

Nanoscale Magnetism and Transport in CNMS



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Central Issues in Nanomagnetism

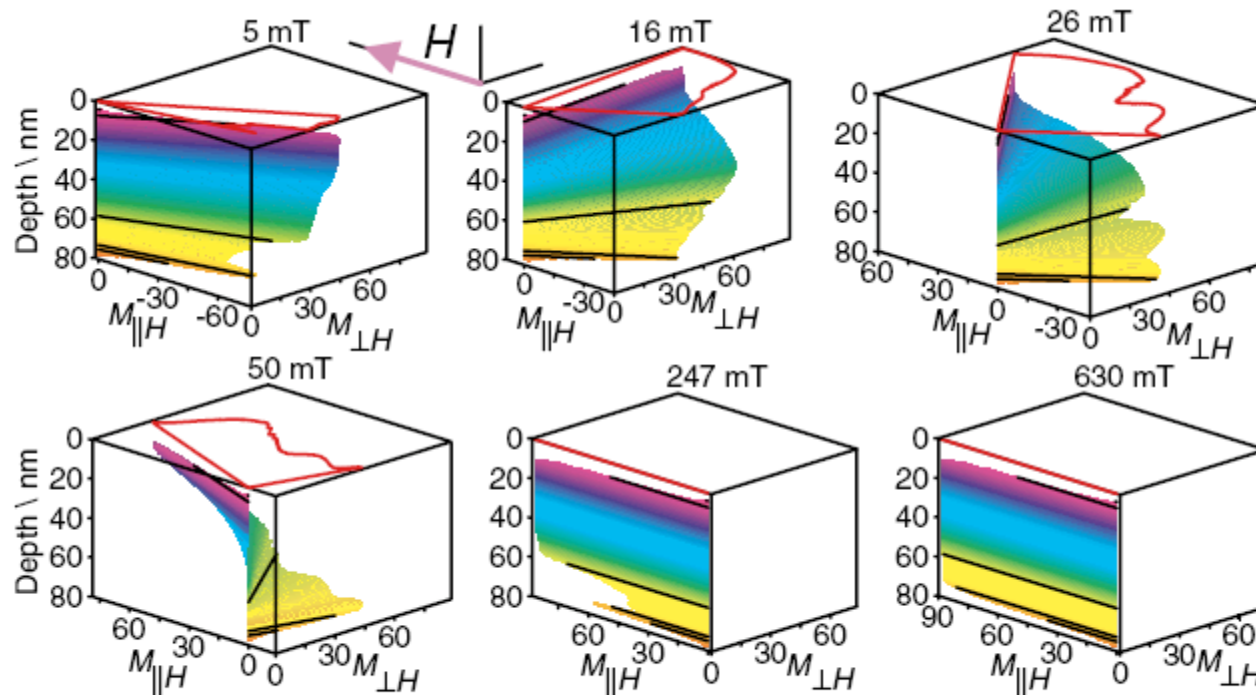


- Effect of dimensionality on spin structure, dynamics, etc.
- The role of interaction in nanostructure assemblies
- The mechanism and the speed of reversal (coherent rotation or domain wall motion)
- Current-driven spin switching
- Heterostructure physics – interfacial problems
- Nanophase separations in bulk materials (Manganites, DMS)
- Inhomogeneous mixtures of nano-objects and bulk materials

Neutron Applications in Nanomagnetism



- Magnetic structures and ordering of nanostructures
- Phase separation and/or correlations, including magnetically / electronically inhomogeneous bulk materials
- Vector Magnetization depth profiling of films & multilayers
- Correlation between chemical and magnetic roughness
- Finite size effects on magnetic excitations of nanostructures



**PNR on
exchange
spring
magnets**

K.V. O'Donovan
et al., PRL (02)

What can CNMS do for neutron users?



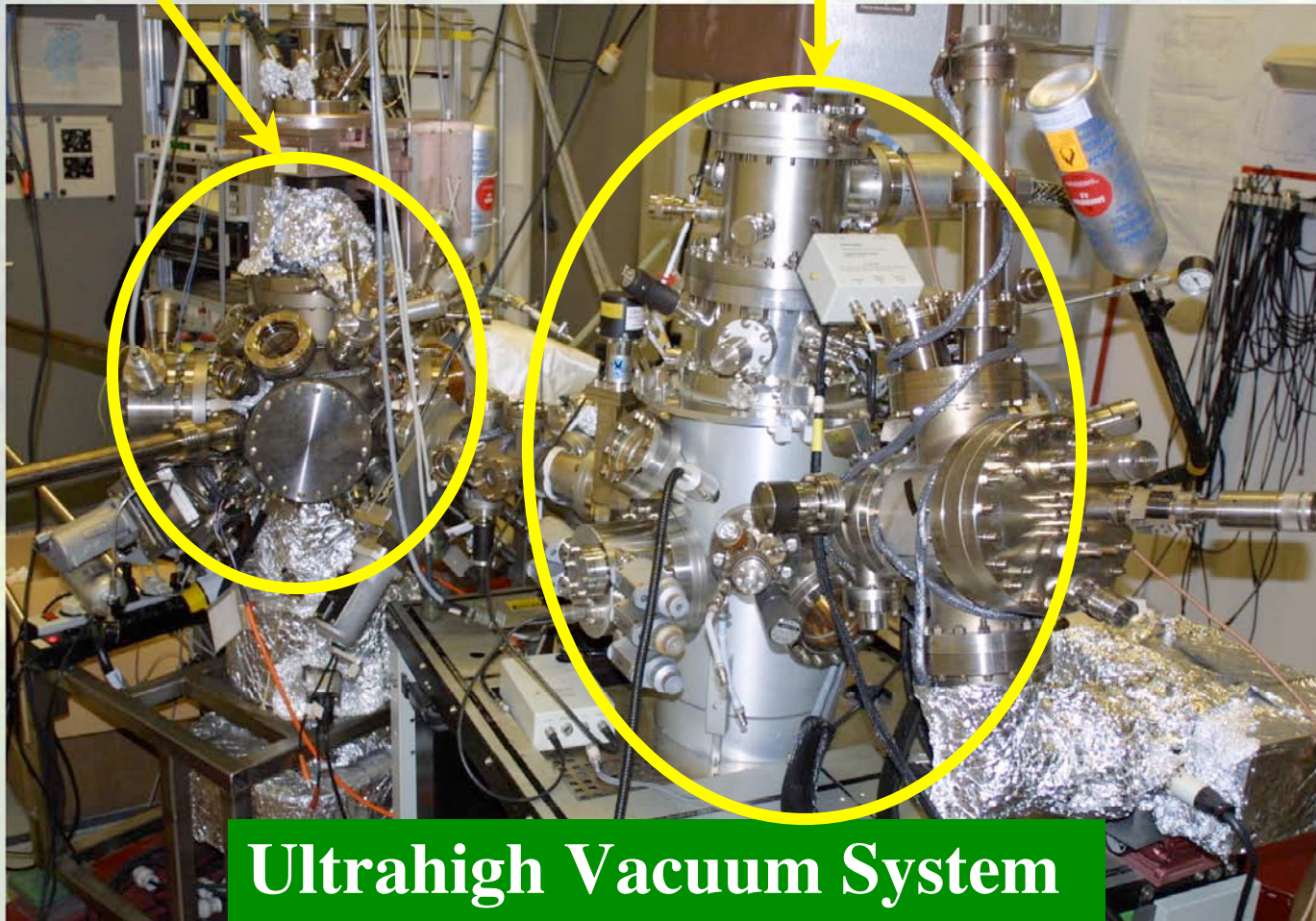
**Novel
Synthesis**

**Advanced
Characterization**

**Theory &
Modeling**

**Novel
Synthesis of
Nanostructures**

**In-situ Structure, Chemical,
Magnetic and Transport
Characterization**

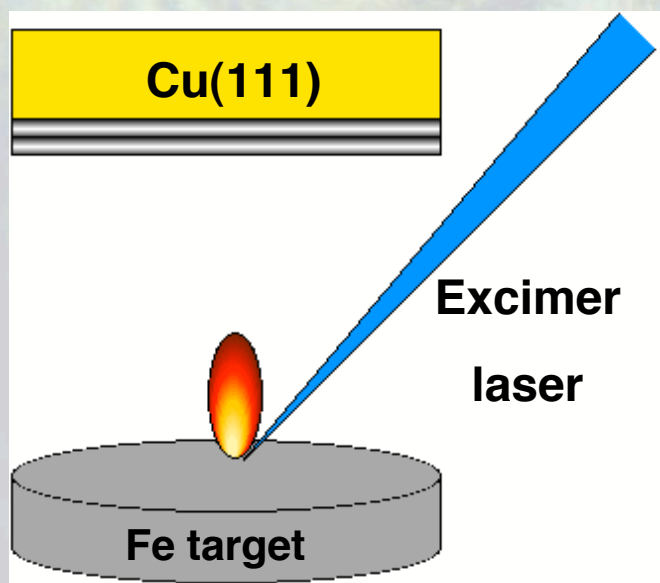


Ultrahigh Vacuum System

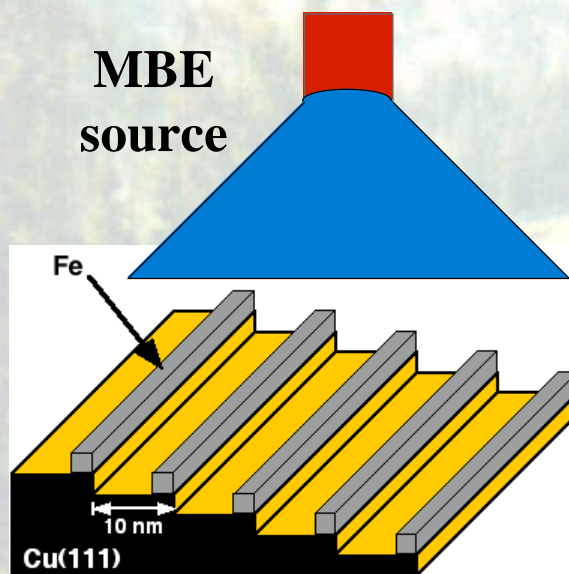
Novel Growth of Artificial Nanostructures



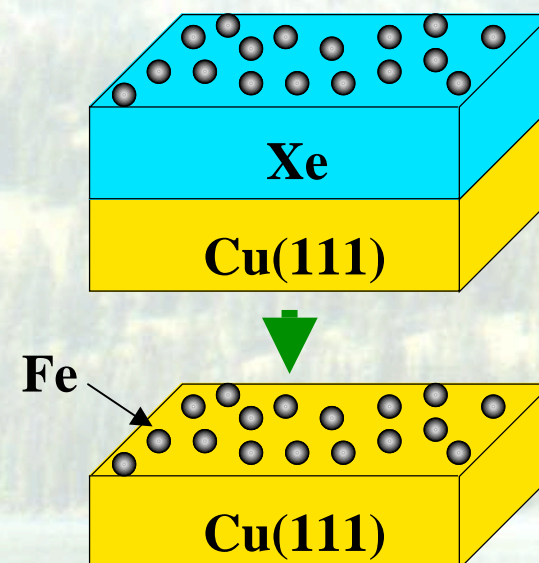
Thin Films by laser MBE



Nanowires by Step decoration



Nanodots by BLAG



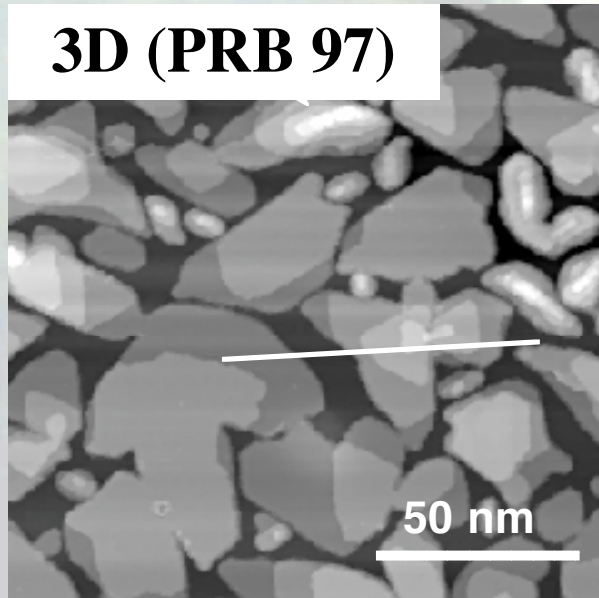
- Metals & alloys
- Complex Oxides
- FM semiconductors

- Nonequilibrium growth
- Epitaxy

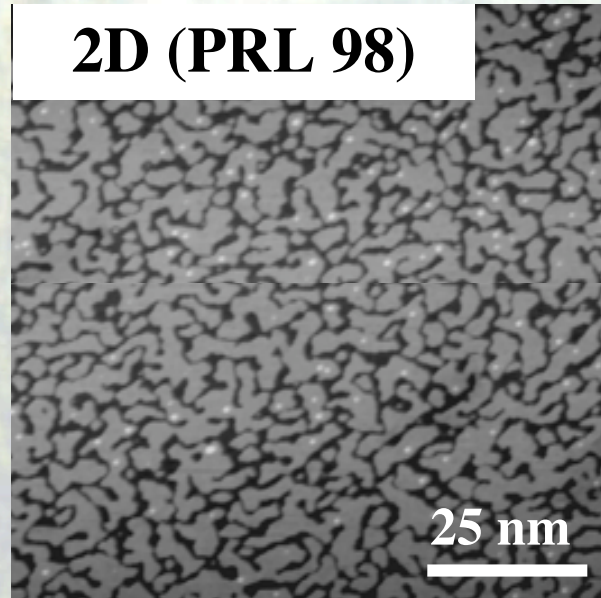
Controlled Growth of Magnetic Nanostructures: Fe on Cu(111)



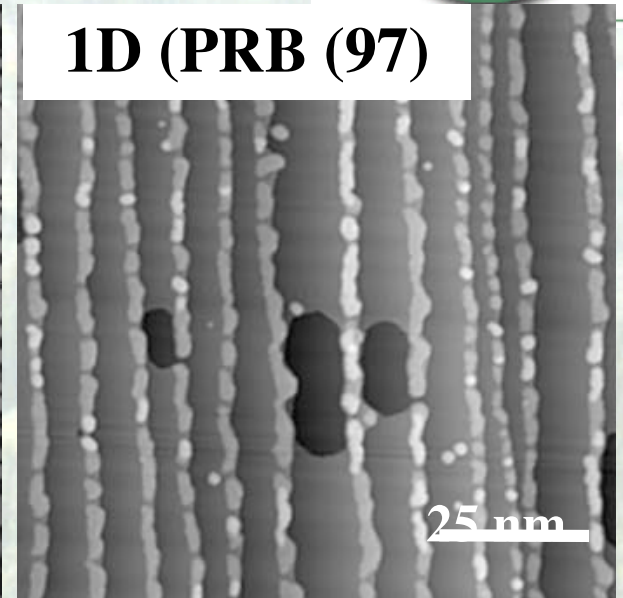
3D (PRB 97)



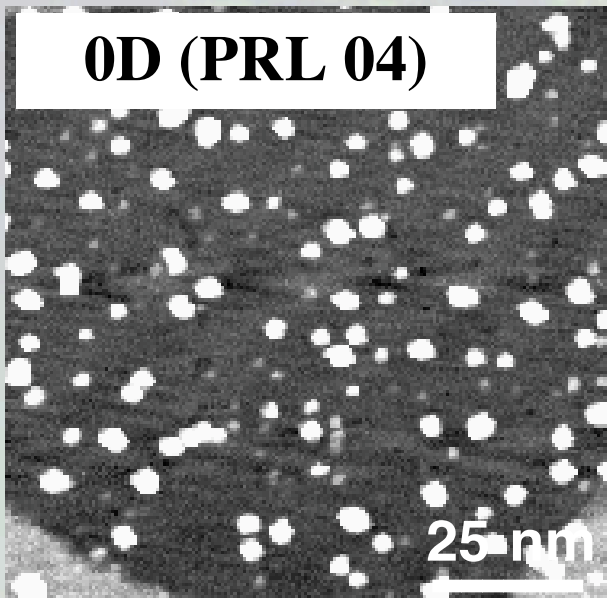
2D (PRL 98)



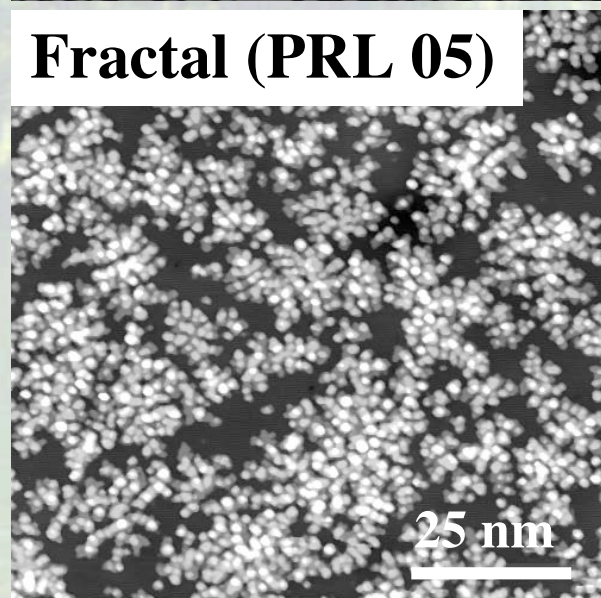
1D (PRB (97))



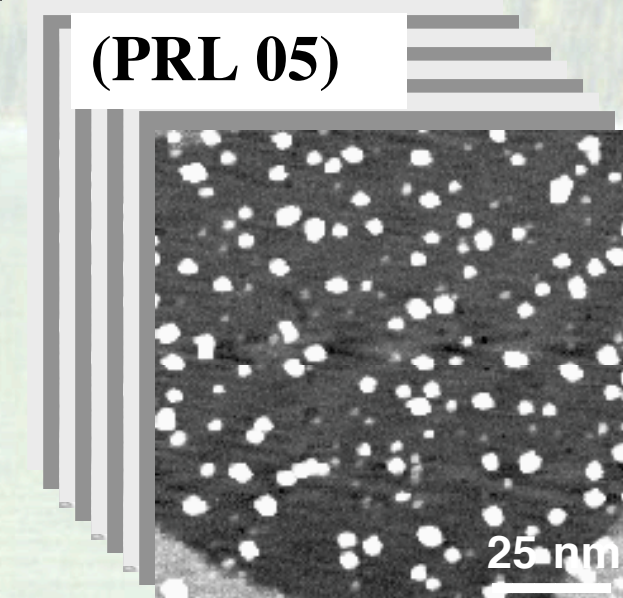
0D (PRL 04)



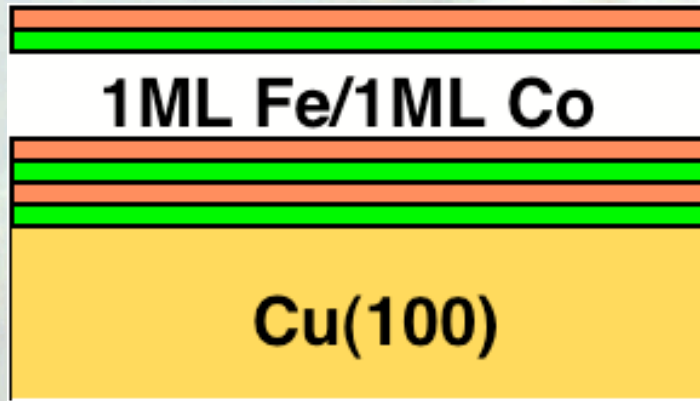
Fractal (PRL 05)



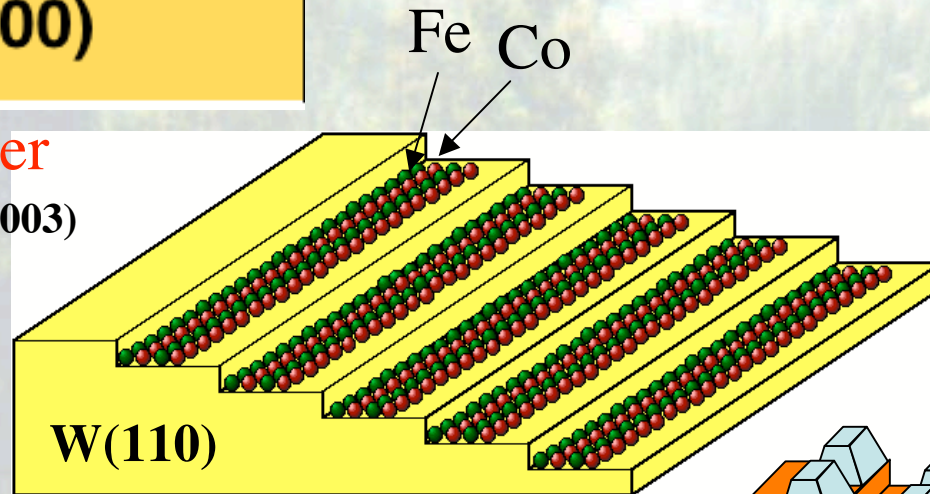
(PRL 05)



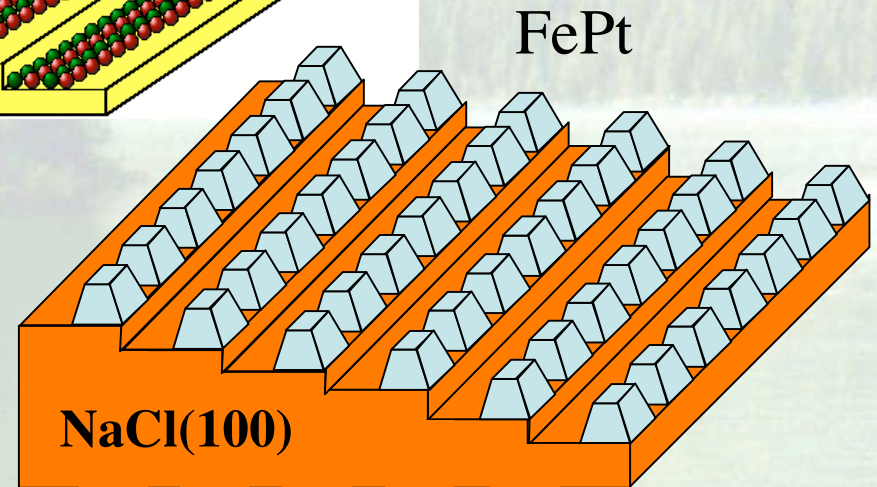
Magnetic Nanostructures by Design



Layer-by-layer
PRL 91, 226106 (2003)



Stripe-by-stripe
APL 81, 1890 (2002)



Dot-by-dot PRL 89, 235502 (2002)

Unique (In-situ) Growth and Characterization Capabilities



- **In-Field SEMPA System**

- MBE + Vector imaging of magnetic domains (in field ~ 0.3 T)

- **Nanotransport System**

- Laser MBE for metal and oxides multilayers

- **Low-temperature Four-tip STM System**

- MBE + Quantum transport

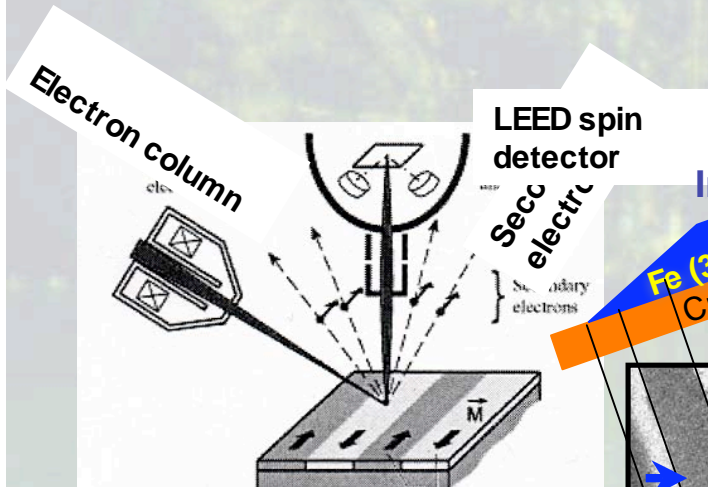
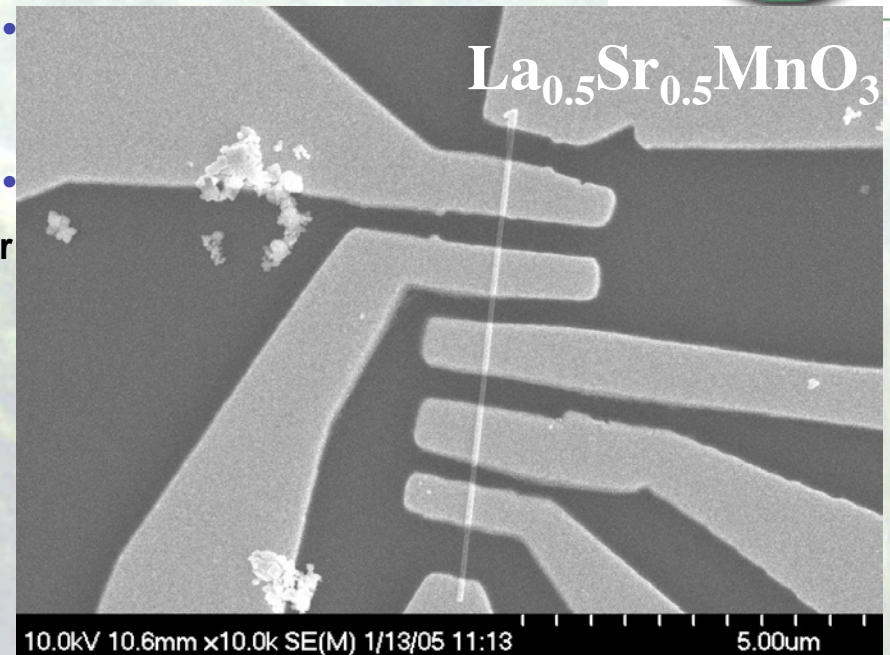
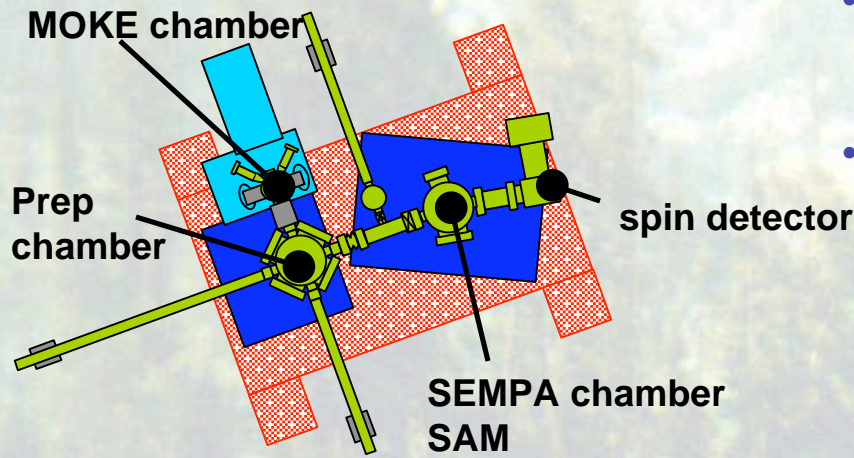
- **High-field, Low-temperature STM System**

- MBE + Surface Excitons + Spin-Polarized STM

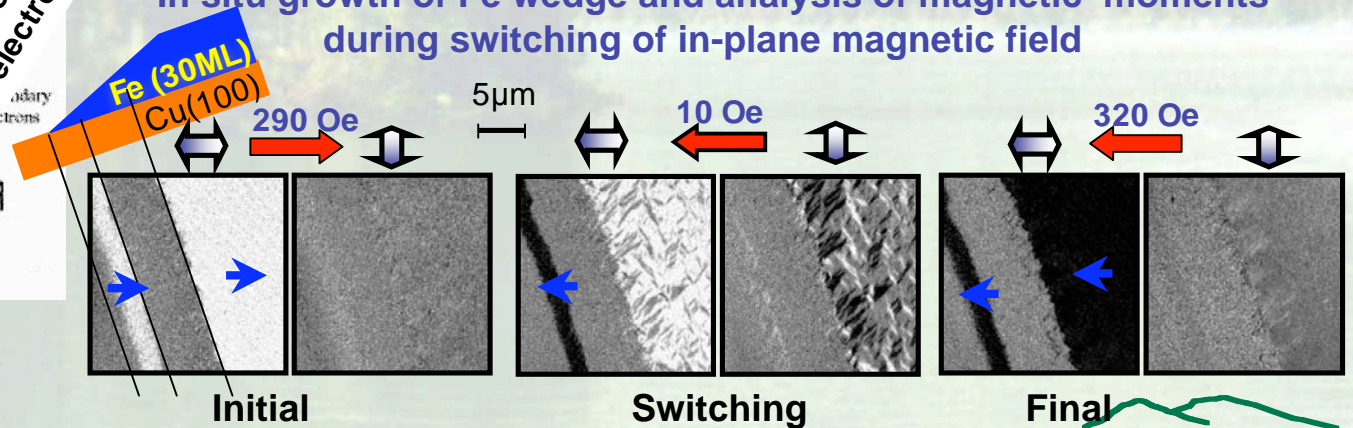
- **High-field Linear and Nonlinear MOKE (affiliated)**

- Surface and Interface magnetism

High-resolution Spin-polarized Scanning Electron Microscope (SEMPA)



In situ growth of Fe wedge and analysis of magnetic moments during switching of in-plane magnetic field

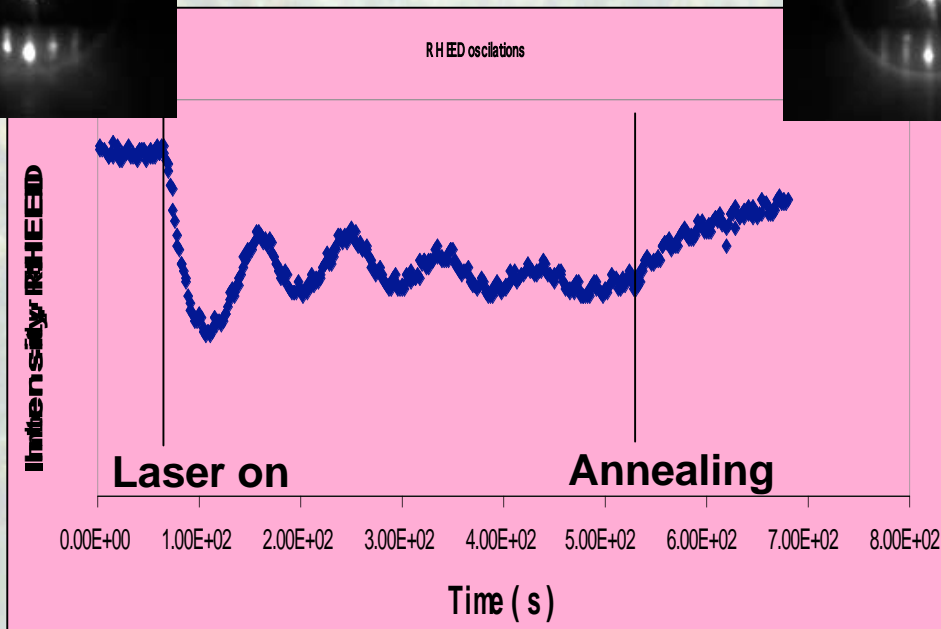
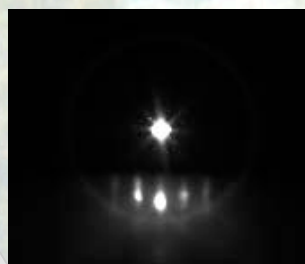
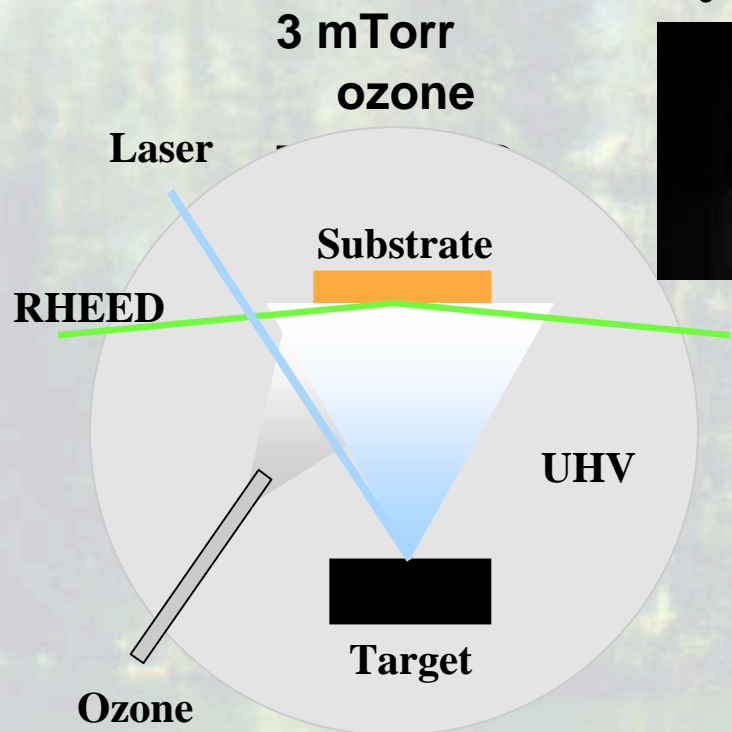


In-situ Growth of $(\text{La}_{5/8-y}\text{Pr}_y)\text{Ca}_{3/8}\text{MnO}_3$ by Laser-MBE



$\text{SrTiO}_3(100)$ with TiO_2 termination

250ML LPCMO

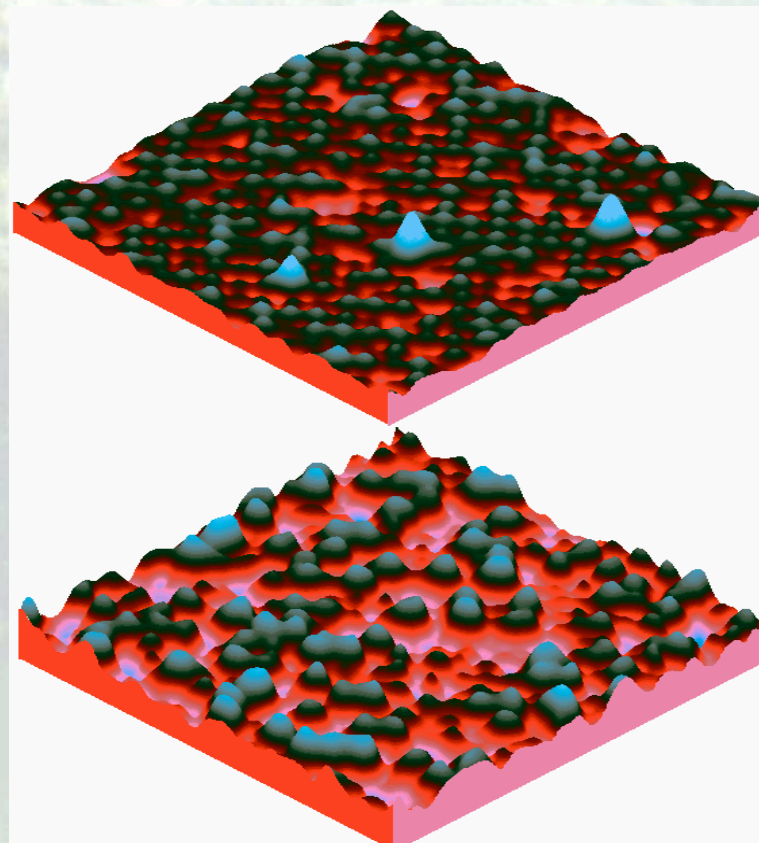
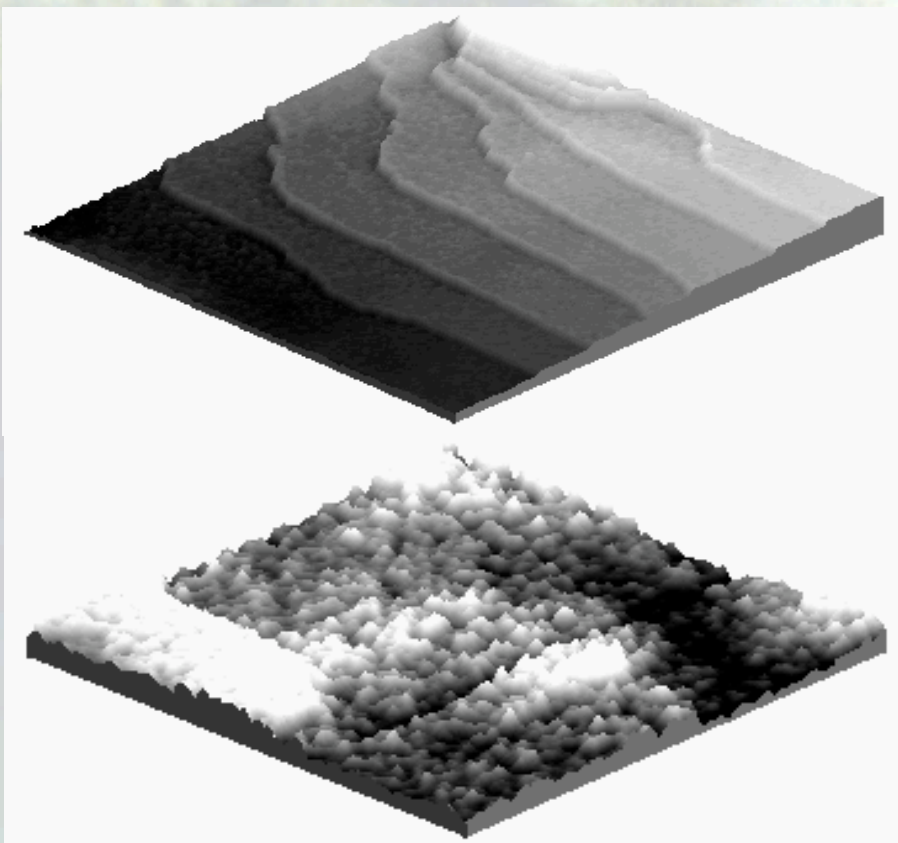


Electronic Phase Separation at Two Length Scales



Sub-micron

Atomic Scale



320 nm x 320 nm

10 nm x 10 nm

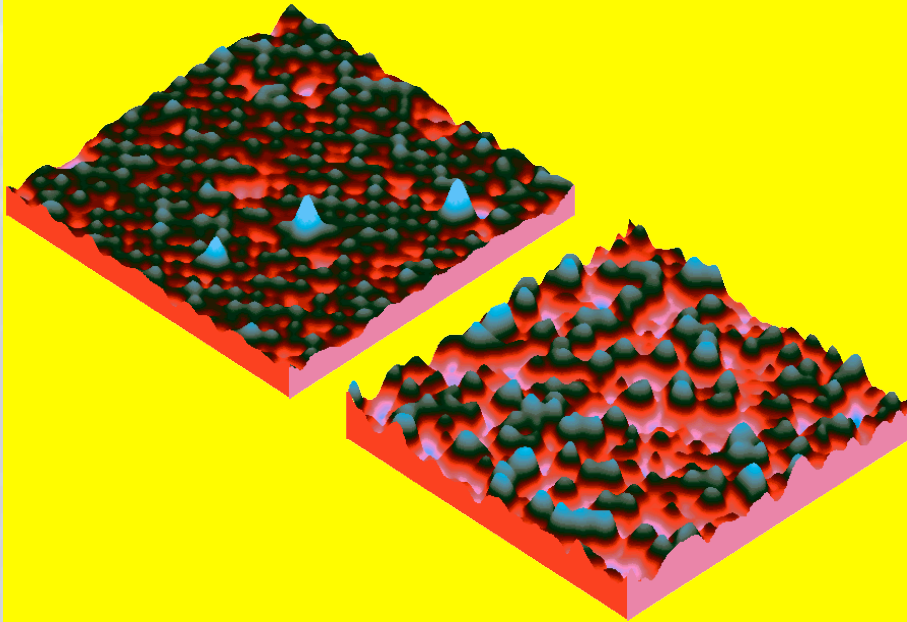
PRL 05

Future Research

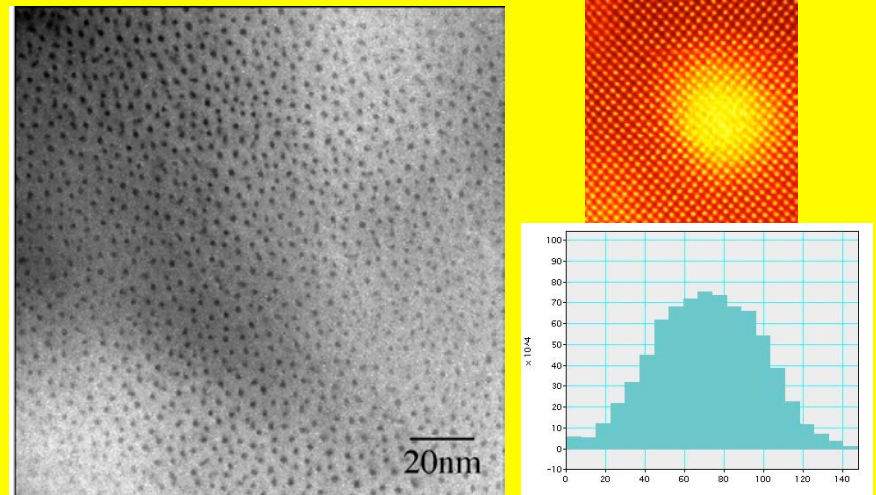


High resolution real-space imaging + Neutron

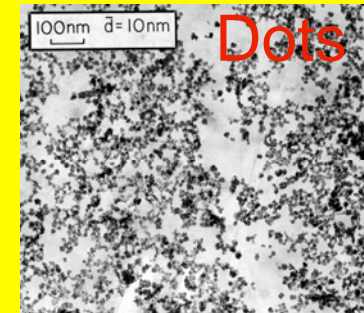
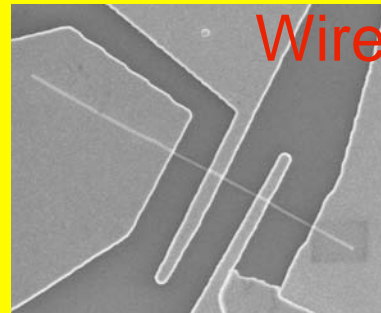
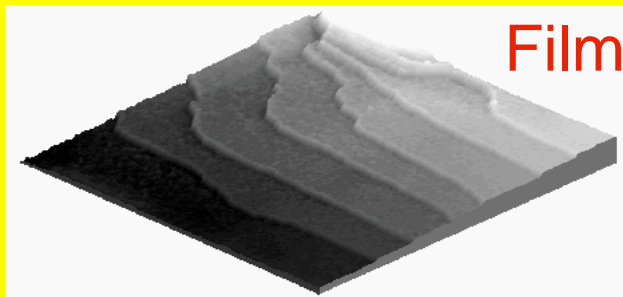
Polarons in LPCMO manganites



Magnetic polarons in MnGe DMS



Nano + Complexity (TMO) + Neutron



Future Development



- **UHV Suitcase**
 - Sample transfer between UHV systems
- **SEMPA at variable temperatures**
 - Temperature-dependence of domain structures
- **Ultrafast Kerr microscope**
 - Domain dynamics at fs scale
- **Spin-current microscope**
 - Profiling spin injection at atomic scale
- **Scanning nano-SQUID (Teizer, Texas A&M)**
 - Magnetic moment of single nano-object