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Time-Reversal Symmetry Breaking and Consequent Physical Responses Induced by All-In-All-Out Type Magnetic Order on the Pyrochlore Lattice

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Pyrochlore-type 5d transition-metal oxide compounds $Cd_2Os_2O_7$ and $R_2Ir_2O_7$ (R=rare earth) undergo a metal-insulator transition accompanied by a magnetic transition. Recently, the magnetic structures of $Cd_2Os_2O_7$ [1] and $Eu_2Ir_2O_7$ [2] were investigated by means of resonant x-ray magnetic scattering. The x-ray data indicated the all-in/all-out type magnetic order. The all-in/all-out order breaks the time-reversal symmetry, while the spontaneous magnetization is essentially absent. The magnetic order can be viewed as ferroic magnetic octupolar order. The magnetic order is expected to provide several unique physical properties like quadratic magnetization. linear magneto-capacitance, linear magneto-resistance, linear magneto-mechanical coupling and so on [3]. The symmetry breaking results in two non-equivalent domains, "all-in/all-out" and "all-out/all-in." Interestingly, some theoretical works predict that a peculiar metallic state would appear on the domain wall. The observation and control of the domain distribution are essential for studying verious exotic physical responses. We have developed an x-ray technique for domain imaging and started studying the effects of external stimuli on the domain distribution [4]. This work was performed in collaboration with S. Tardif, S. Takeshita, H. Ohsumi, D. Uematsu, H. Sagayama, J. J. Ishikawa, S. Nakatsuji, J. Yamaura, and Z. Hiroi.

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