Investigating hyperfine structure properties of Caesium and measuring Earth's magnetic flux density using optical pumping.

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Abstract

Determining the Hyperfine Landé g-factor of the $6^2S_{1/2}$ $F = 4$ sub-state.

1 Aims of the experiment

To create a plot of resonant frequency of the transition between two states as a function of Helmholtz coil current and extract information by fitting a function to the data. Alter the set-up to detect and record Rabi oscillations and determine what information can be extracted from the oscilloscope recording of the oscillations.

2 Background

Optical pumping is the technique by which level populations of a system can be manipulated such that a single magnetic sub-level can be fully and (semi-)inescapably populated. The most famous use of this is to achieve population inversion for producing laser light.

This is achieved by designing a pumping mechanism with selection rules that create a 'terminal' energy sub-state to which all of a system's population moves towards. Take the example of a system with an upper and lower level both of which have total angular momentum $F = 4$. These can be split into magnetic sub-states $m_F \in \mathbb{Z} : m_F \in [-F, F]$. Initially the populations can be described by a Boltzmann distribution where the majority of the population lays in the lowest m_F levels. Circularly polarized with the selection rule for absorption $\Delta m_F = 1$ is then incident on the system. Electrons in levels $m_F = -4, -3, ..., 3$ will be excited to the equivalent $m_F + 1$ level in the excited level before decaying to the ground state m_F levels allowed by the selection rule $\Delta m_F = -1, 0, +1$. However, if the ground state sub-level it de-excites into is $m_F = 4$ then there is no $m_F + 1$ level in the excited state to move into, neither is there a lower energy state to de-excite further into. Until new de-excitation channels are introduced the electron is effectively trapped in this state.

3 Saturation spectroscopy apparatus

4 Analysis

5 Results

Parameter	Value
Earth's magnetic flux density	0.4858 ± 0.017 G
NOAA Earth's magnetic flux density	0.4859 ± 0.0015 G
σ difference	0.0054
Landé g-factor	0.2484 ± 0.0086
Calculated Landé g-factor	0.24994
σ difference	0.0054

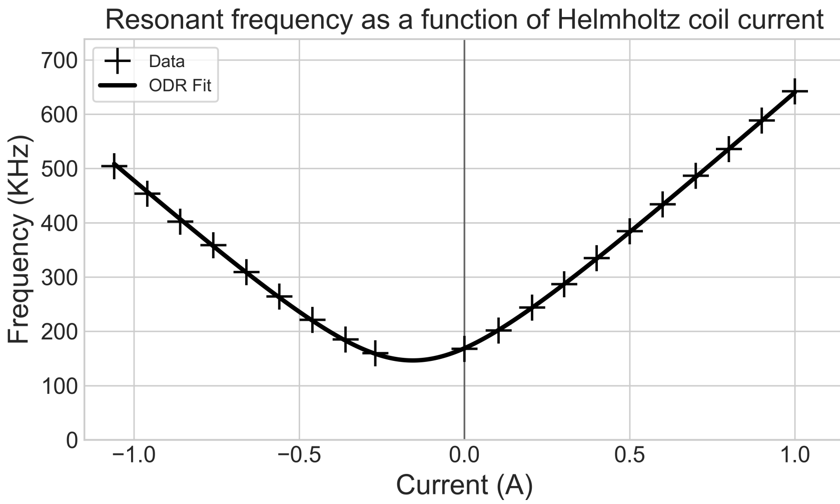

Figure 2:

6 Discussion

7 Conclusion

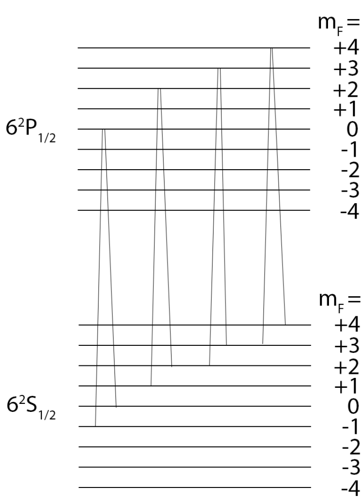

Figure 1: Unshielded background spectrum.