FAKULTI : FAKULTI SAINS

TAJUK : PERMOHONAN PELANJUTAN PEMBETULAN TESIS

BUTIRAN PELAJAR

NAMA : MOHD ASMU'I BIN MOHD AKIL

NO K/P @ ISID : 841007-11-5481

NO MATRIK : PS11311

PROGRAM : DOKTOR FALSAFAH (FIZIK)

JENIS PENGAJIAN : PENYELIDIKAN

BENTUK PENDAFTARAN : SEPENUH MASA

PENYELIA : DR. AMIRUDDIN BIN SHAARI

PENYELIA BERSAMA: PROF. DR. ZULKAFLI BIN OTHAMAN

BIL SEM: 18/16

STATUS : PEPERIKSAAN

PEMERIKSA LUAR: PROF. DR. MOHD KAMIL ABD. RAHMAN (UiTM)

PEMERIKSA DALAM: PROF. MADYA DR. YUSOF BIN MUNAJAT

PENGERUSI: PROF. DR. NORIAH BINTI BIDIN

PEMBANTU PENGERUSI: DR. HUSNI HANI JAMEELA BINTI SAPINGI

TAJUK TESIS: MODELLING OF OPTICAL AND ELECTRONIC CHARACTERISTICS FOR BROADBAND ALUMINIUM GALLIUM ARSENIDE TERAHERTZ QUANTUM CASCADE LASER

MUKASURAT : 1/1

KETERANGAN PELAJAR

1.1 Pelajar telah menjalani peperiksaan dan kronologi seperti di bawah:

Bil	Tarikh	Perkara
1	21 Jun 2017	Peperiksaan lisan dijalankan dan pelajar mendapat keputusan c1/12 bulan dan perlu disemak oleh semua panel pemeriksa. Tarikh akhir pelajar perlu menghantar tesis adalah pada 21 Julai 2018.
	18 Julai 2018	SPS menerima permohonan pelajar dan juga surat sokongan dari penyelia untuk melanjutkan tempoh penghantaran pembetulan tesis kali pertama.
3	20 Ogos 2018	Pelajar telah menghantar tesis pembetulan ke SPS untuk semakan panel pemeriksa.
4	11 Februari 2019	Hasil semakan tesis pembetulan mendapati pelajar perlu membuat pembetulan semula dan diberi tempoh selama 6 bulan sehinga 12 Ogos 2019.
5	12 Ogos 2019	Tarikh akhir pelajar perlu menghantar pembetulan tesis ke SPS. SPS menerima permohonan pelajar dan juga surat sokongan dari penyelia untuk melanjutkan tempoh penghantaran pembetulan tesis kali kedua.

ULASAN DAN TINDAKAN FAKULTI

1.1 Pelajar telah memohon untuk pelanjutan tempoh penghantaran pembetulan tesis selama sebulan dengan sebab di bawah:

i) Belliau masih dalam proses pemurnian pembetulan tesis.

ii) Terdapat pertambahan komen dari panel pemeriksa yang tidak dibangkitkan semasa sesi peperiksaan lisan sebelum ini dan juga semasa pembetulan kali pertama.

iii) Pelajar memerlukan lebih masa untuk meneliti komen tersebut.

1.2 Dokumen seperti dilampiran.

1.3 Dengan ini dipohon supaya Mesyuarat JAPSU untuk menyemak dan meluluskan permohonan pelajar untuk melanjutkan tempoh penyerahan tesis pembetulan selama sebulan sehingga 8 September 2019.

12/8/2019.

KELULUSAN

Disokong / Tidak ~~disokong~~

19/8/2019

Dekan/TD (Akademik)
& Cop Rasmi

PROF. MADYA. DR. NOOR HAZARINA BT HASHIM
Pengerusi
Sekolah Pengajian Siswazah
Universiti Teknologi Malaysia
81310 UTM Johor bahru, Johor.

Tarikh :

Setuju / Tidak Setuju
(Ulasan)

Pengerusi Mesyuarat
Jawatankuasa Akademik
Pengajian Siswazah Universiti
(JAPSU) &
Cop Rasmi

Tarikh : _____

12 Ogos 2019

Prof. Madya. Dr. Noor Hazarina binti Hashim
Dekan,
Sekolah Pengajian Siswazah,
Universiti Teknologi Malaysia,
81310 UTM Johor Bahru,
Johor

Y. Bhg. Prof. Madya,

RAYUAN PELANJUTAN PENYERAHAN TESIS PEMBETULAN KEDUA BAGI PROGRAM IJAZAH KEDOKTORAN

Adalah saya dengan hormatnya merujuk perkara di atas.

2. Merujuk kepada perkara di atas dan surat bertarikh 11 Februari 2019 (UTM.01.04/14.14/1/6/3/9 Jld 9(1)), saya Mohd Asmu'i Bin Mohd Akil (PS113111) ingin memohon pelanjutan penyerahan tesis pembetulan kedua selama **sebulan** dari tarikh penyerahan (12 Ogos 2019) kepada tarikh **8 September 2019 (Ahad)**.

3. Sehubungan dengan itu, setelah berbincang dengan penyelia, pelanjutan ini amat diperlukan kerana saya masih memerlukan sedikit masa lagi untuk memurnikan penulisan tesis termasuk pengesahan pembetulan dari penyelia. Sepanjang tempoh pembetulan kedua yang telah diberikan ini, saya telah menggunakan sepenuh usaha saya untuk menyiapkan pembetulan seperti yang telah dicadangkan oleh pihak pemeriksa. Namun, terdapat pertambahan komen daripada pihak pemeriksa luar yang tidak dibangkitkan di dalam pembetulan pertama sebelum ini malah ketika viva. Hal ini amat menyukarkan saya dan memerlukan saya untuk meneliti komen yang diberikan.

Diharap pihak Y. Bhg. Prof. dapat memahami keadaan dihadapi saya kini dan mempertimbangkan rayuan ini sewajarnya. Segala kerjasama didahului dengan ucapan ribuan terima kasih.

Yang benar,

Mohd Asmu'i Bin Mohd Akil (PS113111)
No 12, Jalan Utama 16,
Taman Mutiara Rini,
81310 Skudai, Johor
019-9406339

RECEIVED
14 AUG 2019
School of Graduate Studies

Dr. Amiruddin Shaari
Senior Lecturer
Physics Department
Faculty of Science
Universiti Teknologi Malaysia

UTM UNIVERSITI TEKNOLOGI MALAYSIA | Sekolah Pengajian Siswazah

Sekolah Pengajian Siswazah
Universiti Teknologi Malaysia
81310 Johor Bahru
Johor, Malaysia

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Ruj. Kami : UTM.01.04/14.14/1/6/3/9 Jld 9 (1)
Tarikh : 11 Februari 2019

Mohd Asmu'i Bin Mohd Akil
No.12 Jalan Utama 16
Taman Mutiara Rini
81300, Skudai
Johor

Saudara,

PEMBETULAN TESIS

Dengan hormatnya saya diarah merujuk kepada perkara tersebut di atas.

2. Sukacita dimaklumkan bahawa Panel Pemeriksa telah menyemak tesis yang telah diperbetulkan. Walaubagaimanapun Pemeriksa mendapati masih terdapat beberapa pembetulan lagi yang perlu dilakukan sebagaimana tercatat dalam tesis dan borang laporan yang dilampirkan.

3. Saudara dikehendaki membuat pembetulan semula dan diberi tempoh **6 bulan** dari tarikh surat ini iaitu sehingga 12/08/2019 dan mengembalikan kepada Sekolah Pengajian Siswazah untuk pengesahan selanjutnya. Saudara juga dikehendaki menyediakan senarai semakan pembetulan yang telah di buat.

4. Saudara dinasihatkan untuk memberi perhatian kepada komen yang dinyatakan. Pembetulan hanya dibenarkan sebanyak tiga (3) kali selepas peperiksaan lisan (viva- voce).

5. Haruslah diingatkan bahawa kegagalan saudara menyerahkan tesis yang telah dibetulkan dalam tempoh yang ditetapkan, boleh menyebabkan rekod saudara/i sebagai pelajar UTM **ditamatkan tanpa sebarang penganugerahan.**

Di atas kerjasama yang akan diberikan pihak Universiti mengucapkan berbanyak-banyak terima kasih.

Sekian, terima kasih.

"Berkhidmat untuk Negara kerana Allah"

Yang benar,

PROF. MADYA DR. NOOR HAZARINA BINTI HASHIM
Timbalan Dekan (Pembangunan Sistem dan Profesional)
Sekolah Pengajian Siswazah
Universiti teknologi Malaysia
b.p Dekan
Tel: +607-553 7781
Emel: m-hazarina@utm.my

Dr. Amiruddin Shaari
Senior Lecturer
Physics Department
Faculty of Science
Universiti Teknologi Malaysia

end-to-end encryption. Tap for more info.

Salam dr amiruddin.

Sy farhana dari SPS. Berkenaan dgn pelajar dr bernama mohd asmui.. beliau hantar permohonan lanjut hantar pembetulan tesis kali kedua hingga 8 sept 2019.

Dr hazarina minta sy contact dr utk dapatkan pengesahan dan pendapat dari dr. sama ada boleh diluluskan atau tidak kerana dah lama sgt buat pembetulan.

9:04 AM ✓✓

Waalaikumsalam
Saya menyokong permohonan sdr Asmui memandangkan banyak perubahan dan tambahan yang beliau perlu lakukan
Saya sangat berharap agar pihak SPS dapat meluluskan permohonan beliau dan saya akan berusaha lebih keras lagi untuk memastikan sdr Asmui menyiapkan pembetulan tesis beliau dalam masa yang diberikan
Terima kasih 12:19 PM

Tq dr untuk respon nya.. permohonan beliau akan dibawa ke mesy japsu utk semakan pada 19 ogos ini. 12:24 PM ✓✓

UNIVERSITI TEKNOLOGI MALAYSIA

IJAZAH DOKTOR FALSAFAH *(DEGREE OF DOCTOR OF PHILOSOPHY)*
LAPORAN PEMERIKSAAN SEMULA TESIS *(REPORT ON THESIS REEXAMINATION)*

Nama Calon *(Name of Candidate)*	:	**Mohd Asmu'i bin Mohd Akil**
Fakulti *(Faculty)*	:	**Faculty of Science**
Tajuk Tesis *(Title of Thesis)*	:	**Simulation of Optical and Electronic Characteristics of Terahertz Quantum Cascade Laser**
Nama Pemeriksa dan Institusi *(Name of Examiner and Institution)*	:	**Prof. Dr. Mohd Kamil Abd. Rahman** **School of Physics and Material Studies,** **Faculty of Applied Sciences,** **University Teknologi MARA,** **40450 Shah Alam,** **Selangor**
Tarikh Viva *(Date of Viva)*	:	**21/06/2017**
Keputusan Viva *(Viva's Result)*	:	**C1**

SILA TANDATANGAN DI DALAM RUANG YANG DISEDIAKAN UNTUK PERAKUAN
(*Please initial in space provided for the recommendation*)

TANDATANGAN
(*INITIAL*)

1. **Perakuan *(Recommendation)***
Setelah memeriksa tesis, saya perakukan *(After examining the thesis, I recommend that)*

LULUS/*PASS*

(a) Pelajar telah membuat pembetulan sepertimana yang tercatat dalam laporan pengerusi peperiksaan lisan. Pelajar dianugerahkan Ijazah Kedoktoran. *(The candidate has done all the necessary amendments and corrections and be awarded the degree of Doctor of Philisophy* ☐

atau *(or)*

(b1) Pelajar telah membuat pembetulan namun terdapat sedikit lagi pembetulan yang perlu dibuat. Pelajar dianugerahkan Ijazah Kedoktoran selepas pembetulan dan hanya perlu disahkan oleh penyelia. *(The candidate be awarded the degree of Doctor of Philisophy subject to minor corrections as listed elsewhere in this report being made in the thesis to the satisfaction of the Supervisor)* ☐

atau *(or)*

(b2) Pelajar telah membuat pembetulan namun terdapat lagi pembetulan yang perlu dibuat. Pelajar dianugerahkan Ijazah Kedoktoran selepas pembetulan dan disahkan telah berbuat demikian oleh Pemeriksa Dalam/Luar. *(The candidate be awarded the degree of Doctor of Philisophy subject to corrections as listed elsewhere in this report being made in the thesis to the satisfaction of the Internal/External Examniner(s))* ☑

atau *(or)*

IJAZAH LEBIH RENDAH/*LOWER DEGREE*

(d) Pencapaian calon tidak memuaskan untuk ijazah Doktor Falsafah tetapi dicadangkan satu ijazah yang lebih rendah. *(The candidate not be awarded the degree of Doctor of Philosophy but a lower)* ☐

atau *(or)*

GAGAL/*FAIL*

(e) Pelajar gagal membuat pembetulan yang ditetapkan dalam peperiksaan lisan pertama. Oleh itu pelajar tidak dianuferahkan Ijazah Kedoktoran. *(The candidate not be awarded the degree of Doctor of Philosophy)* ☐

Tandatangan *(Signature)*: .....

Tarikh *(Date)*: ...22 Jan 2019.....

2. **Sila berikan ulasan terhadap perkara berikut untuk dijadikan asas perakuan** ***(Please comment on the following aspects as the grounds for recommendation)***

2.1 Tajuk Tesis *(Title of the Thesis)*

Acceptable

2.2 Abstrak *(Abstract)*

1. Problem statement is not clear and not specific, especially the sentence "..... undermine its suitability to meet current industrial expectations." What exactly is the curent industrial expectation this issue is addressing? The problem statement has to be specific ... is it in terms of *power*? .... *bandwidth*? or something else?
   Thus, state exactly the current status of the problem and the specific expectation required by the industries.

2. The **research Findings** are not clearly stated. The research findings must reflect-back into solving the research problems (above ☝) and not something else.
   - State clearly what are the **research findings** – these were **derived** from the results obtained?
   - Do not to show all the results obtained from the research, just show the significant results and followed by the research findings – anyone who reads the findings will gain benefit from it.
   - From the research outputs, state clearly **what are the main factors that limit QCL performance** for future designs of QCL.

2.3 Pengenalan, Masalah Penyelidikan, Objective, Skop dll *(Introduction, Research Problems, Objectives, Scope etc)*

Research Problems are not specific, and not clear.
Rewrite the Research Problems: - state clearly and SPECIFICALLY what are the current problems with QCL (output power, bandwidth, others), structural designs, etc. The Problem Statement should be based on **facts** (based on theory and published work), and not some assumptions.
- It has to be **scientific or technical problem/s**.
- It is a widely known fact that simulation or modeling of a device can save the cost of fabricating and testing of the device. So please do not use this reason as the problem statement. It is **not a research problem**.

Rewrite the Research Objectives based on the research problems – that is finding ways to solve the problems.

Tandatangan *(Signature)*:..... Tarikh *(Date)*: 22 Jan 2019.....

2.4 Kajian Literatur *(Literature Review)*

This thesis does not show to have much improvement on Literature Review as compared to the Thesis previously written, where comments and suggestions were made in the thesis and during viva examination so as to improve on this chapter.

Thesis reports the simulation of QCL, but none of the references in Table 2.1 has any work done in simulating QCL. Must cite 1 or 2 references on QCL simulation and make critical review of them. Example: from E. Bellotti et al. (2008 and 2009) and others.
Section 2.2 (Previous Works on QCL structures) is insufficient **and again, it is unacceptable**. (about 1½ page long).
It is NOT much of a Literature Review, but more of **Literature Survey (Reporting the summary of other researchers' work)**. It must be a **Critical Review** where every comment/summary of each cited reference must be linked to each others' works, while giving your own opinions, ideas and suggestions.

Section 2.3 of page 15 was rewritten where the content of this Section was PLAGIARISED (previous thesis) from the work of Benjamin S. Williams, M.I.T. 2003 PhD Thesis "Terahertz Quantum Cascade Lasers".
The whole of section (2.3) was rewritten based on Benjamin's thesis; **HOWEVER, Benjamin S. Williams was NOT cited in the list of References**. Extorting the work from others while not giving appropriate acknowledgement and recognition is unethical.
Literature Review takes about less than 9% (5 pages from 56 pages), while the rest of the Chapter is background theory on QCL with large number of mathematical equations and techniques on simulation.
Literature Review is insufficient; lack of depth and width, hence is not accepted, **again!**
This thesis needs to have a separate Chapter on "Theory and Simulation/Modeling of QCL", while Literature Review can have a chapter on its own.

2.5 Methodologi *(Methodology)*

Section 3.2: The section of the modified code is given in Appendix B.2. However, there no statement stating clearly what was modified from the original program code. This is rather important because this modification will be the evident as original contribution to new knowledge. Thus, it must be specified clearly.

The simulation is based on Equation (2.63) where it was expanded to Equations (2.64) and (2.65). HOWEVER, there are "errors" in these 2 equations. Please make the corrections.

Give evidences or proofs from previous work **or from this work**, that the 15% of aluminium in the barrier layers that was ignored/neglected does not have any effect on the simulation outputs. The actual structures have 15% aluminium in the barrier layers, where 15% is not a small amount. Probably it would be better to show both of the results, one with and one without the aluminium to prove the assumption.

The schematic diagram of QCL in Figure 3.3 is **NOT CORRECT**. If the quantum layers were to be grown in the z-direction, then the electric current flowing through the top and bottom Au contact layers will be short-circuited and burn the laser. See Figure C.1, where this is how structure should be drawn.

Redraw the QCL structure as Figure 3.3, showing clearly *x-y-z* axes, active-layers, Au contact-layers, waveguide with mirror facets and dimensions for its width, thickness and **cavity length**.

Apparently, there is **no new or novel design of QCL structure or double metal QCL waveguide was proposed or simulated in thesis.**

- Draw an overall flowchart showing the process flow how all the objectives can be achieved and research outcomes have solved the research problems.

Tandatangan *(Signature)*: ..... Tarikh *(Date)*: 22 Jan 2019 .....

2.6 Analisis *(Analysis)*

- Results were discussed but the analyses are insufficient. Many important phenomena were not clearly explained.
- A few phrases/paragraphs were repeated copied, exactly the same phrases for all the 4 QCL designs, see paragraphs on page 72, 76, 80, 81, 84, and 85.
- The habit of copy and paste shows lacking in the ability to analyse results.
- There is also insufficient analysis on the Gain Spectra. In-depth discussion on gain spectra is very important because it is fundamental to support the principle behind in achieving broad bandwidth – this is one of the research objectives.

The reason given for simulation only in the TM modes in metal waveguides is unacceptable. A 30-μm width is NOT significantly larger than to the height of a 13-μm waveguide (height is more than 1/3 of the width) and the width cannot be assumed infinite. A 13-μm waveguide should be sufficient to support TE modes, unless the simulation for TE modes proved otherwise.

It is rather known facts that refractive index increased with frequency in most dielectric and semicond materials and optical confinement is better for larger (40-μm) waveguides. The **simulations results from these two phenomena are obvious and not new**, thus they are not significant to the study.

Insufficient analysis of plasmonic effect on the optical confinement in the waveguide. It seems that high optical confinement is based on dielectric properties and not plasmonic effect at THz frequencies (see 1st paragraph page 109). However, the discussion on page 111 explained otherwise. The summary has to be very clear of the final findings from the simulations and explanations should complement and support one another.

2.7 Keputusan dan Perbincangan *(Results and Discussions)*

Part #1: The DM program code has been verified from experimental results of Kumar [2], based on Equation (2.63). Make correction to errors in Equations (2.64) and (2.65).
- Show and explain exactly how anticrossing values were taken from Fig. 4.3.

Part #2: Following verification of DM program codes, 4 other QCL designs were simulated the same (see page 71 to 88). The **Summary** of the results is repeating what were previously discussed. There is **nothing significant in the summary** that can be of benefit to support next stage of the study, due to insufficient analysis.

What is most important in the Summary is the **research findings**: what **NEW** parameter settings, limitations, electronic transport mechanism properties that could help widen the width of the spectrum as suggested in Objective (2) and (3). To what level of Objectives 2 and 3 had been achieved?

Part #3: Here again, there is **no analysis** on the discussion of **Gain Spectra** for all the 4 QCL designs. All explanations are of a **Reporting style** – where it just report what were displayed in the plots, BUT there is NO EXPLANATION given to what cause it to behave the way it is and why:

1. There a shift in the spectral peak gain as voltage varies?
2. Broadening of spectra as voltage varies?
3. Disappearing of gain spectra when stimulated emission was included?
4. WHAT parameter/s influence and determine the width of gain spectra?
5. HOW can the spectral width be controlled or manipulated?

These questions do not have any answer, because there was no analysis done on the Gain Spectra to relate to the physical properties and structural design of all the 4 QCL.

Parts #1, #2 and #3 covers 34 pages from page 67 to 101 (30% of the thesis), but unfortunately these 3 **Parts** did **not contribute towards the novelty of the study or contribution to new knowledge, because they lack detail analyses.**

It has been proven that Double Metal Waveguide QCL demonstrates high optical mode confinement but here in the thesis, it does not have any suggestion to further improved it.

Tandatangan *(Signature)*: ..... Tarikh *(Date)*: 22 Jan 2019

2.8 Kekuatan Tesis *(Strength of the thesis)*

The strength of the thesis could probably be in the background study on the theory of THz QCL and techniques in simulation.

2.9 Kelemahan Tesis *(Weakness of the thesis)*

1. No new design of QCL were proposed and simulated. All simulations were based on previous QCL design by others.
2. Significantly lacking in critical analysis in all discussion of results.
3. DM Program Code claimed be modified from original work, but what exactly were modified is not mentioned. Hence, novelty or contribution to new knowledge is questionable.
4. No new significant finding or novelty can be found in the thesis.
5. Insufficient content of Literature Review in terms of depth and width of Review.

2.10 Kepentingan Kajian *(Significance of the study)*

The study on THz QCL is of significant importance to the area of interest, to the country and to the global community.

Tandatangan *(Signature)*: Tarikh *(Date)*: 22 Jan 2019

3.0 Perakuan penganugerahan *(Recommendation for the award)*

The candidate awarded the degree of Doctor of Philosophy (PhD) subject to all corrections being made as listed in the examiners report, viva panel report and elsewhere in the thesis to the satisfaction of the Examiners.

5.1 Lain-lain ulasan *(Other comments)*

1. All sections of discussion must have detail analysis of the results – simply by answering: HOW and WHAT cause it to happen and WHY it occurs that way? Without any analysis, it is similar to a **REPORT** of a study - and NOT a THESIS.

2. Highlight the novelty of the study – difficult to identify it in the thesis.
All QCL designs are taken from other researchers' work, dated in 2009 and 2012, where no new design was proposed to improve QCL performance.

Tandatangan *(Signature)*: ..... Tarikh *(Date)*: 22 Jan 2019

UNIVERSITI TEKNOLOGI MALAYSIA

IJAZAH DOKTOR FALSAFAH *(DEGREE OF DOCTOR OF PHILOSOPHY)*
LAPORAN PEMERIKSAAN TESIS *(EXAMINER'S REPORT ON THESIS)*

Nama Calon *(Name of Candidate)* : **Mohd Asmu'i Bin Mohd Akil**

Tajuk Tesis *(Title of Thesis)* :: **Simulation of Optical and Electronic Characteristics of Terahertz Quantum Cascade Laser.**

Fakulti *(Faculty)* : **Fakulti Sains**

Nama Pemeriksa dan Institusi *(Name of Examiner and Institution)* : **Prof Madya Dr. Yusof Bin Munajat**
Fakulti Sains,
UTM, Johor Baharu.

SILA TANDATANGAN DI DALAM RUANG YANG DISEDIAKAN UNTUK PERAKUAN **TANDATANGAN**
(*Please initial in space provided for the recommendation*)
(*INITIAL*)

1. **Perakuan *(Recommendation)***
Setelah memeriksa tesis, saya perakukan *(After examining the thesis, I recommend that)*

a) Calon dianugerahkan ijazah Doktor Falsafah *(The candidate be awarded the degree of Doctor of Philosophy)*;..... _____

atau *(or)* b1) Calon dianugerahkan ijazah Doktor Falsafah setelah membuat pembetulan kecil *(The candidate be awarded the degree of Doctor of Philosophy subject to minor corrections)*;..... _____

atau *(or)* b2) Calon dianugerahkan ijazah Doktor Falsafah setelah membuat pindaan dan pembetulan kepada tesis seperti yang disenaraikan dalam laporan ini dan disahkan telah berbuat demikian oleh Pemeriksa Dalam/Luar berkenaan; *(The candidate be awarded the degree of Doctor of Philosophy subject to the amendments and corrections as listed elsewhere in this report being made in the thesis to the satisfaction of the Internal/External Examiner(s))*;..... _____

atau *(or)* c) Calon tidak dianugerahkan ijazah Doktor Falsafah tetapi dibenarkan menghantar semula tesis untuk pemeriksaan setelah menjalani kajian dan penyelidikan lanjutan. *(The candidate not be awarded the degree of Doctor of Philosophy but be permitted to resubmit the thesis for further examination in a revised form after a further period of study and research)*;..... _____

atau *(or)* d) Pencapaian calon tidak memuaskan untuk ijazah Doktor Falsafah tetapi dicadangkan satu ijazah yang lebih rendah. *(The candidate not be awarded the degree of Doctor of Philosophy but a lower)*; ..... _____

atau *(or)* e) Calon tidak dianugerahkan ijazah Doktor Falsafah. *(The candidate not be awarded the degree of Doctor of Philosophy)*..... _____

2. **Pendapat *(Opinion)***
Saya berpendapat *(In my opinion)*

a) Tesis ini mengandungi banyak sumbangan asli ke arah pembangunan ilmu dalam bidang berkenaan *(The thesis has substantial original contribution to the knowledge of the subject concerned)*;..... _____

b) Keaslian tesis dibuktikan dengan penemuan fakta-fakta baru *(The thesis affords evidence of originality by the discovery of new facts)*; ..... _____

c) Keaslian tesis dibuktikan dengan kebolehan memberi kritikan yang bernas dan jelas *(The thesis affords evidence of originality by exercising of independent critical ability)* ..... _____

d) Tesis ini memuaskan dari segi penyampaian *(The thesis is satisfactory in regards to literary presentation;)*.... _____

e) Terdapat hasil kajian dalam tesis sesuai untuk diterbitkan *(A significant amount of findings in the thesis are worthy of publication;)* .....

3. **Merit**(*Merit*)
Dalam membuat perakuan di atas, saya sahkan calon adalah cemerlang untuk ijazah ini dan dianugerahkan ijazah dengan **merit**. (*In making the above recommendation, I consider that the candidate is outstanding for this degree and should be awarded the degree with merit)*..... _____

Tandatangan *(Signature)*: ..... Tarikh *(Date)*: 24/12/2018.....

4. Sila berikan ulasan terhadap perkara berikut untuk dijadikan asas perakuan (***Please comment on the following aspects as the grounds for recommendation***)

4.1 Tajuk Tesis *(Title of the Thesis)*

The title has been changed according to the suggestion; Simulation of optical and electronic characteristics of terahertz quantum cascade laser.

4.2 Abstrak *(Abstract)*

The abstract was rewritten and highlight the significant finding by theoretically analyzing the broadband design of Tera Hertz Quantum Cascade Laser (QCL).

4.3 Kajian Literature *(Literature review)*

The candidate prepares literature review on various topics. Still have some issues that not address carefully. Figure 2.1(a) and (b) still not explained in details. Rate equation still there and not removed from the text. Since the study based on the modelling, previous conducted methods must be properly reviewed and new approach of equations used in the studies must be highlight clearly.

Tandatangan *(Signature)*: ..... Tarikh *(Date)*: 24/12/2018.....

4.4 Methodologi *(Methodology)*

The studies based on the modelling and claim in predicting the performance of broadband THz QCL. There are two major work involved. Firstly, the simulation of electron transport in the active region of THz QCL The code was improved by modifying the code to solve the numerical quantum transport in a four level THz QCL system. Secondly, the numerical study of narrow waveguide THz QCL to support the broadband emission, extensively the optical mode with the addition of narrow waveguide effect of the devices. The coding is shown in the appendix B and C.
However still have some issues that not address carefully in this Methodology. In the flow chart Figure 3.1 the modification part must be clearly highlight. The details explanation must be highlight at the end of subtopic 3.2 to support the strength of the thesis. The same thing must be highlight the modification in Figure 3.2 and the explanation at the end of subtopic 3.3.

4.5 Analisis *(Analysis)*

No significant improvement of the study based on the modification done to the existence equations. Based on the analysis, most of the results just plot the graph of previous researcher experiment data and the simulation calculation done by candidate using the existence equations. The modelling should show much better and high performance of THz QCL based on some new assumption and approach can be engineered that can expect improvement result.
Candidate make a comparison for different design of band structure the simulation of electron transport in the active region of THz QCL Candidate make a claim the improvement to the coding of the programming. Candidate also makes a deep explanation of numerical study of narrow waveguide THz QCL to support broadband emission extensively the optical mode of the device.

Tandatangan *(Signature)*: ..... Tarikh *(Date)*: 24/12/2018.....

4.6 Keputusan dan perbincangan *(Results and discussions)*

According to the results obtained,

a. Candidate not really develops new assumption and approach that can improve the THz output.
b. The modelling results and discussion digested and compared with previous researcher.
c. Candidate raises the issue of electron transport in the active region and the optical mode of the device.
d. Schematic diagram shown almost well presented, but the graph of I-V not represents the good practice of plotting.

4.7 Kekuatan Tesis *(Strength of the thesis)*

The modelling results and discussion digested and compared with previous researcher.
Candidate raises the issue of electron transport in the active region and the optical mode of the device.

4.8 Kelemahan Tesis *(Weakness of the thesis)*

Candidate not really develops new assumption and approach that can improve the THz output.

Tandatangan *(Signature)*: ..... Tarikh *(Date)*: 24/12/2018.....

4.9 Kepentingan Kajian *(Significance of the study)*

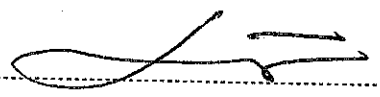
The study "Simulation of Optical and Electronic Characteristics of Terahertz Quantum Cascade Laser" implies the importance of simulation study on Terahertz Laser devices to the output of the waveform. It can contribute to the development of THz Quantum Cascade Laser and human capital in this field. Hopefully it is used as the catalyst and reference point for further research.

4.10 Perakuan penganugerahan *(Recommendation for the award)*

I hereby certify that the candidate be awarded the degree of Doctor of Philosophy subject to the amendments and corrections as listed elsewhere in this report being made in the thesis to the satisfaction of the internal/external examiners.

4.11 Lain-lain ulasan *(Other comments)*

Refer to the thesis.

Tandatangan *(Signature)*:  Tarikh *(Date)*: 24/12/2018

UTM
UNIVERSITI TEKNOLOGI MALAYSIA

LAPORAN PENILAIAN OLEH PEMERIKSA
IJAZAH DOKTOR FALSAFAH MELALUI PENYELIDIKAN
(EXAMINERS' REPORT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY BY RESEARCH)

Tajuk Tesis : **MODELLING OF OPTICAL AND ELECTRONIC CHARACTERISTICS FOR BROADBAND ALUMINIUM GALLIUM ARSENIDE TERAHERTZ QUANTUM CASCADE LASER**
(Title of Thesis)

Nama Pelajar : **MOHD ASMU'I BIN MOHD AKIL**
(Name of Candidate)

Nama Penyelia Utama : **DR.AMIRUDDIN BIN SHAARI**
(*Name of Main Supervisor)*

Kami, sebagai Panel Pemeriksa, telah menilai tesis di atas dan mengadakan ujian lisan untuk ijazah kedoktoran *(We, the Panel of Examiners, have successfully evaluated the above thesis and examined him/her for the degree of Doctor of Philosophy*) pada *(on)* dan mencapai satu keputusan seperti berikut: *(and arrived at the following decision:)*

A: KEPUTUSAN/RESULT

KEPUTUSAN VIVA *(Decision:)*	TEMPOH PEMBETULAN TESIS: *(Duration of corrections:)*	TESIS YANG TELAH DIBETULKAN PERLU DISAHKAN OLEH: *(The corrected thesis will be verified and certified by:)*	Sila tanda (/)
a	Tiada pembetulan/no correction	Penyelia/Supervisor	
b1	Maksimum 3 bulan (Maximum 3 months)	Penyelia/Supervisor	
b2	Maksimum 6 bulan [Maximum 6 months]	Pemeriksa Dalam/Internal Examiner	
		Pemeriksa Luar/External Examiner	
c1	Maksimum 12 bulan [Maximum 12 months] Pemeriksaan semula tesis [Thesis Reexamination]	Pemeriksa Luar dan Dalam [External and Internal Examiners]	✓
c2	Maksimum 12 bulan [Maximum 12 months] Pemeriksaan semula tesis dan viva [Thesis reexamination and reviva]	Pemeriksa Luar dan Dalam [External and Internal Examiners]	
d	3 Bulan/3 months)	Penyelia/Supervisor	
e	Gagal [Fail]	-	

B. PERAKUAN PANEL PEMERIKSA

	NAMA/[NAME]	TANDATANGAN/ [SIGNATURE]	TARIKH/[DATE]
PEMERIKSA LUAR [EXTERNAL EXAMINER]	**PROF. DR.MOHD KAMIL ABD. RAHMAN**		**21/06/2017**
PEMERIKSA LUAR 2 EXTERNAL EXAMINER 2			
PEMERIKSA DALAM 1 INTERNAL EXAMINER 1	**PROF. MADYA DR.YUSOF BIN MUNAJAT**		**21/06/2017**
PEMERIKSA DALAM 2 INTERNAL EXAMINER 2			
PENGERUSI [CHAIRMAN]	**PROF.DR.NORIAH BINTI BIDIN**		**21/06/2017**
PEMBANTU PENGERUSI [ASST. CHAIRMAN]	**DR. HUSNI HANI JAMEELA BINTI SAPINGI**		**21/06/2017**

* Potong yang tidak berkenaan (* Delete where not applicable)

UTM UNIVERSITI TEKNOLOGI MALAYSIA

LAPORAN PENILAIAN OLEH PEMERIKSA
IJAZAH DOKTOR FALSAFAH MELALUI PENYELIDIKAN
(EXAMINERS' REPORT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY BY RESEARCH)

C. MERIT/MERIT [ ] YA/YES [✓] TIDAK/NO

- Calon adalah cemerlang untuk ijazah ini dan dianugerahkan ijazah dengan merit.
  The candidate is outstanding for this degree and should be awarded the degree with merit.

- Calon layak dianugerahkan dengan 'Merit' sekiranya keputusan peperiksaan lisan adalah A atau B1 sahaja.
  The candidate may be awarded with 'Merit' provided that the result of viva-voce session is A or B1 only.

D. PERNYATAAN LAIN:

nil.

E. PERAKUAN PANEL PEMERIKSA

	NAMA [NAME]	TANDATANGAN [SIGNATURE]	TARIKH [DATE]
PEMERIKSA LUAR [EXTERNAL EXAMINER]	**PROF. DR.MOHD KAMIL ABD. RAHMAN**		**21/06/2017**
PEMERIKSA LUAR 2 EXTERNAL EXAMINER 2			
PEMERIKSA DALAM 1 INTERNAL EXAMINER 1	**PROF. MADYA DR.YUSOF BIN MUNAJAT**		**21/06/2017**
PEMERIKSA DALAM 2 INTERNAL EXAMINER 2			
PENGERUSI [CHAIRMAN]	**PROF.DR.NORIAH BINTI BIDIN**		**21/06/2017**
PEMBANTU PENGERUSI [ASST. CHAIRMAN]	**DR. HUSNI HANI JAMEELA BINTI SAPINGI**		**21/06/2017**

* Potong yang tidak berkenaan (* Delete where not applicable)

SEKOLAH PENGAJIAN SISWAZAH
UNIVERSITI TEKNOLOGI MALAYSIA
LAPORAN PENGERUSI DOKTOR FALSAFAH / IJAZAH SARJANA
(CHAIRMAN REPORT OF DOCTOR OF PHILOSOPHY / MASTER OF PHILOSOPHY)

TARIKH *(Date)*	:	**21/06/2017**
MASA *(Time)*	:	**9.00 pagi**
TEMPAT *(Venue)*	:	**Bilik Viva 1** **Sekolah Pengajian Siswazah,** ***(School of Graduate Studies)*** **Tingkat 2, Blok F54** ***(2nd floor,Block F54)*** **UTM, Johor Bahru**
NAMA PELAJAR *(Name of Student)*	:	**Mohd Asmu'i Bin Mohd Akil**
PROGRAM *(Programme)*	:	**Doktor Falsafah (Fizik)**
FAKULTI *(Faculty)*	:	**Fakulti Sains**
PENGERUSI *(Chairman)*	:	**Prof. Dr. Noriah Binti Bidin**
PEMBANTU PENGERUSI *(Assistant Chairman)*	:	**Dr. Husni Hani Jameela binti Sapingi**
PEMERIKSA LUAR *(External Examiner)*	:	**Prof. Dr.Mohd Kamil Abd. Rahman**
PEMERIKSA DALAM *(Internal Examiner)*	:	**Prof. Madya Dr.Yusof Bin Munajat**
TAJUK *(Title)*	:	**Modelling Of Optical And Electronic Characteristics For Broadband Aluminium Gallium Arsenide Terahertz Quantum Cascade Laser**

KOMEN SELEPAS VIVA
(The following are comments from the Viva Session)

TAJUK BARU *(New Title)* **:**
Seperti yang dicadangkan oleh Panel Pemeriksa (*As proposed by Panel of Examiner)* jika ada, *(if any) (Nota: Sila rujuk panduan tajuk tesis yang dilampirkan):*

Simulation of Optical and Electronic Characteristics of Terahertz Quantum Cascade Laser

KOMEN *(General Comments)* **:**
The novelty of the thesis is that for a particular structure, the simulation can predict the gain spectrum of the broadband THz QCL.

In the thesis should clearly put the improved coding that has been done & the particular equation that is used. The limitation of the simulation must be declared.

The verification of simulation work must be done i.e. comparing the simulation result with the experimental work. Just compare the simulation result with the experimental result at the same current density applied as in experiment. There must be an additional equation/effect to be inserted in the coding so that it will produced the result that is similar with the experimental results.

Abstrak (*Abstract*)

Highlight the significant findings.

Bab 1 (*Chapter 1*)

The problem statement is not clear. It must be very specific - the lack of prediction on gain spectrum of broadband THz QCL. What is the limitation in the experimental work that can be explained by the simulation model/theory.

Each objective must be novel and written clearly. To improve the existing code on the prediction of broadband THz QCL to study its gain medium. Insert the reference of the code.

Declare the limitations/assumptions that has been considered in the modeling.

The scope of study is too brief. There is now flow of work.

Bab 2 (*Chapter 2*)

Literature review is too brief. Only 1.5 page. Should write more.

Pg 14-17 is copied from another PhD thesis – Benjamin from MIT 2003. Re-write all of it in own words.

Pg 17 – nothing is explained about optical gain though the title 2.3.1 is about optical gain.

Pg 17-19 Insert the reference of the equations.

Elaborate more on phonon resonance in 2.3.3.

Bab 3 (*Chapter 3*)

Summary of the improved part of the existing code should be explained in the chapter.

Pg 55 – do not use the word 'user'. Change to passive voice.

Pg 56 – explain why all the parameters (dielectric constant, size, doping, etc) are chosen.

Bab 4 *(Chapter 4)*

Define the broadband range. It must be consistent throughout the thesis.

Verification of the simulation work must be done.

Analysis of the results must be in depth. Give the reason why the results appear as it is. The significance of the result. Explain why and how it happened. Use the equations in Chapter 2 to support the arguments.

Pg 67 – Elaborate the name of each designs. Can be named base on the reference.

Pg 70 – Explain why current density J is used to plot the graph instead of current I. Put the experimental result together with the simulation result on the same graph.

Pg 73 – Elaborate more on the sentence 'mistakenly locked'.

Grammar error must be corrected.

Pg 84 – Section 4.4.5 the summary is too brief.

Mention the plots is refer to which equation.

Pg 100 – Explain why only TM mode is chosen for analysis. Otherwise must include the result for TE mode as well.

Re-write some of the subtitles (e.g. the subsection 4.6.3). It must be meaningful.

Put in the theoretical limit of the quantum efficiency if possible

Bab 5 *(Chapter 5)*

Highlight the findings and you have achieved the objectives

Bab 6 *(Chapter 6) - Reference*

The reference is not standard. It is not sequential.

The latest reference is 2014.

Bab 7 *(Chapter 7)*

Bab 8 *(Chapter 8)*

Bab 9 *(Chapter 9)*

UNIVERSITI TEKNOLOGI MALAYSIA UTM(PS)-08/09 (PIND. 1/04)

IJAZAH DOKTOR FALSAFAH *(DEGREE OF DOCTOR OF PHILOSOPHY)*
LAPORAN PEMERIKSAAN TESIS – LUARAN *(EXAMINER'S REPORT ON THESIS - EXTERNAL)*

Nama Calon *(Name of Candidate)*	: **Mohd Asmu'i bin Mohd Akil**	Tajuk Tesis *(Title of Thesis)*	: **Modelling of Optical and Electronic Characteristics for Broadband Aluminium Gallium Arsenide Terahertz Quantum Cascade Laser**
Fakulti *(Faculty)*	: **Faculty of Science**		
Nama Pemeriksa dan Institusi *(Name of Examiner and Institution)*	: **Prof Dr Mohd Kamil Abd Rahman** **Faculty of Applied Sciences,** **University Teknologi MARA** **40450 Shah Alam, Selangor**		

SILA TANDATANGAN DI DALAM RUANG YANG DISEDIAKAN UNTUK PERAKUAN **TANDATANGAN**
(Please initial in space provided for the recommendation) *(INITIAL)*

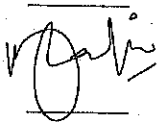
1. **Perakuan *(Recommendation)***
Setelah memeriksa tesis, saya perakukan *(After examining the thesis, I recommend that)*

a) Calon dianugerahkan ijazah Doktor Falsafah *(The candidate be awarded the degree of Doctor of Philosophy)*;..... _____

atau *(or)* b1) Calon dianugerahkan ijazah Doktor Falsafah setelah membuat pembetulan kecil *(The candidate be awarded the degree of Doctor of Philosophy (PhD) subject to minor corrections)*;. _____

atau *(or)* b2) Calon dianugerahkan ijazah Doktor Falsafah (PhD) setelah membuat pindaan dan pembetulan kepada tesis seperti yang disenaraikan dalam laporan ini dan disahkan telah berbuat demikian oleh Pemeriksa Dalam/Luar berkenaan; *(The candidate be awarded the degree of Doctor of Philosophy (PhD) subject to the amendments and corrections as listed elsewhere in this report being made in the thesis to the satisfaction of the Internal/External Examiner(s))*; _____

atau *(or)* c) Calon tidak dianugerahkan ijazah Doktor Falsafah (PhD) tetapi dibenarkan menghantar semula tesis untuk pemeriksaan setelah menjalani kajian dan penyelidikan lanjutan. *(The candidate not be awarded the degree of Doctor of Philosophy (PhD) but be permitted to resubmit the thesis for further examination in a revised form after a further period of study and research)*; _____

atau *(or)* d) Pencapaian calon tidak memuaskan untuk ijazah Doktor Falsafah (PhD) tetapi dicadangkan satu ijazah yang lebih rendah. *(The candidate not be awarded the degree of Doctor of Philosophy (PhD) but a lower degree)*; ..... 

atau *(or)* e) Calon tidak dianugerahkan ijazah Doktor Falsafah (PhD). *(The candidate not be awarded the degree of Doctor of Philosophy (PhD))* _____

2. **Pendapat *(Opinion)***
Saya berpendapat *(In my opinion)*

a) Tesis ini mengandungi banyak sumbangan asli ke arah pembangunan ilmu dalam bidang berkenaan *(The thesis has substantial original contribution to the knowledge of the subject concerned)*;..... _____

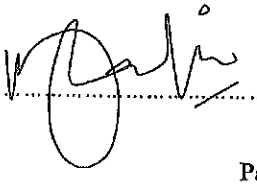
b) Keaslian tesis dibuktikan dengan penemuan fakta-fakta baru *(The thesis affords evidence of originality by the discovery of new facts)*; _____

c) Keaslian tesis dibuktikan dengan kebolehan memberi kritikan yang bernas dan jelas *(The thesis affords evidence of originality by exercising of independent critical ability)* _____

d) Tesis ini memuaskan dari segi penyampaian *(The thesis is satisfactory in regards to literary presentation;)*.... _____

e) Terdapat hasil kajian dalam tesis sesuai untuk diterbitkan *(A significant amount of findings in the thesis are worthy of publication;)* _____

3. **Merit(*Merit*)**
Dalam membuat perakuan di atas, saya sahkan calon adalah cemerlang untuk ijazah ini dan dianugerahkan ijazah dengan **merit**. *(In making the above recommendation, I consider that the candidate is outstanding for this degree and should be awarded the degree with **merit**)* ..... _____

Tandatangan *(Signature)*:  Tarikh *(Date)*: 18 Apr 2017.....

4.4 Methodologi *(Methodology)*

Section 3.2: Algorithm on the computer modelling program is not clear with poor use of English.
Laser structure designs of QCL for the modelling must be shown.
Source code program (**claimed to be newly improved**) for modelling QCL must be included in the thesis (in Appendix).
The newly improved code has not been written anywhere in Methodology and its **improved codes could not be evaluated**.

The I-V characteristics and gain spectra that were modeled are based on four QCL designs from 3 cited references.
The candidate **did not design any new or novel structure of THz QCL for modelling** to improve previous designs.

There is **no continuation and flow of study** from previous work above and on the modelling of optical modes in double metal QCL waveguide. This double metal QCL waveguide only has GaAs as it gain medium, while previous work was on AlGaAs/GaAs materials were used in the model.
The double metal QCL **waveguide design is adapted from 2 published works** by other researchers (Turcinkova and Markus Rosch).
There is **no new or novel design on double metal QCL waveguide constructed or modelled.**

4.5 Analisis *(Analysis)*

The thesis lacks depth in analysis on the results obtained. The thesis tends to present the results more of a reporting manner.
Critical analysis in discussing the results is very important element in providing significant contribution to a PhD thesis.

4.6 Keputusan dan Perbincangan *(Results and Discussions)*

The I-V curves from modelling of the four designs of QCL **do not match with I-V curves** of the experimental results from the 3 cited journals.
Thus, it is obvious that the **modelling fails to model** the THz QCL and the **candidate cannot claim** that the modelling of "*I-V curves are in good agreement with the experimental results*" as stated in the Conclusion.
The newly improved code fails to model and showed no improvement.
A full paragraph (11 lines) on page 67 was copied and paste with almost the exact sentenses to pages 72, 76 and 80.
The candidate seems to have very poor ability on discussing and analyzing the results obtained; and has the bad habit of copy-and-paste style of writing.
In Methodology, it is stated that QCL will be modelled across a range on frequency from 1 – 10 THz, but none of the results presented are within this range. The results mostly presented with frequency range less than 10 THz.

Results plotted from the modeling should be referred-back to the mathematical equations in Chapter 2 to reflect all the parameters used in the model. Since there are quite a large number equations written in the Chapter 2 but to which equations are used for the model is not clearly stated.

How is the "Losses" in QCL relates to the optical gain of the laser?
The "Losses" are below 30 cm^{-1} for the range of 2 – 3.5 THz; but the optical gains have values from 80 – 170 cm^{-1}.
We all know that lasing occurs only when gain is equal or more than the losses in the laser cavity.
Why can't the modelling of "loss and gain" employs the same QCL structure designs, so that they can be compared?
Why bother modeling double metal QCL waveguide if there is no continuation of flow in the study? These two structures are quite different.

Tandatangan *(Signature)*: ..... Tarikh *(Date)*: 18 Apr 2017.....

UNIVERSITI TEKNOLOGI MALAYSIA

IJAZAH DOKTOR FALSAFAH *(DEGREE OF DOCTOR OF PHILOSOPHY)*
LAPORAN PEMERIKSAAN TESIS *(EXAMINER'S REPORT ON THESIS)*

Nama Calon : **Mohd Asmu'i Bin Mohd Akil**
(Name of Candidate)

Tajuk Tesis :: **Modelling of Optical and Electronic Characteristics for Broadband Aluminum Gallium Arsenide Terahertz Quantum Cascade Laser.**
(Title of Thesis)

Fakulti : **Fakulti Sains**
(Faculty)

Nama Pemeriksa dan Institusi : **Prof Madya Dr. Yusof Bin Munajat**
(Name of Examiner and Institution) **Fakulti Sains,**
UTM, Johor Baharu.

SILA TANDATANGAN DI DALAM RUANG YANG DISEDIAKAN UNTUK PERAKUAN **TANDATANGAN**
(*Please initial in space provided for the recommendation*)
(INITIAL)

1. **Perakuan *(Recommendation)***
Setelah memeriksa tesis, saya perakukan *(After examining the thesis, I recommend that)*

a) Calon dianugerahkan ijazah Doktor Falsafah *(The candidate be awarded the degree of Doctor of Philosophy)*;.....

atau *(or)* b1) Calon dianugerahkan ijazah Doktor Falsafah setelah membuat pembetulan kecil *(The candidate be awarded the degree of Doctor of Philosophy subject to minor corrections)*;.....

atau *(or)* b2) Calon dianugerahkan ijazah Doktor Falsafah setelah membuat pindaan dan pembetulan kepada tesis seperti yang disenaraikan dalam laporan ini dan disahkan telah berbuat demikian oleh Pemeriksa Dalam/Luar berkenaan; *(The candidate be awarded the degree of Doctor of Philosophy subject to the amendments and corrections as listed elsewhere in this report being made in the thesis to the satisfaction of the Internal/External Examiner(s))*;.....

atau *(or)* c) Calon tidak dianugerahkan ijazah Doktor Falsafah tetapi dibenarkan menghantar semula tesis untuk pemeriksaan setelah menjalani kajian dan penyelidikan lanjutan. *(The candidate not be awarded the degree of Doctor of Philosophy but be permitted to resubmit the thesis for further examination in a revised form after a further period of study and research)*;.....

atau *(or)* d) Pencapaian calon tidak memuaskan untuk ijazah Doktor Falsafah tetapi dicadangkan satu ijazah yang lebih rendah. *(The candidate not be awarded the degree of Doctor of Philosophy but a lower)*; .....

atau *(or)* e) Calon tidak dianugerahkan ijazah Doktor Falsafah. *(The candidate not be awarded the degree of Doctor of Philosophy)*.....

2. **Pendapat *(Opinion)***
Saya berpendapat *(In my opinion)*

a) Tesis ini mengandungi banyak sumbangan asli ke arah pembangunan ilmu dalam bidang berkenaan *(The thesis has substantial original contribution to the knowledge of the subject concerned)*;.....

b) Keaslian tesis dibuktikan dengan penemuan fakta-fakta baru *(The thesis affords evidence of originality by the discovery of new facts)*;

c) Keaslian tesis dibuktikan dengan kebolehan memberi kritikan yang bernas dan jelas *(The thesis affords evidence of originality by exercising of independent critical ability)*

d) Tesis ini memuaskan dari segi penyampaian *(The thesis is satisfactory in regards to literary presentation;)*

e) Terdapat hasil kajian dalam tesis sesuai untuk diterbitkan *(A significant amount of findings in the thesis are worthy of publication;)*

3. **Merit**(*Merit*)
Dalam membuat perakuan di atas, saya sahkan calon adalah cemerlang untuk ijazah ini dan dianugerahkan ijazah dengan **merit**. (*In making the above recommendation, I consider that the candidate is outstanding for this degree and should be awarded the degree with* ***merit***)

Tandatangan *(Signature)*: Tarikh *(Date)*: 12/6/2017

4. Sila berikan ulasan terhadap perkara berikut untuk dijadikan asas perakuan (***Please comment on the following aspects as the grounds for recommendation***)

4.1 Tajuk Tesis *(Title of the Thesis)*

Title of the thesis is not suitable since the title is not fully reflects the objectives. The title and objectives need to be rewrite in order cover the content of study. The title should more specific and highlights the contribution of study.

4.2 Abstrak *(Abstract)*

The abstract is satisfactory and written describing the studies. However the content of study needs to be revised because not fully cover the important part of thesis. The final outcome must be highlighting the contribution of studies.

4.3 Kajian Literature *(Literature review)*

The candidate prepares literature review on various topics; however it is not directly relevant to the study. Since the study based on the modelling, candidate should review previous conducted methods and highlight the new approach. The literature must be properly cited and really used in the studies. The related Equation must be quote clearly.

Tandatangan *(Signature)*: _____ Tarikh *(Date)*: 12/6/2017_____

4.4 Methodologi *(Methodology)*

Research methodology is not well structured and the aim of study is blurring. The description of methodology is not clear and not detailed. Research methodology must have research activities that related to the objectives. The result should answer the objectives. The objectives then reflect the title.
The studies is based on the modelling and said to improve the coding, but no appendix to show the coding or programming of the studies. The equations used in the studies also not all quote properly.
The studies should focus on one design model and highlight the new improvement that has been done as your contribution. The optical modes for broadband waveguide also need clear description to relate with your first study.

4.5 Analisis *(Analysis)*

This study based on modelling of THz Quantum Cascade laser. First using Density Matrix Method study the individual active region of THz QCL by comparing with experimental work. Second using Finite Element Method study the ability of optical mode for broad range emission.
The analysis shows the bias in THz QCL, the energy of levels versus electric field, the evolution population densities by bias changes and I-V curves from previous researcher Kumar. Then the analysis expended to other researcher of THz QCL.
Based on the analysis, most of the results just plot the graph of previous researcher experiment data and the calculation done by candidate. I can't see extra information that is impossible to measure experimentally. The modelling should show much better and high performance of THz QCL based to some new assumption and approach can be engineered that can expect improvement result.

Tandatangan *(Signature)*: _____ Tarikh *(Date)*: 12/6/2017_____

4.6 Keputusan dan perbincangan *(Results and discussions)*

According to the results obtained,

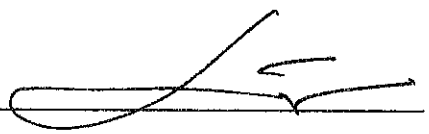
a. The modelling results and discussion digested and compared with previous researcher.
b. Schematic diagram shown almost well presented, but the graph of I-V not represents the good practice of plotting.
c. Candidate not able to developed new assumption and approach that can improve the THz output.

4.7 Kekuatan Tesis *(Strength of the thesis)*

4.8 Kelemahan Tesis *(Weakness of the thesis)*

Most of the weakness of the thesis as follows;

1. The title not really represent to the objectives.
2. The objectives must be from good Research Problem.
3. Every objective must follow the related research activities.
4. The literature review must be from the most relevance cited reference.
5. Research methodology description must be clear based on detail research activities.
6. The equations used in the programming must be quote precisely.
7. The results should answer the research problems.
8. The study based on the modelling and the new coding or programming should put in the appendix.
9. The graph of I-V not represents the good practice plotting of graph.
10. The final result is the THz output, but how your new assumption and approach can improve the output.

Tandatangan *(Signature)*:  Tarikh *(Date)*: 12/6/2017

4.9 Kepentingan Kajian *(Significance of the study)*

The study "Modelling of Optical and Electronic Characteristics for Broadband Aluminum Gallium Arsenide Terahertz Quantum Cascade Laser", implies the importance application of the THz spectroscopy and imaging. It can contribute to the development of THz Quantum Cascade Laser and human capital in this field. Hopefully it is used as the catalyst and reference point for further research.

4.10 Perakuan penganugerahan *(Recommendation for the award)*

I hereby certify that the candidate not be awarded the degree of Doctor of Philosophy but be permitted to resubmit the thesis for further examination in a revised form after a further period of study and research.

I would like to reserve my final decision till the viva presentation.

4.11 Lain-lain ulasan *(Other comments)*

Refer to the thesis.

Tandatangan *(Signature)*: _____ Tarikh *(Date)*: 12/6/2017