

Charge and orbital order represent two of the most significant concepts in condensed matter physics. These deceptively complex phenomena can influence and produce a number of important physical properties; including colossal magneto-resistance, metal-insulator transitions, and electric polarization. The result is often a rich phase diagrams, and a demonstration of how diverse families of strongly correlated electron systems can be.

The aim of my PhD, and the topic of my thesis, was to use the technique of resonant x-ray diffraction to study these phenomena in several topical systems. Specifically, magnetite, the first compound in which charge order was proposed; iron oxyborate, a compound which possesses a charge separation that approaches one full electron; a bilayered manganite which demonstrates a temperature dependent switching of the orbital occupation; and lutetium ferrate, a multiferroic material whose electric polarization is a direct consequence of geometrically frustrated charge order. These studies have lead to five publications in journals such as Physical Review B, and a sixth paper based on this work will be submitted shortly.

A combination of hard and soft x-ray resonant diffraction was used to assess the size of the charge disproportionation, as well as the orbital and structural anisotropy in these systems.

Thanks to the studies contained within the thesis, a number of key results were obtained. We have demonstrated that in contrast to some recent studies on magnetite, the resonant scattering signal can be explained using a highly simplified charge ordered structure, without the need to invoke a complicated orbital configuration. We found that the orbital rotation in $\text{Pr}(\text{Sr}_{0.1}\text{Ca}_{0.9})_2\text{Mn}_2\text{O}_7$ does not involve a change in the type of orbital, as well as evidence for an increase in the charge separation at low temperatures. We also used resonant scattering to definitively demonstrate the near-integer charge disproportionation in the $3d$ electron band in iron oxyborate.

In addition, two highly important results were also obtained for the first time. We demonstrated a new mechanism by which circularly polarized light may be produced from incident x-rays with linear polarization: on resonance it is possible for the isotropic and anisotropic scattering components to interfere in such a manner that the result is circularly polarized light. Such a claim is supported by the use of theoretical simulations included within the thesis. Secondly, by performing the first successful soft x-ray scattering experiment on lutetium ferrate, we found an anisotropic component that can only be explained by invoking orbital order. This represents the first indication that lutetium ferrate is orbitally ordered, in contrast to previous studies, which have concluded that the system is an orbital glass.

These results are relevant to a wide range of physics, chemistry and materials researchers, and will not only be useful for those studying these, and related compounds, but also in defining the capabilities of resonant x-ray scattering as a complimentary technique to neutron scattering.