Ultrafast Faraday Rotation In Magnetophotonic Microcavities

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Abstract: Femtosecond dynamics of Faraday effect in magnetophotonic microcavities is experimentally demonstrated by using polarization-sensitive correlation scheme. Complex spectral-dependent behavior of Faraday rotation dynamics is shown.

1. Introduction

Faraday effect is a non-reciprocal phenomenon that can be greatly enhanced in multilayered structures due to multiple reflection interference. Such enhancement was demonstrated in magnetophotonic crystals and microcavities [1,2]. The effect is well-studied in the steady-state case. If the medium is illuminated by short laser pulses, non-stationary behavior of Faraday rotation can be found on the timescale of pulse duration [2]. A layered optical material can modulate electric filed amplitude and phase of a femtosecond pulse in space and time. For example, Faraday angle of the initial part of the pulse can differ from that of its tail and steady-state value. It was shown numerically for a layered structure that time dependence of Faraday angle can both increase in time if the wavelength of laser radiation corresponds to spectral transmittance maximum, and decrease in the case of spectral transmittance minimum [3].

In this work ultrafast dynamics of Faraday rotation is demonstrated experimentally in magnetophotonic microcavities by polarization-sensitive correlation spectroscopy technique.

2. Set-up and samples

The experimental technique used in Ref. [4] was modified for time-resolved magnetooptical measurements. The set-up consists of polarization-sensitive and correlation parts (Fig. 1). Femtosecond pulses of a tunable Ti:Sapphire laser pass through a 45deg.-oriented Glan-Taylor polarizer, the sample with saturating DC magnetic field applied, photoelastic modulator (PEM), mounted coaxially to polarizer and analyzed by Glan-Taylor prism mounted perpendicularly to optic scheme plane. The radiation is separated by a 50% beamsplitter into two channels, one of which contains variable delay line. Both beams are co-focused on the nonlinear crystal, generating non-collinear double-frequency radiation that is detected by a lock-in amplifier. The signal locked in to the doubled PEM frequency and its DC component are detected. The Faraday angle is proportional to the ratio of AC to DC signals.

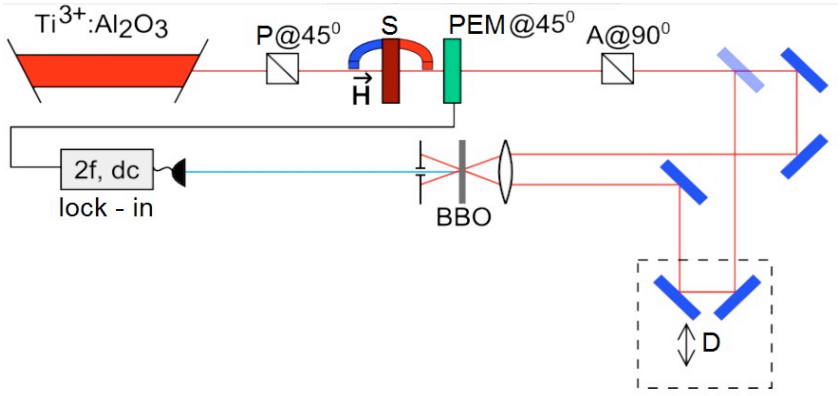

Fig. 1. Experimental setup scheme. P - polarizer, S - sample, H - magnetic field, PEM - photoelastic modulator, A - analyzer, D - variable delay, BBO - nonlinear crystal.

The magnetophotonic microcavity is fabricated from half-wavelength-thick Bi-doped yttrium iron garnet placed between two Bragg reflectors of five pairs of alternating quarter-wavelength-thick silicon oxide and tantalum oxide. The cavity mode is approximately 896 nm. The sample is grown on a glass substrate by the rf sputtering of corresponding targets in Ar atmosphere. The second sample is 16-μm-thick iron garnet film grown on a 500-μm-thick fused quartz substrate.

4. Results

Fig. 2a shows time dependence of Faraday rotation in the microcavity mode (896 nm), where low group velocity of light is expected and for a detuned wavelength of 892 nm.

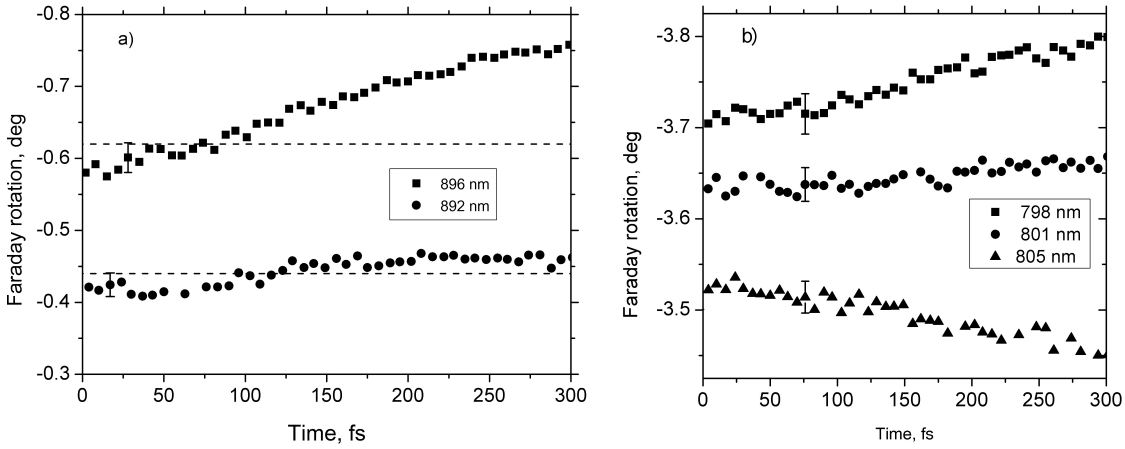

Fig. 2. a) Time dependence of Faraday rotation in magntophotonic microcavity. Squares correspond to wavelength of microcavity mode and circles correspond to detuned wavelength. Dash lines correspond to steady-state value of Faraday angle. (b) Time dependence of Faraday rotation in thin magnetic film. Squares correspond to 798 nm wavelength of source and maximum of transmittance spectrum, triangles correspond to 805 nm wavelength and minimum of transmittance spectrum and circles correspond to 801 nm and intermediate case.

Faraday rotation increases as fast as of 0.15 degrees during 300 fs, which is 3 times faster than that for detuned wavelength. The effect comes from the non-reciprocity of the Faraday rotation and accumulation of the polarization angle. For the film sample there are 3 cases of Faraday angle behavior depending on light wavelength (Fig. 2b). If the wavelength of laser radiation corresponds to maximum in transmittance spectrum of the sample (798 nm), the Faraday angle rises with time. If the wavelength corresponds to minimum of spectrum (805 nm) than angle decreases with time. In the middle case there is no Faraday rotation changes during 300 fs. The effect can be explained by constructive and destructive multiple-reflection interference in the film and confirmed by the numerical calculations.

5. References

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