PhD Topic: Antiferromagneic Honeycomb Lattices

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Description of the Project:

Antiferromagneic Honeycomb Lattices (figure 1) such as $M_4Nb_2O_9$ (M – Co, Ni or Mn) has attracted immense attention in the scientific community recently because of their interesting physical properties such as magnetoelectric (ME) coupling and multiferroic (MF) properties with anisotropic quantum critical excitations. Such ME and MF phenomena can be exploited in the field of magneto-electronic devices [1]. The electric polarization (**P**) rotates in an opposite direction at twice the speed relative to the rotation of the magnetic field (2Θ-rotation) in the basal *ab*-plane of the Honeycomb lattice because of the MF/ME coupling. The spin-dependent electric dipole plays a major role in deciding the strength of magnetoelectric coupling. The magnitude and direction of **P** is expected to change its sign when the magnetic field direction is reversed (field-sweeping process) [2,4]. Such a property has been explained by means of the first principles calculation and by the itinerant band picture [5-7]. Mathematically, such behavior has been described by the product of spin operators at different crystallographic sites (type-I theory) or at the same crystallographic site (type-II theory). In such case the electric polarization completely depends on the symmetry analysis of the crystal structure of Honeycomb Lattices (e.g. $Co_4Nb_2O_9$). The current project focused on the synthesis and investigation of the magnetoelectric properties in several Honeycomb Lattices at both bulk and low-dimensional nanostructures.

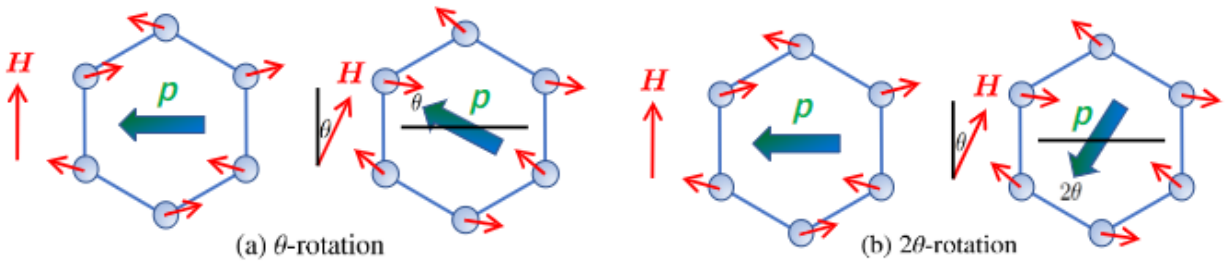

Figure 1: Schematic representation of the spins (red color arrows) of the Honeycomb Lattice and the corresponding induced electric polarization vector (**P** solid green arrow) under two different arrangements (a) Θ-rotation and (b) 2 Θ -rotation of the electric polarization. Here Θ is the angle between the direction of the magnetic field **H** and unit normal. Short red arrows represent alignment of spins. P is the induced electric polarization.

References:

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[3] G.Deng et al., *Phys. Rev. B* **97**, 085154 (2018).
[4] N. D.Khanh, N.Abe, S.Kimura, Y.Tokunaga, and T.Arima, *Phys. Rev. B* **96**, 094434 (2017).
[5] I. V.Solovyev and T. V.Kolodiazhnyi, *Phys. Rev. B* **94**, 094427 (2016).
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