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:

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

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

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 was wrapped one has to sold it onto contacts of a stick, which provides a mechanism to tune the measured frequency to find the resonance frequency. One has du be carefully

2.2

2.3

3 Data Analysis

4 Discussion and conclusions

References

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