Tailoring magnetic states of matter atom-by-atom

Some of the most fascinating and perplexing physical phenomena in materials, such as complex magnetic order and superconductivity, are based on the collective nature of quantum particles. To this end, understanding and ultimately tailoring “quantum matter” necessitates a fundamental understanding of the interplay of the charge, spin, and orbital degrees of freedom. Experimental techniques which can access individual spins at the level of single atoms and the ability to manipulate their interactions with their environment are in demand. I will review the exciting developments, in which spin-resolved scanning tunneling microscopy (STM) can be utilized toward magnetic imaging at the single atom level and combined with bottom-up fabrication of atomic magnets toward what we coin “magnetic LEGOs.” I will exemplify the behavior of individual magnetic atoms coupled to metallic systems, and the resultant excitations of such systems. Moreover, I will show how individual atoms can be coupled to realize non-collinear magnets and novel quantum states of matter.