

The advancement of research in quantum technologies has led to the development of atomic sensors and hence nuclear magnetic resonance (NMR) gyroscopes. NMR gyroscopes have high sensitivity. The most important parameter of atomic sensors such as NMR is their relaxation time. The accuracy of NMRG with two isotopes of Xe atoms directly affects the accuracy of navigation. The accuracy of gyroscope depends on the relaxation time of the Xe atoms. In this study, the relaxation times of Xe atoms in different concentrations of buffer gas were measured. Free induction decay (FID) method was used as the measurement method. The results are reproducible and reliable as they were obtained by test automation using Labview.

Introduction

Glass Production



Fig.1 Atomic Vapor Cell

Spherical cells with an inner diameter of approximately 10 mm are produced in our laboratory using the glass-blowing technique [1], and these cells are combined along a glass line with a cesium ampoule attached. Different amounts of gases are filled into the produced cell. An example of a produced cell is shown in Fig. 1.

For research purposes, spherical alumina silicate cell with a radius of 10 mm were produced. The cell contain ^{133}Cs (Cesium), ^{129}Xe , ^{131}Xe , N_2 , and helium buffer gas.

One of the parameters characterized in the produced cells is the relaxation time. In this study, particular focus is given to the relaxation time.

Experiment

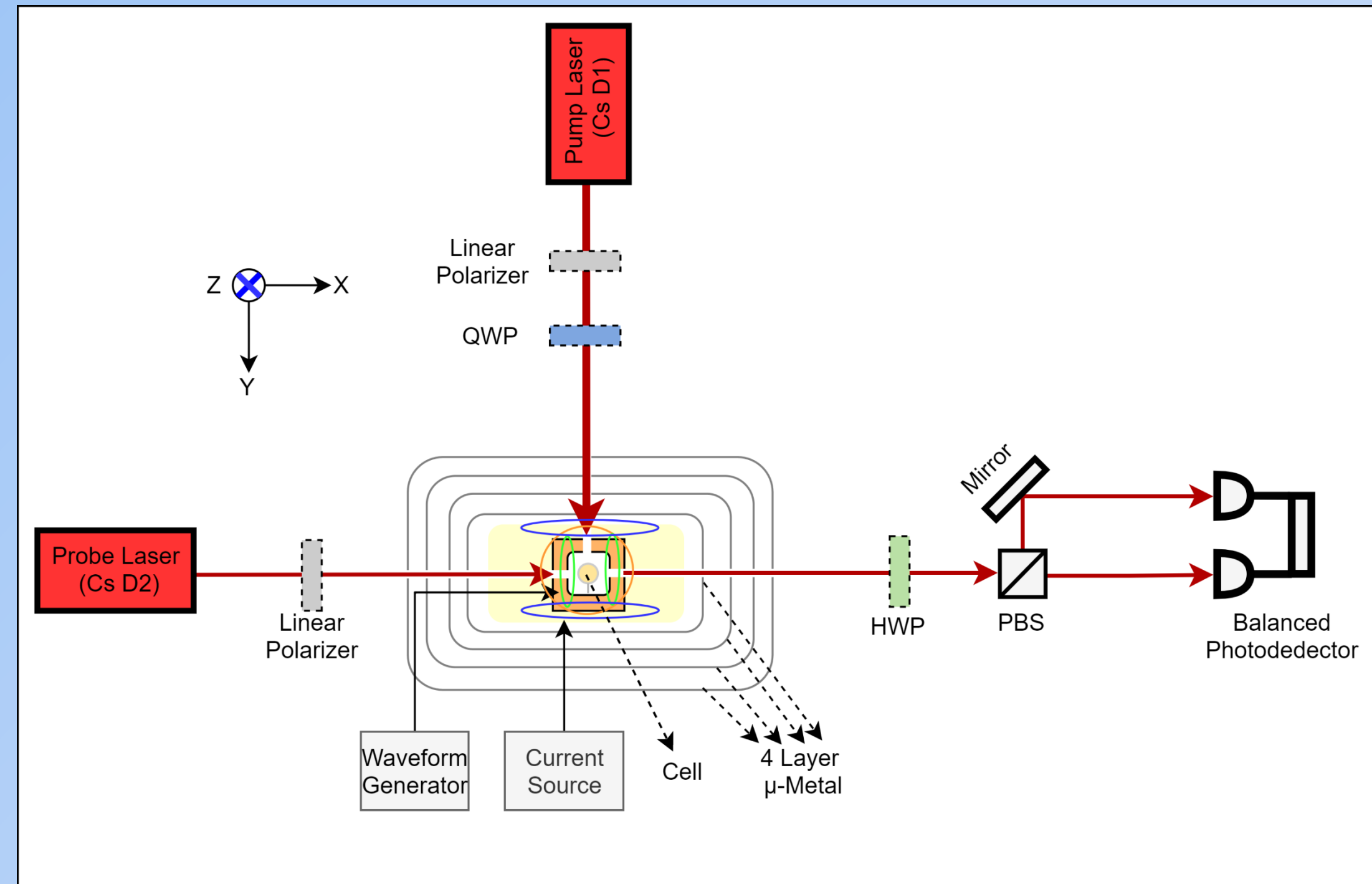


Fig.2 Experimental set-up

The characterization of the produced cells is performed using the measurement setup shown in Figure 2. The pump laser beam, generated from a DBR laser tuned to the D1 line of Cs atoms, is converted into circular polarization using a quarter-wave plate and directed along the y-axis. A DC magnetic field is also applied along the y-axis, in the same direction as the pump laser beam. A $\pi/2$ pulse is applied along the x-axis from a waveform generator. The probe laser beam, generated from a DBR laser tuned to the D2 line of Cs atoms, is converted into linear polarization using a half-wave plate and directed along the x-axis. The probe laser beam intersects the pump laser beam perpendicularly at the center of the atomic vapor cell. As a result of the interaction with the atomic vapor cell, a damping signal is obtained.

Relaxation Time (T_2)

The loss of transverse magnetization is governed by the magnetic interactions between spins and is referred to as spin-spin or transverse decay. The time constant associated with this decay is known as relaxation time (T_2).

The lifetime of the magnetization in the transfer axis is called the relaxation time (T_2) decay time and one of the measurement methods of this period is measured by the Free Induction Method (FID) method. When a $\pi/2$ pulse is applied to the system in a direction perpendicular to the magnetization vector, the magnetization vector is transferred to transfer axis perpendicular to the pump laser beam and the DC magnetic field. This process starts a process by disrupting the initial stable magnetization state of the system. The measurement is based on the relaxation of the total magnetization created in the transfer axis by the pulse signal applied with a certain pulse width and period.

The basic criterion for determining the pulse period is to reapply the pulse after ensuring that the decay period has completely ended. The following Eq. 1 is used to theoretically calculate the pulse width. In Eq.1, γ is the gyromagnetic ratio and B is the DC magnetic field applied to the system [2,3,4].

$$t_{\pi/2} = \frac{1}{4} t_1 = \frac{\pi}{2\gamma B} \quad (1)$$

A sample FID signal from the literature is presented in Fig.3.

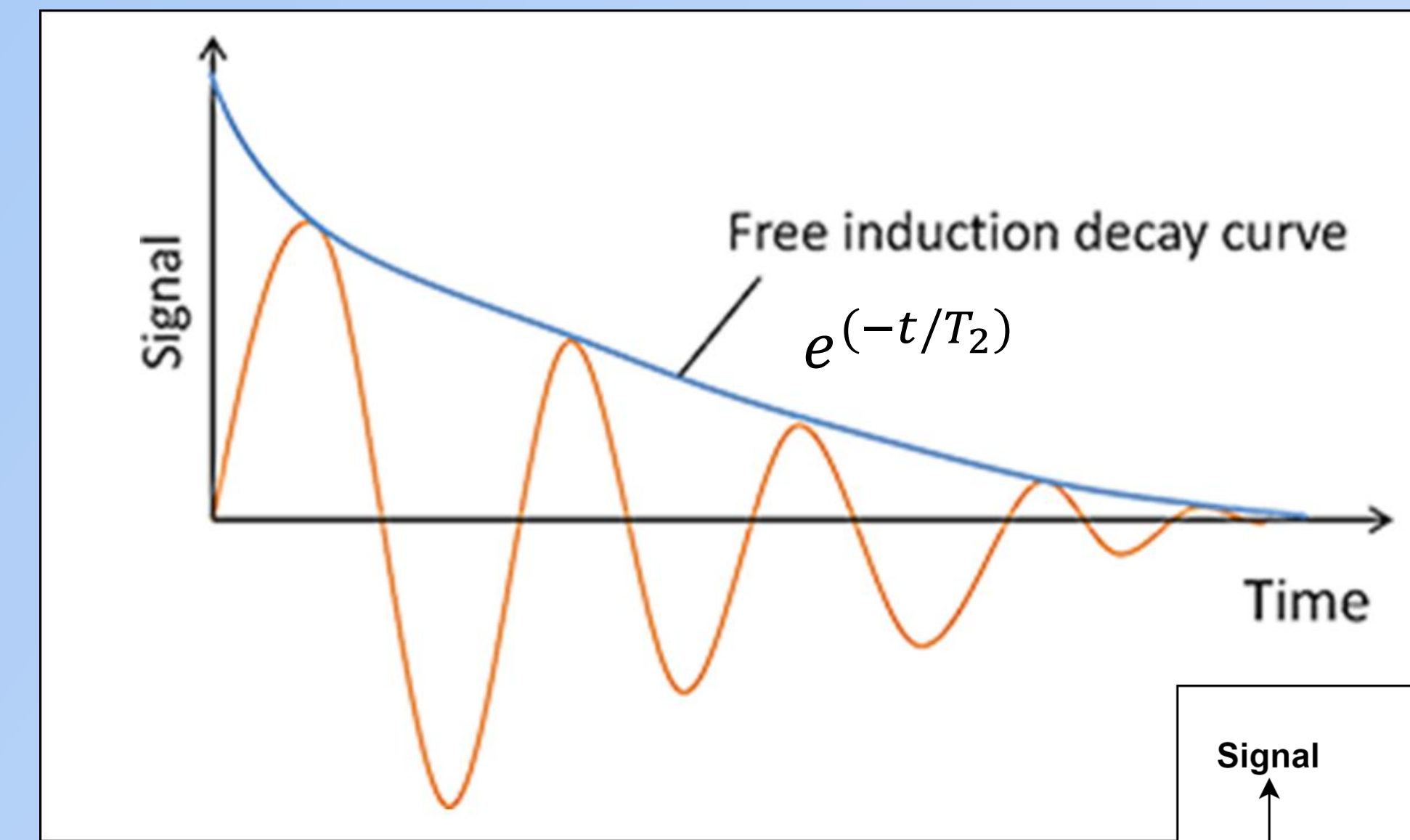


Fig.3 An example FID signal

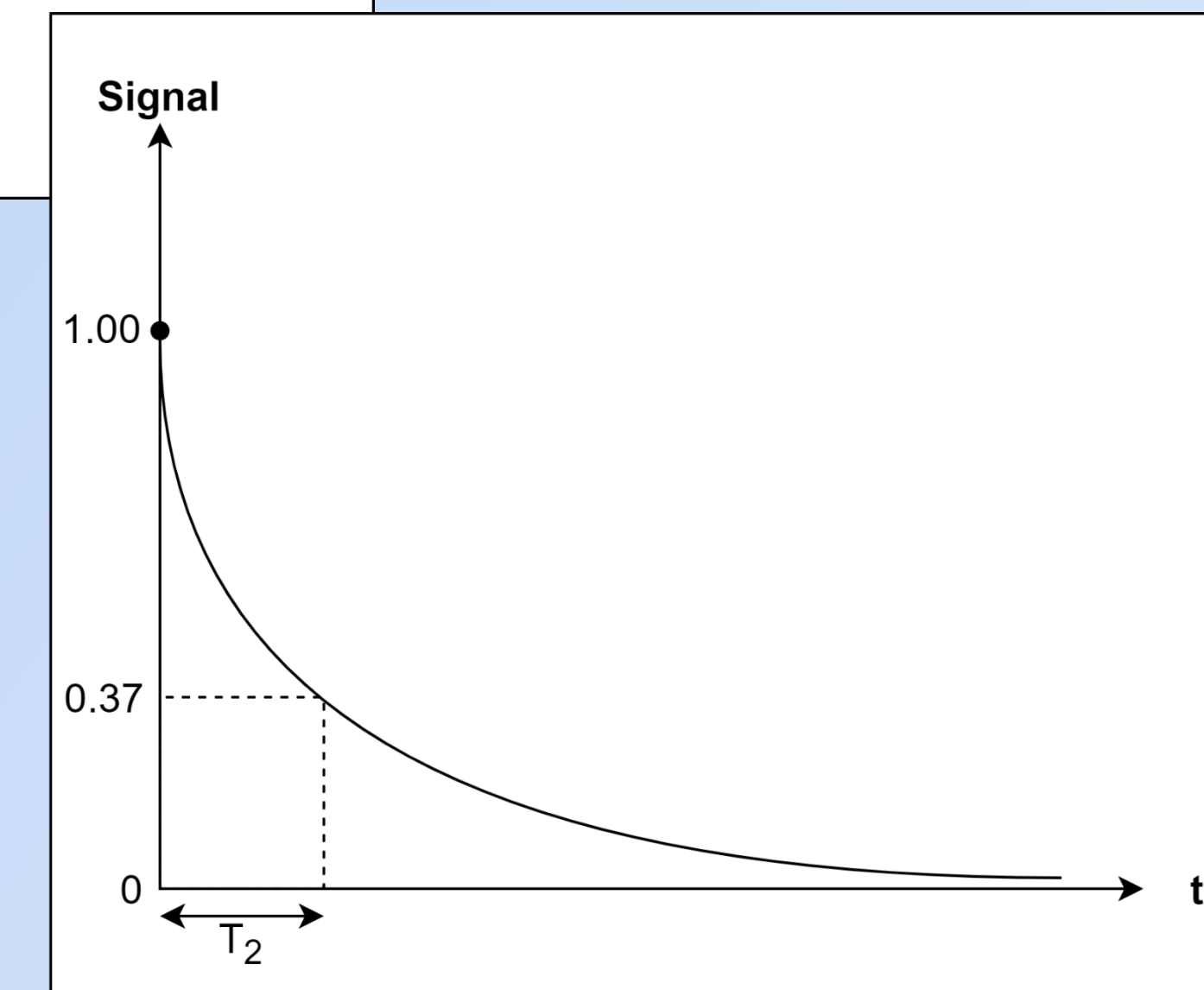


Fig.4 Relaxation time obtained by fitting the FID signal

Relaxation time obtained by fitting the FID signal is presented in Fig.4. Relaxation time (T_2) represents the duration required for transverse magnetization to decrease to 37% of its initial value, meaning that 63% of the original signal is lost [5,6].

Results

The result graph obtained for ^{129}Xe and ^{131}Xe is shown in Fig. 5 and 6

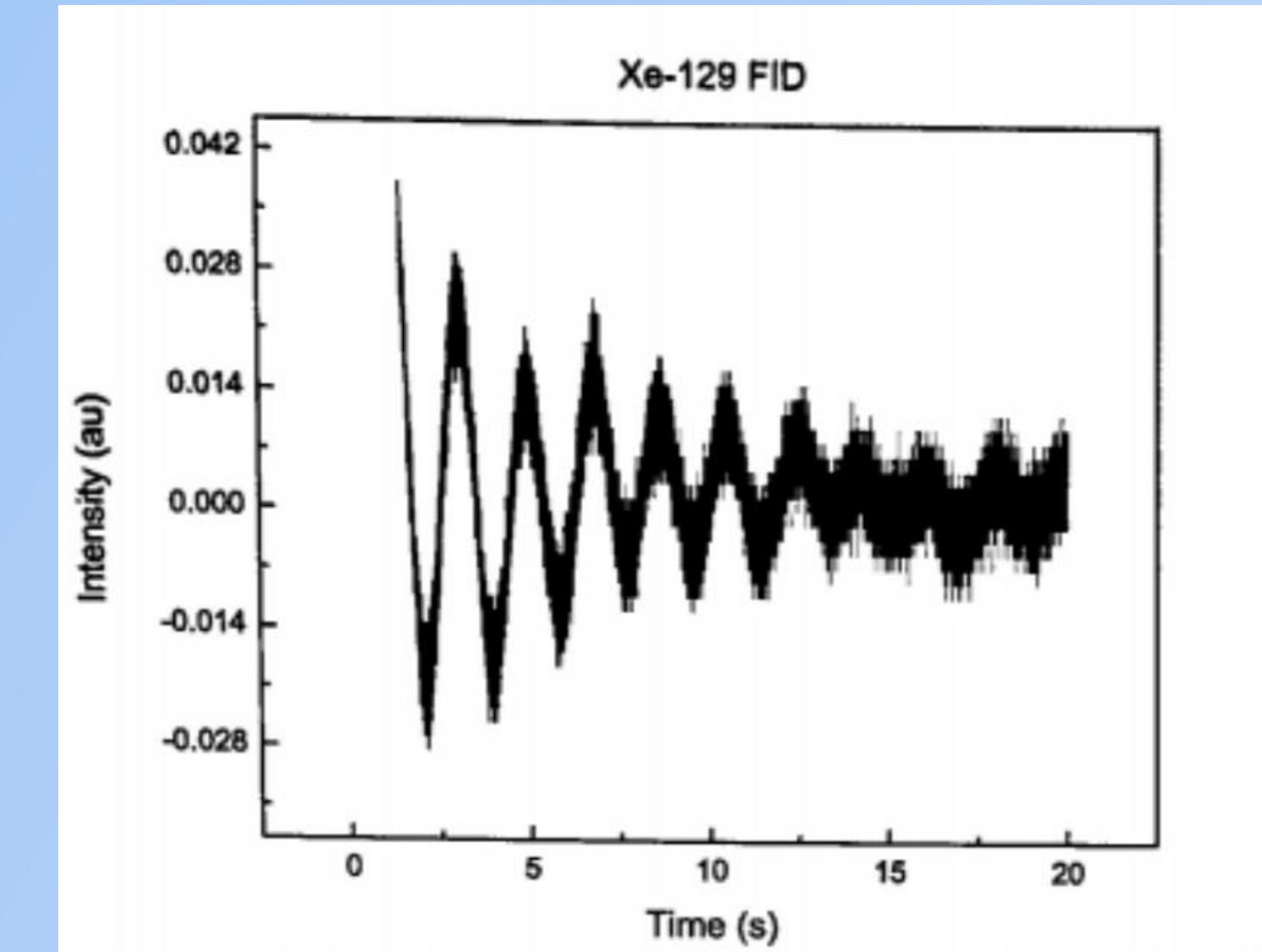


Fig.5 ^{129}Xe FID signal

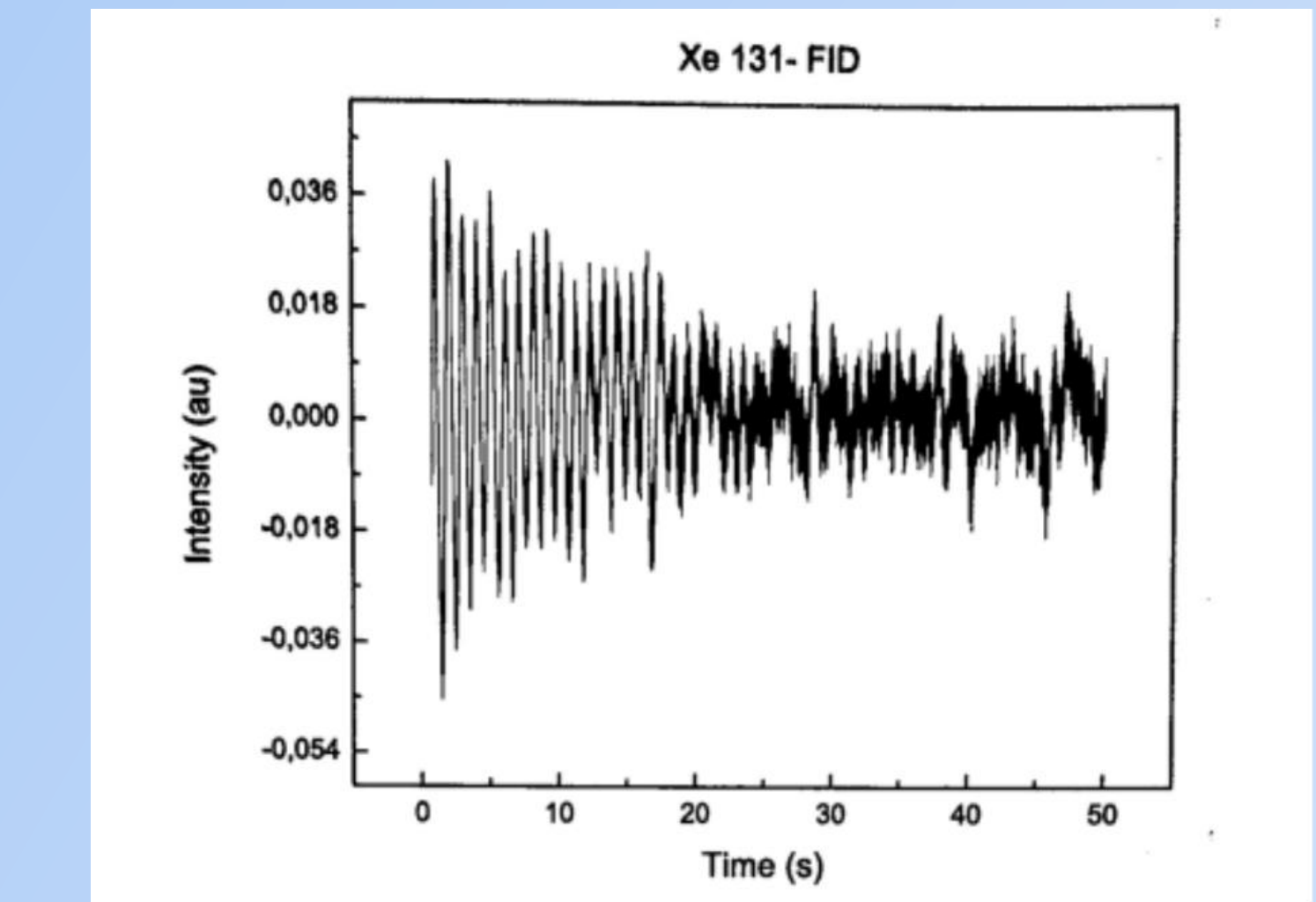


Fig.6 ^{131}Xe FID signal

As a result of the experiment, the relaxation times were found to be ^{129}Xe for isotope 12 s and ^{131}Xe for isotope 24 s.

The relaxation time parameter that we examined in the characterization is of critical importance in atomic sensors. As a type of an atomic sensors, nuclear magnetic resonance gyroscopes (NMRG) utilizes ^{129}Xe and ^{131}Xe atoms along with an alkali metal to measure the rotation rate. Angle random walk (ARW) is main parameter to determine the sensitivity of a NMRG ant it is defined in Eq.2:

$$ARW = \frac{3600}{T_2 * SNR * \sqrt{\Delta f}} [^\circ/\sqrt{h}] \quad (2)$$

Here, T_2 is the spin relaxation time of Xe atoms, SNR is the signal-to-noise ratio and Δf repetition rate of the feedback loop. As seen in Equation, spin relaxation time is one of the key parameter to improve the sensitivity of NMRG.

Conclusion

Since transient magnetization events occur in systems, the relaxation time (decay time), which represents the life time of the magnetization, is examined. This duration is a critical parameter in determining the sensitivity of the sensors.

References

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