



**Apparatus for the lifetime
measurement of Samarium excited
states**

by

Bahram Mojarrabi B.Sc.(Hons)

Thesis submitted for the degree of Master of Science

in the

Faculty of Science

University of Adelaide

March 1996

CONTENTS

Abstract

Declaration

Acknowledgement

List of symbols

1) Chapter 1: Introduction	1
1.1) Introduction	1
1.2) Scope of the thesis	8
2) Chapter 2 : Mathematical description of the Hanle effect	9
2.1) Introduction	9
2.2) Classical treatment	10
2.3) Semi-classical formalism	13
2.3.1) Density matrix	14
2.3.2) Application of the density matrix to the theory of the Hanle effect	15
2.3.3) The equation of motion of the density matrix	17
2.3.4) Extension to Lambda system	23
2.4) Conditions for observation of the zero field level crossing	24
2.5) Suggested steps for determination of lifetime of the excited states	28

2.6) Applications of the zero field level crossing	29
3) Chapter 3 : Optogalvanic spectroscopy	32
3.1) Introduction	32
3.2) Basic properties of a dc discharge	35
3.3) Hollow cathode discharges	40
3.4) Sm-Ne discharge mechanism	43
Chapter 4 : Setting up the apparatus, experimental procedure and results.	48
4.1) Introduction	48
4.2) Design and construction of the apparatus	49
4.2.1) The vacuum system and magnetic coils	49
4.2.2) Construction of the oven	52
4.2.3) Diode laser and the construction of the temperature controller	58
4.3) Experimental set up and procedure	64
4.4) Data analysis	69
4.5) Conclusion	75
References	77
Appendix 1) Derivation of the Hanle signal from the time evolution of the density matrix	85
Appendix 2) Saturation intensity derivation	87
Appendix 3) Detection of Sm beam by reflection pulse technique	88
Appendix 4) Schematic diagram of temperature controller	100

Abstract

This thesis describes the construction of the apparatus for the measurement of the lifetime of the 9F_1 level of Samarium by the Hanle effect. The construction work involves the design and building of the vacuum system, the magnetic coils and the laser frequency stabiliser instruments. The project involved the assembly of the oven and the fluorescence signal detection system in addition to the direct calibration of the diode laser wavelength. A technique known as Optogalvanic spectroscopy was used to calibrate the laser wavelength. The basic properties of DC discharges and in particular the Samarium -Neon Hollow Cathode discharges are also reviewed.

The theory of Hanle effect in a three-level V-system is also presented.

A new method for the detection of the atomic beam of some materials is presented.

DECLARATION

I certify that this thesis does not contain without acknowledgement any material previously submitted for the award of a degree or diploma; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

I give my consent to this copy of thesis being made available for photocopying and loan if accepted for the award of the degree.

.....

Bahram Mojarrabi

BSc (Hon)

Acknowledgements

I wish to thank my supervisor Dr M.W Hamilton for his help and support throughout the research of this thesis.

The guidance and advice of Dr D. McCoy at several stages throughout the course of this project has been greatly appreciated.

I'd sincerely like to thank Professor Jesper Munch for his help and the critical reading of the thesis. I extend my gratitude to Dr Peter Veitch for allowing me to use his personal computer.

Thanks also to Professor J.R Prescott and Mr Peter Berry-Smith for their contribution in the development of guidelines regarding the safe handling of the Samarium.

I would also especially like to thank Mr Laurentiu Stamatescu and Mr Peter Atanackovic, Dr Chaangjiang Weil and Ms Kerry Corbett for their effective suggestions and help.

I also express my gratitude to Dr Ursula McGowan of the ACUE and Ms Kerry Corbett for their help with the English grammar .

I also wish to express my humble gratitude to Mr Bob Hurn, Mr John Schache and Mr Blair Middlemiss and most importantly Mr Bob Nation and Mr Graham Eames for their enormous help in the construction of the Apparatus.

I also gratefully acknowledge the help from Mr John Smith and Mr Michael Shorthose with the construction of the electronic apparatus and invaluable technical assistance.

Many thanks also goes to the members of the optics group, especially Mr Vladimyros Devrelis, Robert Purviskis, Dr Yuri Matyagin, and Mr Armin Ardekani for their friendship and their helpful discussions.

I also wish to thanks Mrs Arlene Shaw, Ms Carmel Palumbo, Mrs Margaret Whiteford, Mrs Heather Duff and Mrs Mary Genovese for their beautiful smile s and kind heart s. Thanks also to Sharon Frecken and Tanya Weir for keeping us in touch with the letters.

I also extend my thanks to Ms Quyen Nguyen and Mrs Pamela Vogiatzis, my dear friends for their help in organising the manuscript.

I am deeply grateful to my perfect wife my dear Yae and my beautiful mother, brother and sisters. My pen is unable to fully describe their beauty.

Errata

abstract, line 2) '*...the 9F_1 level....*' should be changed to '*...the $4f^6 6s 6p$ 9F_1 (14863.85 cm^{-1})....*'

page 11, line 8) '*It is the time in which*' should be changed to '*It is the rate in which.....*'

page 21, line 20) '*..... on the absorption coefficient.*' should be changed to '*....on the laser intensity .*'

page 27, lines 14-15) '*....depends on Lande g factor as well as hyperfine g factor.*' should be changed to '*....depends on the hyperfine g factor as well as Lande g factor.*'

page 28, last line) '*...for the Earth's magnetic field.*' should be changed to '*...for the Earth's magnetic field as well as the stray magnetic field from the oven.*'

page 33, line 15) '*....ionisation cross section....*' should be changed to '*....ionisation probability....*'

page 87, line 6) '*....steady state values of $\sigma^{++}, \sigma^{--}, \sigma^{+-}$ into....*' should be changed to '*....steady state values of σ^{++}, σ^{--} into....*'

page 87, line 8) '*.....algebraic manipulation, one can....*' should be changed to '*....algebraic manipulation involving equation (A 1.4), one can.....*'

h	Planck's constant
\hbar	$\frac{h}{2\pi}$
H	total Hamiltonian
I	laser intensity
I_s	saturating intensity
I_{nuc}	nuclear moment
i	current
J	total angular momentum
J_e	electron current density
J_{ion}	ion current density
L_c	cavity length
L	inductance
l	the length of the coil
λ	wavelength of the transition
$ m\rangle, m$	Zeeman eigenstates
m	magnetic moment
m_e	electron mass
M	metastable level
M	magnetisation
μ_B	Bohr magneton
μ	magnetic permeability
μ_r	relative permeability

N	number of the turns of the coil
ω_l	Larmor frequency
ω	Laser frequency (angular)
P	pressure
P	power of the laser
R	mirror reflectivity
R	resistor
R_B	ballast resistor
R_g	generator resistor
r	coil radius
ρ	density matrix
ρ_r	reflection coefficient
S	cross section area of the coil
T_e	electron temperature
τ	lifetime
θ	angular divergence of the atomic beam
η	electron mean free path
v	interaction Hamiltonian
V	Potential
ν_L	frequency of the laser
V_{sn}	shot noise amplitude
V_o	power supply voltage

V_{ref}	reflected wave amplitude
v	mean velocity of the atomic beam
w	Rabi frequency
χ_m	magnetic susceptibility
Z_l	load impedance