Modelling of microwave-assisted switching in magnetic ellipsoids

R. Yanes, F.García-Sánchez, R.Rozada
O.Chubykalo-Fesenko

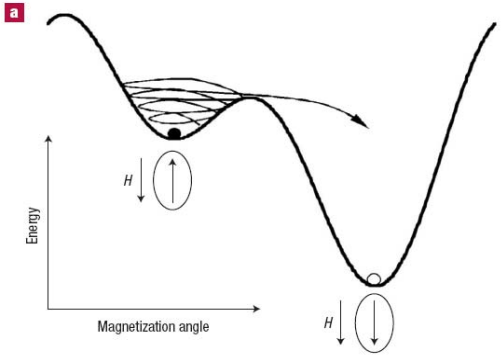
Instituto de Ciencia de Materiales de Madrid, Spain, CSIC

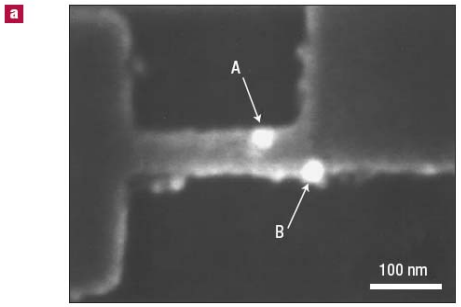
P.Martin Pimentel, B.Leven, B.Hillebrands

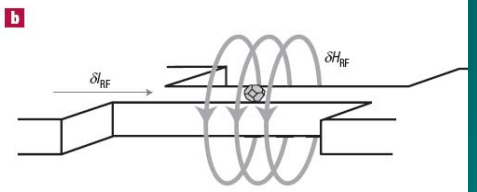
Technische Universitat Kaiserslautern, Germany

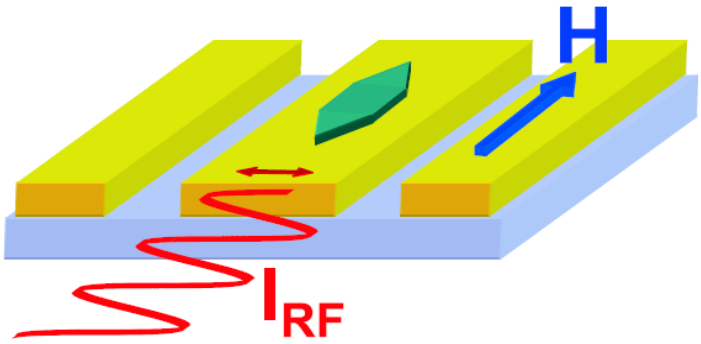
Motivation:

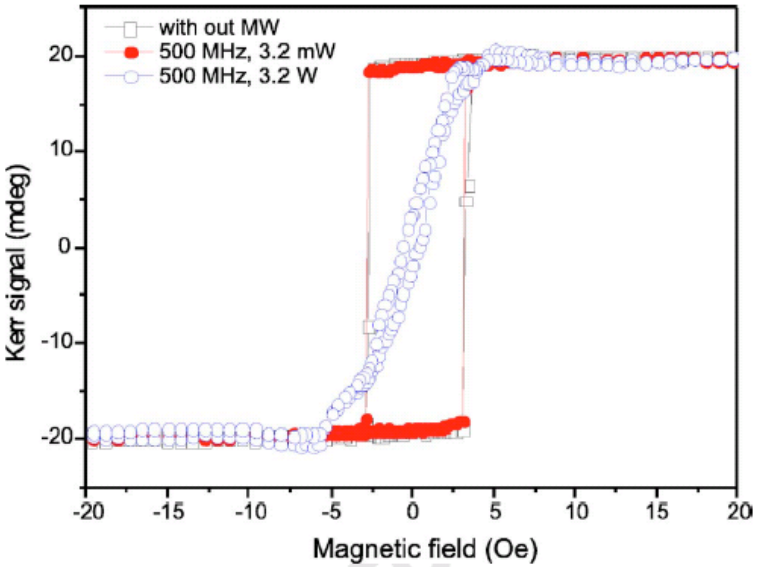
Microwave-assisted switching is reported to be faster an to require smaller applied field.



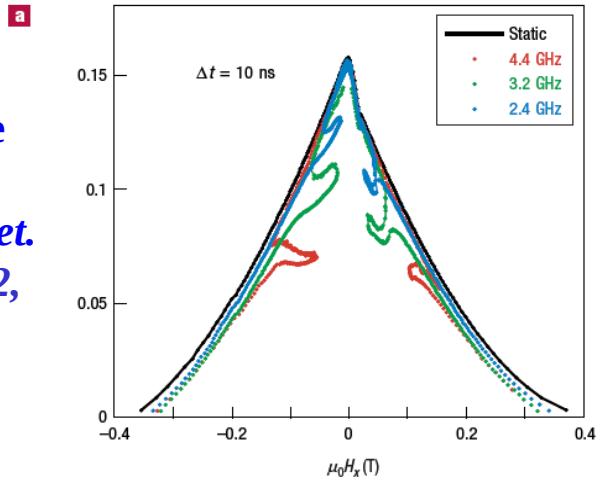








Micro-SQUID experiment on one Co nanoparticle (20nm) ***C.Thirion et. al; Nature Mater. 2, 524 - 527 (2003)***



Experiment: permalloy ellipsoid 160x 80 μm

H.T.Nembach et al; Apl. Phys Lett 90 (2007) 062503

Reported effects:

- Fast precessional switching

C. H.Back et al Phys Rev Lett 81 (1998) 3251

- Enhanced domain nucleation and wall mobility

H.T.Nembach et al Appl. Phys. Lett 90 (2007) 062503.

A.Krasyuk et al Phys. Rev.. Lett. 95, 207201, (2005)

- Nonlinear effects

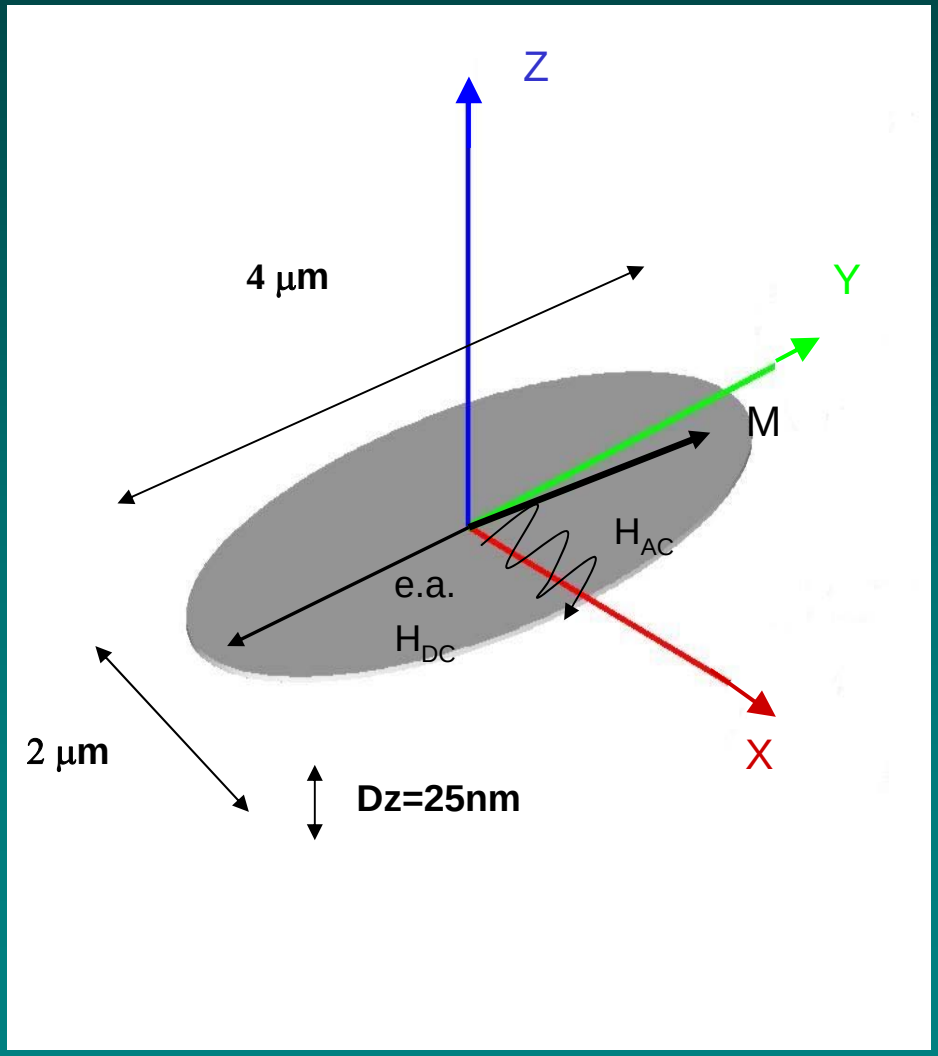
C.Thirion et al Nature 2 (2003) 524.

- Vortex core reversal under microwave fields

B. Wayenberge et al Nature 444 (2006) 461

New in this study – larger system, nucleation-propagation mechanism of magnetisation reversal.

Simulated system: permalloy ellipsoid



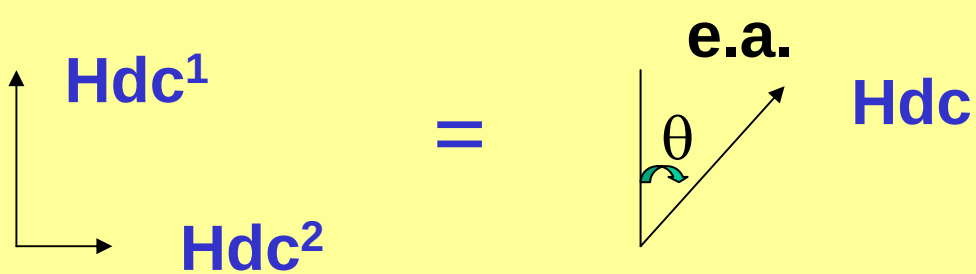
- H_K=7.7Oe
- Ms=1.08T

α_{LLG}=0.012

Full micromagnetic simulations using *Magpar* program (70342 finite elements)

Parallel implementation

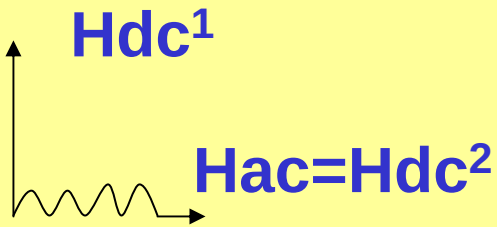
Switching field astroid

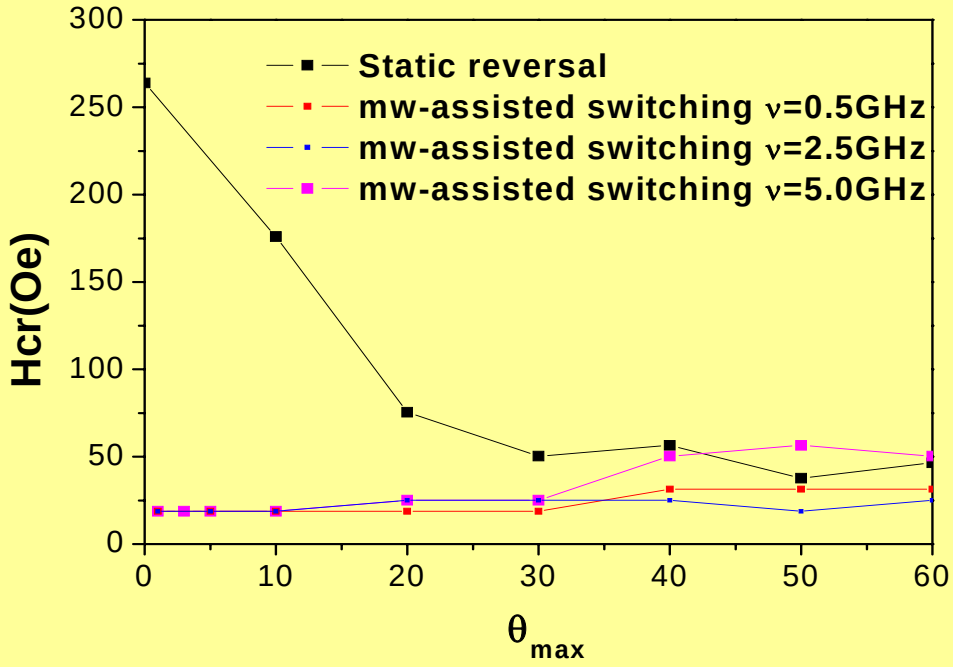


Under microwave field the total applied field is no longer along the Y axis

The most important contribution to decrease the coercivity

will be compared to

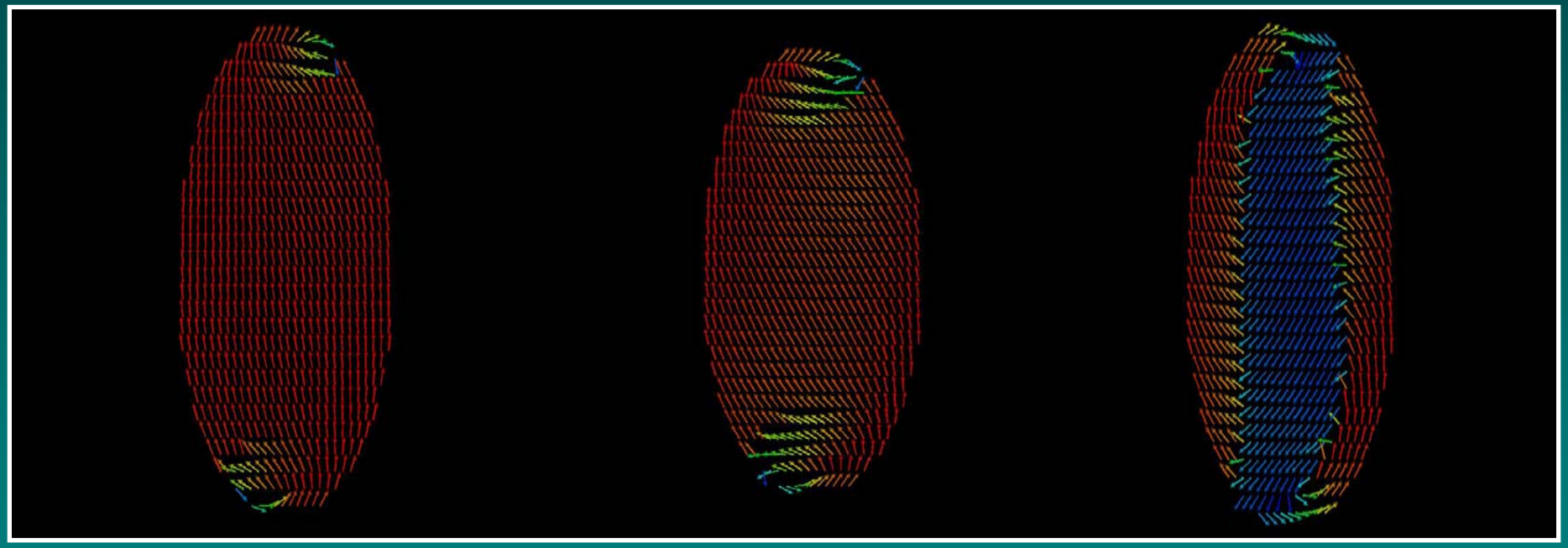




Static hysteresis process I

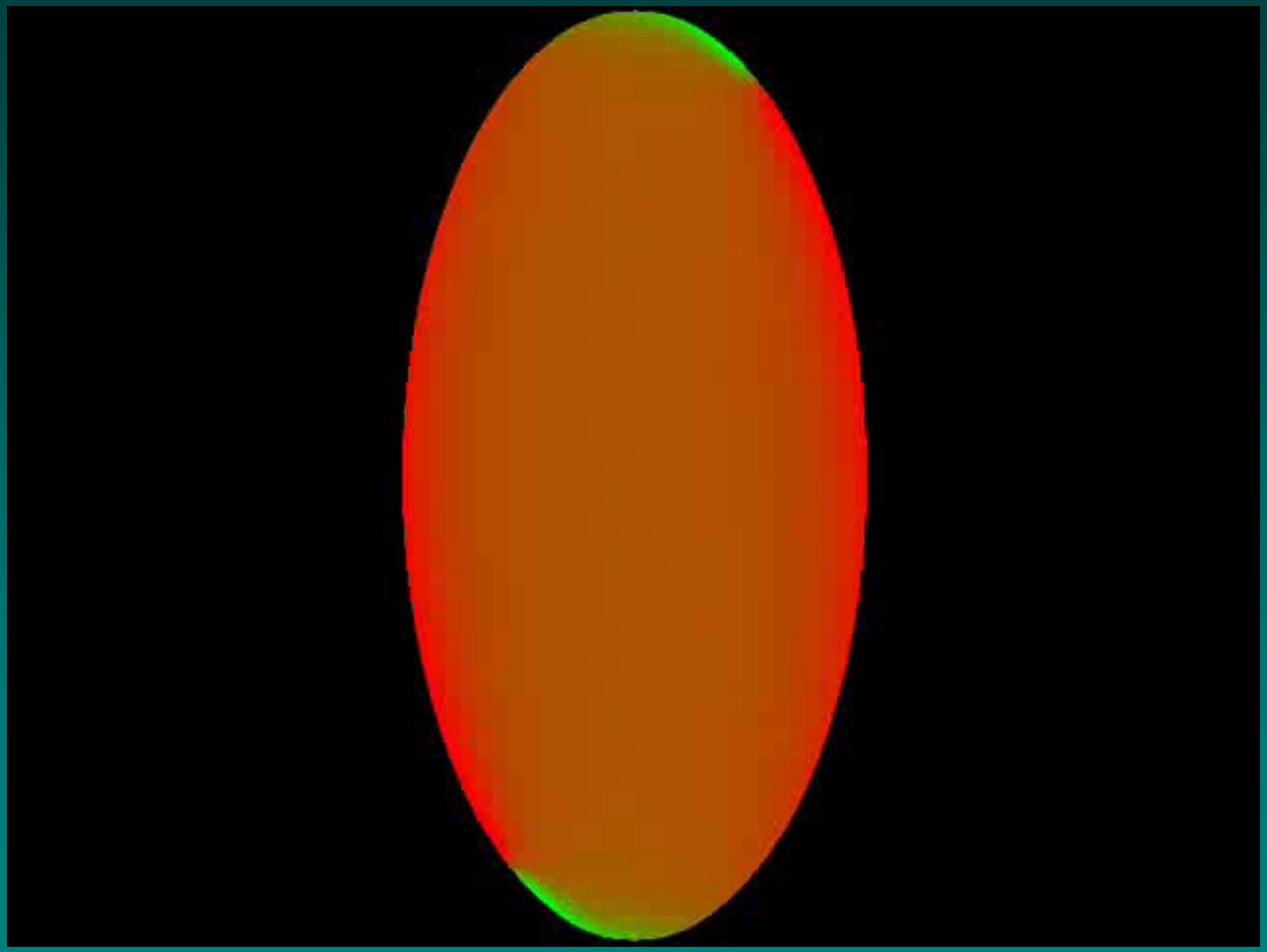
Magnetisation processes are different for static and mw-assisted reversal

Magnetisation configurations (static field) for $\theta=50^{o}$



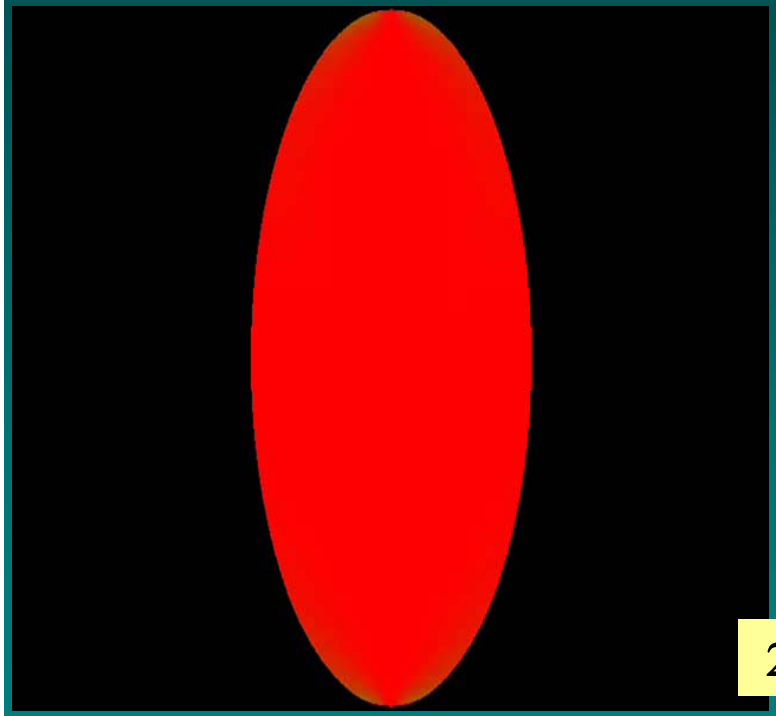
- The switching process starts with two vortex nucleation
- The switching process proceeds with two Néel-type domain wall propagation

Static hysteresis process II

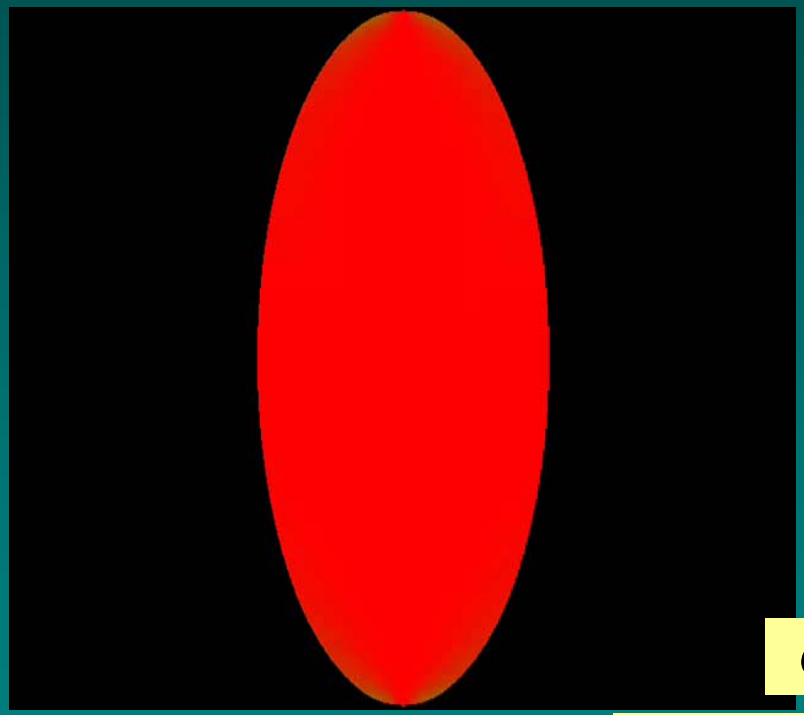


Microwave-assisted magnetisation reversal I

- **Ripple structure is observed**
- **Constant spinwave generation is essential**
- **Number of domains increases with frequency**
- **Domain wall mobility and relaxation in the opposite well is important.**



2.5GHz



6GHz

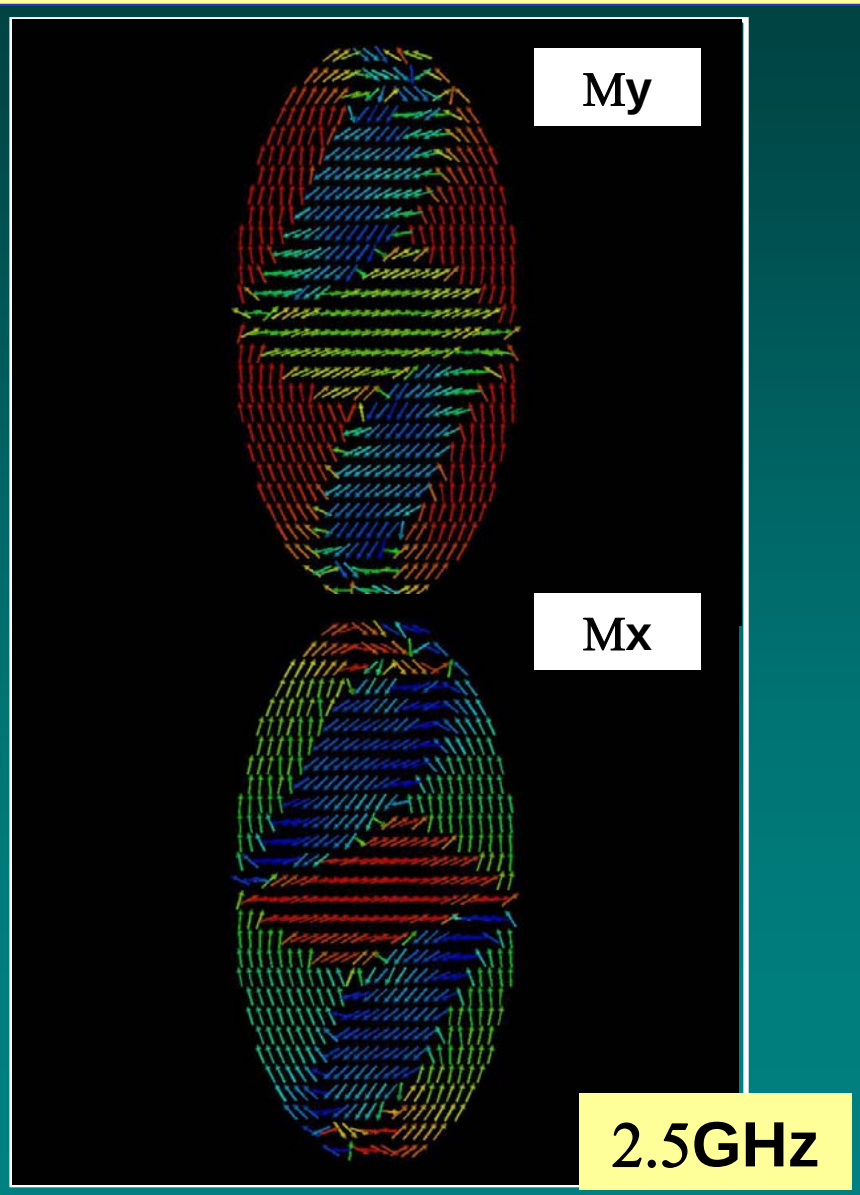
- Nucleation is almost equally fast
- Domain wall mobility is slow in the right ellipsoid

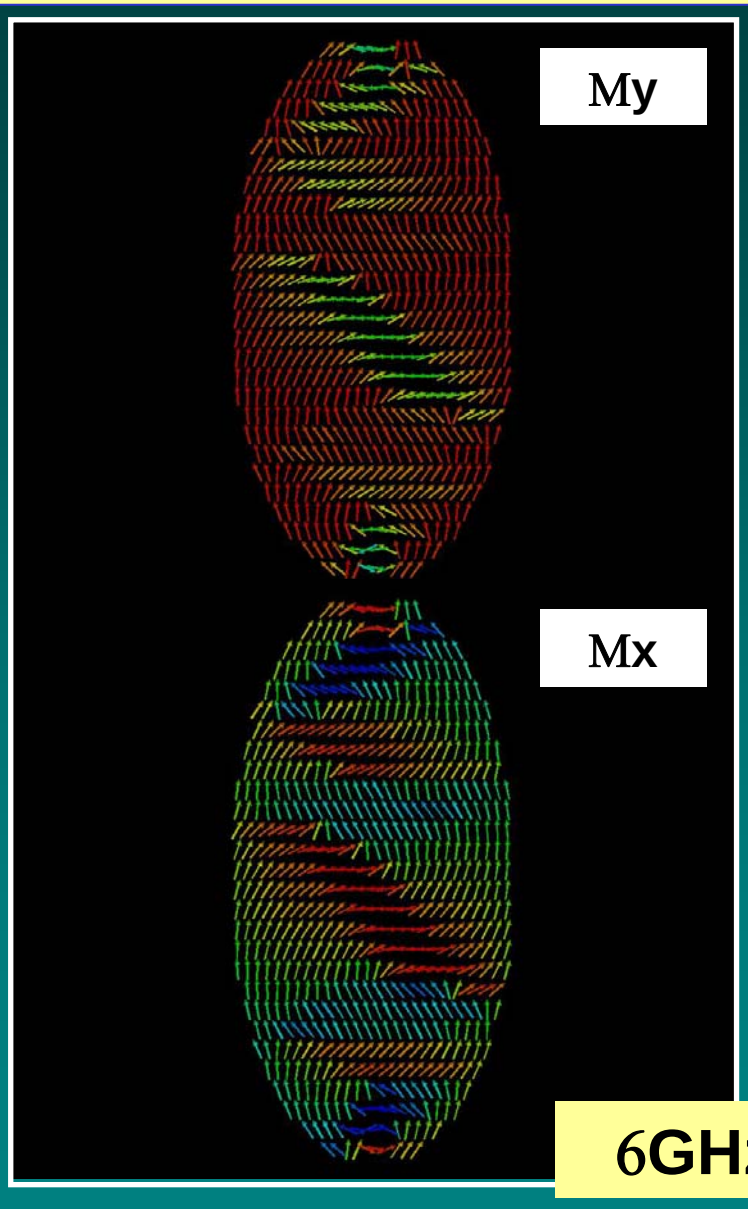
$m_y>0$

$m_y<0$

$m_y=0$

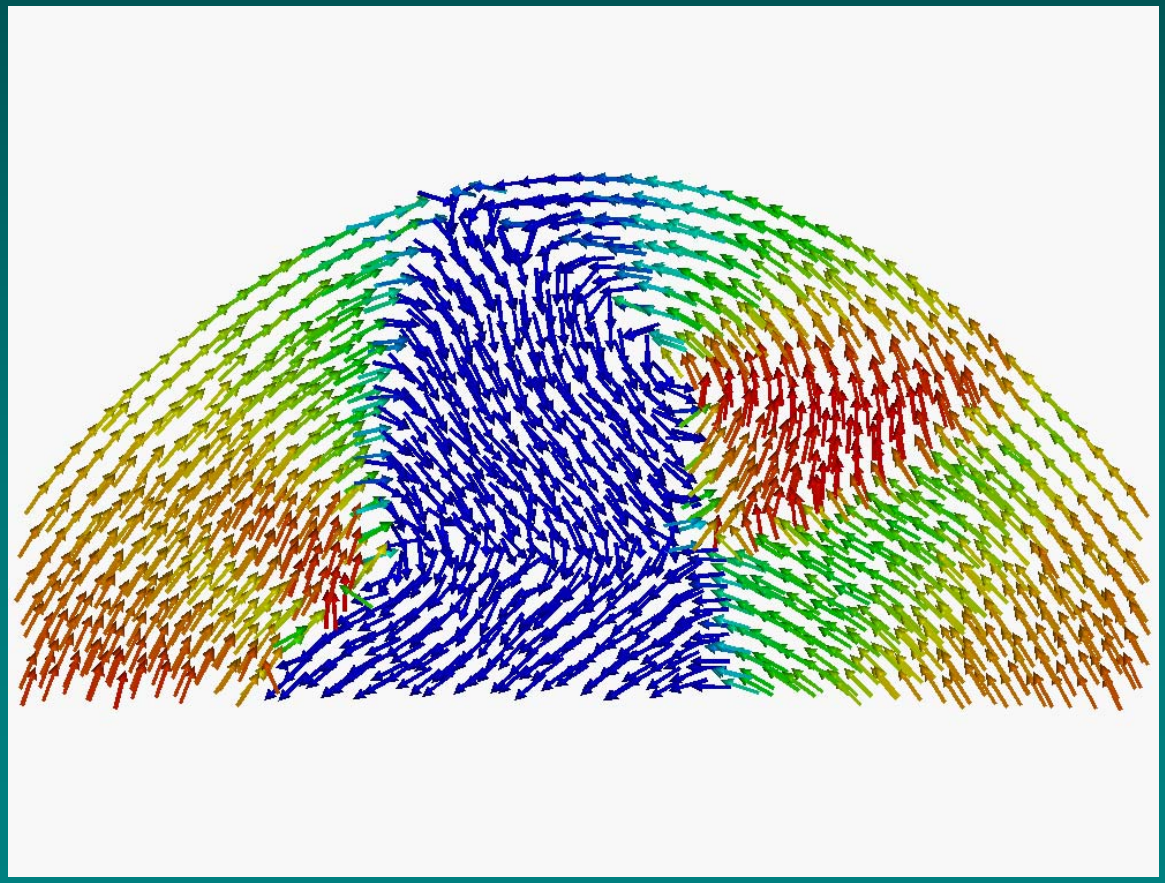
Microwave-assisted magnetisation reversal II



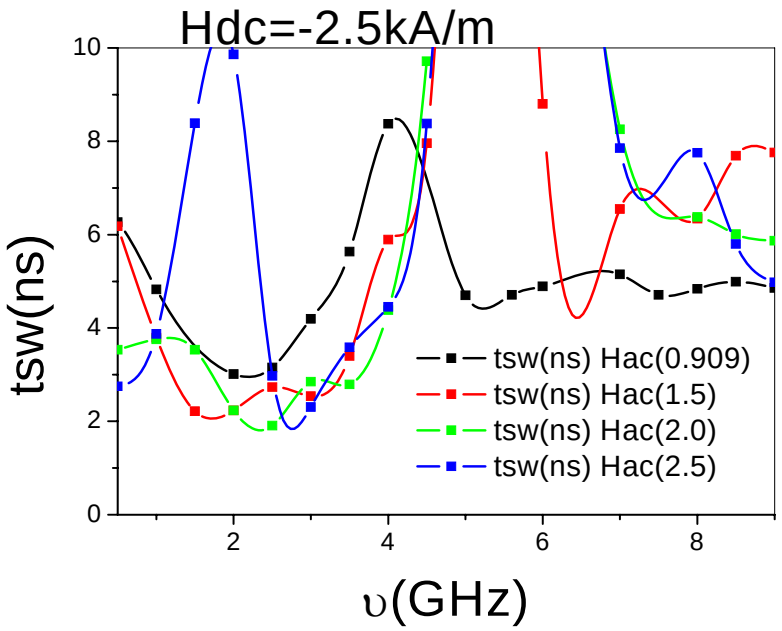


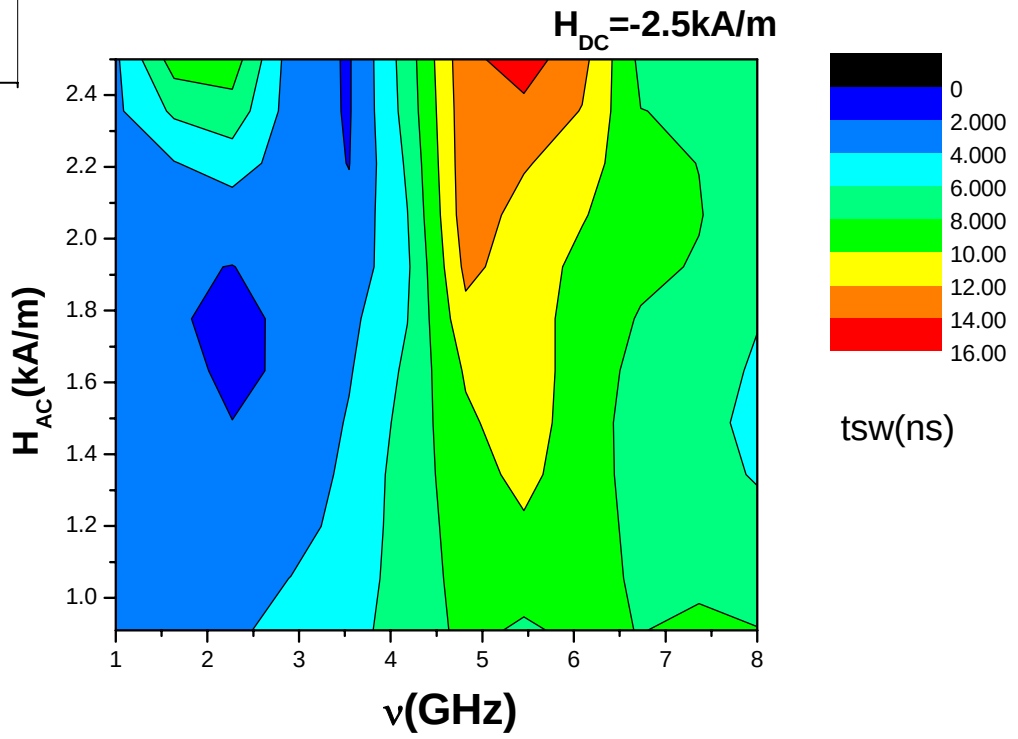
Configuration during mw-assisted switching

- Domain walls have Neel (or cross-tie) form
- Multiple vorteces are observed



Reversal time with mw-assistance



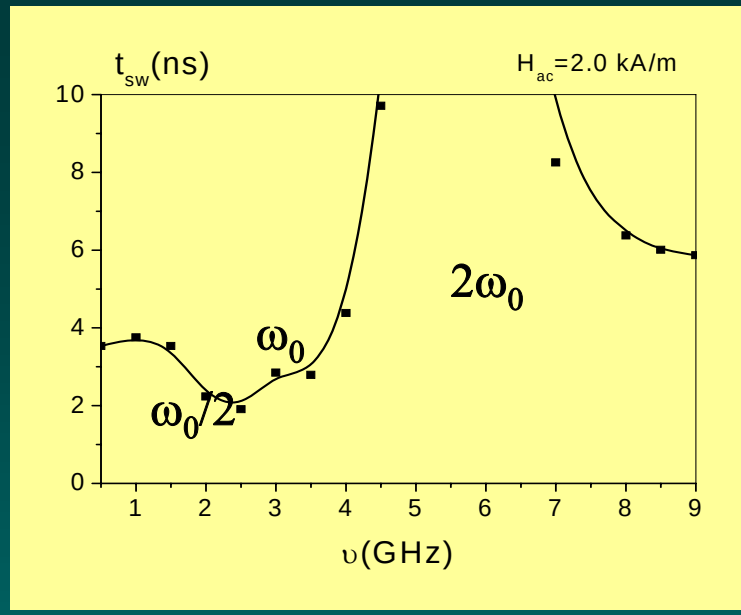


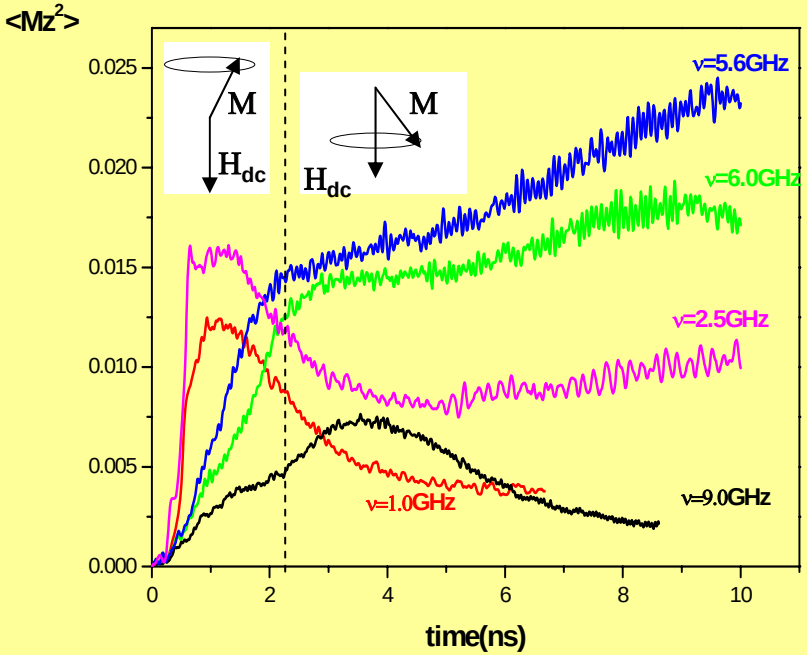
Discussion on the precession

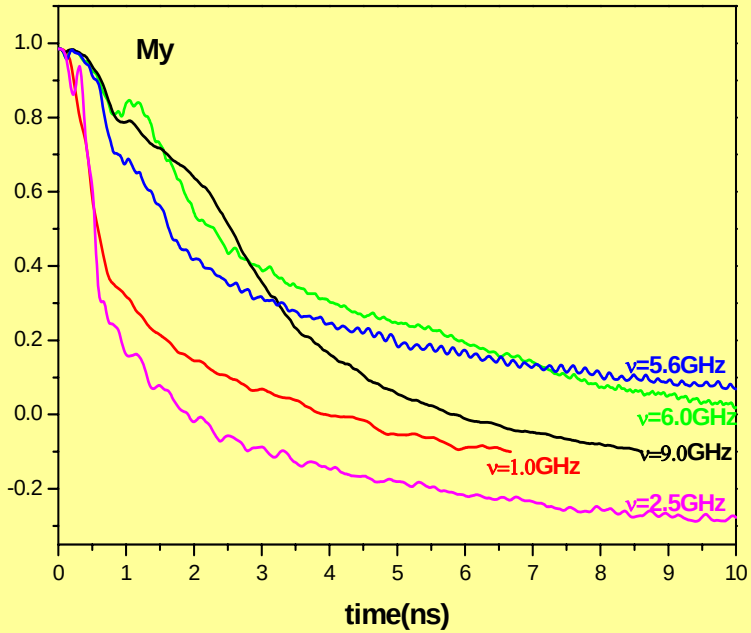
- **Nucleation is faster with the frequencies close to the FMR frequency in the upper well (3.1 GHz)**

- **The switching time results from a competition between a fast nucleation and a fast relaxation and propagation of the inverted magnetisation**

- **At frequencies corresponding to maximum time the energy is efficiently converted into precession**





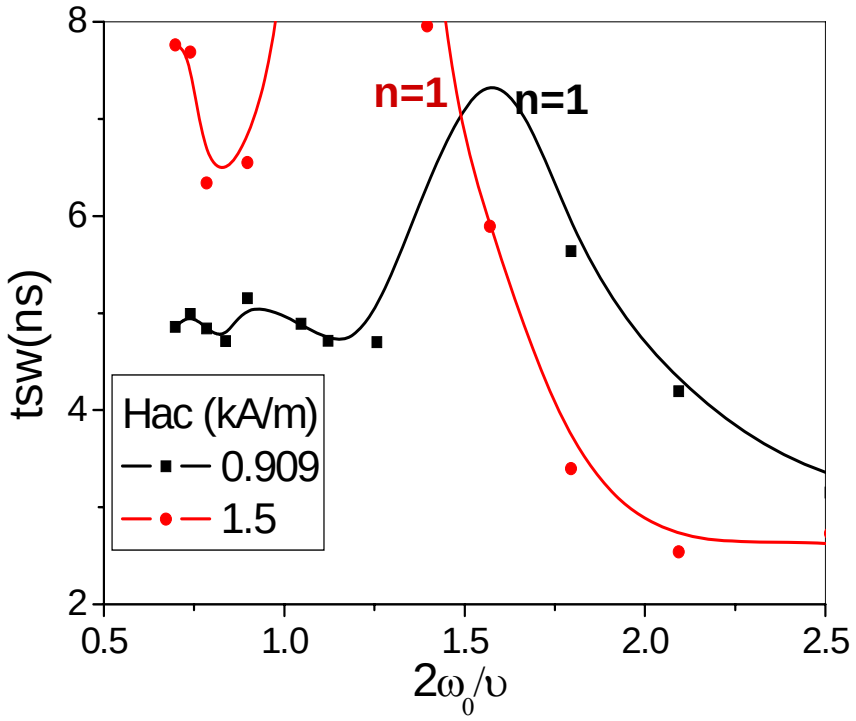


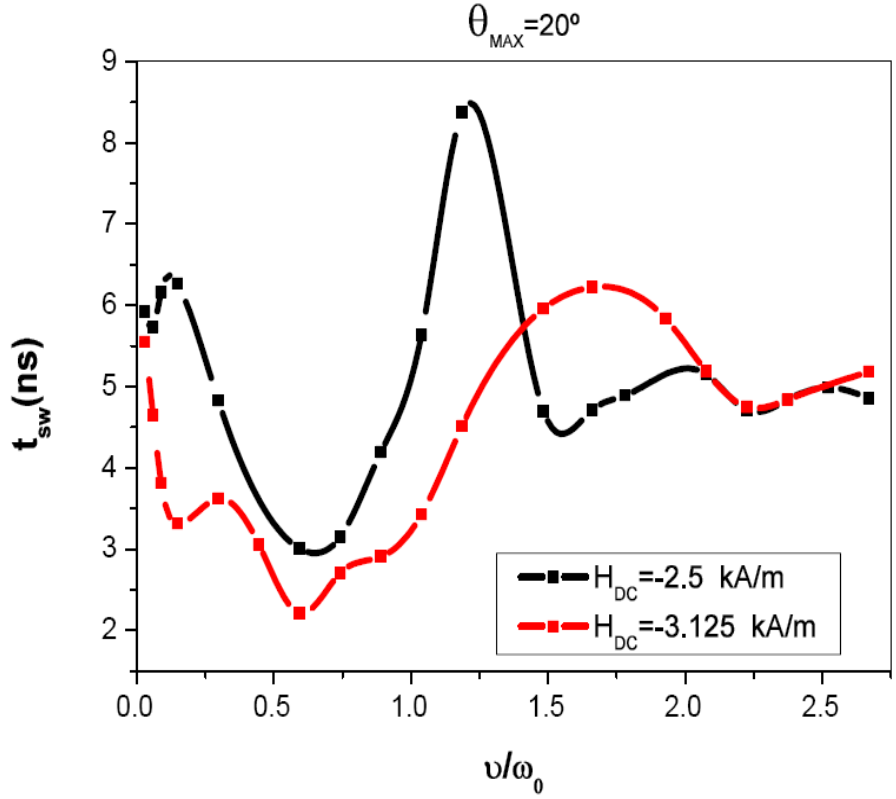
Resonant frecuencies and switching time

- **The resonant frequencies are shifted to smaller values due to nonlinear effects.**

$$\nu = 2\omega_0 \, I\, n - f(h_{ac}) \rightarrow \textbf{max}$$

ω_0 – resonant frequency in the opposite well





Conclusions

- Mw-assisted reversal requires less field due a different reversal mode

  - **Two vorteces + domain walls (static reversal)**
  - **Ripple structure (mw-assisted switching)**

- The phenomena in micron-size elements is complex and several phenomena play important role:

  - **Spin-wave generation leading to ripple structure.**
  - **Domain wall and vortex mobility and reversal.**

- Reversal time oscillates as a function of applied field and mw frequency.

  - **The switching time results from a competition between a fast nucleation and a fast relaxation.**
  - **The nucleation is efficient with FMR frequency in the upper well.**
  - **The domain wall mobility is suppressed at frequencies equal to 2 FMR frequency due to the fact that the mw energy almost totally goes to precession.**