visualize different topological spin textures (skyrmions, anti-skyrmions) using NV magnetometry in combination with magnetic force microscopy and micromagnetic simulations. Furthermore, I will discuss the effect of CoxPt1-x thickness, DMI sign, and applied magnetic field on their size and chirality [6].

BIO

Dr. Laraoui is an Assistant Professor of Mechanicals and Materials Engineering at University of Nebraska-Lincoln (UNL) and holds a courtesy appointment at UNL's Department of Physics and Astronomy. He is a FGR2 leader of the 2021 NSF $20M EPSCoR center on Emergent Quantum Materials and Technologies (EQUATE) and an IRG 3 leader of the recent Grand Challenge funded $4.1M center on Quantum Approaches Addressing Global Threats. Dr. Laraoui obtained his PhD in Physics from The University of Strasbourg in France, under the supervision of Dr. Jean-Yves Bigot, where he developed a time resolved magneto-optical microscope to study the magnetization dynamics of magnetic nanomaterials excited with femtosecond laser pulses. Soon after his graduation, Dr. Laraoui received a Marie Curie fellowship from the European Research Training Network to carry a postdoctoral position in the group of Burkard Hillebrands at the University of Kaiserslautern in Germany. He used Brillouin Light Scattering Microscopy to study spin current control of spin waves in spin-torque nano-oscillators. After that, Dr. Laraoui joined City College of New York as a Research Associate to work on NV magnetometry for high-resolution magnetic and temperature imaging at the nanoscale. In 2016, Dr. Laraoui joined University of New Mexico' Center for High Technology Materials as a Research Assistant Professor and used NV magnetic microscopy to study single iron-oxide magnetic nanoparticles, hemozoin biocrystals, and perform two-dimensional NMR spectroscopy of microfluidics at the submicron scale. In August 2019, Dr. Laraoui joined UNL as a tenure-track Assistant professor, and his primary research focuses on developing new quantum materials based on color centers in diamond and defects in van der Waals materials (e.g., hexagonal boron nitride) for applications in magnetic imaging, quantum sensing, and quantum photonics

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