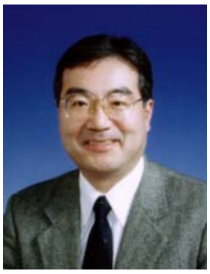

Title of Project : Ultrafast manipulation of magnetization with optical or lattice-wave excitations and its applications

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Research Area : Engineering, Applied Physics / Fundamental Engineering

Keyword : Spintronics

【Purpose and Background of the Research】

The speed (frequency f) of manipulating a single electron spin increases with an external magnetic field: f (GHz) = 176 B (Tesla). It has been shown, however, that the f value for ordered spins, magnetization M in particular, would saturate at a certain value, because slight disorder among spins is amplified when spins rotate in high magnetic fields [I. Tsudosa, *et al.*, Nature **428**, 831 (2004)]. This suggests that M would not be able to follow the increasing speed of information processing in the future.

In order to overcome this problem, I here propose the manipulation of direction of a M vector with excitation of wave function. The wave function, which describes electrons in a matter, consists of orbital and spin components. Essential point of my proposal is to excite the orbital component which is known to be very fast, and, through the spin-orbit interaction, manipulate each spin homogeneously at once. This process would circumvent dynamic amplification of spin disorder in the process of spin rotation, and would lead us to ultrafast manipulation of M. When accomplished, new applications based on new spin devices would be expected.

【Research Methods】

There are orbital and local spin sub-systems in magnetic solids. The orbital sub-system results from overlap of wave functions of the outmost electrons of individual atoms. The local spin sub-system consists of parallel alignment of spins which belong to somewhat inner electrons. Electrons in the orbital sub-system travel very fast and tie nuclei together to form a lattice sub-system. Simultaneously, they yield a current loop which works as a field to determine the direction of collective spins (magnetization M) through the spin-orbit interaction. Therefore, it is anticipated that optical excitation of orbital sub-system gives rise to the modification of the current loop and thus a change in the direction of M [1].

There are two mechanisms to be studied. Firstly, orbital-spin complex excitation in which orbital and spins are excited simultaneously. Secondly, spin-lattice waves induced by the excitation of orbital sub-system and orbital lattice coupling. We pursue experimentally these two mechanisms with two experimental groups. Materials of interests are ferromagnetic metals and semiconductors [2] having strong spin- orbit interactions. Wires and dots containing domain walls would also be studied.

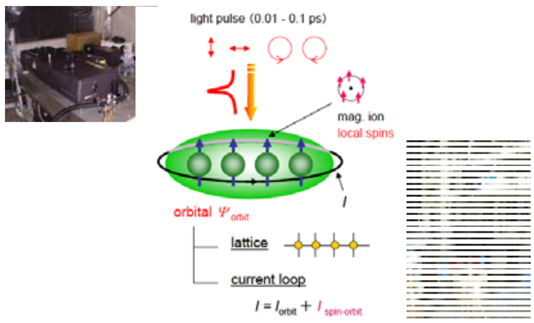

Figure 1 Concept of research method

【Expected Research Achievements and Scientific Significance】

Our target is to establish a mean of manipulating magnetization in tera-/peta-frequency region without an external magnetic field. Efforts toward this goal would lead us to the experimental preparation of optical buffer memory and optical switch, both with low power operation. These are key components for optical networking and space-light modulation.

【Publications Relevant to the Project】

1. Y. Hashimoto, S. Kobayashi, and H. Munekata: "Photoinduced Precession of Magnetization in Ferromagnetic (Ga,Mn)As"; Phys. Rev. Lett. **100**, 067202 1-4 (2008).
2. H. Munekata, H. Ohno, S. von Molnár, A. Segmüller, L.L. Chang, and L. Esaki: "Diluted magnetic III-V semiconductors"; Phys. Rev. Lett. **63**, 1849-1852 (1989).

【Term of Project】 FY2010-2014

【Budget Allocation】 164,200 Thousand Yen

【Homepage Address and Other Contact Information】
http://www.isl.titech.ac.jp/~munelab/