

---

# **Domain structures and domain wall pinning in arrays of elliptical NiFe nanoelements**

**W. Scholz, D. Suess, T. Schrefl, and J. Fidler**  
**Vienna University of Technology**

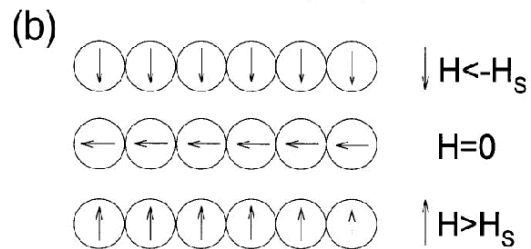
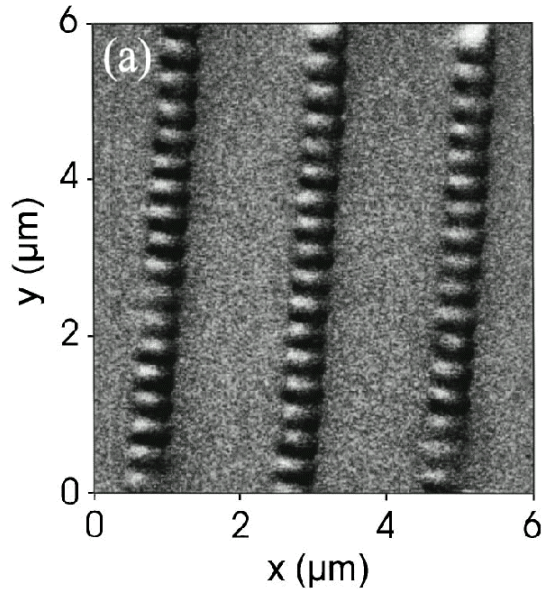
**MMM 2001  
Seattle, Washington  
November 12-16, 2001**

# Outline

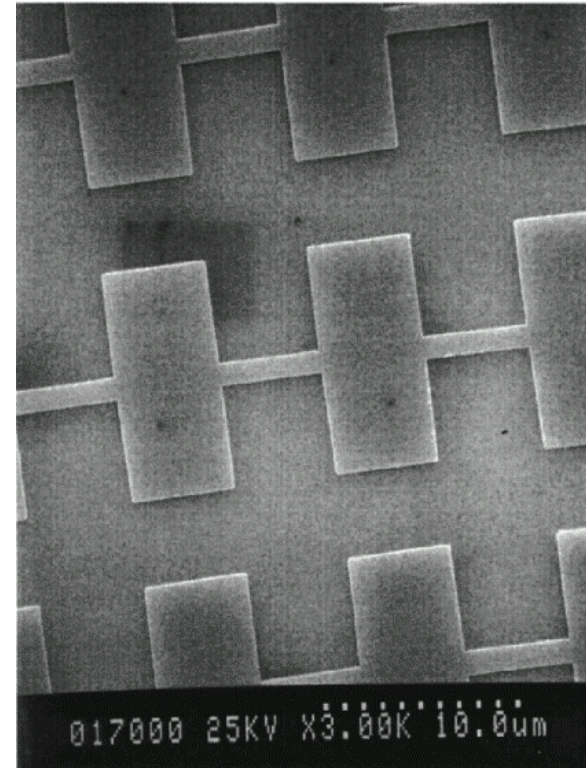
---

- **Experimental investigations**
- **Micromagnetic model**
- **Single particle**
- **Chains of particles**
  - **separated particles**
  - **influence of shape**
  - **connected particles**
- **Summary**

# Experimental investigations



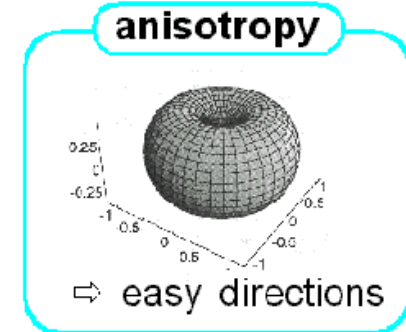
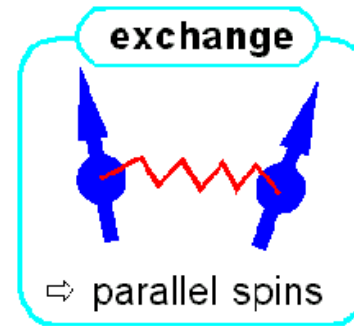
J. I. Marín et al., Magnetization reversal in long chains of submicrometric Co dots. *Appl. Phys. Lett.*, 72(2):255-257, January 1998



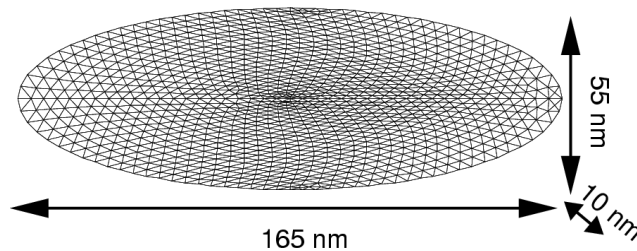
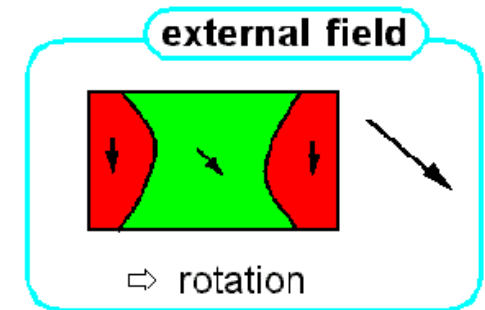
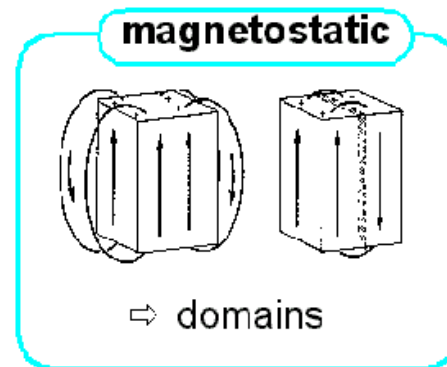
C. C. Yao et al., Magnetoresistance in modulated width  $\text{Ni}_{80}\text{Fe}_{20}$  wires. *J. Appl. Phys.*, 85(3):1689-1692, February 1999

# Micromagnetics

- **Effective field  $H_{\text{eff}}$  :**
  - exchange
  - anisotropy
  - magnetostatic
  - external field
- **Gilbert equation of motion**
  - time integration using BDF with preconditioning



$$\frac{\partial \mathbf{J}}{\partial t} = -|\gamma| \mathbf{J} \times \mathbf{H}_{\text{eff}} + \frac{\alpha}{J_s} \mathbf{J} \times \frac{\partial \mathbf{J}}{\partial t}$$



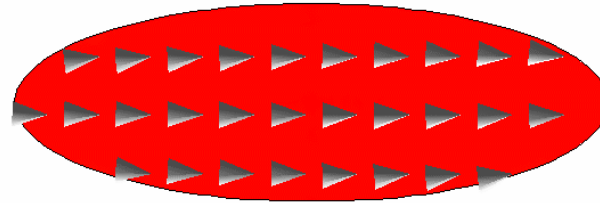
- **3D FE models with up to 15000 nodes 60000 elements**

# Single particle

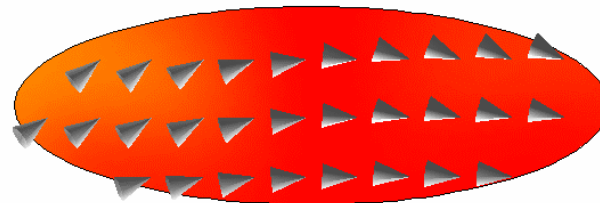
- Elliptical particle  
Permalloy ( $\text{Ni}_{80}\text{Fe}_{20}$ )  
 $J_s = 1 \text{ T}$   
 $A = 13 \text{ pJ/m}$   
 $K = 0$   
 $\delta \approx 160 \text{ nm}$

perfectly rectangular  
hysteresis loop  
 $H_{sw} = 238 \text{ kA/m}$

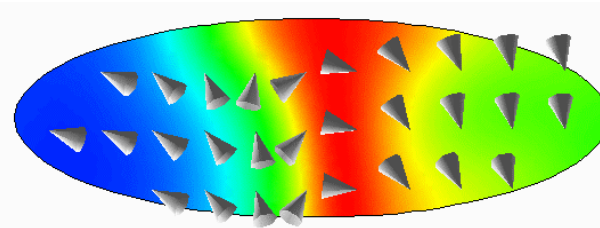
Inhomogeneous  
magnetization  
reversal process



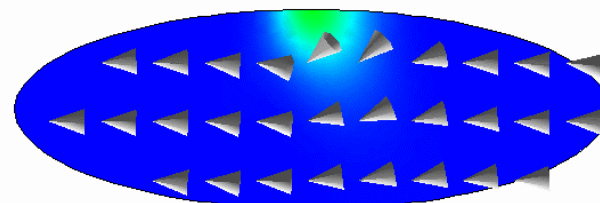
$t = 0.00 \text{ ns}$



$t = 0.05 \text{ ns}$



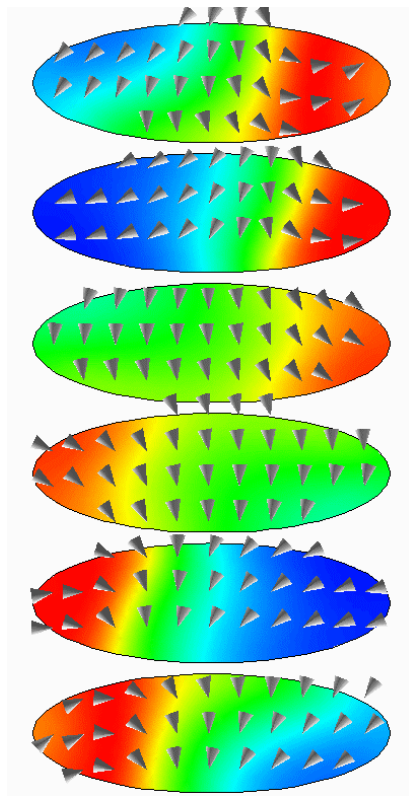
$t = 0.15 \text{ ns}$



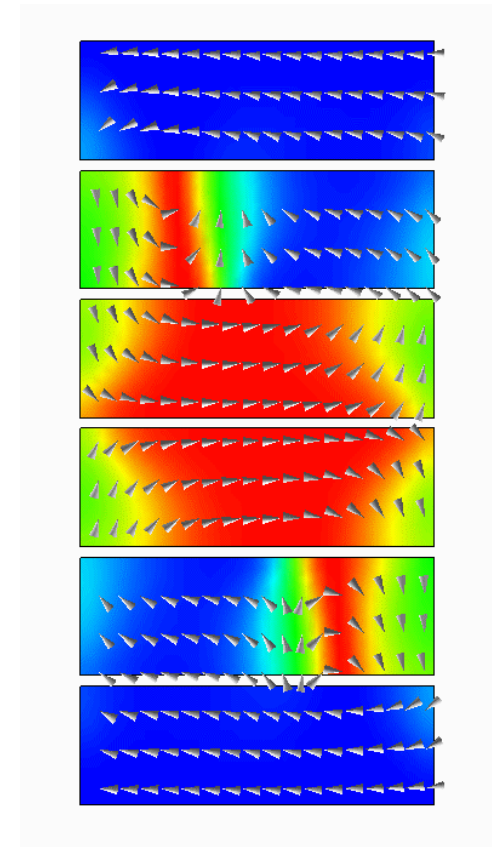
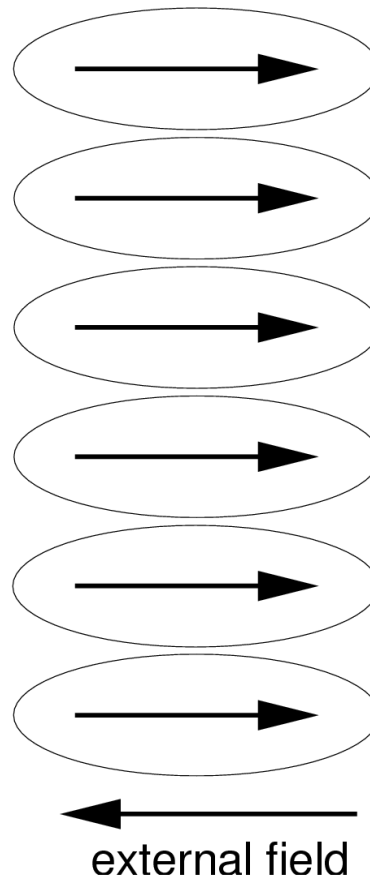
$t = 0.20 \text{ ns}$

# Chain of particles

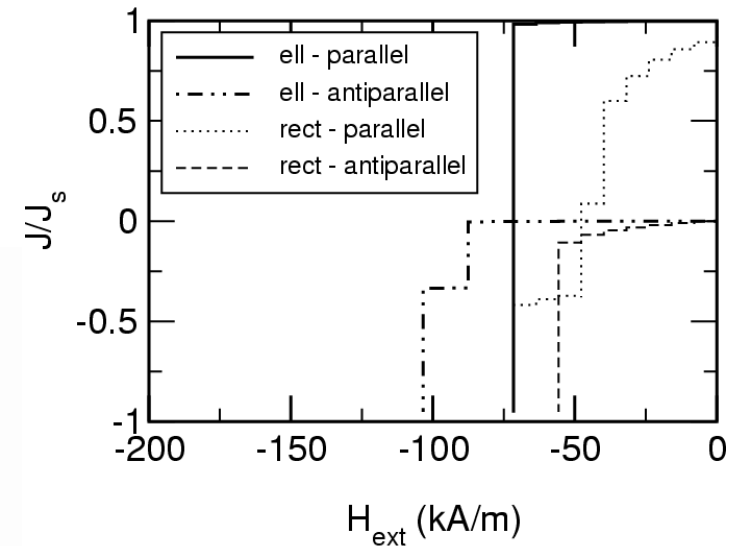
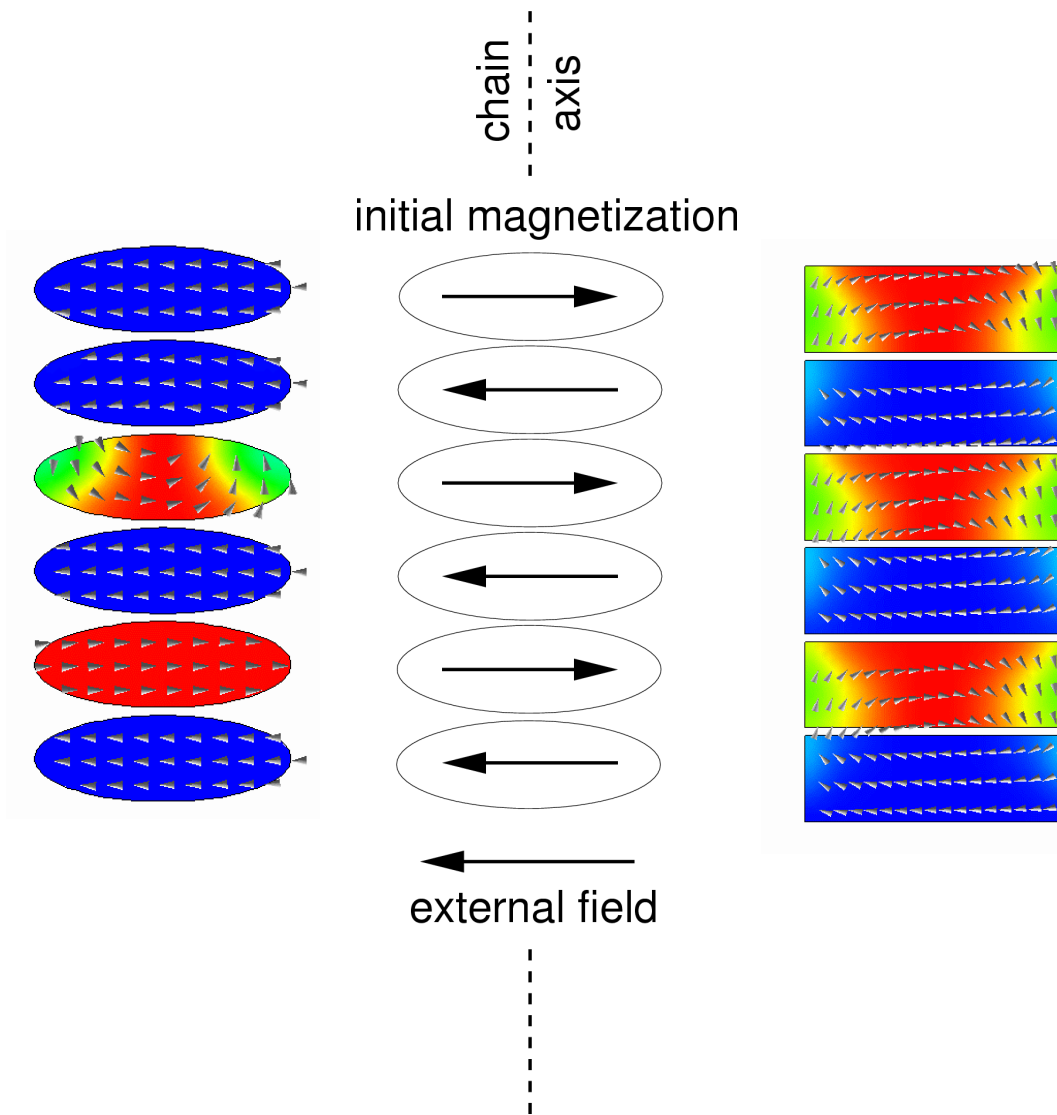
- Elliptical particles
- Rectangular particles



initial magnetization



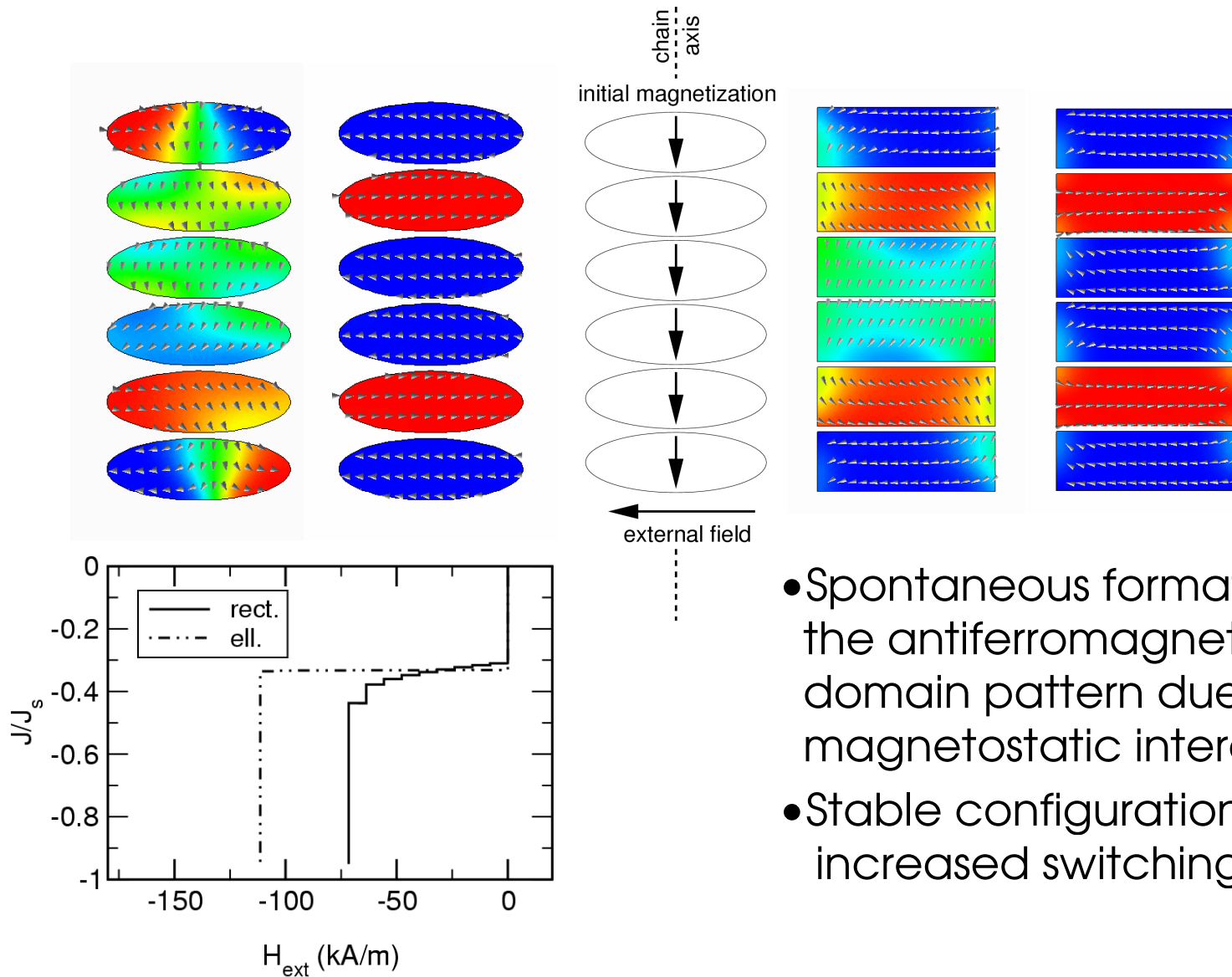
# Separated particles



- Gap of 5 nm
- Elliptical particles:
  - Parallel alignment:  $H_{sw} = 72$  kA/m
  - Antiparallel alignment:  $H_{sw} = 104$  kA/m

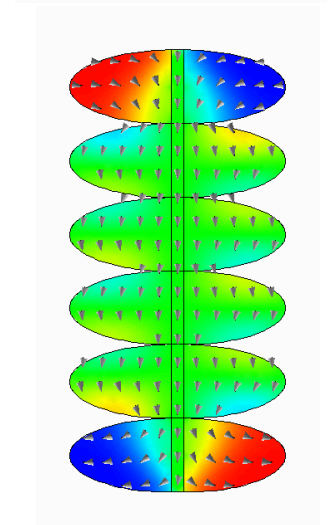
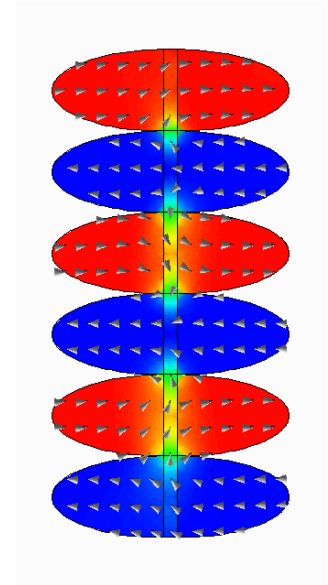
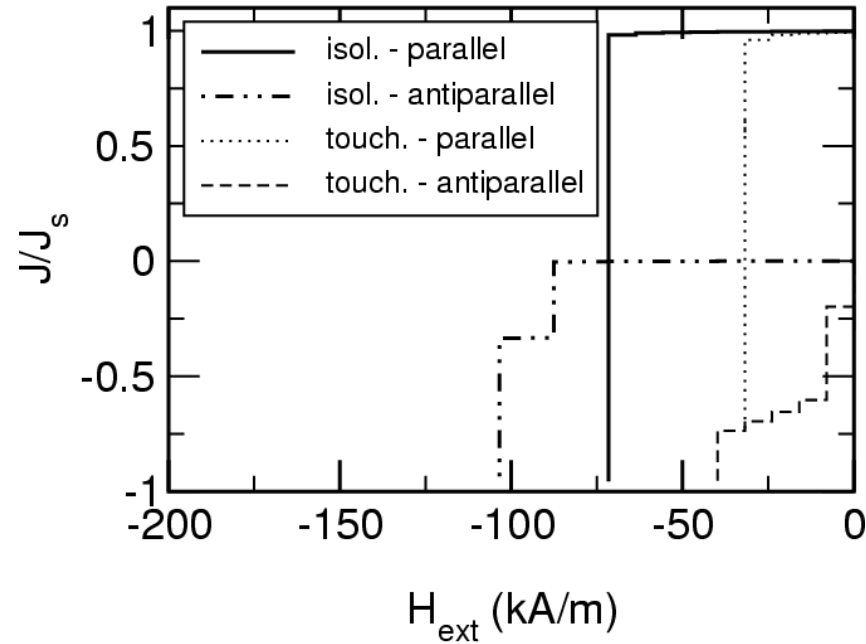
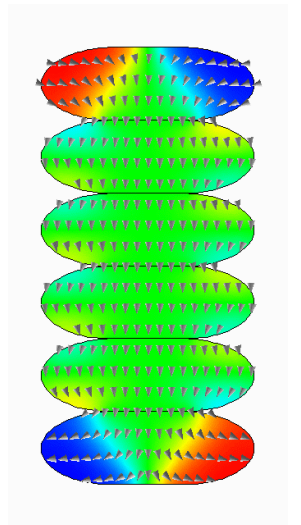
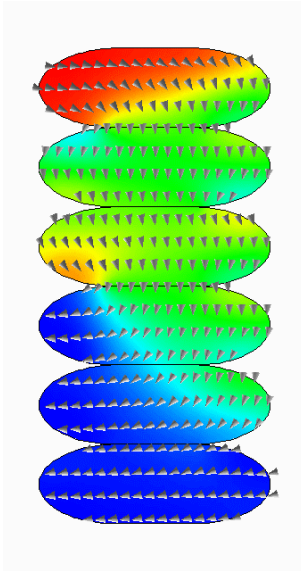


# Spontaneous alignment





# Connected particles



- Contact faces of 50x10 nm: "big" domains
- Contact faces of 10x10 nm: "artificial pinning"

# Summary

---

- **Study of permalloy nanoparticles for data storage devices and sensor applications**
- **Strong influence of shape and magnetostatic interactions**
- **Competition between shape anisotropy of the particles and shape anisotropy of the chain**
- **Spontaneous formation and stability of domain patterns with antiparallel magnetization**
- **Artificial pinning of magnetic transition regions at small contact faces**

# Acknowledgements

---

- **Austrian Science Fund FWF**  
Project: Y-132 PHY, 13260 TEC
- The authors would like to thank Prof. Ivan K. Schuller for stimulating discussions.