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# Current-induced asymmetric magnetoresistance via (quantum?) spin flip scattering

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#### Finding of Asymmetric magnetoresistance

#### We were trying DW motion by spin Hall effect.

- we measured AMR to check Hs and how high current we can apply.









Further increase above threshold current





Negative asymmetric MR for Ta Ta has negative spin Hall angle. No effect by Cu insertion Cu is transparent to spin current.

Spin Hall effect seems to relate to this MR.



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## Unidirectional spin Hall magnetoresistance in ferromagnet/normal metal bilayers

Can Onur Avci<sup>\*</sup>, Kevin Garello, Abhijit Ghosh, Mihai Gabureac, Santos F. Alvarado and Pietro Gambardella<sup>\*</sup>



The authors attributed this effect to spin accumulation. We observed phenomena that cannot be explained by spin accumulation.





Anomalous increase of asymmetric MR with temperature! Cannot be explained by spin accumulation. Magnon scattering?! Magnons generated by STT?



#### Does this MR originate from magnon scattering produced by STT ?



 Simulation cannot explain the linear dependence for lower current. It can explain only the increase above threshold.
Something happens before STT-induced magnetization oscillation.







- Time scale of asymmetric MR > several ns "cannot be explained by spin accumulation"
- Experiment shows the monotonic decrease of τ with J, while simulation based on STT shows a peak at Jc.





- Current-induced Joule heating < 1ns</p>
- Temperature rising time is independent of current density.

The time scale for asymemtric MR is longer than 1ns and depends on current.

Thermoelectric effect is not the origin of asymmetric MR.

We propose the mechanism via spin-flip process.



### dc current-induced magnon excitation via spin-flip process





- (1) Magnons generated by spin-flip process.
- (2) Conduction electrons are scattered by magnons.(3) Asymmetric MR
  - Asymmetric MR shows cosine dependence.
  - Asymmetric MR becomes maximum when **o** and **S** are antiparallel.

#### Angle dependences are consistent with the spin-flip mechanism.







11



Spin-flip mechanism can explain J dependence of  $\tau$ . Is there really magnon excitation by spin-flip process?





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#### Long-distance transport of magnon spin information in a magnetic insulator at room temperature

L. J. Cornelissen<sup>1\*</sup>, J. Liu<sup>1</sup>, R. A. Duine<sup>2</sup>, J. Ben Youssef<sup>3</sup> and B. J. van Wees<sup>1</sup>



They observed excitation and transport of magnons! Any difference between insulator and metal?







#### Non-local measurement of propagating magnons



Cornelissen L.J. et al. NPHYS. 11, 1022 (2015) Goennenwein S et al. APL 107, 172405 (2015)

Asymmetric MR has a finite value at low temp.

Magnons generated by quantum spin flip? -> Go to Low temperature measurements.



• We found the dc current-induced asymmetric MR.



Possible mechanism is the magnon scattering generated by spin-flip.

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