Nobel prize

- **Otto Stern, USA:** Nobel Prize in Physics 1943, "for his contribution to the development of molecular ray method and his discovery of the magnetic moment of the proton"
- **Isidor I. Rabi, USA:** Nobel Prize in Physics 1944, "for his resonance method for recording the magnetic properties of atomic nuclei"
- **Felix Bloch, USA and Edward M. Purcell, USA:** Nobel Prize in Physics 1952, "for their discovery of new methods for nuclear magnetic precision measurements and discoveries in connection therewith"
- **Richard R. Ernst, Switzerland:** Nobel Prize in Chemistry 1991, "for his contributions to the development of the methodology of high resolution nuclear magnetic resonance (NMR) spectroscopy
- **Kurt Wüthrich, Switzerland:** Nobel Prize in Chemistry 2002, "for his development of nuclear magnetic resonance spectroscopy for determining the three-dimensional structure of biological macromolecules in solution"
- **Paul C. Lauterbur, USA and Peter Mansfield, United Kingdom:** Nobel Prize in Physiology or Medicine 2003, "for their discoveries concerning magnetic resonance imaging"

Theory

- Nuclear spin and nuclear magnetic moment

$$\vec{u} = \gamma \vec{s}.$$

- Interaction with magnetic field

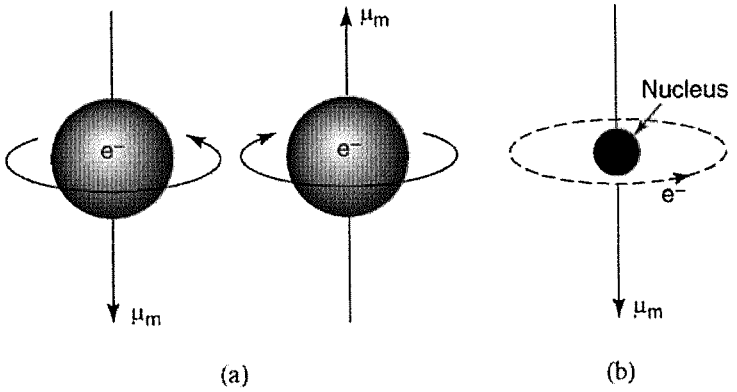
$$E = -\vec{u} \cdot \vec{B}_o.$$

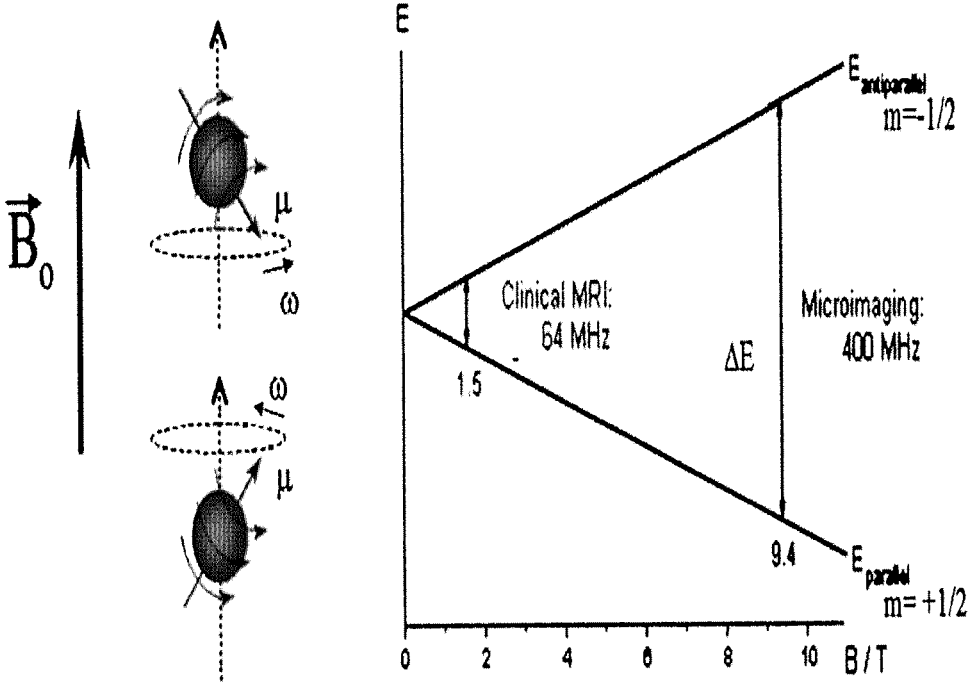
$$E = (\gamma m_z \hbar B_o) = u_z B_o$$

$$\Delta E = \gamma \hbar B_o$$

$$\Delta E = \hbar\omega = \hbar 2\pi f = hf$$

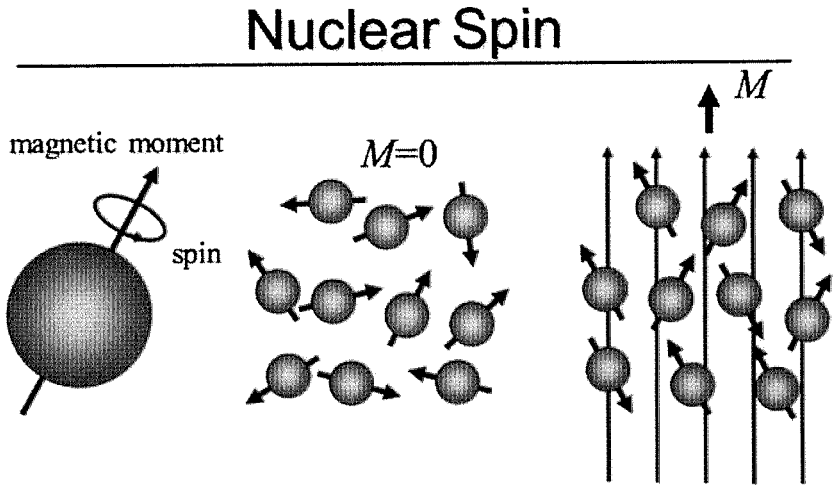
$$f = (\gamma B_0)/2\pi$$





Theory

- Spin-lattice relaxation time : T_1 : component of M ll to B



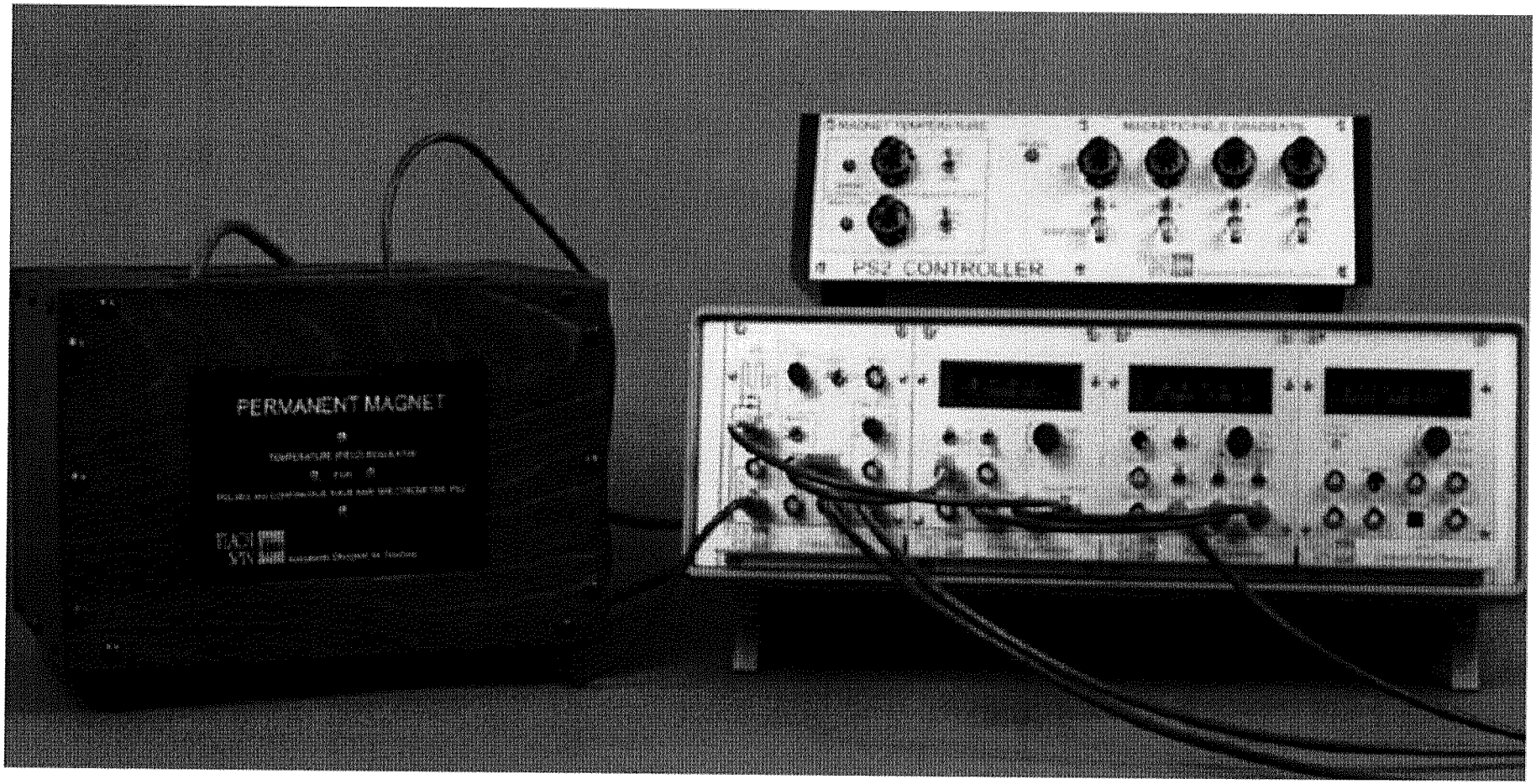
If a nucleus has an unpaired proton it will have spin and it will have a net magnetic moment or field

- Spin-spin relaxation time : T_2

Component of M $\perp$ B

Experiment

- A) Experimental set up



Experiment

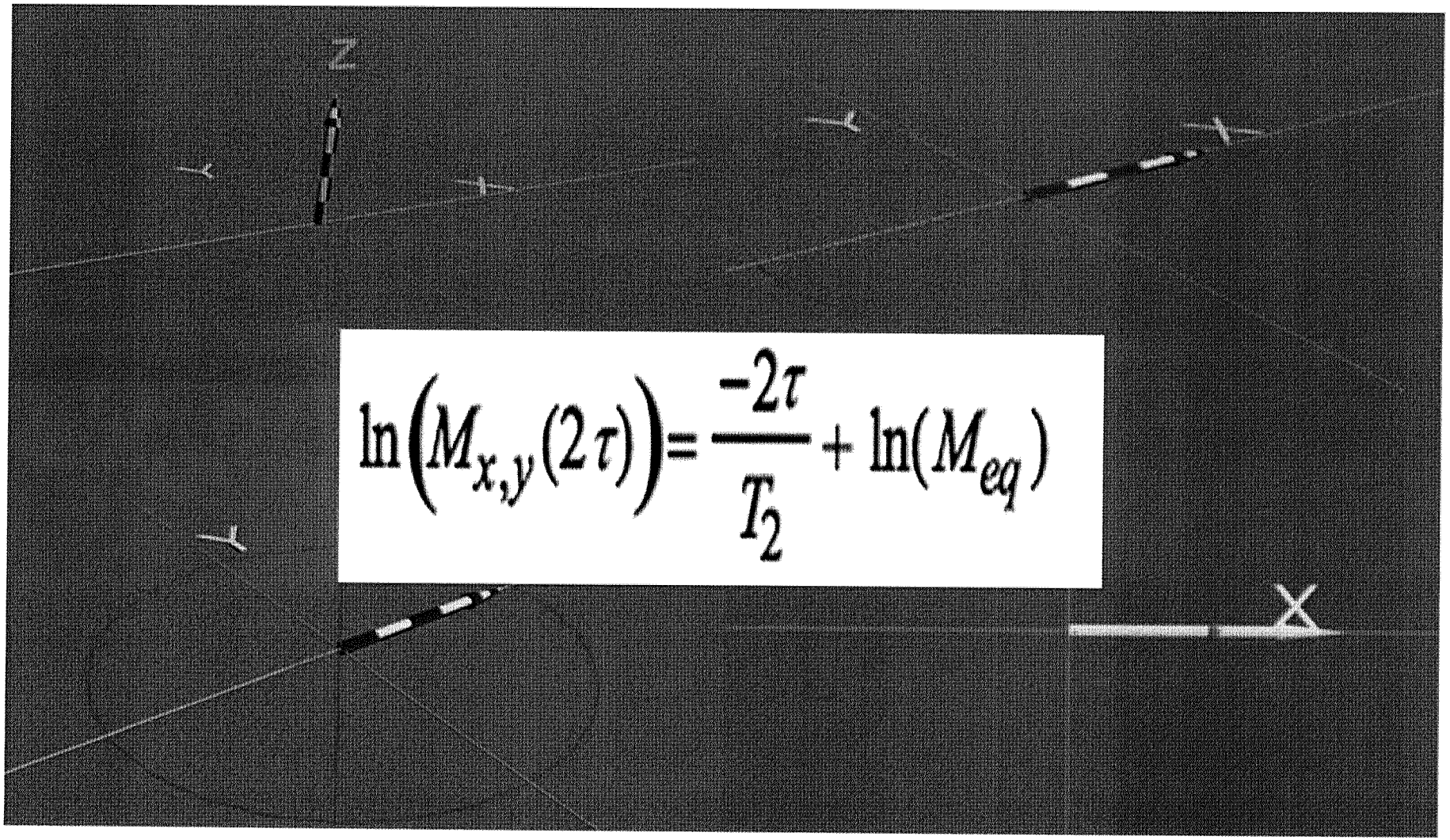
- B) Method for measuring T_1

$$180^0 \text{---} \tau \text{---} 90^0$$

$$\ln\left[\frac{M_{eq} - M(\tau)}{2M_{eq}}\right] = \frac{-\tau}{T_1}$$

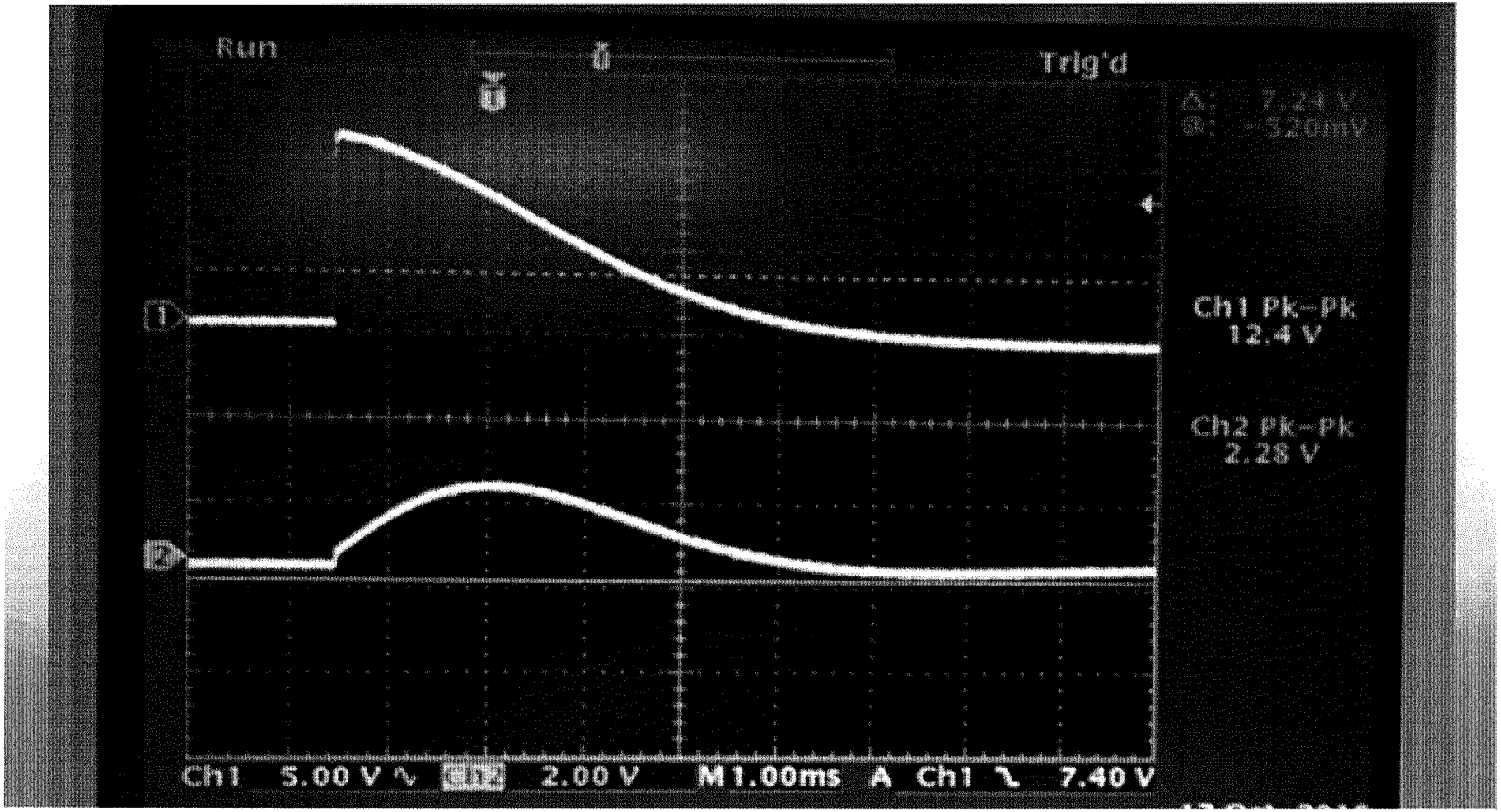
Experiment

- C) Method for measuring T_2 90^0--- τ ---180^0 --- τ --- echo (2τ)



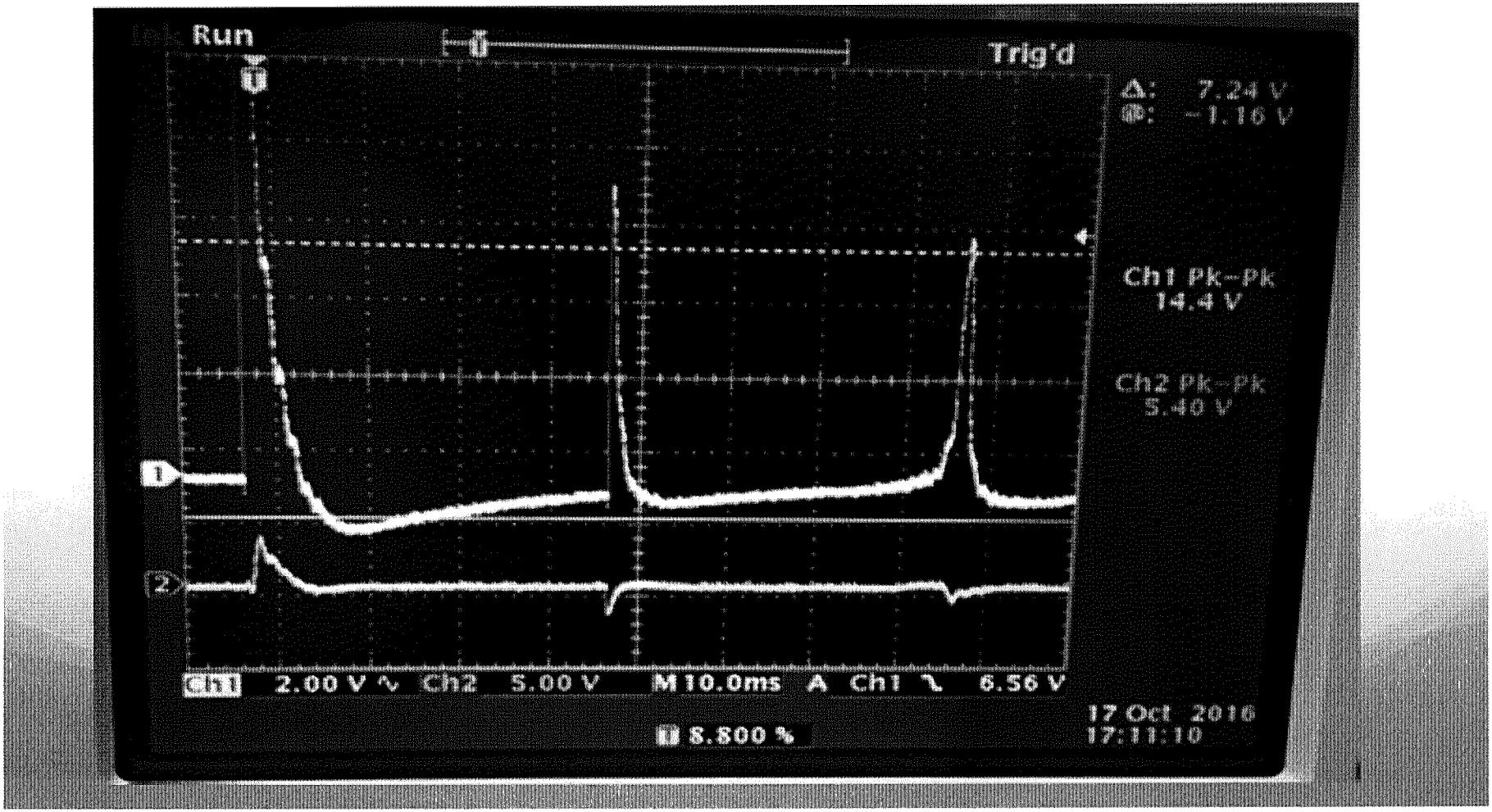
Results

- T_1 signal (M(t)) for glycerin



Results

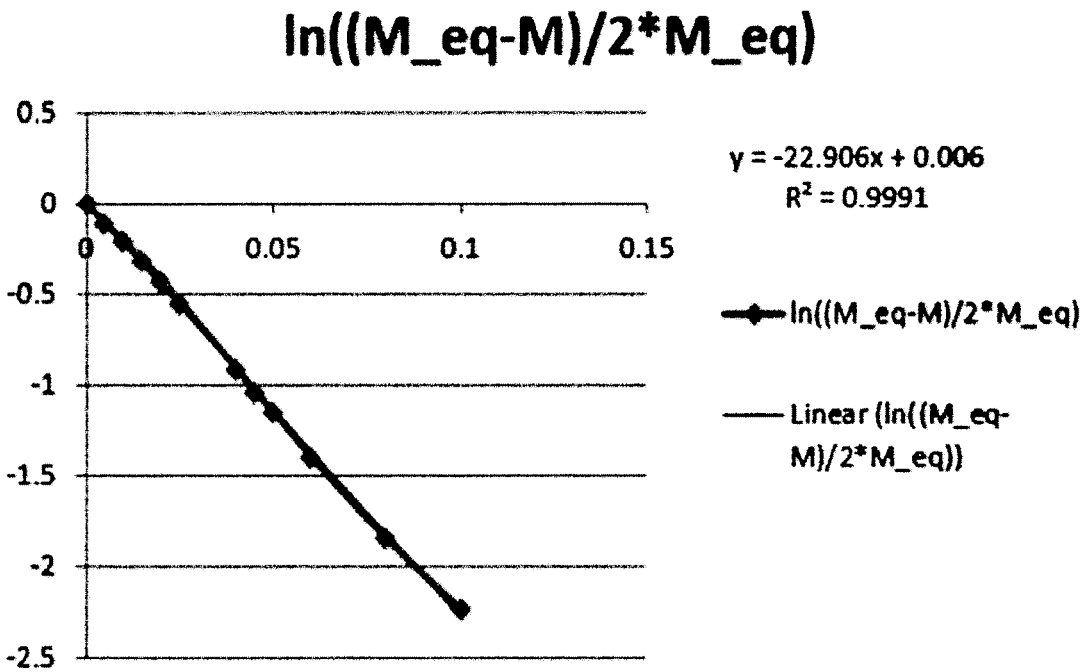
- T_2 signal (M(t)) for glycerin



Results

- T_1 results

tau	M(t) two	M_eq	ln((M_eq-M)/2*M_eq)
0	-12.6	12.7	-0.003944778
0.005	-9.95	12.7	-0.114589322
0.01	-7.8	12.7	-0.214324288
0.015	-5.8	12.7	-0.316978442
0.02	-3.8	12.7	-0.431388793
0.025	-1.95	12.7	-0.550308839
0.04	2.55	12.7	-0.917275469
0.045	3.73	12.7	-1.040863498
0.05	4.7	12.7	-1.155307632
0.06	6.44	12.7	-1.400568989

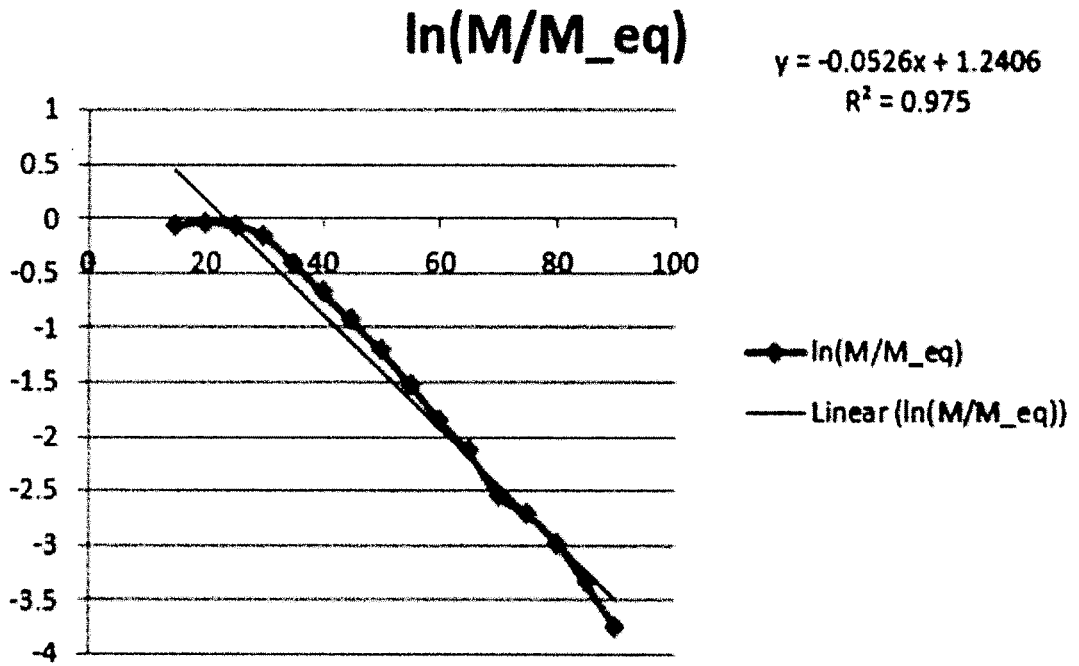


T_1 = 0.04366 s , error = 7 %

Results

- T_2 results

tau	M(t)	M_eq	ln(M/M_eq)
15	12	12.7	-0.0566953
20	12.3	12.7	-0.0320027
25	12	12.7	-0.0566953
30	10.9	12.7	-0.1528392
35	8.5	12.7	-0.4015358
40	6.5	12.7	-0.6697998
45	5	12.7	-0.9321641
50	3.8	12.7	-1.2066009
55	2.8	12.7	-1.5119826
60	2	12.7	-1.8484548
65	1.5	12.7	-2.1361369
70	1	12.7	-2.541602
75	0.85	12.7	-2.7041209
80	0.65	12.7	-2.9723849
85	0.45	12.7	-3.3401097
90	0.3	12.7	-3.7455748

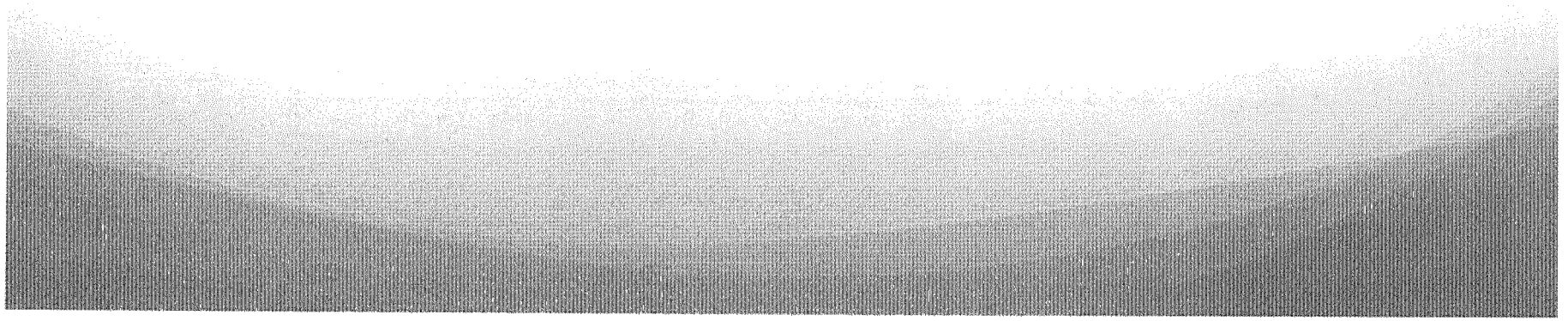


T_2 = 0.01901 s , error = 9%

Results

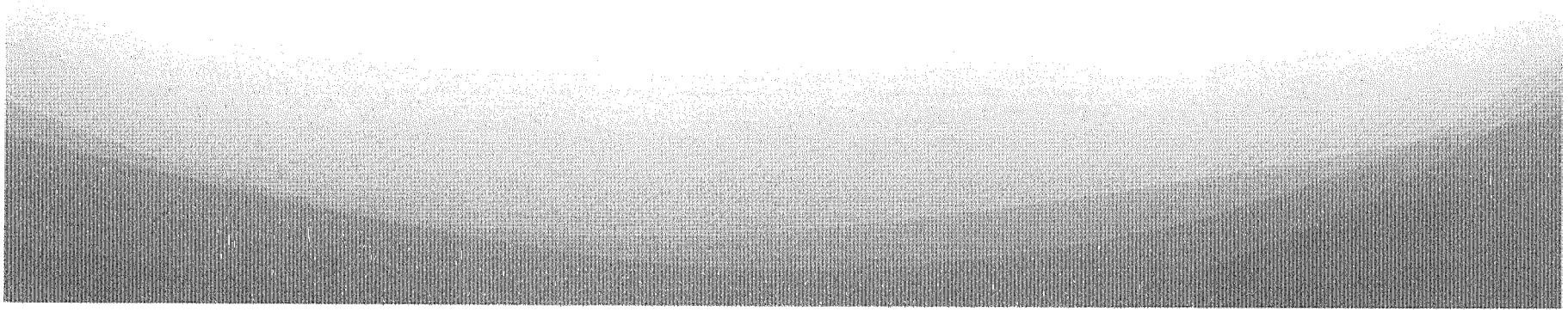
- Confirming the data

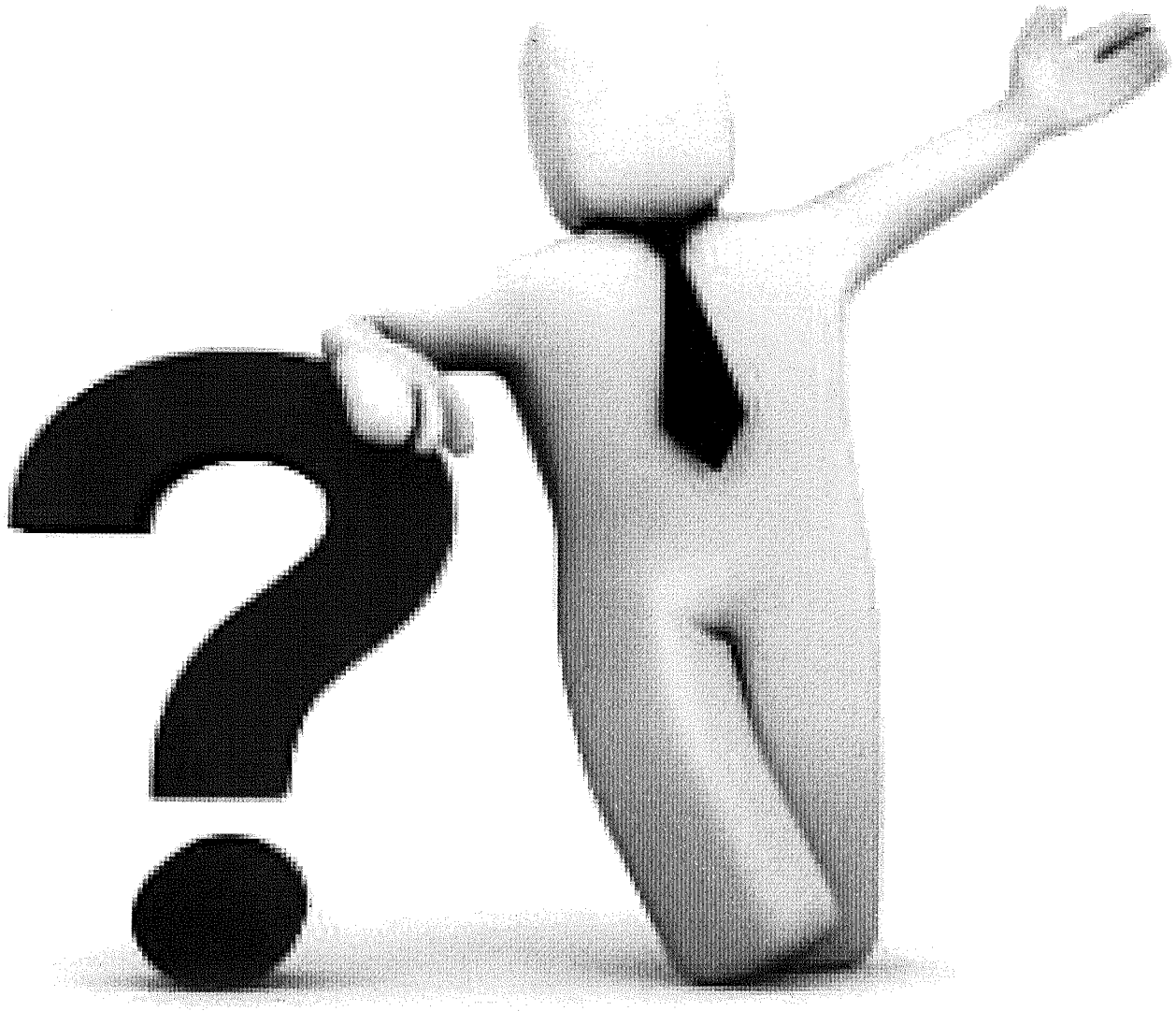
- Sources of error: heating



Conclusion

- NMR is a very helpful technique (used in…)
- Nuclear spin and magnatic moment
- T_1 and T_2

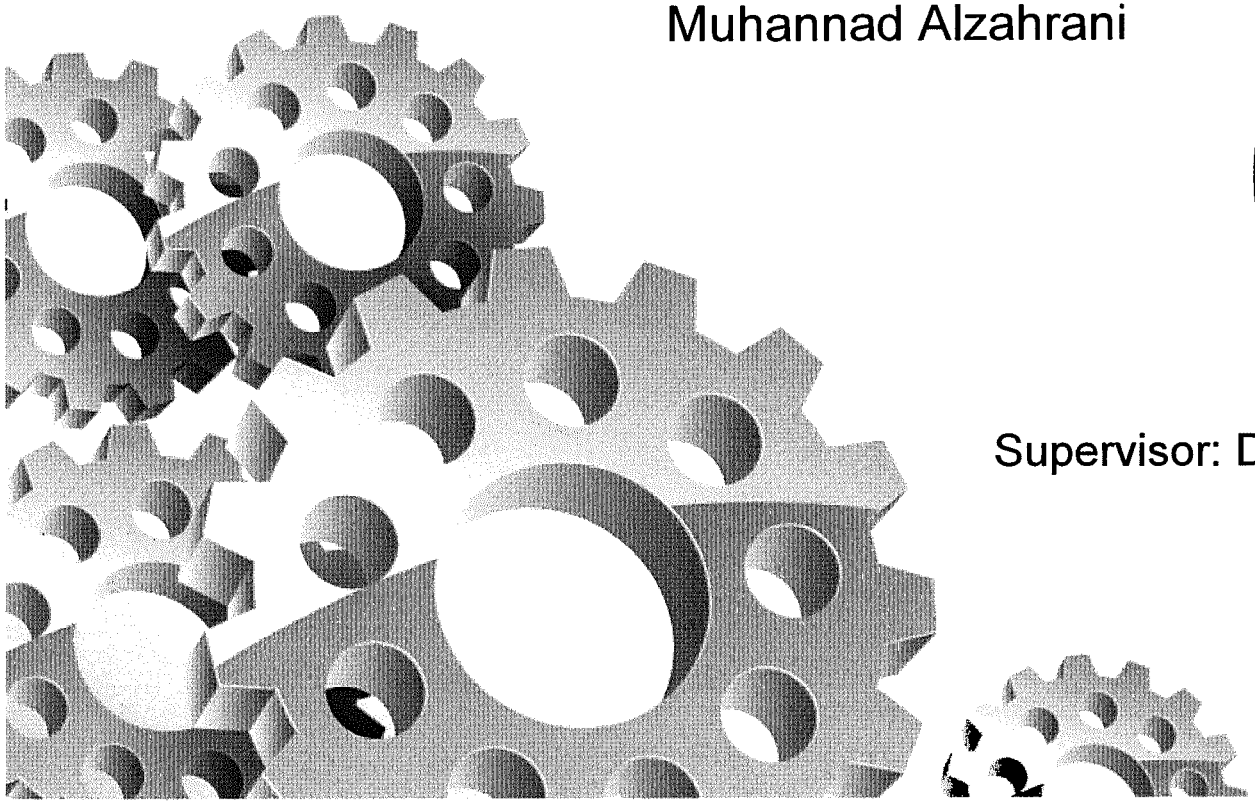




X-ray diffraction

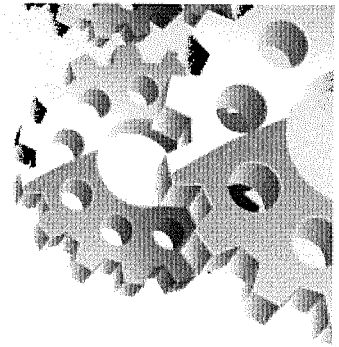
Muhannad Alzahrani

21/25



Supervisor: Dr. Akhtar Naqvi

Presentation Outline



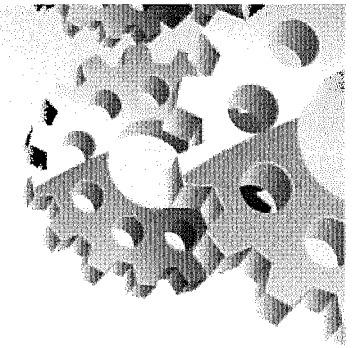
- Introduction
- Theoretical Background
- Experimantal Procedure
- Results and Discussion
- Conclusion

Introduction (1)

- X-ray was first discovered by Wilhelm Rontgen in 1895
- The typical wavelength of of X-ray is 0.01 to 10 nm.
- Mainly use in Physics to to explore the crystalls structure.
- Other uses include medical CT scans and airport security devices.

First X-ray Photo

Introduction (2)



We have done three experiments:

1-Fine structure of characteristic X-ray for molybdenum anode.

2-determination of Plank's constant via Duant-Hunt relation

3- diffraction of X-ray at a monocrystal (Verifying Bragg's relation)

Theoretical Background (1)

- For the first experiment...
- Energy is quantized (QM), and transitions are associated with emission or absorption of energy.
- Fine structure → Splitting lines of transitions.
- K_α and K_β are proved to be line duplets, will be explored by means of X-ray diffraction.
- These transitions obey selection rules
  $|\Delta l| = 1, |\Delta j| = 0, 1$

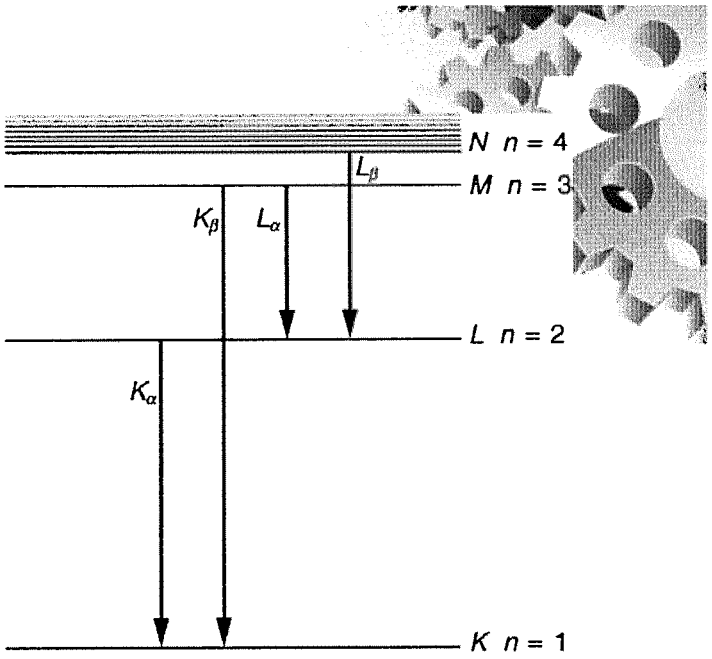
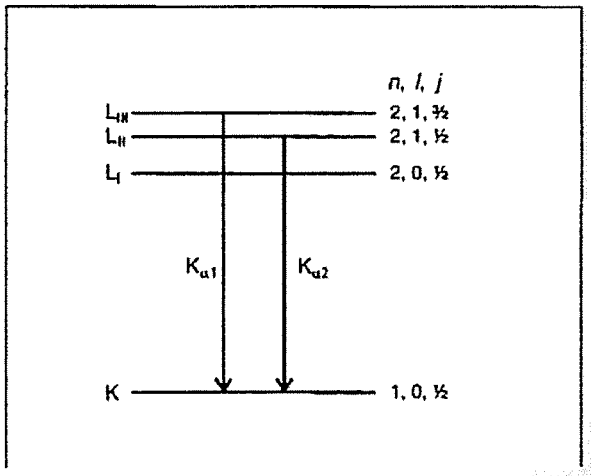


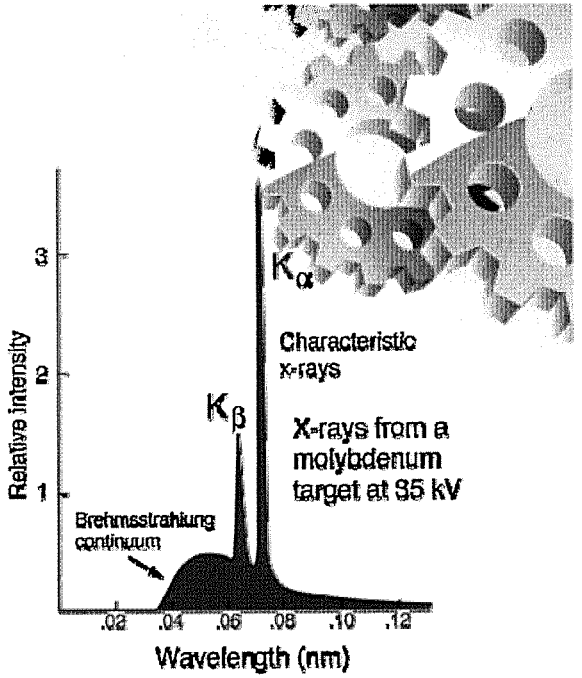
Fig. 1 Diagram of fine structure of the characteristic line K_α



Theoretical Background (2)

• For the second experiment...

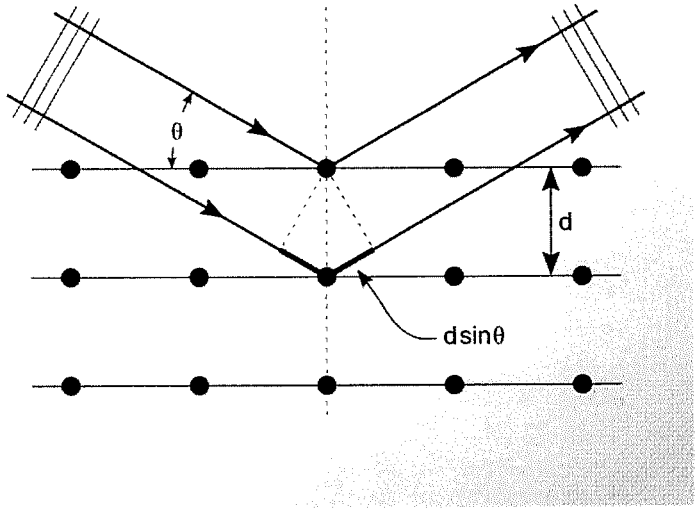
• Duant and Hunt found that at the Brehmsstrhlung continuum in the relative intensity and wavelength curve that
$\lambda_{min} \sim 1/U$, the exact relation is
$\lambda = (hc/e)(1/U) = A / U$



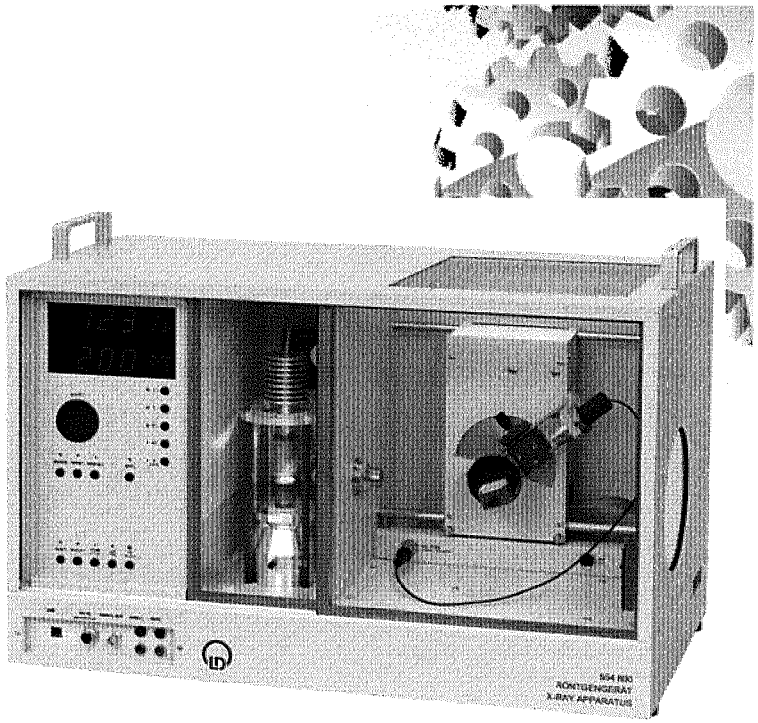
•For the third experiment...

• Crystalls are arrays of lattice elements or parallel lattice planes (Bragg).

• Bragg got the relation $2d \sin(\theta) = n\lambda$ (constractive interference condition)



Experimental Procedure (1)



• All experiments had been carried out by Leybold X-ray diffraction machine.

• The device consists of three parts:
  1- Control Panal: To adjust the different parameters involved
  2- X-ray emmitor.
  3- Experiment room: Containing an X-ray source, the crystal and the detector.

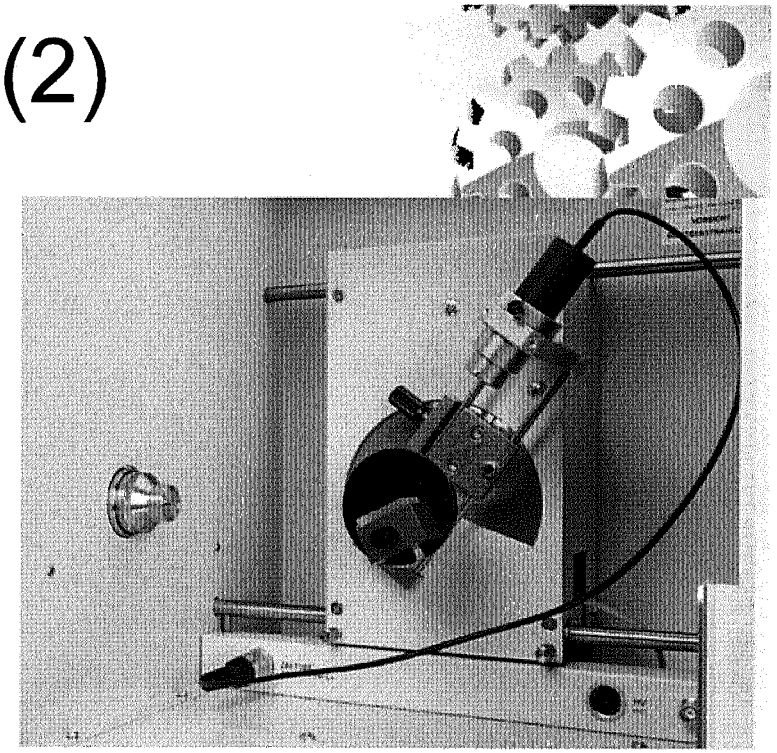
• The last part is a cable attached to a computer to transmitt the data via X-ray apparatus software

Experimental Procedure (2)

- All three experiments have almost the same procedure.
- First, we need to maxmize the counting rate via manipulating the voltage and angles.
- Next, we enter the relevant parameters using the control panal.

- Then, we need to adjust the distances between the X-ray emitter, the crystal and the detector.

- Finally, we have to choose the appropriate plot type in the X-ray apparatus software.



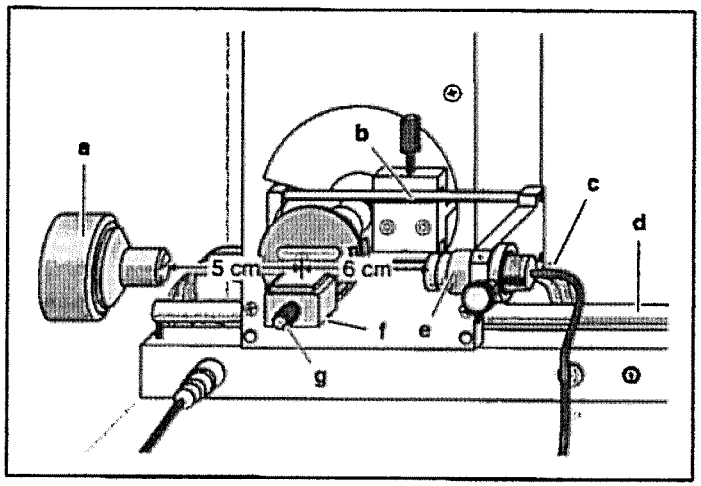
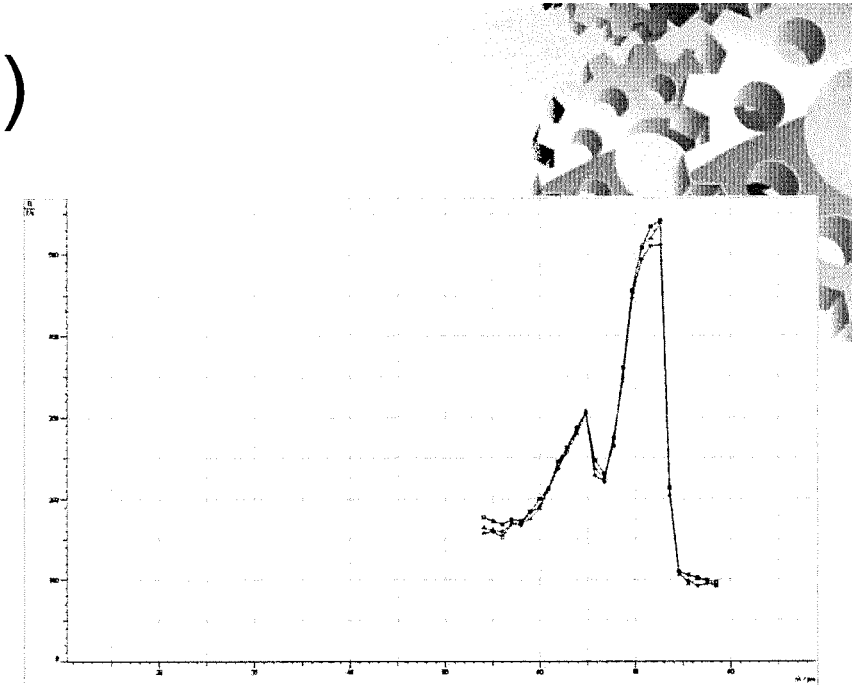


Fig. 4 Experiment setup in Bragg configuration

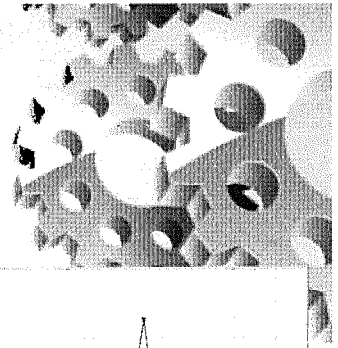
Results and discussion (1)

- For the first experiment, we have done first order diffraction three consecutive times to find K_α and K_β.
- The first and second peaks corresponds to the K_β and K_α respectivley.
- The obtained values for K_α and K_β respectivley were 73.1 and 65.0, while the literature values are 71.8 and 63.09 (Good agreement)
- Yet, first order diffraction is not enough to resolve $K_{\alpha 1}$ and $K_{\alpha 2}$



First order diffraction for NACl monocrystall

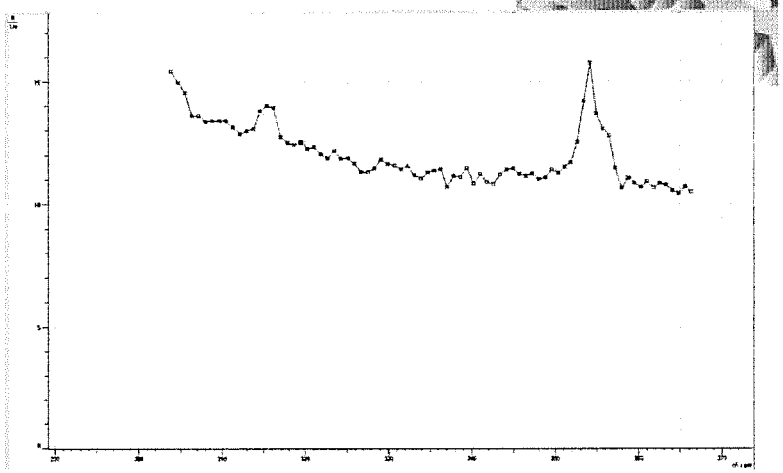
Results and discussion (2)



- The consecutive peaks represents K_γ, K_β, $K_{\alpha 1}$ and $K_{\alpha 2}$.

- The obtained for K_γ, K_β, $K_{\alpha 1}$ and $K_{\alpha 2}$ were 62.2, 63.1, 70.8 and 71.4 (pm), and the literature values were 62.09, 63.26, 70.93 and 71.36 (pm) and the agrrement is good.

- The difference between the curve here and the one in the manual is the upward shift in this case.

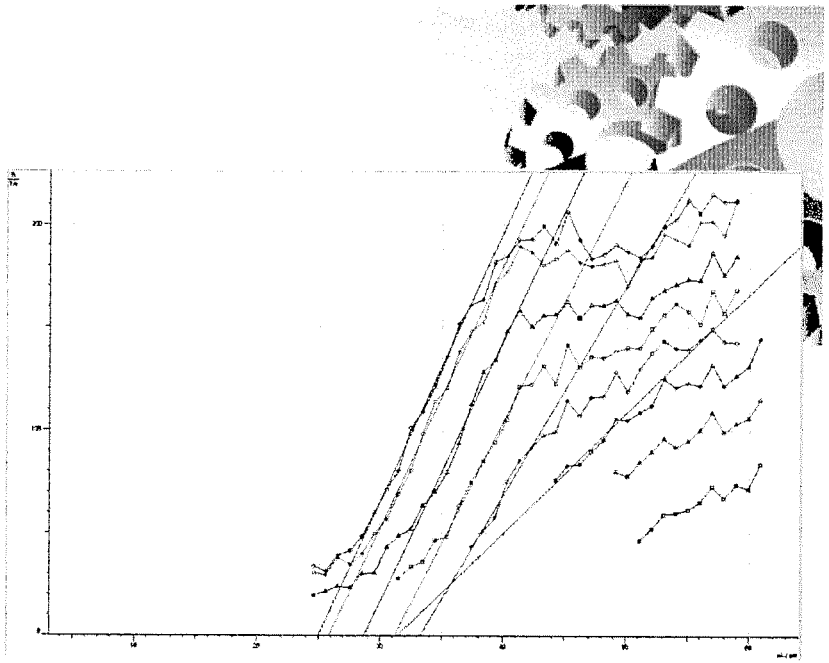


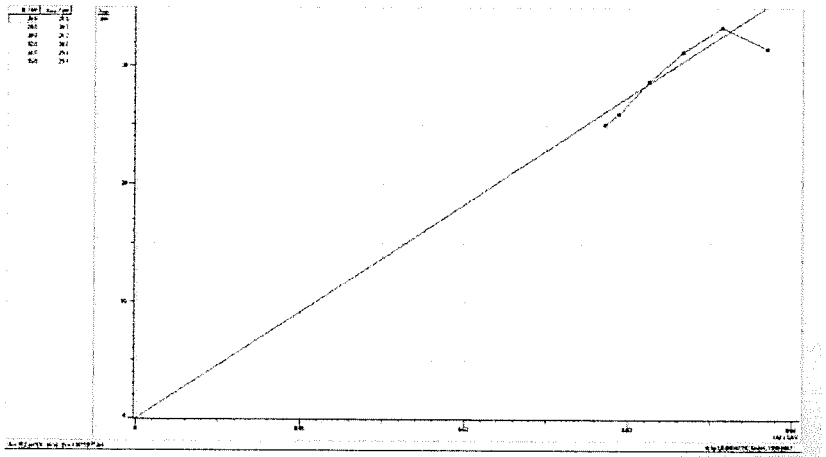
Fifth order diffraction in NACl monocrysall

Results and discussion (3)

- In the third experiment, finding Plank's contant. It is done via performing the experiment for different values of the voltage and finding the corresponding λ_{min} (Upper graph), then plot a regrssion line to find A (Lower graph).

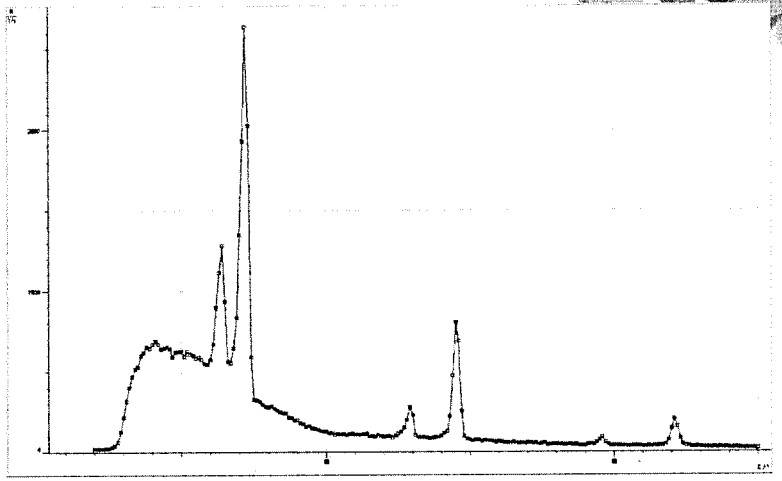
- The obtained value of h was 4.87 *10^-34 J.s, with a considerable deviation from the literature value (6.38*10^-34 J.s), error is 27% (No explanation).

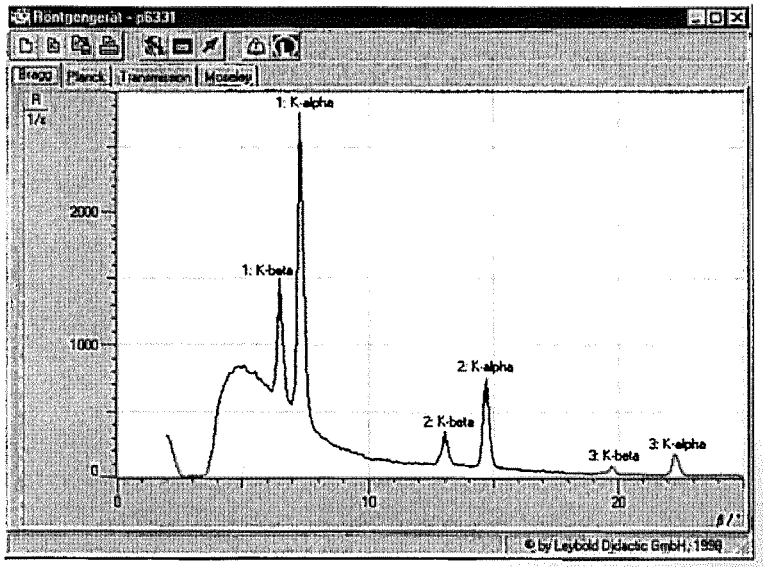




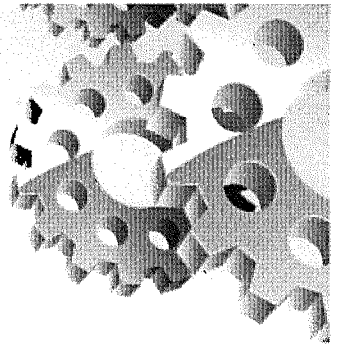
Results and Discussion (4)

- In the third experiment, we verified Bragg's relation.
- The graph is a plot of Internsity of the diffracted beam vs. angle.
- We did not calculate the wavelenghts explicitly, but the plot is almost identical to the one in the manual.





Conclusion



- X-ray diffraction is an indespensible tool in many fields.
- K lines of transition are duplets.
- Bragg's relation is true within experimental sensitivity.
- Counting rate must be high to obtain accurate results

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Diode Laser Experiment

Presented by

Hesham Almaleki

Supervised by

Dr. Akhtar Naqvi

21/25

❖ Outline

- **Introduction.**
- **Theory.**
- **Instruments used.**
- **Experiment setup.**
- **Procedure**
- **Conclusion**

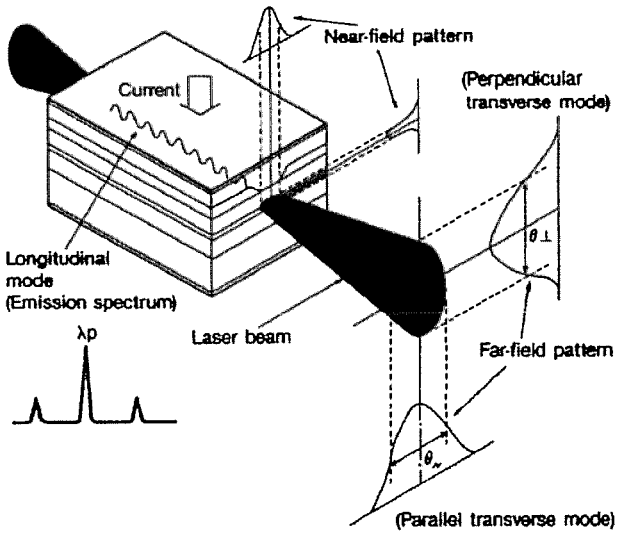
❖ Introduction

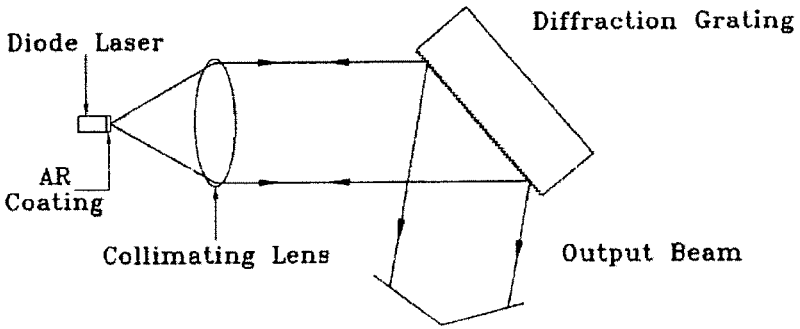
Diode laser is composed of:

- Internal (Bare) DL.

  Laser diodes consist of a p- n diode with an active region where electrons and holes recombine resulting in light emission. Their linewidths are large compared to the linewidths of atomic transitions. In addition they are extremely sensitive to optical feedback

- External Cavity DL (ECDL).





❖ Theory

- Rubidium has two naturally occurring isotopes: ^{85}Rb and ^{87}Rb.
- The nuclear spin quantum number for ^{85}Rb is I = 5/2, whereas for ^{87}Rb, I=3/2.
- Each energy level will occupy a certain state.
- The energy states can be described by:

$$^{2S+1}L'_J$$

where

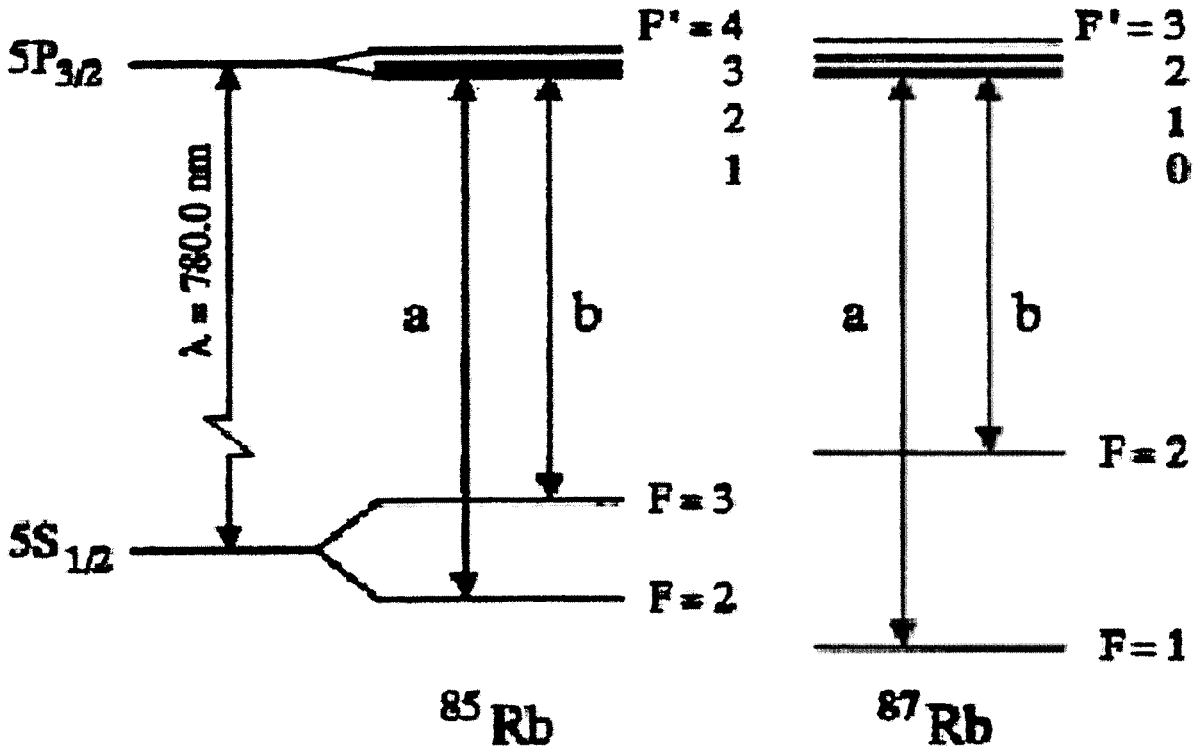
- S: is the spin quantum number.

- L': is the angular momentum quantum number (S, P, D, ..., for orbital angular momentum quantum number L = 0,1,2).

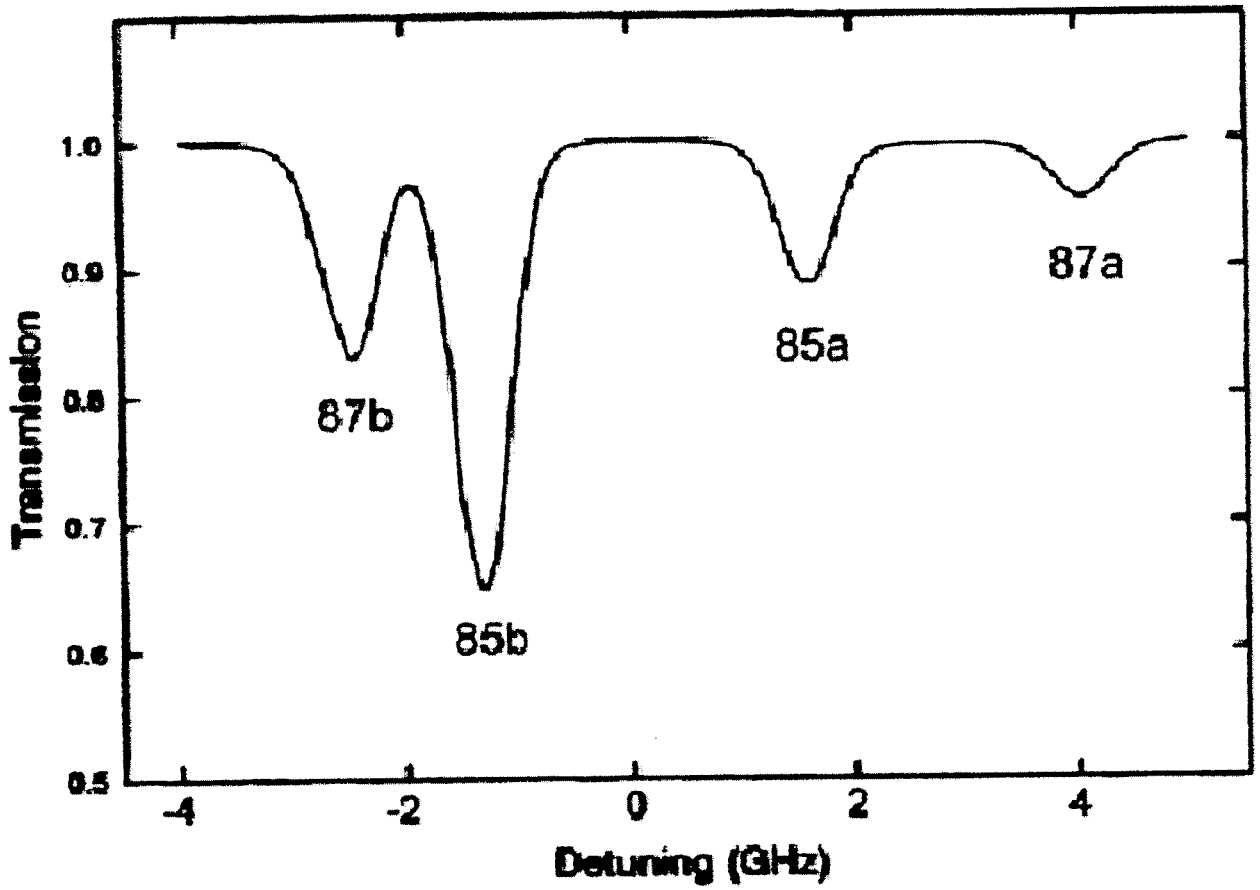
- J = L + S is the total angular momentum quantum number.

- For the ground state of rubidium, S = 1/2 and L = 0, giving J = 1/2 and the ground state, $^2S_{1/2}$.
-

- For the first excited state we have S = 1/2, and L = 1, giving J = 1/2 or J= 3/2, so there are two excited states $^{1/2}$P and $^{3/2}$P.

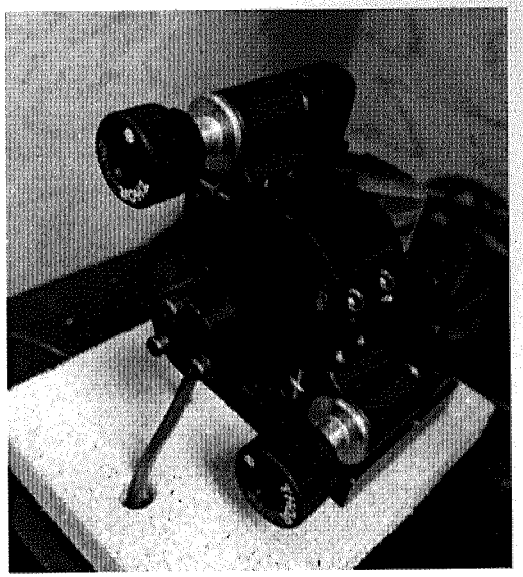


- The absorption spectrum for a rubidium vapor cell, with the different lines shown.



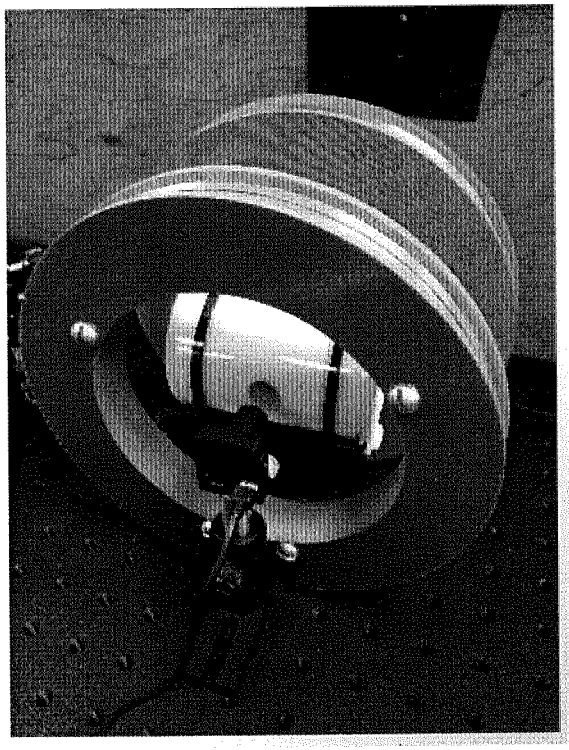
❖ Instruments used

- **Diode laser.**



- **The Absorption Cell Assembly.**

  The absorption cell assembly consists on an outer glass cylinder, an insulation layer, a heater assembly, a thermocouple to monitor the temperature and the gas filled Rb cell itself.

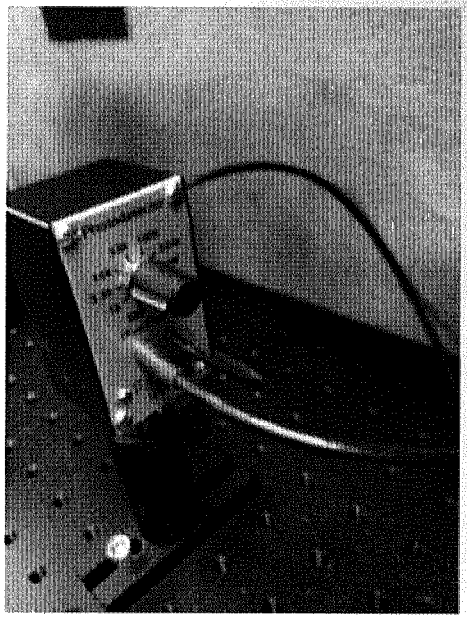


- **The Magnetic Field Coils.**

  The magnetic field coils are a Helmholtz pair which produces a uniform field at the Rubidium cell.

-

❖ Instruments used

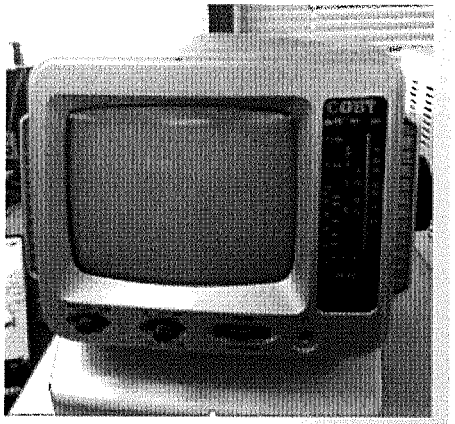


- **The Photodiode Detectors.**

  The apparatus is supplied with a couple of photodiode detectors. A switch on the back of the detector allows you to change the gain setting from 10 M_ to 333 _ in ten steps. We can send the detector signal directly to an oscilloscope or to the DETECTOR MODULE of the Controller.

- **A couple of lenses.**
- **An oscilloscope.**
- **TV connected to a camera.**
- **ND filter.**
- **The Magnetic Field Coils.**

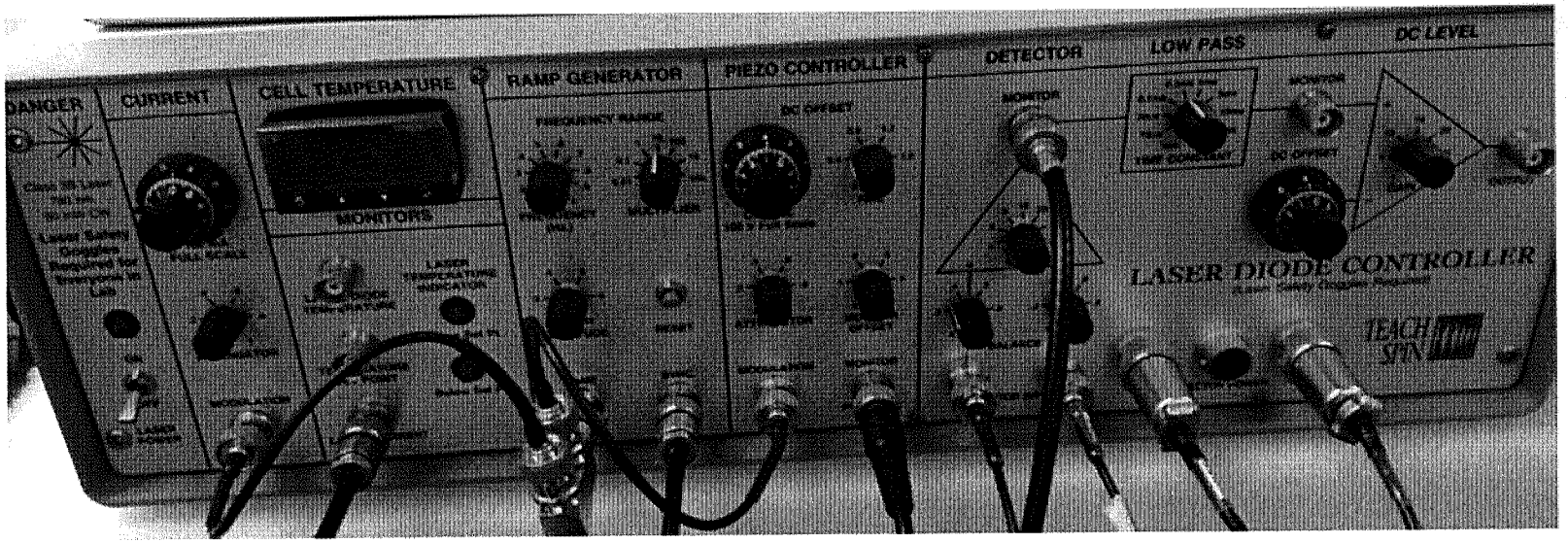
  The magnetic field coils are a Helmholtz pair which produces a uniform field at the Rubidium cell.



-

❖ Instruments used

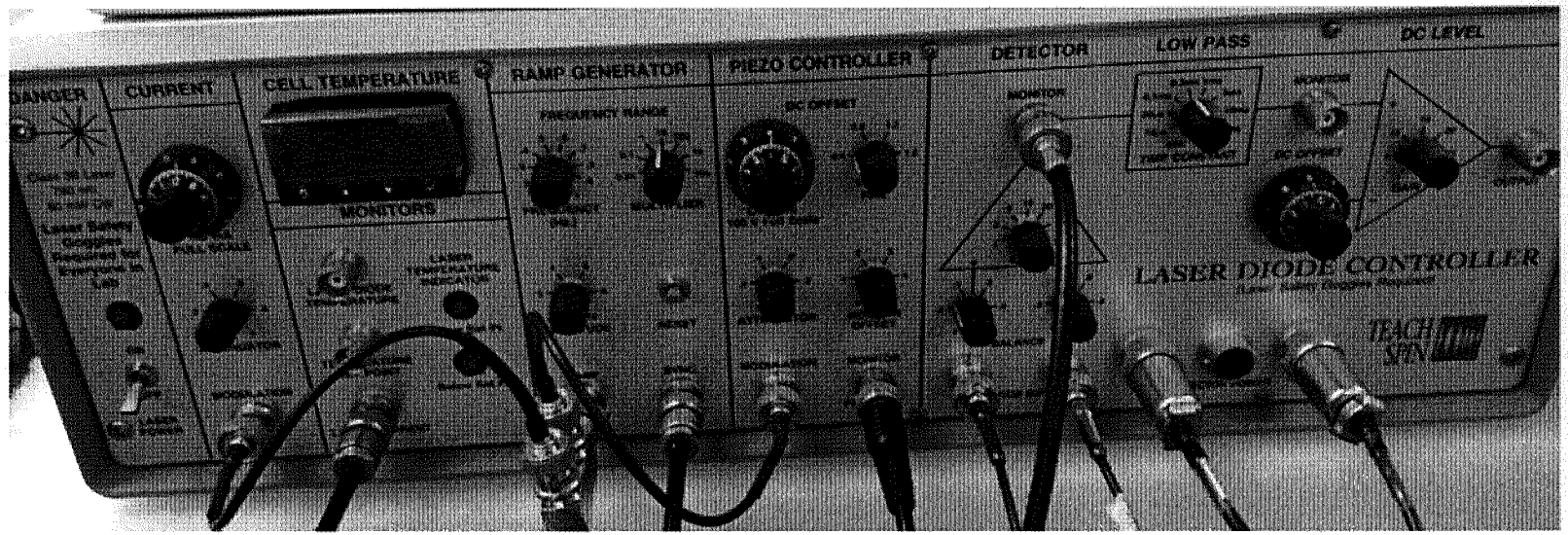
- **The Controller.**



- **DETECTOR/LOW PASS/DC LEVEL:** This module provides power for three detectors and offers two detector inputs and a series of Monitor options. You can look at either detector or a combined signal.
- **PIEZO CONTROLLER:** This controls the piezo modulation, which determines the way the angle of the grating is changed and thus the change or "sweep" of the laser frequency.

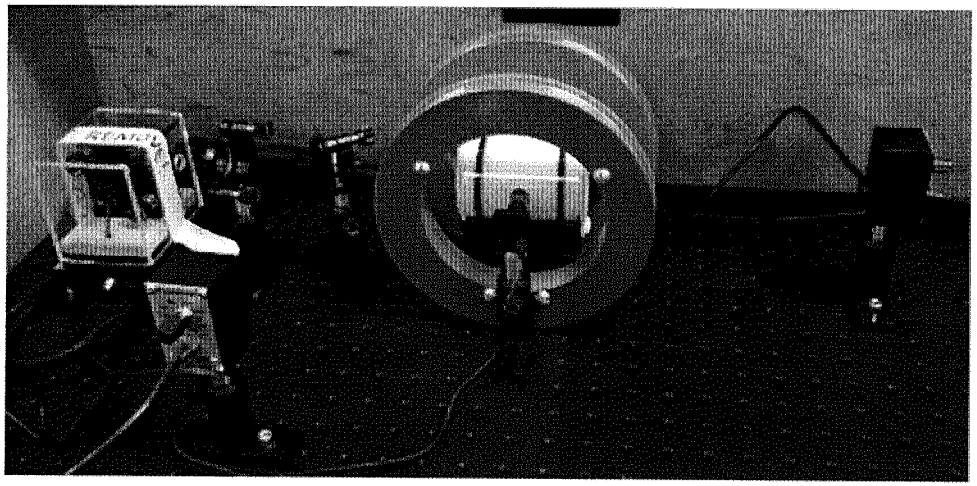
❖ Instruments used

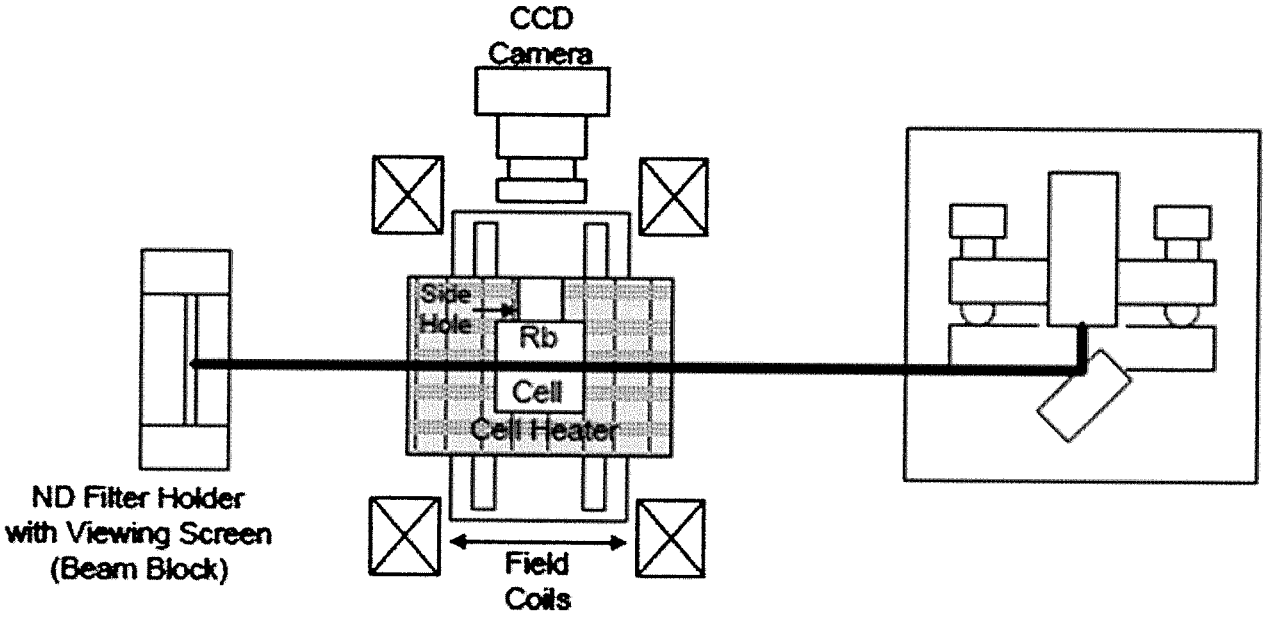
- **The Controller.**

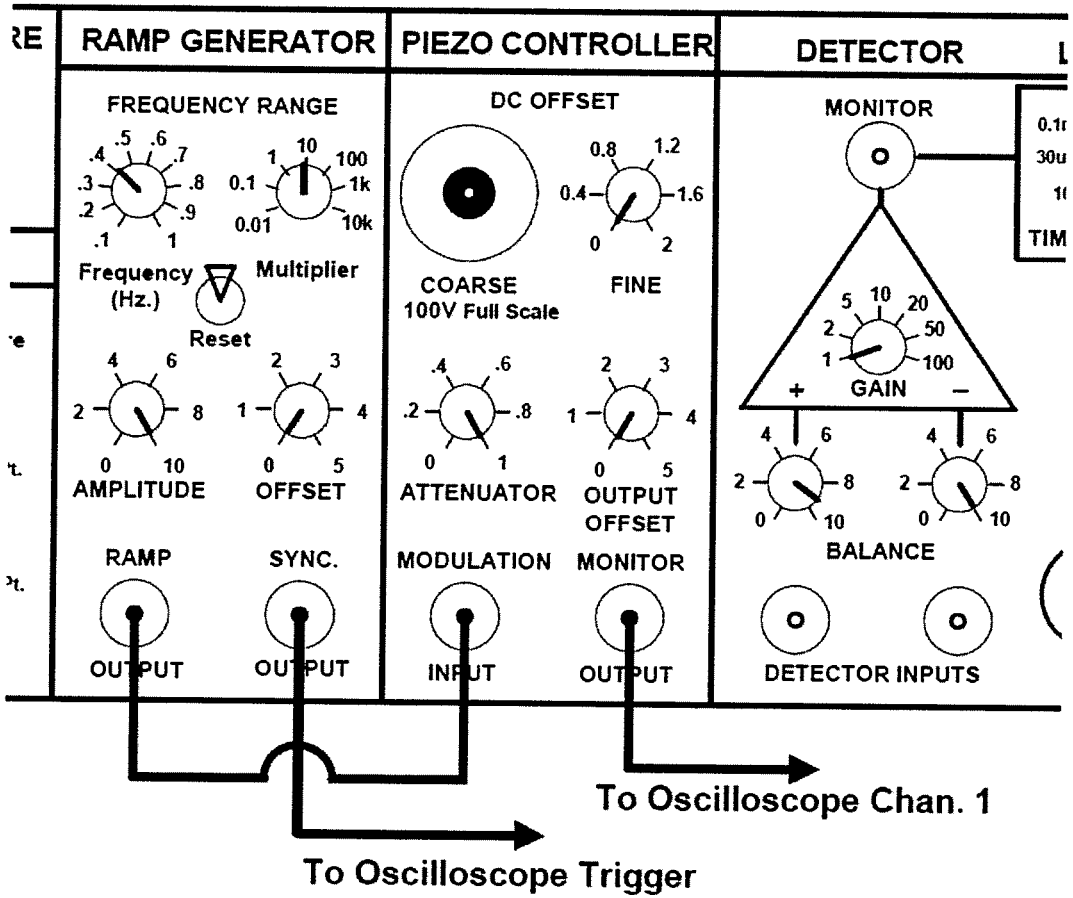


- **RAMP GENERATOR:** This provides a bipolar variable amplitude and frequency triangle wave.
- **CELL TEMPERATURE:** The cell temperature is both set and monitored through keys on the LED display.
- **CURRENT**: The current module controls the current to the laser.

❖ Experiment setup







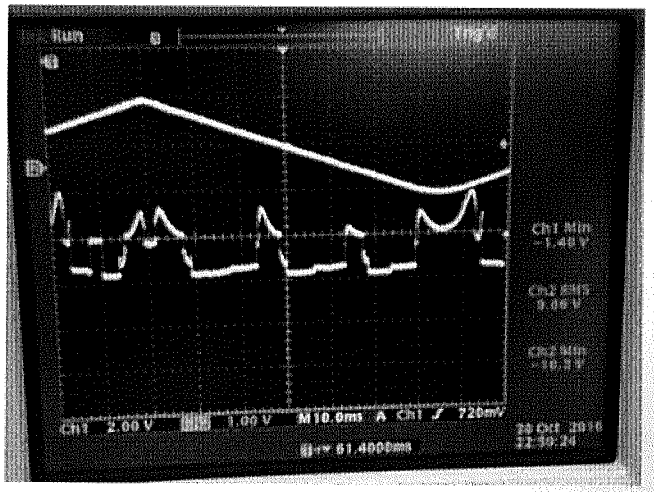
The connection between the oscilloscope and the controller.

❖ Procedure

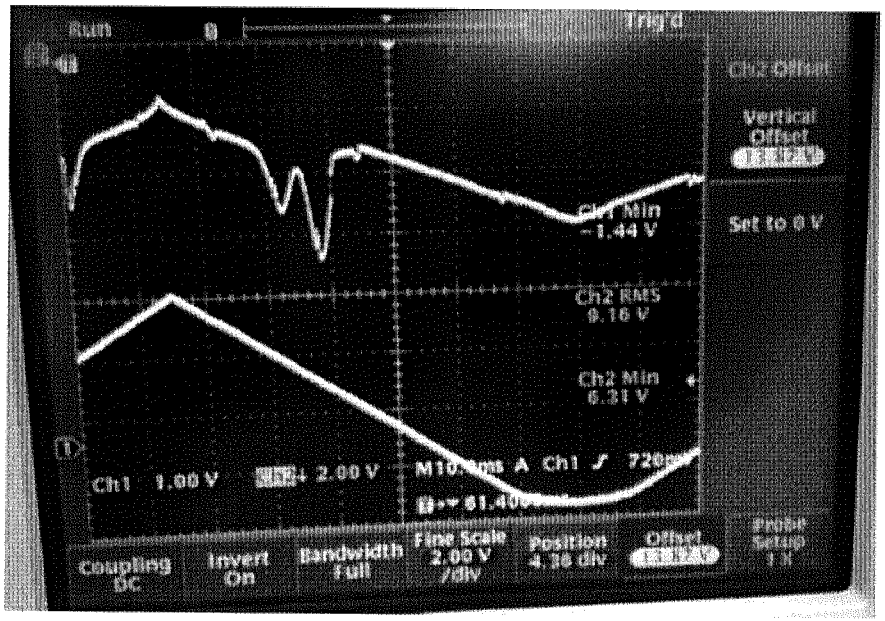
- Set the cell temperature to be 45 degrees.
- You have to wait for the cell to reach this temperature.
- Set the Laser diode voltage to be 2.719 V.
- Turn the piezo OUTPUT OFFSET knob to zero.
- Set the ramp generator frequency to about 10 Hz.
- Turn the piezo ATTENUATOR knob to one (1).
- Set the ramp generator AMPLITUDE knob to ten (10).
- Use the DC OFFSET knob of piezo controller to produce a large-amplitude triangle wave that is not clipped at the top or bottom.
- Put the Photodiode Detector in place to intercept the laser beam coming through the Rb cell. Assemble the glass neutral density filter in a fixed mirror holder and place it in a post holder.
- Place the attenuator between the laser and the Rb cell (not between the cell and
- photodiode).

Upper trace (Channel 1) shows piezo monitor signal.

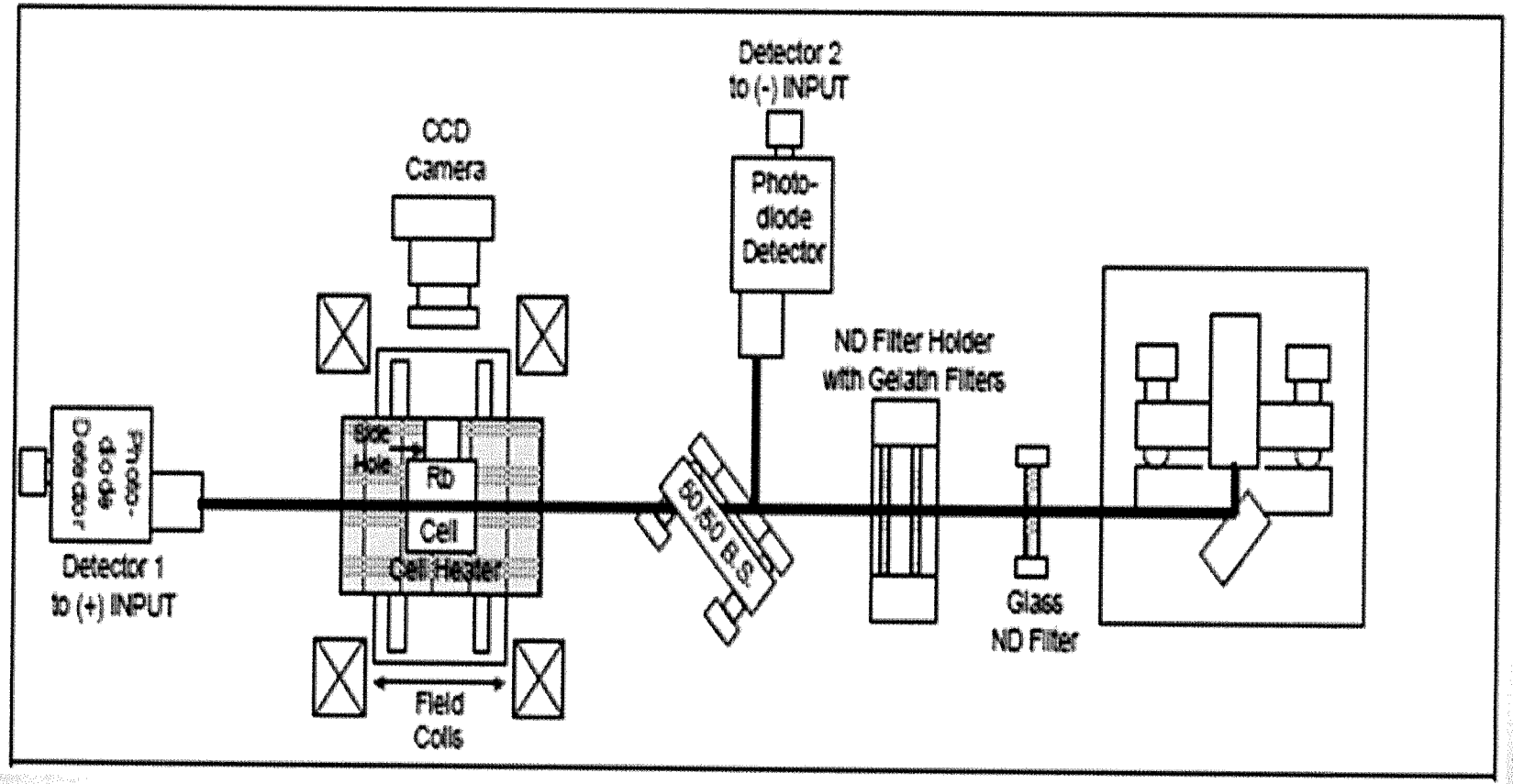
Lower trace (channel 2) shows Detector output.

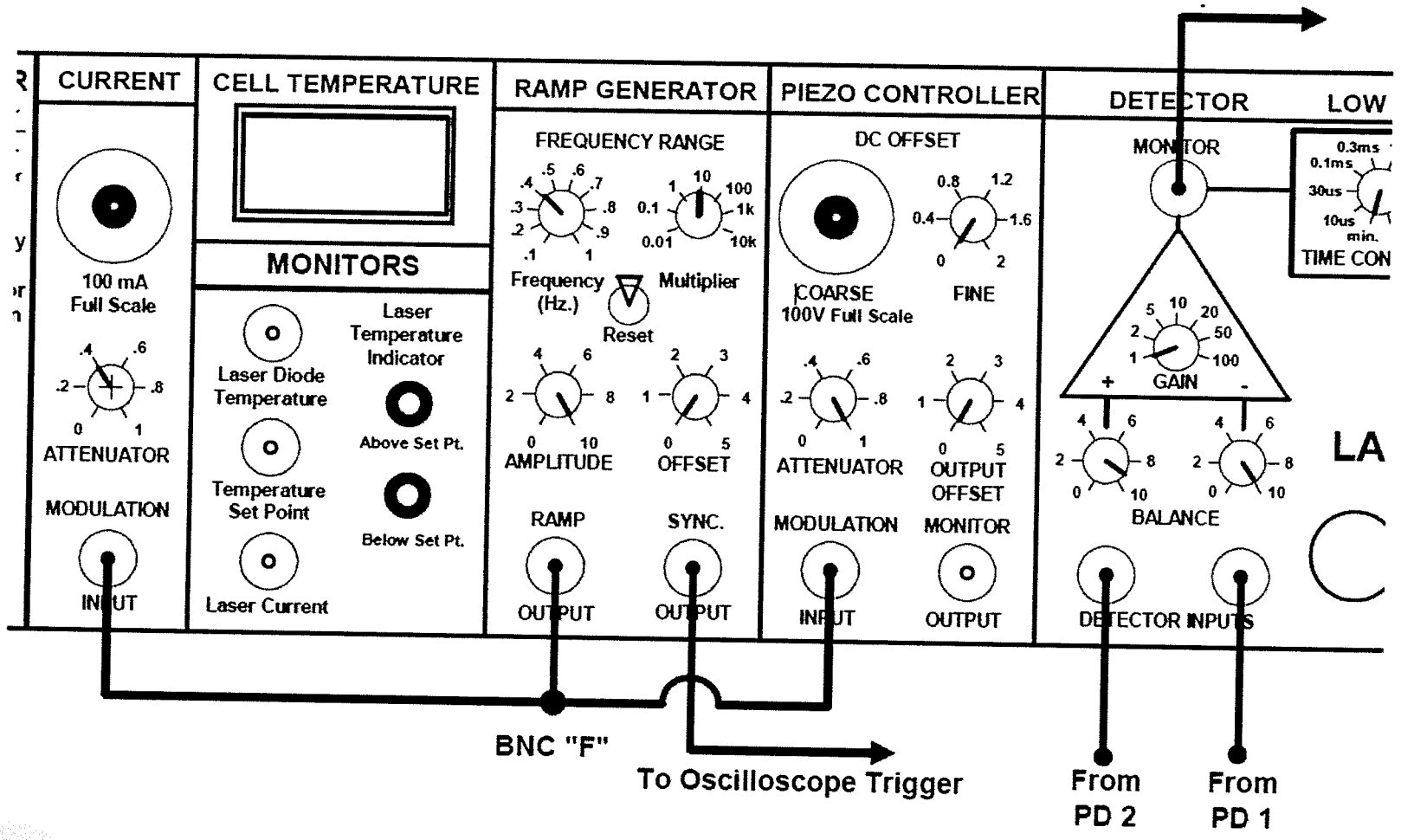


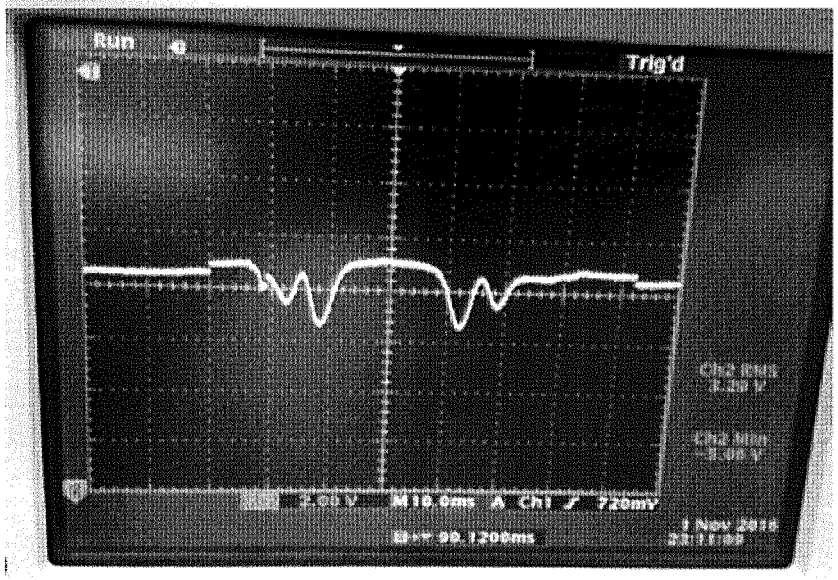
- Set the laser CURRENT ATTENUATOR knob to zero. Attach the BNC splitter "F" connector to the RAMP OUTPUT on the RAMP GENERATOR. Plug one BNC from the RAMP OUTPUT to the MODULATION INPUT of the PIEZO CONTROLLER, and the second BNC from RAMP OUTPUT to the CURRENT MODULATION INPUT.
- Turn the ramp generator amplitude up to maximum, and watch what happens when you turn up the current attenuator knob. With some tweaking you should be able to produce a full trace over the Rb spectrum.
- Use the oscilloscope invert function used to show the trace in what looks more like an absorption spectrum. We get a full trace over the Rb spectrum as shown:

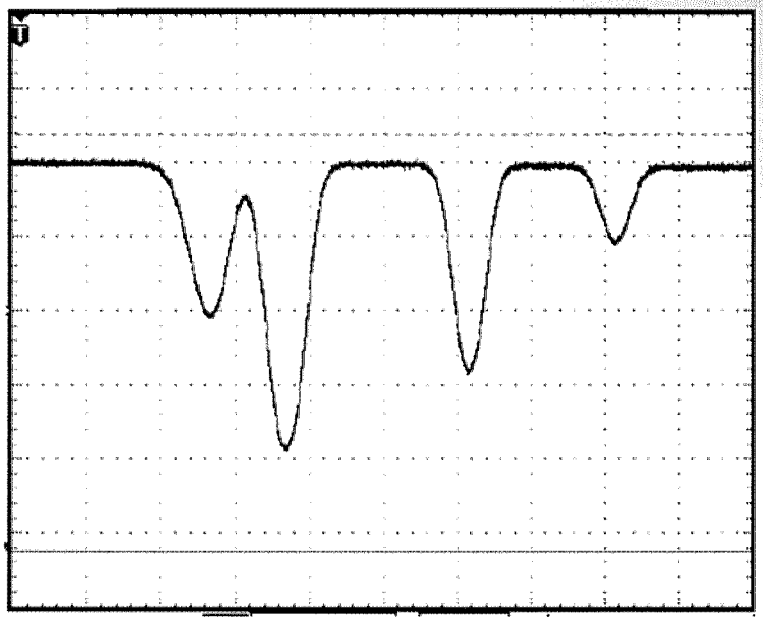


Now we need to compare the laser beam that passed through the Rb vapor, and the one that is directly detected. In order to do this, We need to install a 50/50 Beam splitter, so we need a second photodiode detector to intercept the beam that has been split off by the Beam Splitter.



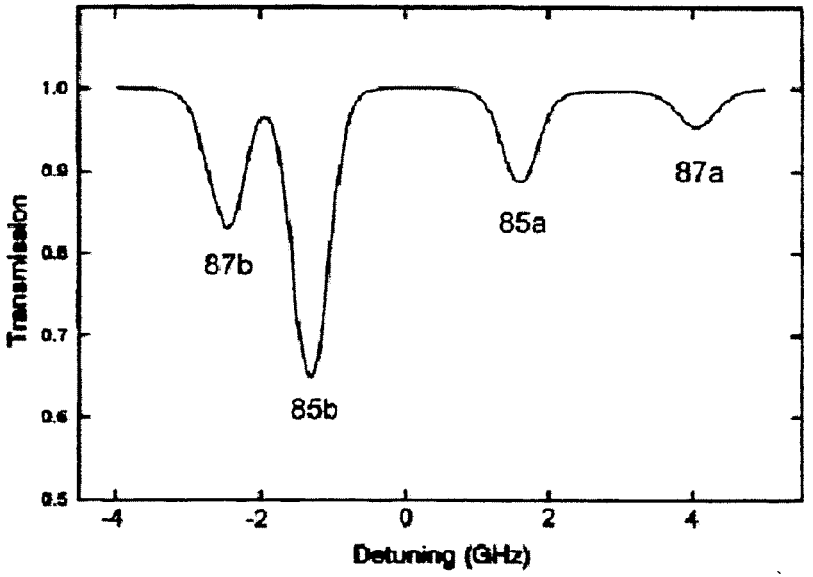

CURRENT
CELL TEMPERATURE
RAMP GENERATOR
PIEZO CONTROLLER
DETECTOR
LOW
100 mA
Full Scale
ATTENUATOR
MODULATION
INPUT
MONITORS
Laser Diode Temperature
Laser Temperature Indicator
Above Set Pt.
Temperature Set Point
Below Set Pt.
Laser Current
FREQUENCY RANGE
Frequency (Hz.)
Multiplier
Reset
AMPLITUDE
OFFSET
RAMP
SYNC.
OUTPUT
OUTPUT
DC OFFSET
COARSE
100V Full Scale
FINE
ATTENUATOR
OUTPUT OFFSET
MODULATION
MONITOR
INPUT
OUTPUT
MONITOR
GAIN
BALANCE
DETECTOR INPUTS
TIME CON
LA
BNC "F"
To Oscilloscope Trigger
From PD 2
From PD 1





❖ Conclusion

In this experiment, we used the laser diode spectroscopy to show how the energy levels are splitted in an atomic system. The resultant graph we get for the four absorption lines (Figure 12) is very similar to the theoretical one



Optical Pumping

Student : Ahmad Al-Jama

Supervisor : Dr.Akhtar Naqvi

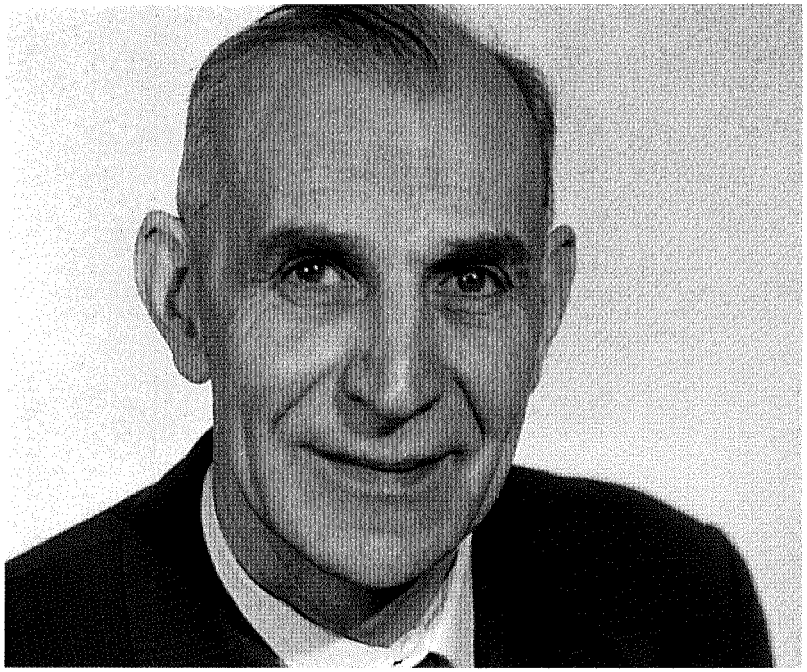
20/25

Outline

- Introduction
- Theoretical Background
- Experimental
- Results and Discussion
- Conclusion

Introduction

- Optical pumping is the process that uses photons to change the distribution of the stated occupied by a collection of atoms.
- In 1966, Alfred Kastler won a Nobel Prize for his work on optical pumping.



Introduction

- Rubidium has the electron configuration :

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s$

- This means it's a Hydrogen-like atom.
- For such atoms, the complete inner shells can be ignored.

Theoretical Background

- Fine Structure :

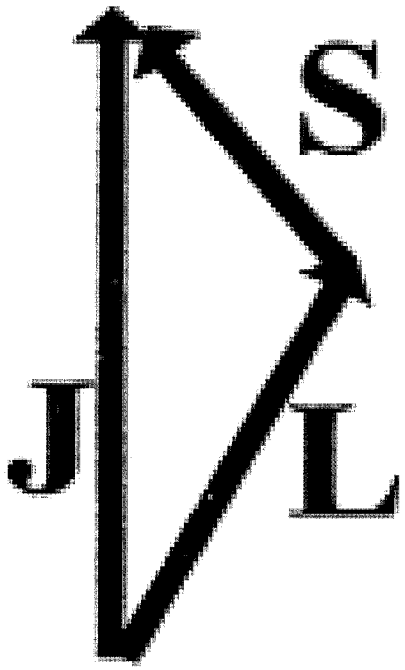
  Results from **J = S + L**

- Hyperfine Structure :

  Results from **F = I + J**

- The Zeeman Effect :

$$\Delta E = g_F \mu_0 B M_F$$



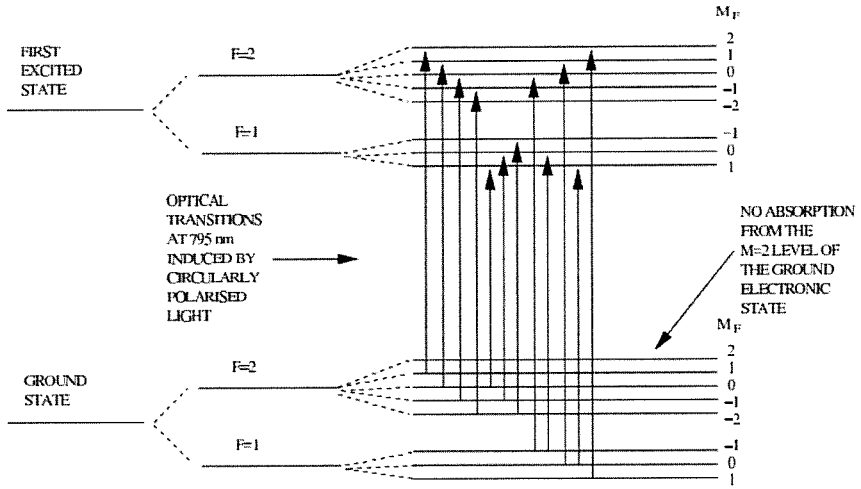
Theoretical Background (Cont'd)

- Absorption :

$$I = I_0 e^{-\sigma_0 \rho l}$$

- Optical Pumping :

Using circularly polarized light to excite electrons where they can no longer be excited.



Experimental Procedure : Equipments

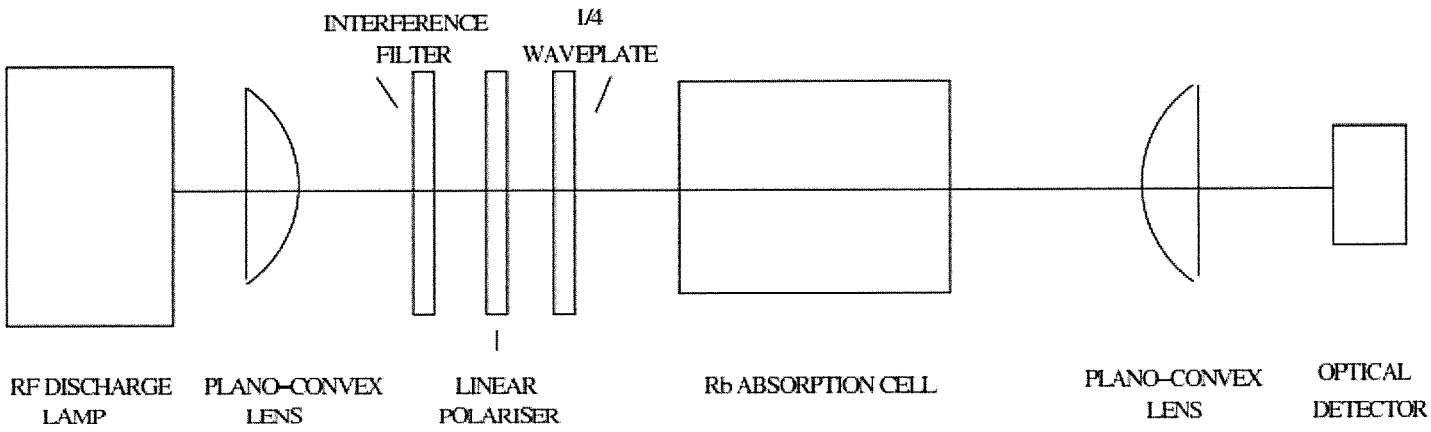
- Rubidium Discharge Lamp : Filled with Rb gas and Xenon Buffer Gas.
- Lenses : One used to collimate the beam. The other used to focus it into the detector.
- Filter : Excludes all lines except the near-IR 795 nm line.
- Polarizer : Produces linearly-polarized light.
- ¼ Waveplate : Produces circularly-polarized light.

Experimental Procedure : Equipments (Cont'd)

- Cell and heater : The cell is an insulated perspex cylinder with a bulb of rubidium and neon buffer gas. The bulb can be heated to change the Rb pressure and density.
- Magnetic field coils : The vertical field is to cancel the local field due to the Earth's magnetic field. The horizontal field is for the Zeeman effect and the sweep field is for viewing the B =0 resonance.
- RF coils and signal generator : the RF magnetic field coils are located on the cell. The field is produced by a signal generator plugged into the electronics box.

Experimental Procedure : Equipments (Cont'd)

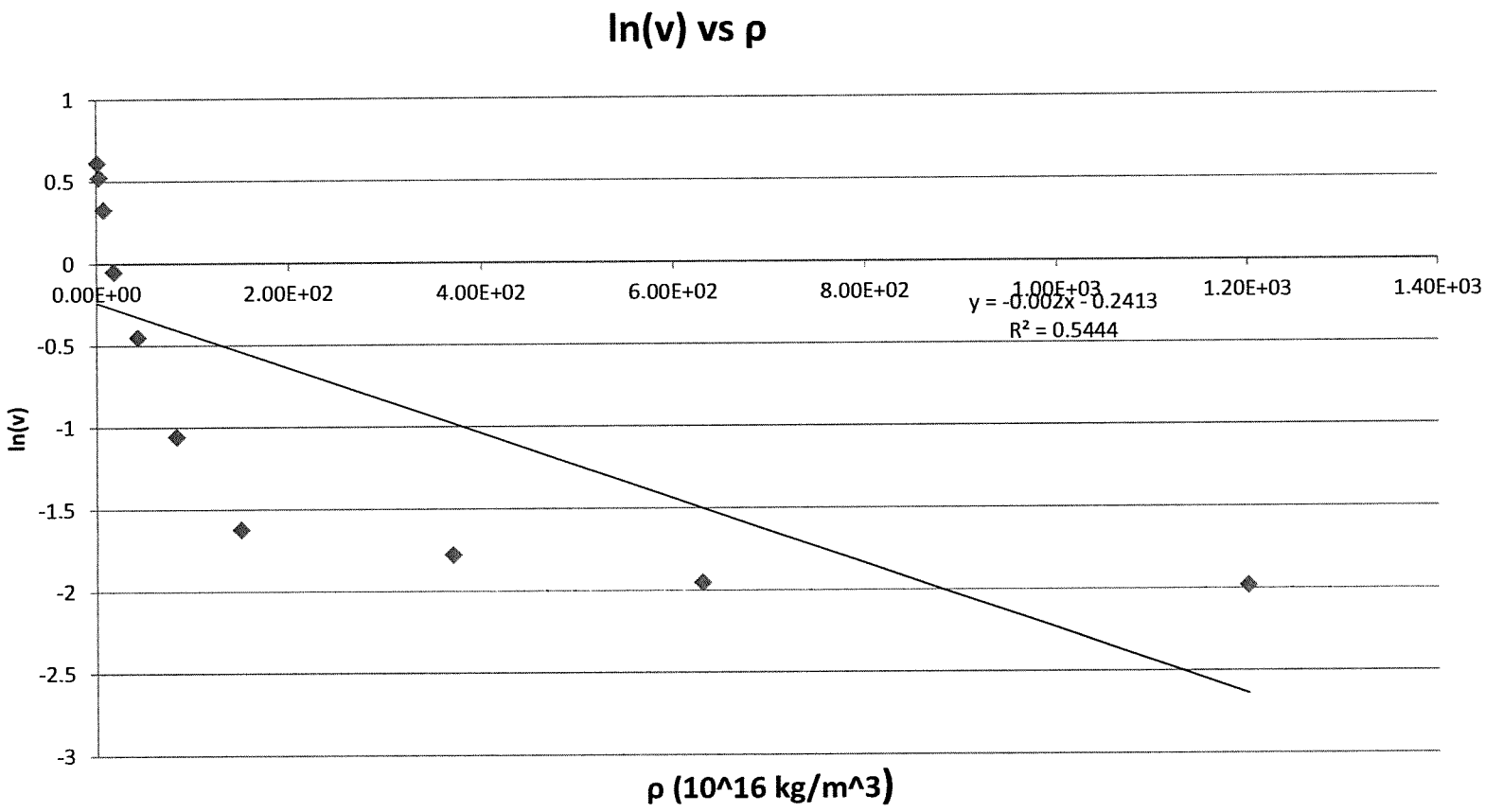
- RF coils and signal generator : the RF magnetic field coils are located on the cell. The field is produced by a signal generator plugged into the electronics box.



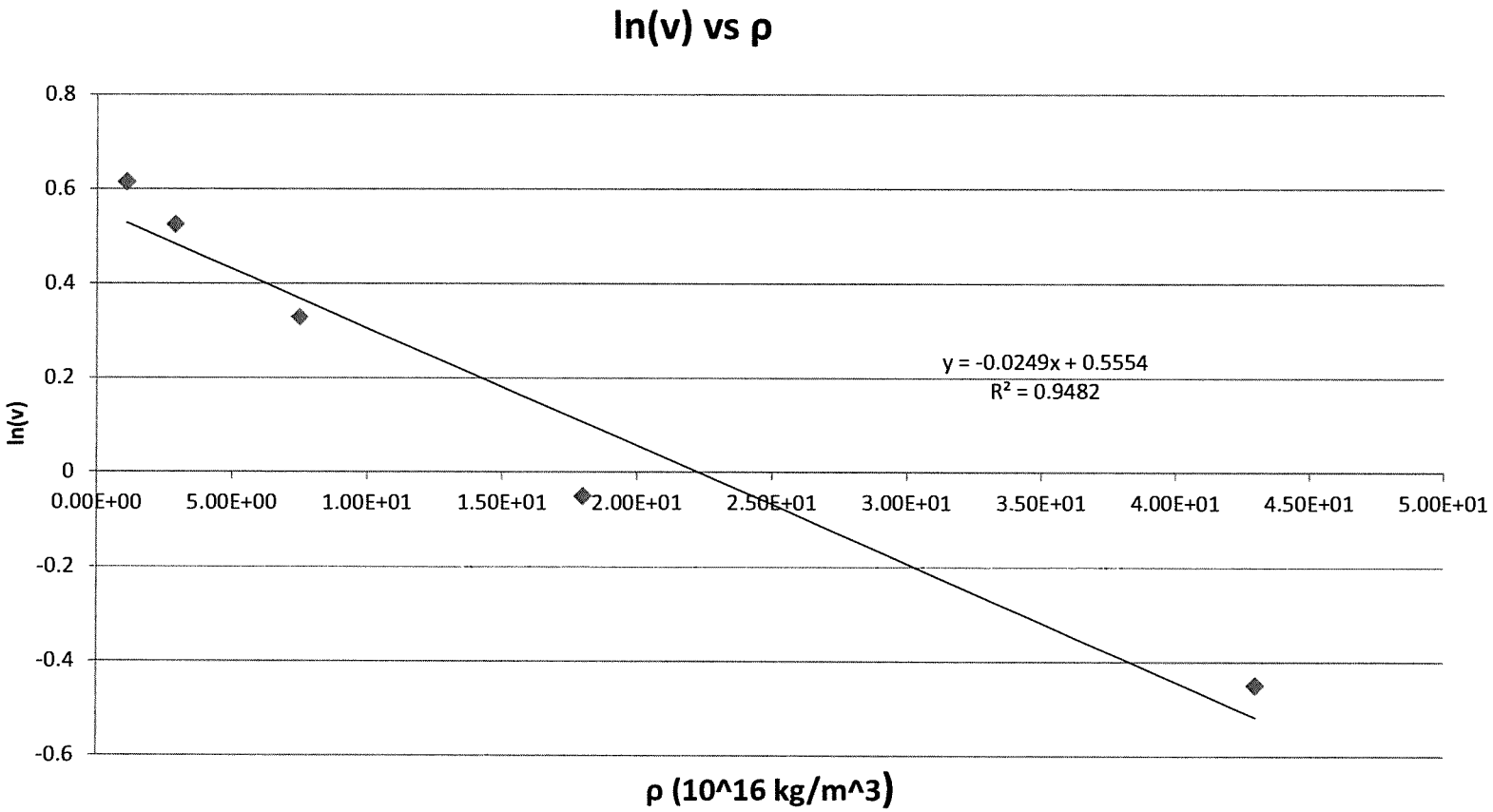
Experimental Procedure : Absorption Cross Section

- We used the optical set-up in the last slide ***without*** the polarized and the ¼ plate.
- We sat the cell's temperature to different values between 300 and …. (10 K steps), and measured the voltage at each temperature.

Results and Discussion



Results and Discussion



Conclusion

$$\sigma = \frac{0.0249}{0.025 * 10^{16}} = 1.00 * 10^{-16}$$

Thanks for listening

Electron Spin Resonance

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Senior Physics Laboratory-(PHYS403) Winter2016
(Term 161)
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Instructor/ Dr. Akhtar A. Naqvi
Assistant/ Tyrence Engalla

20/25

Outline

- *OBJECTIVES*
- DEFINITION
- THEORY
- INSTRUMENTATION
- EXPERIMENTAL PROCEDURE
- EXPERIMENTAL RESULT
- CONCLUSION

- ***OBJECTIVES:***
- looking for the "spin-flip" transition of a free (unpaired) electron exposed to a magnetic field.
- Measure g, a dimensionless quantity that relates the difference in energy between two levels and the magnetic field present

- It is also called electron paramagnetic resonance (EPR) or electron magnetic resonance (EMR).
- Is a branch of absorption spectroscopy in which radiation of microwave frequency is absorbed by paramagnetic substances.
- It was invented by Zavoisky in 1944.

Definition

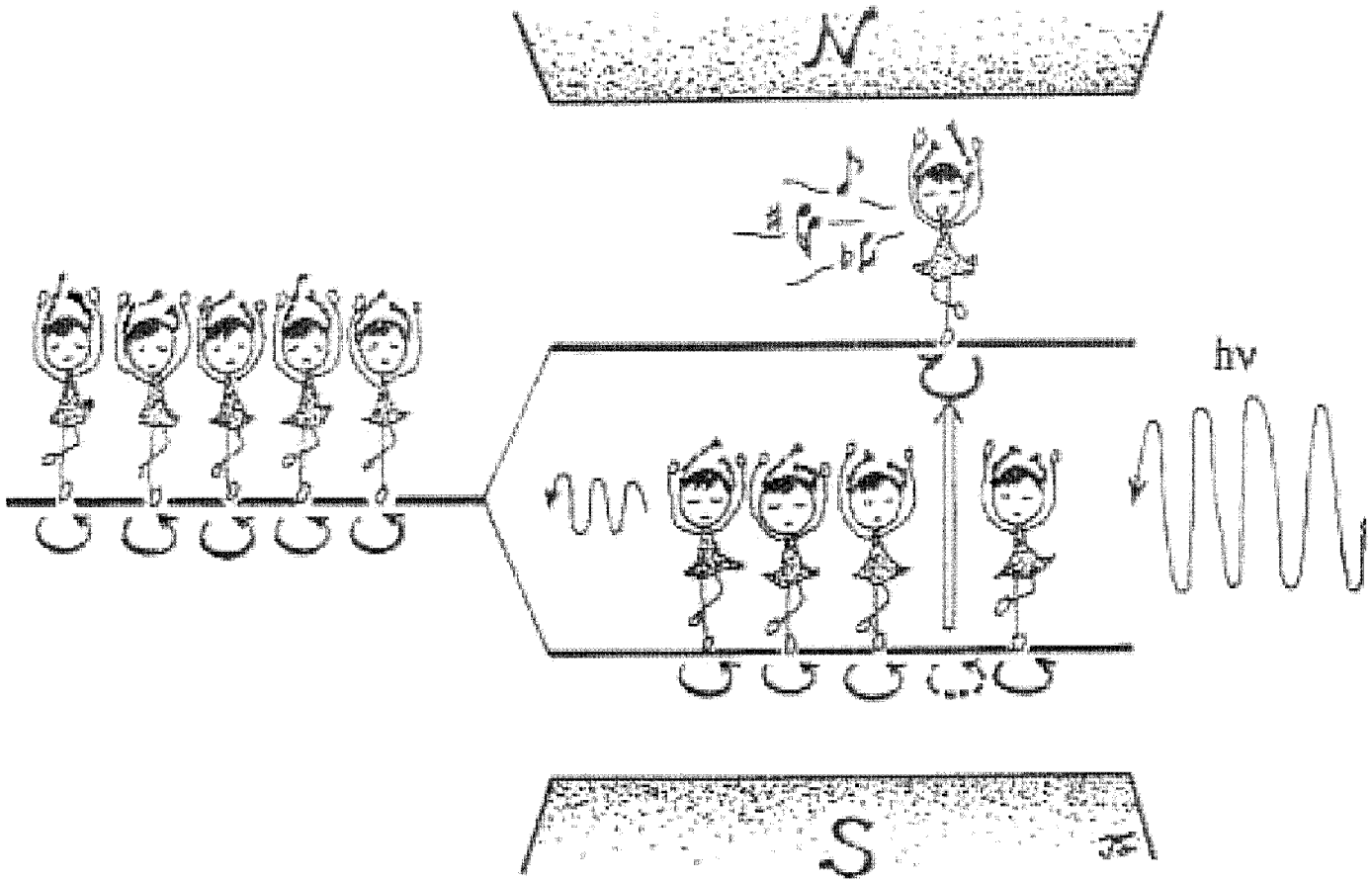
Comparison of ESR with NMR

NMR	ESR
• Different energy states are produced due to the alignment of the nuclear magnetic moments relative to applied magnetic field and the transition between these energy states occurs on the application of an appropriate frequency in the radio frequency region. • NMR absorption positions are expressed in terms of chemical shifts. • Nuclear spin spin coupling causes the splitting of NMR signals.	• Different energy states are produced due to the alignment of the electronic magnetic moments relative to applied magnetic filed and the transition between these energy states occurs on the application of an appropriate frequency in the microwave region. • ESR absorption positions are expressed in terms of "g" values. • Coupling of the electronic spin with nuclear spins(hyperfine coupling) causes the splitting of ESR signals.

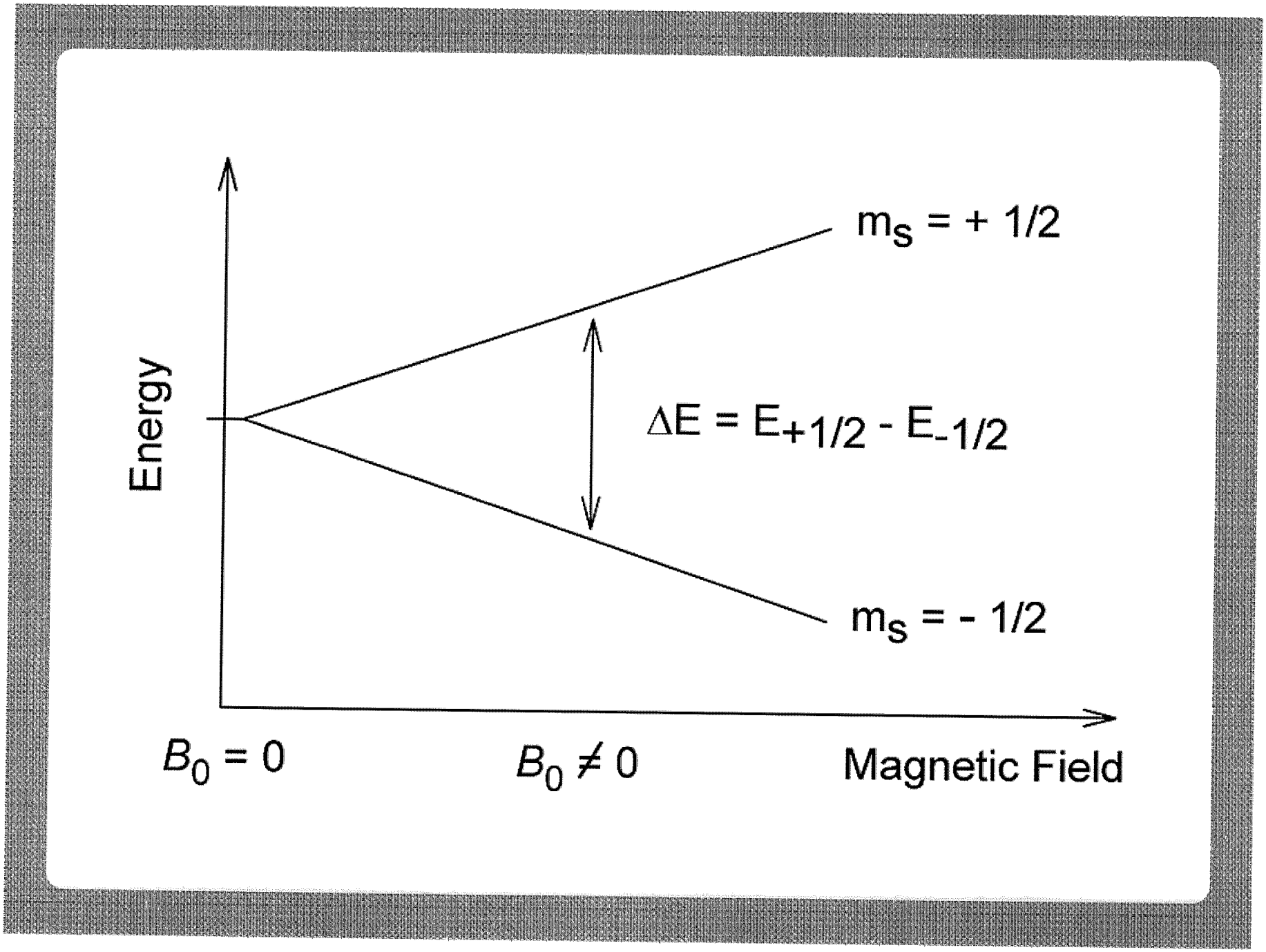
- The energy levels are produced by the interaction of the magnetic moment of an unpaired electron in a molecule ion with an applied magnetic field.
- ESR spectrum is due to transition these energy levels by absorbing radiations of microwave frequency.

THEORY

- Like a proton, an electron has a spin, which gives it a magnetic property known as a magnetic moment.
- When an external magnetic field is supplied, the paramagnetic electrons can either orient in a direction parallel or antiparallel to the direction of the magnetic field
- This creates two distinct energy levels for the unpaired electrons.

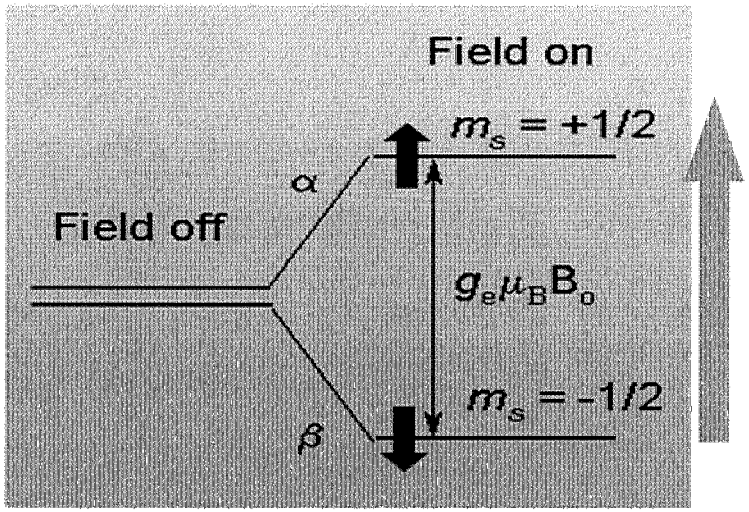

N
hν
S

- For an electron of spin s=1/2, the spin angular momentum have values of
  m_s= +1/2 or -1/2
- In the absence of magnetic field, the two values give rise to doubly degenerate energy levels(same energy).
  The low energy state will have the spin magnetic moment alligned with the field (m_s= -1/2), and high energy state - opposite to field (m_s= +1/2).


Energy
m_s = + 1/2
$\Delta E = E_{+1/2} - E_{-1/2}$
m_s = - 1/2
$B_0 = 0$
$B_0 \neq 0$
Magnetic Field

- From quantum mechanics, the electron has a magnetic dipole moment (μ_s) that is related to its intrinsic angular momentum, or spin, by the vector equation:
- $\mu_s = g_s u_B (S/\hbar)$
- g_s =a constant characteristic of the electron, the g-factor
- μB =the Bohr magneton = eh /2me =5.788 x 10–9eV G
- S =the spin of the electron
- $\hbar$ =Planck's constant = 6.582 x 10–16 eV-sec
- Because of its quantum nature, the electron can orient itself in one of only two ways, with energies equal to $E_0 = \pm$ gs $\mu B/2$; where E_0 is the energy of the electron before the magnetic field was applied. The energy difference between these two possible orientations is equal to $g_s \mu_B B$; where B is the magnitude of the magnetic field.

$$\left[1 + \frac{j(j+1) - l(l+1) + 3/4}{2j(j+1)}\right]$$

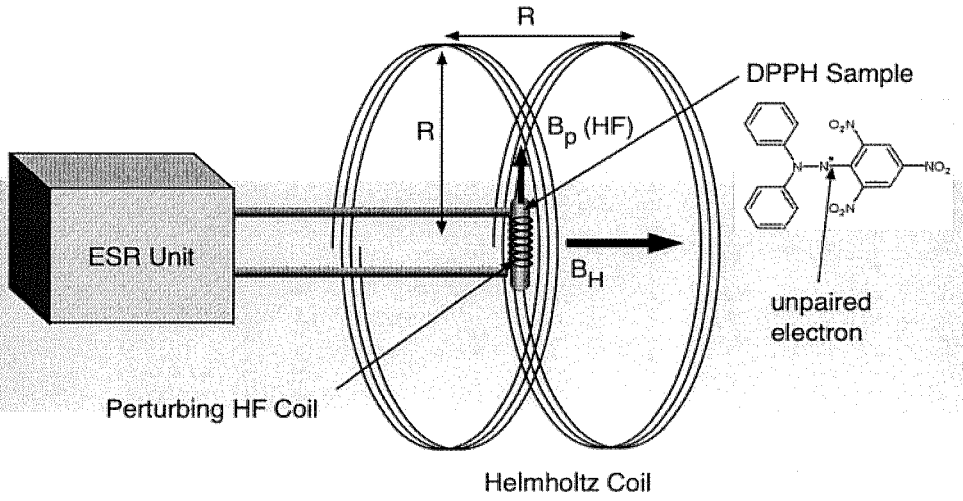


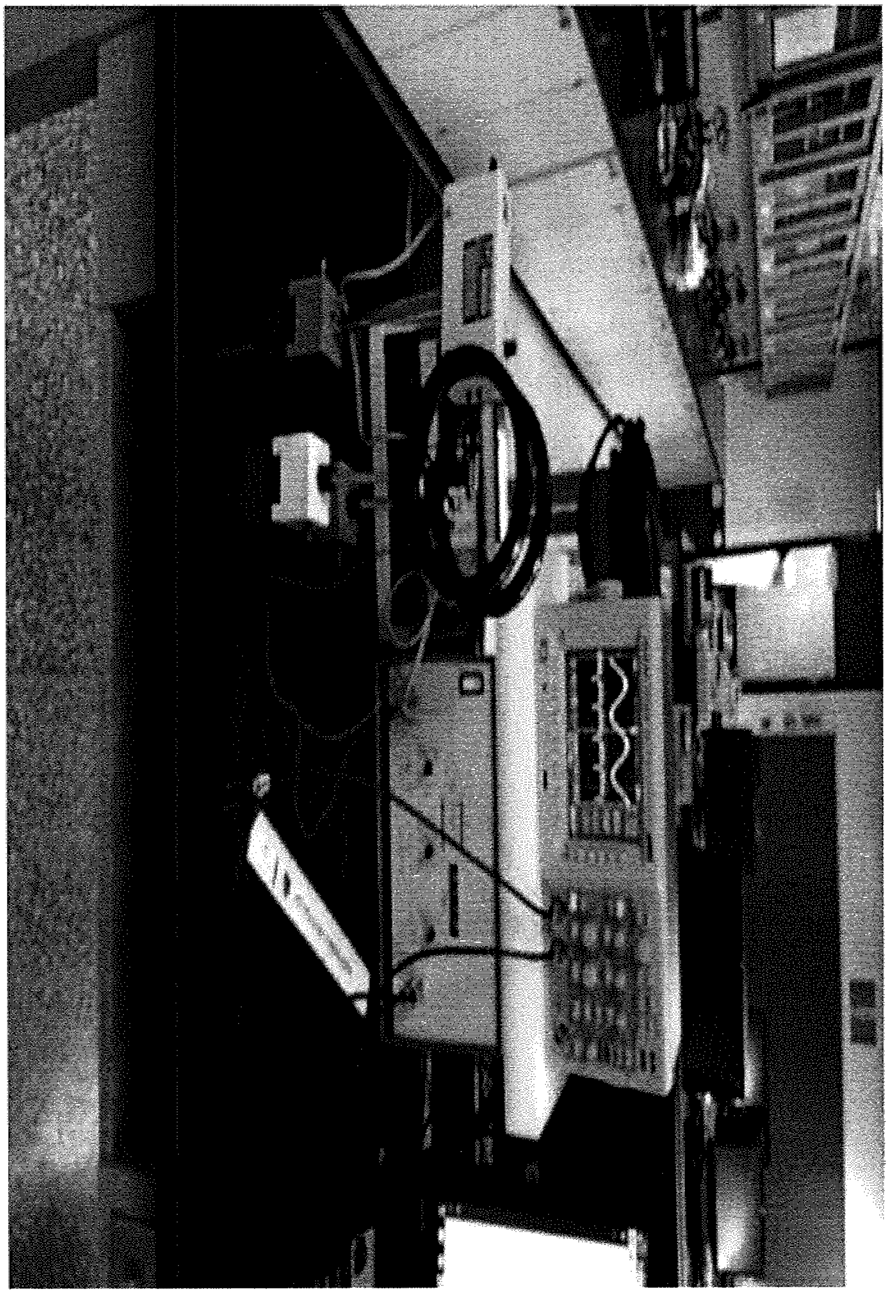
$\Delta E = h\nu = g\beta B$

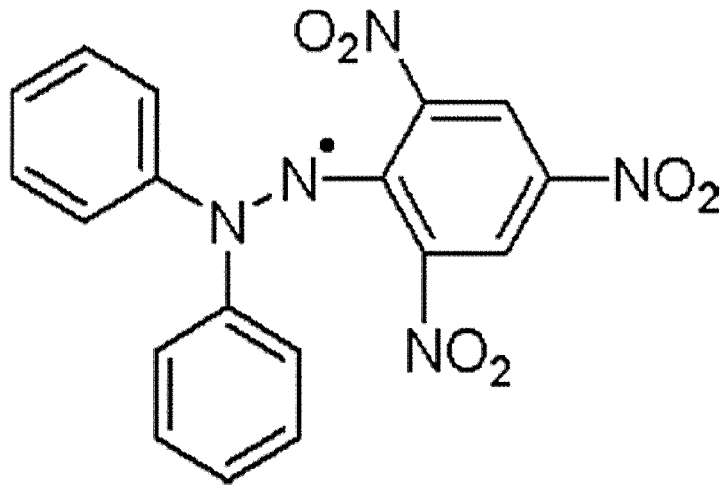
h Planck's constant 6.626196 x 10^{-27} erg.sec
ν frequency (GHz or MHz)
g g-factor (approximately 2.0)
β Bohr magneton (9.2741 x 10^{-21}erg.Gauss^{-1})
B magnetic field (Gauss or mT)

INSTRUMENTATION

- **The ESR Probe Unit**: Provides all required voltages and also digitally indicates the frequency of the oscillatory circuit. It includes The Probe Unit with base Three, RF Probes and a DPPH sample in a vial, the Passive Resonant Circuit and the Current Measuring Lead for the Probe Unit.
- **The ESR Adapter:** can be used to connect the Probe Unit to the necessary power supply, frequency meter, and oscilloscope (included in the ESR Basic System, but not in the Complete ESR System).
- **A pair of Helmholtz Coils with bases:** deliver a highly uniform magnetic field in which to place the sample material for the ESR measurement
- **The Control Unit**: provides most of the instrumentation needed to use the ESR Probe Unit. It supplies the voltages needed to drive the Probe Unit and the Helmholtz coils; it provides a digital readout of the RF oscillations produced by the Probe Unit; it provides outputs for a dual trace oscilloscope.
- **Oscilloscope:** display and analyze the waveform of electronic signals.







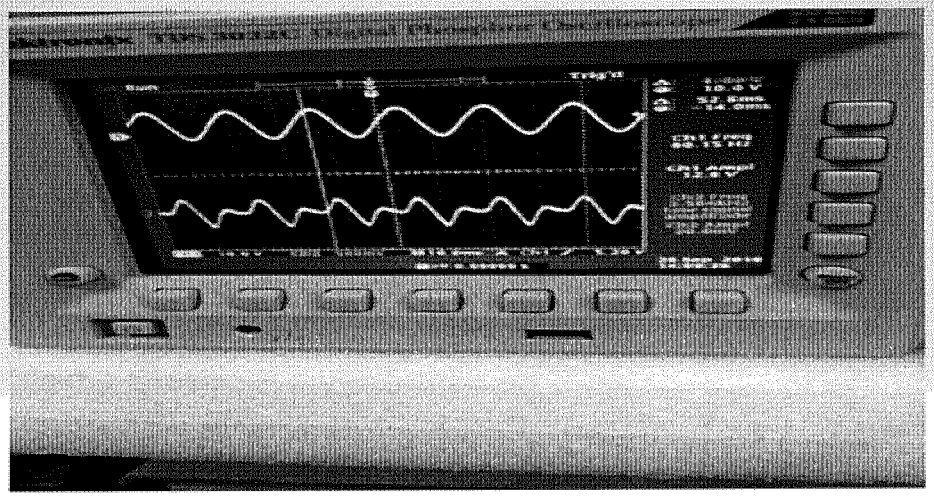
DPPH is chemically stable

Splitting factor g = 2.0036 (Diphenyl-Picryl-Hydrazyl (DPPH)

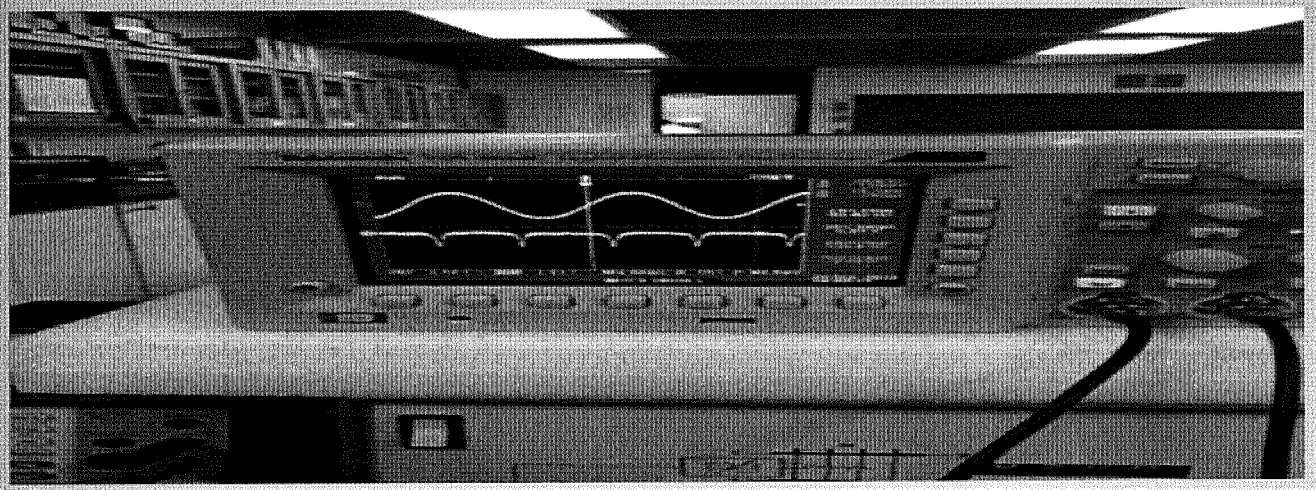
$1{,}53 * 10^{21}$ unpaired electrons per gm

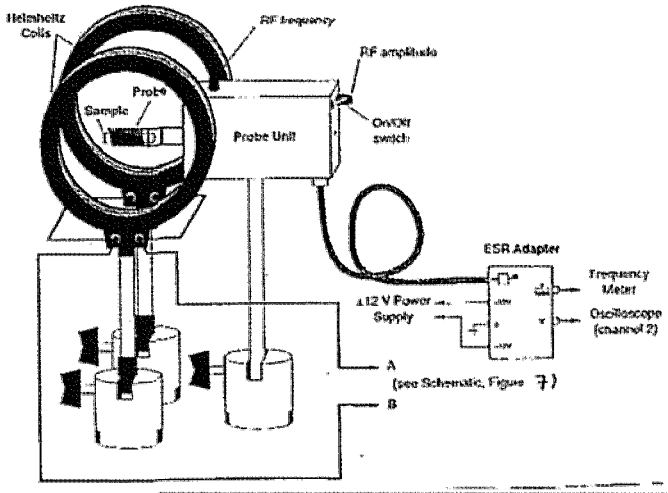
EXPERIMENTAL PROCEDURE

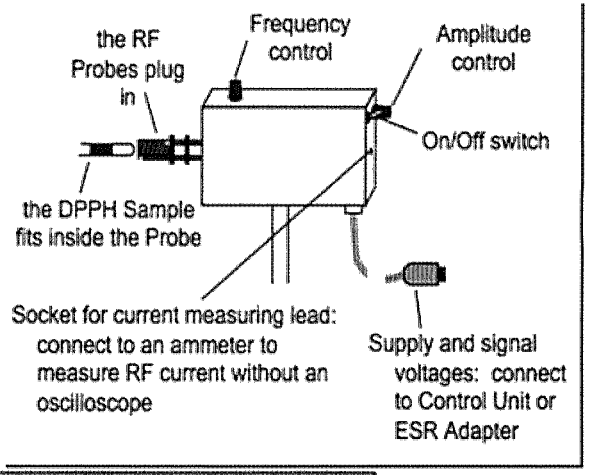
- **1-**I connected the helmholtz coils to the Control Unit (The coils were connected in parallel—terminal A to terminal A, and Z to Z.) and put them in parallel and facing in the same direction, and their separation was equal to approximately one half their diameter.
- **2**-I Connected the X output of the Control Unit to channel 1 of a dual trace oscilloscope.
- **3-** In the Control Unit, I set U_{mod}, the center knob to zero, then slowly vary U_0, the left knob, from 0 to 10 V and to observe the trace on the oscilloscope. (U_0 controls the DC current going to the Helmholtz coils.)
- **4- I** set U_0 at approximately midscale, then I turned U_{mod} clockwise, to increase the AC component of the current to the Helmholtz coils. The trace on the oscilloscope was a smooth sine wave.
- **5-** I added the Y output of the Control Unit to channel 2 of the oscilloscope and set the oscilloscope controls for channel 2 as follows: Sensitivity: 0.5 or 1 V/div Coupling: DC

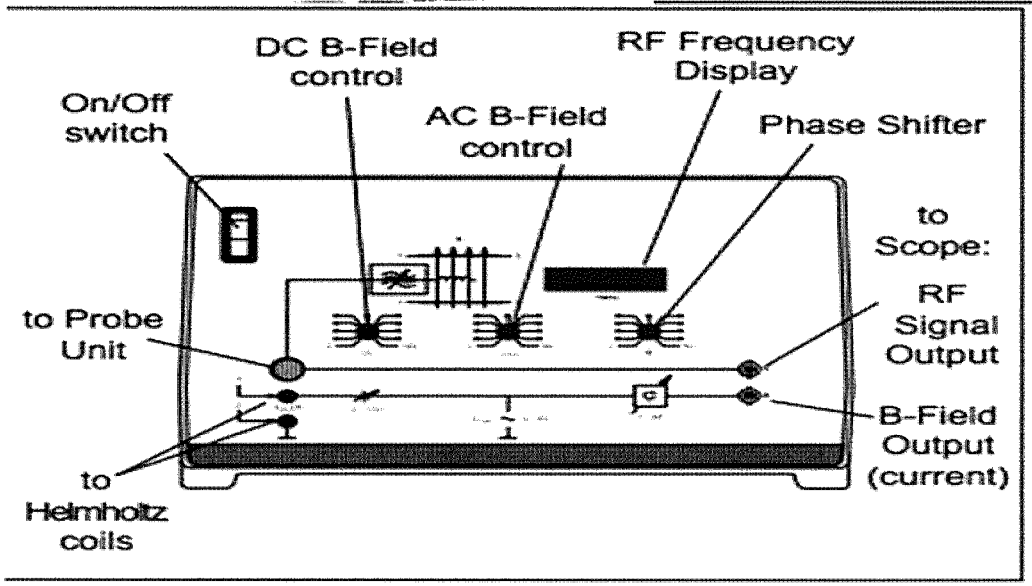


- **6-** After plugging the medium sized RF Probe into the Probe Unit and inserting the sample of DPPH into the coil of the probe. I turn on the Probe Unit by flipping the On/Off switch to the up (I) position and turned the Amplitude knob on the Probe Unit to a medium setting, the Frequency control knob on the Probe Unit to produce an output of approximately 50 MHz.
- **7-** I put U_{mod} to about the 4th position above zero and Increased U_0 from zero to a medium value, so the Helmholtz coil current is about 1.0 A, the oscilloscope traces showed:

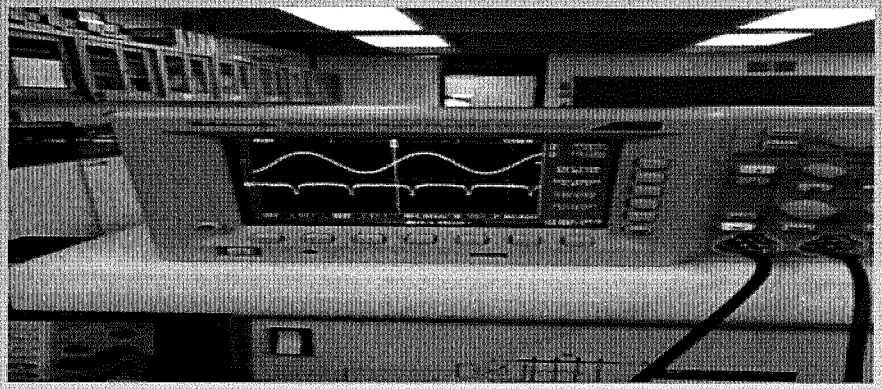



Helmholtz Coils
RF frequency
RF amplitude
Probe
Sample
Probe Unit
On/Off switch
ESR Adapter
Frequency Meter
±12 V Power Supply
Oscilloscope (channel 2)
A
(see Schematic, Figure 7)
B


the RF Probes plug in
Frequency control
Amplitude control
On/Off switch
the DPPH Sample fits inside the Probe
Socket for current measuring lead: connect to an ammeter to measure RF current without an oscilloscope
Supply and signal voltages: connect to Control Unit or ESR Adapter

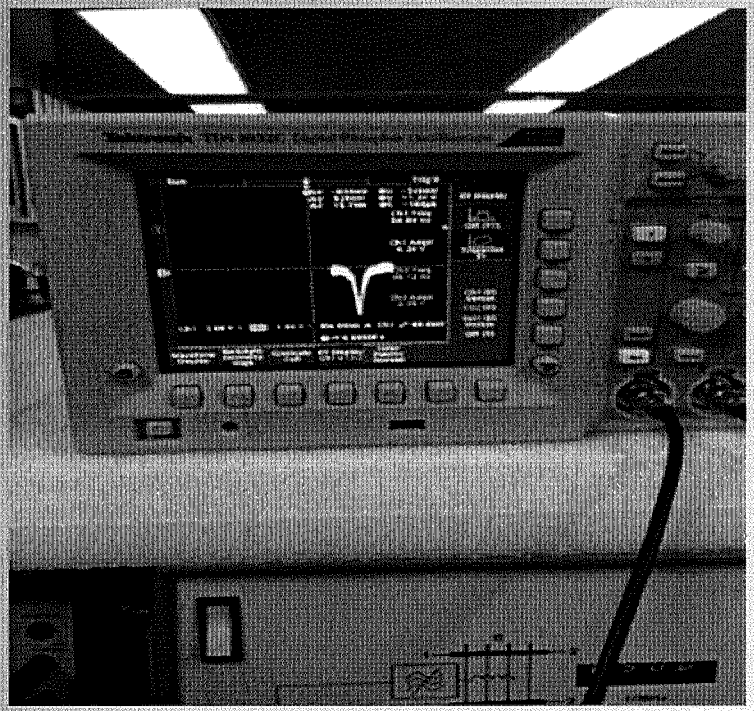

DC B-Field control
RF Frequency Display
On/Off switch
AC B-Field control
Phase Shifter
to Scope:
RF Signal Output
to Probe Unit
B-Field Output (current)
to Helmholtz coils

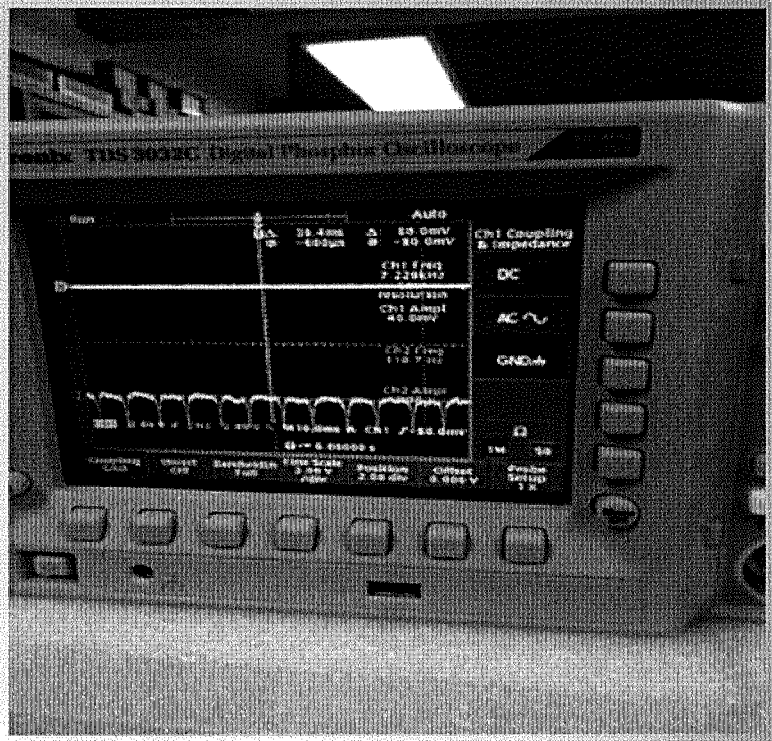
- In this figure, the channel 1 trace displays the current to the Helmholtz coils, which is proportional to the magnetic field produced by the coils. The channel 2 trace displays the envelope of the voltage across the RF oscillator, with the pulses showing the points of resonance absorption.



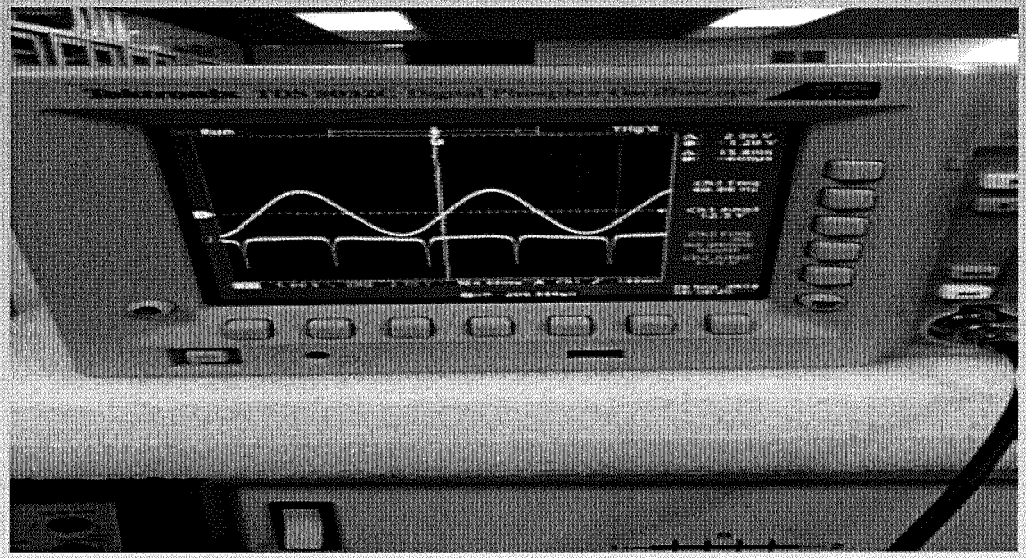
- **8-** As before, two resonance pulses can be observed since the magnetic field passes through the correct value twice each cycle. By adjusting the Phase Shifter, the two peaks can be brought into coincidence. The resulting trace was:

To refine the adjustment of the DC current until the resonance pulses occur when the AC component of the current to the Helmholtz coils is zero. I did this step by: 1) Make the channel 1 of the oscilloscope (the trace showing the current to the Helmholtz coils) is in the AC coupled mode. 2) from the oscilloscope controls, I grounded the input to channel 1, zero the trace, and then ungrounded the input.





- I adjusted the DC current and noticed how the resonance pulses move closer together or farther apart. By adjusting the DC current and the phase shifter, until the pulses occur just when the AC current to the Helmholtz coils is zero.



EXPERIMENTAL RESULT

- **Determining the resonance magnetic field B_0:**

In Table, the current through the series-connected Helmholtz coils I_0 in the case of resonance is listed as a function of the frequency v of the alternating high frequency field and the values calculated for the magnetic field are compiled

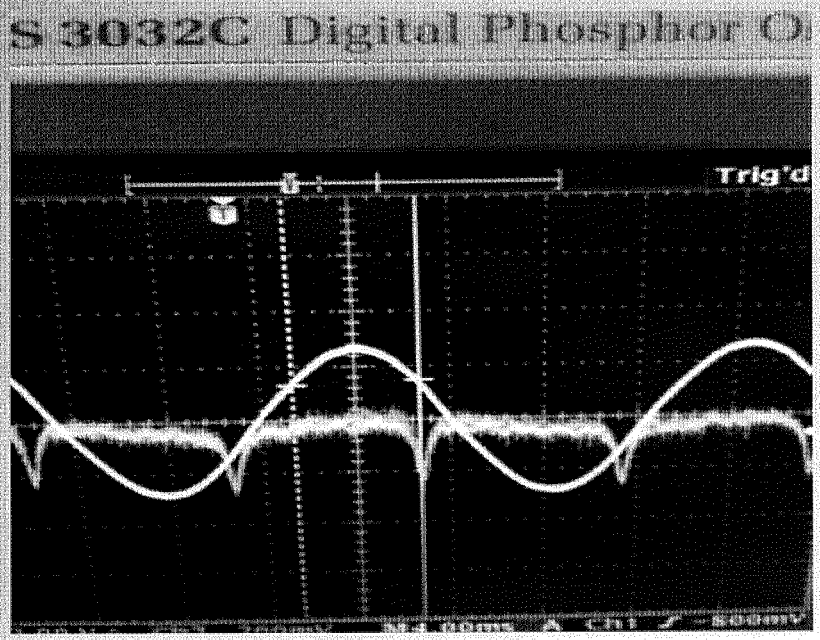
v/MHz	I (ampere)	plug-in coil	B(millitesla)
15	0.127	big	0.53721
20	0.168	big	0.71064
25	0.206	big	0.87138
30	0.3	big	1.269
35	0.305	medium	1.29015
40	0.326	medium	1.37898
45	0.377	medium	1.59471
50	0.428	medium	1.81044
55	0.463	medium	1.95849
60	0.512	medium	2.16576
80	0.677	small	2.86371
85	0.717	small	3.03291
90	0.76	small	3.2148
95	0.819	small	3.46437
100	0.851	small	3.59973

$$B = \mu_0 \cdot \left(\frac{4}{5}\right)^{\frac{3}{2}} \cdot \frac{n}{r} \cdot I \text{ with } \mu_0 = 4\pi \cdot 10^{-7} \frac{Vs}{Am}$$

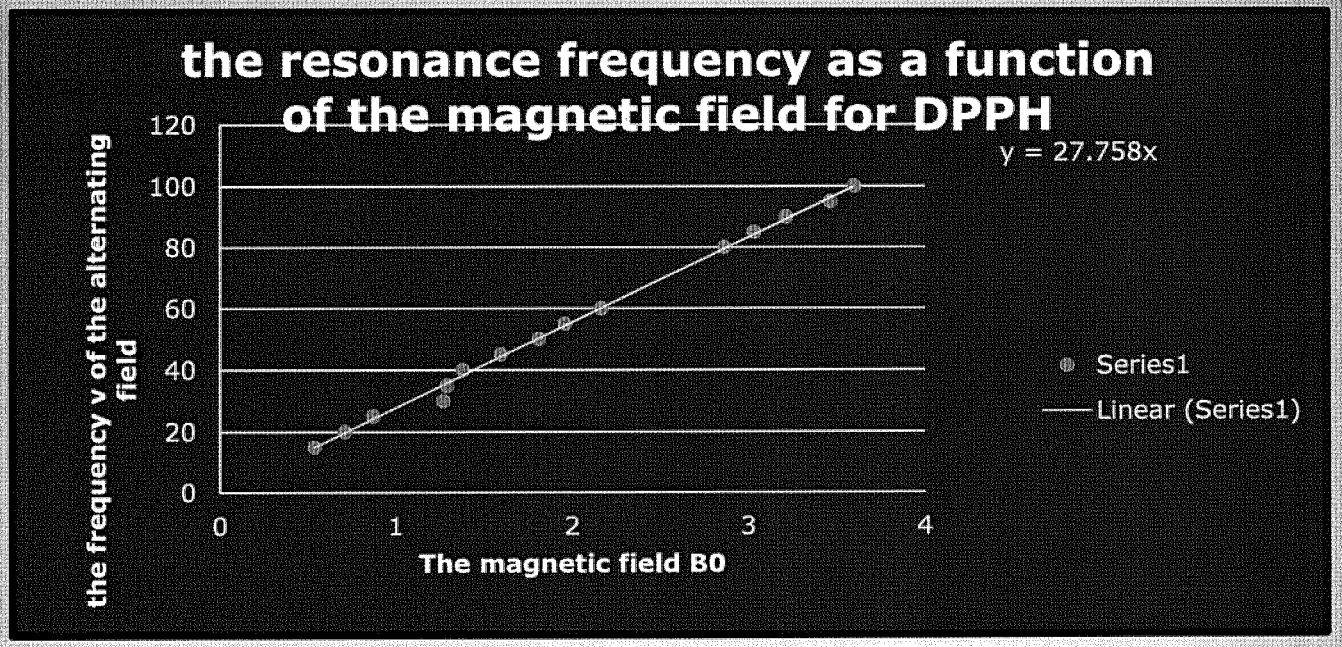
(n: number of turns per coil, r: radius of the coils) With n = 320 and r = 6.8 cm, B=4.23 mT. I /A

-Determining the half-width δB_0:

The half-width read from the oscilloscope, 1.5 cm corresponding to:



- δU = 1.5 cm. 0.2(v/cm) =0.3 V (1.5 cm is the distance between the two vertical lines)
- Calibration of the full modulation voltage U_{mod}:
- U_{mod}= 10cm . 0.5 (v/cm)= 5V
- (10cm is the Extend the resonance signal in the X direction exactly
- over the total width of the screen) which corresponds to I_{mod} = 0.282 A (RMS of AC).



- The last plot is the resonance frequency as a function of the magnetic field for DPPH. It shows a plot of the measured values. The slope of the straight line through the origin drawn in the plot is
- $\frac{\nu}{B_0} = 27.758 \frac{MHz}{mT}$
- From this the g-factor follows : $g = \frac{h.\nu}{u_0.B_0} = \frac{6.625\,10^{\uparrow}(-34)\ \mathrm{Ws}}{9.273\,10^{\uparrow}(-24)\ \mathrm{Am})} . 27.758\ \frac{MHz}{mT} = 1.983$
- Value quoted in the literature: g(DPPH) = 2.0036. The percentage error is
- %Error=100. [(2.0036-1.983)/ 2.0036] =1.028%
- Peak-to-peak Amplitude $2\sqrt{2}$of RMS
- $\delta I = (\delta U / U_{mod}) * I_{Mod} = (0.3\ V / 5\ V) * 0.282\ A * 2\sqrt{2} = 0.0478\ A$
- Then
- $\delta B = (4.23\ mT) * \delta I / A = 4.23\ mT * 0.0478\ A/A = 0.202\ mT$
- Value quoted in the literature: δB0 (DPPH) = 0.15-0.81 mT

$$\% \text{ Error} = \left| \frac{\text{Theoretical Value} - \text{Experimental Value}}{\text{Theoretical Value}} \right| \text{X } 100$$

Conclusion

- ESR is a very sensitive and powerful technique to probe the electronic structures of paramagnetic entities in molecular levels
- I determined the g-factor of DPPH. The slope in the plot of the frequency versus applied magnetic field was used to calculate the g-factor of DPPH.
- ESR is used in various branches of science, such as biology, chemistry and physics,

THE END

Simple questions ?