Thermally Excited Ferromagnetic Resonance (TE-FMR) in Magnetic Tunnel Junctions (MTJs)

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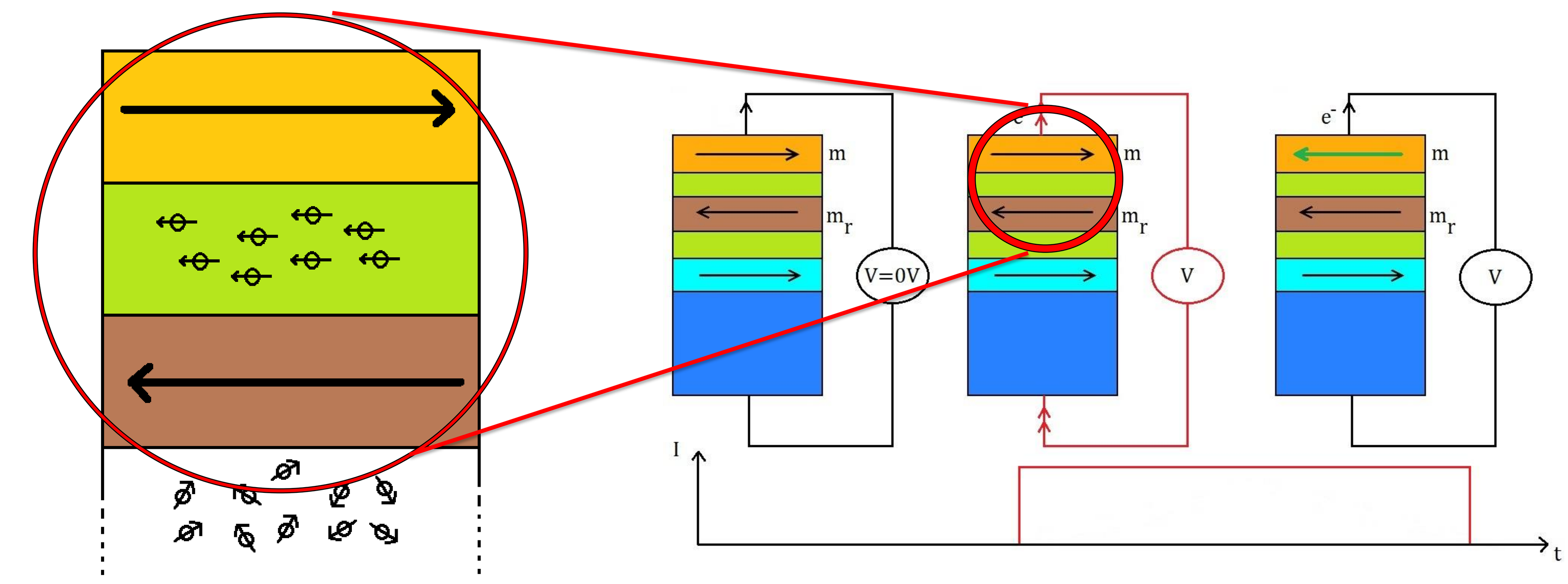
Motivation:

- A spin polarized current can exert a spin transfer torque to the magnetisation of a layer. [1]
- A better understanding of the magnetic behavior is required to achieve significant improvements in Magnetic Random Access Memory (MRAM) memories.
- Spin valve structure can act as a frequency tunable microwaves source or resonator whose output power is in the µW range [2]
- We present a way of measuring principal torque parameters in harmony with peer reviewed papers.

Spin Polarisation & Spin Transfer Torque (STT)



1. A current flowing through a polarized layer becomes spin polarized.

2. This current can transfer its polarization to the magnetisation of another layer and may switch it.

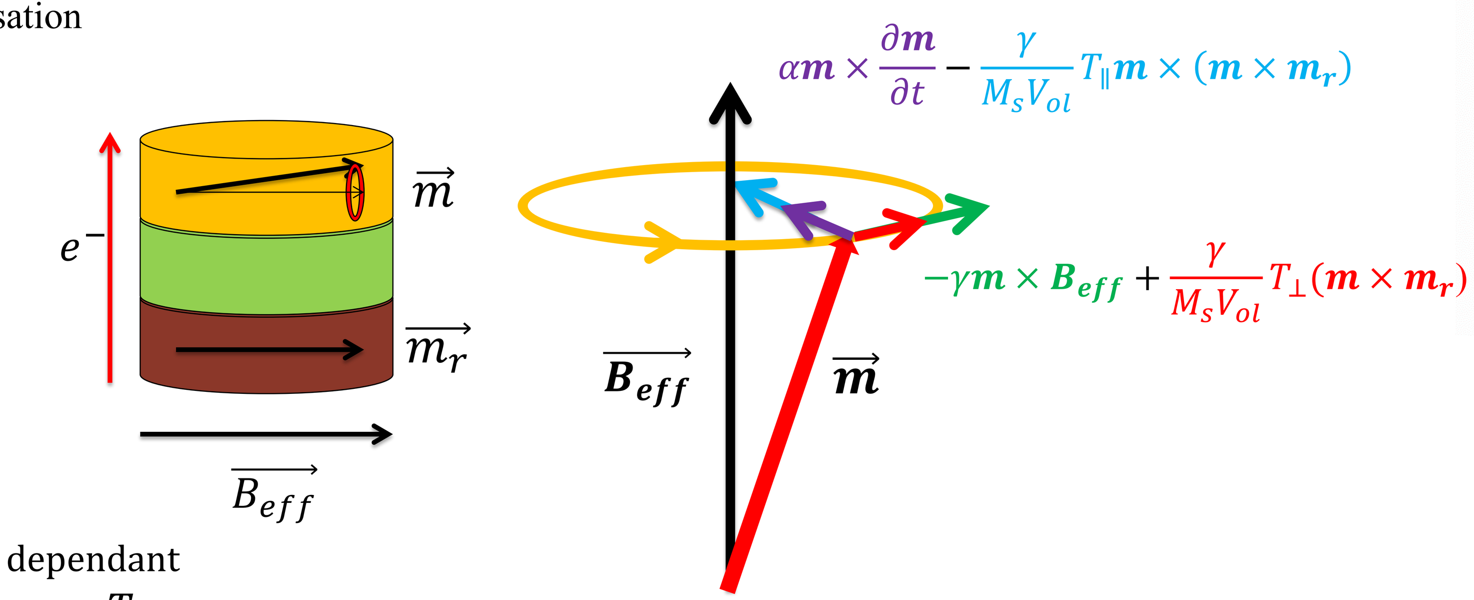
Landau-Lifshitz-Gilbert equation (LLG)

or how to describe the temporal magnetisation of a layer with both voltage and field applied ?

$$\frac{\partial \boldsymbol{m}}{\partial t} = -\gamma \boldsymbol{m} \times \boldsymbol{B_{eff}} + \alpha \boldsymbol{m} \times \frac{\partial \boldsymbol{m}}{\partial t} - \frac{\gamma}{M_s V_{ol}} T_{\parallel} \boldsymbol{m} \times (\boldsymbol{m} \times \boldsymbol{m_r}) + \frac{\gamma}{M_s V_{ol}} T_{\perp} (\boldsymbol{m} \times \boldsymbol{m_r})$$

Field torque | Damping | Spin Parallel Torque (damping like) | Perpendicular torque (field like)

V_{ol}= Volume of the free layer
M_s=saturation magnetisation
α= damping factor



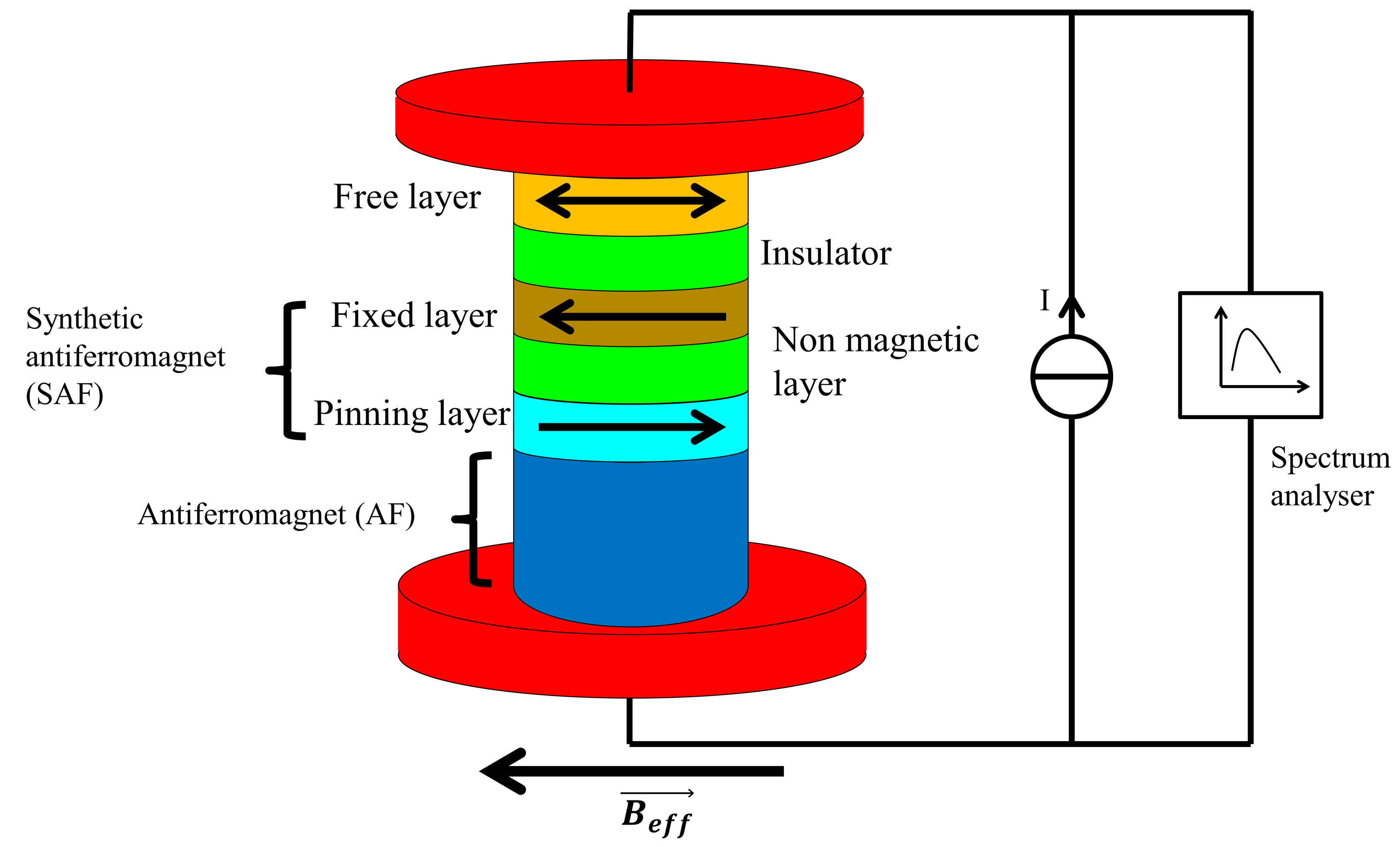
$T_{\parallel}$ and $T_{\perp}$ are voltage dependant

If we set : $a_{\parallel} V = \frac{T_{\parallel}}{M_s V_{ol}} = B_{\parallel}$

$a_{\perp} V^2 = \frac{T_{\perp}}{M_s V_{ol}} = B_{\perp}$

How to derive the parallel and the perpendicular torque parameters : $a_{\parallel}$ and $a_{\perp}$?

Spin-Valve structure and TE-FMR setup:

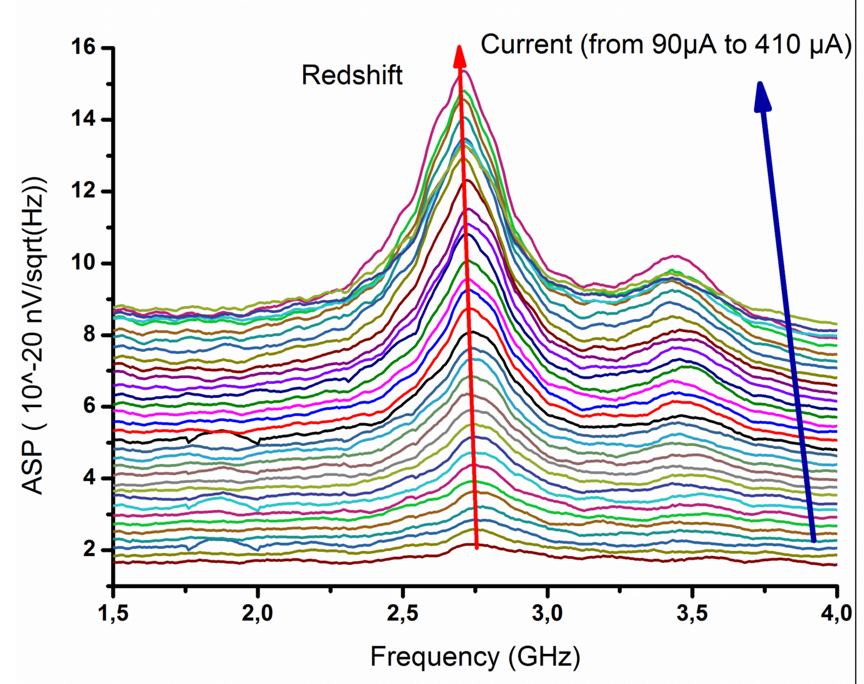


Method & Results

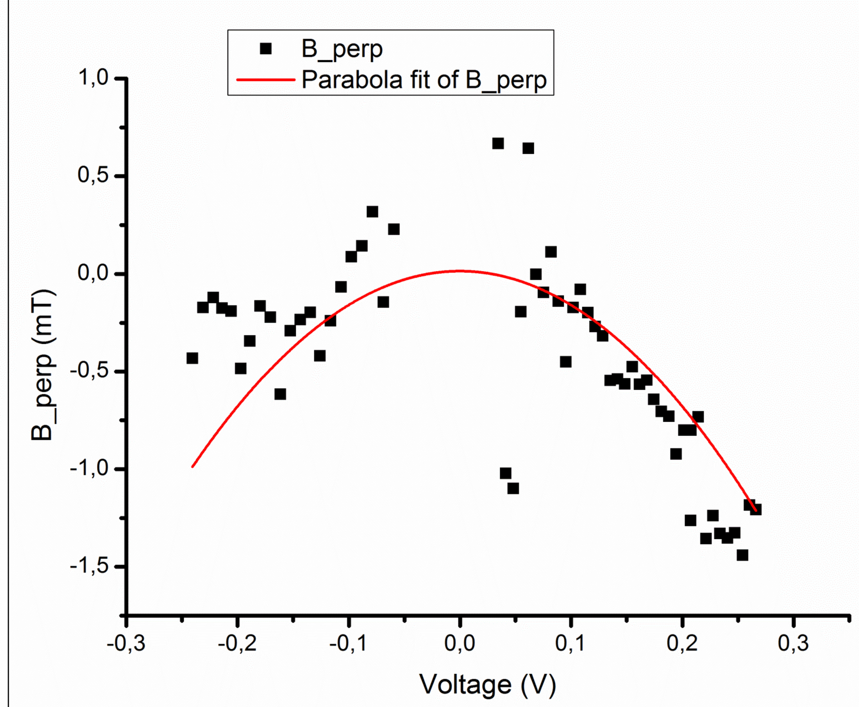
1. The resonance frequency and the width of the peak depend respectively on the perpendicular and parallel torque.

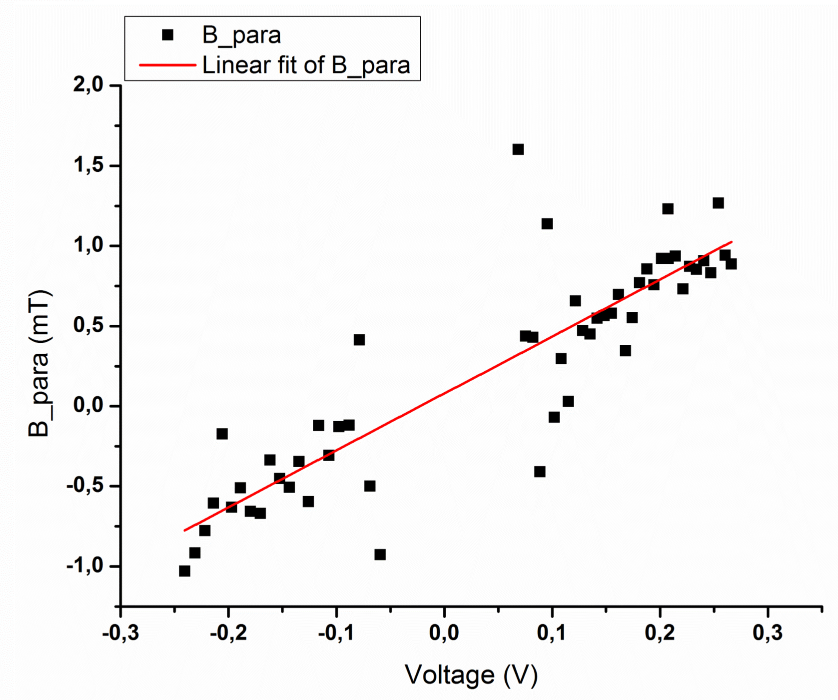
$$f = \frac{\gamma}{2\pi}\sqrt{\left(B_{eff} + \frac{T_{\perp}}{M_s Vol}\right)\left(B_{eff} + \frac{T_{\perp}}{M_s Vol} + \mu_0 M_s\right)}$$

$$\Delta f = \frac{\gamma}{2\pi}(2B_{eff} + \mu_0 M_s) + \frac{\gamma}{2\pi} \frac{T_{\parallel}}{M_s Vol}$$



2. From those formulas we can extract $B_{\perp}$ (from the peak position) and $B_{\parallel}$ (from the width of the peaks) as a function of the voltage.





From $a_{\perp} V^2 = \frac{T_{\perp}}{M_s V_{ol}} = B_{\perp}$

$T_{\perp}$=7,07 × 10^{-20} J/V^2

From $a_{\parallel} V = \frac{T_{\parallel}}{M_s V_{ol}} = B_{\parallel}$

$T_{\parallel}$=1,45 × 10^{-20} J/V

In harmony with paper [2] where $T_{\perp}$=20,9 × 10^{-20} J/V^2 and T=2,79 × 10^{-19} J/V was derived with the same method from similar structures.

Summary:

- The torque parameters were derived from a TE-FMR measurement and are in good agreement with the paper [1].
- Uncertainty for B_{eff} because it is composed of anisotropy, coupling, oersted, coercive and external fields.
- Difficult to measure accurate values for M_s which can lead to errors in the final measurement.

References:

[1] M. D. Stiles, A. Zangwill *Anatomy of spin-transfer torque.* PHYSICAL REVIEW B 66, 014407 ~2002

[2] Alina M. Deac et al. *Bias-Driven high-power microwave emission from MgO-based tunnel magnetoresistance devices*, nature physics, VOL 4, October 2008

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