EXPERIMENTAL SET UP FOR CHARACTERIZATION OF ACOUSTO-OPTIC MODULATOR SYSTEM

NORSHAHIDA BINTI ISMAIL

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Science (Physics)

Faculty of Science
Universiti Teknologi Malaysia

JAN 2010

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Science (Physics)

Dedication to my beloved Husband, Kamro Bin Hasan @Jaafar,
Daughter, Nur Ainul Mardhiah Binti Kamro
Father, Ismail Bin Hamid,
Mother in law, Tuan Sena Binti Tuan Ngah,
Brothers, sisters
And friends........

ACKNOWLEDGEMENT

In the name of Allah, Most Gracious, Most Merciful. Praise is to Allah, the Cherisher and Sustainer of the worlds. For His Mercy has given me the strength and time to complete this project.

I would like to express my sincere gratitude and appreciation to my supervisor, Profesor Dr. Rosly Abd Rahman for his support, supervision and mentoring. Profesor Rosly is always available to provide support and suggestions and answer questions. Without his patience and consideration I certainly would not have finished this work.

I would like to acknowledgement the help and kindly assistance of the following persons; Mr. Ahmad Bin Imbar, Mr. Nasir, Mr. Salehudin, Mr. Abd. Rasid Isnin, Mrs. Ruzilah and Mr. Sakifli for assisting in carrying out experimental works and colleagues from Optoelectronics, Laser and Advanced Optical Materials Research Group (AOMRG) Lab for their continuing corporation, encouragement and useful comment to complete the work

My thanks are also due to Government of Malaysia through IRPA grant vote 74534 for giving us financial support. Without this financial support, this project would not be possible.

Thanks also to all my friends and course mates for their views, concerns and encouragement. Last but not least, my appreciations go to my family for continuing support, patience throughout the present work and who have favored me with correspondence, I have much pleasure in expressing my obligation. May Allah bless those who have involved in this project.

ABSTRACT

Acousto-optic effect can be used in many useful devices such as modulators, switches, filters, frequency shifters and spectrum analyzers. In this study, the modulating effect was generated by low cost SF_6 glass with a lithium niobate transducer. Tunable Helium Neon Laser was used as the main light source. The function generator was used to generate external input signal and to vary the amplitude of acoustic wave. The modulated output signal was measured and analyzed using laser beam profiler, spectrometer, Si photo detector and power meter. The investigation shows that there was a shift of the horizontal main beam spot position when the driving frequency of the modulator is changed. A shift of beam spot between 4.0 mm to 5.5 mm was observed for a frequency range between 70 MHz to 90MHz. This is accordance with the expected theoretical model of the modulator. Results also show that a modulator can produce output signals, which are of the same type as the input signal. Increasing the amplitude of modulating signal in the range of 119 mV to 196 mV decreases the amplitude of modulated square wave signal from 2.6 V to 0.4 V. There was a decrease in the output power of the zero order diffraction but an increase in the first order diffraction with respect to the increase of the RF driving power.

ABSTRAK

Kesan akusto-optik banyak digunakan dalam pelbagai peranti seperti pemodulasi, pensuisan, penapisan, penganjak frekuensi, dan penganalisa spektrum. Dalam kajian ini, kesan modulasi dijanakan oleh bahan kaca SF_6 dengan pemindah aruh Lithium Niobate. Laser Helium Neon boleh laras digunakan sebagai sumber cahaya utama. Penjana denyut digunakan untuk menjana isyarat masukan luaran dan mengubah amplitud kuasa akustik. Isyarat keluaran termodulasi diukur dan dianalisis menggunakan penganalisa alur laser, pengesan spectrum, pengesan-foto dan meter kuasa. Kajian ini menunjukkan bahawa berlaku anjakan melintang pada titik cahaya apabila pembawa frekuensi pemodulasi diubah. Anjakan titik sinaran antara 4.0 mm hingga 5.5 mm dapat dilihat untuk jarak frekuensi antara 70 MHz hingga 90 MHz. Ianya mematuhi jangkaan model teori pemodulasi. Keputusan juga menunjukkan bahawa pemodulasi boleh menghasilkan isyarat keluaran yang mana sama dengan bentuk isyarat masukan. Pertambahan amplitud isyarat modulasi antara 119 mV hingga 196 mV akan mengurangkan amplitud isyarat termodulasi daripada 2.6 V hingga 0.4 V. Didapati bahawa kuasa keluaran bagi pembelauan tertib sifar menyusut tetapi ianya meningkat bagi pembelauan tertib pertama bilamana kuasa pemacu RF bertambah.

TABLE OF CONTENTS

CHAPTER **TITLE** **PAGE**

1 INTRODUCTION

2 **THEORY**

3 **EXPERIMENTAL WORKS**

5 CONCLUSIONS AND SUGGESTIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AO	Acousto-optic
AOM	Acousto-optic modulator
CW	Continuous wave
DC	Direct current
FWHM	Full wave half maximum
OSC	Oscillator
RF	Radio frequency
LBP	Laser Beam Profiler

LIST OF SYMBOLS

c	Light velocity
z	Distance between zero order beam and first order beam
f	Frequency of acoustic waves
H	Height of transducer
K	Wave vector of photon
L	AO interaction length along the direction of propagation of light
M	Figure of merit
m	Diffraction order
n	Refractive index of material
Q	Quality factor
V	Velocity of sound in material
$\hbar$	Planck constant
$K^{'}$	Wave vector of new photon
k_a	Wave number of acoustic wave (Wave vector of phonon)
k_i	Wave number of incident light (Wave vector of incident photon)

K_d	Wave number of scattered light (Wave vector of scattered photon)
P_a	Acoustic power
v	Speed of sound
ω_d	Frequency of Scattered light (Angular frequency of photon)
ω_i	Frequency of incident light (Angular frequency of photon
ω_o	Angular frequency of new phonon
θ_B	Bragg angle
θ_{shift}	Shift angle
I_o	Incident optical beam density
θ_m	Separation angle between *m*th diffracted order beam and undiffracted order beam
θ_i	Incident angle
θ_d	Diffracted angle
θ_0	Angle
t_r	Rise time
ρ	Density of material
η	Diffraction efficiency
Λ	Wavelength of the acoustic waves
λ	Optical beam wavelength

Ω_a	Frequency of the acoustic wave
Δt	Oscillation time,
Δn	Amplitude of the refractive index change due to the acoustic strain
n_i	Refractive index of incident beam
n_d	Refractive index of diffracted beam

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

1.1 Introduction

Applications of laser light often require a means for modulating some properties of the laser light wave, such as intensity (amplitude), phase wavelength (frequency) or polarization (direction of propagation) (Schawlow, 1969; Hammer, 1975). A modulator is a device that alters a detectable property of a light wave corresponding to an applied electric signal (Hammer, 1975).

There are number of methods that can be used to modulate laser light such as mechanical, electro-optic, acousto-optic and magneto-optic. Most mechanical methods such as rotating mirror and mechanical shutter or chopper used for laser beam modulation are slow, unreliable and have much inertia to allow for faster light modulation (Kaminow and Turner, 1996; Schawlow, 1969). Thus the mechanical methods are seldom used in modern modulation equipment. Hence, the interaction between laser wave and electric, magnetic or acoustic fields acting through the electro-optic, magneto-optic and acousto-optic effect are used to modulate laser-beam (Kaminow and Turner, 1996; Chen 1970). Modulation of laser-beam by using these effects is faster and more reliable than the mechanical methods.

Optical modulators, using acousto-optic, magneto-optic or electro-optic effects, as the principal components for external modulation of light wave have presently played the important role in modern long-haul ultra-high speed optical communications and photonic signal processing systems. Other common uses of acousto-optic media include devices for modulating light for communication, detecting light, convolving or correlating signals, optical matrix processing, analyzing the spectrum of signals, optical sources, laser mode lockers, Q-switchers, delay lines, image processing, general and adaptive signal processing, tomography transformations, optical switches, neural networks, optical computing, and much more.

1.2 Background of Study

Brilliouin predicted light diffraction by an acoustic wave propagating in a medium of interaction in 1922. In 1932, Debye and Sears, Lucas and Biquard carried out the first experimentation to check the phenomena. The particular case of diffraction on the first order, under a certain angle of incidence, (also predicted by Brillouin), has been observed by Rytow in 1935. Raman and Nath (1937) have design a general ideal model of interaction taking into account several orders. This model was developed by Phariseau (1956) for diffraction including one diffraction order. Then, with development of the laser in 1960s, acousto-optics became an engineering pursuit as devices to control photons became necessary (Parygin, Balakshy, Voloshinov, 2001). Research and development over the last decades has produced many types of acousto-optic devices including optical modulators (Robert J.F., 2003).

One of the earliest uses of an AOM in electro-optics system is for large screen television images projection in theaters (Goutzoulis, Pape, 1994). Today it is not only being used in scanning and imaging but also apply in telecommunication (Parygin, Balakshy, Voloshinov, 2001). An effective and efficient communication system is now used in the paperless world. The study of acousto-optic modulator design and fabrication is increasingly important due to its high gain in modulation (Goutzoulis, Pape, 1994).

There are three main types of acousto-optic devices, namely, bulk acousto-optic devices, integrated optic devices and all-fibre acousto-optic devices (Goutzoulis, Pape, 1994). Since this technology is considered new in our country, the study will start from the most basic level of the AOM design which is bulk acousto-optic devices. In bulk devices an optical beam which propagates through an optical medium in the presence of an acoustic wave, can generate a diffracted beam, producing a frequency shift in the diffracted ray. These devices are called Bragg cell and have many advantages. The main problem in applying Bragg cells to optical fibre is that they contribute to insertion loss interface reflection and diffraction loss in the bulk medium.

1.3 Objective of Research

The objective of this research are:

i. Investigate the principles of an AOM
ii. Identify critical parameters in the design of AOM
iii. Construction of AOM system
iv. Evaluation of the performance of the AOM setup

1.4 Problem Statement

Acousto-optic Modulator is the most important device used to modulate signal in optical telecommunication technology. This is an initial study in the design and construction of an acousto-optic modulator. The success of designing and constructing AOM will bring about new applications for use in research at UTM. Even though this type of modulator is available in the market, but there is a need to produce or manufacture this kind of modulator for local use. This research will be a good start for Malaysia to get involve in AOM manufacturing.

1.5 Scope of Research

In this research, a equipments use in the experiments was studied. The equipments include Tunable HeNe Laser, NEOS Technology AO Modulator (24080), AO Modulator Driver, Laser Beam Profiler (LBP), PDA 55 Amplified Silicon Detector, Fiber Optic Spectrometer, Polarizer and analyzer and Power And Energy Meter System.

A preliminaries experiment is carried out using a fibre coupled AOM using chalcogenide glass with refractive index 2.6. This study focus on investigating the characteristic of AOM, studying the theory and working principle of AOM and other equipment in experimental set up, to get the relationship between driving voltage from RF driver and output power from modulator causes by the changes in output level from radio frequency (RF) driver, to observe several light source sensitivity.

The AOM was precisely aligned with rotating stage in order to diffract the light at Bragg angle. The characterization of AOM was carried out in term of laser beam profile, power and signal configuration.

1.6 Thesis Outline

This thesis composes of six chapters. The first chapter of this thesis presents an introduction and overview of the previous research works regarding the AOM. The objective and scope for this research is briefly address and clarify the aim of this research.

Chapter 2 presents the theoretical background related to this research. It explains the principle of acousto-optic interaction.

Chapter 3 explains the equipments and how the methodology of the research is conducted. In this chapter, the method for the characterization of the modulation output is outline. This includes the experimental setup and procedures for Bragg angle alignment, laser beam profiling and the measurement of output power.

The characterization of AOM output is detail out in Chapter 4. The characterization parameters observed includes the beam profile, power and signal. In laser beam profile characterization the RF signal is varied and details analysis that covers diffraction angle, diffraction efficiency and optimum frequency is carried out. The optimum frequency is important to drive the AOM for the next characterization methods. The laser beam power is characterized by varying the RF drive power. The modulation signal is characterized based on pulse width. This is conducted by varying the RF drive power and RF input pulses.

Finally the conclusion of the project is described in Chapter 5. This includes the summarization of the whole project. Some works to be carried out in the future are suggested.