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TU Dresden

Advanced practical course

Lab report

Nuclear Magnetic Resonace

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1 Introduction

1.1 Motivation

Nuclear Magnetic Resonance is a physical phenomenon that can be observed while placing an ensemble of nuclei into a static magnetic field and stimulate it with a high-frequent alterning field. A necessary condition for this effect is that the atoms of the sample have a *nuclear spin* different from zero. It is the central concept that is used for *NMR-Spectroscopy*, a standard methodology for the investigation of the structure and interaction of complex molecules and solid state bodies by measuring local magnetic fields, and the *magnetic resonance tomography* which is an imaging technique used in clinical diagnistics for describing the morphilogic and physiologic build-up of tissues and organs. For all of those applications some important parameters of particular physical compensation-processes, the so called *relaxation times* T_1 and T_2 need to be quantified. In the following experiment exactly those material-characteristic observables are determined for an ensemble of ^{57}Fe-nuclei. But at first some basic knowledge.

1.2 Nuclear Zeeman-Effect

Every quantum mechanic angular momentum - especially every spin - is correlated with a magnetic moment μ The proportionality factor is called the *gyromagnetic ratio* γ. So the intrinsic magnetic momentum matching to the nuclear spin $\vec{\mathcal{I}}$ considered in the experiment is given by:

$$\vec{\mu} = \gamma\vec{\mathcal{I}} \tag{1}$$

$$\gamma = g_I \frac{\mu_N}{\hbar} \overset{^{57}Fe}{=} 0.8661 \cdot 10^7 \ \mathrm{T^{-1}s^{-1}} \tag{2}$$

Where μ_N is the *nuclear magneton* and g_I is the Landé-factor which both are core-specific parameters. If those magnetic moments are placed in a static magnetic field $\vec{B} = (0, 0, B)^T$ then the Hamiltonian of the system and its Eigenvalues to the Eigenstates of the spin-operator $|I, m_I\rangle$ are given by:

$$\mathcal{H} = -\vec{\mu}\vec{B} \overset{(1)}{=} -\gamma\mathcal{I}_z B \tag{3}$$

$$\langle\mathcal{H}\rangle = \langle I, m_I|\,\mathcal{H}\,|I, m_I\rangle = -\gamma B\,\langle I, m_I|\,\mathcal{I}_z\,|I, m_I\rangle = -\gamma B\hbar m \equiv E_m \tag{4}$$

Where the Eigenvalues of the Spin-operator for given spin-quantumnumber I and magnetic quantum number $m_I = -I, \ldots, I$ were used. So the outer magnetic field annuls the $2I + 1$-fold degeneration of the energystates. The nuclear spin-quantum-number of ^{57}Fe is I $= 1/2$ so there are two additional energystates with a energydifference:

$$\Delta E = \hbar\gamma B = \hbar\omega_L \tag{5}$$

As equation (5) suggests, there may occur optical transitions between the terms which lead to an emission of photons with the angular frenquency w_L. One finds that this frequency is equivalent to the *Larmor-Frequency* that describes the precession of a magnetic moment caused by the torsional moment $\vec{M} = \vec{\mu} \times \vec{B}$ in a magnetic field. The classical description of this process leads to the same result as quantum mechanics do. If we consider the ensemble of N nuclei as canonical, then the number of spins in the state $|s, m\rangle$ in the thermodynamic equivilibrium is given by the Boltzman-statistics:

$$N(s, m) = N \cdot \frac{e^{-\frac{E_m}{k_B T}}}{Z} = N \cdot \frac{e^{\frac{\hbar\gamma B m}{k_B T}}}{Z} \tag{6}$$

Where Z = const. is the canonical partition function and T is the absolute temperature of the environment. This implies that the spins prefer to be polarised not uniformely but in the direction of the B-field so this leads to a mean magnetic moment $\langle \vec{\mu} \rangle \neq 0$. This leads to an oberservable macroscopic magnetisation in the volume V:

$$\vec{M} = \frac{d\vec{\mu}}{dV} \cong \frac{N}{V} \langle \vec{\mu} \rangle \neq 0 \tag{7}$$

These changes in magnetisation are used to induce voltages that can be measured.

2 Experimental procedure

2.1 Preparation of a high frequency resonant circuit

First one has to prepare a copper coil with a diameter big enough to hold an iron powder assay. After the coil is wrapped one has to sold it onto the contacts of a stick, which provides a mechanism to tune the measured frequency to find the resonance frequency. While solding one has to be careful to make sure, that one do not take to much tin, because the resisteaces of tin and copper are different. In the same way the soldered point should connect the contact and the coil directly, otherwise this could influence the results while tuning to the resonance frequency.

2.2

2.3

3 Data Analysis

4 Discussion and conclusions

References

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