Magneto-optic spectroscopy by resonant light fluctuations in rubidium vapor

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Abstract

When a resonant light beam interacts with an atomic sample its phase and intensity fluctuation are modified by the interaction with the atoms. In consequence, the analysis of the light noise spectra can reveal information about the atomic dynamics. Under usual conditions the atomic contribution to the noise is small compared with the intrinsic field fluctuations, especially in the low frequency region. In this work we present a method, combining heterodyne detection and the non linear Faraday effect, allowing the sensitive detection of the slow Larmor precession of atoms in the presence of a weak magnetic field.

Introduction

It has been shown that the analysis of the noise spectral composition can be used as an interesting spectroscopic tool[1][2][3].

In the presence of a constant magnetic field the atomic dipole moment of individual atoms precesses at the Larmor frequency Δ. For macroscopic atomic samples the steady state average magnetic moment is a constant. However the transient evolution of the macroscopic density matrix towards the steady state show damped oscillations at the Larmor frequency. These transients are mainly trigged by the fluctuations of the exciting field and also by the quantum fluctuations of the atomic dipole (associated to spontaneous emission).

Under usual conditions the atomic contribution to the light fluctuations (noise) is small compared to the intrinsic fluctuations carried by the exciting beam. This is a specially restrictive condition in the low frequency domain (< 1 MHz) since in this range there is a large amount of technical noise.

In this work we present a technique allowing the sensitive detection of weak low frequency atomic transients. The method takes advantage of the non-linear Faraday effect that takes place when degenerate two level atoms subjected to a constant magnetic field are excited by a linear polarized optical beam. Because the two circular polarization components have different refractive index, a rotation of the exciting field polarization is produced

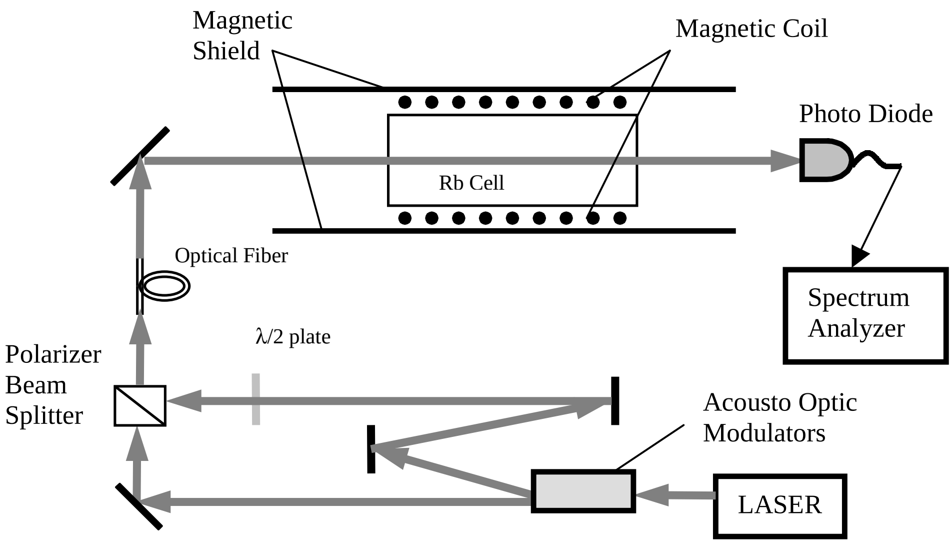

Figure 1: Experimental setup for a fluctuation spectroscopy using heterodyne magneto-optical techinique.

associated to a Raman resonance between ground state Zeeman sublevels[4]. In consequence when the fluctuating incident field is resonant with a ground state Raman transition it will generate a component of the atomic dipole moment in the plane perpendicular to the polarization of the exciting field. Detection of light fluctuations in the plane perpendicular to the polarization of the incident light shows an essentially background free atomic contribution. To further reduce technical noise an heterodyne technique is used allowing noise analysis at a convenient frequency (400 MHz). With this technique we are able to detect the Larmor precession of atoms under fields of the order of 0.1 Gauss.

Experiment

The experiment was carried on the ^{87}Rb $5S_{1/2}(F=2)\rightarrow 5P_{1/2}(F=1)$ transition (795nm) in a vapor cell. The setup scheme is shown in Figure 1. A diode laser produces a vertical linear polarized resonant light beam. Before interaction with the atoms, a small part of the beam is frequency shifted by 400MHz with acousto-optic modulators generating a *reference* (off resonant) field for heterodyning. Both fields *with orthogonal polarizations* are superimposed in a optical fiber and sent to the vapor cell. The light is detected by a fast photo diode (1GHz bandwidth) and sent to a spectrum analyzer. Since the beat signal is proportional to the scalar product of the two fields, only the component of the light fluctuations along the reference field polarization direction is detected. The spectrum of the observed light fluctuations is centered at the beat frequency ν_b = 400MHz.

A typical curve is seen in Figure 2. The central peak results from the residual beat between the two fields. The side bands represent the atomic contribution. We have checked that the distance between the sidebands and the central peak is given by $2\Delta = 2\gamma B$ (γ being the gyromagnetic factor of the ground state of ^{87}Rb). Comparing with [1] it can be seen that this heterodyne magneto-optic technique improves good signal/noise relation for the detection of low frequency components.

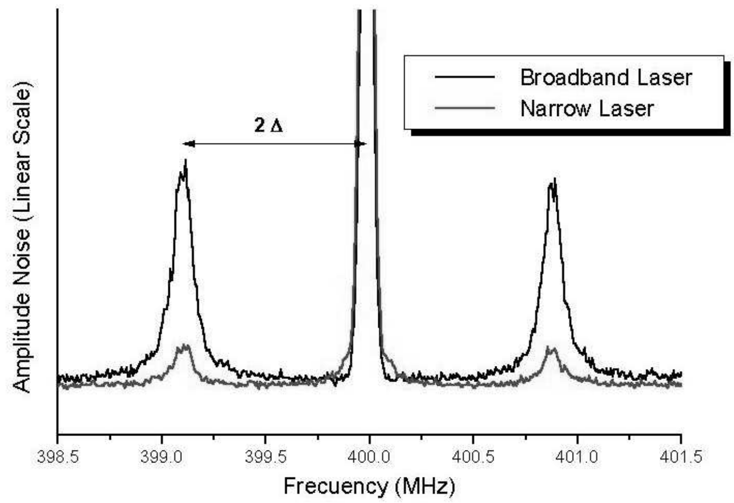

Figure 2: Noise spectra showing the atomic Larmor precession transients for the ^{87}Rb $5S_{1/2}(F=2)\rightarrow 5P_{1/2}(F=1)$ transition. The distance between the sidebands is proportional to the magnetic field and the atomic gyromagnetic factor.

In order to analyze the signal dependence on the laser phase fluctuations we have used two kind of lasers. A free running diode laser, stabilized in temperature and current, that has a width of the order of 50 MHz and a diode laser injected by a frequency stabilized extend cavity diode laser (spectral width around 1MHz). Approximately the same power is obtained in both cases. In Figure 2 we compare the noise atomic contribution for these two kind of exciting fields. Keeping the same intensity beams we see that the signal that results from the excitation by a narrow laser is much smaller than the broad one. We conclude that the phase fluctuations in the incident field play an important role in the dynamics of the dipole fluctuations. We also have checked that the atomic signal decreases as the magnetic field dependent Zeeman shift becomes comparable with the optical transition width.

Conclusions and Perspectives

We have presented a new experimental scheme allowing the noise spectroscopy of atoms under weak magnetic fields. Although the influence of the exciting beam fluctuations on the atomic response is clearly demonstrated, current investigation focus on the relative contribution of the field induced fluctuation as compared with quantum fluctuations of the atomic dipole due to spontaneous emission.

Acknowledgements

The authors thank the PEDECIBA and CSIC, Uruguayan agencies.

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