IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Understanding the Critical Role of Quantum Mechanical Effects in Nanoscale Semiconductor Electronic and Optoelectronic Devices

Project number: IMURA0080

Monash University supervisors: Dr Malin Premaratne
Monash University contact: malin@eng.monash.edu.au

IITB supervisors: Prof. V. Ramgopal Rao
IITB contact: rrao@ee.iitb.ac.in

Research Academy theme/s

List only the research academy theme/s that is relevant to the project

1. Advanced computational engineering, simulation and manufacture
2. Nanotechnology

The research problem

Moore's law summarizes the economies of scale in getting the same function by making a device smaller. Even though this law has been valid for the last four decades, due to fundamental limitations, such aggressive scaling may not be sustainable in future because, with the miniaturization to nanoscales, the relevant physical laws change from semiclassical to quantum mechanical. Thus, we are reaching an era where the range and accepted functional behaviour derived from common device models is no longer valid. These dramatic changes can be qualitatively understood by noting that the reduction of physical size of a device very close to atomic scales, the wave nature of electronics cannot be neglected as the de Broglie wavelength (i.e. a characteristic length related to the wave nature of the particle) of an electron in a semiconductors is of the same length scale as the device itself. The relevant physical laws change from semi-classical to quantum-mechanical in such devices. Thus, very successful semi-classical descriptions of quantum-mechanical devices tend to become invalid and previously ignored quantum mechanical effects such as space quantization, nonuniform distribution of impurity atoms, quantum ballistic transport and quantum-mechanical tunnelling tend to become significant.

Project aims

This project will investigate the modelling and numerical simulation of such fundamental physical effects in nanoscale devices using state of the supercomputing platforms.

Expected outcomes

Having a greater understanding and knowledge of such quantum mechanical effects will enable us to design new devices that have far superior performances to conventional technologies and, in some cases, allow access to entirely new phenomena only available in nanoscales.