National Institute of Physics
University of the Philippines Diliman

Condensed Matter
Physics Laboratory

SEMICONDUCTOR GROUP

walk through
our research output over the years

explore
our cutting-edge fabrication and characterization facilities

meet
our members and collaborators

CMPL - Semiconductor group throughout the years

Dr. Arnel Salvador
Program Coordinator
aasalvador@up.edu.ph

This brochure summarizes completed and ongoing projects of the Condensed Matter Physics Laboratory - Semiconductor group for the last five years (2017-2023) with the goal of informing our funding partners where we are right now as well as introducing our group to our future collaborators. The report includes our work on terahertz emitters, solar cells, vertical cavity surface emitting lasers, graphene-based field effect transistors, piezoelectric-micromachined ultrasonic transducers, and nanostructures for surface-enhanced Raman spectroscopy and sensor applications.

Our group traces its roots to the late 1990 World Bank/DOST Engineering Science Education Program (ESEP) that provided the needed equipment to do III-V semiconductor thin film growth via molecular beam epitaxy and materials characterization. We initially concentrated on GaAs-based optoelectronic devices and field effect transistors for RF applications. The continuous support from DOST (PCASTRD and now PCIEERD), CHED (through Philippine California Research Institute (PCARI) and Leading Advanced Knowledge in the Science and Agriculture (LAKAS) program), UP Sytems, and UP Diliman OVCRD, as well as our industry partners, have enabled us to expand and upgrade our facility so that we are now also able to venture into new fields such as MEMs, photoconductive antennae for THZ detection, sensors, device fabrications, and other vacuum and non-vacuum techniques for film growth.

Training future scientists is a key essential mission of the laboratory and one of the main reasons it was able to sustain a vigorous research program. In the past two decades, this laboratory has trained over a hundred MS and 20 PhD graduates in Physics and Materials Science and Engineering. A majority of them are now affiliated with semiconductor companies and academic institutions. We currently have three professors in our group (Dr. Salvador, Dr. Somintac, and Dr. Estacio) who are involved in mentoring students, and we hope to increase this number in the near future. We maintain international collaborations to ensure that our students are also abreast of recent developments in the field of materials science and physics. We have linkages with research groups in higher education institutes and state universities so that there is a sustainable environment to increase the number of researchers pursuing work in the sciences and engineering.

In 2022 semiconductors account for

47.4
percent of total exported goods from the Philippines

1.6 trillion Pesos
of equivalent exported goods

highest share
of electronic product exported

Published by Statista Research Department

research

interests

Graphene Field Effect Transistors (GFET)

Vertical cavity surface emitting laser (VCSEL)

Terahertz photoconductive antenna (PCA)

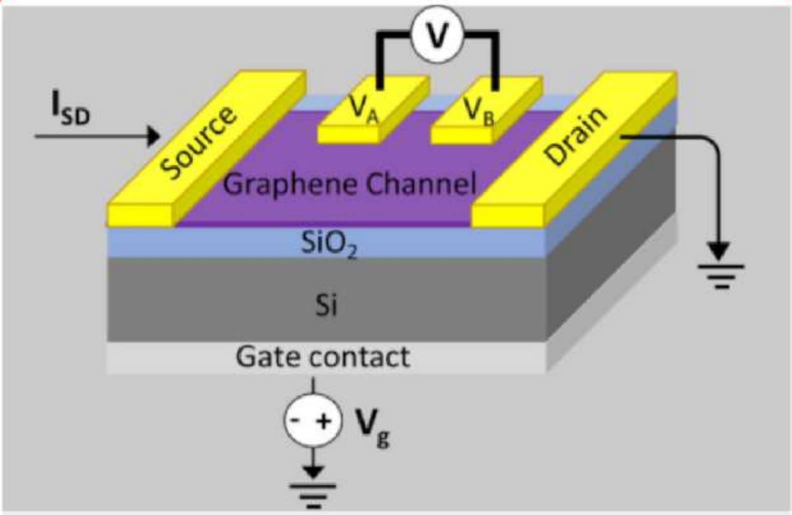
In-house Raman microscopy and spectroscopy

Graphene field effect transistor

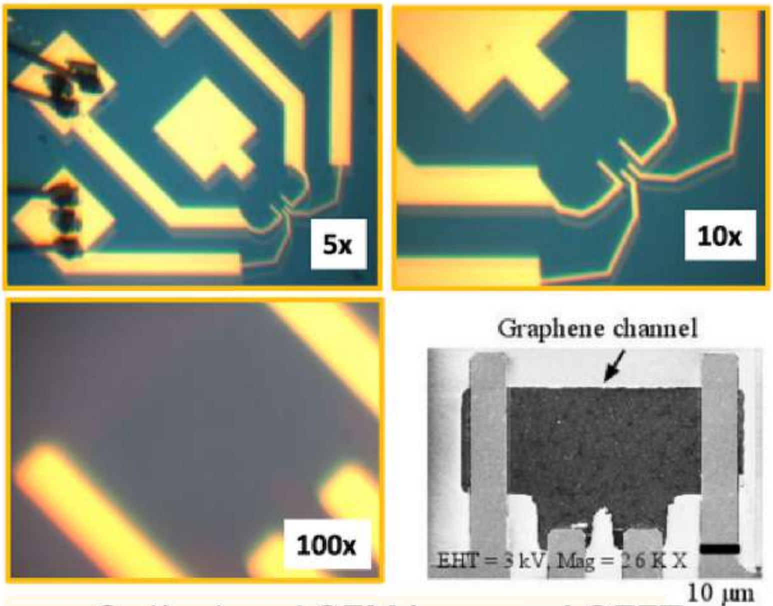
Our research in GFET is focused on **wearable low-cost** and **low-power graphene-based sensors** that can be integrated into smartphones and smartwatches.

This work is under the **Chemical and Environment Portable Sensor Technologies (CE-PoST)** Project funded by **CHED/PCARI grant** and in collaboration with the **Berkeley Sensor and Actuator Sensor (BSAC)** at the **University of California, Berkeley Campus**.

Prof. Liwei Lin at NIP - UPD

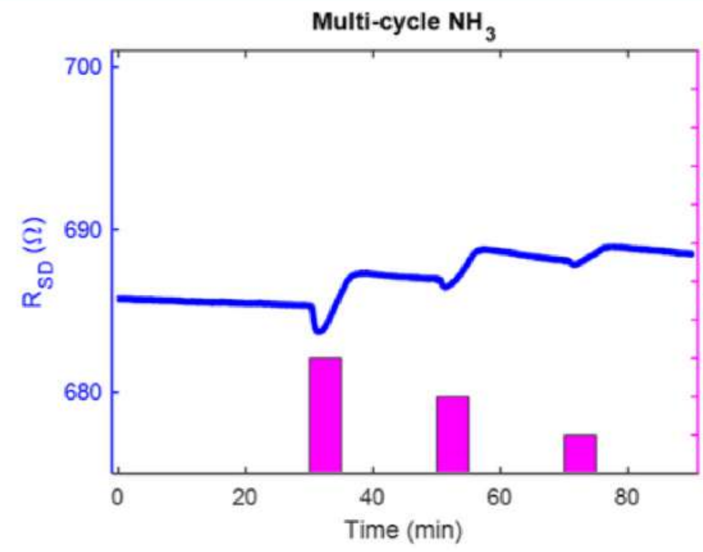


Schematic diagram of GFET



Optical and SEM image of GFET

Graphene field effect transistor



gas sensing capability of GFET

fabrication of GFET by our research team in Berkeley

Research Article

Influence of chamber design on the gas sensing performance of graphene field-effect-transistor

Lorenzo Lopez Jr.[1,2,3] · Vernalyn Copa[1,2,3] · Takeshi Hayasaka[3] · Maria Angela Faustino-Lopez[1,2] · Yichuan Wu[3] · Huiliang Liu[3] · Yumeng Liu[3] · Elmer Estacio[1,2] · Armando Somintac[1,2] · Liwei Lin[3] · Arnel Salvador[1,2]

Received: 1 November 2019 / Accepted: 2 April 2020

Abstract

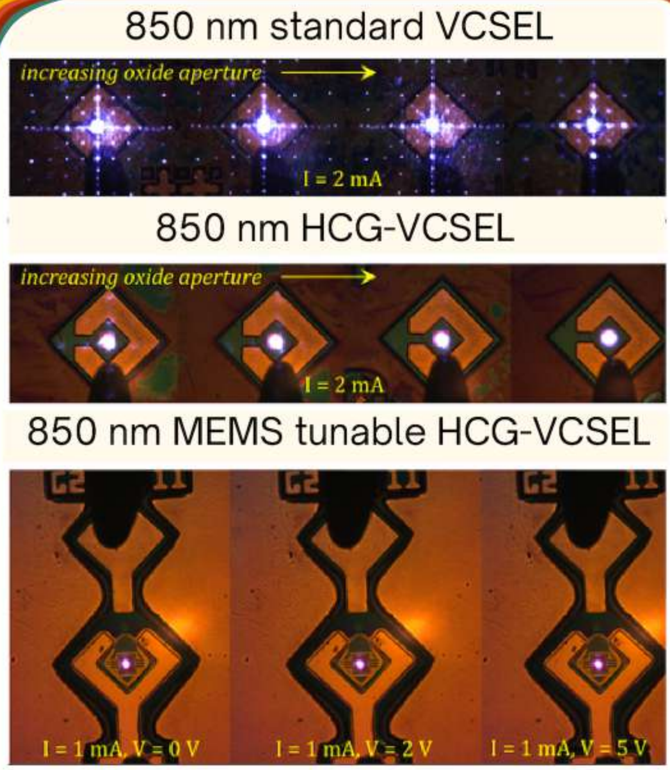
We report on the influence of chamber design on the gas sensing performance of a graphene field-effect-transistor (GFET). A conventional chamber (V = 400 ml) and a cap chamber (V = 1 ml), were used to perform dynamic measurements on a GFET. To gain a-priori knowledge on the gas flow in the chambers, Naiver–Stokes and convection-diffusion equations were numerically-solved using COMSOL Multiphysics. We numerically and experimentally observed two main factors that can affect the GFET performance: (1) the gas flow direction through the chamber and (2) the chamber volume. At 5-min exposure time, at least 200% higher GFET sensitivity was calculated from the cap chamber, which is expected since the conventional chamber is 400 times larger. Interestingly, even when the conventional chamber is fully saturated (at 90-min exposure time), the GFET sensitivity in the cap chamber is still better by 28.57%. We attributed this behavior to the swirling vapor flow in the cap chamber brought about by the U-shaped path. This effect causes multiple interaction of H_2O molecules with the GFET, resulting to higher computed sensitivity. However, at higher relative humidity, the GFET becomes populated, reducing the number of H_2O molecules that can re-interact with the sensor. In terms of GFET transient characteristics, a 154% and 86.9% faster response and recovery, respectively, were observed in the cap-design. This was due to its smaller volume that minimized poorly purged region in the chamber. But if the chambers have the same volumes, we may infer a faster GFET response and recovery from the conventional chamber where the gas flow is unperturbed. These results could contribute in designing a time efficient and cost-effective gas sensing system.

our work was published in SN Applied Sciences

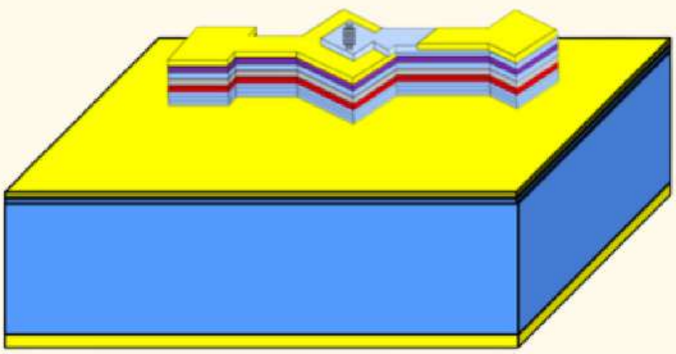
Vertical cavity surface emitting laser (VCSEL)

VCSEL heterostructure comprises a **cavity layer sandwiched between** two oppositely-doped distributed **Bragg reflectors** (DBR).

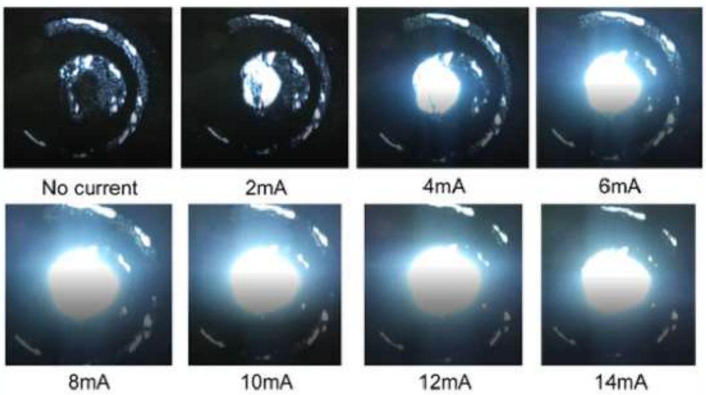
At the center of the cavity layer is an **active region consisting of multiple quantum wells and/or quantum dots**.



Device fabricated by our research team at UC Berkeley



Schematic diagram of MEMS tunable HCG-VCSEL



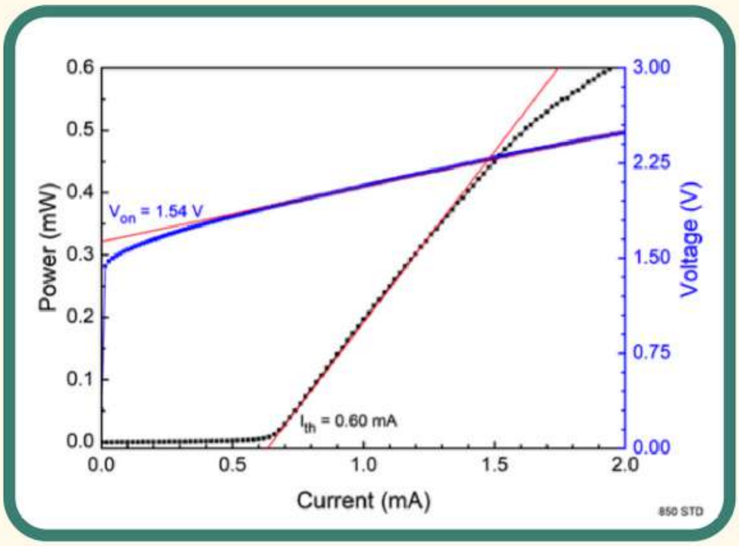
Home-grown VCSEL with thermal oxidation at CMPL, NIP

Our work is under the **3rd-Generation VCSEL for Resilient Communication Networks (3V-ReCoN)** project funded by **CHED-PCARI**.

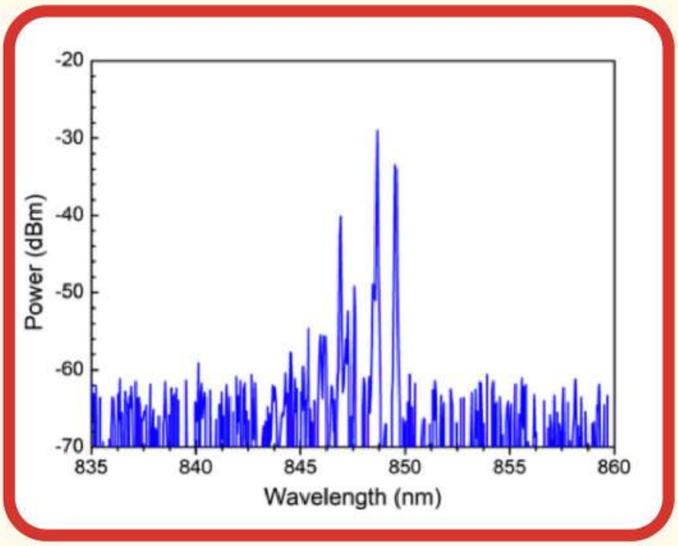
The aim of the collaboration with **Connie Chang-Hasnain (CCH) Optoelectronics Research Group** of the **University of California Berkeley** (UCB) is to design and develop a **3rd-generation VCSEL** operating at 1060 nm with speeds of up to 10 GHz. This requires a complex interplay between the **crystal growth** and the **device fabrication** for ease of manufacturing.

Vertical cavity surface emitting laser (VCSEL)

L-I-V curve of the 850 nm standard VCSEL with the current and voltage threshold



Emission spectra of the 850 nm standard VCSEL



Characterization of fabricated VCSEL using characterization equipment in NIP

Dr. Connie Chang-Hasnain visited NIP and gave a special lecture on VCSELs

Our work on VCSEL in reported in Semiconductor Science and Technology last 2022

Semiconductor Science and Technology

PAPER

Indirect stress and air-cavity displacement measurement of MEMS tunable VCSELs via micro-Raman and micro-photoluminescence spectroscopy

Philippe Martin Tingzon[5,1,2], Horace Andrew Husay[2], Neil Irvin Cabello[2], John Jairus Eslit[3], Kevin Cook[4], Jonas Kapraun[4], Armando Somintac[2], Maria Theresa De Leon[3], Marc Rosales[3], Arnel Salvador[2] + Show full author list

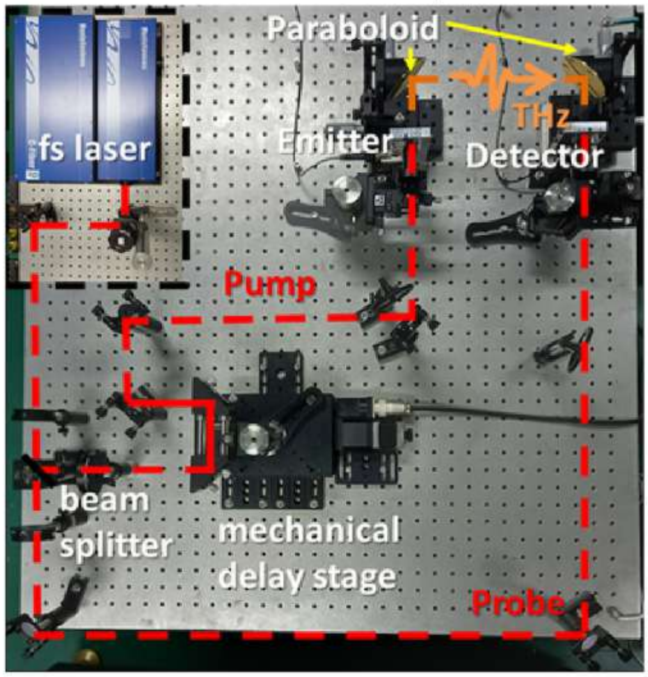
Published 28 January 2022 • © 2022 IOP Publishing Ltd
Semiconductor Science and Technology, Volume 37, Number 3
Citation Philippe Martin Tingzon *et al* 2022 *Semicond. Sci. Technol.* **37** 035013
DOI 10.1088/1361-6641/ac4abc

Terahertz photoconductive antenna (PCA)

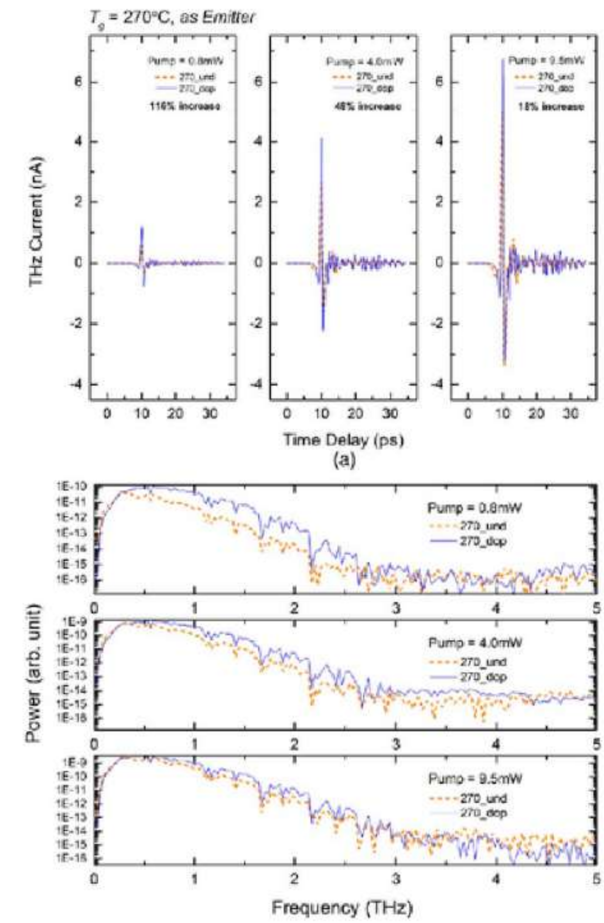
Terahertz **(THz)** corresponds to the **100 GHz** to **10 THz** frequencies. THz waves have **potential applications in spectroscopy**, imaging, and non-destructive material evaluation. **PCAs** are **key components** of modern **THz-TDS** systems

In-house fabricated PCA devices by CMPL Semiconductor group

THz-TDS setup



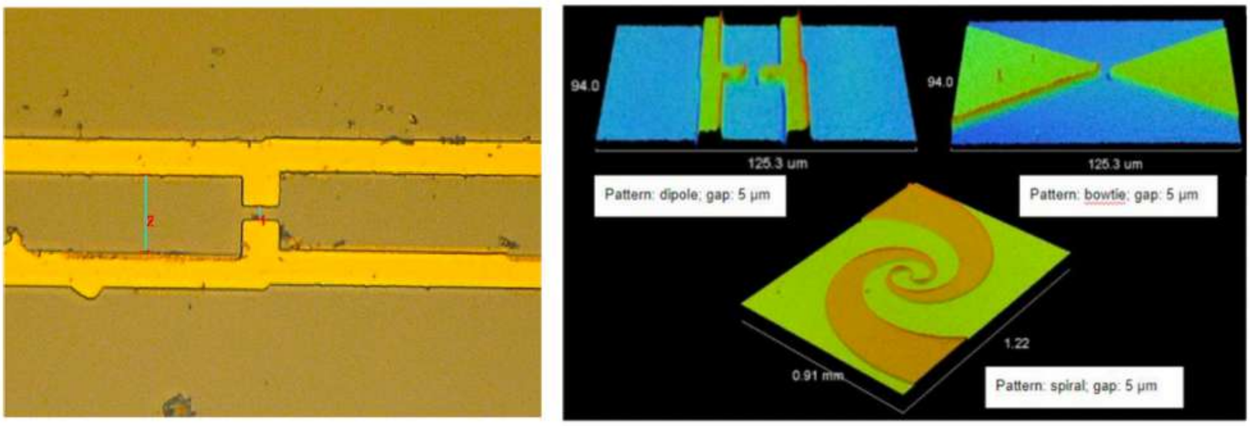
Photoconductive antennas (**PCA**s) were fabricated from molecular beam epitaxy (MBE)- grown layers for **high-efficiency**, **broad-bandwidth**, and **cost-effective** generation and detection of **THz radiation**.



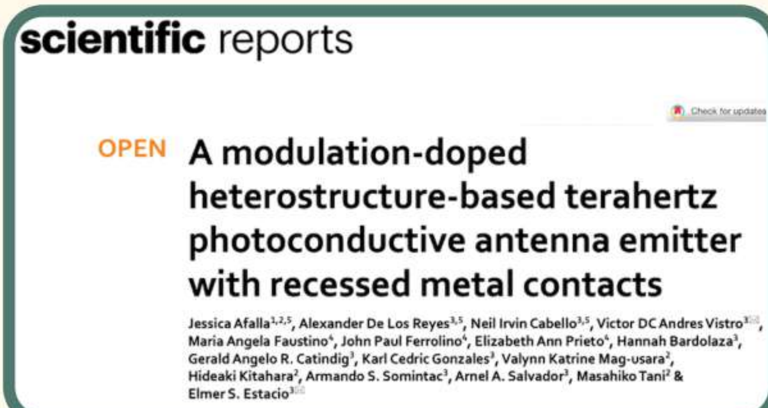
Successful demonstration of terahertz emitter and detector based on trilayer LT-GaAs with a doped buffer

Our work on terahertz PCA was funded by the **Department of Science and Technology Grants-in-Aid Program** (Project No. 04001) in collaboration with the **Research Center for Development of Far-infrared Region** - **University of Fukui** (FIR-UF) spearheaded by **Prof. Masahiko Tani**.

THz photoconductive antenna (PCA)



Optical image and optical surface profilometric image of the fabricated LT-GaAs/SI-GaAs PCA



scientific reports

Check for updates

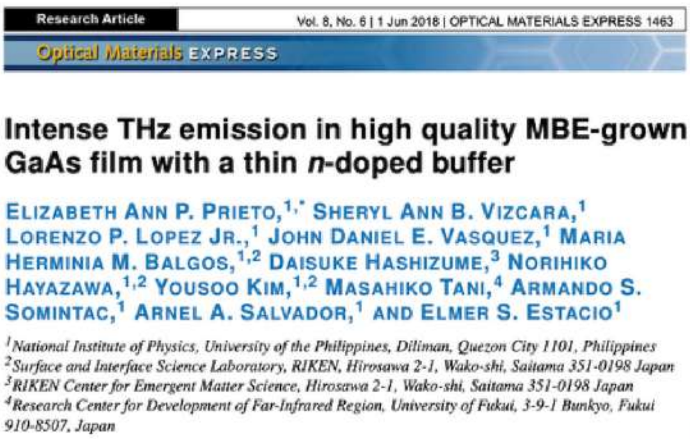
OPEN

A modulation-doped heterostructure-based terahertz photoconductive antenna emitter with recessed metal contacts

Jessica Afalla[1,2,5], Alexander De Los Reyes[3,5], Neil Irvin Cabello[3,5], Victor DC Andres Vistro[3], Maria Angela Faustino[4], John Paul Ferrolino[4], Elizabeth Ann Prieto[4], Hannah Bardolaza[3], Gerald Angelo R. Catindig[3], Karl Cedric Gonzales[3], Valynn Katrine Mag-usara[2], Hideaki Kitahara[2], Armando S. Somintac[3], Arnel A. Salvador[3], Masahiko Tani[2] & Elmer S. Estacio[3]

our published work on Nature Scientific Reports

we have a pending patent with trilayer terahertz emitter and detector device



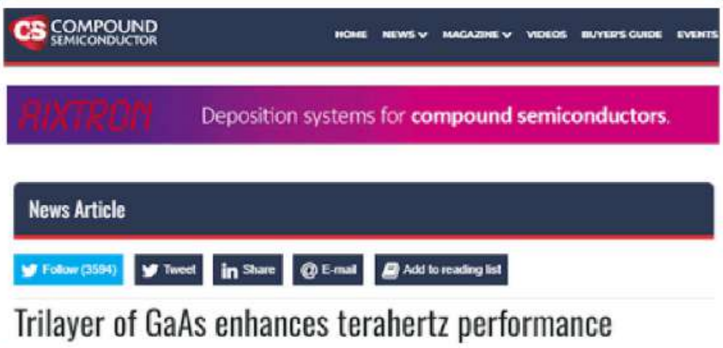
Research Article Vol. 8, No. 6 | 1 Jun 2018 | OPTICAL MATERIALS EXPRESS 1463

Optical Materials EXPRESS

Intense THz emission in high quality MBE-grown GaAs film with a thin *n*-doped buffer

ELIZABETH ANN P. PRIETO,[1,*] SHERYL ANN B. VIZCARA,[1] LORENZO P. LOPEZ JR.,[1] JOHN DANIEL E. VASQUEZ,[1] MARIA HERMINIA M. BALGOS,[1,2] DAISUKE HASHIZUME,[3] NORIHIKO HAYAZAWA,[1,2] YOUSOO KIM,[1,2] MASAHIKO TANI,[4] ARMANDO S. SOMINTAC,[1] ARNEL A. SALVADOR,[1] AND ELMER S. ESTACIO[1]

[1] *National Institute of Physics, University of the Philippines, Diliman, Quezon City 1101, Philippines*
[2] *Surface and Interface Science Laboratory, RIKEN, Hirosawa 2-1, Wako-shi, Saitama 351-0198 Japan*
[3] *RIKEN Center for Emergent Matter Science, Hirosawa 2-1, Wako-shi, Saitama 351-0198 Japan*
[4] *Research Center for Development of Far-Infrared Region, University of Fukui, 3-9-1 Bunkyo, Fukui 910-8507, Japan*



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News Article

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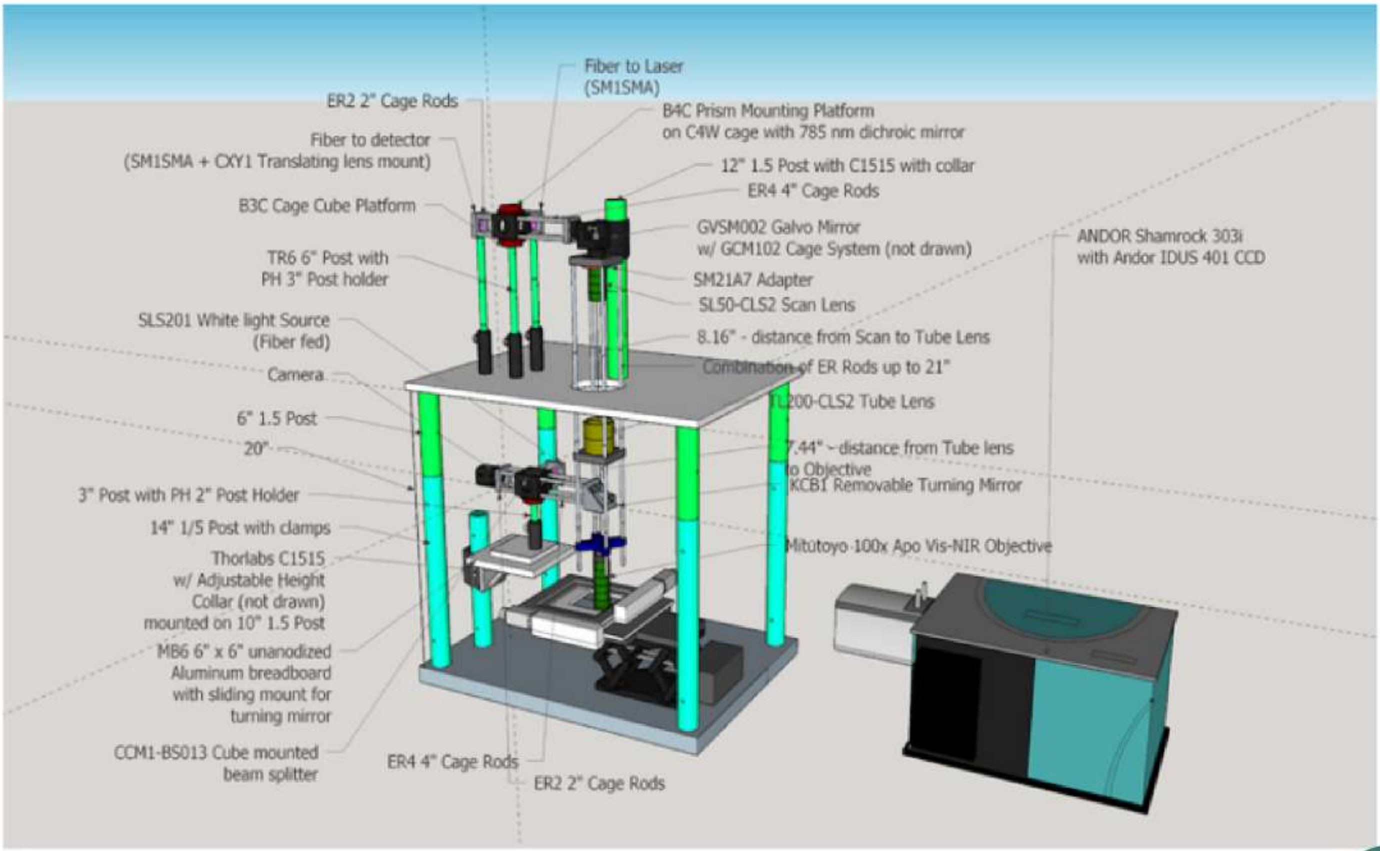
Trilayer of GaAs enhances terahertz performance

trilayer LT-GaAs featured in Compound Semiconductor magazine



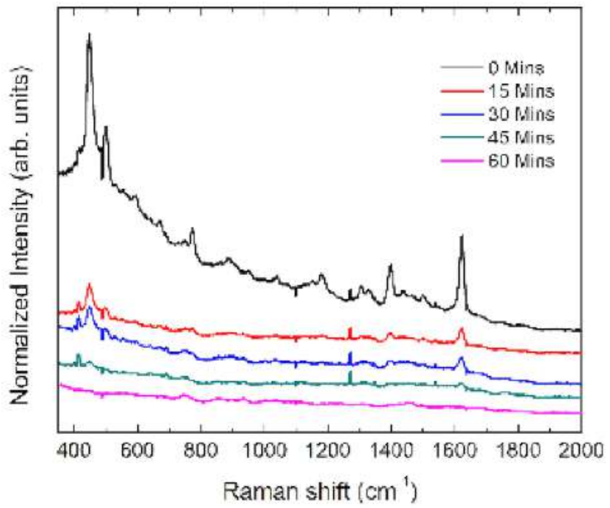
Schematic diagram of RMS setup

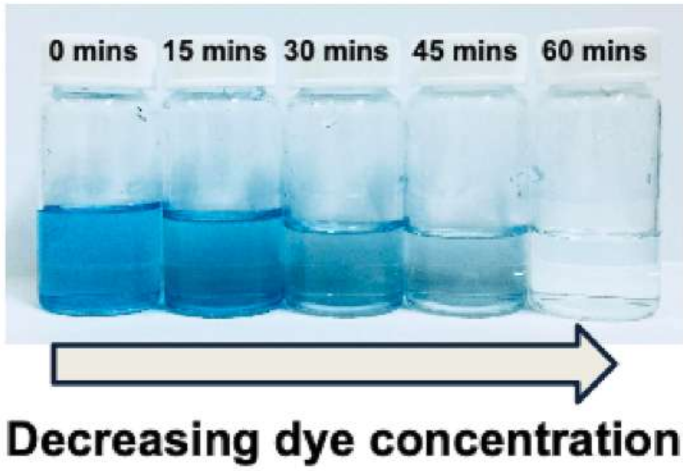
Raman Microscopy and Spectroscopy (RMS)

In-house RMS is built under the project "**Development of a Raman Microscopy and Spectroscopy Setup**", which was funded by the **Department of Science and Technology (DOST)** through its Innovation Council, **Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD).**

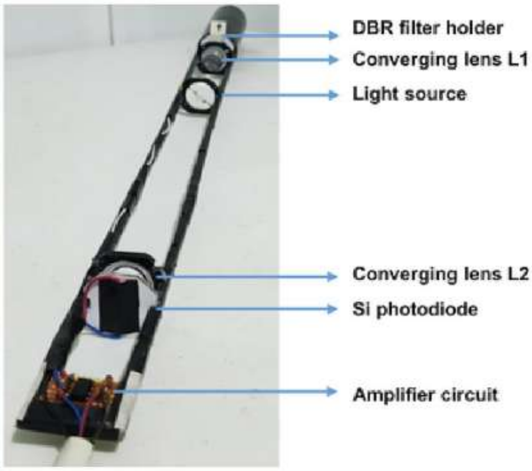
Image of RMS setup during characterization

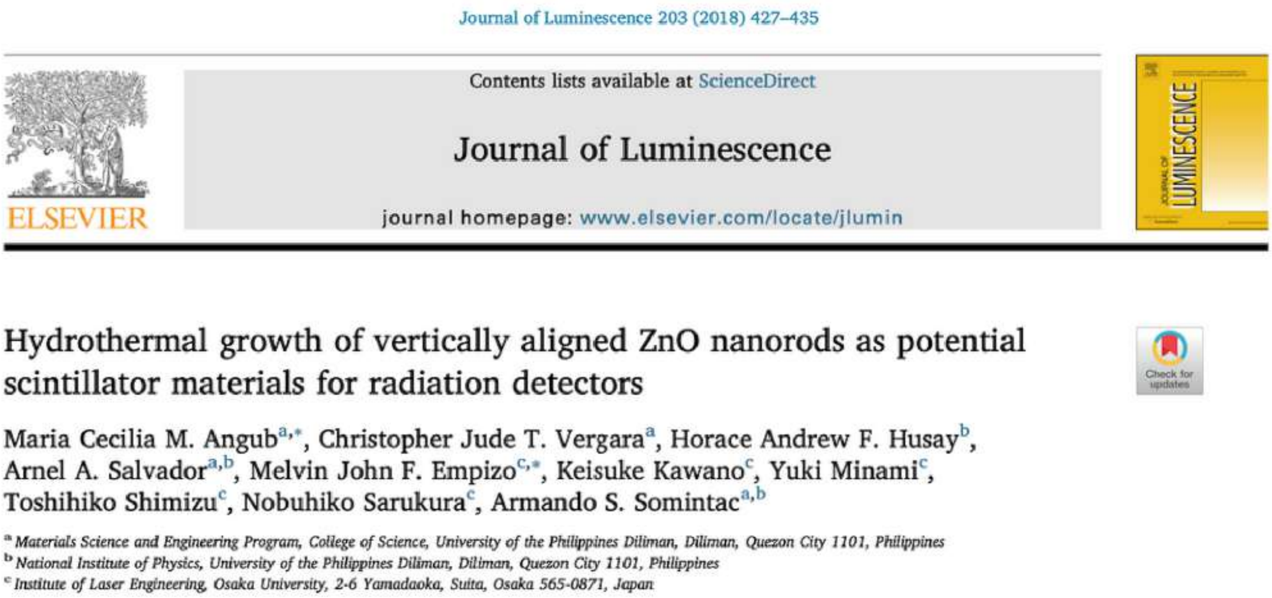
Decreasing Methylene Blue (MB) dye concentration after photodegradation measured by the Raman setup





Extended application is for algae torch which can measure the algae count which can be used for field works





Journal of Luminescence 203 (2018) 427–435

Contents lists available at ScienceDirect

Journal of Luminescence

journal homepage: www.elsevier.com/locate/jlumin

Hydrothermal growth of vertically aligned ZnO nanorods as potential scintillator materials for radiation detectors

Maria Cecilia M. Angub[a,*], Christopher Jude T. Vergara[a], Horace Andrew F. Husay[b], Arnel A. Salvador[a,b], Melvin John F. Empizo[c,*], Keisuke Kawano[c], Yuki Minami[c], Toshihiko Shimizu[c], Nobuhiko Sarukura[c], Armando S. Somintac[a,b]

[a] Materials Science and Engineering Program, College of Science, University of the Philippines Diliman, Diliman, Quezon City 1101, Philippines
[b] National Institute of Physics, University of the Philippines Diliman, Diliman, Quezon City 1101, Philippines
[c] Institute of Laser Engineering, Osaka University, 2-6 Yamadaoka, Suita, Osaka 565-0871, Japan

THz research collaboration

There is an ongoing **collaboration** with the team of **Dr. Elmer Estacio** and **Prof. Masahiko Tani** under the **Research Center for Development of Far-Infrared Region (FIR)** at the **University of Fukui, Japan.** This linkage is active in both research collaboration and academic exchange from both sides.

this collaboration resulted in **28 published papers**

36 IEEE TRANSACTIONS ON TERAHERTZ SCIENCE AND TECHNOLOGY, VOL. 12, NO. 1, JANUARY 2022

Terahertz Emission Enhancement of Gallium-Arsenide-Based Photoconductive Antennas by Silicon Nanowire Coating

Neil Irvin Cabello, Alexander De Los Reyes, Vladimir Sarmiento, John Paul Ferrolino, Victor DC Andres Vistro, John Daniel Vasquez, Hannah Bardolaza, Hideaki Kitahara, Masahiko Tani, *Member, IEEE*, Arnel Salvador, Armando Somintac, and Elmer Estacio

Applied Physics Express 14, 093001 (2021) **LETTER**

https://doi.org/10.35848/1882-0786/ac1b0d

Thickness dependence of the spintronic terahertz emission from Ni/Pt bilayer grown on MgO via electron beam deposition

John Paul Ferrolino[1*], Neil Irvin Cabello[2], Alexander De Los Reyes[2], Hannah Bardolaza[2], Ivan Cedrick Verona[2], Valynn Katrine Mag-usara[3], Jessica Pauline Afalla[3], Miezel Talara[3], Hideaki Kitahara[3], Wilson Garcia[2], Armando Somintac[2], Arnel Salvador[2], Masahiko Tani[3], and Elmer Estacio[2]

[1]Material Science and Engineering Program, University of the Philippines Diliman, Quezon City, 1101 Philippines
[2]National Institute of Physics, University of the Philippines Diliman, Quezon City, 1101 Philippines
[3]Research Center for Development of Far Infrared Region, University of Fukui, Bunkyo 3-9-1, Fukui City 910-8507, Japan

some our papers published in **(1) IEEE Transactions on Terahertz Science and Technology** and **(2) Applied Physics Express**

Visit of Dr. Estacio and Mr. Vince Juguilon to FIR-UF to participate in the teaching and research program

annual exchange of students and researchers between NIP and FIR

Recent research visit of Prof. Tani and his students at the National Institute of Physics to fabricate PCA device

Radiation damage investigations on functional materials

This is a **joint research** project on the successful **fabrication**, **analysis**, informatics of **ion irradiation** on the properties **of functional materials**.

It aims to investigate the effects of **gamma-ray** and **ion irradiation** on the properties of **functional materials** such as GaAs, homostructures, ZnO bulk crystals and thin films, and silicate glasses under the **DOST** - Japan Society for the Promotion of Science (**JSPS**) Joint Research Program.

Filipino Scholars Symposium in Kansai Opening Program at the Osaka University Icho Kaikan

Research collaboration between five (5) institutions

material development

A. Salvador*, R. Sarmago†, A. Somintac, E. Estacio, V. Samson‡, C. Sadia

material informatics

A. Padama§, D. Putungan, A. Santos, J. Gabayno|, R. Gammag

material analysis

N. Sarukura*, T. Shimizu, K. Yamanoi, M. Empizo¶, N. Guillermo

2 out of 3 ISI-indexed papers that have been published

physica status solidi b — *basic solid state physics*

Original Paper

Spray Pyrolysis Deposition of Al-Doped ZnO Thin Films for Potential Picosecond Extreme Ultraviolet Scintillator Applications

Erick John Carlo D. Solibet, Raymund C. Veloz, Melvin John F. Empizo, Horace Andrew F. Husay, Keisuke Kawano, Kohei Yamanoi, Toshihiko Shimizu, Nobuhiko Sarukura, Elmer S. Estacio, Arnel A. Salvador, Armando S. Somintac, ... See fewer authors

First published: 18 June 2020 | https://doi.org/10.1002/pssb.201900481

Surface Science 703 (2021) 121726

Contents lists available at ScienceDirect

ELSEVIER — Surface Science

journal homepage: www.elsevier.com/locate/susc

Density functional theory-based investigation of hydrogen adsorption on zinc oxide (10$\bar{1}$0) surface: Revisited

Manuel M. Balmeo[a], John Symon C. Dizon[a,*], Melvin John F. Empizo[b], Erick John Carlo D. Solibet[c], Verdad C. Agulto[b], Arnel A. Salvador[b,c], Nobuhiko Sarukura[b], Hiroshi Nakanishi[d], Hideaki Kasai[d], Allan Abraham B. Padama[a,*]

[a] Institute of Mathematical Sciences and Physics, College of Arts and Sciences, University of the Philippines Los Baños, College, Laguna 4031, Philippines
[b] Institute of Laser Engineering, Osaka University, 2-6 Yamadaoka, Suita, Osaka 565-0871, Japan
[c] National Institute of Physics, University of the Philippines Diliman, Diliman, Quezon City 1101, Philippines
[d] National Institute of Technology, Akashi College, 679-3 Nishioka, Uozumi, Akashi, Hyogo 674-8501, Japan

ongoing projects

We currently have three (3) ongoing projects:

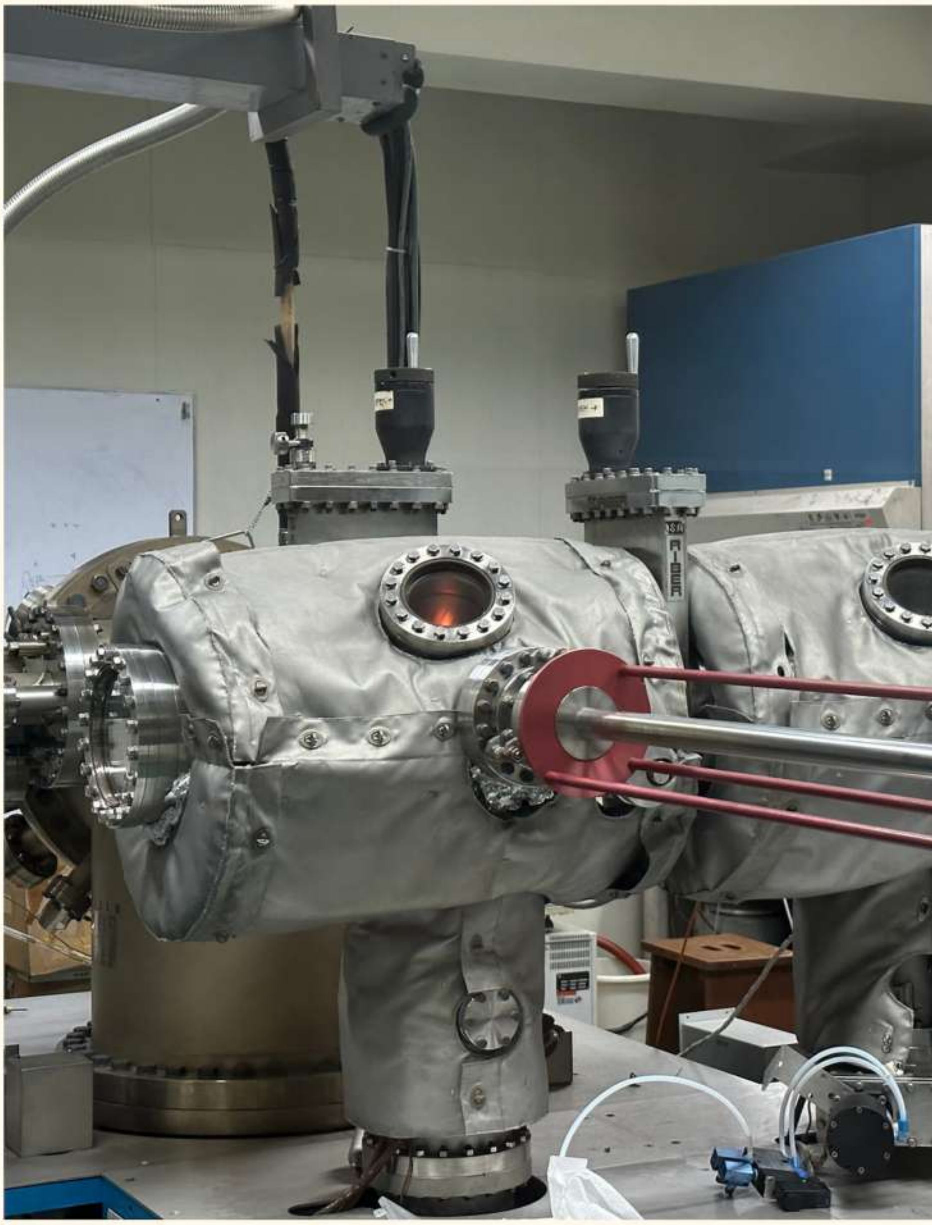
1. MBE Growth of InGaAs and Heterostrucutres Suited for Telecom-Wavelength Excited Terahertz Device Applications
2. Development of Low-cost, Fast-scan Terahertz Spectroscopy for Real World Applications
3. Chemical and Environment - Portable Sensors and Transducers: Phase 2 (CE-PoST2)

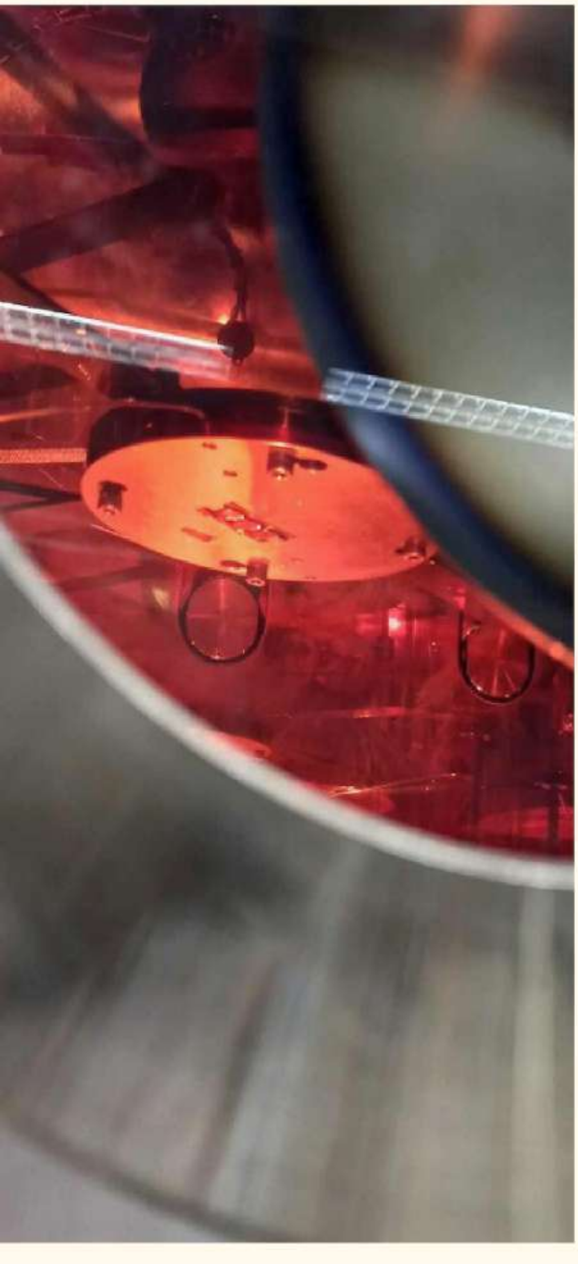
MBE Growth of InGaAs and Heterostrucutres Suited for Telecom-Wavelength Excited Terahertz Device Applications

Project Leader:
Dr. Arnel Salvador

Implementation Date
January 3, 2023 to
January 2, 2025

Funding Agency:
DOST-PCIEERD





Project Objectives

- **Design, MBE-growth, and characterization** of indium gallium arsenide (**InGaAs**), quantum dots (**QD**s), quantum wells (**QW**s), and high-electron mobility transistor (**HEMT**) semiconductor heterostructures

- **Device fabrication** of the MBE-grown InGaAs, QDs, QWs, and HEMTs as **THz emitters and detectors**

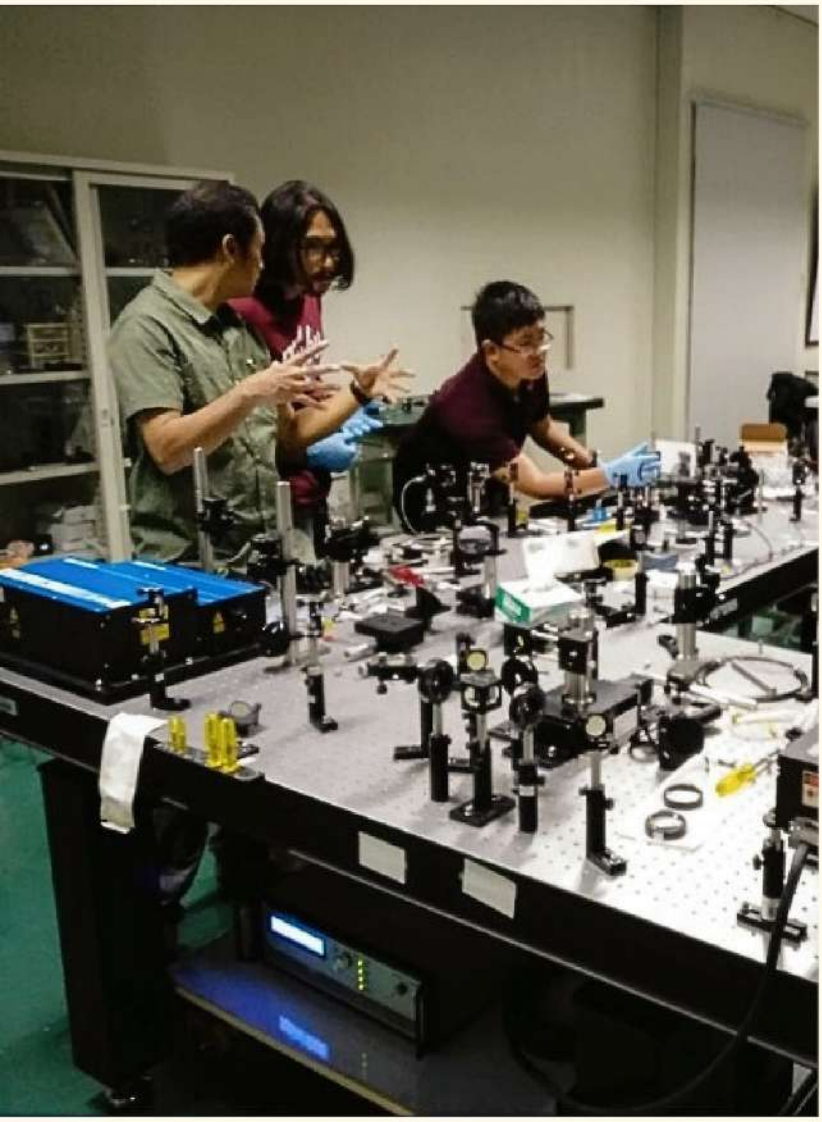
- **Ultrafast characterization** of fabricated THz devices via THz-TDS

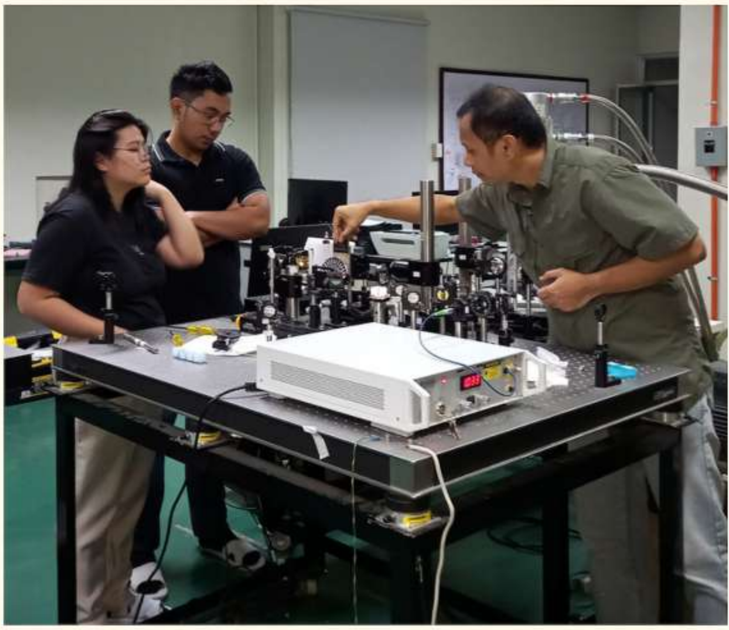
Development of Low-cost, Fast-scan Terahertz Spectroscopy for Real World Applications

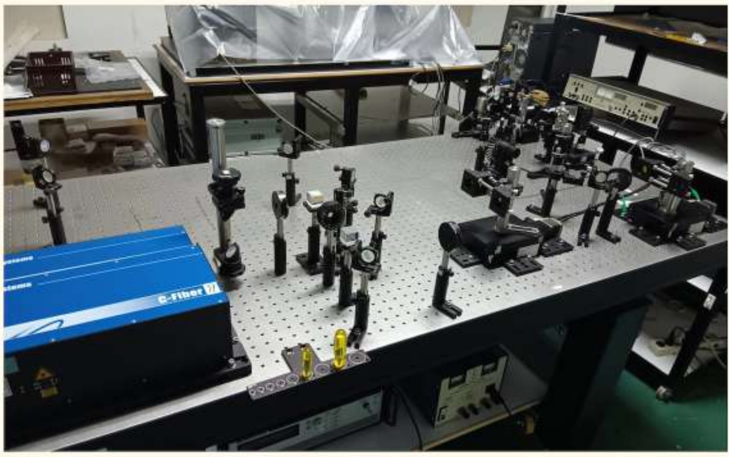
Project Leader:
Dr. Elmer Estacio

Implementation Date
January 3, 2023 to January 2, 2025

Funding Agency:
DOST-PCIEERD







Project Objectives

Develop a rapid scan terahertz time-domain spectroscopy system (**THz-TDS**)

Chemical and Environment - Portable Sensors and Transducers: Phase 2 (CE-PoST2)

Project Leader:
Dr. Arnel Salvador

Implementation Date
July 1, 2022 to June 30, 2024:

Funding Agency:
CHED LAKAS Program

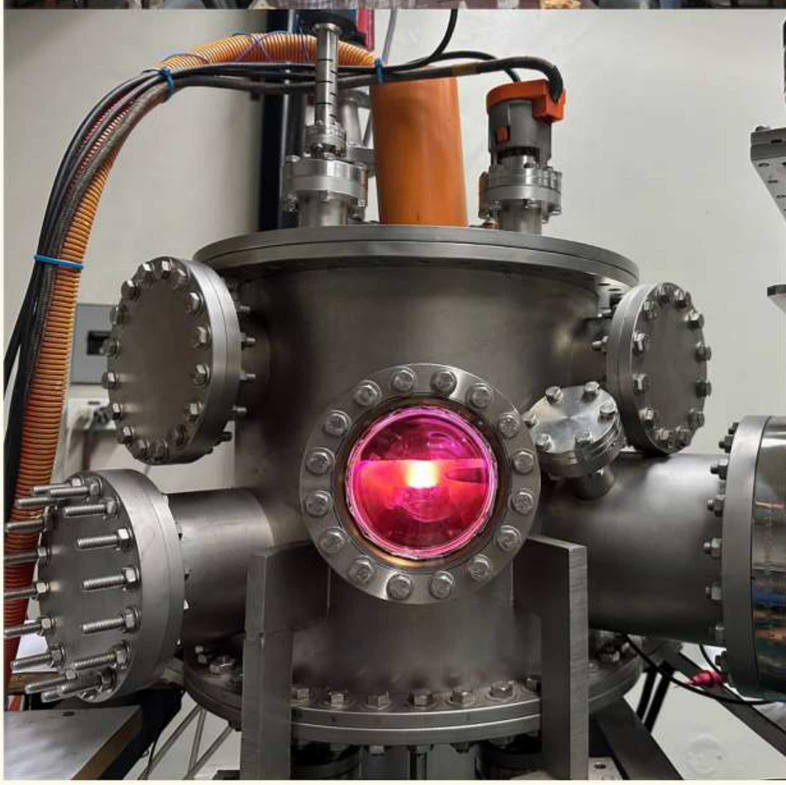
Project Objectives

Growth of AlN using magnetron sputtering system

Design and fabrication of piezoelectric micromachined ultrasonic transducer (**PMUT**) device using in-house facility

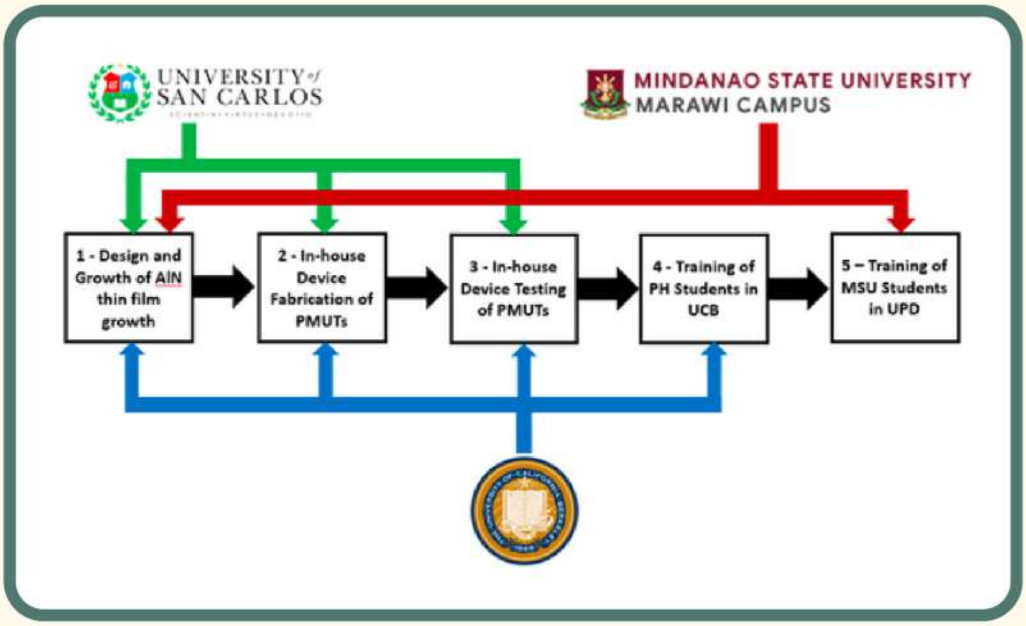
PMUT **device testing** and **characterization**


XRD Course Part-2 Beyond Powders, September 2023, Application Competence Center, Malvern Panalytical, Almelo, The Netherlands

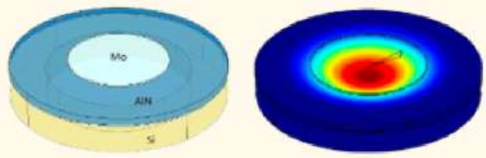


In this project, we are working with **Prof. Liwei Lin** of **Berkeley Sensor and Actuator Sensor (BSAC)** of the **University of California Berkeley**

We are also fostering cooperation with two universities in the Philippines: **Mindanao State University Marawi Campus** and **University of San Carlos**



We are also working on simulations of PMUT devices using COMSOL



simulation facility of University of San Carlos for PMUT design

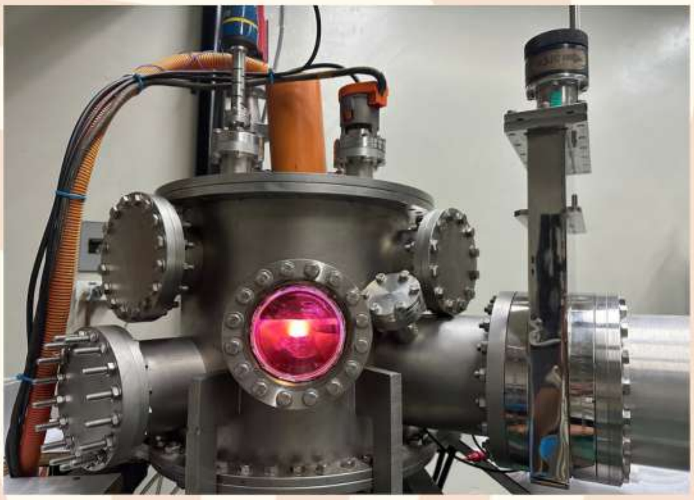
magnetron sputtering system of MSU Marawi and site visit of Diliman team

Cooperating local implementing agencies

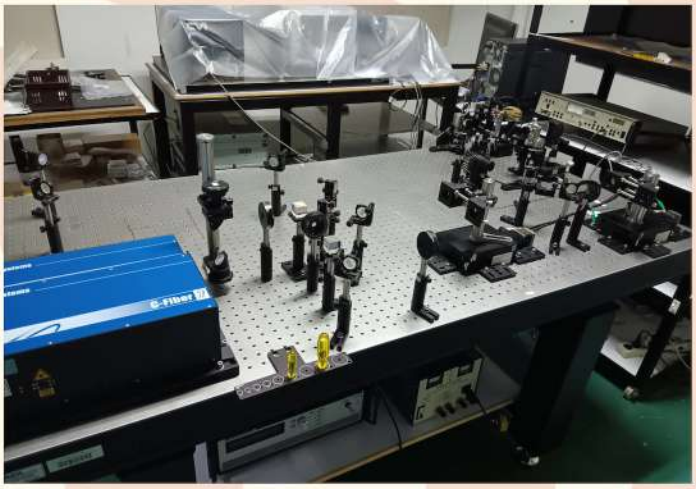
Our Capabilities

Device fabrication and characterization facilities in the CMPL-Semiconductor laboratory at the National Institute of Physics

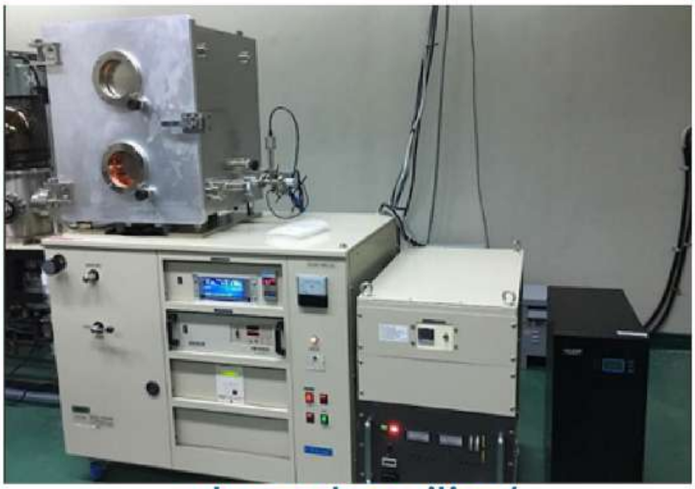
molecular beam epitaxy



magnetron sputtering



THz-TDS



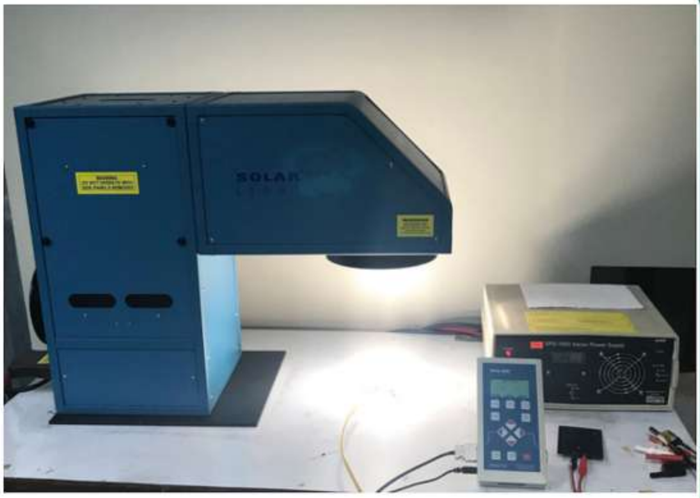
e-beam deposition/
thermal evaporator

probe station

X-ray diffractometer

Our Capabilities

Device fabrication and characterization facilities in the CMPL-Semiconductor laboratory at the National Institute of Physics

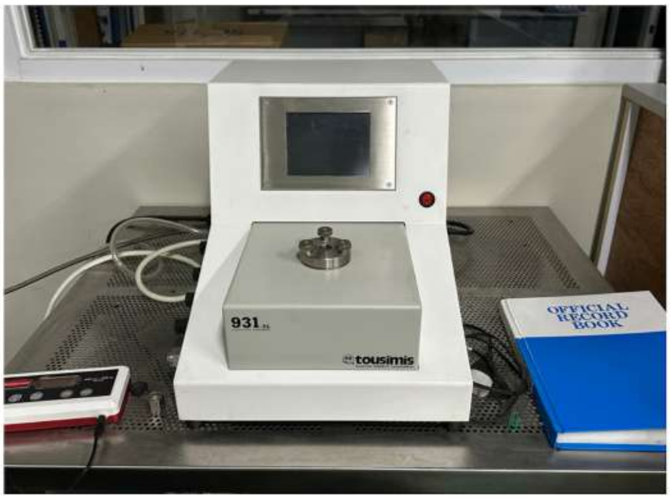


sun simulator

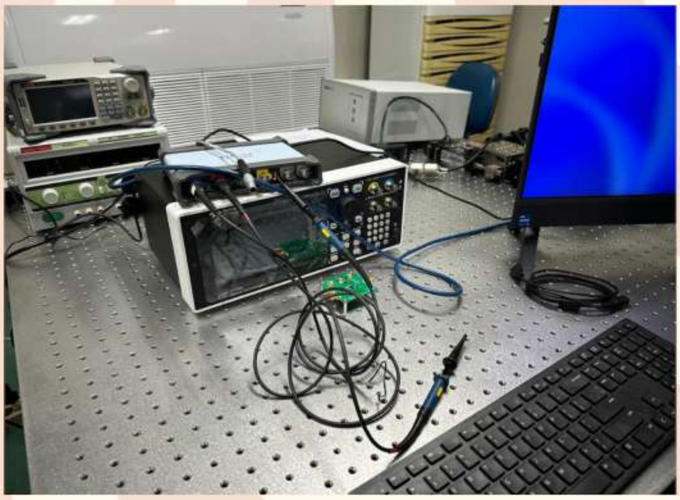
wire bonder

mask aligner

Raman spectroscopy



critial point dryer

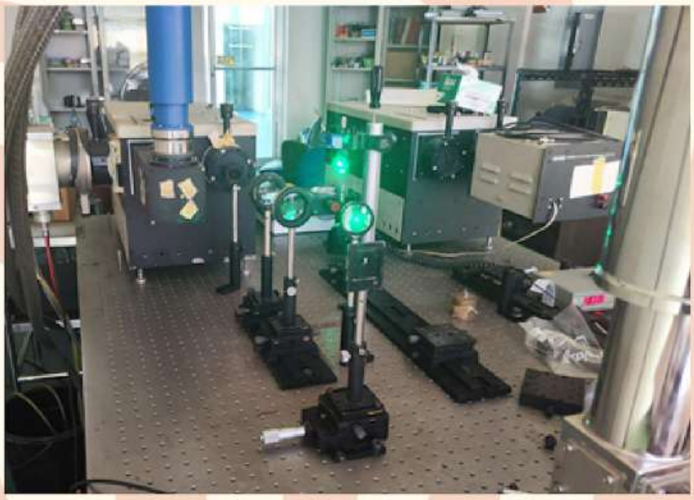


electronic characterization

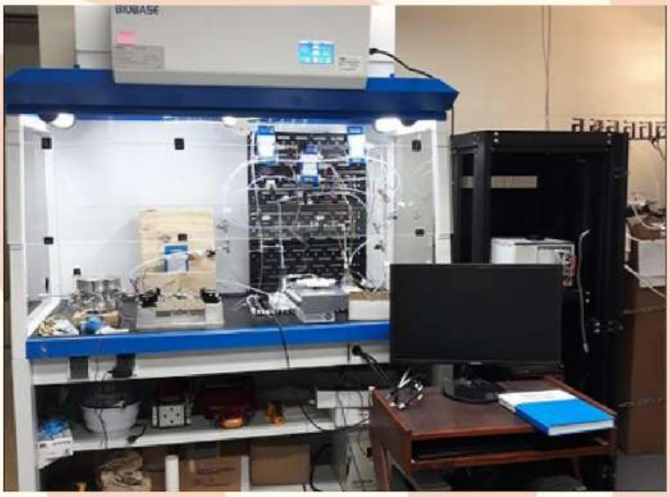
Our Capabilities

Device fabrication and characterization facilities in the CMPL-Semiconductor laboratory at the National Institute of Physics

inductively coupled plasma reactive ion etching



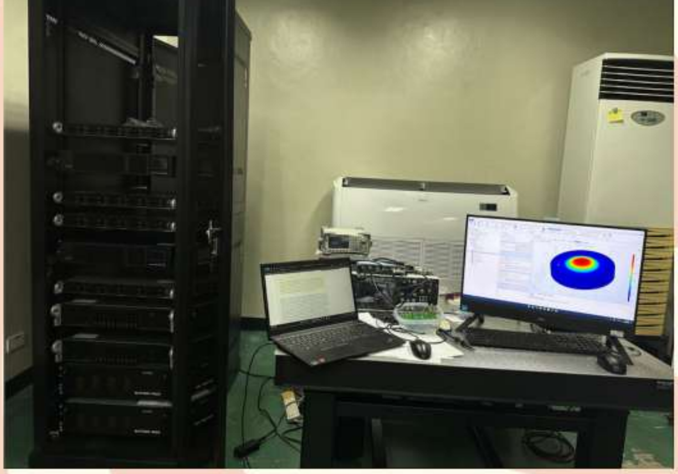
photoluminescence spectroscopy



gas sensing

wyko interferometer

rapid thermal annealing



COMSOL server

CMPL Semicon Group

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Dr. Gerald Angelo Catindig

Collaborators

Dr. Hannah Bardaloza

Dr. Cyril Salang

PhD graduates

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Ma. Herminia Balgos	Jessica Pauline Afalla	Karim Omambac

CMPL also acknowledges the contribution of its MS and BS graduates to the progress and achievements of the laboratory.