Precision Metrology at the Nanoscale.

Lectures by: Dr Gopalakrishnan Balasubramanian,

Max-Planck Institute for Biophysical Chemistry, Göttingen, Germany.

Abstract: Understanding physical quantities at the nanoscale is a frontier research topic that has profound and broad impact covering fundamental physics to emerging technologies. It should be noted that in these scales the materials exhibit the quantum nature. Hence a quantum sensor is required to effectively harness these quantum effects for sensing and precision measurements.

In these lectures, I will introduce basics of atomic physics, spectroscopy and spin resonance, essential quantum principles and then fundamentals of metrology with examples. We would see in details quantum sensors and systems like Superconducting quantum interference device (SQUID), Single-electron transistors (SET), Optomechanics, Atomic vapours, Trapped ions and Nitrogen-Vacancy defects in diamond. We would subsequently look at magnetic sensing or precision magnetometry in detail and analyse various state-of-the-art methods, their principles and applications.

Following this, we will discuss in great detail, about the spins associated with Nitrogen-Vacancy (NV) centres in diamond. This quantum sensor has unique advantages for precision measurement of magnetic field, electric field, temperature and strain. After discussing several benchmarking applications, I will introduce the need for sensing single biomolecules and the prospects of an NV spin magnetometer for developing such a microscope to probe molecular structure and dynamics. I will also present some developments and challenges in NV based precision sensing and imaging of magnetic and electric fields. The lectures will include also topics such as Nanoscale magnetic sensing, Spin noise spectroscopy, Holonomic quantum control and Nanoscale NMR/MRI.