Electronic multipole order in systems with orbital degrees of freedom

Yoshio Kuramoto

Department of Physics, Graduate School of Science, Tohoku University

The dipole order of electrons has long been known as ferromagnetism and antiferromagnetism. The importance of higher electronic multipoles has recently been recognized, and now considered as a key element to understand strange phenomenon such as some phase transition where the order parameter has not been identified. Especially, ordering of octupole moments has been suggested by a number of experiments including rare-earth elements with strong spin-orbit interaction. However, the mechanism has not been identified to stabilize higher multipoles as compared with dipoles. Our research group takes the electronic multipole degrees of freedom strategically, and aims at clarifying the hierarchical dynamical structure of solids by close collaboration of experiment and theory. The followings are topics being studied.

Observation of multipole order by neutron and X-ray scatterings

By using the spectrometer of Tohoku University at JAERI Tokai, we have measured neutron scattering spectra of filled skutterudites, rare-earth borides and borocarbides, and transition metal oxides. Neutrons are suitable to determine crystal and magnetic structures. On the other hand, scattering of high-intensity X-rays, available at Tsukuba and SPring-8, is suitable to probe orbital or quadrupole order of electrons. Higher multipoles such as octupoles may be more easily detected by X-rays. We shall describe results obtained by these probes, and explain their significance.

Excitation spectrum in multipole ordered state

Multipole order should accompany characteristic dynamics in analogy with spin waves emerging in magnets. In Tb and Ho borocarbides, inelastic neutron scattering have revealed incommensurate nearly diffusive structures around the phase transition. We shall describe experimental results and possible mechanism to explain this behavior.

Interaction of multipoles with conduction electrons

Interaction of multipoles with conduction electrons may give rise to Kondo-like phenomena. In fact, some Pr skutterudites show evidence of Kondo effect as well as non-Fermi liquid behavior under magnetic field. Our theoretical members aim at clarifying many-body effects by microscopic methods with full use of analytic and numerical techniques.