NANOSCIENCE COLLOQUIUM

Multi-modal materials, spin glasses and brain-inspired computing with spins

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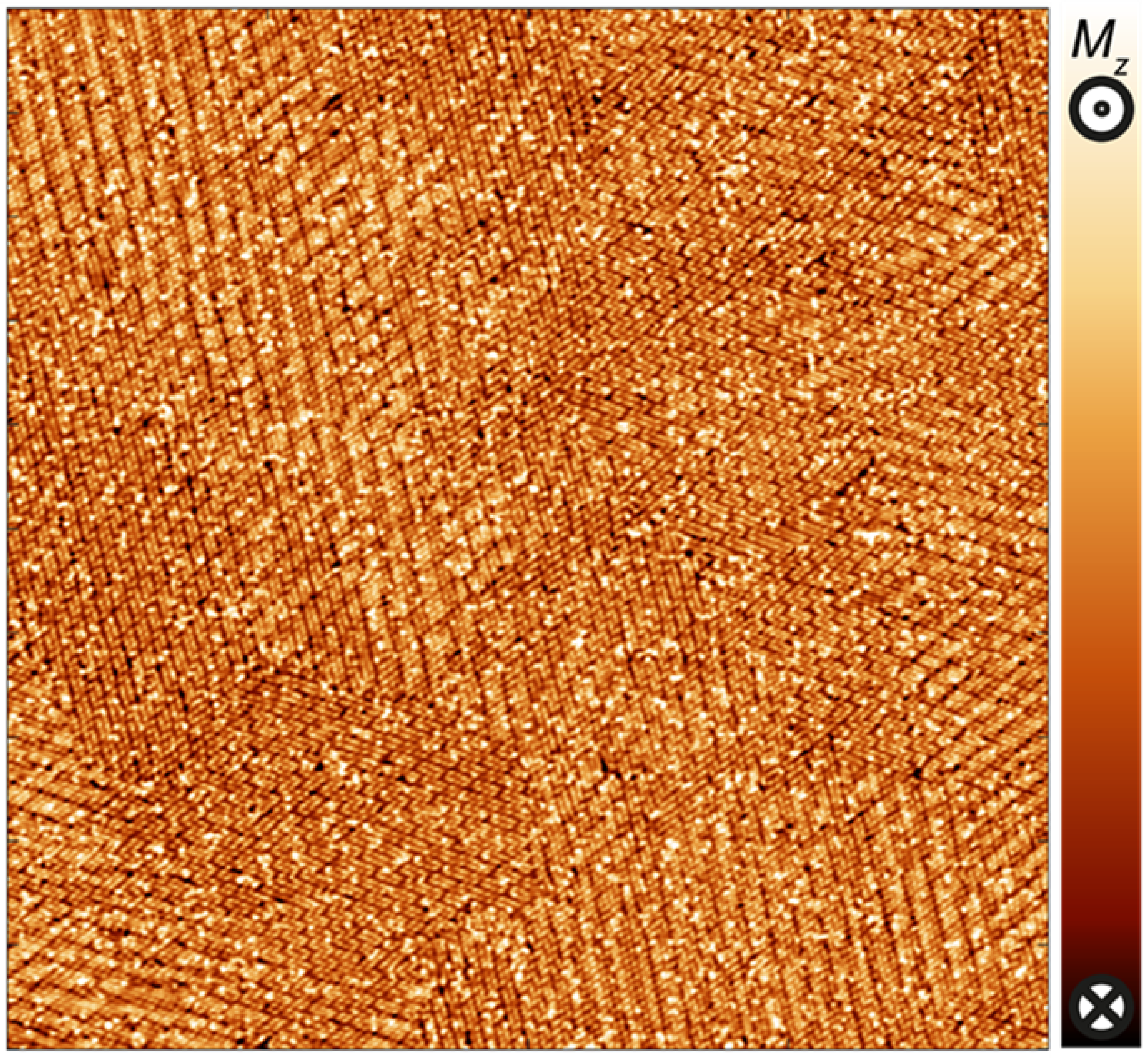
ABSTRACT: The ever increasing demands on AI-based computing is leading to a significant demand on the global energy consumption. This has created a high demand for new materials-based solutions for computing where the focus is no longer about “smaller and faster” but rather computing with more efficiency. One route toward this end draws inspiration from the efficiency of the brain, where hardware is being created that mimics computational models from theoretical neuroscience. There is a deep link between theoretical neuroscience and concepts in statistical physics, such as the theory of spin glasses, as evidenced by the Nobel prize winning work of Hopfield and Hinton. In this talk, I will first review the links between the physics of interacting spin systems and brain-inspired computing. I will then discuss two recent material developments that exhibit behavior related to these two models: (1) the complex magnetism of elemental neodymium, and (2) the stochastic dynamics of coupled magnetic atoms on semiconducting black phosphorus. Focusing primarily on experimental results based on scanning tunneling microscopy, I will illustrate how elemental neodymium is a realization of a new type of spin glass called a self-induced spin glass. I will discuss its energy landscape and dynamics, and its analogy to glasses. I will then show a bottom-up system, where we demonstrated that we can mimic the iconic Boltzmann machine. These developments are based on a new type of atomic magnetic memory, which can lead to complex stochastic behavior. I will conclude my talk with an outlook toward future perspectives and linking this work to other fields in material science.

Figure 1: Spin-polarized STM image of elemental neodymium (Nd(0001)), in its self-induced spin glass state and various patterns that emerge locally.



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02 Dec 2025 1:15 pm | Bd.600 R.301 CHyN

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