Femtosecond Time-Resolved Transverse Kerr Effect Measurements in Magnetoplasmonic Crystals

A. Yu. Frolov, P. P. Vabishchevich, M. R. Shcherbakov, T. V. Dolgova, A. A. Fedyanin
Faculty of Physics, Lomonosov Moscow State University, 119991 Moscow, Russia
frolov@nanolab.phys.msu.ru

Abstract: Experimental technique for observation of femtosecond dynamics of the transverse magneto-optical Kerr effect by measurements of second-order cross-correlation functions is presented.

Application of external magnetic field to a magnetic medium causes alteration of reflected light amplitude that is so-called magneto-optical Kerr effect. This effect is usually considered as a stationary one. However, there are experimental situations with dynamics of the magneto-optical response on the scale of several tens of femtoseconds. For example, excitation of surface plasmon polaritons (SPP) in a magnetized sample by femtosecond laser pulses can lead to time moduation of magneto-optical transversal Kerr effect (TKE) intensity that differs from its steady-state value. In this work the technique for femtosecond TKE dynamics observation is presented.

The sample under study is a magnetoplasmonic crystal that is a one-dimensional nickel grating with a period of 1.5μm fabricated by metal thermal sputtering onto a perforated polymer substrate. SPP resonance and magneto-optical effects (such as transverse Kerr effect) can be found simultaneously in the sample [1,2]. Applying external magnetic field shifts the position of the SPP resonance. SPP lifetime was previously shown to be about 100 fs, and reemission of SPP from the sample interacts with the directly reflected femtosecond laser pulse. To observe femtosecond dynamics of the transverse Kerr effect Er3+-doped fiber laser generating 200 fs pulses with the central wavelength λ =1.56μm is used. The laser pulse is splitted by a beam splitter into two different channels (Fig. 1). In the first channel a p-polarized pulse is reflected from the magnetoplasmionic crystal. The angle of incidence of 2.5° corresponds to the -1st diffraction order of light coupling to the SPP. AC saturating magnetic field is applied to the sample perpendicularly to the plane of incidence. The laser pulse propagating in the second channel is delayed with respect to the pulse in the first channel. The both laser pulses are co-focused onto a nonlinear BBO crystal.

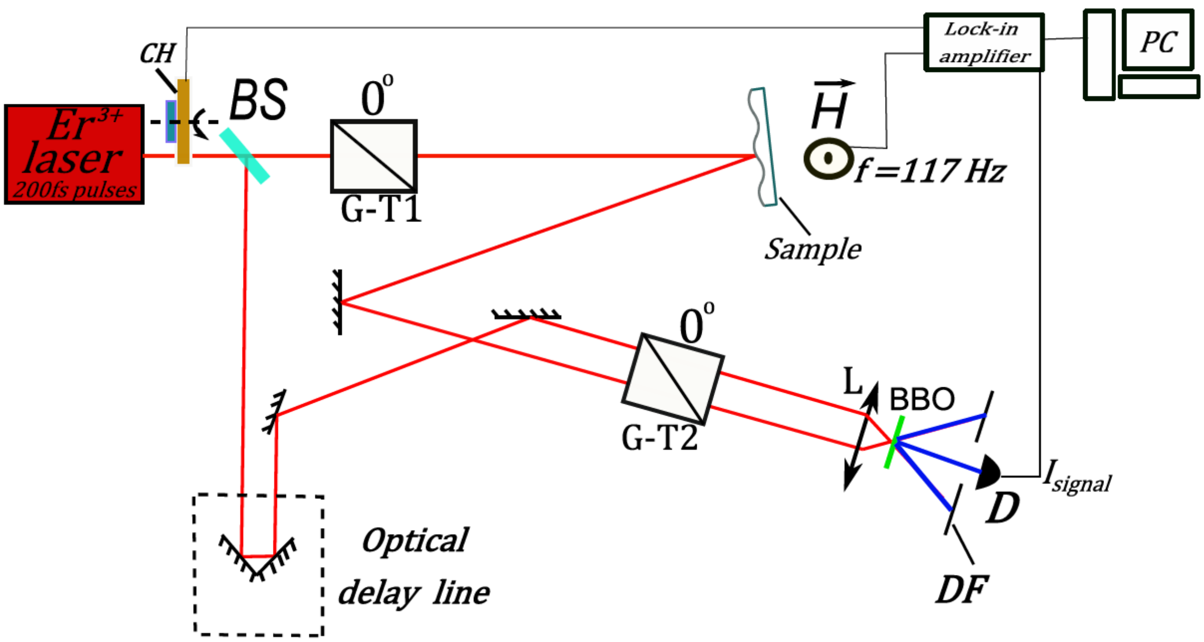

Fig.1. Experimental setup for measurements of second-order correlation functions. CH is a mechanical chopper, BS is a beam splitter, G-T1 and G-T2 are Glan-Taylor polarizers, L is a focusing lens, BBO is a nonlinear optical crystal, D is a detector, H denotes the external AC magnetic field, DF is an aperture.

The signal of the noncollinear sum-frequency generation in the BBO crystal is detected as a function of the delay. The signal I_{signal} is proportional to the second-order intensity cross-correlation function:

$$I_{signal}(\tau) = \int_{-\infty}^{+\infty} I_1(t) I_2(t-\tau)\, dt \qquad (1)$$

where $I_1(t)$ and $I_2(t)$ are intensity functions of the pulses in the first and second channel, respectively. Signal $I_2(t)$ has Gauss temporal profile, however $I_1(t)$ may be of a different shape because of interaction with radiation re-emitted by SPP.

Time-resolved TKE measurements are performed by lock-in detecting of the second-order correlation functions at the frequency of the external magnetic field. Measurements of the time-resolved TKE effect in one-dimensional magnetoplasmonic crystals showed non-trivial dynamics of the TKE effect, e.g., the effect changing its sign within the single femtosecond pulse.

[1] A.A. Grunin, A.G. Zhdanov, A.A. Ezhov, E.A. Ganshina, and A.A. Fedyanin, "Surface-plasmon-induced enhancement of magneto-optical Kerr effect in all-nickel subwavelength nanogratings", Appl. Phys. Lett. **97**, 261908 (2010).

[2] A. V. Zayats et al., “Controlling optical transmission through magneto-plasmonic crystals with an external magnetic field”, New Journal of Physics **10** (2008).