The evaluation of the magnetometry using AOC-related NMOR at Cesium D1 Line

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INTRODUCTION

Optical atomic magnetometers based on alkali atom are one of the most sensitive magnetic sensors. The polarization of alkali ensemble plays a crucial role in revealing the property of magneto-optical rotation that further affects the sensitivity of the optical atomic magnetometers. Alignment-to-orientation conversion (AOC) involves the evolution of atomic polarization induced by an applied electric field or by intense laser light [1], providing alternative method to modify the polarization state of atom. Therefore, we theoretically analyzed and evaluated the AOC-related nonlinear magneto-optical rotation (NMOR) at ^{133}Cs D1 transition (895 nm) experimentally and theoretically, aiming to explore its value in magnetometry.

METHODS

The experimental apparatus [2] is a single beam scheme, as shown in Fig. 1. The temperature of the paraffin coating cell is maintained at 37 ℃. The nonperturbative density matrix theory[3] is used to evaluate the AOC-related NMOR via the AtomicDensityMatrix package [4].

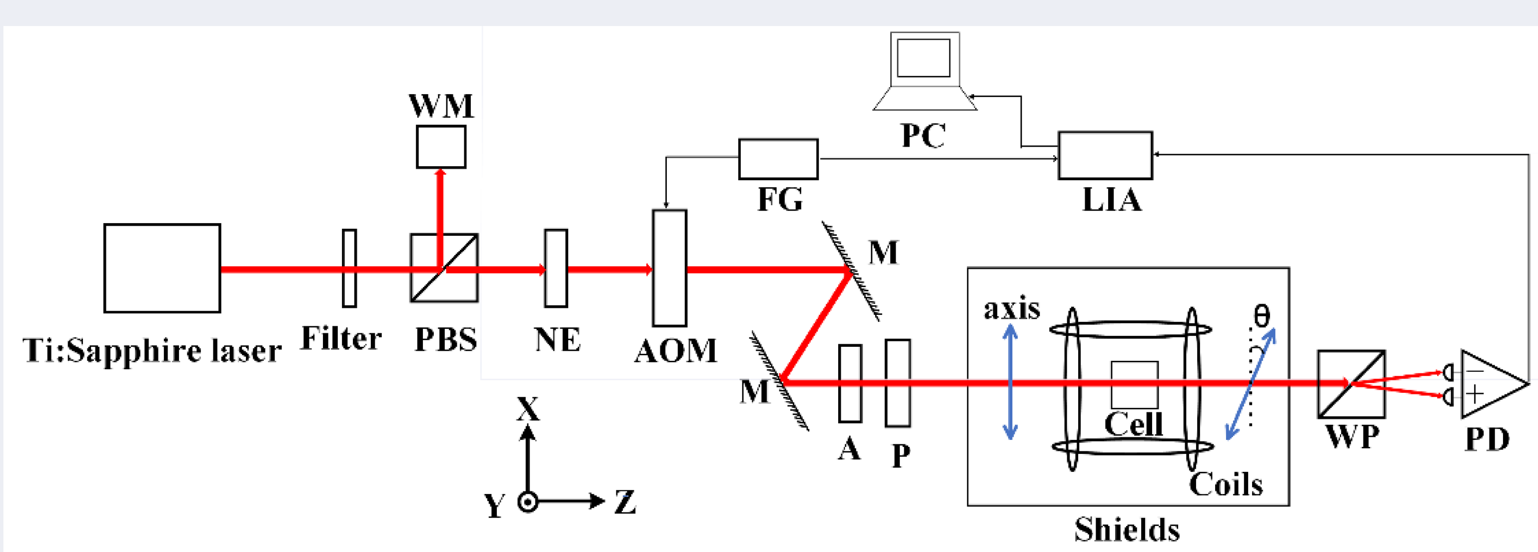

Fig. 1. The diagram of the experimental setup. Some abbreviations are used as follows: wavelength meter (WM), noise eater (NE), mirror (M), function generator (FG), attenuator (A), polarizer (P), Wollaston prism (WP).

RESULTS and DISCUSSIONS

Numerical simulations at the $6^2S^{1/2}$ F=3→$6^2P_{1/2}$ F'=4 transition were performed to interpret the AOC-related NMOR at high intensity. A "twist" structure (red curve) is clearly visible in NMOR curve (Fig.2a). The angular-momentum probability surface (AMPS) [5] shows a superposition of the alignment and orientation (the insets in Fig.2a), indicating that the "twist" structure is caused by AOC effect.

Subsequently, the experiments were performed. A similar "twist" curve was observed at 0.5 mW (Fig. 2b). The amplitude-to-linewidth ratio (ALR) for the AOC-related NMOR is 171 μrad/Hz. The response to AC magnetic signals (38 pT, 80 Hz) were measured (Fig. 2c). The maximum response value in the AOC region is 0.428 mrad/nT, which is a 1.7 fold enhancement of the value in the coherence region (B_z=11 nT). Further experiments with different laser power (Fig. 2d) show that this AOC-related NMOR maintains an available ALR (>30 μrad/Hz) in the high light intensity region (3~50 mW), benefiting from narrow linewidth (~30 Hz) and weak power broadening (1.37 Hz/mW).

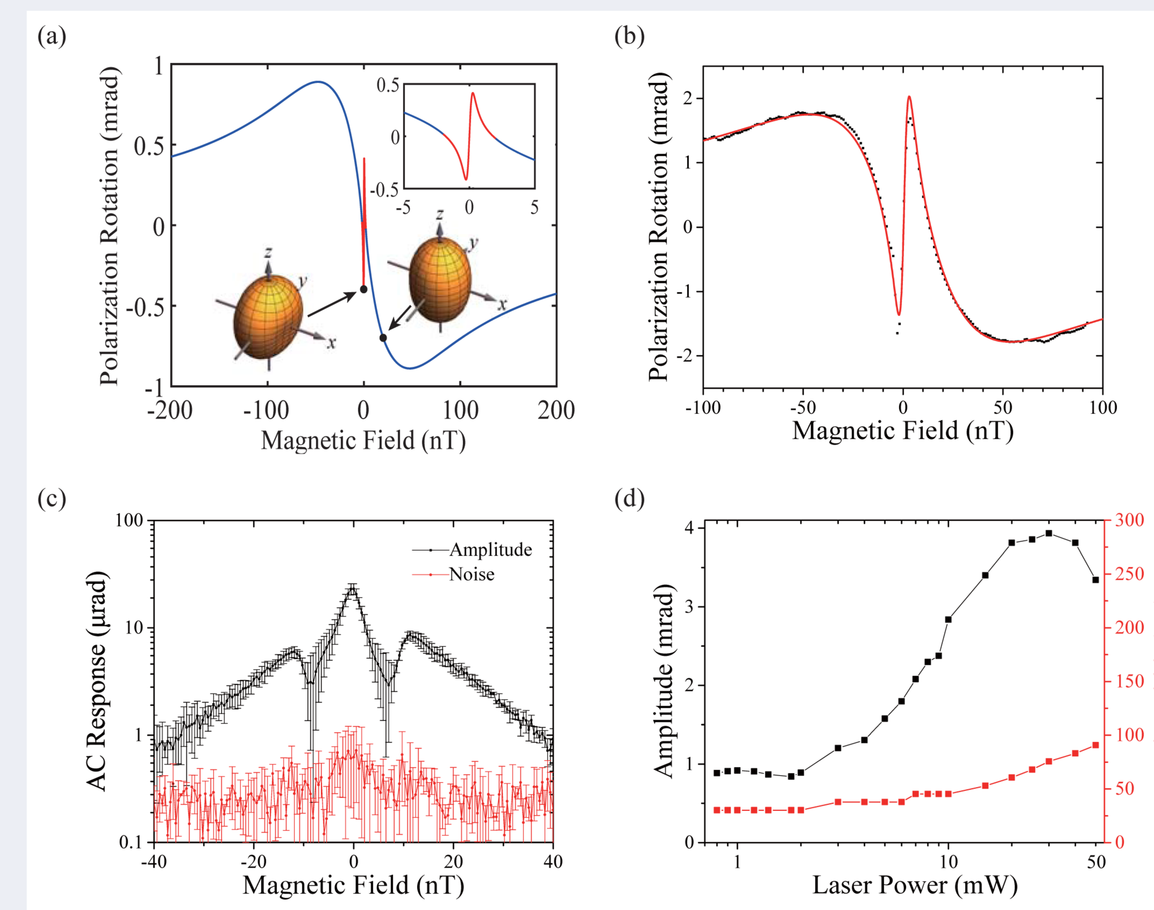

Fig. 2. The evaluation of AOC-related NMOR at the 6 $^2S_{1/2}$ F = 3 → 6 $^2P_{1/2}$ F' = 4 transition. (a) Numerical calculations of the polarization rotation vary as a function of the magnetic field. (b) The measured amplitude and linewidth of AOC-related NMOR versus laser power (c) Response of the magnetometer to a sinusoidal magnetic field at different B_z offsets.(d) The amplitude and linewidth of the AOC-related NMOR versus laser power.

An anomaly reversal at the $6^2S_{1/2}$ F=4 →$6^2P_{1/2}$ F'=3 transition was experimentally observed at laser power above 3 mW (Fig. 3a). Such reversal at F→F–1 transition shows some differences from the results of rubidium D2 line, where the flip of the rotation sign causing by AOC only occurred at the F→F+1 transition [1]. We attributed this phenomenon to the hyperfine sublevels effect and decomposed the rotation of laser polarization φ_{total} to the sum of the $\varphi_{Fg,Fe}$ (contributed from the phase shift of σ+ and σ– between the ground- and excited-states hyperfine sublevels) in the Figs. 3b-3d. Only at high saturation parameter κ=10^7 and low B_z, the contributions from other hyperfine sublevels emerge (Fig. 3c), resulting in a negative rotation.

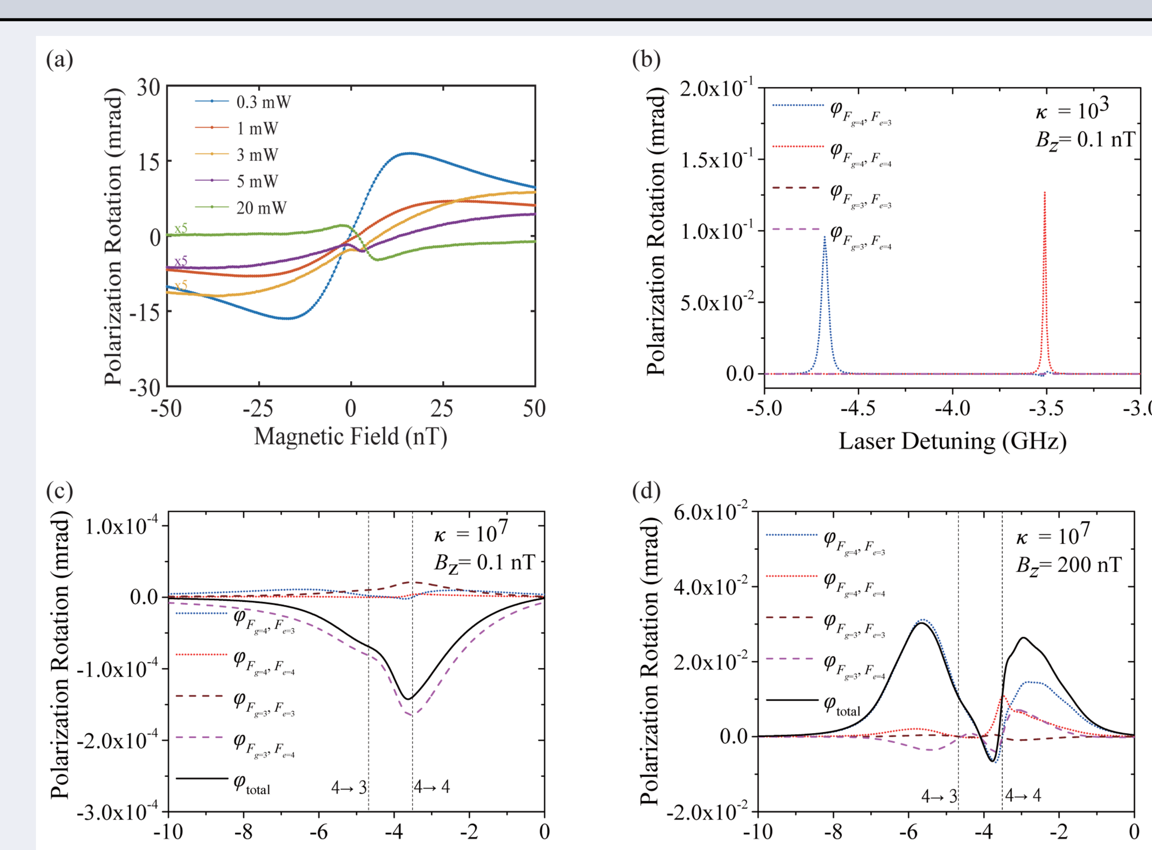

Fig. 3. The investigations of the reversal of laser polarization rotation at the $6^2S_{1/2}$ F=4→$6^2P_{1/2}$ F'=3 transition. (a) Experimental results of the polarization rotation variation as a function of the magnetic field at different laser power. (b-d) Calculated results of the hyperfine sublevels contributed polarization rotation vary with laser detuning at (b) κ=10^3, B_z=0.1 nT, (c) κ=10^7, B_z=0.1 nT, and (d) κ=10^7, B_z=200 nT, respectively. The detuning Δ = 0 GHz corresponds to the center of the cesium D1 line.

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