IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	Lasers based on two dimensional semiconductors	
Project Number	**IMURA0865**	
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IITB Department:	Physics	

Research Clusters:

Research Themes:

Highlight which of the Academy's CLUSTERS this project will address? *(Please nominate JUST **one.** For more information, see www.iitbmonash.org)*		**Highlight which of the Academy's Theme(s) this project will address?** *(Feel free to nominate more than one. For more information, see www.iitbmonash.org)*	
1	*Material Science/Engineering (including Nano, Metallurgy)*	***1***	*Advanced computational engineering, simulation and manufacture*
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*	2	*Infrastructure Engineering*
3	*Math, CFD, Modelling, Manufacturing*	3	*Clean Energy*
4	*CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control*	4	*Water*
5	*Earth Sciences and Civil Engineering (Geo, Water, Climate)*	5	***Nanotechnology***
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*	6	*Biotechnology and Stem Cell Research*
7	***Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng***	7	*Humanities and social sciences*
8	*HSS, Design, Management*	8	Design

The research problem

Define the problem

Nanoscale lasers are an important components for future computers based on integrated nanophotonic circuits. Most current semiconductor lasers consume about a pico joule of energy per bit; which is about a hundred times larger than required. This can be accomplished by miniaturizing the laser to nanoscale dimensions. This project focuses on fundamental research to develop such nanoscale light sources with high energy efficiency. This research will address the bottleneck of energy efficiency, particularly in the communication related domain where energy consumption is increasing at a rate faster than that of energy generation.

Two dimensional semiconductors have emerged as promising materials for the development of chipscale optical sources, owing to their large exciton binding energy and electrostatic tunability of their emission properties. These materials have also been shown to one of the best gain materials available for lasing. In this project, we will develop innovative approaches from a fundamental physical and engineering standpoints to develop efficient nanoscale laser sources by incorporating these 2D materials with optical resonators.

Project aims

Define the aims of the project

The project would involve four parts:

1) Fabrication photonic chips:

Top down approach: EBL here at IIT Bombay & Melbourne Center for Nanotechnology

2) 2D Materials / heterostructures

Via mechanical exfoliation of bulk crystal and CVD here at IIT Bombay

3) Optical characterization

The student will be involved in the development of a chip characterization setup being built here at IIT Bombay which will be used for the microlaser characterization. Part of the material characterization will be performed at Monash University.

4) Simulation and theory

FDTD (Lumerical) and FEM simulations (COMSOL) here at IIT Bombay

The main objectives of this proposal are:

1) Design and fabricate micro and nanoscale mie resonator cavities
2) Integrate 2D semiconductors (TMD) reproducibly with these nanocavities
3) Develop a new technique for coupling out the emission from the TMD/cavity system
4) Characterize the resulting emission as a function of various parameters to optimize a low power high efficiency nanolaser source at the visible wavelength.

Expected outcomes

Highlight the expected outcomes of the project

1) Publications in high impact journals: Since this work has many elements of novelty involved, it is possible to publish the results in prestigious journals as well as conferences
2) Develop a fundamental understanding of the channeling of emission from 2D semiconductors into a nanocavity optical mode.
3) Develop technical expertise in nano-optical characterization and functionalization of photonic integrated circuits

4) Possible identification of other relevant research problems which can be solved by the synergy of the capabilities of IITB and Monash University.

How will the project address the Goals of the above Themes?

Describe how the project will address the goals of one or more of the 6 Themes listed above.

Nanotechnology:
The project will involve building of optical devices using 2D semiconductors, whose thickness is below a nanometer. We will integrate these nanomaterials with cavities of nanoscale dimension, to build optical sources which will have direct relevance to future chipscale information processing and light storage technologies.

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

Capabilities: Through project or coursework

1) Basic solid state Physics theory (proficient)
2) Optics or basic electrodynamics - theory and experiment (medium)
3) Micro and nanofabrication (some exposure)

Qualifying degrees:

1) MSc. Physics
2) B.E./B.Tech./M.Tech. in Engineering Physics, Chemistry, Electrical Engineering or Materials Science

Strong plus:

1) Some cleanroom experience
2) Exposure to basic optical characterization (microscope / Raman / PL, etc)
3) Exposure to Data analysis in MATLAB or Python

Potential Collaborators

Please visit the IITB website www.iitb.ac.in OR Monash Website www.monash.edu to highlight some potential collaborators that would be best suited for the area of research you are intending to float.

Select up to **(4)** keywords from the Academy's approved keyword list **(available at http://www.iitbmonash.org/becoming-a-research-supervisor/)** relating to this project to make it easier for the students to apply.

Novel Functional Materials, Photonics, Nanotechnology