Postdoctoral Fellowship Highlight

Shrawan Mishra, M. Tech, Ph.D., Physics

Years of fellowship: 2012-present (04/2014)

Collaborating Institution: University of Oregon, Eugene

Project: **Developments of new soft x-ray based coherent scattering methods**

As an ALS Postdoctoral Fellow, Shrawan Mishra helped develop novel soft x-ray-based coherent scattering methodologies to investigate the dynamical nature of complex magnetic systems. A particular focus was on emergent quasiparticles such as magnetic monopole and Dirac strings that are present in nano-patterned 2D artificial spin lattices. This work will provide insights into the topological aspects and relaxation dynamics of frustrated spin systems, which up until now has rarely been studied.

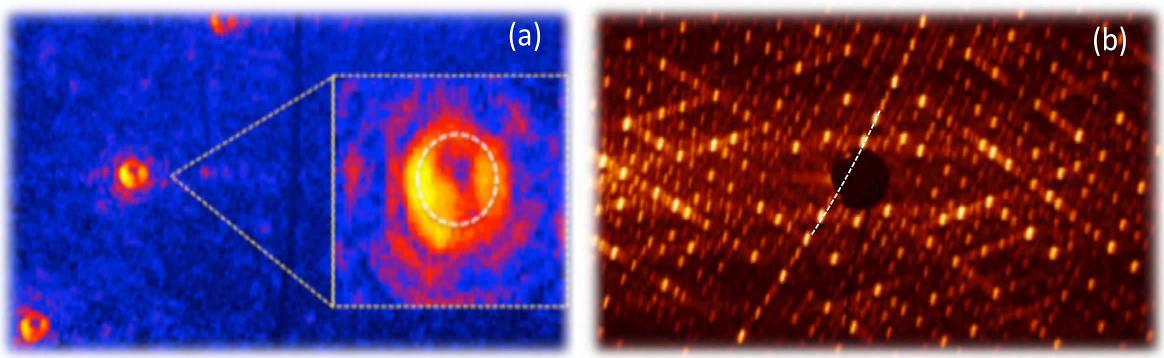

Figure1. Resonant diffraction pattern from (a) 2D- artificial spin ice exhibiting donut shaped intensity profile that reflects the evolution of soft x-rays OAM beam, (b) 2D-quasi crystal shows emergence of line shaped strip that suggests the existence of higher symmetry in aperiodic system.

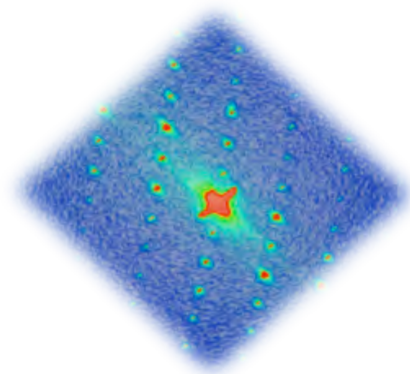

Figure 2. Artificial spin ice as 2D-diffraction grating.

Mishra's postdoctoral work demonstrated an innovative method of generating orbital angular momentum (OAM) vortices in the soft-x-ray regime via resonant coherent soft x-ray scattering from magnetic arrays of nanoscale islands that behave as a 2D-artificial spin ice system. In such a 2D-lattice, the geometric arrangement, shapes, and dimensions of dots can be systematically controlled to engineer frustrated energy landscapes where thermal equilibration favors novel chiral magnetic states. These chiral phases exhibit emergent magnetic charges that resemble magnetic monopoles. Application of a reversible magnetic field can cause two adjacent magnetic monopoles of opposite charge to nucleate or to separate along a chain of magnetically switched dots to form a "Dirac string"-

-like defect. It was found that when resonantly tuned coherent x rays scatter from such an exotic defect, the scattered beam exhibits an intensity minimum on the axis. Such a donut-shaped intensity profile reflects formation of a photon beam with a phase vortex that carries orbital angular momentum.

Shrawan has been working closely with Prof. Steve Kevans's group (University of Oregon). This collaboration is focused on understanding the thermally driven dynamics of an artificial spin-ice system. The presence of various topological spin textures makes this problem extremely challenging owing to the lack of the probability distribution of microstates, which allows the determination of all relevant physical quantities. Consequently, the scientific community currently lacks the appropriate predictions for the dynamics of spin ice. Utilizing soft x-ray-based speckle metrology of various magnetic vortices, Shrawan explored the influences of magnetization changes on speckle patterns. Starting from a traditional artificial square spin-ice structure, he is now studying much more complex systems like Penrose tile-based quasi-crystal lattices for a better understanding of spin relaxation at complex magnetic vortices. These approaches will describe the essential physics of topological spin systems, which will help to identify new avenues for future research on related materials and models on nanoscale.

Sharwan is also involved in collaborative efforts on other beamlines that include investigating the spin structure of Skyrmion sub-lattices and interfacial magnetic structures.

The ALS Postdoctoral Fellowship has enabled Shrawan to develop his skills both in using complex instruments and as a scientist in a challenging environment that is highly valuable and that will provide the user community unique protocols to utilize soft x-ray-based speckle characterization techniques.

Selected Papers (2012 - 2014)

1. *"Altered magnetism and new electronic length scales in magneto-electric $La_{2/3}Sr_{1/3}MnO_3$–$BiFeO_3$ heterointerface." S. K. Mishra, D. Mazumdar, K. Tarafdar, Lin-Wang Wang, S. D. Kevan, C. Sanchez-Hanke, A. Gupta and S. Roy*; *New* Journal of Physics 15, 113042 (2013).

2. "Coupled skyrmion sublattices in Cu_2OSeO_3." M.C. Langner, S. Roy, S. K. Mishra, J. C. T. Lee, X. W. Shi, M. A. Hossain, Y.-D. Chuang, S. Seki, Y. Tokura, S. D. Kevan, R. W. Schoenlein; (In press, Phys. Rev. Lett.)

3. *"Coherent transfer of orbital angular momentum using topological magnetization of artificial spin ice." S. K. Mishra, J. C. T. Lee, V. S. Bhat, X. Shi, D. H. Parks, B. Farmer, J. Woods, L. E. De Long, S. D. Kevan, and S. Roy;(To be submitted)*