Enhancement of magnetic domain wall velocity by oscillating magnetic fields

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Imec
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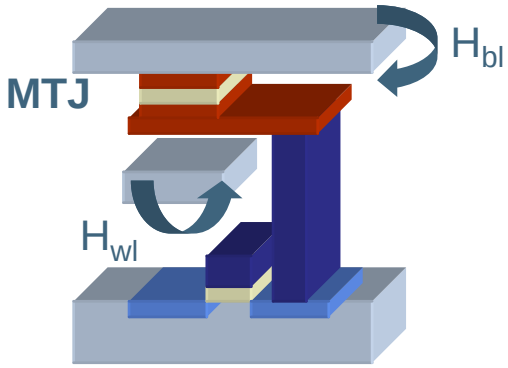
Spintronics: state of the art

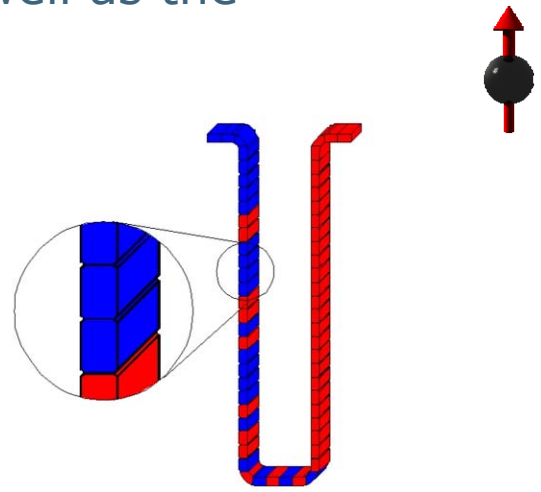
Spintronics: using the **spin** of the electron as well as the **charge** generates an extra degree of freedom!

Information manipulation & storage in magnetic memories & logic



IMEC

Information stored in stack of magnetic/nonmagnetic layers

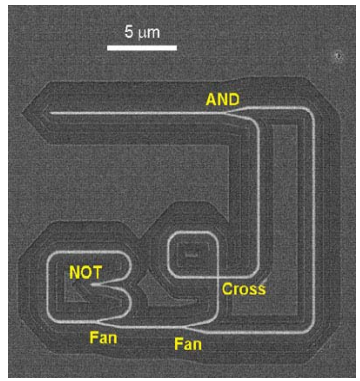


S. Parkin, Patent US 6,955,926 B2 (2005)

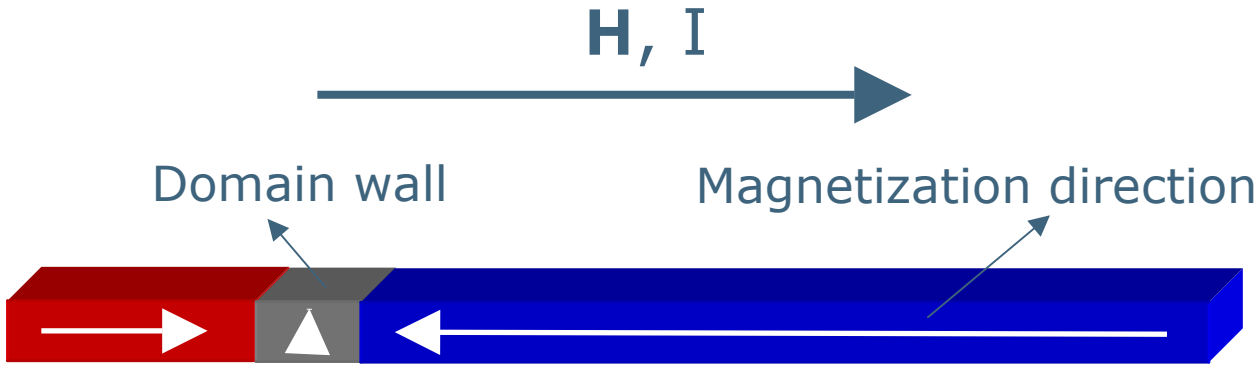
CI **movement** of **domains** rather than moving read head (hard disk)

D.A. Allwood et al., Science 309, 1688 (2005)

Information manipulation in ferromagnetic nanowires



Domain wall propagation & OOMMF



Domain wall = Transition between 2 domains
Propagation due to **exchange** interaction

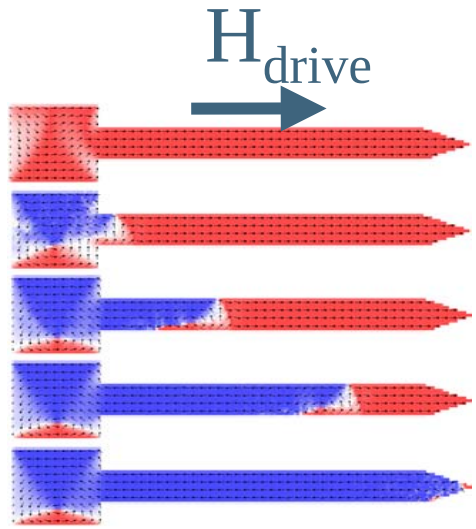
OOMMF (finite element model),

uses LLG equation:

$$\frac{d\vec{M}}{dt} = -\gamma.\vec{M} \times \vec{H}_{eff} + \frac{\alpha}{\left|\vec{M}\right|}\vec{M} \times \frac{d\vec{M}}{dt}$$

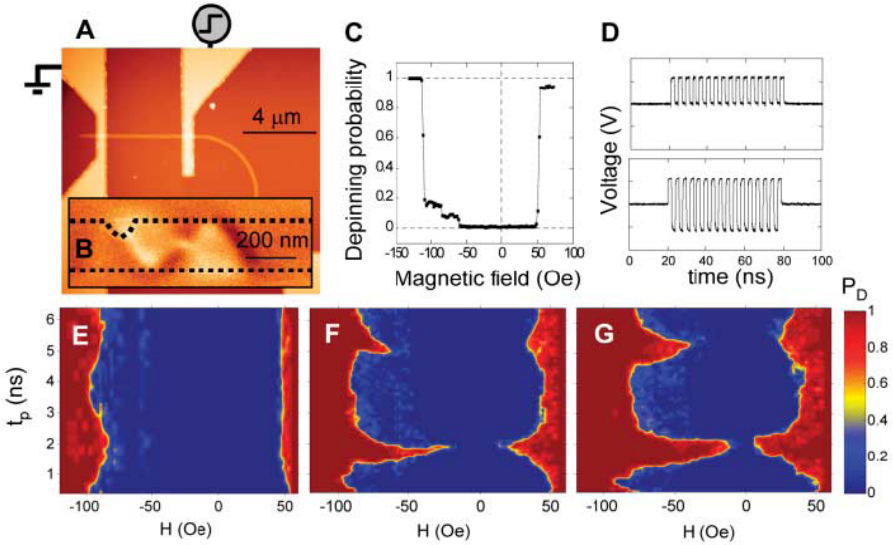
γ = gyromagnetic ratio

α = damping parameter



Current induced domain wall depinning

"Resonant amplification of magnetic domain wall motion by a train of current pulses"



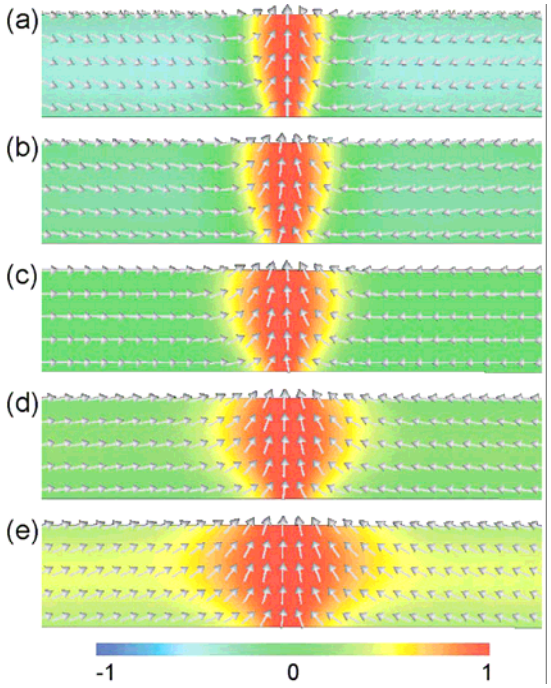
S. Parkin et al., Science 315, 1553 (2007)

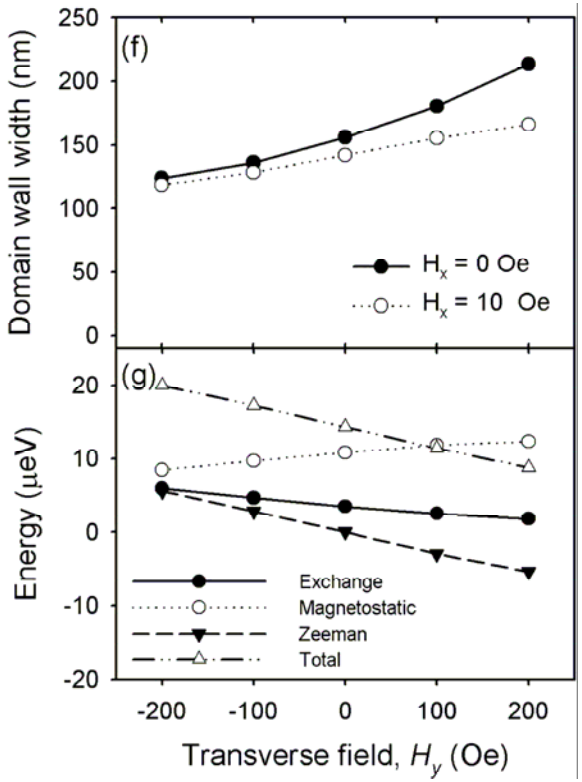
Current induced: **enhancement** of domain wall depinning

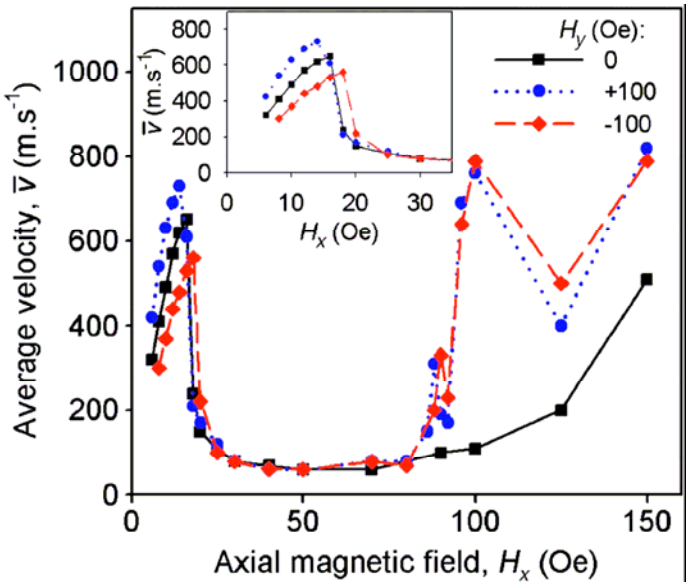
Train of current pulses at resonance frequency more easily depins DW than 1 large pulse

*Can we observe a similar effect in **field** induced measurements??*

DW propagation under transverse DC magnetic fields





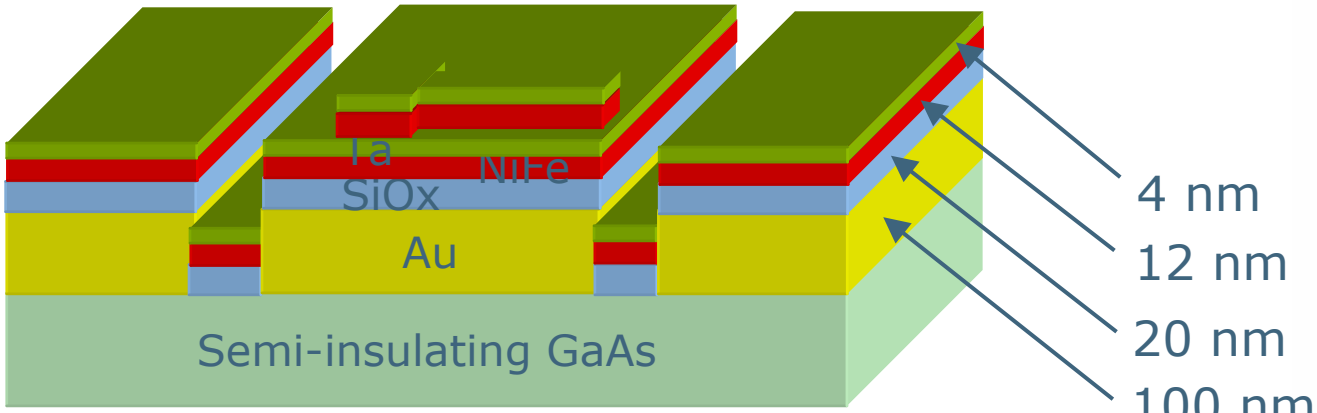


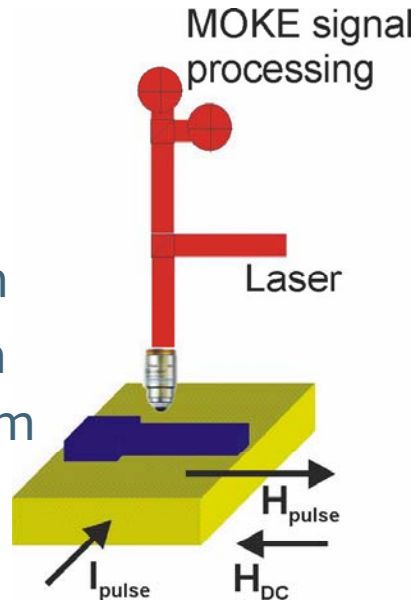
D. Allwood et al., JAP 103 (2008)

Field induced: depending on the sense of the transverse field, the DW velocity of a transverse DW either in- or decreases.

What if we apply a parallel high frequency field $\boldsymbol{H}_{RF}$*?*

Device processing & TRMOKE

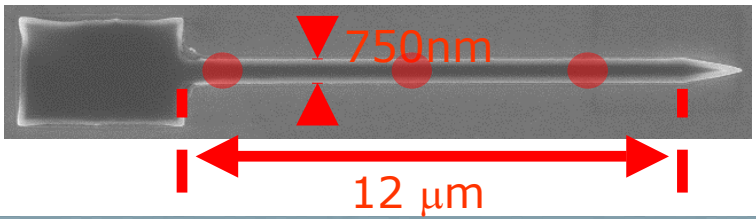


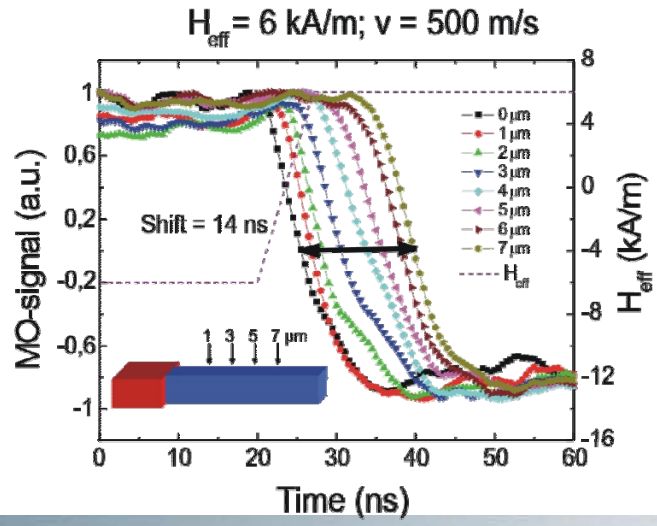


Optically defined Au coplanar waveguide on a GaAs substrate.

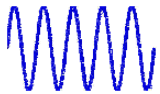
SiOx passivation layer

Nanowires are defined with ebeam lithography in negative resist and dry etching through the $Ni_{80}Fe_{20}$ and Ta.



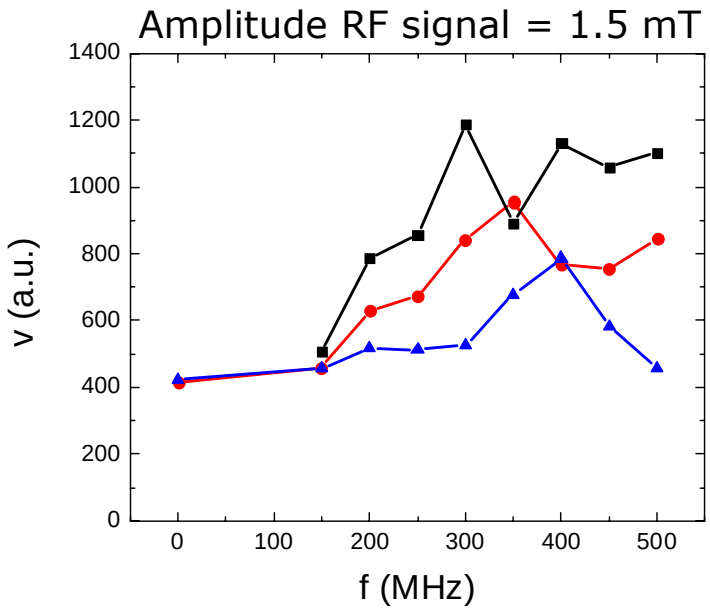


Experimental observations

$H_{reset\ (DC)}$ H_{pulse} + 

RF-signal superimposed
0 < f < 500MHz

$H_{drive} = H_{pulse} - H_{reset}$



Width = 1 μm,
H_{drive} = 4.5 mT

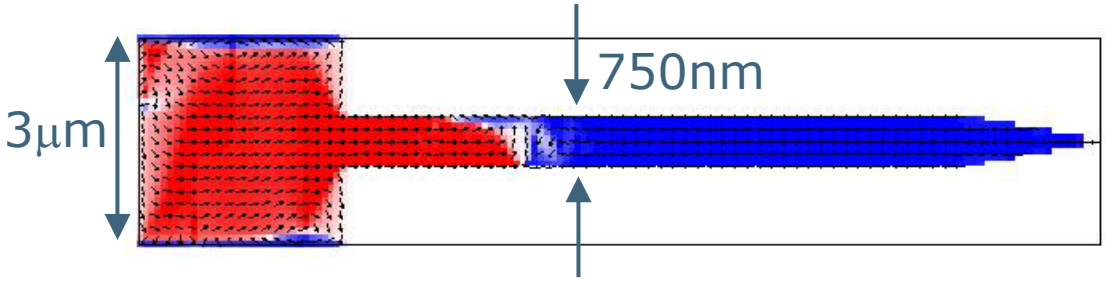
Width = 750 nm,
H_{drive} = 4.5 mT

Width = 750 nm,
H_{drive} = 5.25 mT

Enhancement of v_{DW} at resonance frequency

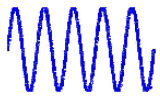
Frequency dependent on wire width and field amplitude.

What do simulations tell us?



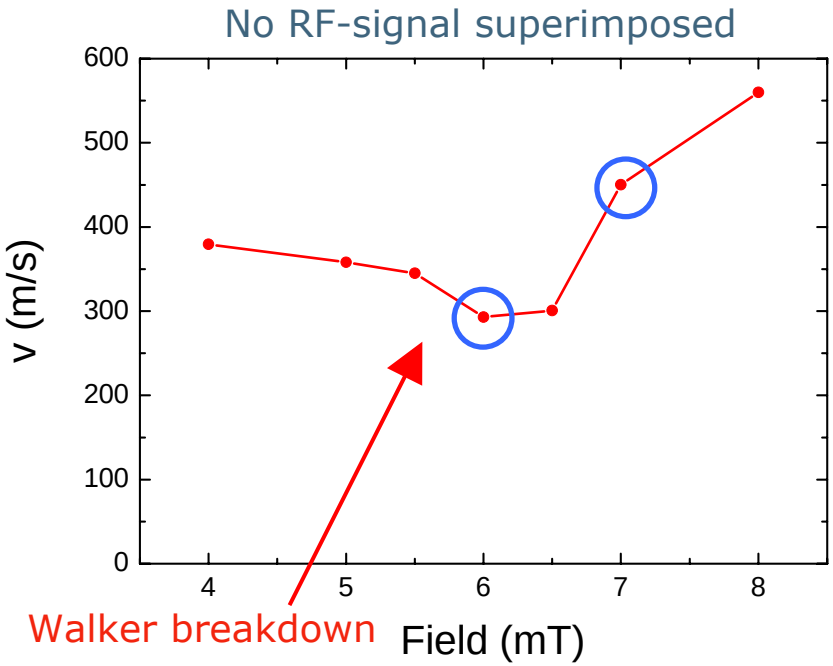
Py: 750nm wide, 12μm long, 12nm thick

H_{drive}

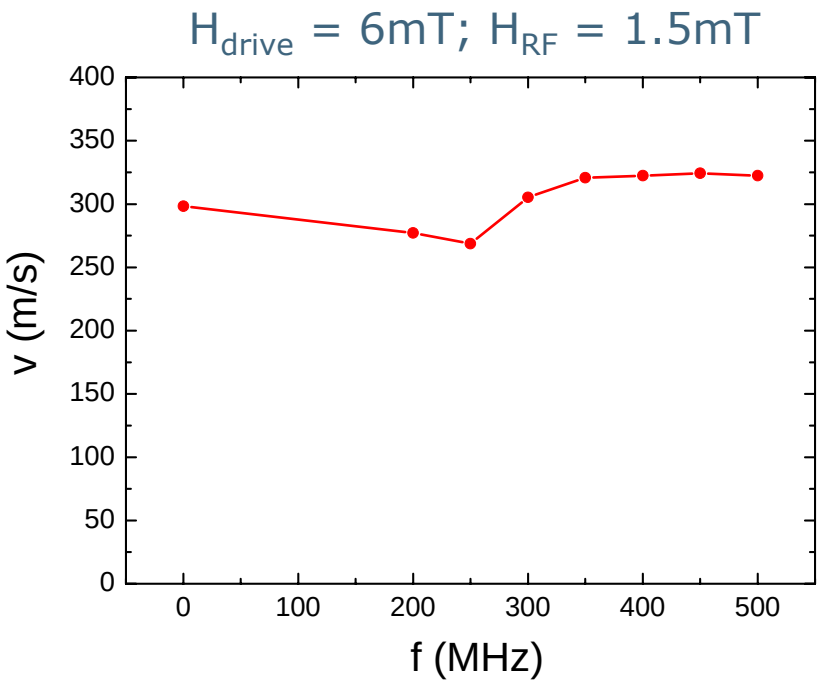


RF-signal superimposed

Scanning frequency:
0 < f < 500 MHz
-> influence on v_{DW}



Enhancement of DW velocity at H_{drive} = 6 mT

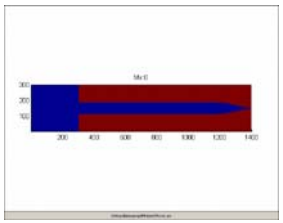


Increase in DW velocity is predicted at f > 300MHz

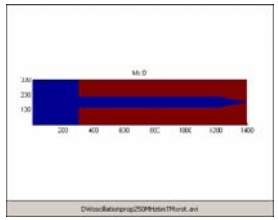
Changing DW shape observed

These effects are not observed at H_{drive} = 7 mT!

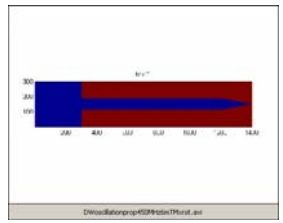
*Hypothesis: **H_{RF}** suppresses chaotic behavior at Walker breakdown??*



f = 0MHz



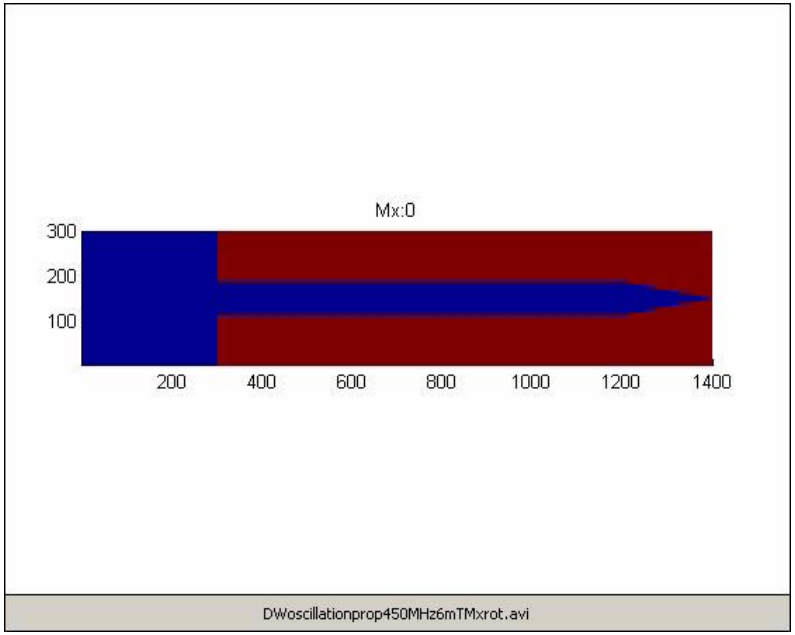
f = 250MHz



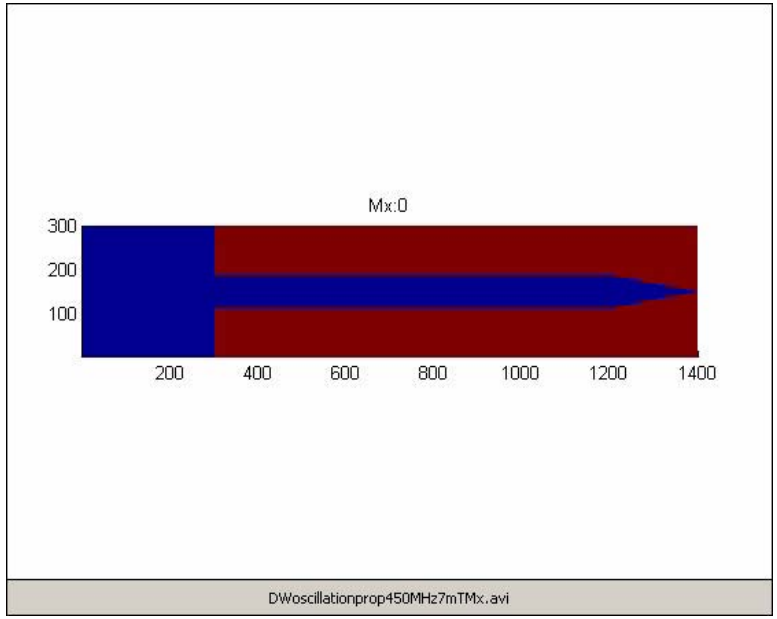
f = 450MHz

Difference between H_{drive} = 6 or 7 mT at 450MHz

6mT (at Walker breakdown)



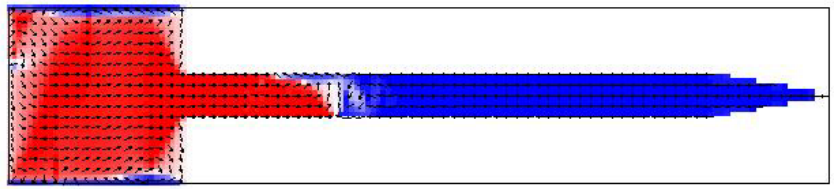
7mT (above $\mathbf{H}_W$)

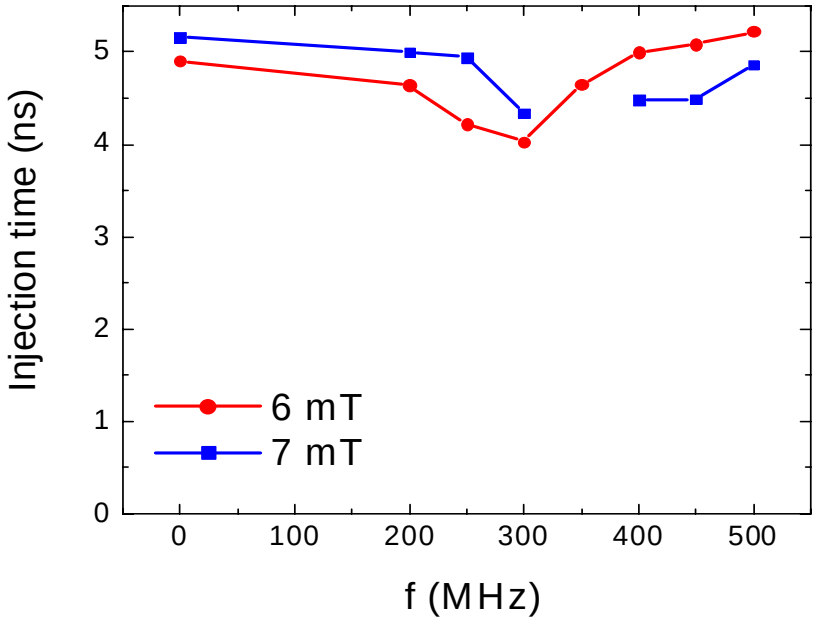


- *H_{drive} = 6mT and f_{RF} = 450MHz → steady DW propagation*
  enhancement of DW velocity
- *H_{drive} = 7mT and f_{RF} = 450MHz → DW oscillation*
  no enhancement observed

Influence on DW injection time

Frequency dependent DW injection time: faster at f ≈ 300MHz





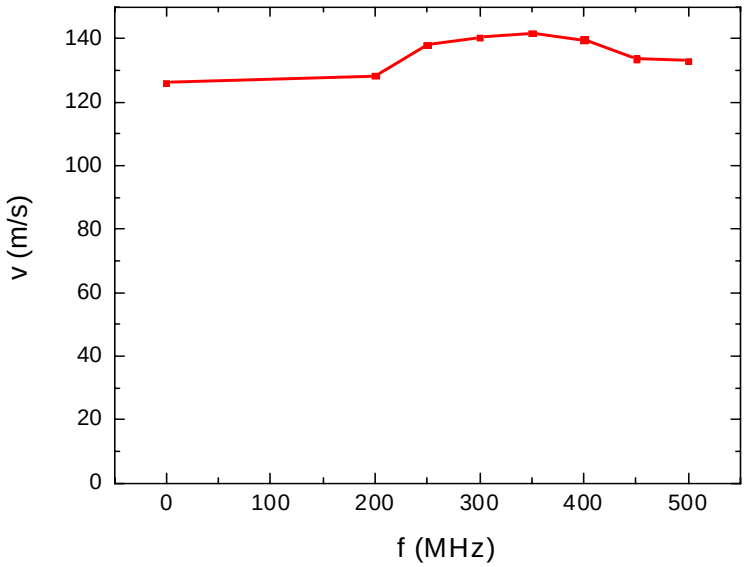
** Change in DW shape?*

** Dependent on nucleation pad geometry?*

→ closer look into simulations.

Second set of experiments

Amplitude RF signal = 1.5 mT



Width = 750 nm,
H_{drive} = 4.5 mT

Difficult to reproduce previous results:

* magneto-optical signal decreased
* sidewall-oxidation of nanowires, change in effective width

→ change in Walker breakdown field…

Conclusions & outlook

OOMMF simulations show:

* Change in DW velocity at Walker breakdown while applying an oscillating magnetic field

* DW injection time decreased by oscillating magnetic field

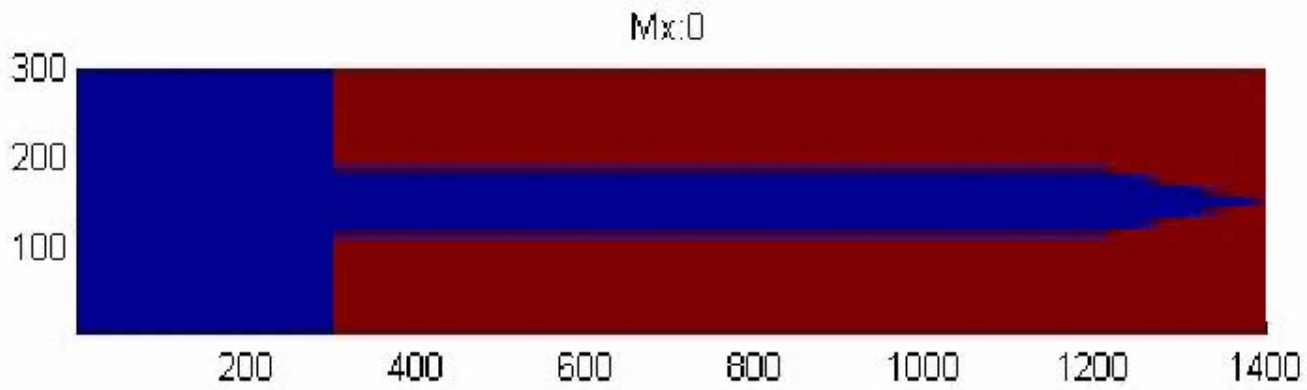
Outlook:

* Change in DW velocity below Walker breakdown??

* Experimentally verify influence of oscillating fields on DW injection time

* Fabrication of new set of samples

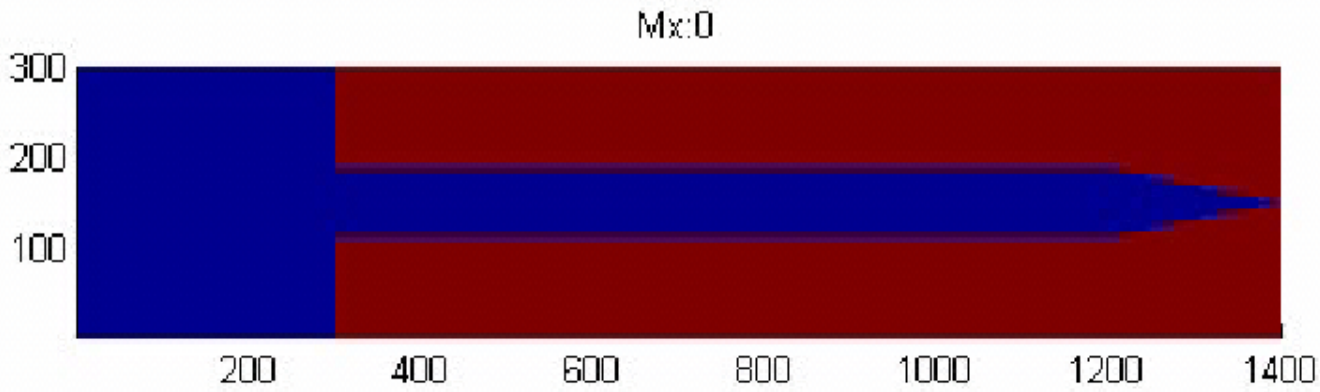

aspire invent achieve
imec



DWoscillationprop0MHz6mTMxrot.avi

Back

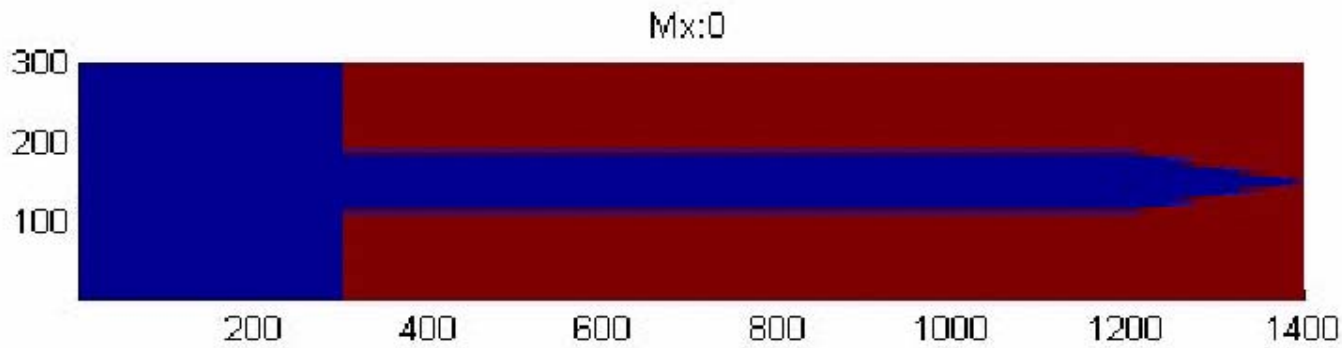
H_{drive} = 6mT; H_{RF} = 1.5mT; f = 0MHz



DWoscillationprop250MHz6mTMxrot.avi

Back

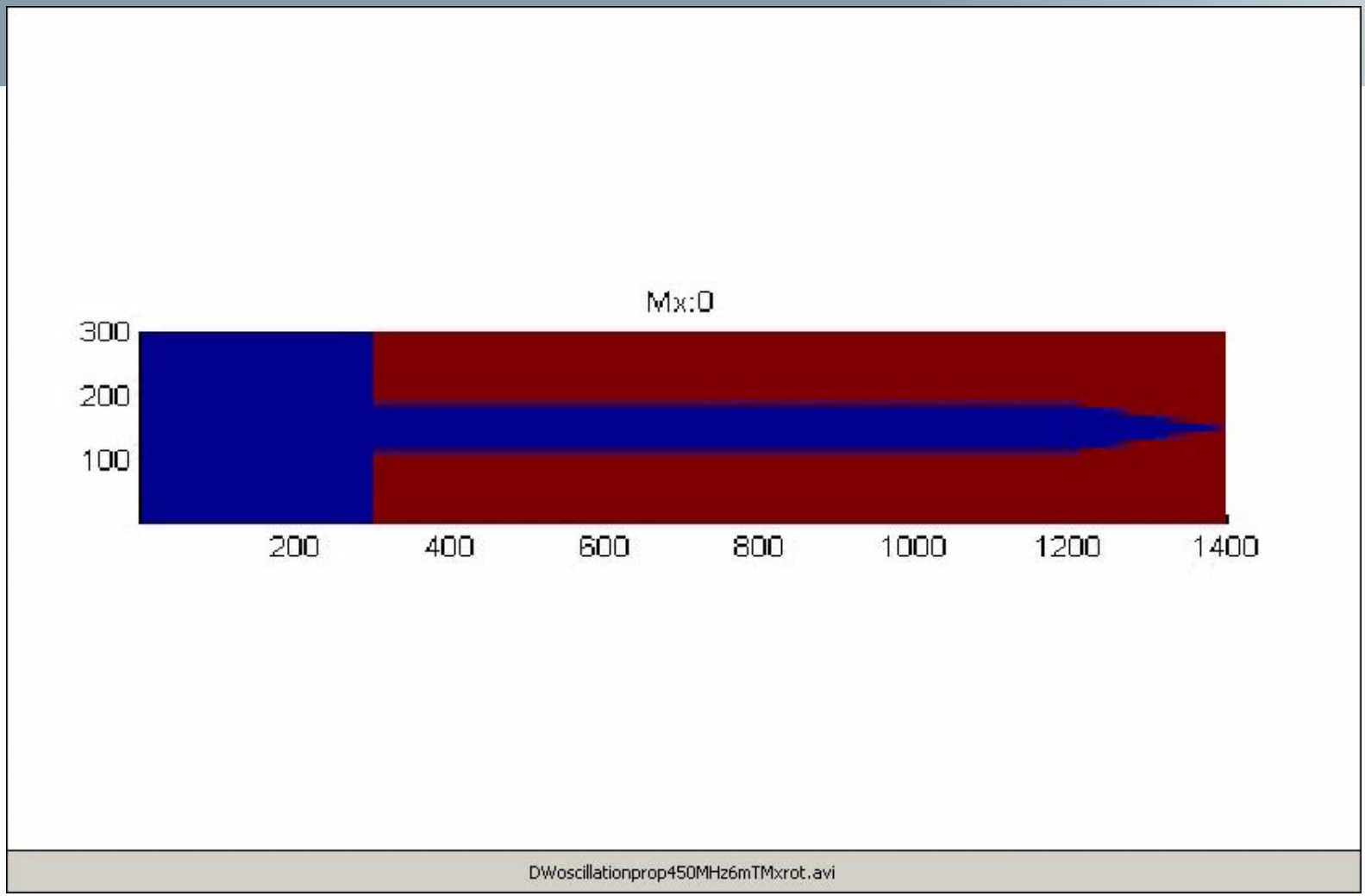
H_{drive} = 6mT; H_{RF} = 1.5mT; f = 250MHz



DWoscillationprop450MHz6mTMxrot.avi

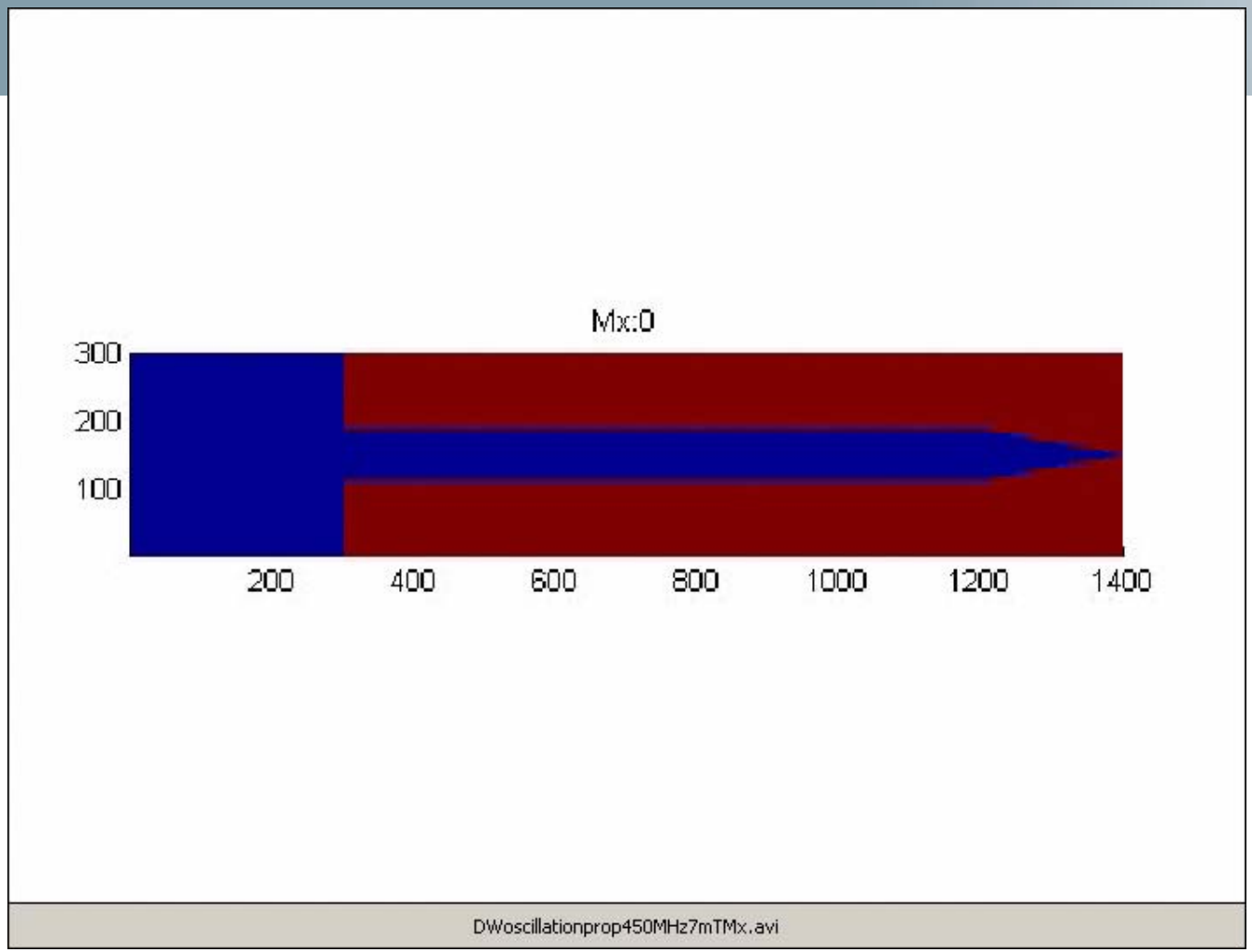
Back

H_{drive} = 6mT; H_{RF} = 1.5mT; f = 450MHz



Back

H_{drive} = 6mT; H_{RF} = 1.5mT; f = 450MHz



Back

H_{drive} = 7mT; H_{RF} = 1.5mT; f = 450MHz