Photo-Induced Magnetic Anisotropy due to Coherent Domain Growth

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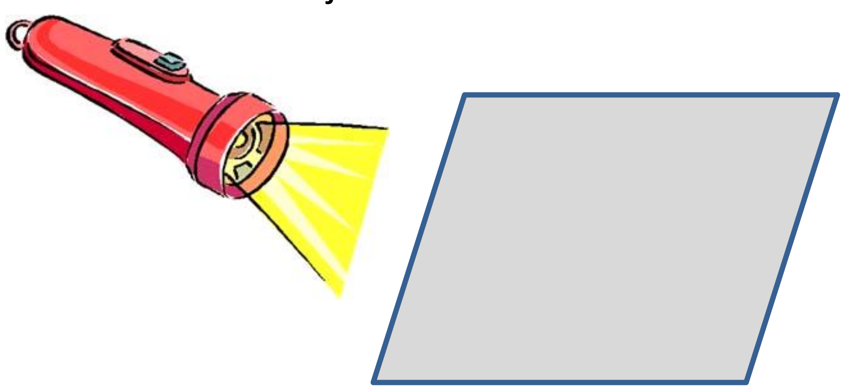
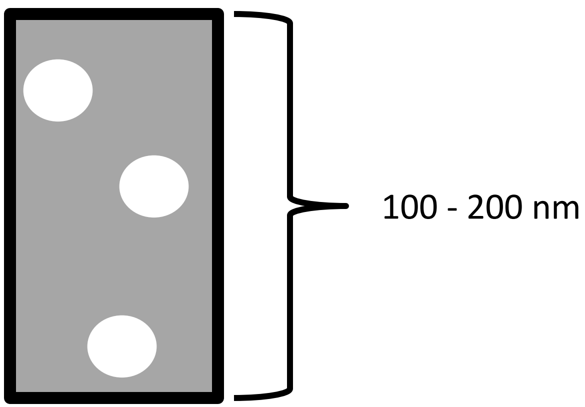
Photo-induced Magnetism

- The physical phenomenon in which the application of visible light to a material causes a change in the magnetization
- Possible applications – memory storage
- Thin films
  - cobalt hexacyanoferrate, $K_jCo_k[Fe(CN)_6]_l \cdot nH_2O$

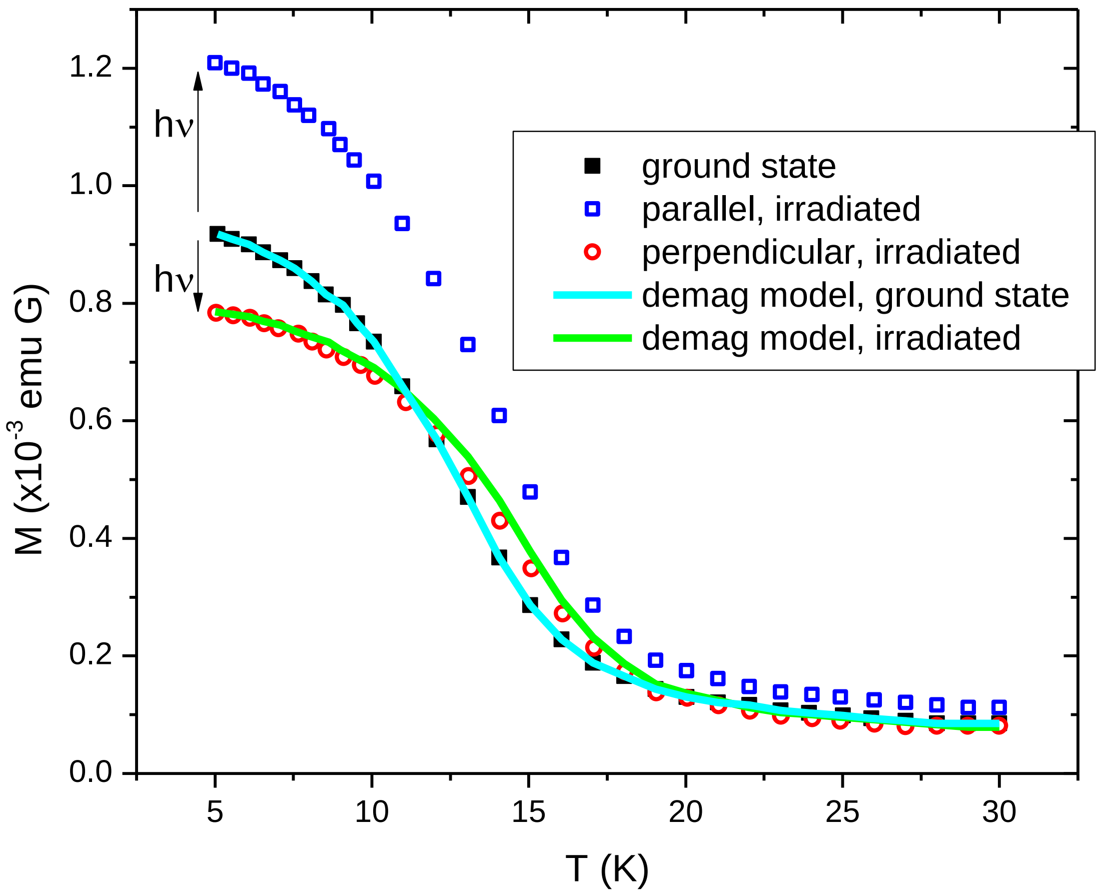


Magnetic Anisotropy – Previous Research

- Park *et al.* observations – 2004
- Sequentially adsorbed thin film

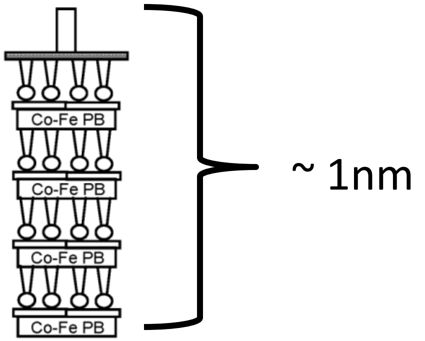


- **Magnetization change:**
  - Increase when parallel
  - Decrease when perpendicular

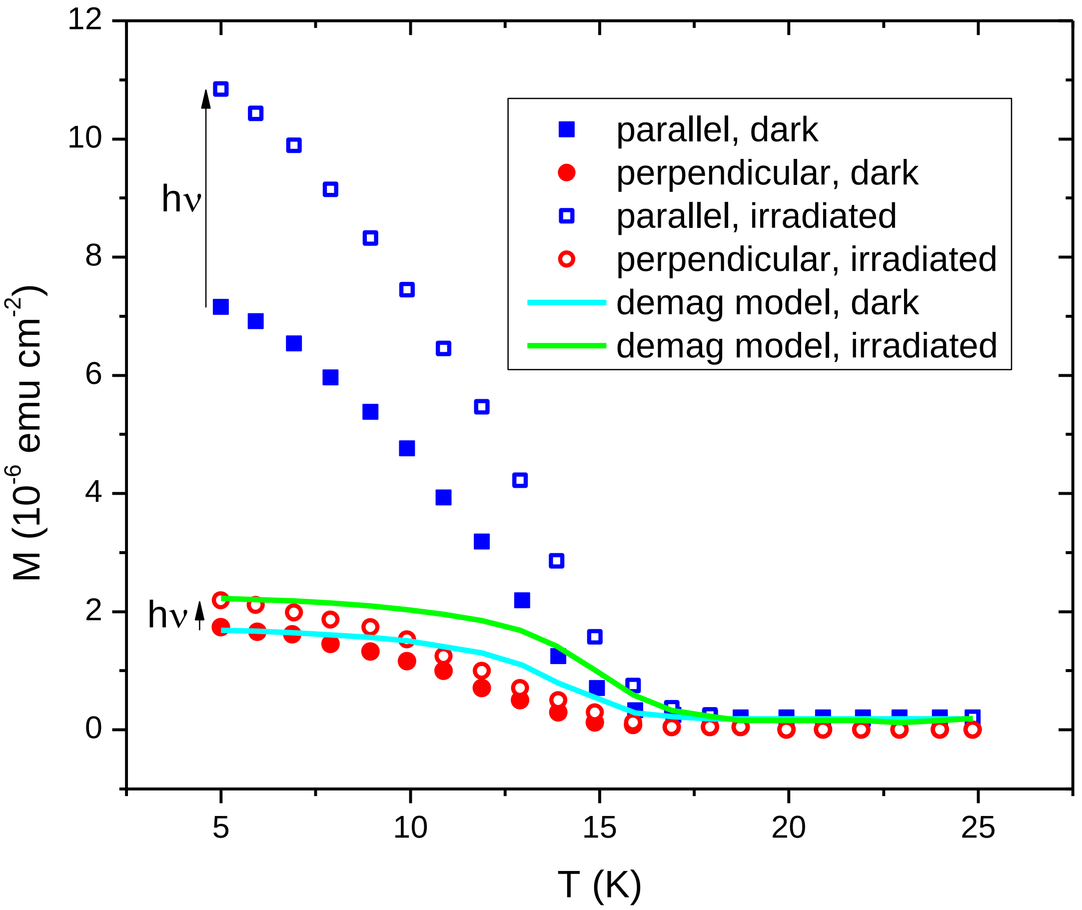


Magnetic Anisotropy – Previous Research

- Yamamoto *et al.* observations – 2005
- Langmuir-Blodgett templated thin film



- **Magnetization change:**
  - Increase when parallel
  - Small increase when perpendicular



Demagnetizing model

- We propose that demagnetizing effects can explain the general phenomenon of photo-induced magnetic anisotropy in coordination polymers.
- In magnetic materials, the internal magnetic field may be different than the applied field.

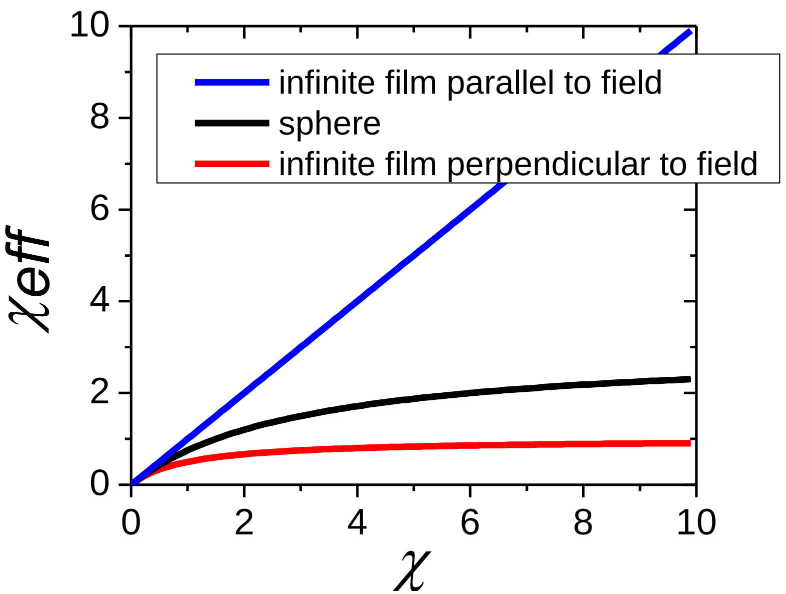
$$H_{eff} = H_{lab} - \frac{N}{4\pi} M$$

N is the geometrical demagnetizing factor,
M is the magnetization per unit volume,
H_{lab} is the applied field,
H_{eff} is the effective field taking into account demagnetization.

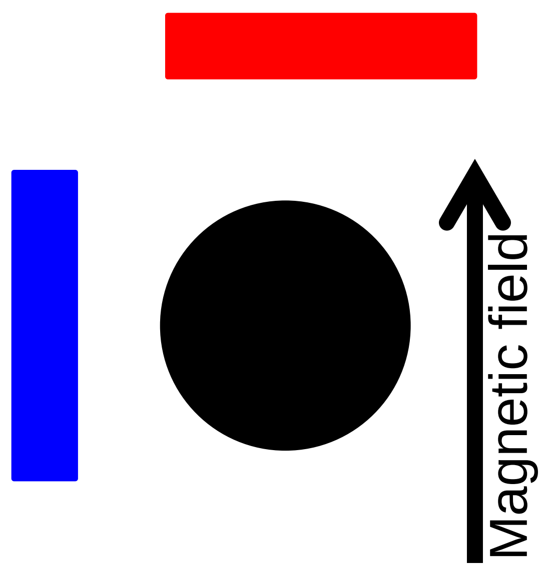
- Solving for the magnetic susceptibility…

Demagnetizing model

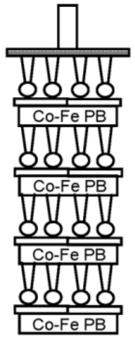
$$M = \chi H_{lab} \longrightarrow \chi_{eff} = \frac{\chi}{1+\chi N} n_{HS}$$



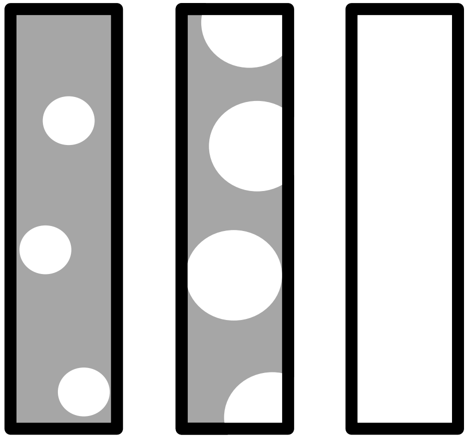
The dependence of the effective susceptibility upon the actual susceptibility and the demagnetizing factor is illustrated here. In the limit of large susceptibility, the effective susceptibility simply goes inversely proportional to the demagnetizing factor.



Modeling Experimental Data



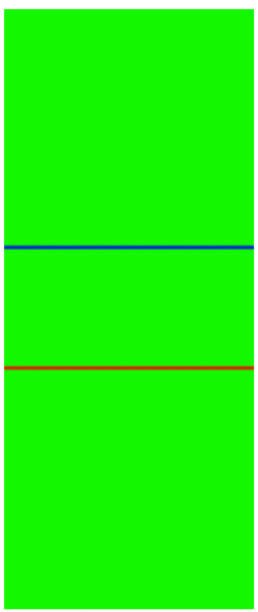
- Langmuir-Blodgett templated film
  - Highly two-dimensional
  - good agreement is found between experimental data of the perpendicular orientation of the film and the demagnetization model
- sequentially adsorbed film
  - Photo-irradiation causes magnetic clusters to grow

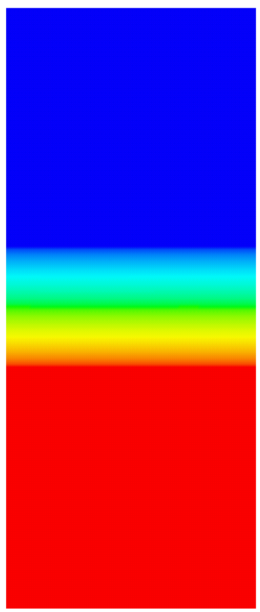


- A more complicated model is needed
- The experimental data may be reproduced if the ground state consists of isolated clusters similar to spheres, and the photoirradiated state is anisotropic in shape similar to infinite planes or anisotropic ellipsoids

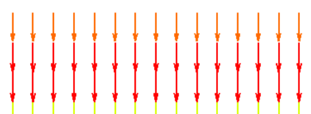
python *FiPy*

- A free, Python-based finite-element package developed in the Center for Theoretical and Computational Material Science (CTCMS) here at NIST
- Used to calculate the magnetic scalar potential and magnetic field given a distribution of magnetic charges
- Was first tested with examples electrostatics



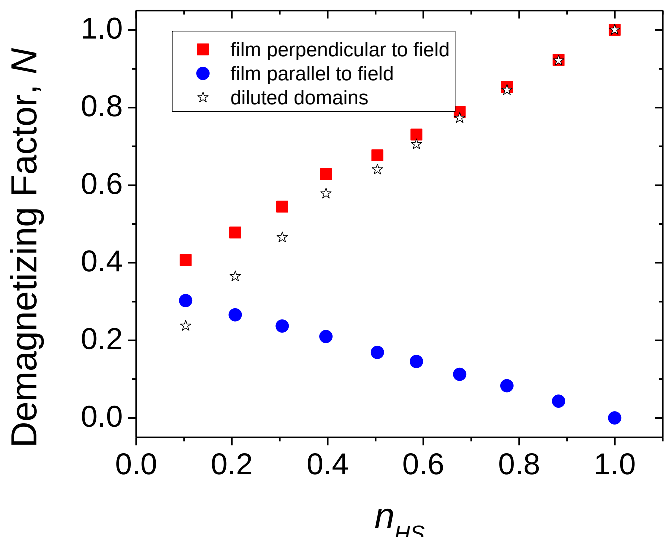


- Numerical results agreed with analytical results



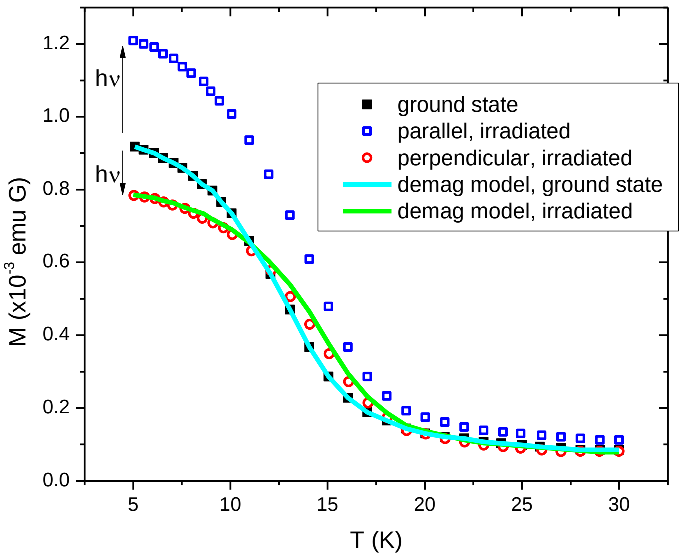
Results

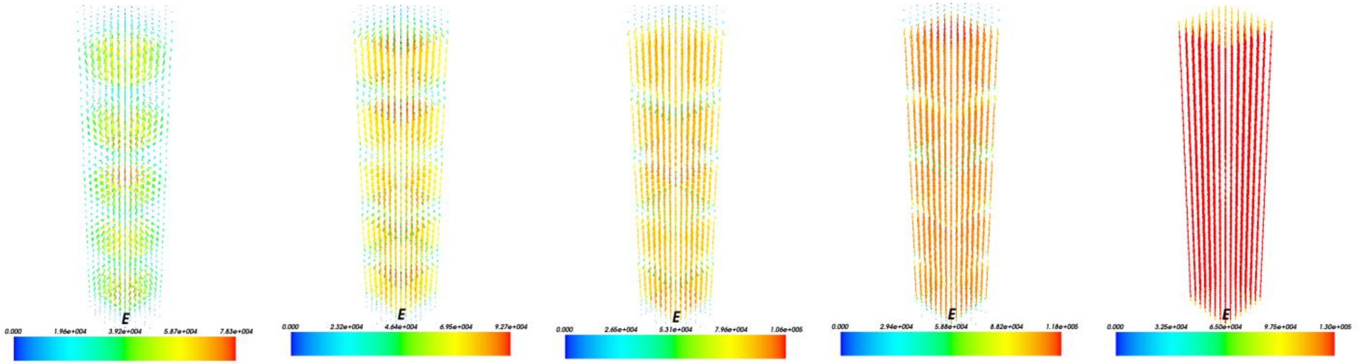
- Magnetic droplets approximated as cubes
- Periodic boundary conditions
- Demagnetizing factor calculated by taking the average magnetic field magnitude within a droplet



$$M = \chi H_{lab}$$

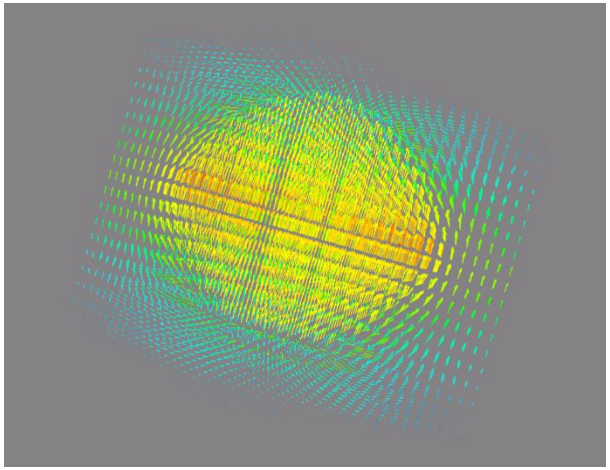
$$\chi_{eff} = \frac{\chi}{1+\chi N} n_{HS}$$





Conclusions, Ongoing Work

- The demagnetizing model can, for the most part, explain the phenomenon of photo-induced magnetic anisotropy
  - Specifically the surprising decrease in magnetization for sequentially adsorbed thin films, and the reduced magnitude of the photoeffect for the templated films.
- More work to use more physical spherical magnetic droplets using the coding framework developed over this summer



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