ME Seminar

MECHANICAL ENGINEERING
INDIAN INSTITUTE OF SCIENCE

Energy efficient Classical, Neuromorphic and Quantum Computing with spins and nanomagnets driven by strain, acoustic waves and voltages

Jayasimha Atulasimha, MNE & ECE, Virginia Commonwealth University

ABSTRACT

Giant magnetoresistance (GMR) and Spin Transfer Torque (STT) are the basis of non-volatile (stores information when powered off) memory known as STTRAM. However, even state-of-the-art extremely scaled magnetic memory devices 10 nm diameter takes 1000 times more energy to switch compared to today's CMOS devices. This motivates our group's research on electrical field control of magnetization in nanoscale magnets that will be discussed: (1) Strain mediated control: voltage-induced strain [1] and acoustic wave switching of the magnetization of nanomagnets (2) Direct voltage control of magnetic anisotropy (VCMA) to manipulate topological state of magnetic skyrmions [2]. In particular, dynamic effects could be key to implementation of energy efficient memory [2], neuromorphic computing devices [3] that are amenable to implement in edge/IoT devices.

On the other hand, we proposed a new technique for addressing spin qubits using voltage-control of nanoscale magnetism that will be discussed. By tuning the frequency of the nanomagnet's electric field drive to the Larmor frequency of the spins confined to a nanoscale volume, and by modulating the phase of the drive, single-qubit quantum gates with fidelities approaching those of fault-tolerant quantum computing can be implemented [4].

Finally, we will discuss two key future directions using quantum technologies: (a) Leveraging quantum effects for extreme scaling of classical computing devices comprising of a few 10s of spin in lateral dimensions 1 nm while being robust at room temperature. (b) Quantum computing based on robust spin ensembles operated at few Kelvin that can be addressed, read out and potentially entangled in a scalable manner.

[1] *Nano Letters*, 16, 1069, 2016; [2] *Nature Electronics* 3, 539, 2020; [3] https://arxiv.org/abs/2112.13527 [4] https://arxiv.org/abs/2203.16720 conditionally accepted, *Communication Physics*.

ABOUT THE SPEAKER

Jayasimha Atulasimha is a Qimonda Professor of Mechanical and Nuclear Engineering with a courtesy appointment in Electrical and Computer Engineering at the Virginia Commonwealth University. His current research interests include nanomagnetism, spintronics, nanomagnetic memory, neuromorphic computing and quantum computing devices. He is a fellow of the ASME, an IEEE Senior Member and past chair for the TC on Spintronics, IEEE Nanotechnology Council.

August 5, 2022, 4:00 pm, A R Auditorium, ME@IISc