



# Microwave detection based on magnetoresistance effect in spintronic devices

**Witold Skowroński**, Monika Cecot, Sławomir Ziętek, Tomasz Stobiecki,  
AGH University of Science and Technology, Kraków, POLAND  
Jerzy Wrona

Singulus Technologies AG, Kahl am Main 63796, GERMANY

Kay Yakushiji, Takayuki Nozaki, Hitoshi Kubota, Shinji Yuasa

Advanced Institute of Industrial Science and Technology (AIST), Tsukuba, JAPAN

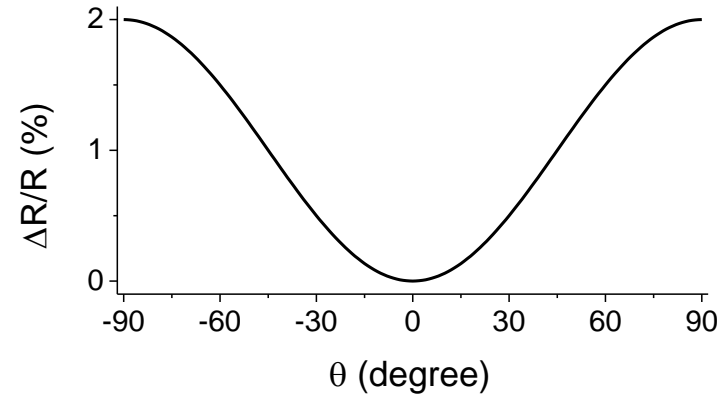
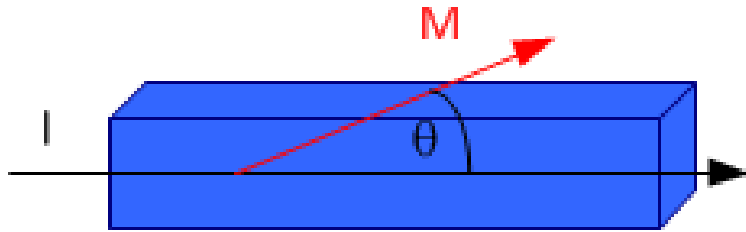


- Magnetoresistance effects:
  - AMR, GMR, TMR
- Spin torque effect
- Spin-diode effect
- Experimental details
- Microwave detection based on spintronic devices

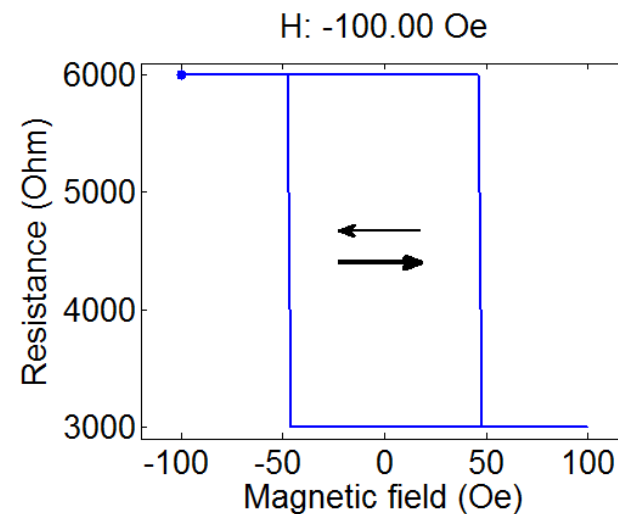
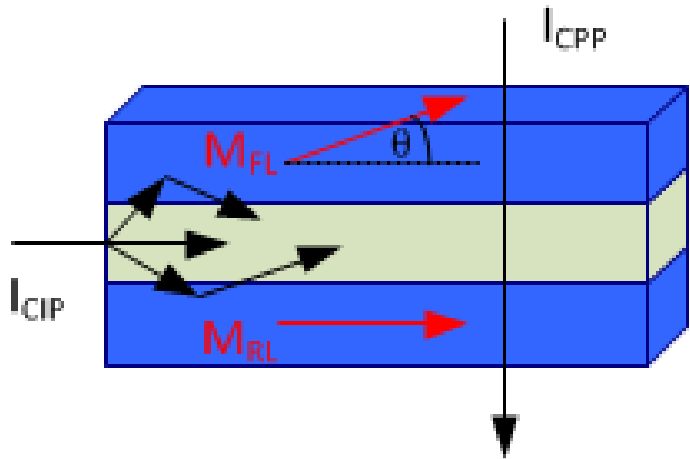
# Magnetoresistance



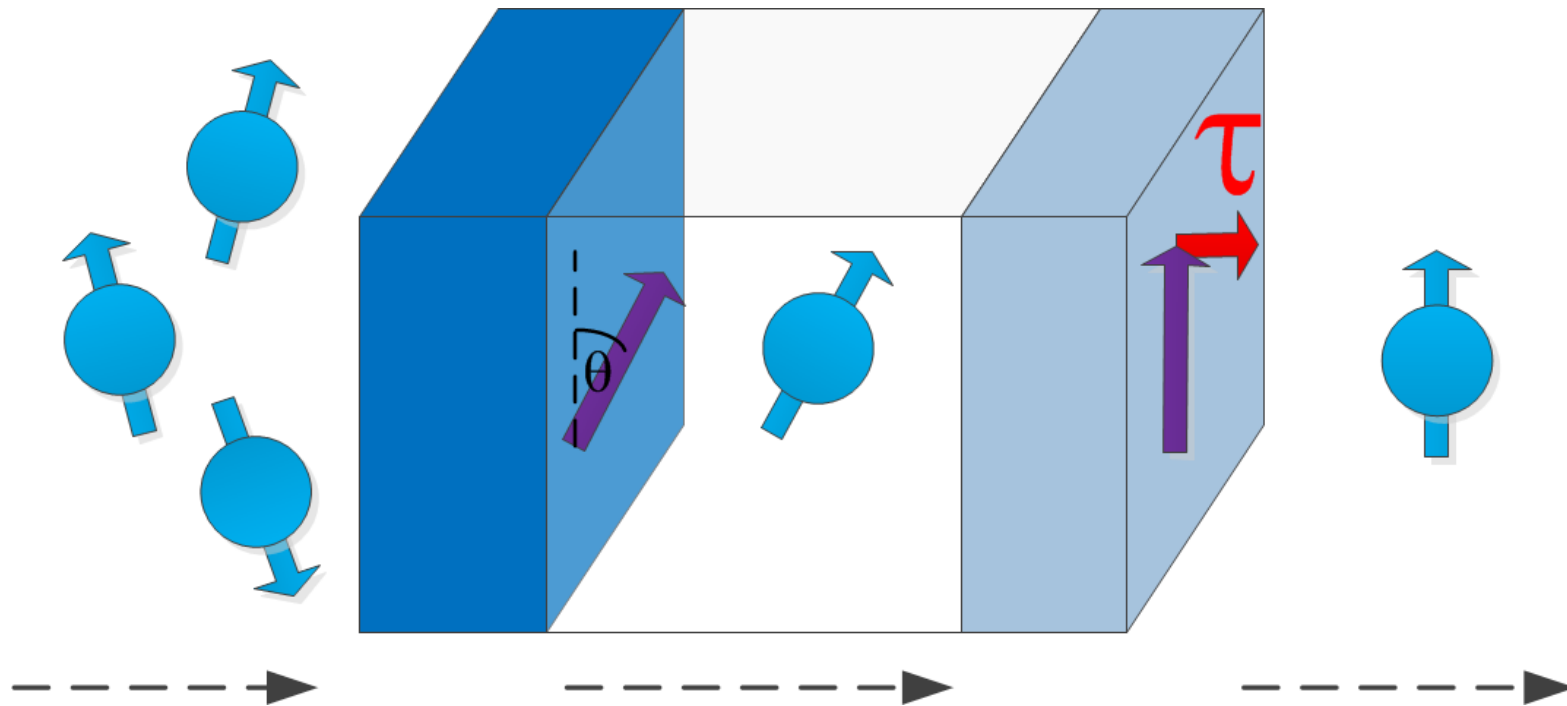
AMR:



GMR/TMR:



# Spin transfer torque

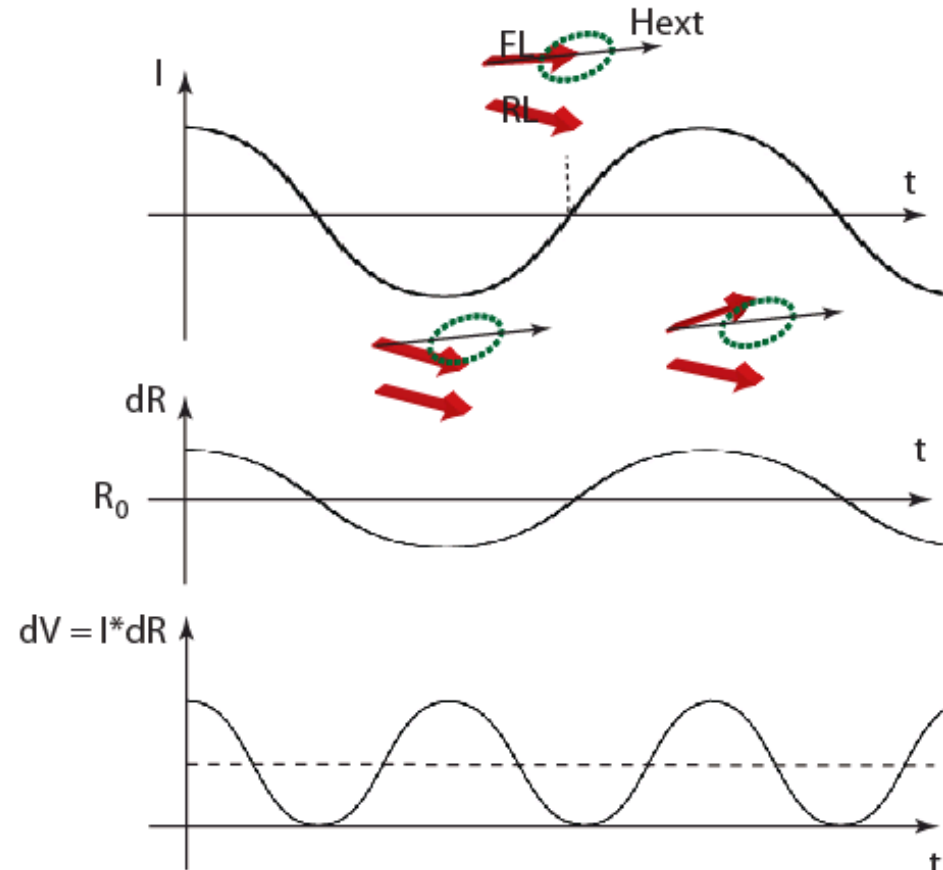


*Slonczewski JMMM 158, L1 (1996)*

*Berger PRB 54, 9353 (1996)*

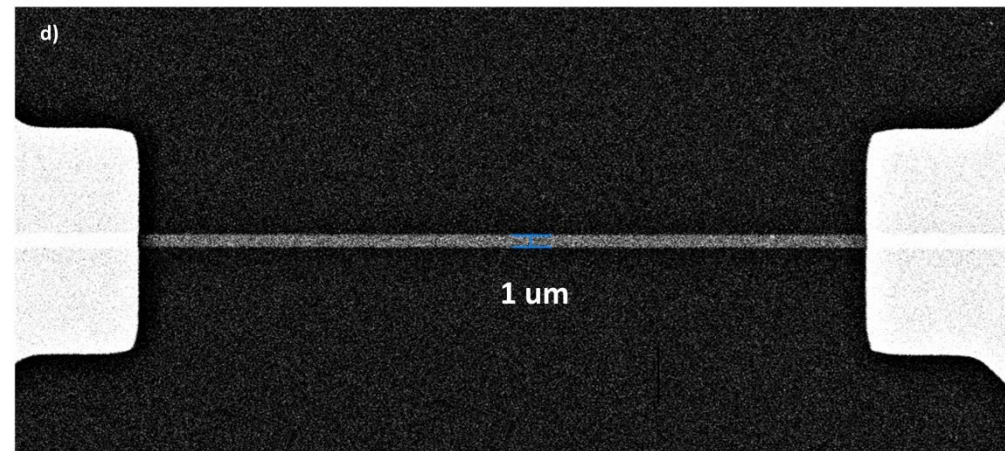
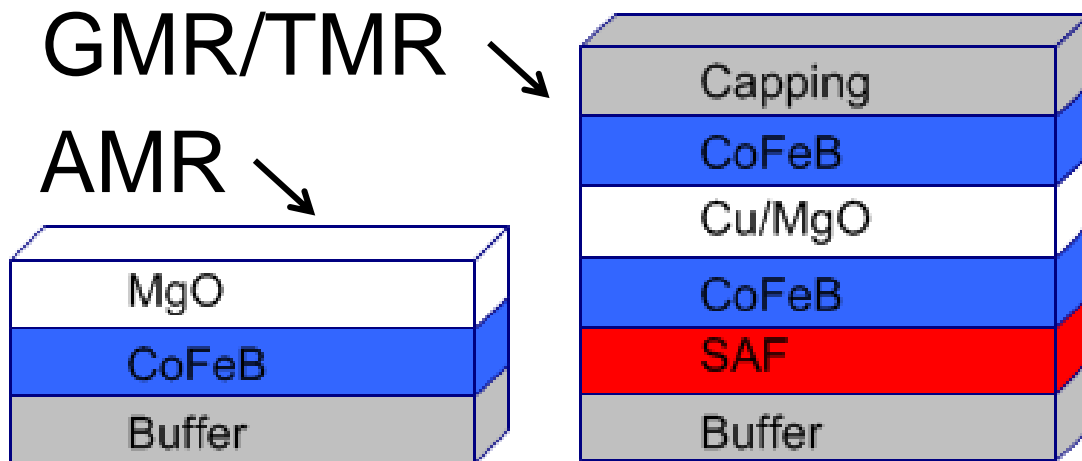
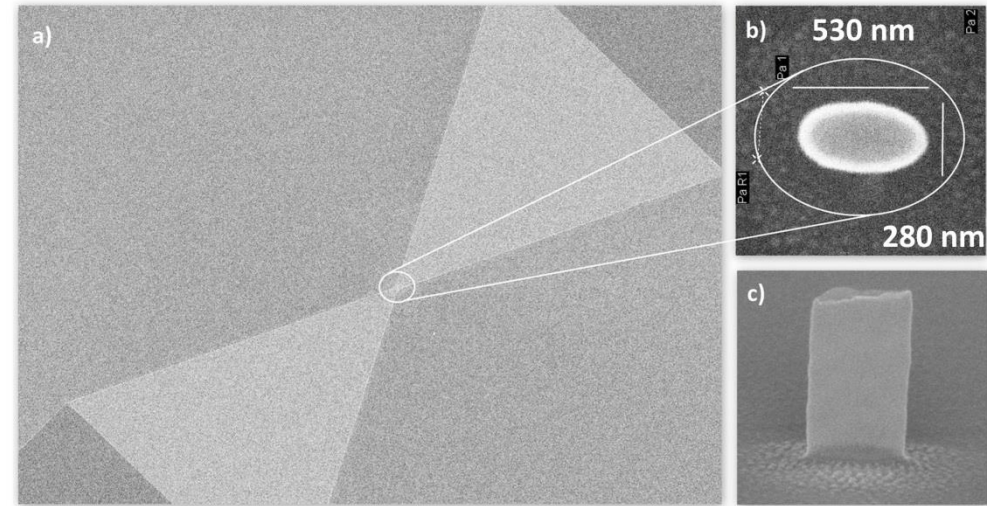


- MR device supplied with RF current
- In the resonance (typically a few GHz) magnetization oscillates
- Mixing of RF current and alternating R produces DC voltage



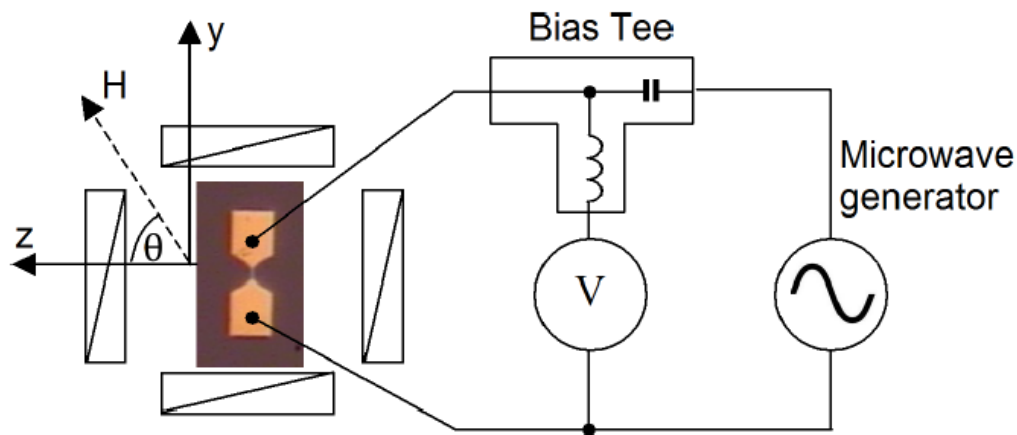
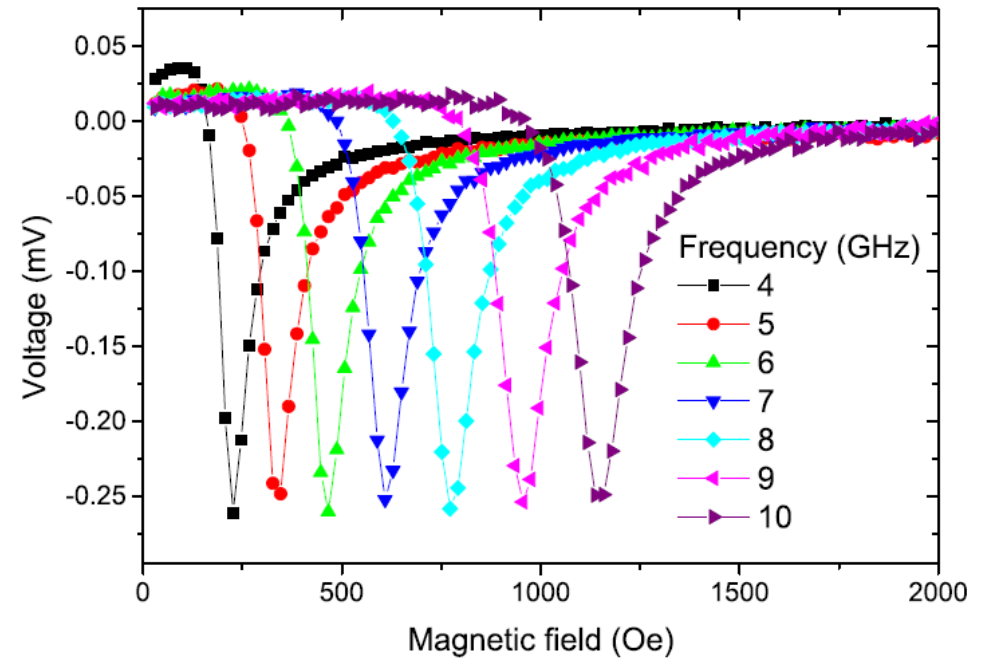


Thin film multilayer structure deposited by means of magnetron sputtering on Si. Microfabrication using e-beam lithography.



# AMR stripe

- AMR up to 0.5%
- Input power  $P = 10$  dBm  
 $P_{\text{eff}} = 0.87$  mW
- Sens = 0.3 V/W



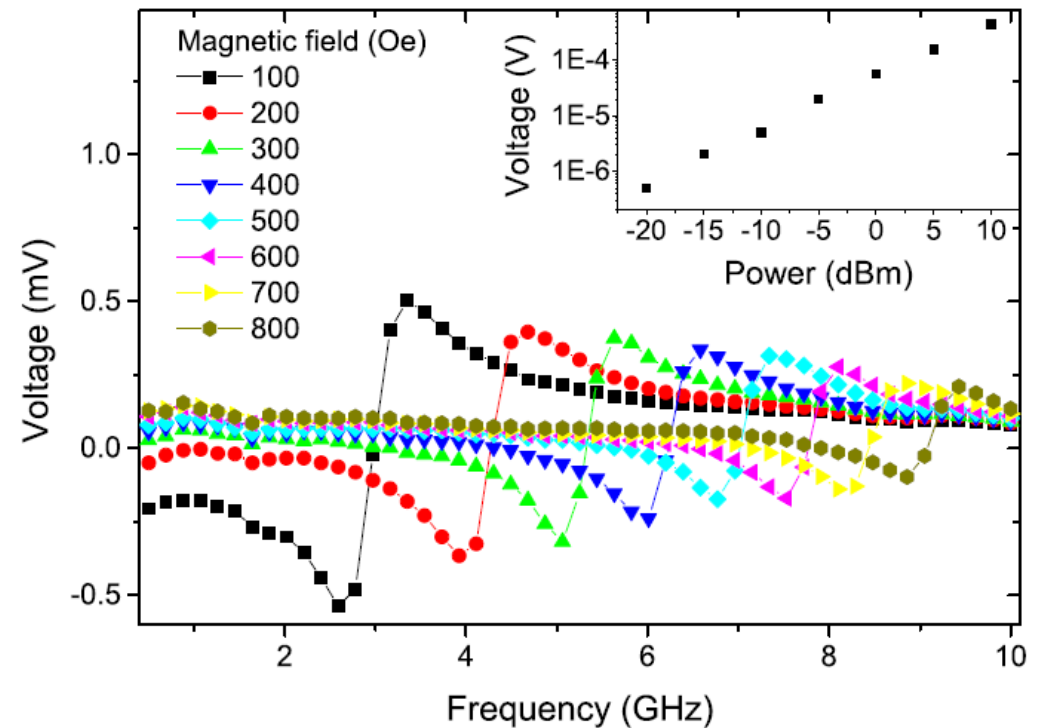
*W. Skowroński et al. arxiv 1537726 (2016)*

*S. Ziętek et al. PRB 91,014430 (2015)*





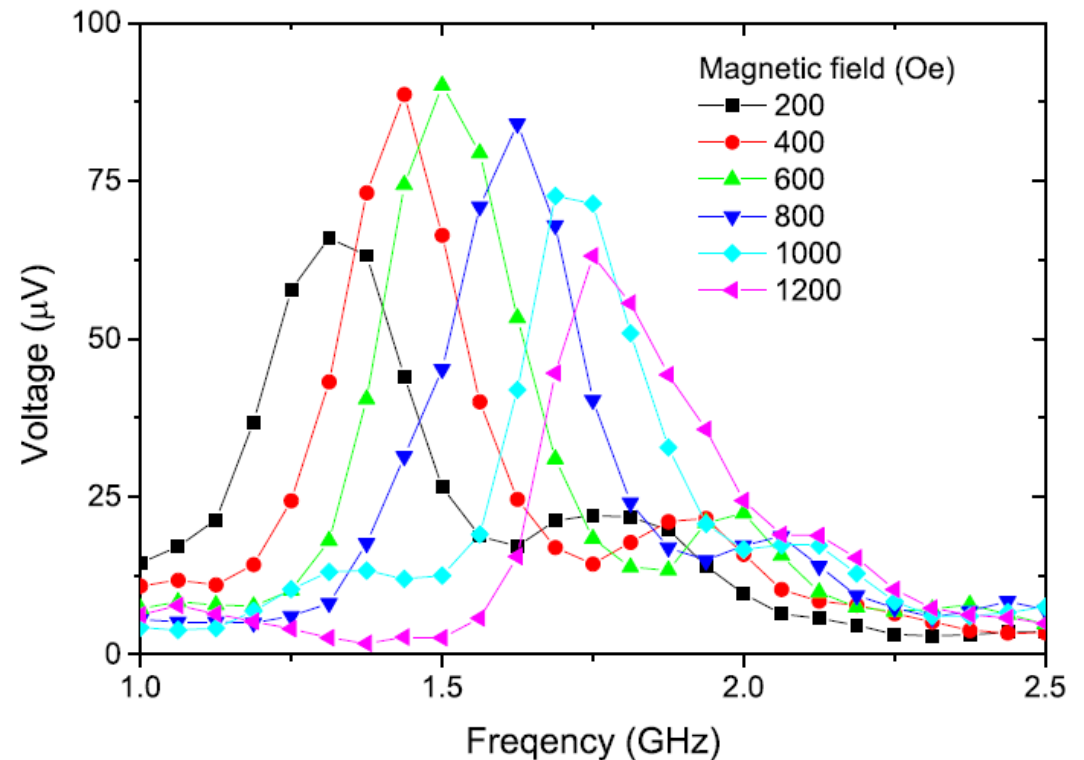
- GMR = 8%,  $P_{\text{eff}} = 3 \text{ mW}$
- Sensitivity = 2.5 V/W
- Wide dynamic range from -20 up to 10 dBm
- Asymmetric shape due to magnetic field-induced precession







- TMR = 100%,  $P_{\text{eff}} = 1.1 \mu\text{W}$
- Effective voltage limit to 1 V due to tunnel barrier breakdown
- Up to 86 V/W sensitivity
- Electric-field tunability of the detection frequency

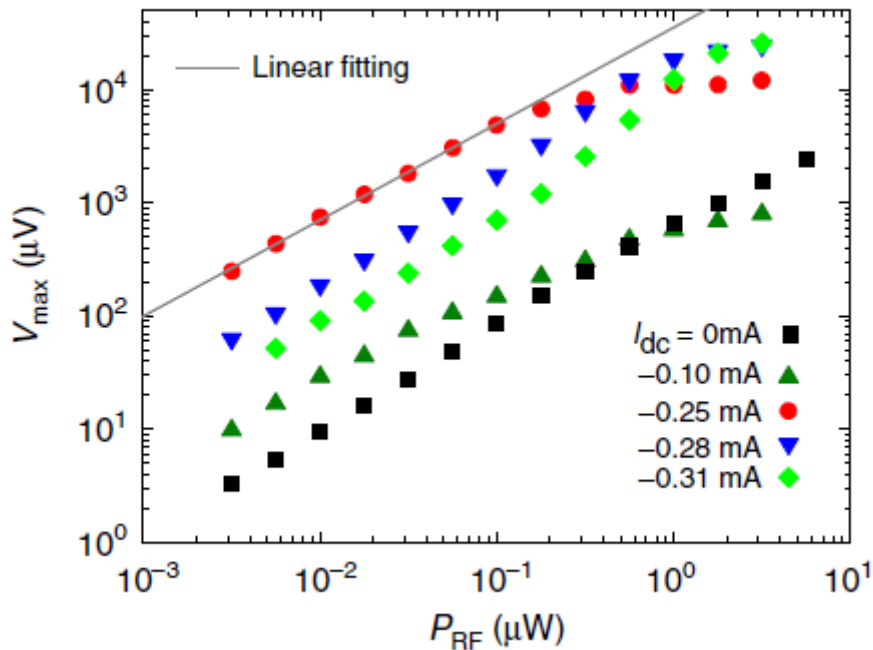


W. Skowroński et al. *APL* 105, 072409 (2014)

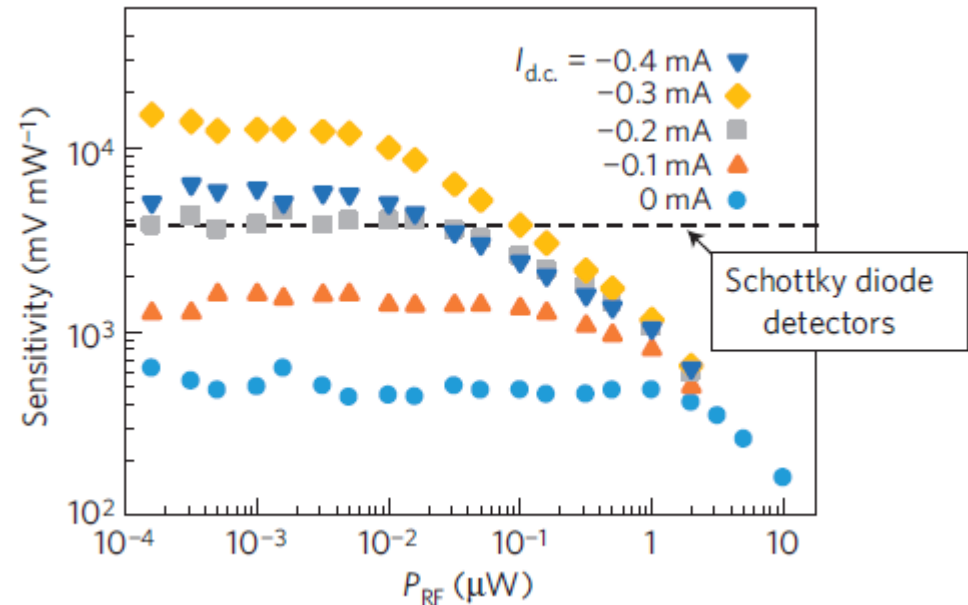


- Optimized FL precession cone angle
- Electrical bias applied during detection

a



b



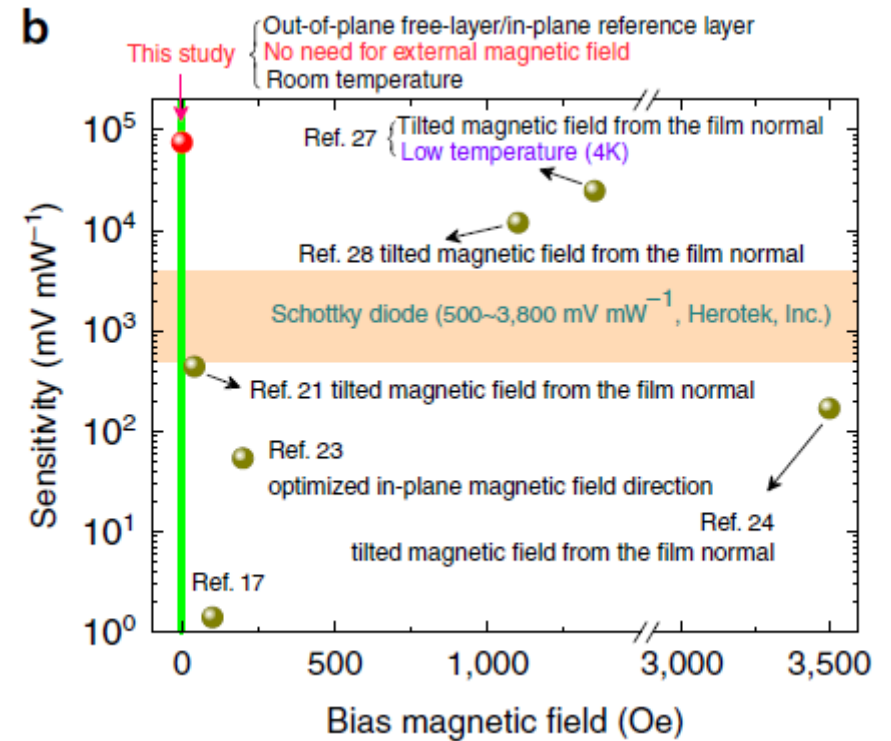
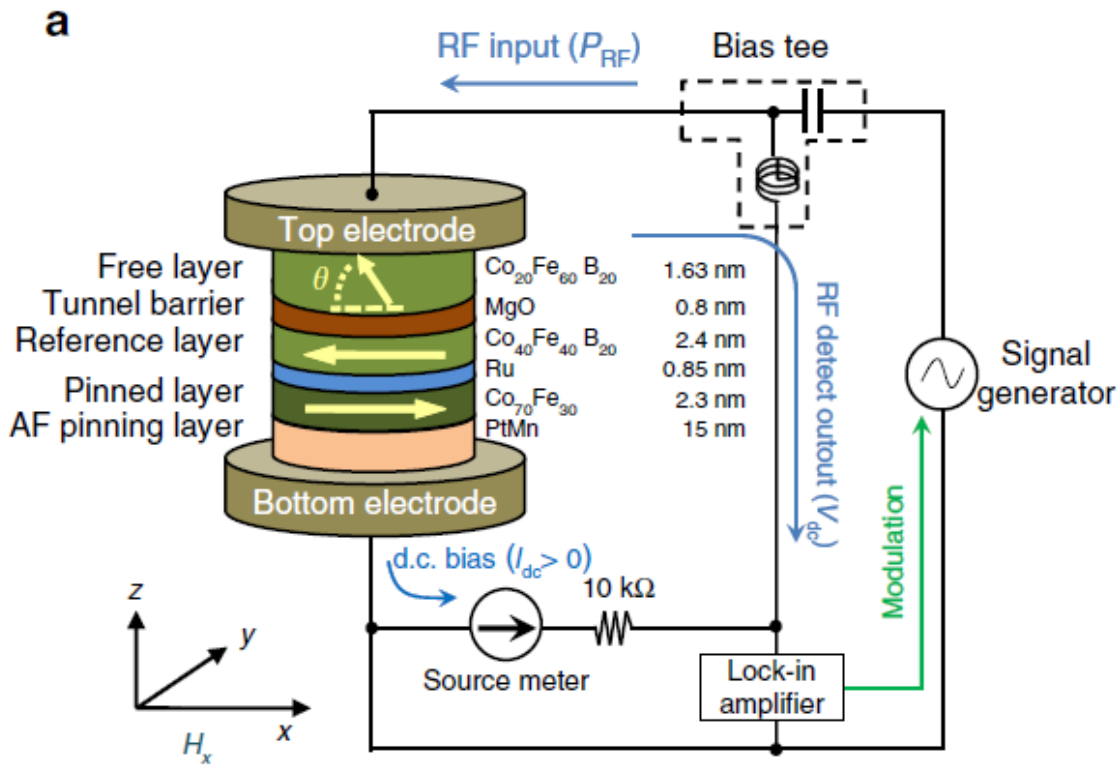
B. Fang et al. *Nature Comm.* 11259, 1 (2016)

S. Miwa et al. *Nature Mater.* 13, 50 (2014)

# Field-free operation



- Standard MTJ configuration with CoFeB



B. Fang et al. *Nature Comm.* 11259, 1 (2016)



- Magnetoresistance and spin diode effects used for detection
- Resonance frequency typically in GHz range
- Sensitivity spans from  $0.3 - 10^5$  V/W depending on the device structure, electrical bias, magnetic field
- At low input power and without magnetic field potential usage in energy harvesting

# Acknowledgements



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Thank you.