Contents

1 Experimental overview

In this experiment we make use of the Hanle Effect to determine the life time of the $^3\mathrm{P}_1$ state of the Mercury Atom.
The experiment is split into six tasks:

1. Calibration of the Helmholtz Coils to compensate the Earth's magnetic field
2. Measure the width of the Hanle-Curve
   (a) for the polarisation 90° at rising temperatures
   (b) for the polarisation 0° at rising temperatures
   (c) for the polarisation 45° at rising temperatures

   by relating the Hanle-Signal to the applied B-field
3. Determine the life time of the $^3P_1$ state of mercury by extrapolating a linear fit to a pressure of 0 Pa
4. Determine the life time from the data obtained at polarisation 45°

2 Theoretical background

In this chapter, all the equations and pictures used, can be found in [1].

2.1 Hanle Effect

In this experiment, we examine the so called Hanle-Effect. What the Hanle Effect is, can be read in the following pages, where the theoretical background shall be explained. We will look at two different explanations. Firstly we will focus on the semi-classical explanation and secondly on the quantum mechanical explanation.

2.1.1 Semi-classical explanation

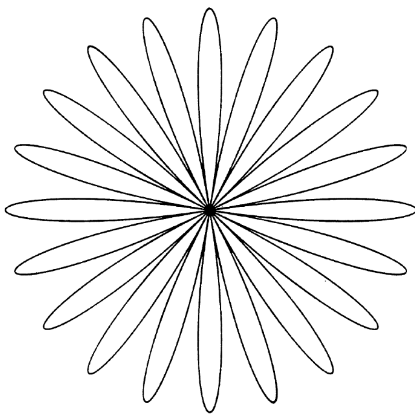
Classically the electron can be seen as a damped harmonic oscillator, which can be exited through linearly polarised light.

This excitation causes the outermost electron to vibrate. Firstly parallel to the polarization direction of the light, until it finally will comes to rest. Now the ansatz is made, that the electron can be seen as a oscillating dipole parallel to the direction of polarization. This dipole has a radiation characteristic of:

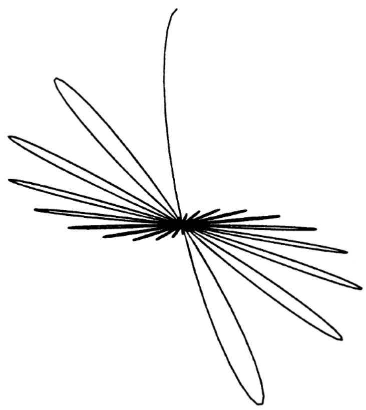
$$I \propto \sin^2(\phi), \tag{1}$$

where ϕ is the angle between the dipole-axis and the direction of detection. herefore it must be, that at an angle of $\phi = 0°$ no radiation can be detected.

Due to a B-field orthogonal to the polarization direction, the electron is precessing inside the B-field. The stronger the magnetic field, the higher is the angular velocity of this precession, which results in a wider angular range before the electron is relaxed. This phenomenon is shown in Figure 1 below.



a) weakly damped oscillator



b) strongly damped oscillator

Figure 1: Precession movement of an oscillator in two diffrent cases

The relaxation of a electron into its groundstate can be written as an exponential decay like the following:

$$N(t) = N_0 e^{-\frac{t}{\tau}}, \tag{2}$$

where $N(t)$ is the occupation number and τ is the mean lifetime of an exited state and $N_0 = N(0)$. Having this relation in mind we can now integrate over the time to calculate the intensity for the radiation of an atom.

$$I = C \int_0^\infty \sin^2(\phi)\, e^{-\frac{t}{\tau}}\, dt \tag{3}$$

Because ϕ can be written as the product of time and lamor frequency $\left(\omega_L = \frac{g_j B \mu_B}{\hbar}\right)$ it follows, that:

$$I = C \int_0^\infty \sin^2(\omega_L t)\, e^{-\frac{t}{\tau}}\, dt \tag{4}$$

If now the polarisation is 90° and therefore parallel to the detector when the photon hits the atom, (t=0 and ϕ=0) the resulting intensity can be written as:

$$I = C\,\tau \frac{(2\omega_L \tau)^2}{1 + (2\omega_L \tau)^2}, \tag{5}$$

while with a polarisation of 0° where t=0 and $\phi = \frac{\pi}{2}$ we get

$$I = C\,\tau \left(1 - \frac{(2\omega_L \tau)^2}{1 + (2\omega_L \tau)^2}\right), \tag{6}$$

those functions correspond to lorentzcurves which are not normalizable which results in the need to use the FWHM[1] to calculate τ.

$$\tau = \frac{\hbar}{g_J \mu_B\, B_{FWHM}} \tag{7}$$

2.1.2 Quantum mechanical explanation

Taking into account the fine structure (Zeeman-effect), it becomes clear that not only the $^3P_1$ but additionally $^3P_2$ and $^3P_0$ can be occupied. These two states relax with the emission of left- or right-circularly polarized light into the ground state. Without an external Magnetic B-field those are degenerate, causing a destructive interference and thus a minimal intensity. Due to Zeeman, this degeneracy can be reversed by applying an external field so that no interference is occurring because every state has a different energy difference to the ground state, and so send out photons with distinguishable wavelengths. So we can now calculate the mean lifetime τ (cf. equation 7) of the $^3P_1$ with the help of the Breit-formula (which can be found in [2])

[1] full width at half maximum

2.2 Line widening

Due to the following effects the spectral lines are widened.

2.2.1 Heisenberg uncertainty

The uncertainty of energy and time is known as:

$$\Delta E \Delta t \geq \hbar \tag{8}$$

whereas in this case Δt is replaced by τ. This means that the energy and the time of a particle can only be determined at the same time to an accuracy of $\hbar$. Therefore we get an uncertainty on the energy difference of:

$$\Delta E \geq \frac{\hbar}{\tau} \tag{9}$$

2.2.2 Doppler effect

Due to the high velocities of atoms in gas, we can not neglect the Doppler effect. some Atoms are moving away and others towards the photomultiplier. which results in red respectively blue shift and so in a widening of the frequency of the spectral line.

$$\Delta\omega = \frac{\omega_0}{c}\sqrt{\frac{kT}{m}} \tag{10}$$

2.2.3 Coherence narrowing

This is an effect that makes the life span appear longer than it really is. Already absorbed Photons that have been re-emitted can be re-absorbed. They retain phase, Precession and spatial orientation of the previous atom and pass them on to the next atom. The probability of this effect, which can also occur often, depends on the vapour pressure of the mercury, which then depends on the temperature. To eliminate this factor we measure at different temperatures (different pressures) and extrapolate to $p = 0$Pa.

$$p = p_c \cdot e^{\left(\frac{T_c}{T}\right)(a_1 T_r + a_2 T_r^{1,89} + a_3 T_r^2 + a_4 T_r^8 + a_5 T_r^{8,5} + a_6 T_r^9)} \tag{11}$$

Where T_c is the critical temperature and p_c the critical pressure, and:

$$T_r = 1 - \frac{T}{T_c}$$
$$T_c = 1764 \text{ K}$$
$$p_c = 167 \text{ MPa}$$

$$a_1 = -4.57618368 \qquad a_2 = -1.40726277 \qquad a_3 = 2.36263541$$
$$a_4 = -31.0889985 \qquad a_5 = 58.0183959 \qquad a_6 = -27.6304546$$

3 Experimental setup

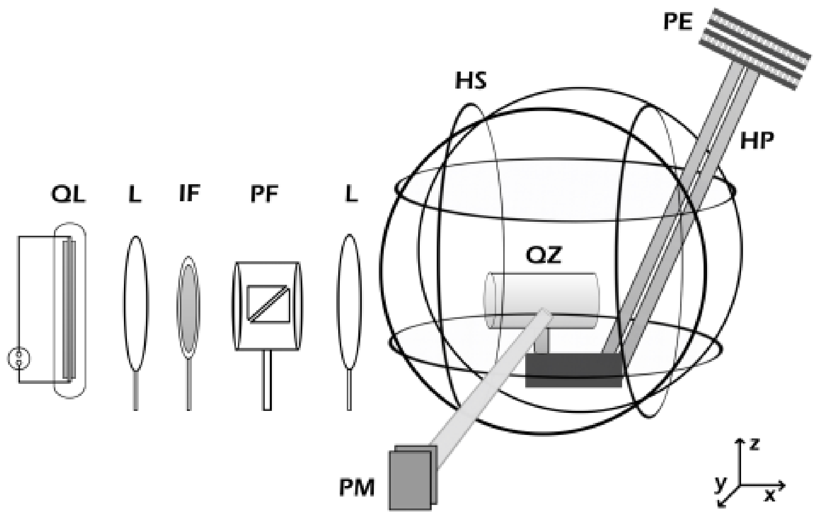


Figure 2: Experimental Setup [1]

The experimental setup (fig. 2) consists of the following elements:

- a mercury vapor lamp (QL) as a light source
- two lenses (L) to focus the optical path
- an interference filter (IF), transmitting only a a wavelenght of (255 ± 5) nm
- a polarisation filter (PF) which allows us to adjust the polarisation with a degree scale
- a mercury vapor resonance cell (QZ) which consists of a quartz glass cylinder with liquid mercury inside.
- the cooling system consists of four Peltier elements (PE) which are connected to the resonance cell by a heat pipe (HP) and are cooled by a water pipe
- three pairs of Helmholtz coils to compensate the earth's magnetic field and to generate the Hanle signal by crossing the zero point where the Zeeman-splitting vanishes.
- a photomultiplier (PM), which measures the fluorescence signal in the direction orthogonal to the incoming beam.

Two of the Helmholtz Coil pairs (the ones in y- and z- direction) are used to anulate the magnetic field of the earth the one in x-direction to set the B-field for the degenerate states.

4 Execution of the experiment

At first the cooling for the PE has to be turned on to cool the Hg-atoms to -16 °C. Secondly the power supplies for the Helmholtz coils and the photo multiplier. which are then calibrated until a signal appears o the oscilloscope. For this we used the following settings:

$$I_y = (-0.1111 \pm 0.005)\text{A} \qquad U_y = (-1.092 \pm 0.01)\text{V}$$
$$I_z = (-0.2739 \pm 0.005)\text{A} \qquad U_z = (-2.427 \pm 0.01)\text{V}$$
$$I_x = (-0.9913 \pm 0.005)\text{A} \qquad U_x = (-10.155 \pm 0.01)\text{V}$$

For the Photo multiplier we set the Full scale to 10^{-6} A and the small scale to 1 A. After the temperature was cooled down, measurements of three polarisations (90° 45° and 0°) are measured for every temperature step of 1°C.

5 Data analysis

5.1 Conversion of Time Into Magnetic Field

The calculations described in this section have been performed with the software pyROOT.

To convert the full width at half maximum Δt which we obtain from the curve fits to the measured data in section 5.2 into a magnetic field B_{FWHM}, we first have to calculate the slope a of the linearly ascending magnetic field. The Amplitude, which is measured in V by the oscilloscope, can be considered as an electric current according to [1], so we can write:

$$a = \frac{dI}{dt} \tag{12}$$

The slope a is obtained by a linear fit to the magnetic field which is displayed in figure 3. Because we did not change the slope during the experiment, we use the result for the entire data analysis. We refrained from plotting the error bars in order to improve the visibility of the data points.

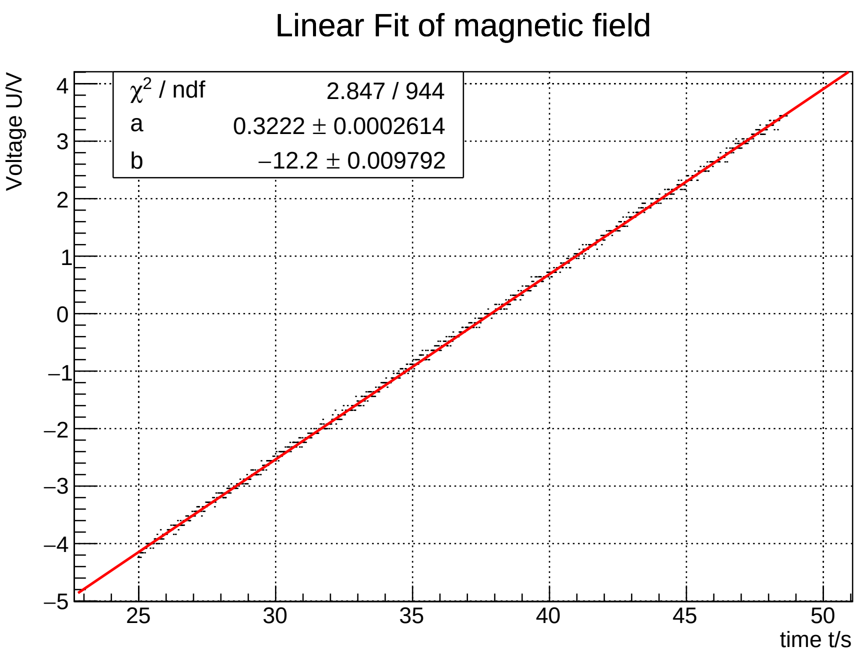


Figure 3: linearly ascending magnetic field

The linear fit yields:

$$a = (0.3222 \pm 0.0003)\frac{\mathrm{A}}{\mathrm{s}} \tag{13}$$

Now we can calcuate the magnetic field B_{FWHM} which corresponds to Δt by employing the conversion factor which is given in [1]:

$$C \equiv \frac{dB}{dI} = 3.363 \cdot 10^{-4}\frac{T}{A} \tag{14}$$

$$\Longrightarrow B_{\mathrm{FWHM}} = C \cdot a \cdot \Delta t \tag{15}$$

We can use B_{FWHM} to calculate the life time τ according to equation 7:

$$\tau = \frac{\hbar}{g_J \mu_B B_{\text{FWHM}}}$$

The uncertainties on the quantities above are calculated according to the gaussian error propagation as follows:

$$s_{B_{\text{FWHM}}} = B_{\text{FWHM}} \sqrt{(\left(\frac{s_a}{a}\right)^2 + \left(\frac{s_{\Delta t}}{\Delta t}\right)^2} \tag{16}$$

$$s_\tau = \tau \frac{s_{B_{\text{FWHM}}}}{B_{\text{FWHM}}} \tag{17}$$

5.2 Calculation of Δt

Polarisation angle 0°: To obtain the Δt values for polarisation angle 0°, we plot the corresponding signal and fit a function which, according to equation 6, is a Lorentz curve. Therefore we can use a fit function of the lorentzian form

$$f(t) = \alpha + \beta \frac{1}{1 + \gamma(t - t_0)^2} \tag{18}$$

Where t_0 is the location parameter, β the height parameter and α the amplitude offset generated by background radiation. The fit parameter γ corresponds to the FWHM Δt according to the relation

$$\Delta t = \frac{2}{\sqrt{\gamma}} \tag{19}$$

The uncertainty on Δt is obtained from the statistical uncertainty s_γ as follows:

$$s_{\Delta t} = \gamma^{-\frac{3}{2}} s_\gamma \tag{20}$$

Exemplarily, we show one of the peaks with its corresponding Lorentz curve fit in figure 4. We refrain from plotting error bars to improve the visibility of the data points.

The peak corresponding to every measurement can be found in appendix 7.2.1.

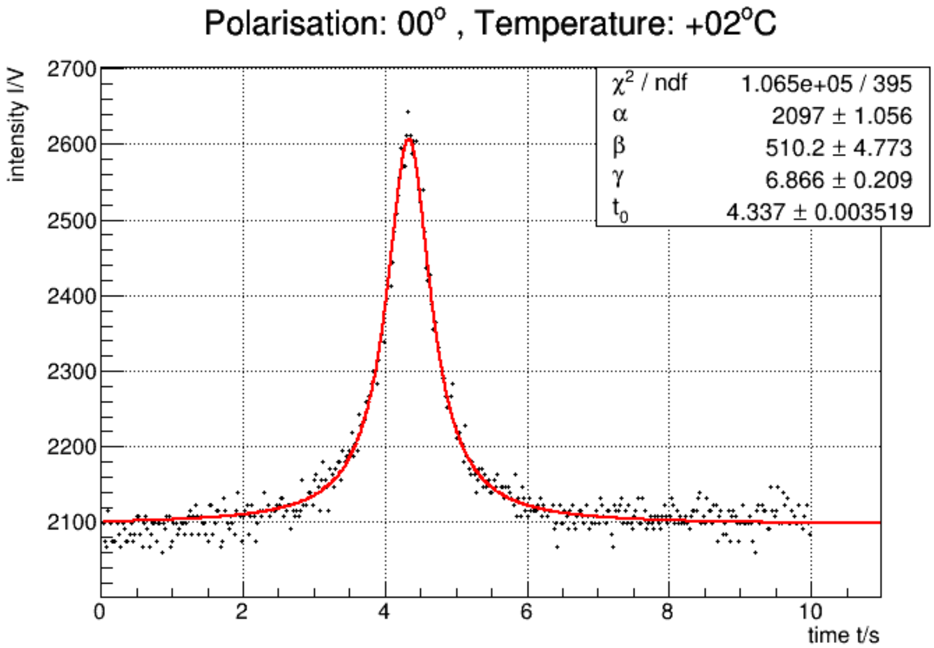


Figure 4: Plot of data and Lorentz curve fit for polarisation 0° and temperature +2°C

Polarisation angle $90°$**:** The calculation of Δt for polarisation $90°$ is analogous to $0°$, but with a minus sign to take into account that the signal is an inverted Lorentz curve:

$$f(t) = \alpha - \beta \frac{1}{1 + \gamma (t - t_0)^2} \tag{21}$$

An example of the $90°$ Lorentz fits is displayed in fig. 5.

The (inverted) peak corresponding to every measurement can be found in appendix 7.2.2.

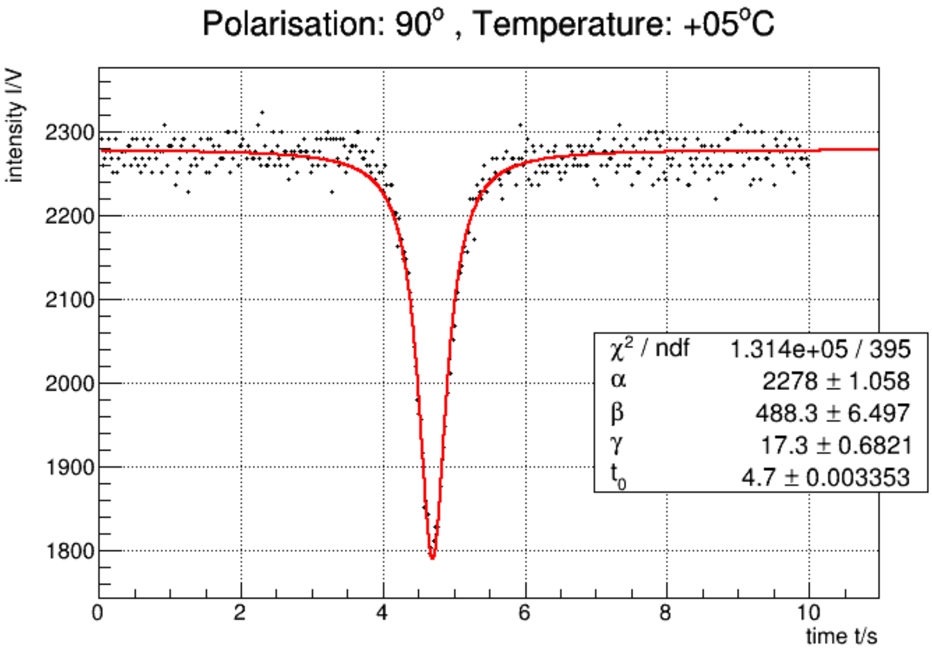


Figure 5: Plot of data and Lorentz curve fit for polarisation $90°$ and temperature $+5°$C

Polarisation angle 45°**:** Concerning the dispersion curves we measured at polarisation angle 45°, we consider the thought process that, according to [1], the curve is the derivative of a Lorentz function (equation 18):

$$f'(t) = \alpha - \frac{2\beta\gamma(t-t_0)}{(1+\gamma(t-t_0)^2)^2} \tag{22}$$

Where we still expect equation 19 to hold.

An example of the 45° dispersion curve fits is displayed in fig. 6.

The dispersion curve corresponding to every measurement can be found in appendix 7.3.

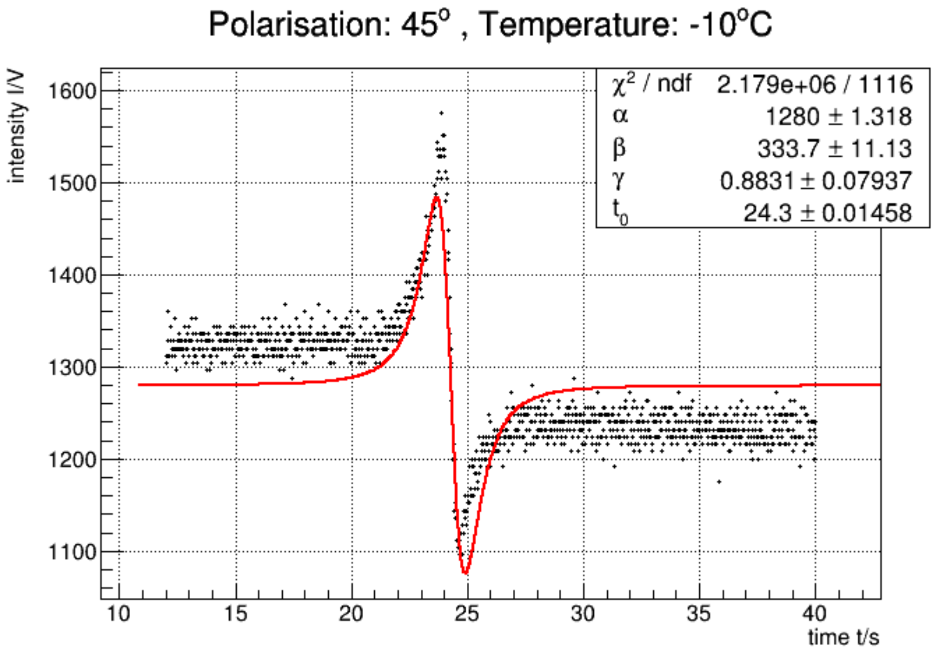


Figure 6: Plot of data and dispersion curve fit for polarisation 45° and temperature -10°C

All the τ values obtained are displayed in appendix 7.1.

5.3 Correction of half life period

Because of coherence narrowing (cf. section 2.2.3), we have to correct the half life periods obtained in section 5.2. This is done by extrapolating the function $\tau(p)$ to $p = 0\text{Pa}$. The pressure p in the mercury cell can be calculated from the measured temperatures according to equation 11:

$$p = p_c \cdot e^{\left(\frac{T_c}{T}\right)(a_1 T_r + a_2 T_r^{1,89} + a_3 T_r^2 + a_4 T_r^8 + a_5 T_r^{8,5} + a_6 T_r^9)}$$

Where $T_r = 1 - \frac{T}{T_c}$ and the constants p_c, T_c and $\{a_i\}_{i=1}^6$ can be considered as exact values [1]. Gaussian error propagation yields:

$$s_p = \sqrt{\left|\frac{\partial p}{\partial T}\right|^2 s_T^2} = p \cdot \left|\frac{\partial \xi}{\partial T}\right| \cdot s_T \tag{23}$$

$$\text{where} \quad \xi \equiv \left(\frac{T_c}{T}\right)\left(a_1 T_r + a_2 T_r^{1,89} + a_3 T_r^2 + a_4 T_r^8 + a_5 T_r^{8,5} + a_6 T_r^9\right) \tag{24}$$

$$\begin{aligned} \text{and} \quad \frac{\partial \xi}{\partial T} &= -\frac{T_c}{T^2}\left(a_1 T_r + a_2 T_r^{1,89} + a_3 T_r^2 + a_4 T_r^8 + a_5 T_r^{8,5} + a_6 T_r^9\right) \\ &+ \frac{1}{T}\left(a_1 + 1.89 a_2 T_r^{0.89} + 2a_3 T_r + 8a_4 T_r^7 + 8.5 a_5 T_r^{7.5} + 9a_6 T_r^8\right) \end{aligned} \tag{25}$$

To get the true half life period τ_0, we plot τ as a function of p and extrapolate a linear fit to $\tau_0 = \tau(p = 0\text{Pa})$. The linear fit has the form

$$\tau(p) = mp + \tau_0 \tag{26}$$

This yields the following values:

polarisation angle [°]	τ_0 [ns]
0	91.17 ± 1.5
90	125 ± 4
45	33.7 ± 0.4

The τ values and the linear fit corresponding to each polarisation angle are displayed in figures 7, 8 and 9.

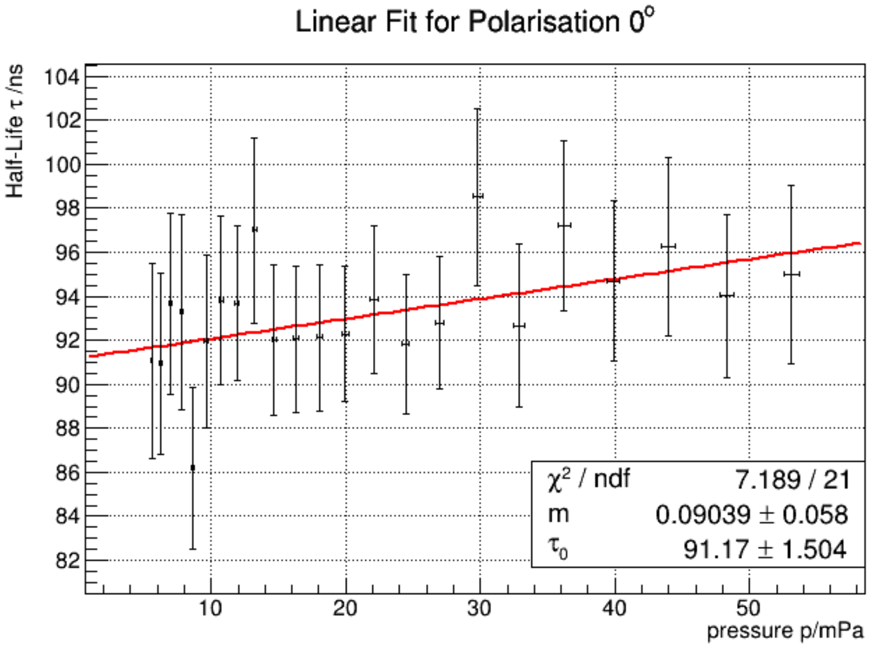


Figure 7: τ (p) data points and linear fit for polarisation angle 0°

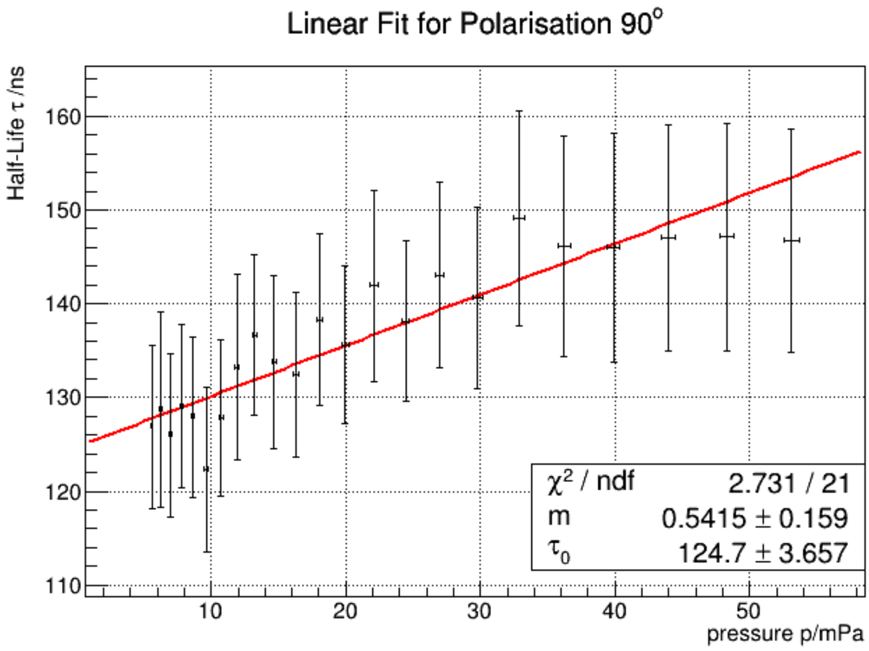


Figure 8: τ (p) data points and linear fit for polarisation angle 90°

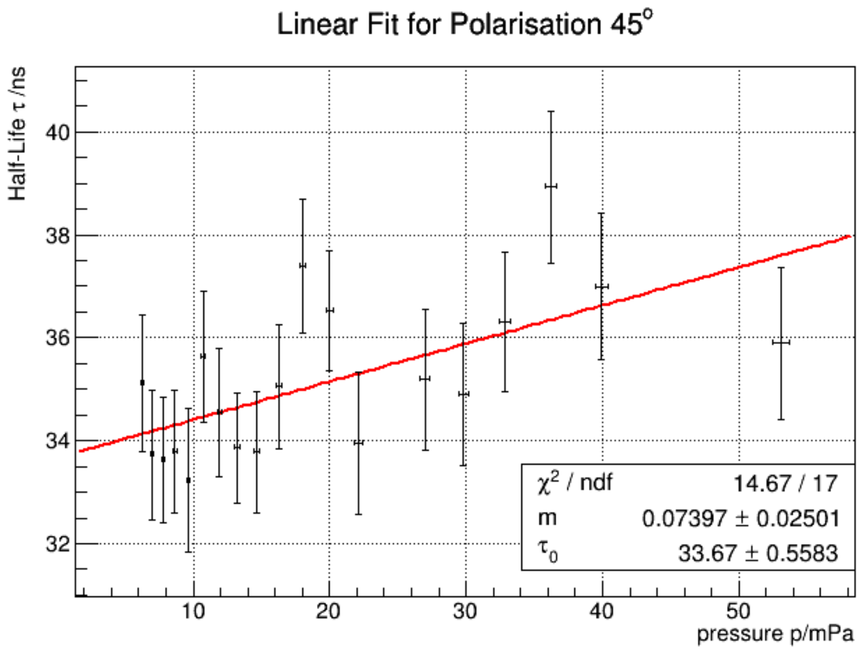


Figure 9: τ (p) data points and linear fit for polarisation angle 45°

6 Summary and Discussion of Results

By measuring the emission of excited mercury atoms at different polarisation angles (with respect to the angle of detection) of the light which excites the atoms, we were able to determine the life time τ_0 of the $^3\mathrm{P}_1$ state of mercury to the following values:

polarisation angle [°]	τ_0 [ns]
0	91.17 ± 1.5
90	125 ± 4
45	33.7 ± 0.4

The value for the polarisation angle 90° coincides within 2σ with the reference value $\tau \approx 19$ns [1]. This is a rather good confirmation of the theory. However, the values for the polarisation angles 0° and 45° are far off the reference value. Particularly so, the bad τ_0 value for 45° comes from the systematically too large fit parameter γ which seems to be caused by an asymmetrically distorted signal. As can be observed in appendix 7.3, the fit function does not match the 45° data very well. The distorted signal, as well as the bad τ_0 value for 90°, could be explained by an imperfect calibration of the Helmholtz Coils which are meant to level out the earth's magnetic field at the location of the mercury cell. Besides, the determination of the offset of the polarisation angle might have not been accurate enough. Also, during the measurements there might have been disruptive magnetic fields caused by the electronic devices in the experimental setup and the neighbouring experiments.

7 Appendix

7.1 $\tau(T)$ values

	τ [ns]		
T [°C]	polarisation 0°	polarisation 90°	polarisation 45°
-15	91 ± 4	127 ± 9	
-14	91 ± 4	129 ± 10	35.1 ± 1.3
-13	94 ± 4	126 ± 9	33.7 ± 1.3
-12	93 ± 4	129 ± 9	33.6 ± 1.2
-11	86 ± 4	128 ± 9	33.8 ± 1.2
-10	92 ± 4	122 ± 9	33.2 ± 1.4
-9	94 ± 4	128 ± 8	35.6 ± 1.3
-8	94 ± 4	133 ± 10	34.5 ± 1.3
-7	98 ± 4	137 ± 9	33.9 ± 1.1
-6	92 ± 3	134 ± 9	33.8 ± 1.2
-5	92 ± 3	134 ± 9	35.0 ± 1.2
-4	92 ± 3	132 ± 9	37.4 ± 1.3
-3	92 ± 3	138 ± 8	36.5 ± 1.2
-2	94 ± 3	136 ± 10	34.0 ± 1.4
-1	92 ± 3	142 ± 9	
0	93 ± 3	138 ± 10	35.2 ± 1.4
1	99 ± 4	141 ± 10	35.9 ± 1.4
2	93 ± 4	149 ± 11	36.3 ± 1.4
3	97 ± 4	146 ± 12	38.9 ± 1.5
4	95 ± 4	146 ± 12	37.0 ± 1.4
5	96 ± 4	147 ± 12	
6	94 ± 4	147 ± 12	
7	95 ± 4	143 ± 12	35.9 ± 1.5

Table 1: $\tau(T)$ values for the different polarisation angles. At 45°, some measurements were not performed.

7.2 Lorentz Curve Fits

7.2.1 0° Peaks

In this section, the measured peaks and the respective Lorentz curve fits are displayed for polarisation angle 0°.

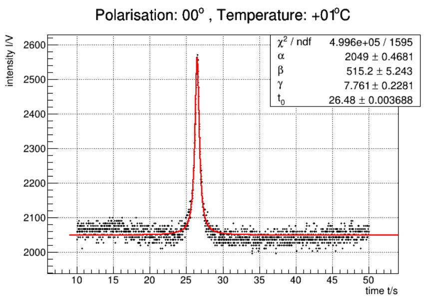


Figure 10: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature +1.0°C

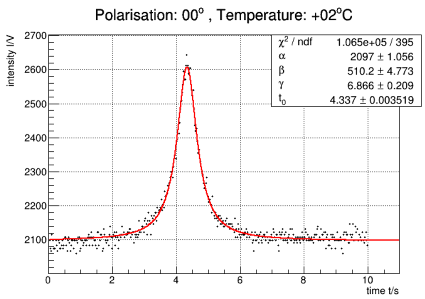


Figure 11: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature +2.0°C

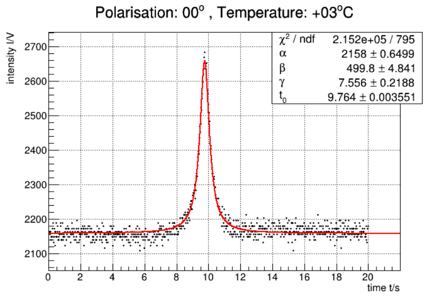


Figure 12: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature +3°C

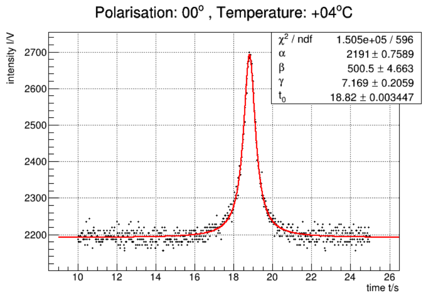


Figure 13: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature +4°C

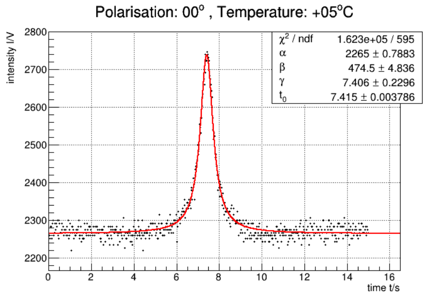


Figure 14: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature +5°C

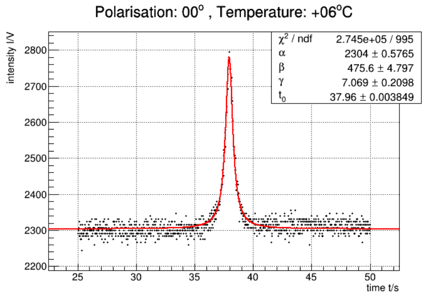


Figure 15: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature +6°C

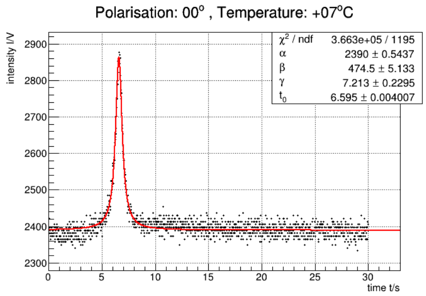


Figure 16: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature +7°C

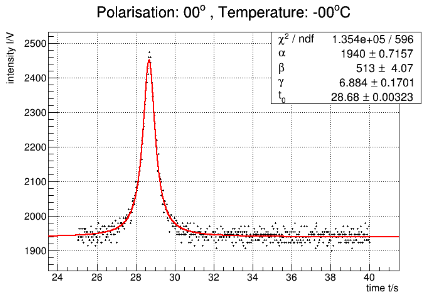


Figure 17: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature 0°C

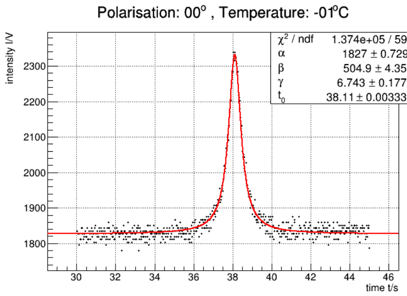


Figure 18: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature -1°C

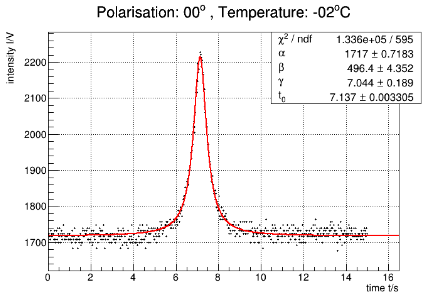


Figure 19: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature -2°C

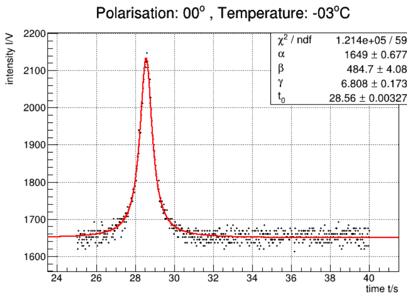


Figure 20: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature -3°C

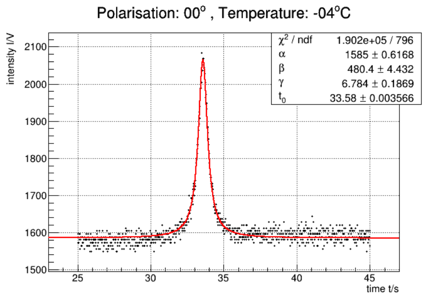


Figure 21: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature -4°C

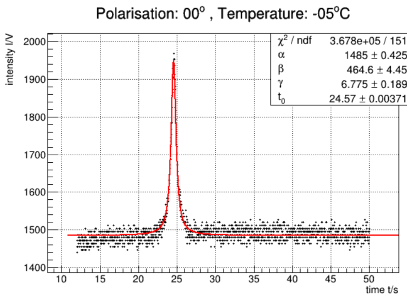


Figure 22: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature -5°C

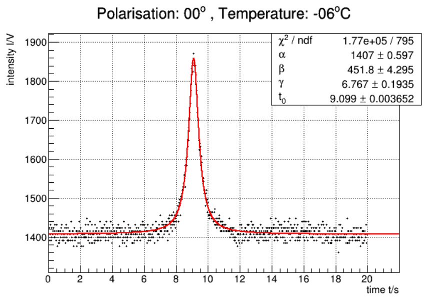


Figure 23: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature -6°C

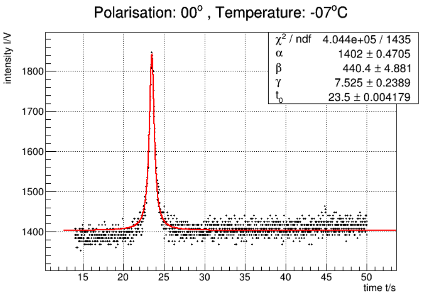


Figure 24: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature -7°C

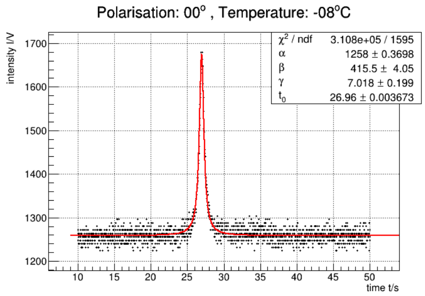


Figure 25: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature -8°C

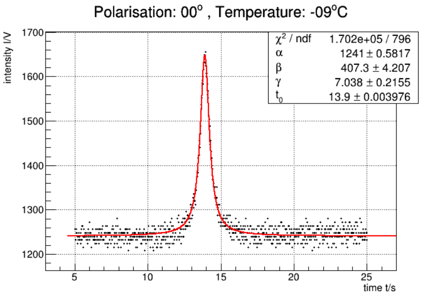


Figure 26: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature -9°C

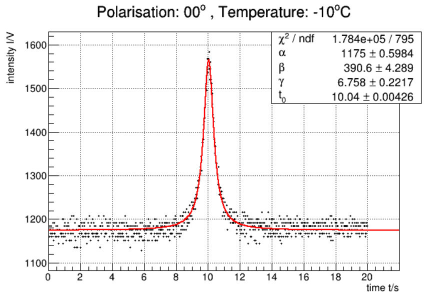


Figure 27: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature -10°C

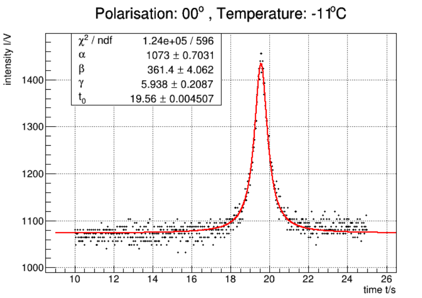


Figure 28: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature -11°C

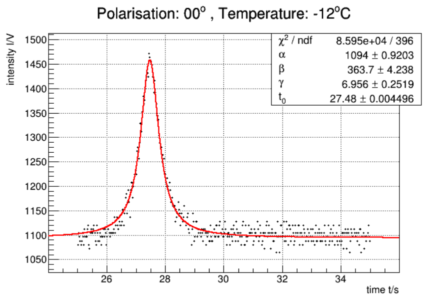


Figure 29: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature -12°C

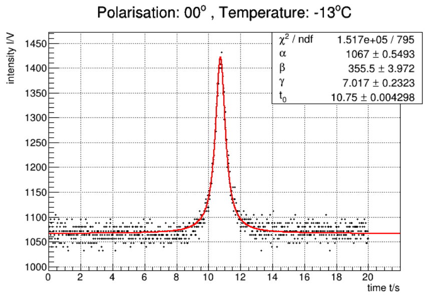


Figure 30: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature -13°C

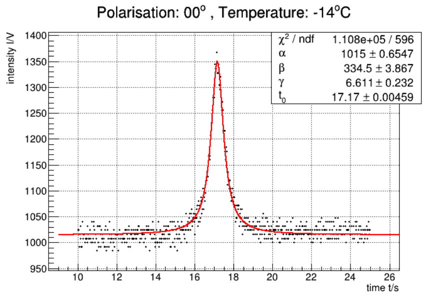


Figure 31: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature -14°C

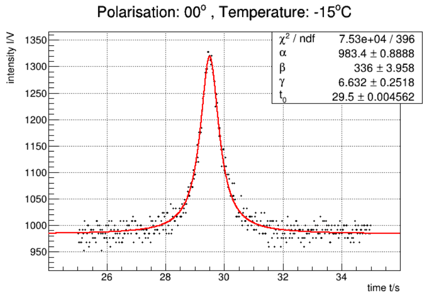


Figure 32: Plot of Data and Lorentz Curve Fit for polarisation 0° and temperature -15°C

7.2.2 90° Peaks

In this section, the measured peaks and the respective Lorentz curve fits are displayed for polarisation angle 90°.

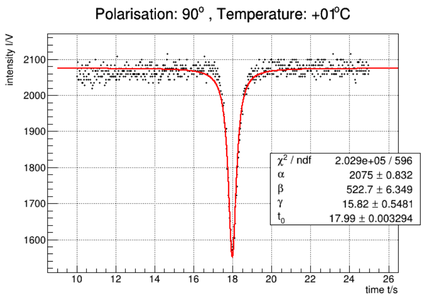


Figure 33: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature +1.0°C

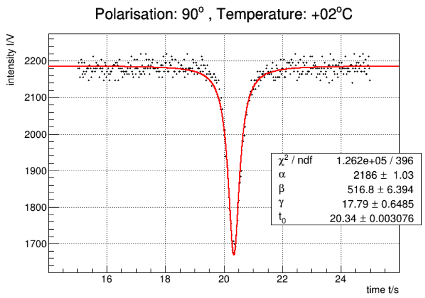


Figure 34: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature +2.0°C

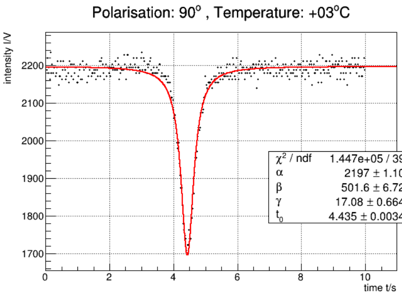


Figure 35: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature +3°C

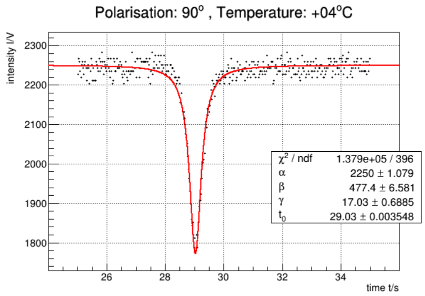


Figure 36: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature +4°C

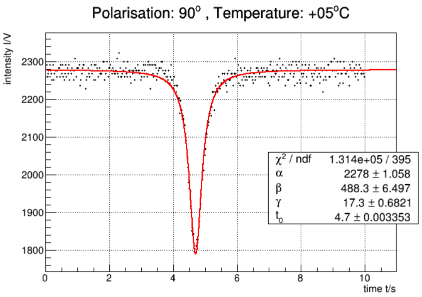


Figure 37: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature +5°C

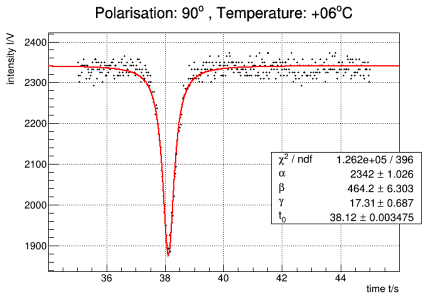


Figure 38: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature +6°C

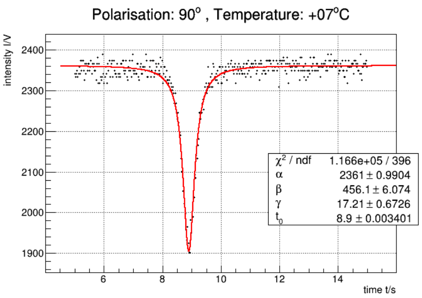


Figure 39: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature +7°C

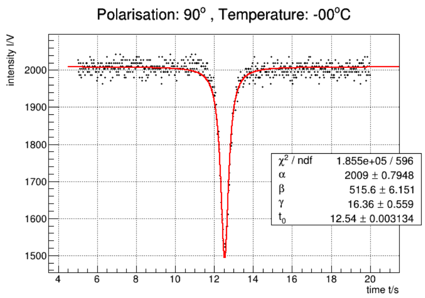


Figure 40: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature 0°C

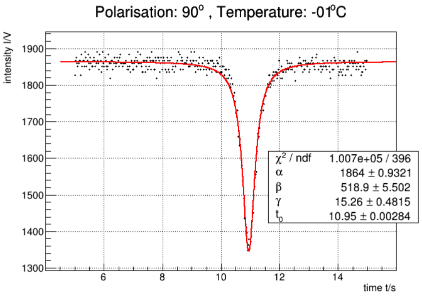


Figure 41: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature -1°C

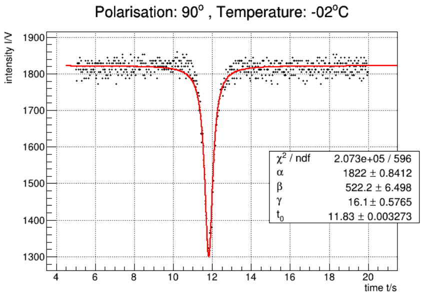


Figure 42: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature -2°C

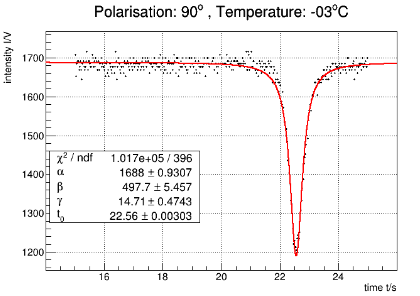


Figure 43: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature -3°C

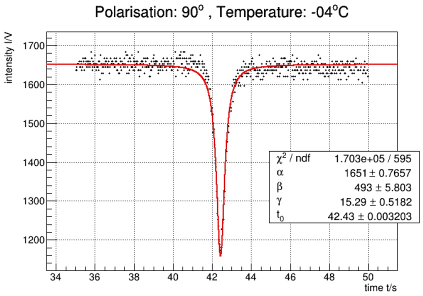


Figure 44: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature -4°C

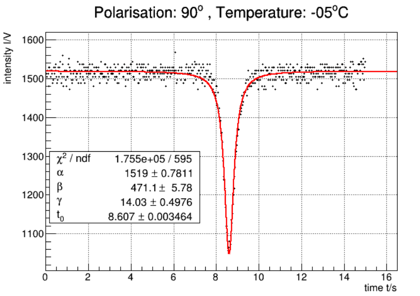


Figure 45: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature -5°C

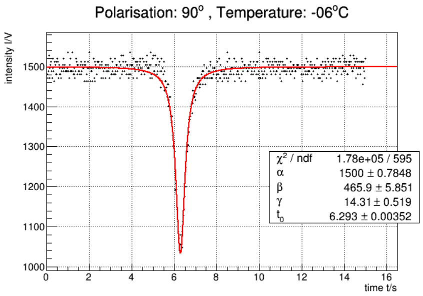


Figure 46: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature -6°C

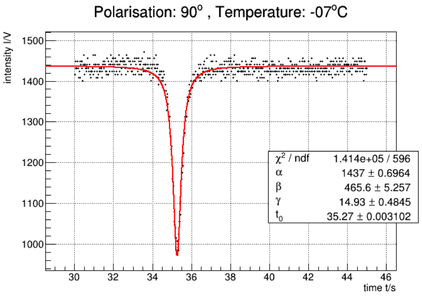


Figure 47: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature -7°C

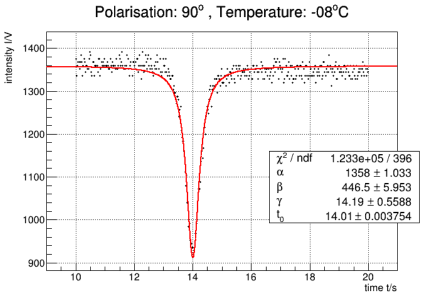


Figure 48: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature -8°C

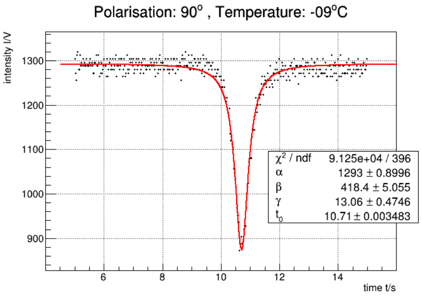


Figure 49: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature -9°C

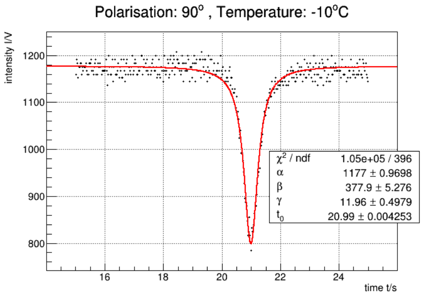


Figure 50: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature -10°C

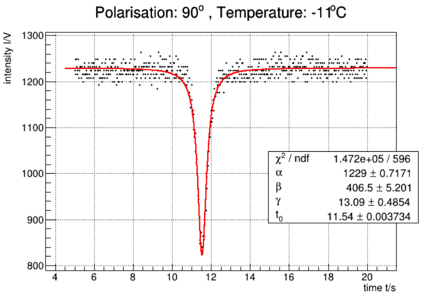


Figure 51: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature -11°C

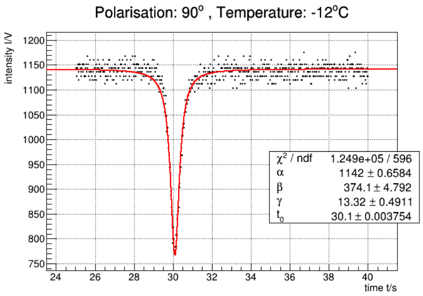


Figure 52: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature -12°C

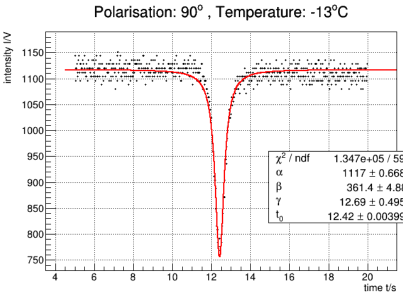


Figure 53: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature -13°C

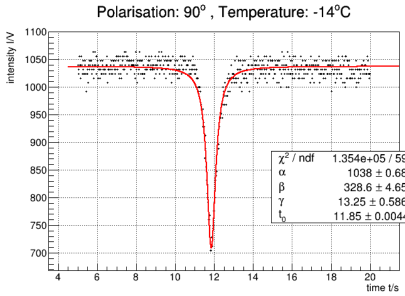


Figure 54: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature -14°C

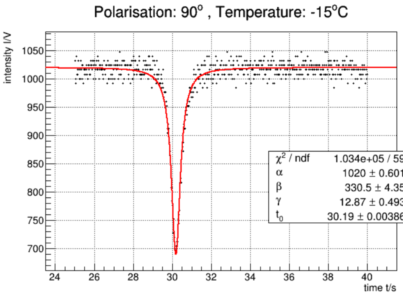


Figure 55: Plot of Data and Lorentz Curve Fit for polarisation 90° and temperature -15°C

7.3 Dispersion Curve Fits to 45° Curves

In this section, the measured peaks and the dispersion curve fits are displayed for polarisation angle 45°.

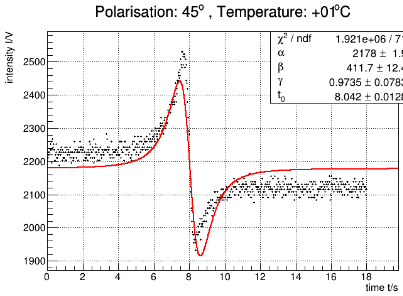


Figure 56: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature +1.0°C

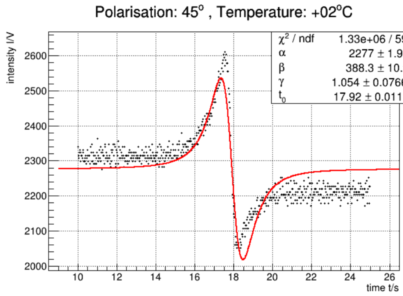


Figure 57: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature +2.0°C

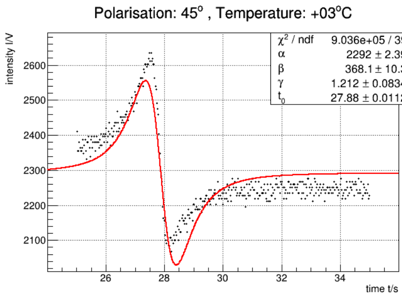


Figure 58: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature +3°C

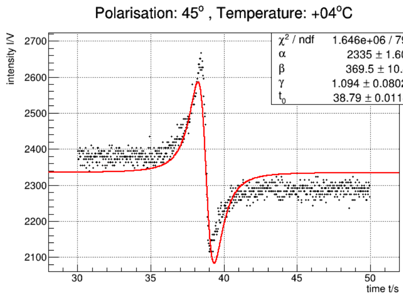


Figure 59: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature +4°C

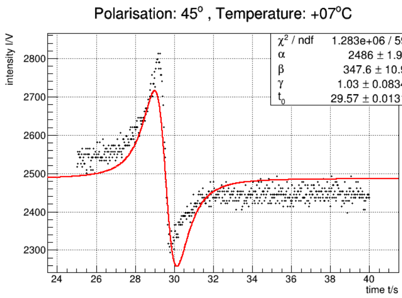


Figure 60: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature +7°C

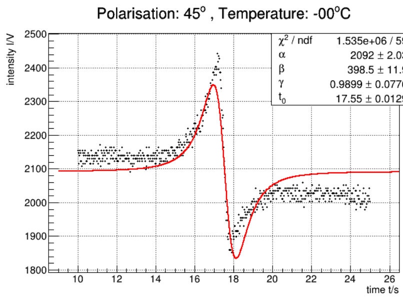


Figure 61: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature 0°C

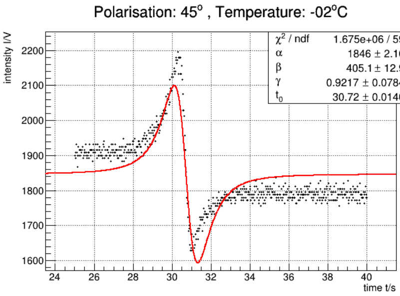


Figure 62: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature -2°C

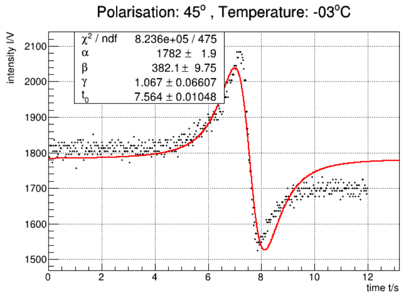


Figure 63: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature -3°C

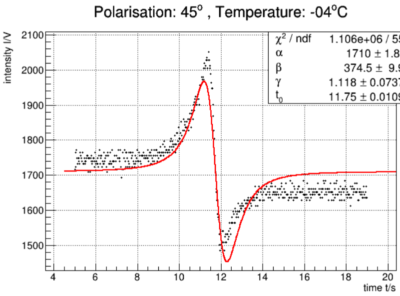


Figure 64: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature -4°C

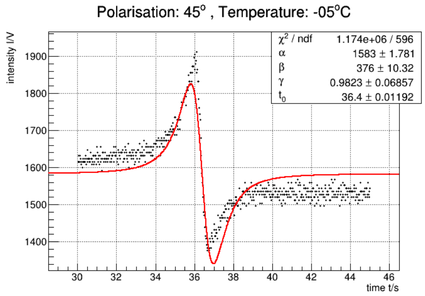


Figure 65: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature -5°C

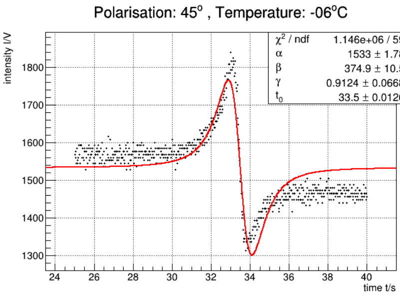


Figure 66: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature -6°C

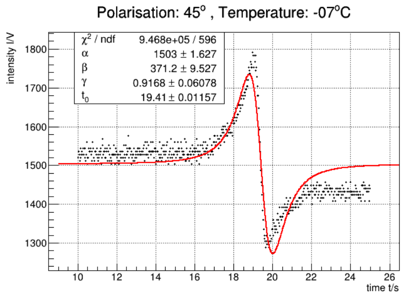


Figure 67: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature -7°C

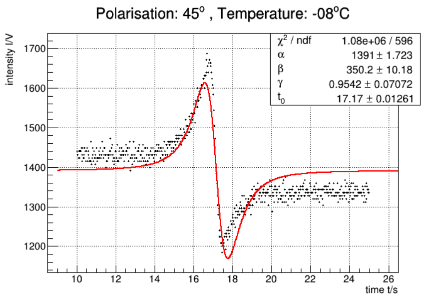


Figure 68: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature -8°C

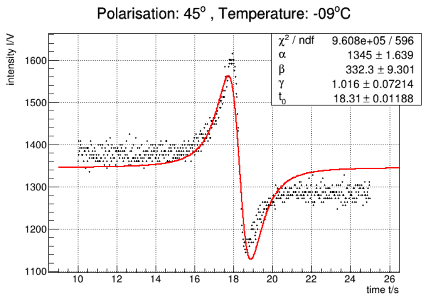


Figure 69: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature -9°C

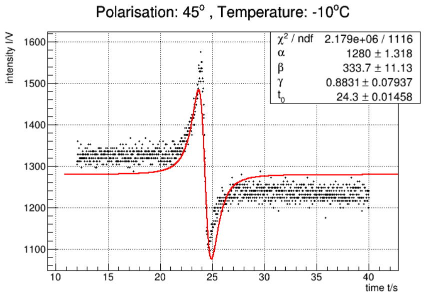


Figure 70: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature -10°C

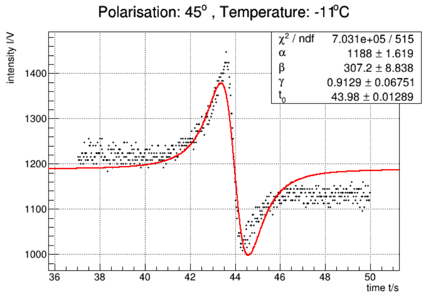


Figure 71: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature -11°C

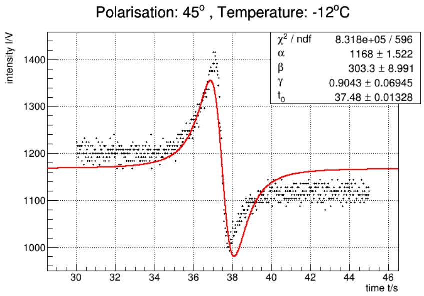


Figure 72: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature -12°C

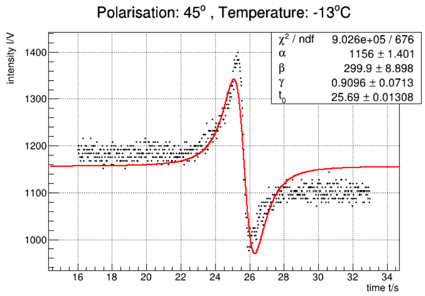


Figure 73: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature -13°C

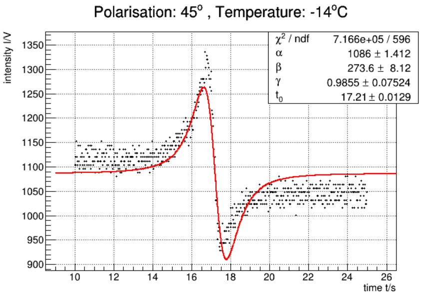


Figure 74: Plot of Data and Lorentz Curve Fit for polarisation 45° and temperature -14°C

7.4 Lab Notes

7.9.2018

Hanle Effect:

Calibration of Helmholtz Coils:

$I_y = 0{,}5959\ A$

$I_z = 0{,}0134\ A$

$I_x = -0{,}9893\ A$

Uncertainty: $s_I = 0{,}0005\ A$

Photomultiplier:

Full scale: $10^{-5}\ A$

Small scale: $0{,}03\ A$

Offset Polarisator: 6°

Uncertainty Polarisation: $s_\alpha = 0{,}5^\circ$

Peltier power supply:

$U = (16{,}0 \pm 0{,}05)\ V$

$I = (7{,}50 \pm 0{,}005)\ A$

$\alpha = 90^\circ, 0^\circ, 45^\circ$ (incl. Offset) for all Temperatures

$T = -15^\circ C, -14^\circ C, \ldots, 7^\circ C$

Uncertainty $s_T = 0{,}5^\circ C$

New Measurement:

90° data_Name ≙ Deg_±Temp eg. 90-15.csv

00+2.csv

0°

45°

new settings

$I_y = -0{,}1111$ $U_y = -1{,}092$

$I_z = -0{,}2739$ $U_z = -2{,}427$

$I_x = -0{,}9913$ $U_x = -10{,}155$

$s_I = 0{,}005$ $s_U = 0{,}01$

Photomultiplier:

Full Scale 10^{-6} A

Small Scale 1 A

10.09.2018

[illegible]

References

[1] KOEHLI, M. / Gessner, M. / Fischer, S. *Versuchsanleitung, Fortgeschrittenen Praktikum Teil 1, Der Hanle Effekt, Universität Freiburg, August 2010.*

[2] *Breit, G.: Quantum Theory of Dispersion: Parts VI and VII , Reviews of Modern Physics, 05.02.1933*