DEVELOPMENT OF INFRARED TRANSMITTER USING VERTICAL CAVITY SURFACE EMITTING LASER

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By

FATIMA LINA AYATOLLAHI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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In The Name Of Allah, Most Gracious, Most Merciful

To

My Parents

And

My Beloved Brother

Abstract of the thesis presented to the Senate of University Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman: **Associate Professor Mohamad Khazani Abdullah, Ph.D.**

Faculty: **Engineering**

Developing good IR transmitter shall consider its complexity and type of emitter. Light emitting diode (LED) which is the most commonly used as an emitter is challenged by emerging technology called vertical cavity surface emitting laser (VCSEL). However, the use of VCSEL for infrared signaling has not been reported before. VCSEL is claimed to be easier and more efficient than LED.

This research is focusing on development of an infrared transmitter using vertical cavity surface emitting laser (VCSEL) instead of LED. Several design options, which are based on simple gates, MAXIM chips and microprocessor, were explored. Finally, test and analysis were carried out to evaluate the suitability of VCSEL as an infrared transmitter. By comparing the output power of VCSEL and LED; it was obtained that VCSEL can provide efficient power utilization.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian keperluan untuk ijazah Master Sains

PEMBANGUNAN TRANSMITER INFRARED MENGGUNAKAN ‘VERTICAL CAVITY SURFACE EMITTING LASER’
Oleh

FATIMA LINA AYATOLLAHI

September 2004

Pengerusi: **Profesor Madya Mohamad Khazani Abdullah, Ph.D.**

Fakulti: **Kejuruteraan**

Untuk membangunkan transmisi IR yang baik, tahap kerumitan rekabentuk dan jenis emitter yang sesuai perlu dikaji. Emiter jenis LED yang digunakan secara meluas untuk tujuan ini kini mendapat saingan daripada teknologi baru berasaskan ‘vertical cavity surface emitting laser’ (VCSEL). VCSEL dipercayai lebih murah, mudah dan cekap.

Kaji selidik ini menumpukan kepada kajian terhadap rupa bentuk VCSEL dan kebarangkalian kepada penggunaannya dalam alat transmisi IR. Beberapa rekabentuk dengan tahap kekompleksan yang berbeza untuk alat transmisi IR dengan berasaskan ‘gate’ biasa, cip MAXIM dan mikroprosesor dipersembahkan dalam tesis ini sebagai asas pembangunan transmisi IR. Seterusnya penyelidikan ini menguji dan menganalisa kesesuaian dan kelebihan VCSEL dalam alat transmisi IR. Hasil kajian yang menunjukkan lengkok ambang arus VCSEL jauh lebih rendah daripada LED, telah membuktikan hakikat kelebihan ini.

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Special thanks to my parents and beloved brother for all the love, supports and encouragement.

I certify that an Examination Committee met on 20 September 2004 to conduct the final examination of Fatima Lina Ayatollahi on her Master of Science thesis entitled "Development of Infrared Transmitter Using Vertical Cavity Surface Emitting Laser (VCSEL)" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

FATIMA LINA AYATOLLAHI

Date:

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LIST OF ABBREVIATIONS

ADC	Analog to Digital Converter
AAC	Augmentative and Alternative Communication
AEL	Accessible Emission Levels
AlGaAs	Aluminum Gallium Arsenide
ASCII	American Standard Code for Information Interchange
BRD	Baud-Rate Divisor
CD	Compact Disk
CD	Carrier Detect
CENELEC	European Committee For Electro Technical Standardization
CPU	Central Processing Unit
CR	Command Register
CRC	Cyclic Redundancy Check
CS	Chip Select
CTS	Clear To Send
DBR	Distributed Bragg Reflectors
DCE	Data Communications Equipment
DIN	Data Input
DOUT	Data Output
DSR	Data Set Ready
DSSS	Direct Sequence Spread Spectrum
DTE	Data Terminal Equipment
DTR	Data Terminal Ready
EBCDIC	Extended Binary Coded Decimal Interchange Code

ELF	Extremely Low Frequency
FCC	Federation of Communications Commission
FHSS	Frequency Hopping Spread Spectrum
FIFO	First-In/First-Out
FSK	Frequency Shift Keying
GaAs	Gallium Arsenide
IAS	Information Access Service
IC	Integrated Circuit
IEC	International Electro Technical Committee
InGaAsN	Indium Gallium Arsenide Nitride
IR	Infrared
IrCOMM	Infrared Serial and Parallel Port Emulation
IrDA	Infrared Data Association
IrLAN	Infrared Local Area Network Access
IrLAP	Infrared Link Access Protocol
IrLMP	Infrared Link Management Protocol
IrOBEX	Infrared Object Exchange Protocol
ISM	Instrumentation, Scientific, And Medical
LD	Laser Diode
LED	Light Emitting Diode
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MPE	Maximum Possible Exposure
NOS	Network Operating System
NRZ	Non-Return to Zero
OEM	Original Equipment Manufacturer

OSNR	Optical Signal-To-Noise Ratio
PC	Personal Computer
PPM	Pulse Position Modulation
QSOP	Quarter Size Outline Package
RD	Received Data
RF	Radio Frequency
RI	Ring Indicator
RL	Load Resistor
RTS	Request To Send
RTZ	Return to Zero Inverse
SIR	Serial Infrared
SPI	Serial Peripheral Interface
TD	Transmitted Data
TinyTP	Tiny Transport Protocol
TTL	Transistor-Transistor Logic
TV	Television
TX	Transmit
UART	Universal Asynchronous Receiver Transmitter
US	United State
VCR	Videocassette recorder
VCSEL	Vertical Cavity Surface Emitting Laser
WAN	Wide Area Network
WDM	Wavelength Division Multiplexing

LIST OF NOTATIONS

λ	Wavelength
λ_σ	Central Wavelength At Normal Incidence
λ_θ	Central Wavelength At The Off-Normal Angle θ
θ	Angle
Ω	Ohm
Hz	Hertz
KHz	Kilo Hertz
MHz	Mega Hertz
GHz	Giga Hertz
nm	Nanometer
μs	Micro Second
bps	Bit Per Second
Kbps	Kilo Bit per Second
Mbps	Mega Bit per Second
Gbps	Giga Bit per Second
ns	Nanosecond
V	Volt
mA	Milli Ampere
nF	Nano-Farad
μF	Micro Farad
dBm	Decibels Referred to 1 Milli Watt

Chapter 1

INTRODUCTION

1.1 Background

Developing good IR transmitter shall consider its complexity and type of emitter. LED which is the most commonly used emitter is challenged by emerging technology called vertical cavity surface emitting laser (VCSEL). However the use of VCSEL for infrared signaling has not been reported before. VCSEL is claimed to be easier and more efficient than LED.

This research is focusing on development of infrared transmitter using vertical cavity surface emitting laser (VCSEL) instead of LED. Several design options, which are based on simple gates, MAXIM chips and microprocessor, were explored. Finally, the test and analysis carried out for its VCSEL suitability as an IR transmitter. This includes spectrum and power measurements by comparing the VCSEL properties with LED; it is found that VCSEL can provide efficient power utilization.

1.2 Motivation and Problem Statement

Infrared (IR) systems use very high frequencies, just below visible light in the electromagnetic spectrum, to carry data. Like light, IR cannot penetrate opaque objects; it is either directed (line-of-sight) or diffuse technology. Inexpensive directed systems provide limited range of approximately 3 feet and typically are used for personal area networks. Occasionally directed systems are used in specific wireless LAN applications (Stallings, 1999).

High performance directed IR is impractical for mobile users and is therefore used only to implement fixed sub-networks. Diffuse or reflective IR wireless LAN systems do not require line-of-sight, but cells are limited to individual rooms (Stallings, 1999).

The distance over which IR waves can communicate is a function of product design (including transmitted power and receiver design) and the propagation path, especially in indoor environments. Interactions with typical building objects, including walls, metal, and even people, can affect how energy propagates, and thus what range and coverage a particular system achieves (Stallings, 1999). Solid objects block infrared signals, which impose additional limitations. Most wireless LAN systems use RF because radio waves can penetrate most indoor walls and obstacles. The range (or radius of coverage) for typical wireless LAN systems varies from under 100 feet to more than 300 feet.

The following situations are the most suitable condition where infrared transmission network solution shall be considered:

- When the building has lots of potential radio interference. Infrared transmission is not affected by radio frequency.
- Infrared is great for setting up a wireless network quickly. It also does not require FCC licensing.

- Another advantage of infrared transmission is high security. The signals do not leave the building because they do not penetrate walls. Infrared technology costs less than radio-based devices.
- If there is an open office environment, line-of-sight infrared transmission gives great speed and reliability when there are no obstructions.

Almost all indoor IR transmitter uses LED. LED Power is low and radiation pattern is broad, so it limits transmission within 2 feet and sensitive to interference.

More advance type of light source such as LD which is less sensitive to interference, and could cover longer distance is required, however LD is expensive. VCSEL, which has similar capability with LED and cheaper then LD, could replace LED. This will open new business opportunity because of its low cost. By using VCSEL, wireless transmission implementation could be more effective and economical, comparing to LED.

1.3 Objectives

The aim of this research ("Research on Development of Infrared Transmitter Using VCSEL") is to explore several options of wireless LAN transceiver design and analyze suitability of VCSEL utilization as signal transmission media. In summary the objectives of this research are:

- To explore several design options of wireless transceiver.
- To implement transmitter driver circuit.

- To analyze VCSEL with driver circuit.
- To collect data on VCSEL characteristics (power, central wavelength, and OSNR).
- To analyze VCSEL characteristics.
- To investigate advantages of VCSEL compare to LD.
- To analyze suitability utilization as signal transmission media and advantages of VCSEL.

1.4 Scope

The research project focuses on the study of an indoor wireless communication; which focuses on the design and analyses of the IR transmitter and IR receiver. The study is done only on the physical layer of the Infrared Data Association (IrDA). The physical layer is responsible for the definition of hardware transceivers for the data transmission.

The Physical layer includes the optical transceiver, and deals with shaping and other characteristics of infrared signals including the encoding of data bits, and some framing data such as begin and end of frame flags (BOFs and EOFs) and cyclic redundancy checks (CRCs). This layer must be at least partially implemented in hardware, but in some cases is handled entirely by hardware.

The research is considering utilization of VCSEL for the wireless transmission implementation. VCSEL is considered because of several advantages over LED. It is easier to handle the test, and perform more efficiently. It is also requires less electrical current to produce a given coherent energy output. Physical characteristics of VCSEL are studied and its spectrum is analyzed. The result of this analysis is described in Chapter 4.

The study model adopted in this project is shown in Figure 1.1.

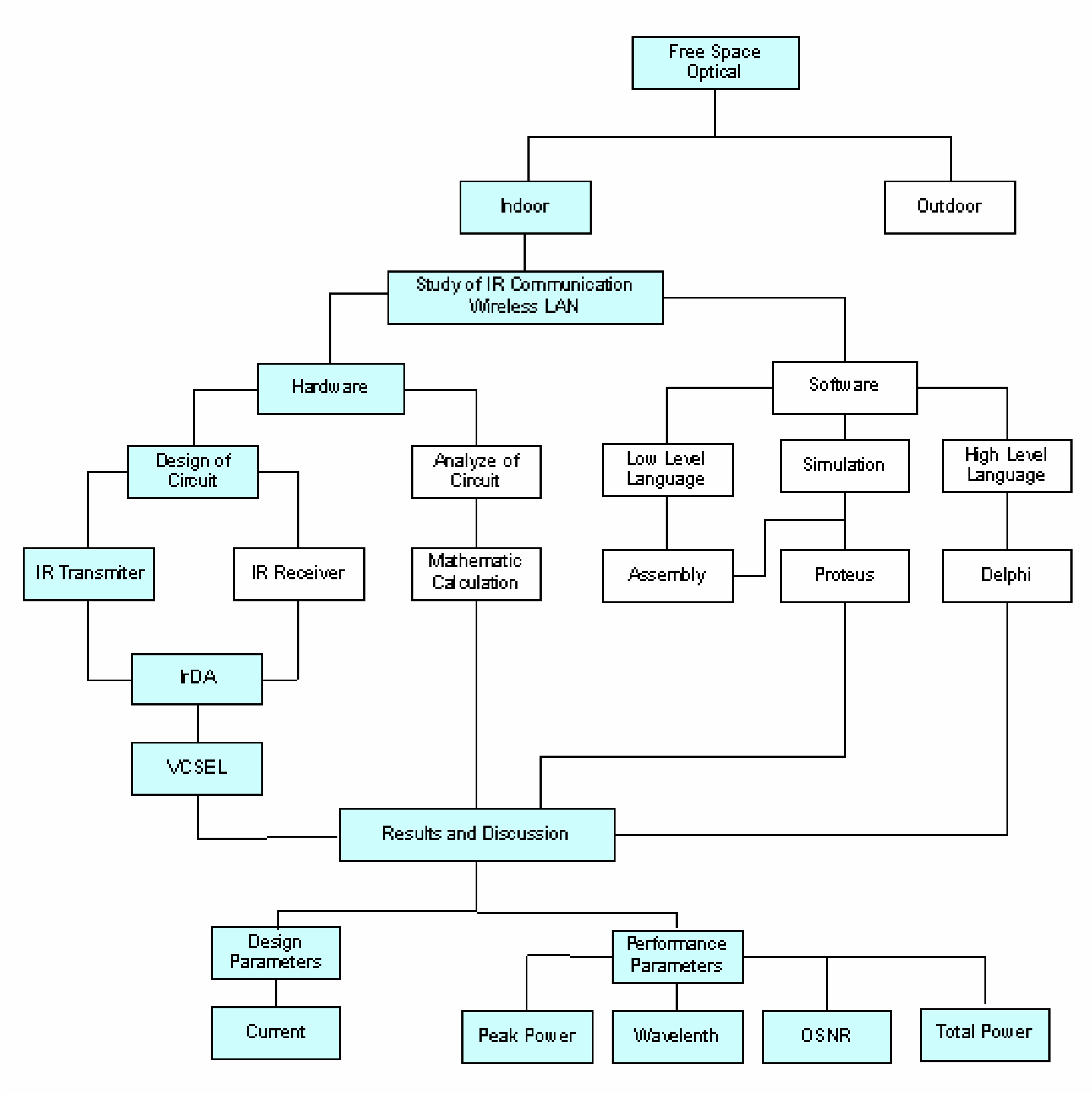

Figure 1.1: Block Diagram of Study Model

1.5 Methodology

The design of the VCSEL transmitter is divided into three stages. The first stage is the design by using a simulation and design software. The second stage is the design by hardware implementation or laboratory experimental setup. The third stage is writing the program with high level programming software to support the hardware for connecting to the computers.

Simulation software approach was chosen in the first stage because of few reasons. The main motive was that the work result must in the product form. It consists of optoelectronics and electronics components. With limit source and equipments, straight forward implementation of the theory into the laboratory hands on, will incur wastage in term of time and material if the circuit malfunction since the suitability of the selected components cannot be verified at the early stage. However, using the simulation software, the performance of the circuit and the selection of the components can be verified earlier on as to whether the theory was valid or otherwise. This will save costs as the suitability and functionality of the components can be identified virtually before making any acquisitions.

The other motive is that the flexibility of the design using software allows extensive study on the design. The results from the simulation will be the reference when the experiment is setup. Although irregularity might occur between the simulation result and the experiment result, it should be understood that the simulation mostly done under ideal conditions while laboratory experiment is exposed to many factors such as noise, material imperfection and inaccurate equipments and devices. Since the