Femtosecond Faraday Rotation Dynamics Spectroscopy

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Abstract: A new polarization-sensitive correlation spectroscopy technique for femtosecond Faraday rotation dynamics measurements is presented.

1. Introduction

Magnetooptical Faraday polarization rotation is a non-reciprocal phenomenon that can be greatly enhanced in multilayered structures such as magnetophotonic crystals and microcavities due to multiple reflection interference [1]. A thin film or a multilayered medium can modulate electric filed amplitude and phase of a femtosecond pulse in space and time. If the medium is illuminated by short laser pulse and the pulse length is comparable to the thickness of the sample, ultrafast dynamics of Faraday rotation can be found [2]. It was numerically shown that time dependence of Faraday angle can either increase or decrease in time depending on the wavelength of the laser radiation.

In this work polarization-sensitive correlation spectroscopy technique for experiments on ultrafast evolution of Faraday polarization rotation is presented.

2. Experimental setup and measurement technique

The setup (Fig.1) based on polarization-sensitive correlation spectroscopy technique [3] is used in experimental measurements. For Faraday rotation dynamics measurements it should be adapted for probes of small polarization rotation angles. Radiation of a femtosecond Ti:Sapp laser is polarized at 45 degrees by a Glan prism and passes through the sample in DC magnetic field oriented parallel to laser beam propagation. Then laser pulses passes through photoelastic modulator (PEM), mounted coaxially with polarizer. PEM creates 47-kHz modulated delay between polarization components. Then radiation is analyzed by a Glan prism, mounted at 90 degrees. After that, the beam is divided by beamsplitter on the signal beam and the gate beam, one of which have relative time delay. The time shift can be varied by the optical delay line in the gate-pulse channel. Both pulses focused and overlapped at the same spot on a nonlinear BBO crystal, generating double-frequency radiation which intensity is proportional to the correlation function of the pulses:

$$u(\tau) = \int I(t) I_{gate}(t-\tau) dt, \qquad (1)$$

where $I(t)$ is intensity of transmitted signal pulse, $I_{gate}(t-\tau)$ - intensity of the gate pulse, τ is the time shift between them. Intensity of the signal transmitted from PEM can be written as:

$$I(t)[1 + 4J_2\theta(t)\cos(2\omega t)], \qquad (2)$$

where J_2 is second-order Bessel function, $\omega \ll \frac{c}{l}$ is the PEM modulation frequency. Therefore, the detected signal is:

$$u(\tau) = \int I(t) I_{gate}(t-\tau) dt + 4J_2 \cos(2\omega t) \int 2\theta(\tau) I(t) I_{gate}(t-\tau)\, dt \;=\; u_{dc}(\tau) + u_{2\omega}(\tau). \qquad (3)$$

The correlation function measured at the double PEM frequency is given by:

$$u_{2\omega}(\tau) = 8J_2\theta(\tau) \int I(t) I_{gate}(t-\tau) dt = \; 8J_2\theta(\tau)\, u_{dc}. \qquad (4)$$

if the changes in Faraday rotation are slower than the gate pulse duration, one can consider Faraday angle dynamics as averaged within the gate pulse. Thus, Faraday rotation angle can be found as:

$$\theta(\tau) \approx \frac{u_{2\omega}(\tau)}{8J_2 u_{dc(\tau)}}. \qquad (5)$$

Correlation function is detected by lock-in for both DC and double PEM frequency signals.

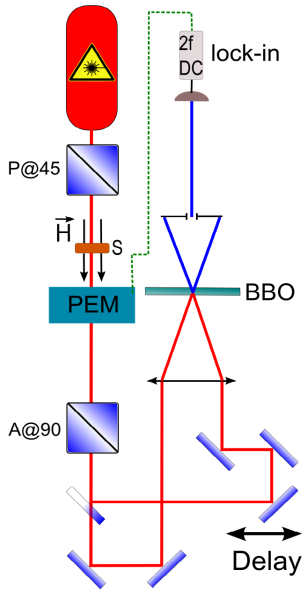

Fig. 1. Experimental setup scheme. P - polarizer, A – analyzer, S - sample, H - magnetic field, PEM - photoelastic modulator.

The technique was tested with a 16-μm-thick iron garnet film grown on a 500-μm-thick fused quartz substrate. Fig. 2a) shows time dependence of Faraday rotation angle in thin magnetic film for different wavelengths of source. In the first case wavelength of laser radiation corresponds to maximum in transmittance spectrum of the sample (798 nm), and the Faraday angle rises with time. In the second case the wavelength corresponds to minimum of spectrum (805 nm) and the angle of rotation decreases with time. In the third case there is no Faraday rotation changes during laser pulse duration. The behavior of the Faraday angle can be explained by constructive and destructive interference of pulses in thin magnetic films. Fig. 2b) demonstrates the measured spectral characteristics of time dependence of Faraday effect in thin magnetic film for three time shifts between gate and signal pulses. This figure shows different behaviors of Faraday angle for different wavelengths.

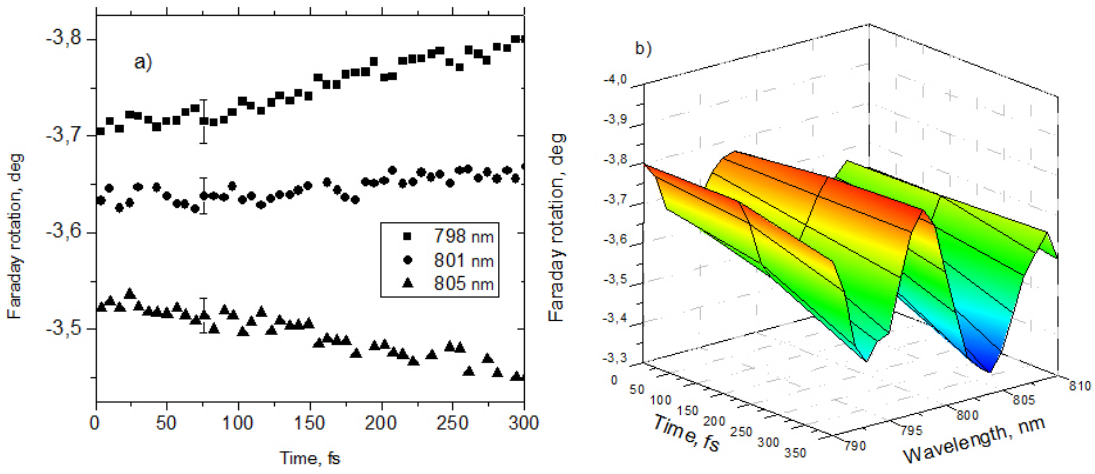

Fig. 2.a) Time dependence of Faraday rotation in thin magnetic film. Squares correspond to 798 nm wavelength of source and maximum of transmittance spectrum, triangles correspond to 805 nm wavelength and of transmittance spectrum and circles correspond to 801 nm and intermediate case. b) Spectral characteristics of time dependence of Faraday effect in thin magnetic film.

4. References

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