TECHNISCHE UNIVERSITÄT WIEN

INSTITUT FÜR FESTKÖRPERPHYSIK
Institute of Solid State Physics

Wiedner Hauptstr. 8–10/138, 1040 Wien
https://www.tuwien.at/phy/ifp

INVITATION to IFP-SEMINAR

From Storage to Spin Qubits in Single Adatoms

Harald Brune

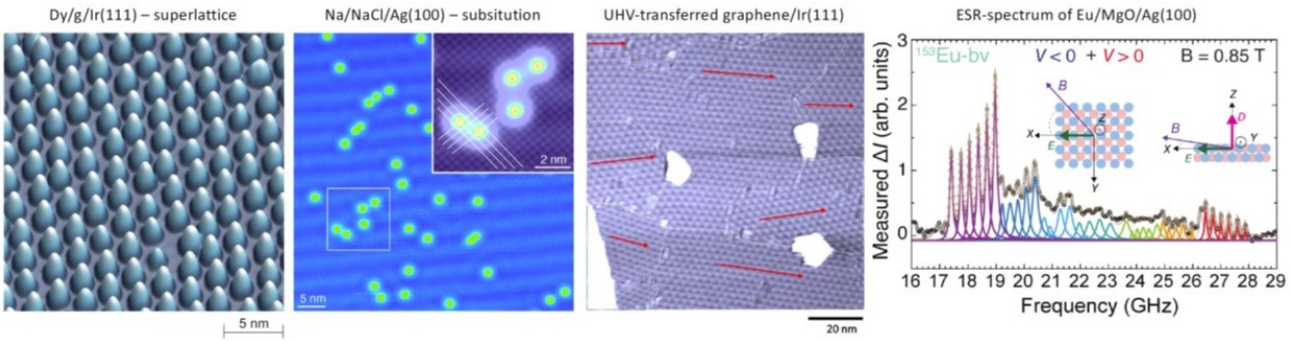
Institute of Physics, École Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne

Host: Neven Barišić
Date: 07.07.2026, 15:30
Place: TU Wien, Freihaus Building
Wiedner Hauptstraße 8-10, 1040 Wien
Seminar Room DC red 07 (red section, 7. OG)
Zoom: https://tuwien.zoom.us/j/67457258854?pwd=ftABPAnIs6BBArlFLd7XRrfL3b6WbA.1

Abstract:

The ultimate size limit of a magnetic memory is a single atom. Richard Feynman expressed the vision that mankind might one day be able to store information in the smallest unit of matter. In 2016 we presented two systems where the magnetic quantum states of individual surface-adsorbed atoms are stable [1,2]. We describe the physics underlying magnetic bistability in quantum systems and summarize the systems known today where magnetic information storage in single atoms is possible [3–7].

To chemically protect these atoms, we developed a method for transferring one monolayer of graphene onto entire 7 mm diameter single-crystal surfaces under ultra-high-vacuum conditions [8]. This effectively seals the surface and, moreover, allows the growth of magnetic nanostructures into the third dimension. One example is the creation of pillars of single-atom magnets. A promising system consists of Dy atoms on MgO(100), which have a magnetic anisotropy energy of $K = 250$ meV [3]. Stacking four or five such atoms, vertically separated by graphene or h-BN layers and coupled ferromagnetically along their axes, is expected to give rise to systems that can potentially exhibit stable magnetization up to room temperature while retaining the lateral size of a single atom.



We conclude by describing our efforts to identify single atoms with long-lived magnetic superposition states that could serve as single-atom magnetic qubits. Encouraged by lanthanide atoms in bulk insulators, which exhibit exceptionally long coherence times [9], we performed electron spin resonance (ESR) measurements on single lanthanide atoms adsorbed on surfaces [10]. ESR-STM contrast re-

quires spin-polarized valence electrons, which we obtain by stabilizing a monovalent $6s^1$ state of the lanthanide adatoms Sm and Eu. This enables access to the $4f$ electronic and nuclear states. However, it also renders the magnetic quantum states more susceptible to electron and phonon scattering, presently limiting the coherence time to $T_2 < 1\ \mu$s.

[1] R. Baltic *et al.*, *Nano Letters* **16**, 7610 (2016).

[2] F. Donati *et al.*, *Science* **352**, 318 (2016).

[3] A. Singha *et al.*, *Nature Communications* **12**, 4179 (2021).

[4] V. Bellini *et al.*, *Nano Letters* **21**, 8266 (2021).

[5] B. V. Sorokin *et al.*, *Advanced Functional Materials* **33**, 2213951 (2023).

[6] M. Pivetta *et al.*, *Physical Review Letters* **136**, 086203 (2026).

[7] L. Persichetti *et al.*, *Journal of the American Chemical Society*, submitted (2026).

[8] D. Merk *et al.*, *Journal of Physical Chemistry C* **129**, 7868 (2025).

[9] M. Zhong *et al.*, *Nature* **517**, 177 (2015).

[10] G. Czap *et al.*, *ACS Nano* **19**, 3705 (2025).

Supported by: FWF Österreichischer Wissenschaftsfonds

Q-M&S. Correlated Quantum Materials & Solid State Quantum Systems