【Grant-in-Aid for Specially Promoted Research】

Science and Engineering

Title of Project : Development of novel photo-induced phase conversion materials based on quantum dynamic control of Charge-Structure-Spin-Photon coupled systems

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Keyword : Optical Properties of Materials, Photoinduced Phase Transition, Ultrafast Structural Dynamics

【Purpose and Background of the Research】

An attractive target for materials science is to achieve control of phase transitions using light (photo-induced phase transitions: PIPTs). To date, PIPT dynamics has been governed by the slow relaxation/dissipation of photo-injected energy leading to decoherence of the multi-electron state in a cooperatively interacting system (classical PIPT). Utilization of the quantum dynamics of a multi-electron state (quantum PIPT) that is coherently and strongly coupled to the electromagnetic field of the excitation photon itself is essential for creating photonic phase-switching materials with ultrahigh speeds and sensitive responses. Combining ultrafast modifications of three main physical degrees of freedom in solids (Charge-Structure-Spin, C-S-S) within the vibrational periods of elementary excitations will enable us to find unique C-S-S-ordered states, which can be obtained only by quantum PIPT (i.e., quantum hidden states: QHS).

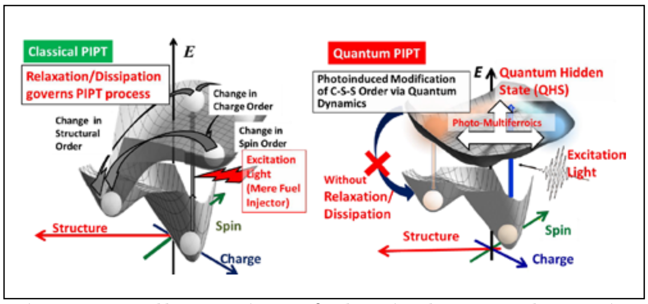

Figure 1 Illustration of classical PIPT dynamics (left-hand side) and quantum PIPT (right-hand side)

【Research Methods】

To clarify the ultrafast C-S-S coupled dynamics in a quantum PIPT system and develop new materials, this project establishes the following three teams and involves deep collaborations among materials scientists, specialists in ultrafast spectroscopy/ electron diffraction, and theoreticians:

Team 1: Search and develop candidate materials that show QHS *via* ultrafast quantum PIPT based on the strong coupling among C-S-S freedoms.

Team 2: Construct an ultrashort (30 fs) pulsed electron-diffraction facility with a spin-polarized /depolarized electron source.

Team 3: Construct a theoretical framework for quantum PIPT.

【Expected Research Achievements and Scientific Significance】

In this project, a pulsed electron-diffraction system with a 30-fs width, combined with a spin-polarized electron source will be constructed to enable observations of ultrafast C-S-S dynamics. The combined use of this system and an ultrafast spectroscopic probe will reveal the quantum natures of the microscopic mechanisms driving the initial PIPT process. The accumulated knowledge will unveil a realistic manner for photo-controlling the sensitive and ultrafast changes in magnetic, electronic, optical, dielectric, and structural properties of materials based on C-S-S strong coupling *via* QHS (photo-multiferroics). This research will have a large impact on the general field of photo-functional materials while opening the door for photonic and quantum control of a wide class of materials with ultrahigh speeds.

【Publications Relevant to the Project】

・"Direct Observation of Collective Modes Coupled to Molecular Orbital Driven Charge Transfer", T.Ishikawa, M.Hada, *R.J.D. Miller, K.Onda, S.Koshihara, et al. Science 350, pp.1501 (2015)
・"Coherent dynamics of photoinduced phase formation in a strongly correlated organic crystal", T.Ishikawa, S.Koshihara, *K.Onda et al. Phys. Rev. B 89, 161102(R) (2014)

【Term of Project】 FY2018-2022

【Budget Allocation】 484,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.chemistry.titech.ac.jp/~koshihara/english2/index.html