## Seminar: Hard Condensed Matter Theory

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

**Room:** Gernot-Gräff-Raum (Staudingerweg 9)
**Time:** November 19th, 2019 at 14:00


# Dr. John Mangeri

FZU Prague


# Control of polarization vortex states in nanoconfined ferroelectrics


Recent developments in chemical synthesis techniques have enabled creation of monodisperse perovskite ferroelectric nanoparticles of various shapes and sizes. These particles can be embedded in a dielectric medium [1] to form novel functional microscale architectures. The on-going effort to harness these nanomaterials for a wide range of applications has shown promising new pathways such as engineering multiferroicity, flexible electronics, to improvements in photovoltaic efficiencies among others. In this talk, I will first highlight the open-source finite element code Ferret that is used for studying equilibrium polarization topologies in these nanostructures. Our research efforts have found that, for particles comprised of $PbTiO_3$ and $BaTiO_3$, the polarization at room temperature is greatly affected by the particle size, shape, and choice of embedded matrix environment [2,3]. Specifically, we observe the presence of vortex-like states at a distinct size range. This leads to radically different polarization vs. electric field response loops that can be controlled by tuning the material parameters. In addition to the high dispersed case, we recently conducted an investigation of an interacting dimer system. The nonlinear polarization switching is shown to be strongly tunable on the interparticle spacing and applied electric field geometry. The physical origin of this effect lies in the long-range elastic strains that propagate between the particles [4]. Surprisingly, the anisotropy of the field response reveals precise control of the ordering of the vortex-like polarization patterns. We also probe whether or not other exotic polar textures can exist in these nanoconfined structures, such as the recently observed polar skyrmions [5] or the predicted Hopfion-like states [6]. I will also highlight related work utilizing the density functional theory to parameterize energy landscapes of multiferroic compounds, such as $BiFeO_3$ and the magnetic skyrmion-host $GaV_4Se_8$, thus enabling this type of phase field modeling of their order parameter topologies.



[1] "Solvothermal synthesis and controlled self-assembly of monodisperse titanium-based perovskite colloidal nanocrystals", D. Caruntu, et al, Nanoscale 7, 12955 (2015).
[2] "Topological phase transformations and intrinsic size effects in ferroelectric nanoparticles", J. Mangeri, et al, Nanoscale 9, 1616-1624 (2017).
[3] "Size, shape, and orientation dependence of the field-induced behavior in ferroelectric nanoparticles", D. Zhu, et al Journal of Applied Physics 125, in-press (2019).
[4] "Electromechanical control of polarization vortex ordering in an interacting ferroelectric-dielectric composite dimer", J. Mangeri, et al, Applied Physics Letters 113, 092901 (2018).
[5] "Observation of room-temperature polar skyrmions" S. Das, et al Nature 568, 368–372 (2019)
[6] "Hopfions emerge in ferroelectrics", I. Lukyanchuk, et al, arxiv:1907.03866 (2019)