Study of Resonant Magneto-Optical Rotation in the Presence of Arbitrarily-Directed Magnetic Fields

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It has been known since 1950's that long electronic spin relaxation times for alkali atoms can be obtained using vapor cells with anti-relaxation coating on inner walls. However application of such cells to the nonlinear resonant magneto-optical rotation (NLRMOR) was first demonstrated by S.I.Kanorsky, A.Weis, and J.Skalla only recently [1]. They used a paraffin-coated glass cell containing cesium vapor and investgated the rotation of the plane of polarization of light in the presence of a longitudinal (i.e. along the light propagation direction) magnetic field (usually called nonlinear Faraday effect – NLFE) and observed characteristic sharp Faraday rotation dependence on the field magnitude with width corresponding to effective relaxation rate $\Gamma \sim 1\ kHz$.

We performed experiments with rubidium vapor in a 8 cm diameter paraffin-coated spherical cell [2]. (This particular cell was manufactured in 1964). The cell was surrounded by a four-layer magnetic shield, with a system of coils installed within the innermost shield allowing one to create a small magnetic field with well characterized transverse (x and y) and longitudinal (z) components. An external-cavity diode laser frequency was tuned to the rubidium D2 ($^2S_{1/2} \rightarrow {}^2P_{3/2}$) resonance at 780 nm. The change of polarization of light pasing through the cell was detected with a polarimeter using modulation technique. Typical observed NLFE curves had widths about 40 μGs (peak-to-peak) corresponding to $\Gamma = 19\ Hz$.

In the presence of transverse magnetic field, we observed strong dependence of NLRMOR curve shape on the field magnitude and orientation – Fig.1. In order to achieve a quantitative description of this characteristic behavior we used a generalization [2] of a simple theoretical model developed in [3]. In this model, the optical rotation originates from a three-step process: 1. Atomic alignment by the incident linearly polarized light; 2. Free precession of the alignment in the arbitrarily directed magnetic field; 3. The effect of the atoms on light where the linearly dichroic medium is thought of as a rotating "polarizer". Solid lines on Fig.1 show the results of fitting experimental data with the model.

The observed strong dependence of optical rotation (Fig.1) on the values of both the longitudinal and transverse fields provides an opportunity of adapting NLRMOR to extremely sensitive 3-axis magnetometry using paraffin-coated cells with spin-relaxation time $\tau \geq 1\ sec$ [4]. *

An additional advantage of magnetometry using NLRMOR comes from the fact that it can in principle be performed without introducing scanning or compensating magnetic fields into the

*The first run with such a cell gave $\Gamma \simeq 8\ Hz$. We think this is determined mostly by spin-exchange collisions and residual magnetic fields. Some improvement is expected after certain refinements in the apparatus, including application of the magnetic shield degaussing.

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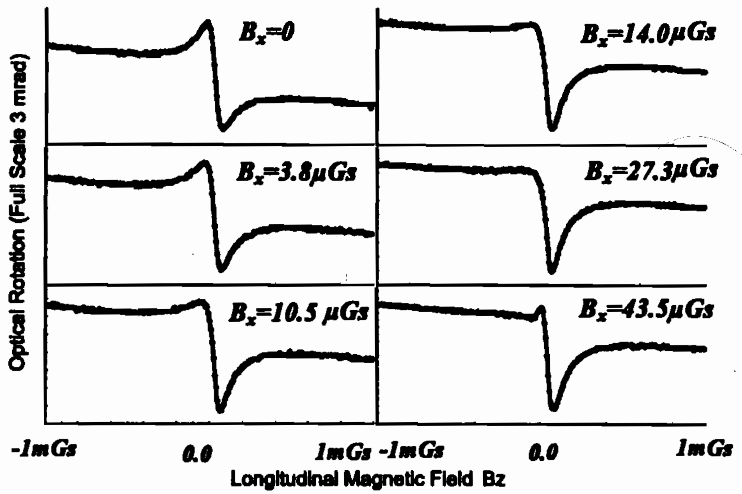

Figure 1: Optical rotation vs longitudinal magnetic field in the presence of transverse fields ($B_y = 65.2\ \mu Gs$). Laser (89 μW power, $\approx 3\ mm$ diam.) was tuned to the $F = 3 \rightarrow F'$ peak of ^{85}Rb D2 line (F' -is the unresolved upper state angular momentum). The vapor cell was at room temperature.

volume under investigation. This can be done by detecting NLRMOR dependence on polarization direction of the laser light.

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