Institute Colloquium

S. N. Bose National Centre for Basic Sciences
(An Autonomous Research Institute established under DST, GOI)

8th November, 2024	4.00 PM	At Silver Jubilee Hall	Webinar Link	YouTube Link

Nanoscale magnetic devices for Energy efficient computing and scalable quantum control

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The energy needs of Google alone in 2019 exceeded that of a country with population of about 20 million [1] and this energy need for computing in our society is growing exponentially! This necessitates finding energy efficient approaches to make our computing needs sustainable. Moreover, in IoT and edge AI devices, both power and hardware resources are at a premium.

Towards this end, our group explores energy efficient approaches based on strain mediated [2] or direct electrical field control [3] of nanoscale magnetism. One such approach, can potentially implement energy efficient non-volatile memory [3, 4] that are robust to switching errors in the presence of thermal noise, while scaling to lateral dimensions of 20 nm and below [4].

Nanoscale magnetic devices also hold promise in enabling energy efficient AI hardware. We have shown that multi-state nanomagnetic devices can be used as highly quantized synapses in deep neural networks [5] and convolutional neural networks [5] with increased energy efficiency. Additionally, dynamics of confined skyrmions in patterned dots can also be used for reservoir computing for long-term prediction of temporal data [6].

In quantum computing, one significant problem is implementing qubits in a scalable manner. We show this can be addressed by driving the magnetization of nanomagnets electrically, generating highly confined microwaves at the Larmor precession frequency of proximally located spins. This can implement single-qubit quantum gates with fidelities approaching state-of-the-art in a scalable manner[7,8]. New experimental [9] and simulation results in these directions will be discussed.

References:

[1] FORBES EDITORS' PICK, Oct 21, 2020,04:26pm EDT
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[5] *IEEE Access*, 10, 84946, 2022; *IEEE Transactions on Neural Networks and Learning Systems* (early access), 2024, 10.1109/TNNLS.2024.3369969
[6] Neuromorph. Comput. Eng. 2 044011; IEEE Access, 11,124725, 2023
[7] *Communication Physics* 5, 284, 2022.
[8] https://arxiv.org/abs/2401.00573
[9] https://arxiv.org/abs/2407.14018

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