論文の内容の要旨

Development of the resonant magneto-optical Kerr effect and the study of transient magnetization dynamics in thin films

(共鳴磁気光学効果の手法開発と薄膜の磁気ダイナミクス研究)

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Magnetization dynamics on a femtosecond timescale, so-called femtomagnetism, has been attracting attention for more than two decades because of its potential for use in the development of novel spintronic devices as well as its fundamental physics. Although the mechanism of magnetization dynamics process on the femtosecond timescale, such as demagnetization and magnetization reversal, remain controversial from the microscopic perspective, the application demands in the field of spintronics expand the realm of the target magnetic systems from pure ferromagnetic materials into multi-component magnetic systems. Furthermore, the high density integration of the data devices with ever-faster processing speed needs the deeper understanding of dynamical properties of ultrathin magnetic films with out-of-plane magnetization. At the same time, in order to reduce the energy consumption and to avoid the notorious heat issues, electric-field driven magnetization control is preferred, which requires to trace spins under the real operating environment with the electric field as well as the magnetic field.

In this thesis, we developed a novel measurement technique, the time-resolved magneto-optical Kerr effect (MOKE) in the extreme ultraviolet / soft X-ray range using a free electron laser (FEL) in order to incorporate the current demands from fundamentals and application in the field of magnetism. We extended the conventional MOKE measurements involved with the optical transition between delocalized states into the resonant MOKE (RMOKE) using the photon energy tuned to the specific absorption edge of core levels. The advantages of the time-resolved RMOKE using FEL revealed in this thesis are the following: (1) element selectivity, (2) time-resolution of sub-picosecond timescale, (3) detection of out-of-plane magnetization, (4) sub-nanometer sensitivity, (5) measurement under the external field (the operando condition), (6) giant magneto-optical response compared with the conventional MOKE. On top of the features described above, the RMOKE scheme has a potential to extend into the nonlinear regime. Because nonlinear effects itself in the EUV / soft X-ray range has not been observed in the preceding studies due to the lack of the intense laser in the energy range, in this thesis we aimed at observation of the nonlinear optical effect, second harmonic generation (SHG). We measured the SHG in the EUV range for the first time using FEL from the non-centrosymmetric gallium ferrite by facilitating the resonant enhancement under a reflection geometry, which opens the way to extend the RMOKE into the nonlinear regime.