WMI

BAdW BAYERISCHE AKADEMIE DER WISSENSCHAFTEN

Technische Universität München

All electrical magnon transport experiments in magnetically ordered insulators

DFG Deutsche Forschungsgemeinschaft
AL 2110/2-1

MCQST

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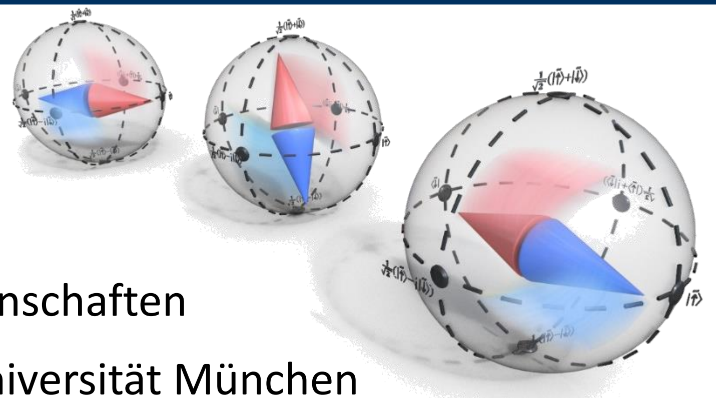

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Acknowledgements

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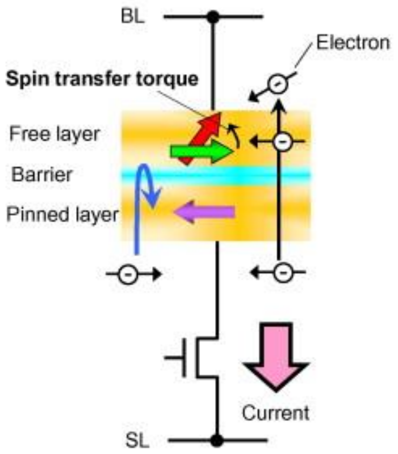
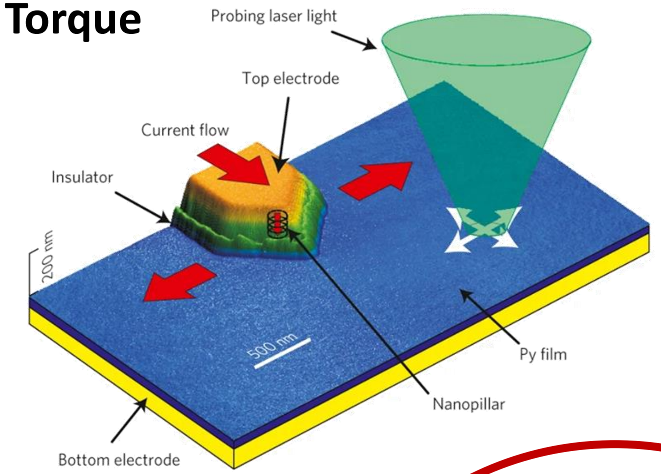
UAM | IfiMAC
Condensed Matter Physics Center

Theory support from
Akashdeep Kamra

Spintronics

Spin-Transfer/Spin Orbit Torque





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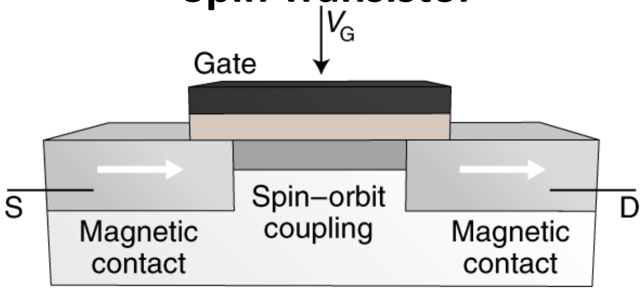
Spin Transistor



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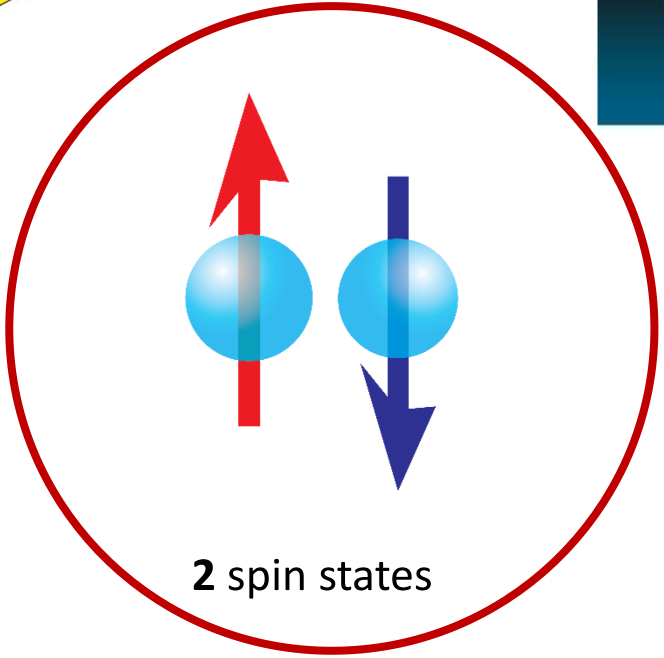
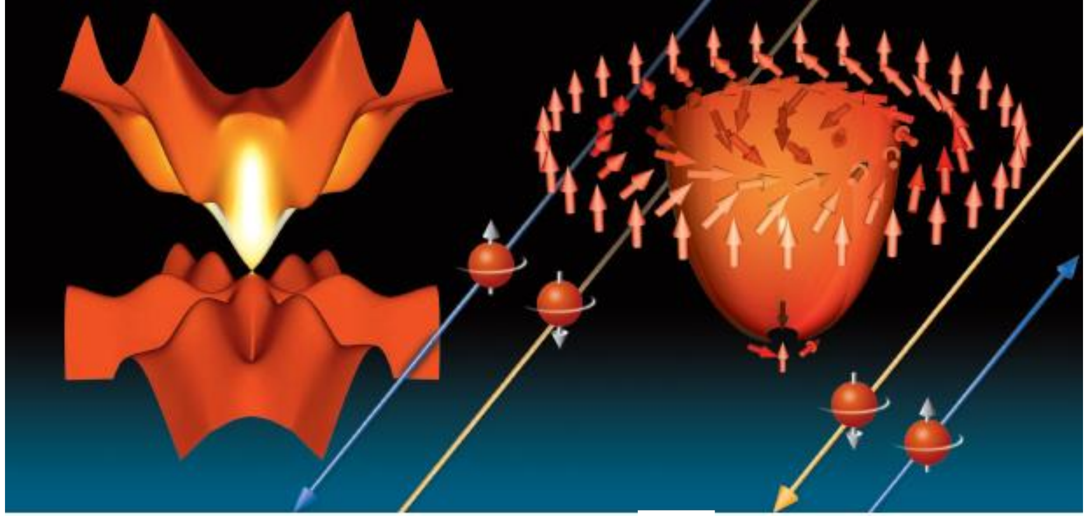
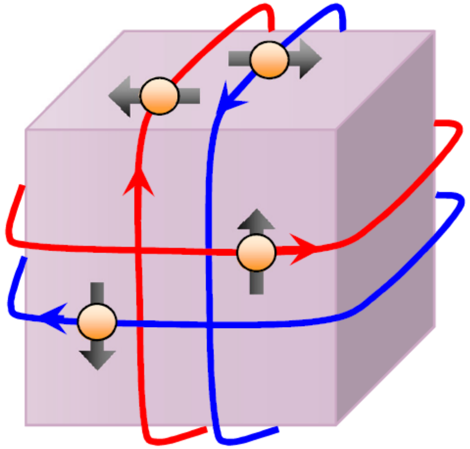
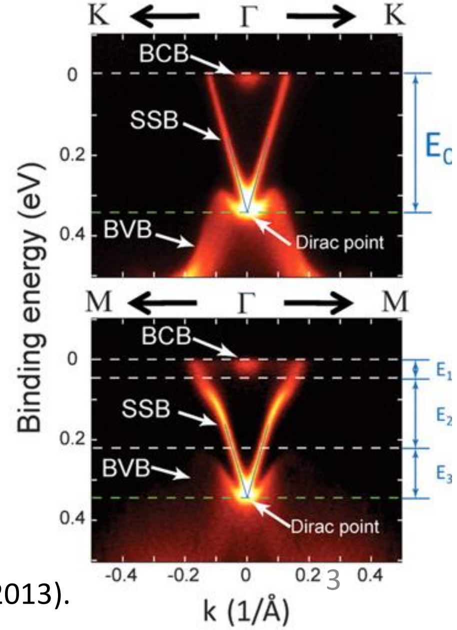


Topological Insulators







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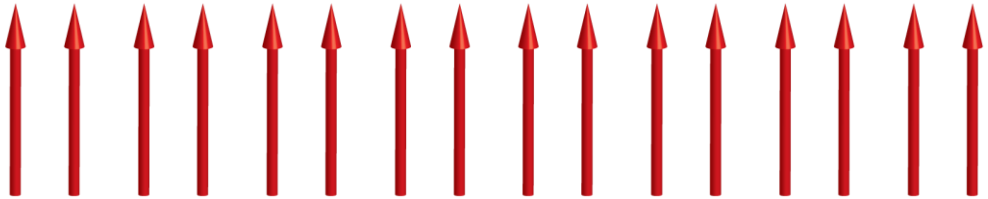
Chen et al., Science **325**, 178 (2009).
Ando, J. Phys. Soc. Jpn. **82**, 102001 (2013).

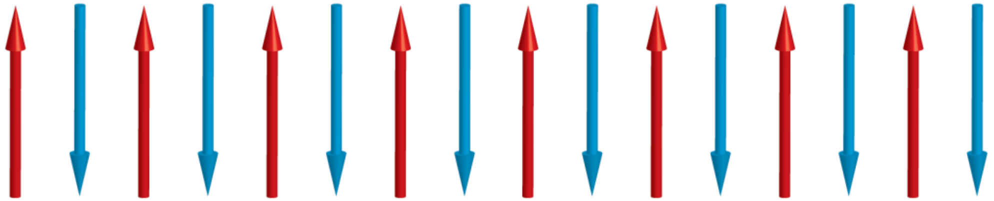
Spin Excitations of the Magnetic Lattice

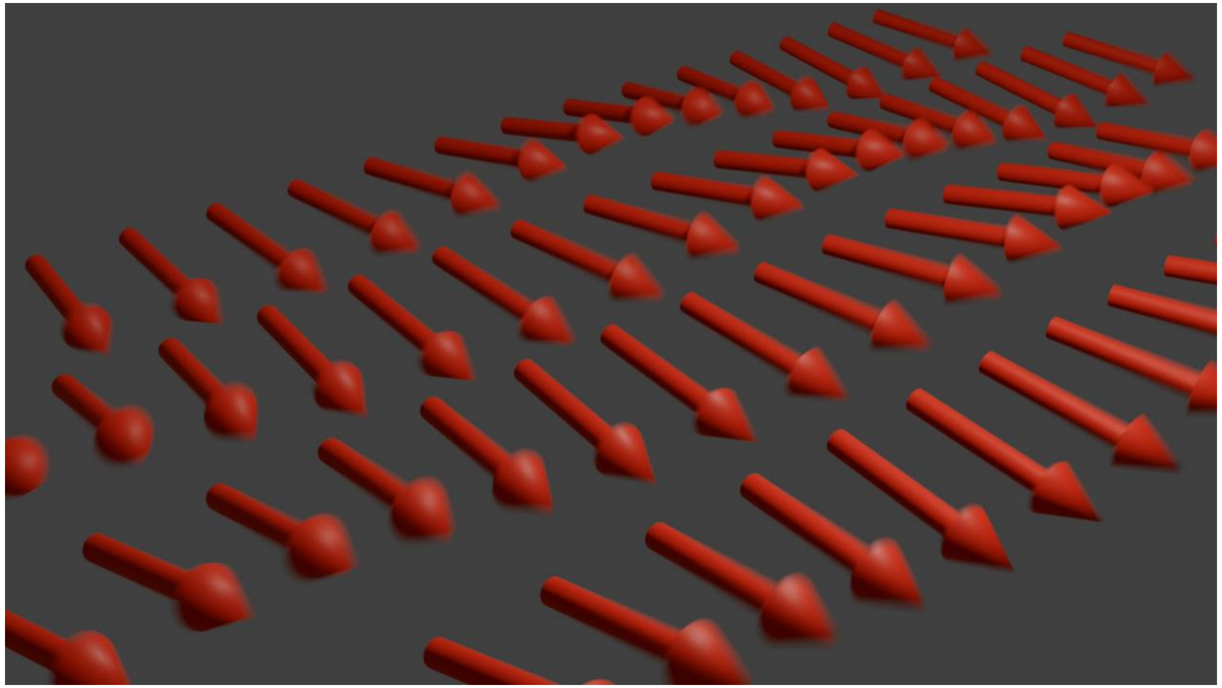
Magnons in Ferromagnets

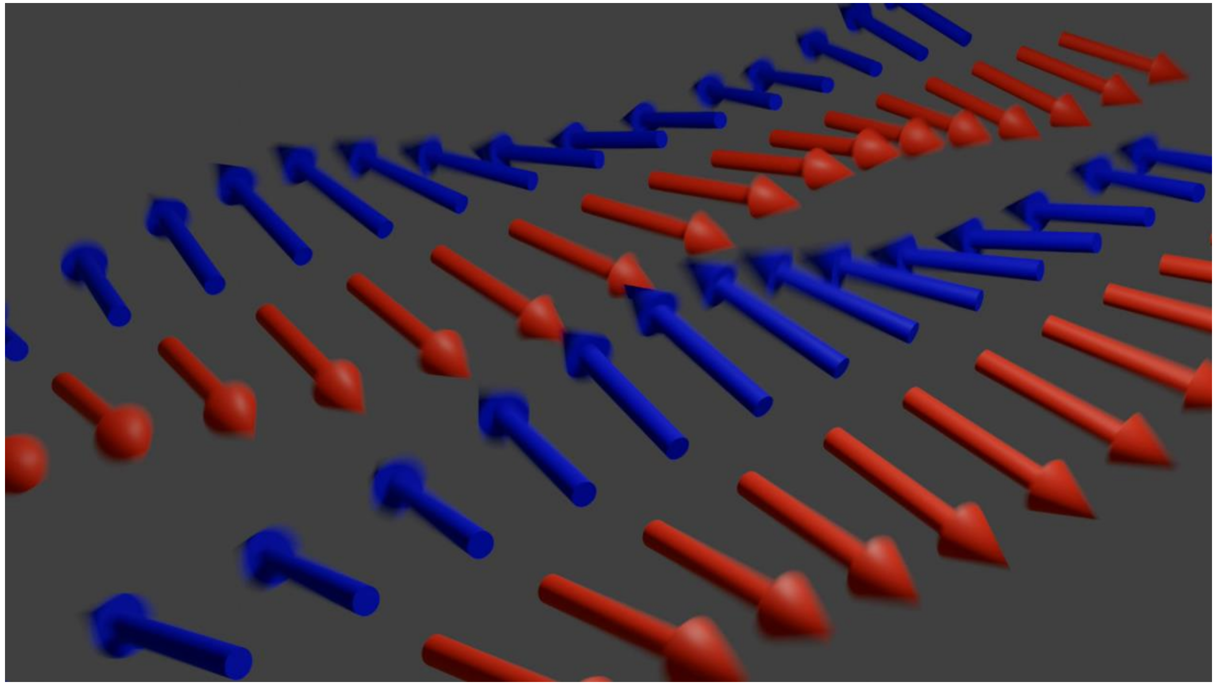


bosonic excitations
GHz-THz
low dissipation
spin angular momentum

Magnons in Antiferromagnets



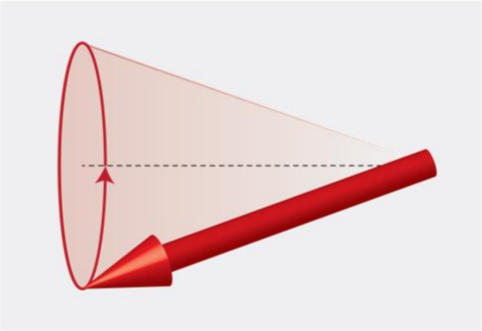




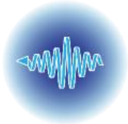
Magnons in Magnetically Ordered Insulators (MOIs)

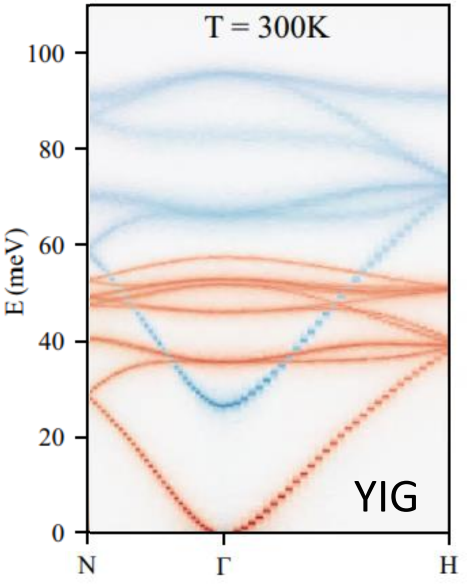
Magnons in Ferromagnets

1 magnon mode in FMI



spin $+\hbar$

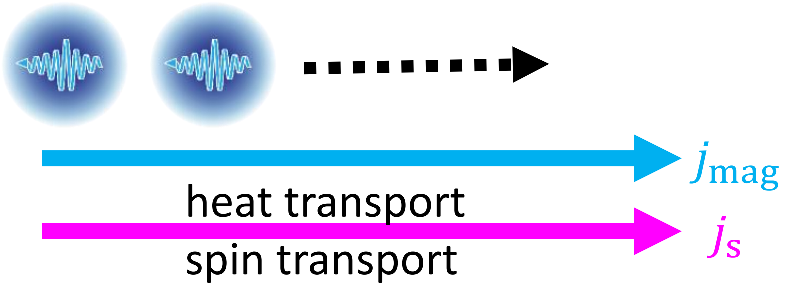




Barker, Bauer, PRB **100**, 140401(R) (2019).

Magnons: quantized excitations of the magnetic lattice

quasiparticles with finite lifetime:
magnon number not conserved
strongly interacting
(magnon-magnon, magnon-phonon, defects)

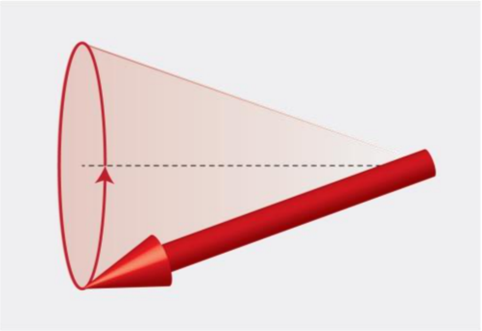


Magnons in MOIs

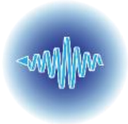
Magnons: quantized excitations of the magnetic lattice

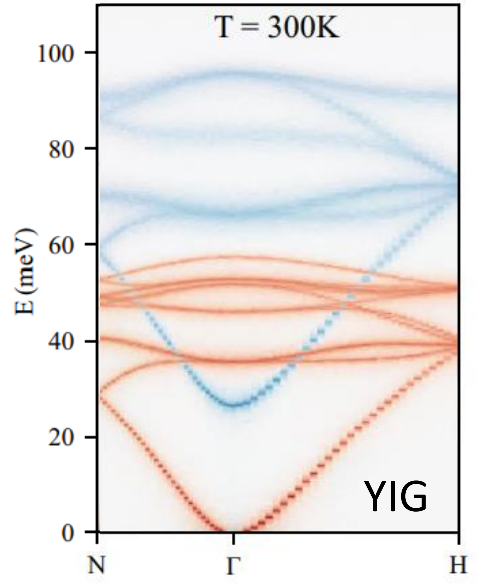
Magnons in Ferromagnets

1 magnon mode in FMI



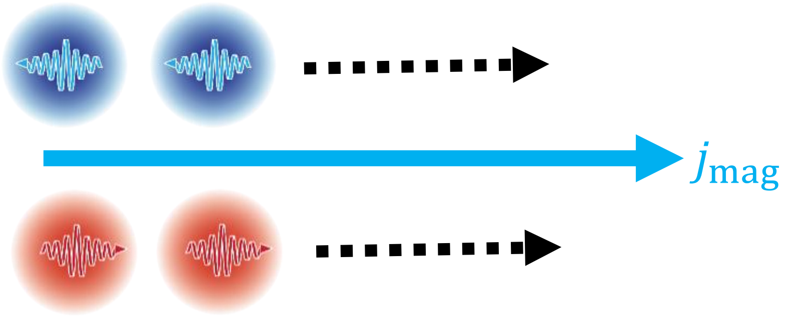
spin $+\hbar$

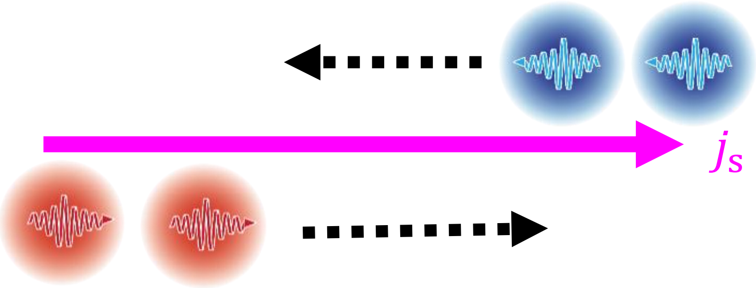




Barker, Bauer, PRB **100**, 140401(R) (2019).

Quasiparticles with finite lifetime:
Magnon number not conserved
Strongly interacting
(magnon-magnon, magnon-phonon, defects)

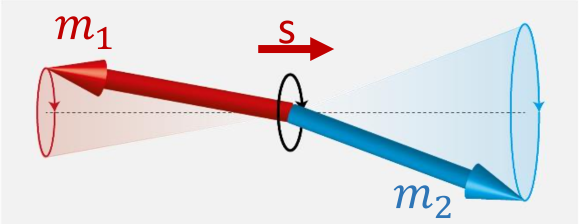




Magnons in Antiferromagnets

2 magnon modes in AFI

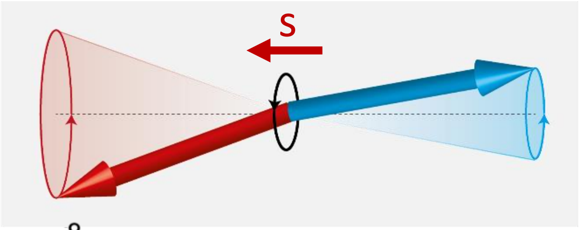
α-mode Right-circular polarized



spin +1

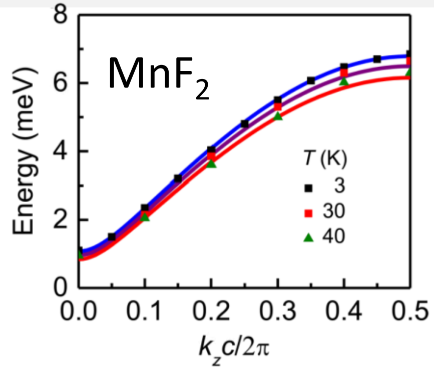
$|\tilde{\uparrow}\rangle$

β-mode Left-circular polarized



spin -1

$|\tilde{\downarrow}\rangle$

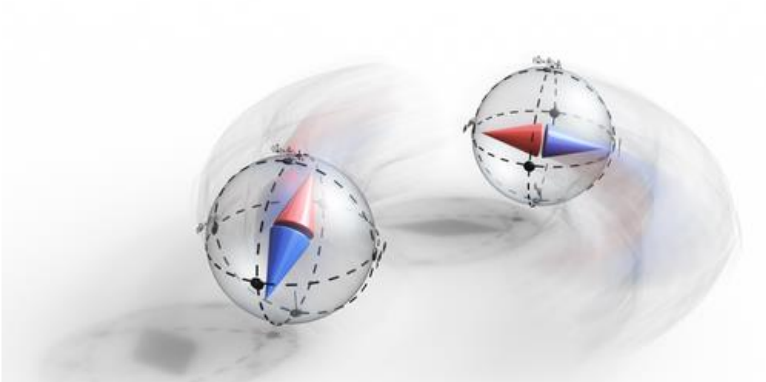


Rezende et al., JAP **126**, 151101 (2019).
Shen, JAP **129**, 223906 (2021).

Dances with Magnons

Magnons in Ferromagnets

Main Stage concert at night by Łukasz Widziszowski/ CC-BY-SA-4.0



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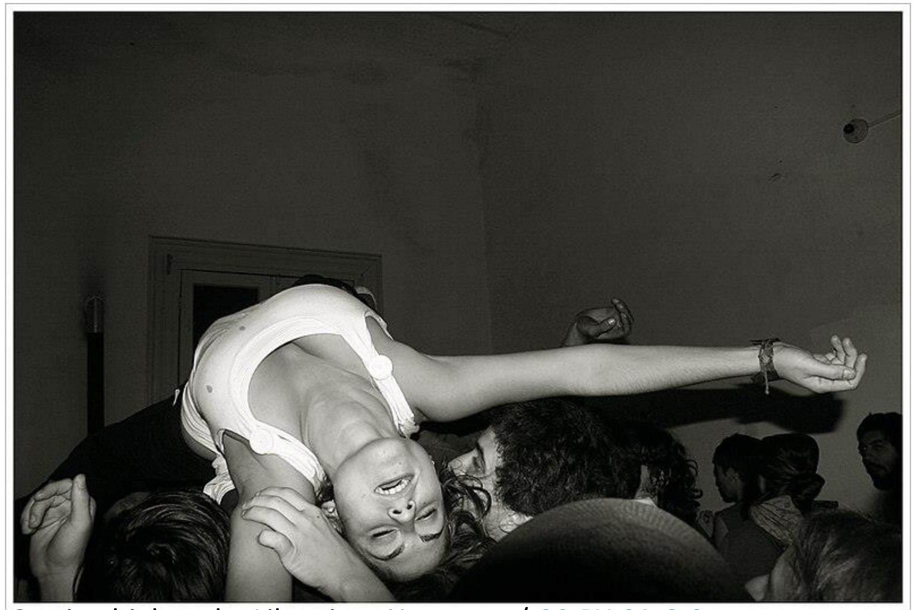
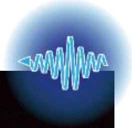
Magnons in Antiferromagnets



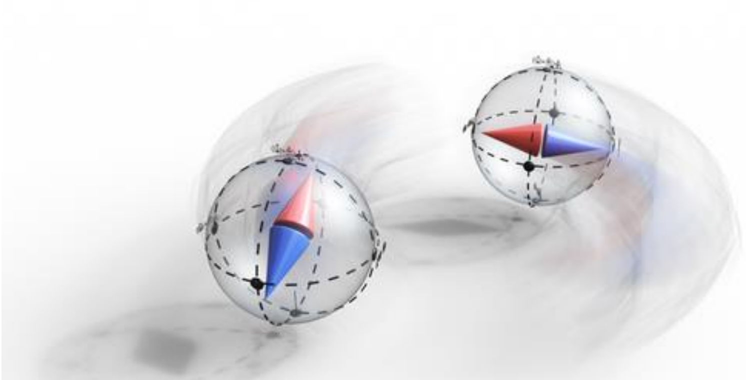
Getting higher.. by Libertinus Yomango / CC-BY-SA-2.0

Dances with Magnons

Magnons in Ferromagnets



Main Stage concert at night by Łukasz Widziszowski/ CC-BY-SA-4.0



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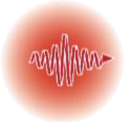
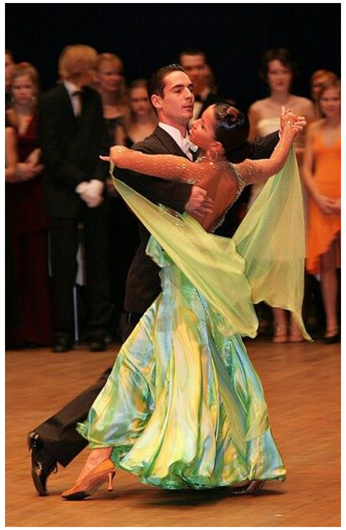
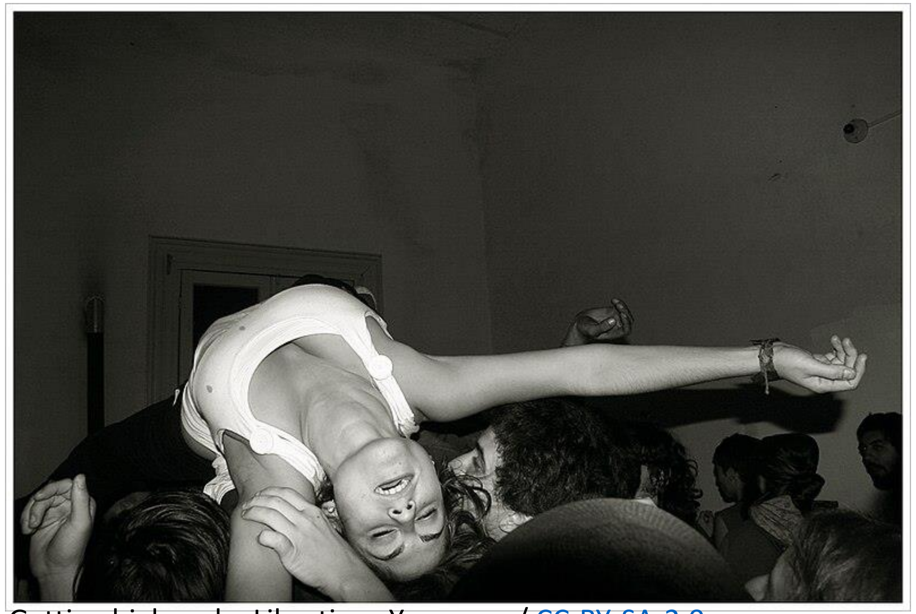
Magnons in Antiferromagnets





A ballroom tango by Che / CC-BY-SA-2.5

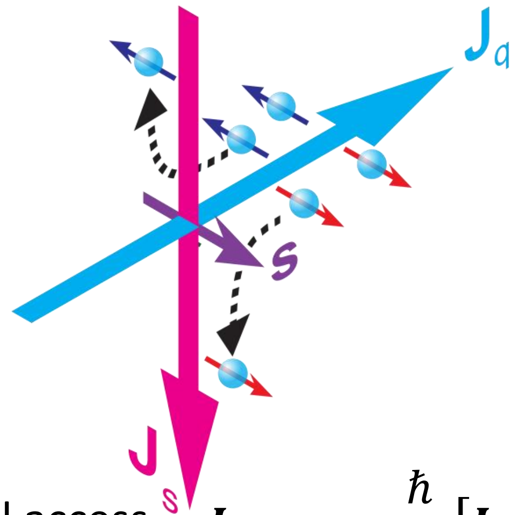


Getting higher.. by Libertinus Yomango / CC-BY-SA-2.0

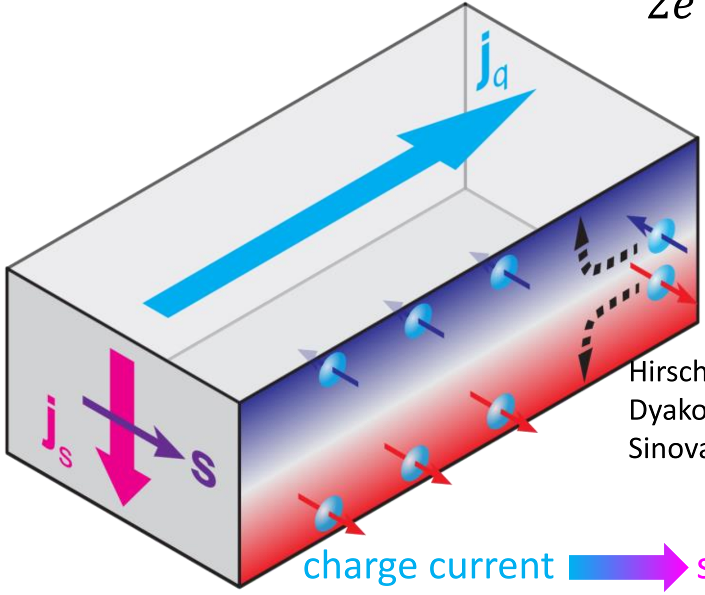
Vienna Opera Ball by Gryffindor / CC-BY-SA-4.0

All-electrical Spin Current Generation and Detection

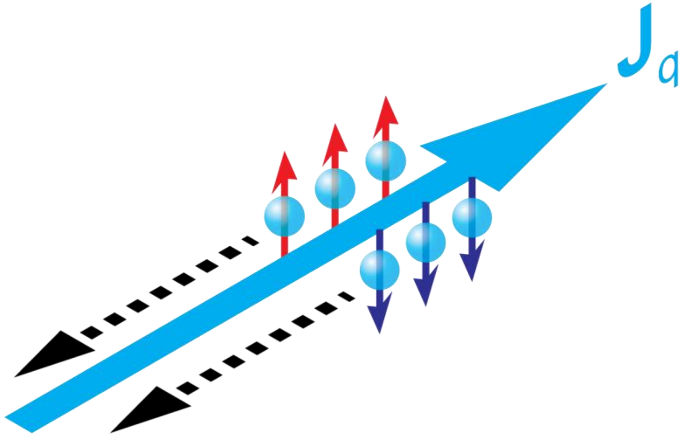
direct spin Hall effect (SHE)



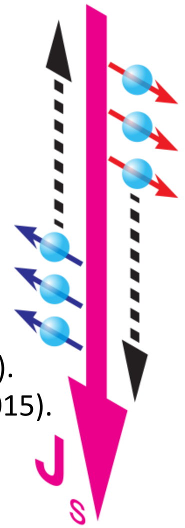
electrical access $\boldsymbol{J}_{\mathbf{s}} = \alpha_{\mathrm{SH}} \frac{\hbar}{2e} [\boldsymbol{J}_{\mathrm{q}} \times \boldsymbol{s}]$



pure charge current



pure spin current



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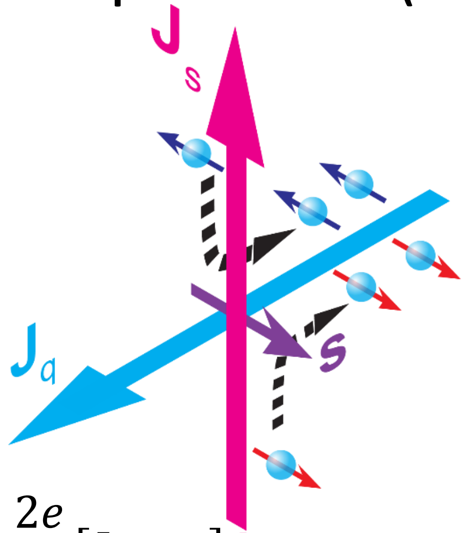
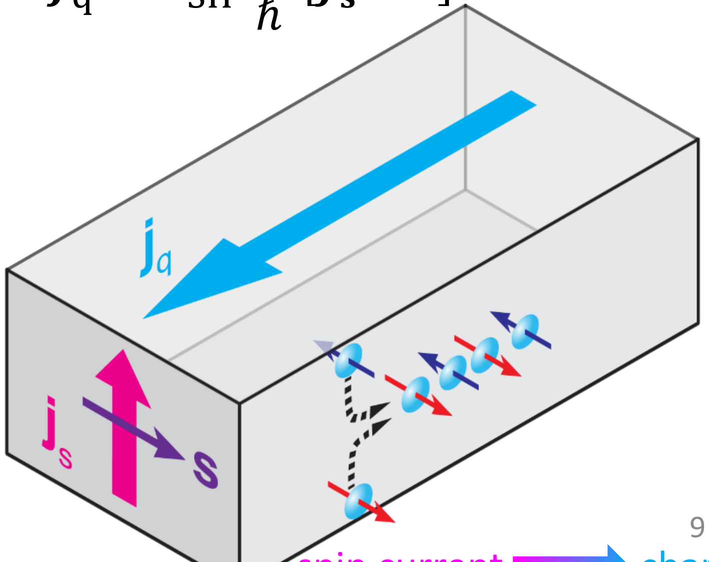
Dyakonov, Perel, JETP Lett.. **13**, 467 (1971).
Sinova et al., Rev. Mod. Phys. 87, 1213 (2015).

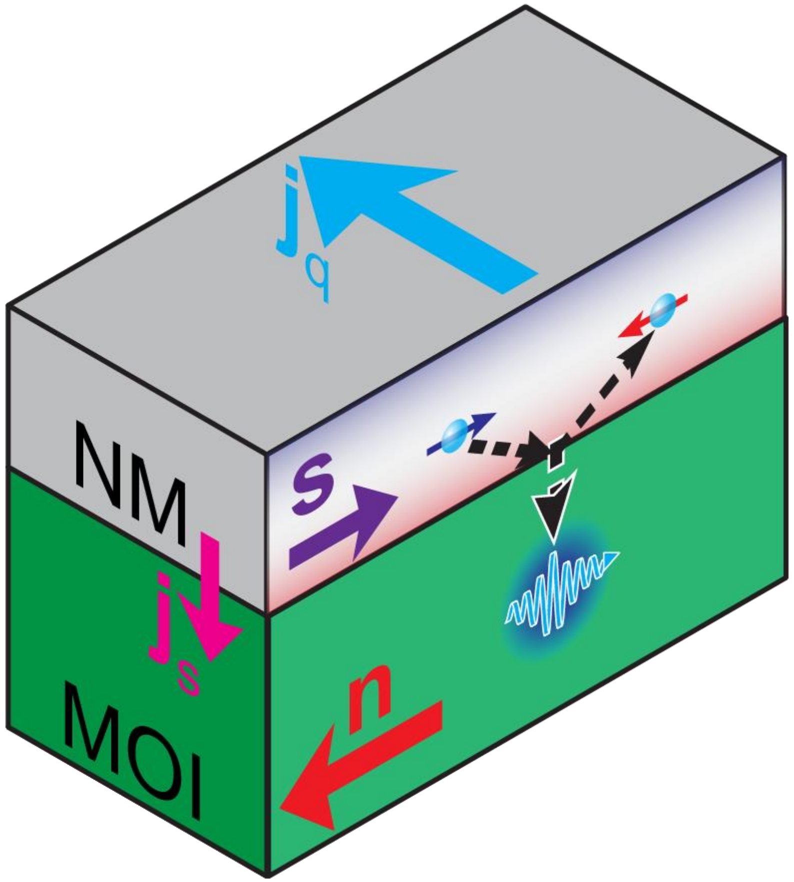
inverse spin Hall effect (ISHE)



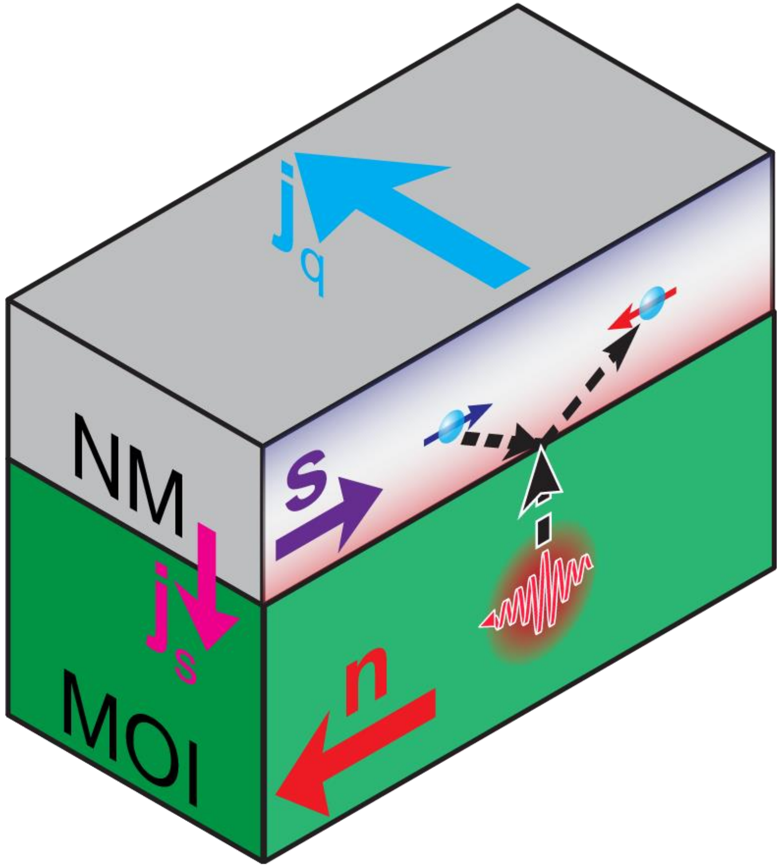
$\boldsymbol{J}_{\mathrm{q}} = \alpha_{\mathrm{SH}} \frac{2e}{\hbar} [\boldsymbol{J}_{\mathbf{s}} \times \boldsymbol{s}]$



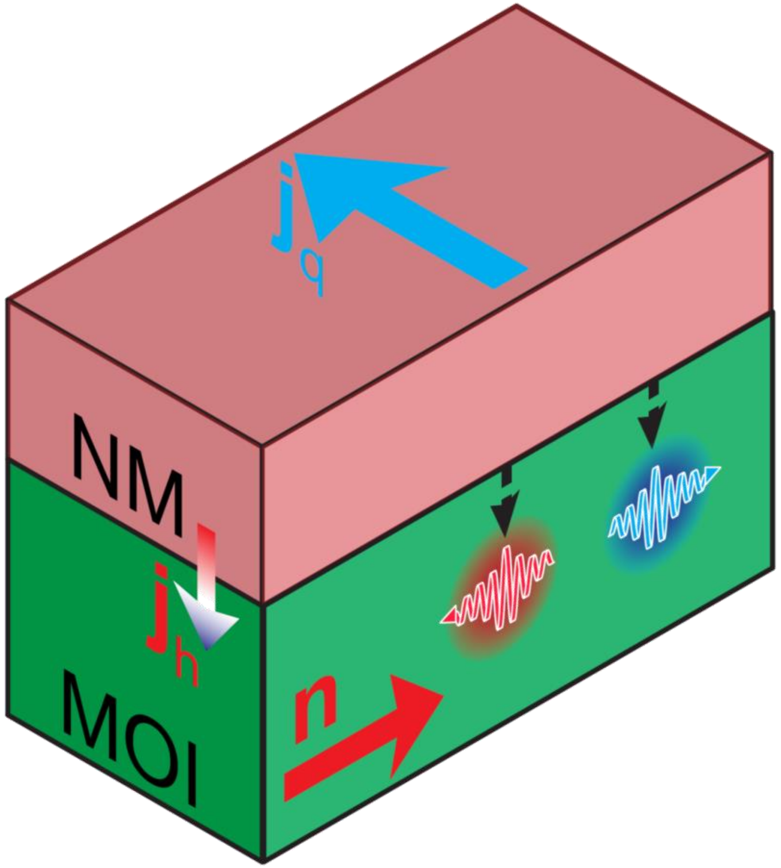
All-Electrical Magnon Transport



SHE induced magnon generation



SHE induced magnon absorption



Joule heating induced magnon generation

Bender and Tserkovnyak, PRB **91**, 140402 (2015).
Cornelissen *et al.*, Nat. Phys. **11**, 1022 (2015).
Goennenwein *et al.*, APL **107**, 172405 (2015).
Cornelissen et al., PRB **94**, 014412 (2016).
Lebrun *et al.*, Nature **561**, 222 (2018).

Electrically controlled magnon accumulation/depletion in thermal magnon gas

All-Electrical Magnon Transport

Reviews:
Althammer, Phys Stat Sol RRL **15**, 2100130 (2021).
Althammer, J. Phys. D: Appl. Phys. **51** , 313001 (2018).

Experiment:
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Wimmer, MA *et al.*, PRL **123** , 257201 (2019).
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J. Han et al., Nat. Nano. **15**, 1748 (2020).
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Wimmer, MA, et al., PRL **125** , 247204 (2020).
R. Schlitz et al., PRL **126**, 257201 (2021).
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J. Gao et al., Phys. Rev. Research **4**, 043214 (2022).
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Theory:
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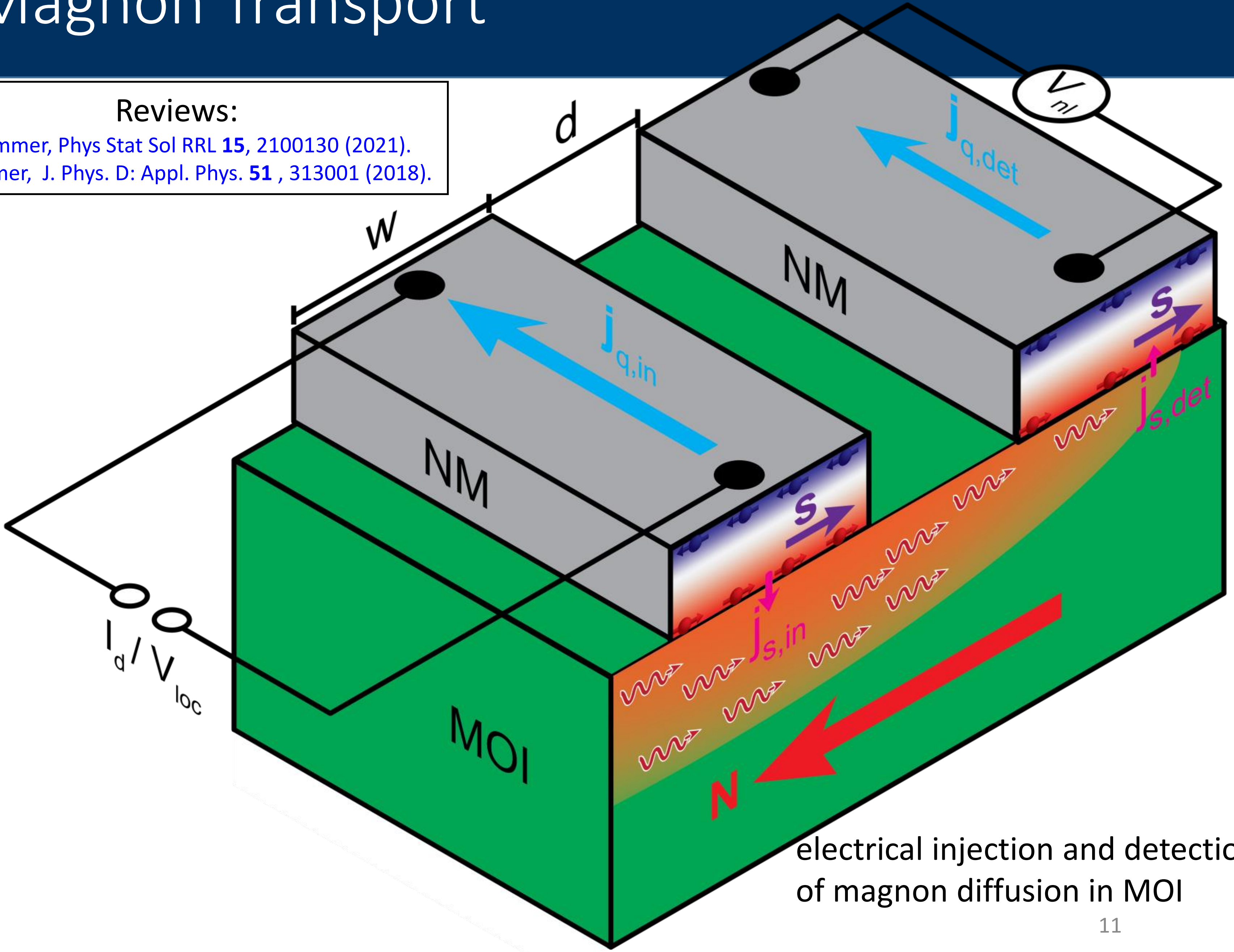
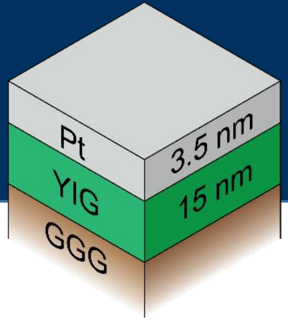
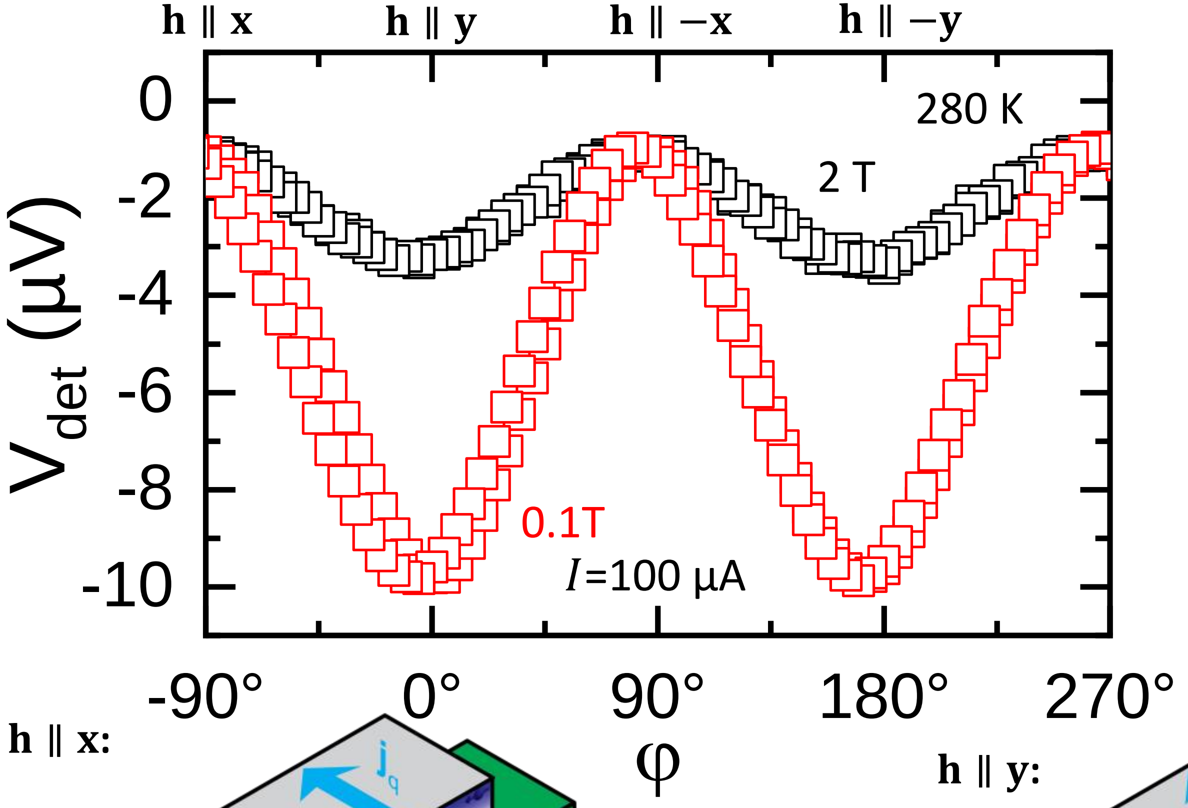
Zhang and Zhang, PRB **86**, 214424 (2012).
Bender and Tserkovnyak, PRB **91**, 140402 (2015).
Takei, PRB **100**, 134440 (2019).
Kamra, MA, et al., PRB **102** , 174445 (2020).

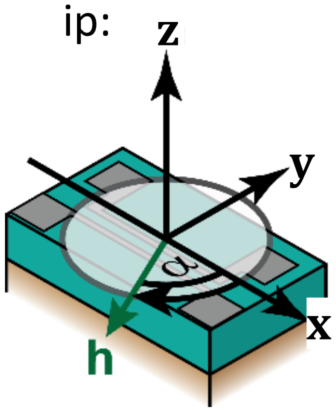


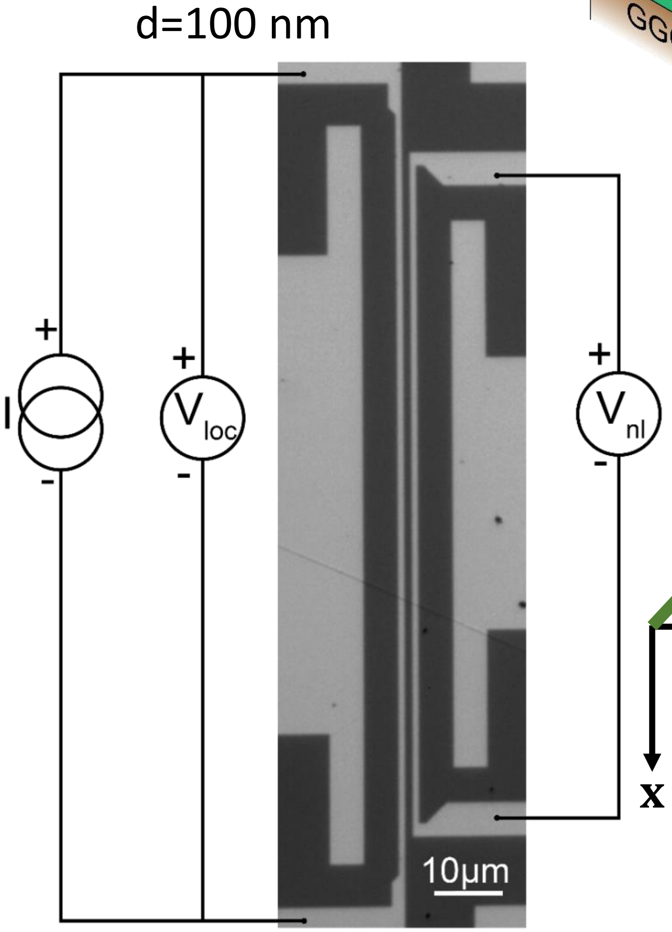
electrical injection and detection of magnon diffusion in MOI

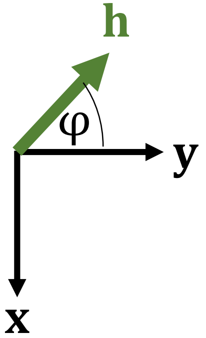
All-Electrical Magnon Transport

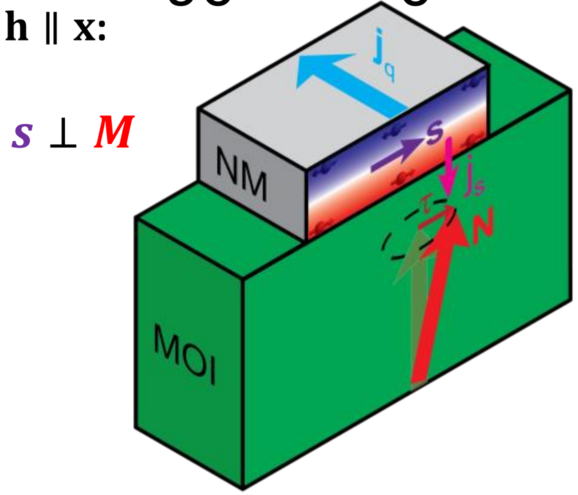


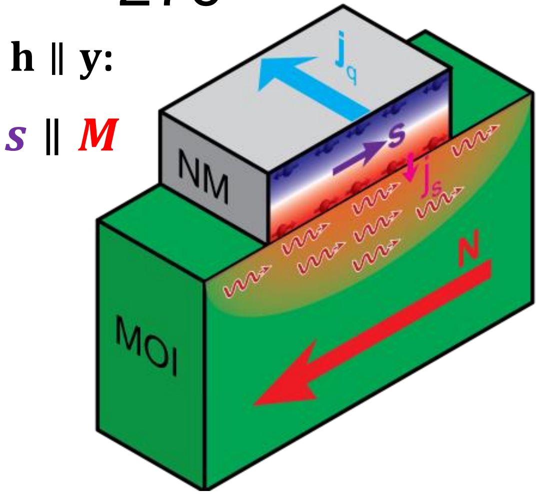












Current reversal technique:

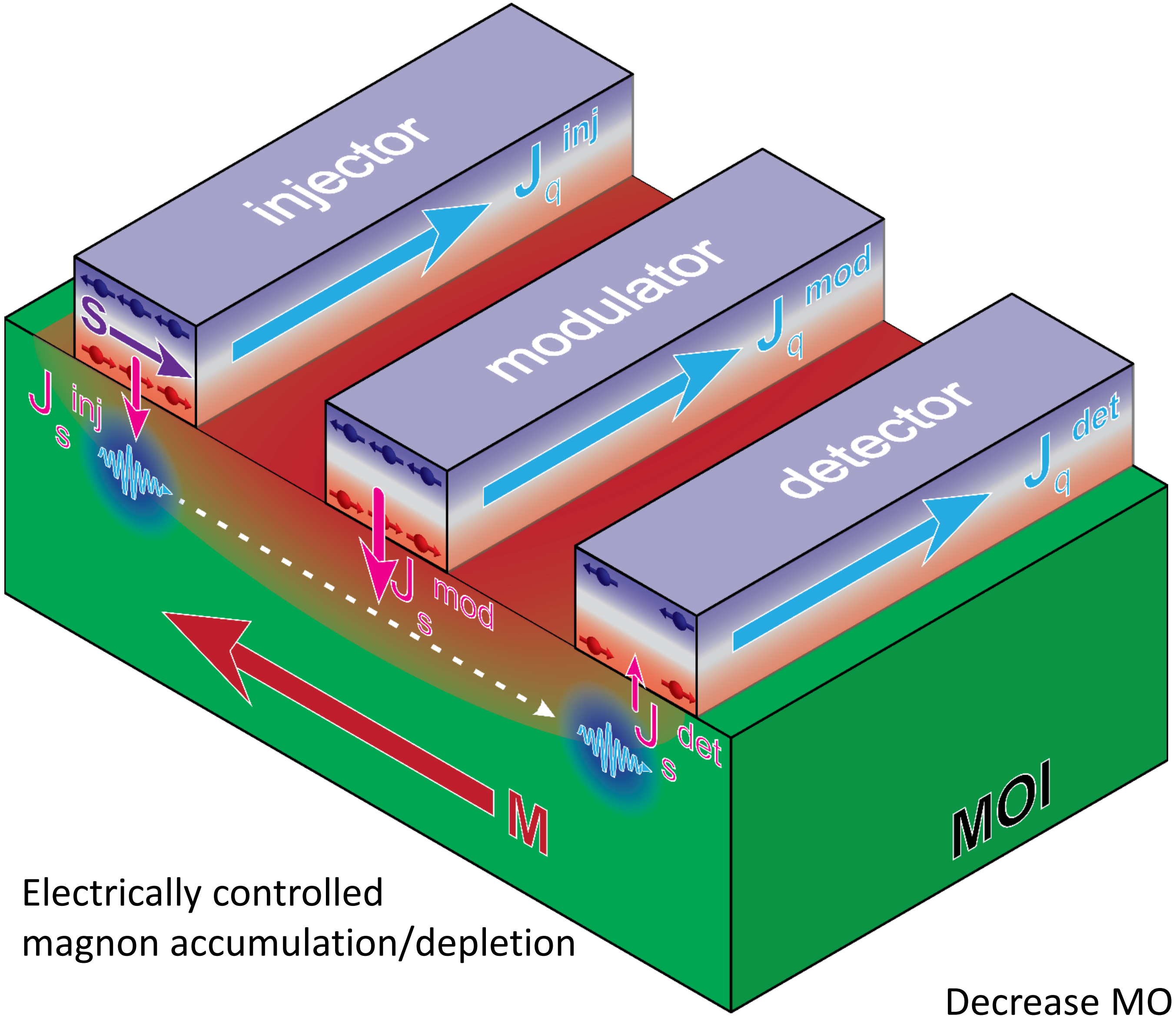
$$V_{\mathrm{det}} = (V_{\mathrm{nl}}(I+) - V_{\mathrm{nl}}(I-))/2$$

→ extract resistive response

Goennenwein et al., APL **107**, 172405 (2015).

Towards 2d: X-Y. Wei et al., Nat. Mater. **21**, 1352 (2022).

All-Electrical Magnon Transport + Modulator

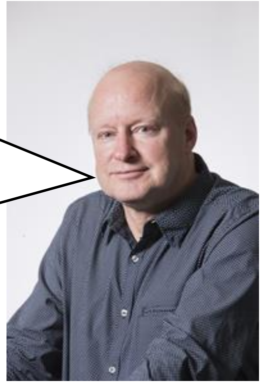


Electrically controlled
magnon accumulation/depletion

Bender, Duine, Tserkovnyak PRL **108**, 246601 (2012)
Ganzhorn *et al.*, APL **109**, 022405 (2016).
Cornelissen *et al.*, PRL **120**, 097702 (2018).
Wimmer *et al.*, PRL **123** , 257201 (2019).
Liu *et al.*, PRB **99**, 054420 (2019). [microwave]
Takei, PRB **100**, 134440 (2019).
Cramer *et al.*, PRB **100**, 094439 (2019).
Schlitz *et al.*, APL **114**, 252401 (2019). [FIB]
Das *et al.*, PRB **101**, 054436 (2020). [magnetic strip]
Gückelhorn *et al.*, APL **117** , 182401 (2020).
Liu *et al.*, PRB **103**, 214425 (2021).
Alves Santos *et al.*, PR Applied **15**, 014038 (2021).
Gückelhorn *et al.*, PRB **104**, L180410 (2021).

In a thinner device, it could be possible to increase the amount of magnons in the channel to a level where they would form a Bose-Einstein condensate.

Prophet Bartradamus

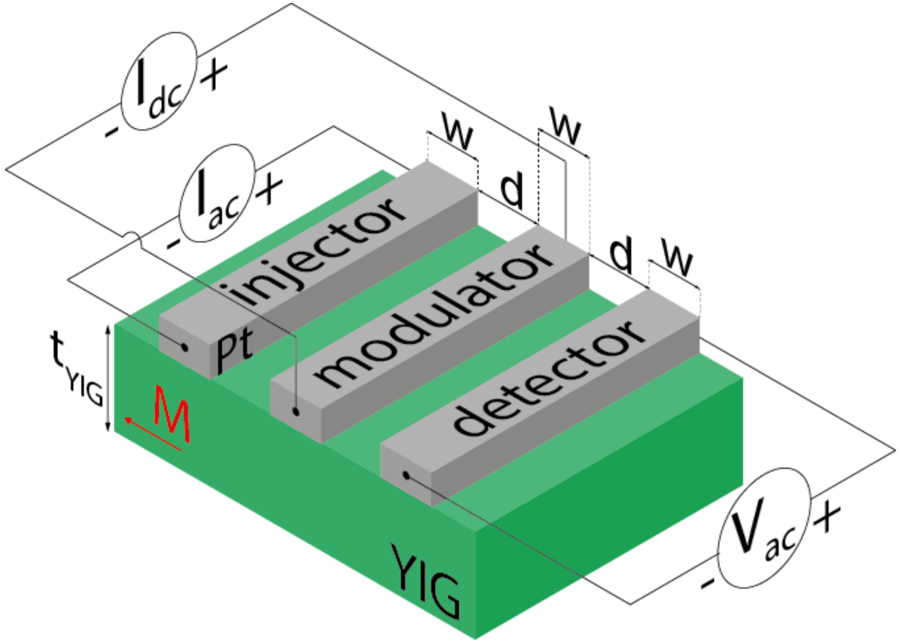


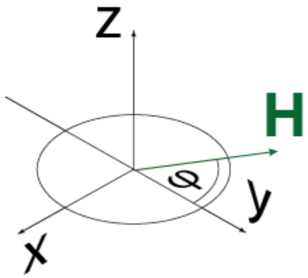
https://phys.org/news/2018-03-transistor-closer.html#jCp

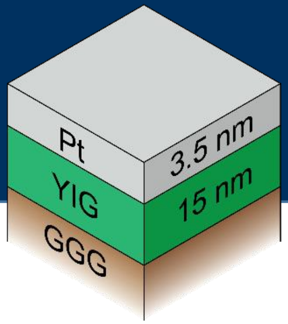
Decrease MOI thickness to enter nonlinear regime

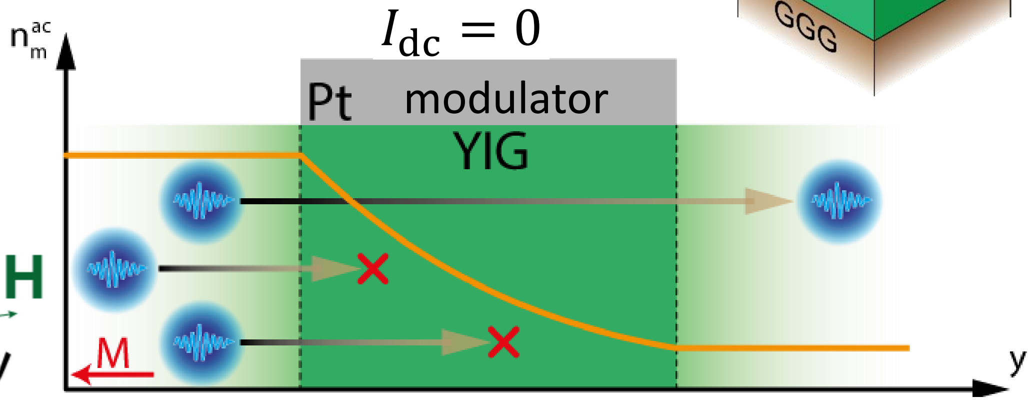
SHE Injection Zero Damping State

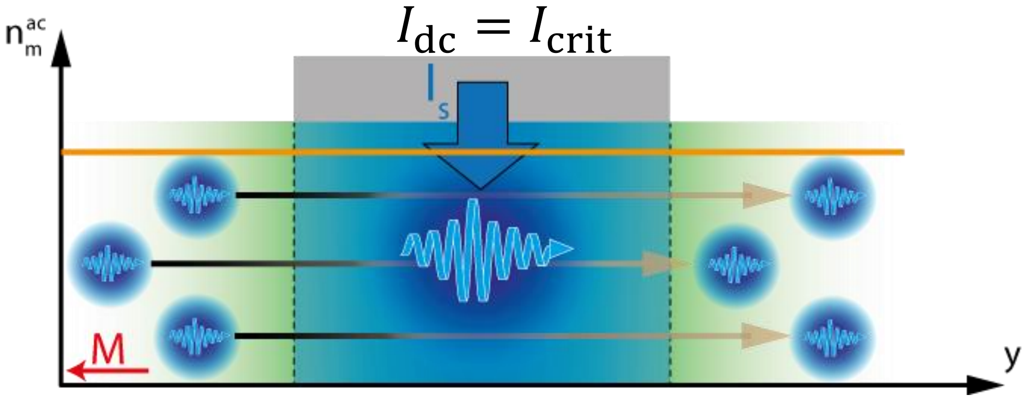
T. Wimmer







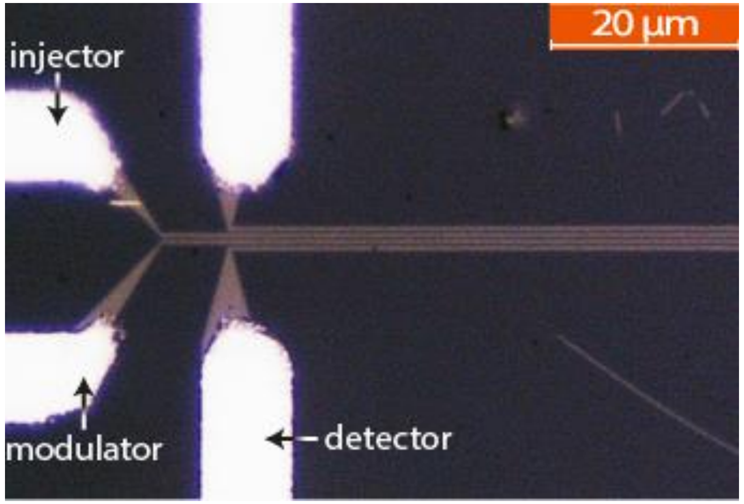




$$\Gamma_D = \Gamma_{ST}$$

damping rate of magnetic material

Spin torque rate via DC pumping



AC-measurement

injector: AC-current bias (50 µA Peak)

modulator: DC-current bias (-750…750 µA)

Detector: Measure first harmonic V_{ac}

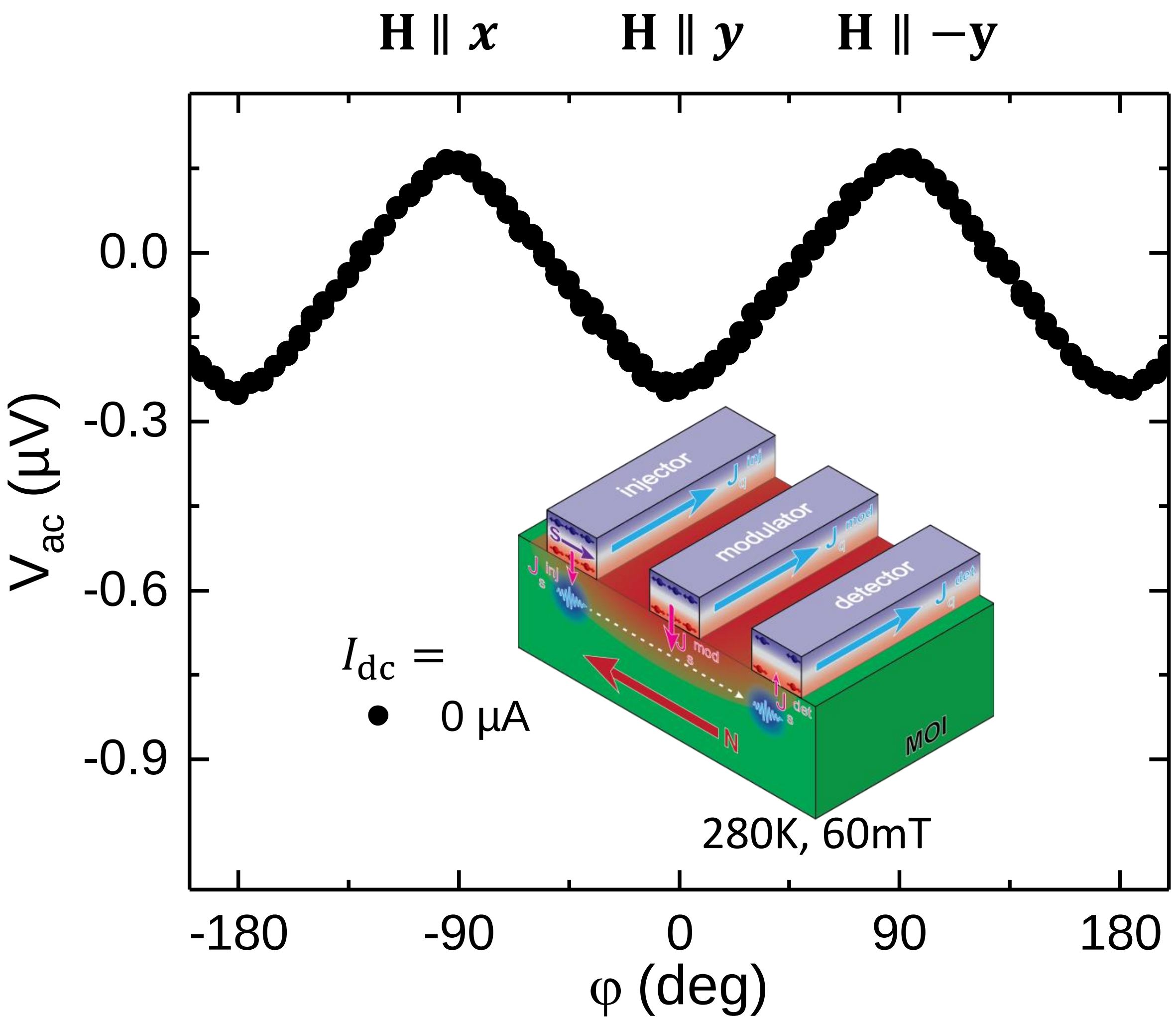
$d = 400\ nm$

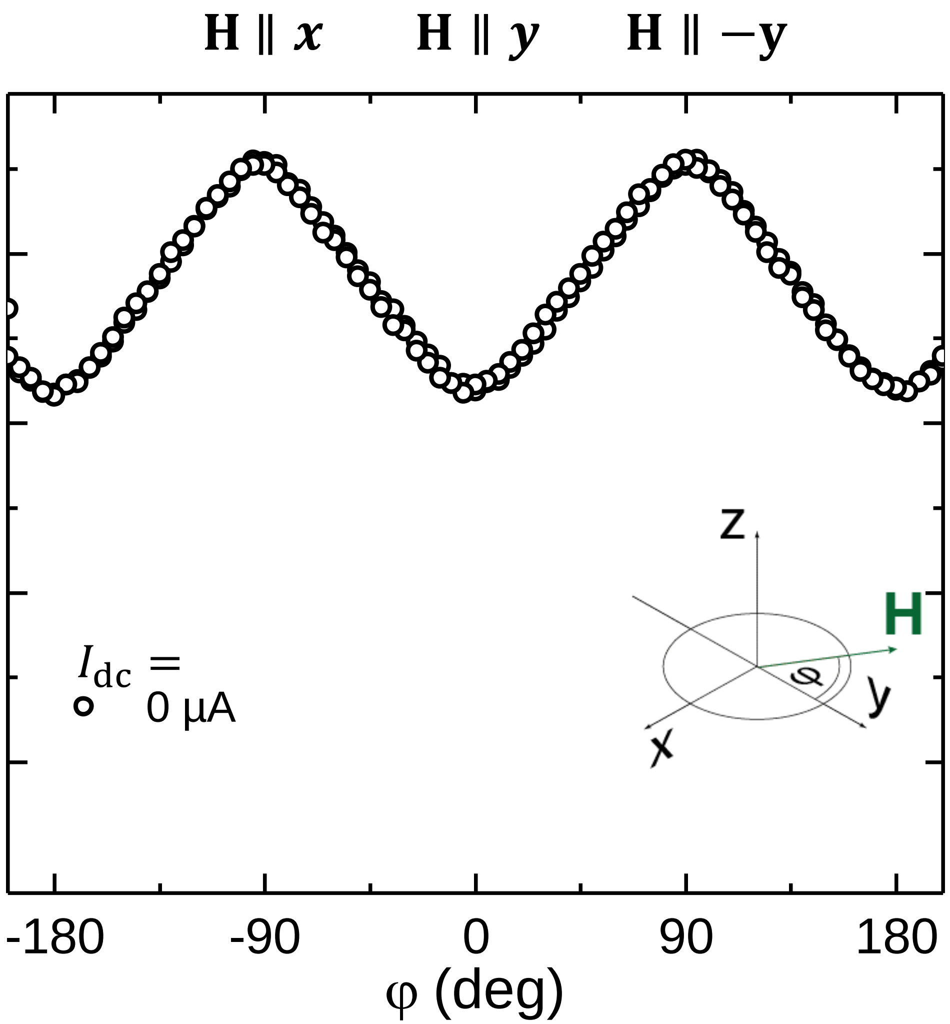
$w = 500\ nm$

$t_{YIG} = 13.4\ nm$

Wimmer, MA *et al.*, PRL **123** , 257201 (2019).

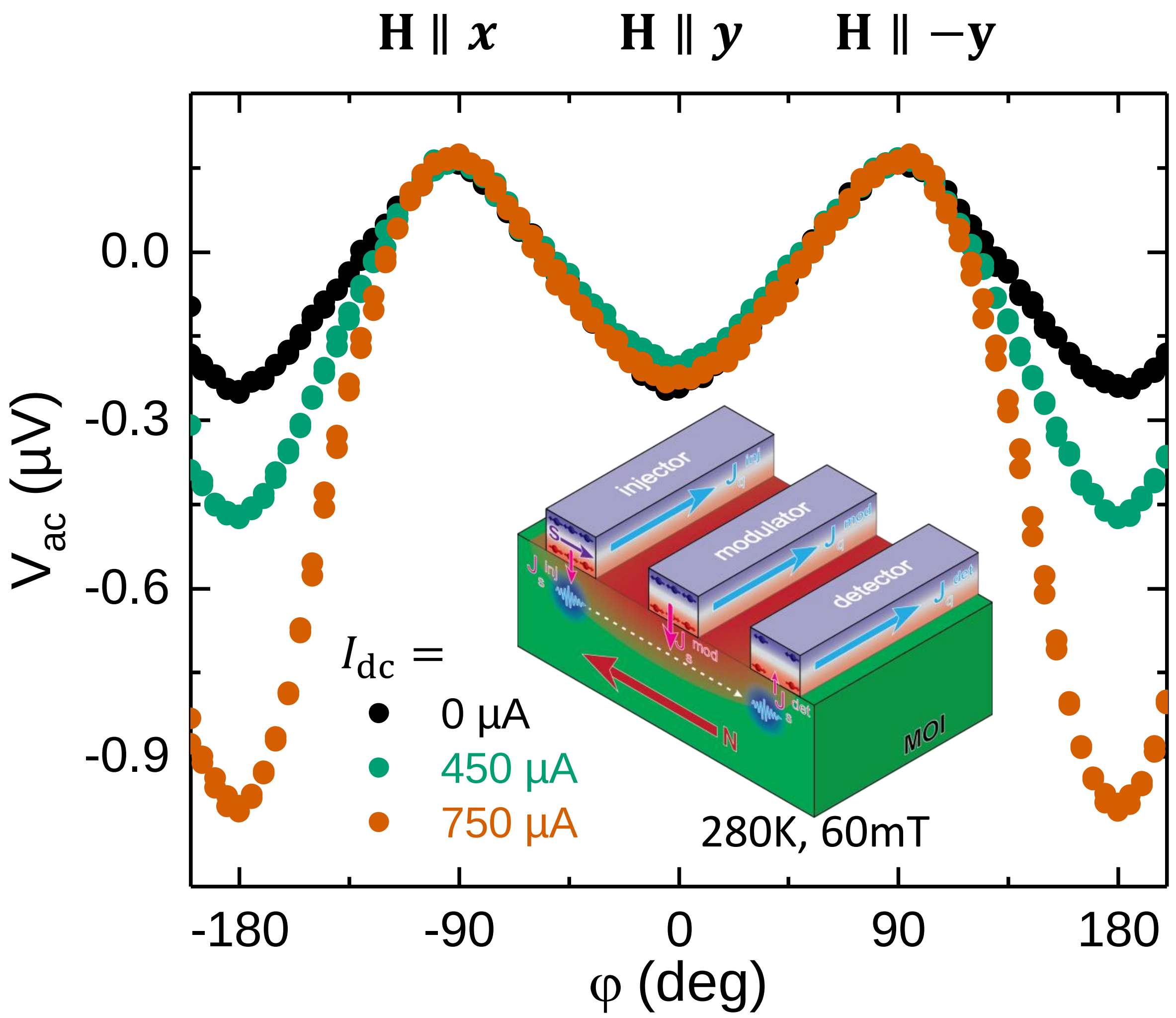
Spin Current Modulation

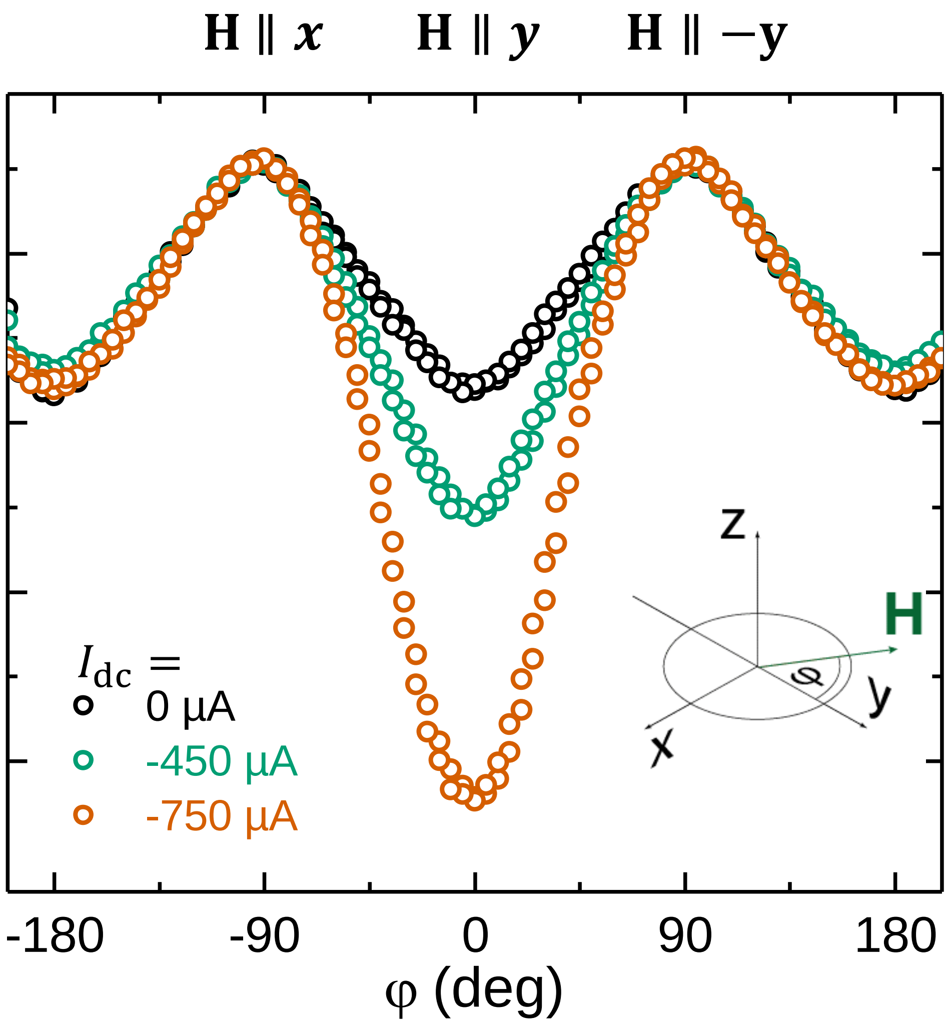




Cornelissen *et al.*, PRL **120**, 097702 (2018).
Wimmer, MA *et al.*, PRL **123** , 257201 (2019).
Gückelhorn, MA *et al.*, APL **117** , 182401 (2020).
Liu *et al.*, PRB **103**, 214425 (2021).

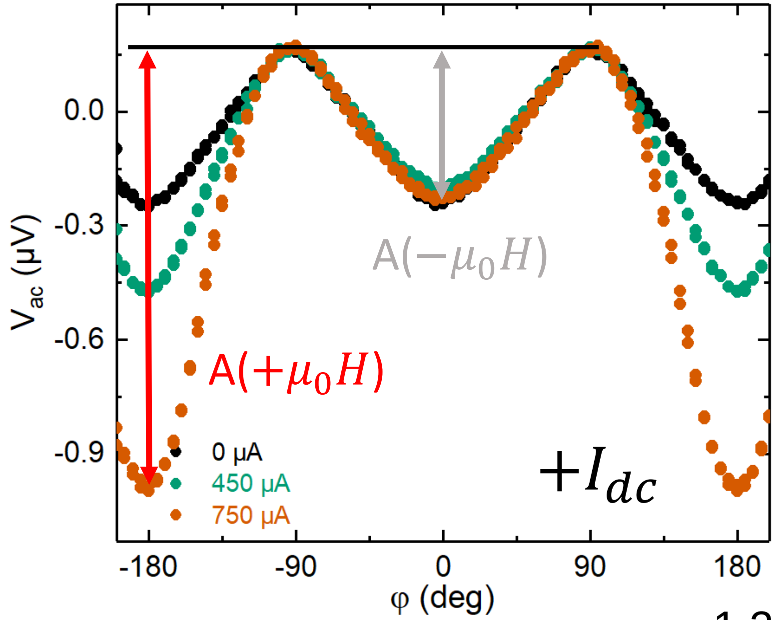
Spin Current Modulation

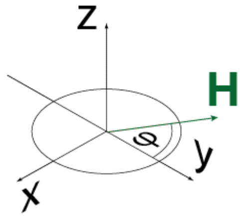


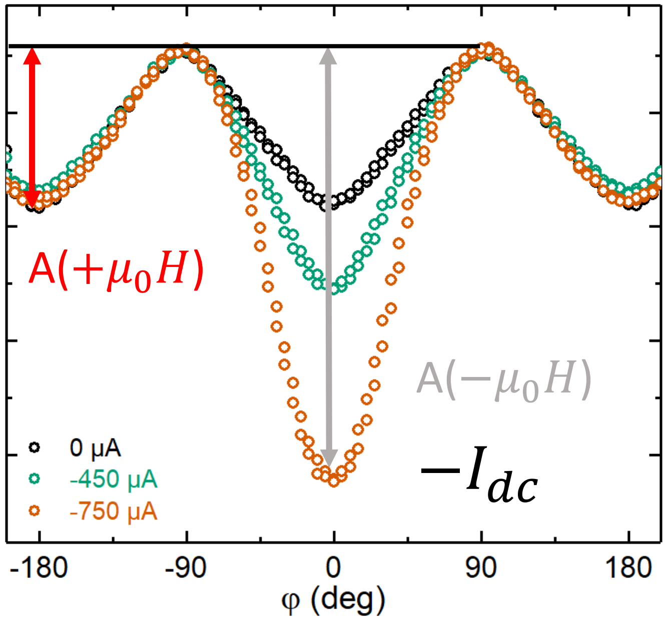


Cornelissen *et al.*, PRL **120**, 097702 (2018).
Wimmer *et al.*, PRL **123** , 257201 (2019).
Gückelhorn *et al.*, APL **117** , 182401 (2020).
Liu *et al.*, PRB **103**, 214425 (2021).

Amplitude vs I_{dc}

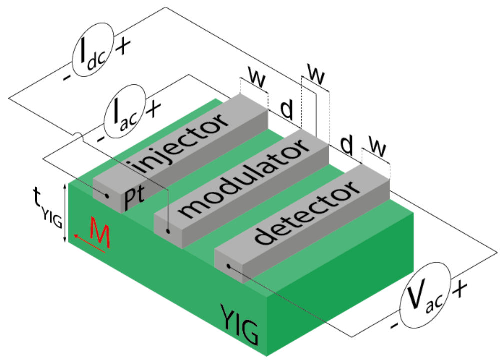


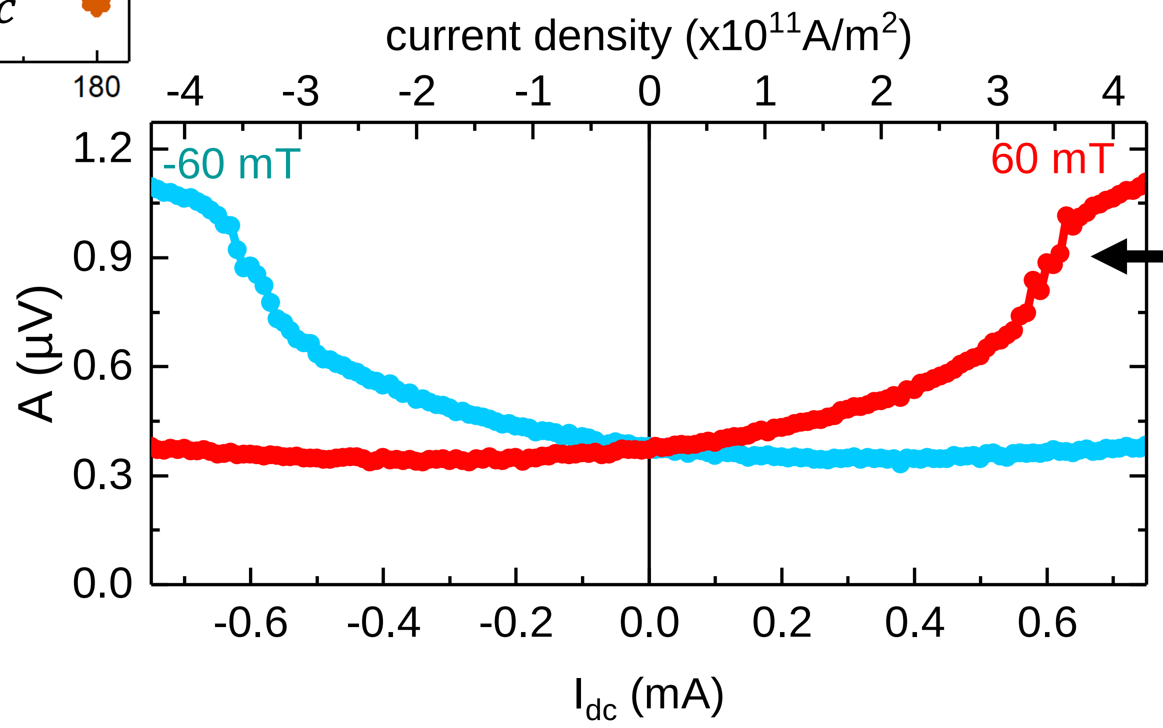




Tuning of magnon conductance via:

1. SHE injected magnons ($\propto I_{dc}$)
2. Thermally injected magnons ($\propto I_{dc}^2$)

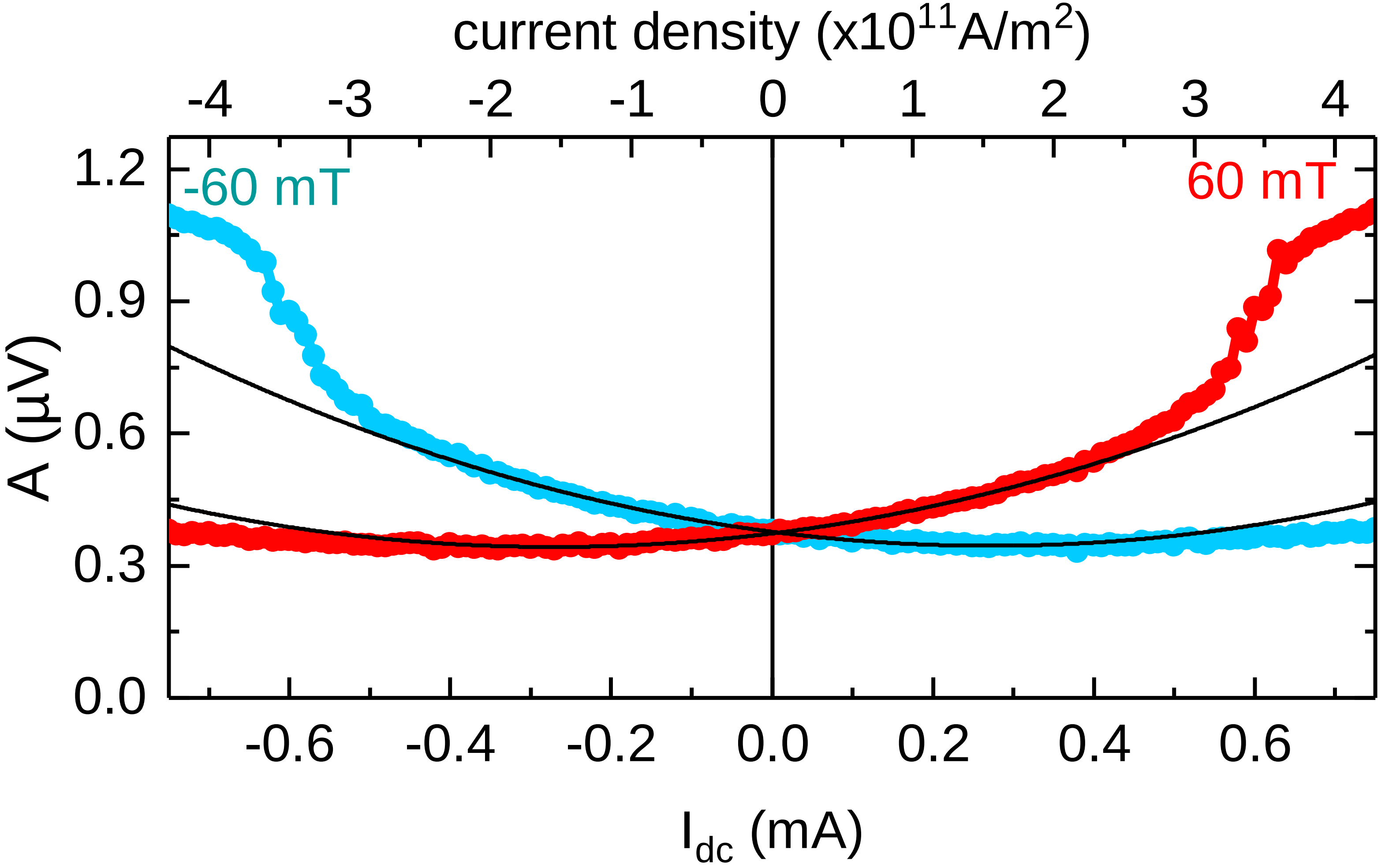


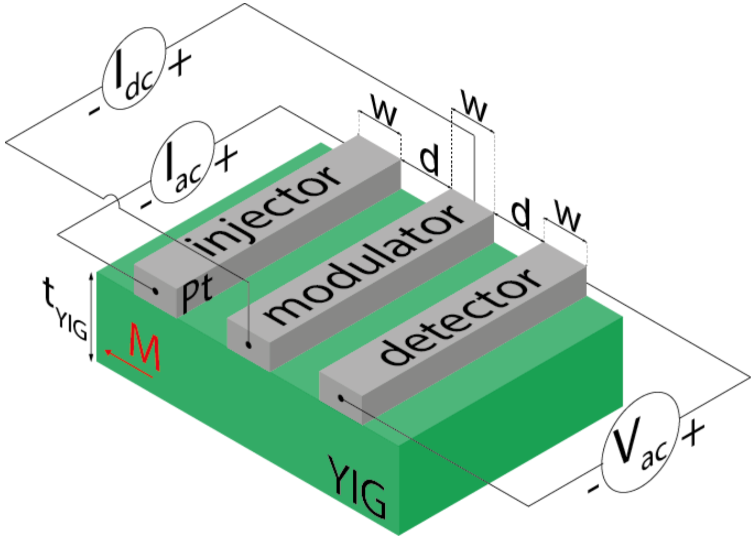


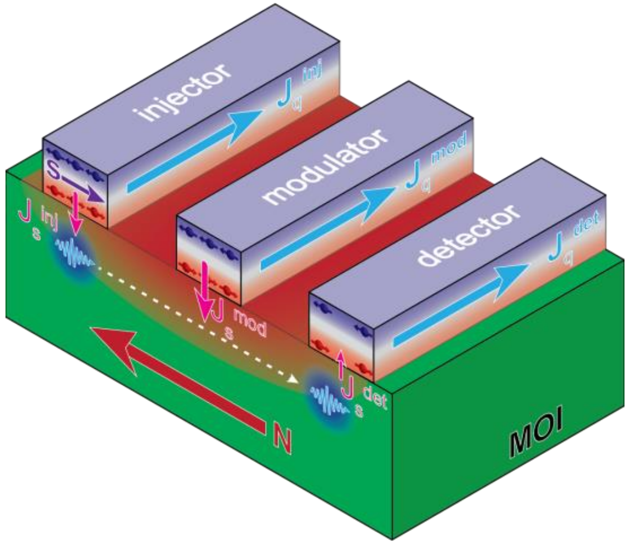
Threshold behaviour

Cornelissen *et al.*, PRL **120**, 097702 (2018).
Wimmer *et al.*, PRL **123** , 257201 (2019).
Gückelhorn *et al.*, APL **117** , 182401 (2020).
Liu *et al.*, PRB **103**, 214425 (2021).

Electrical Manipulation of Magnon Transport





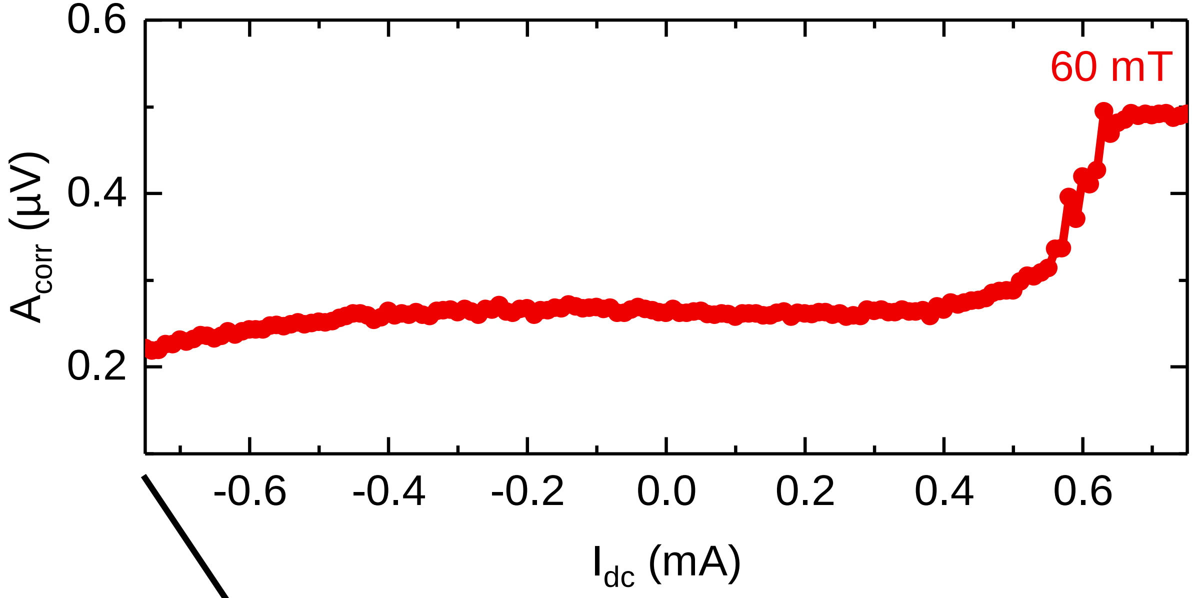


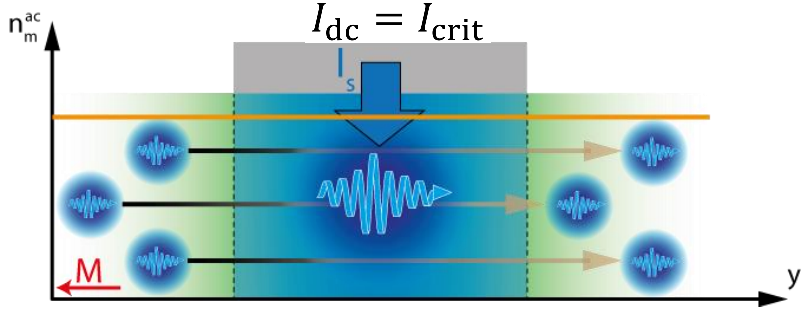
Fit function

$$A(I_{dc}) = A_0 + a_{SHE} I_{dc} + a_{Therm} I_{dc}^2$$

Wimmer, MA *et al.*, PRL **123** , 257201 (2019).

Spin Resistance





$\rho^s_{NC} \approx 0.5\ \mu\Omega\mathrm{m}$

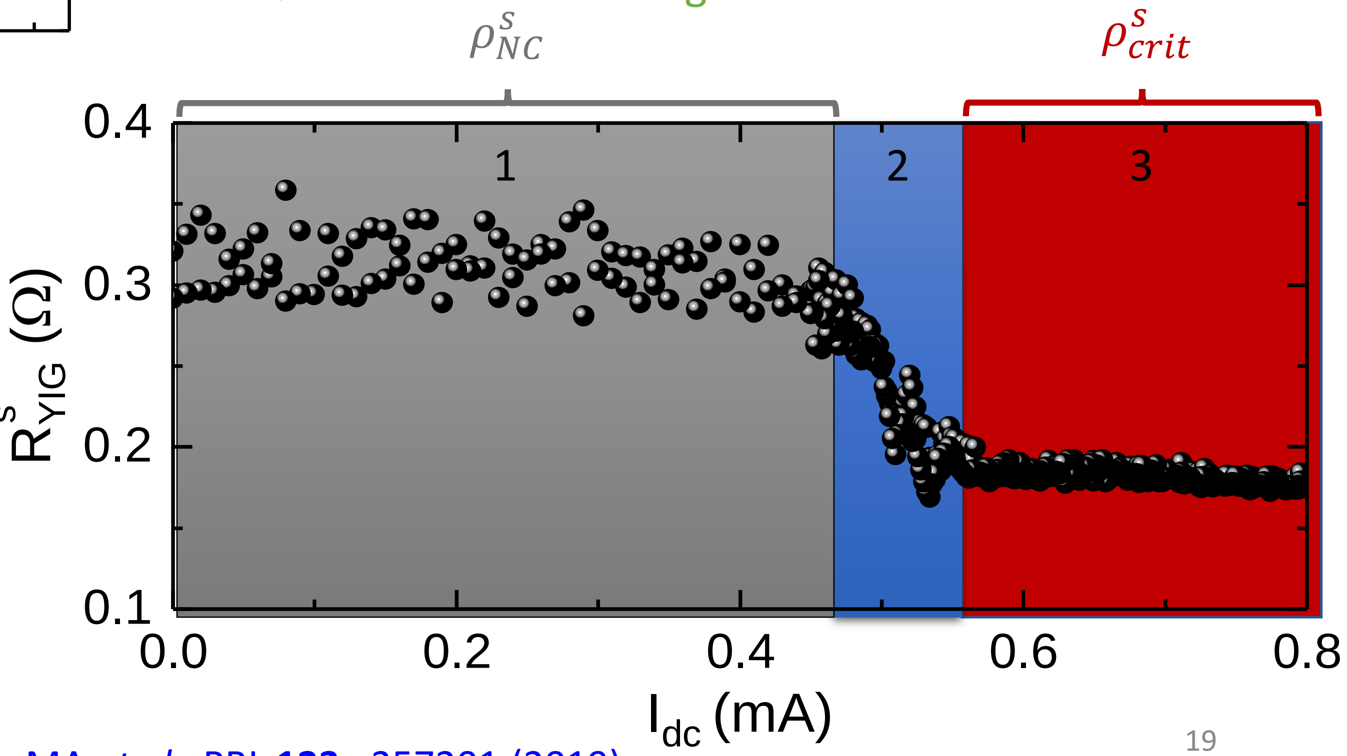
$\rho^s_{crit} \approx 8\ n\Omega\mathrm{m}$

Spin resistivity drop by almost two orders of magnitude

Spin resistance of Pt strip

$$R^s_{YIG} \approx \frac{R^s_{Pt}}{\eta_s} \propto \frac{1}{A_{corr}}$$

Spin transfer efficiency from injector to detector

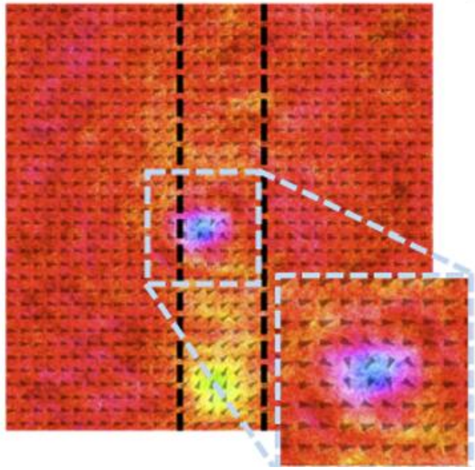


3 different resistance regimes

Wimmer, MA *et al.*, PRL **123** , 257201 (2019).

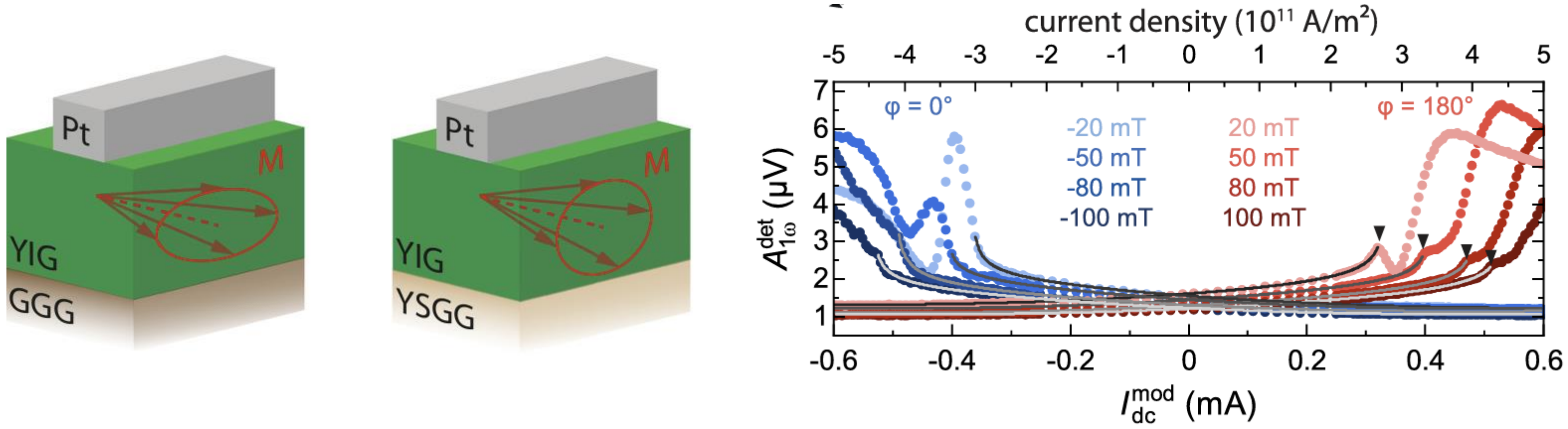
Further Work

Bullet modes, instabilities



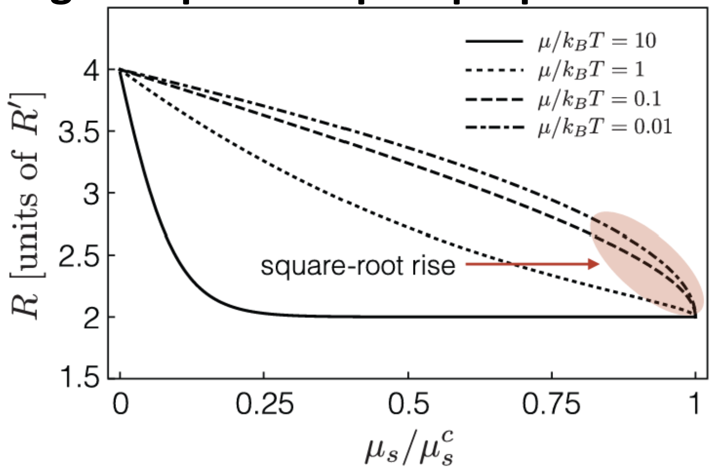
Ulrichs, PRB **102**, 174428 (2020).
Troncoso, Brataas, Duine, PRB **99**, 104426 (2019).

Magnon transport with reduced effective magnetization



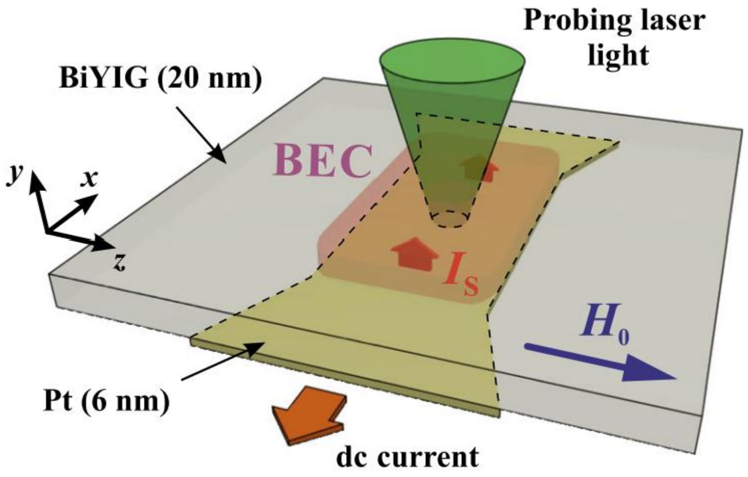
Gückelhorn *et al.*, PRB **104**, L180410 (2021).

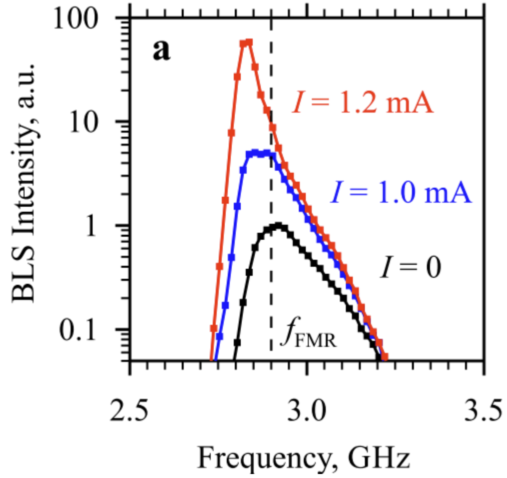
Magnon spin transport properties



Takei, PRB **100**, 134440 (2019).

Spin current driven Bose-Einstein condensation of magnons

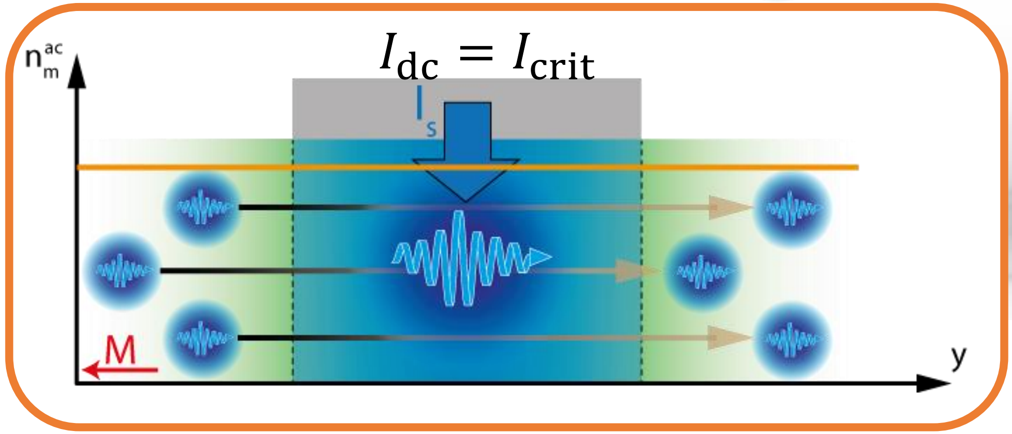


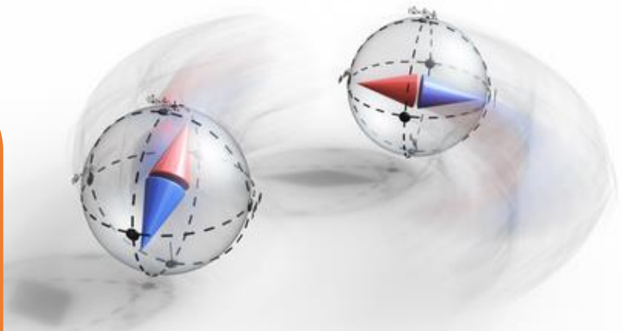


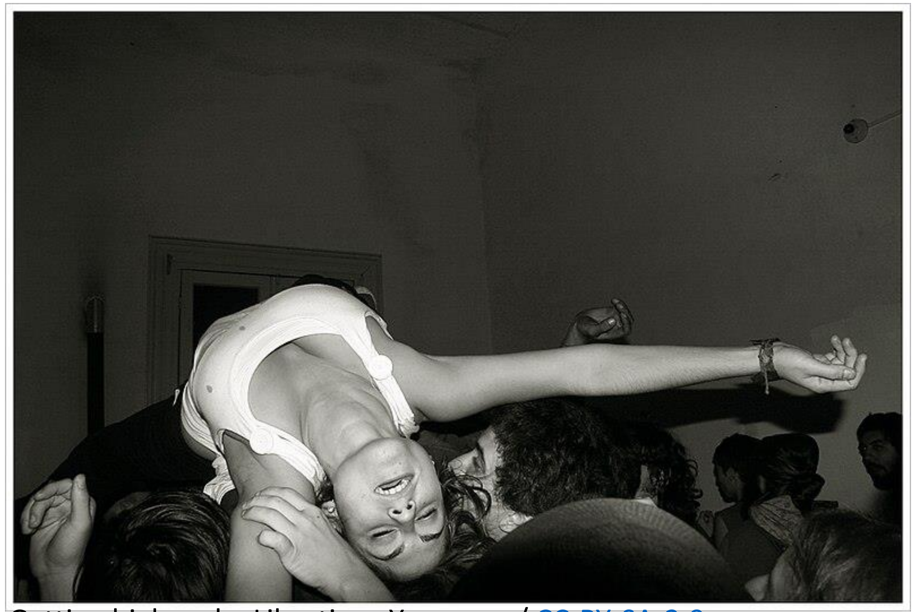
Divinskiy *et al.*, Nat. Comm. **12**, 6541 (2021).

Dances with magnons

Magnons in Ferromagnets



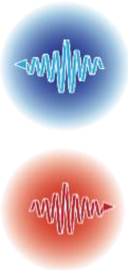


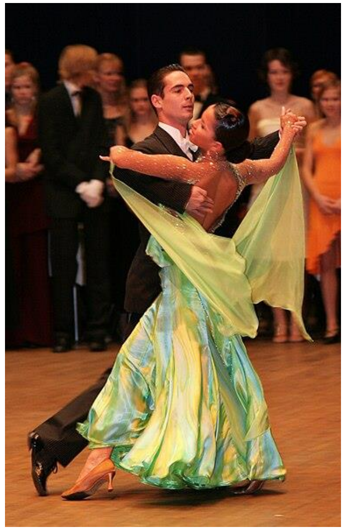


Getting higher.. by Libertinus Yomango / CC-BY-SA-2.0

© Chris Hohmann, MCQST

Magnons in Antiferromagnets





A ballroom tango by Che / CC-BY-SA-2.5

Vienna Opera Ball by Gryffindor / CC-BY-SA-4.0

Antiferromagnetic Magnons

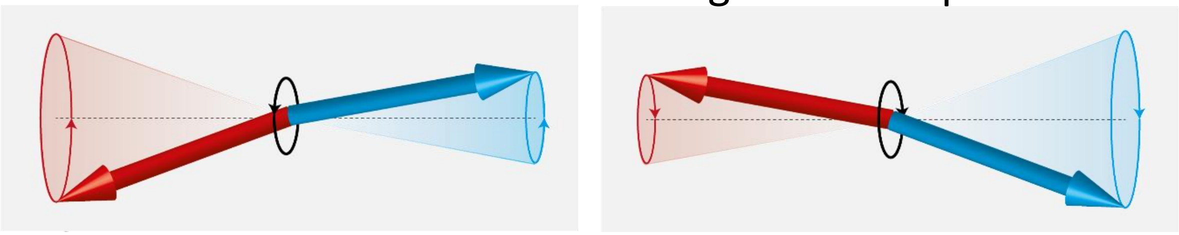
Easy axis antiferromagnet | **2** magnon modes in AFMs | **Easy plane antiferromagnet**

β-mode

Left-circular polarized

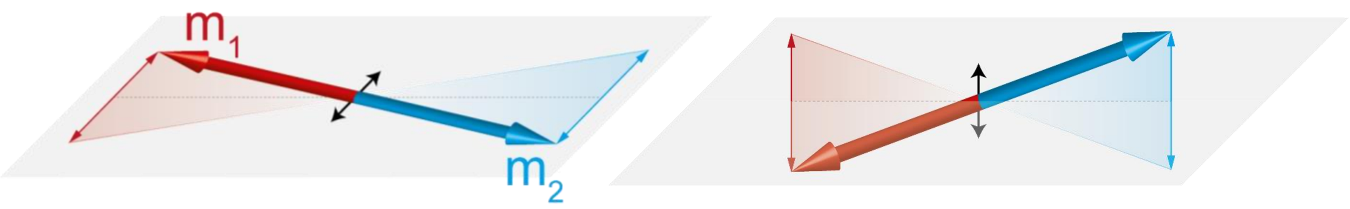
α-mode

Right-circular polarized



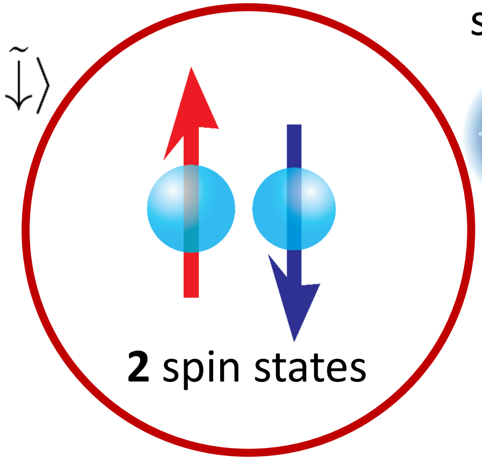
linear polarized

linear polarized

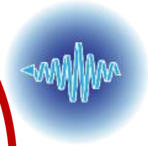


spin -1

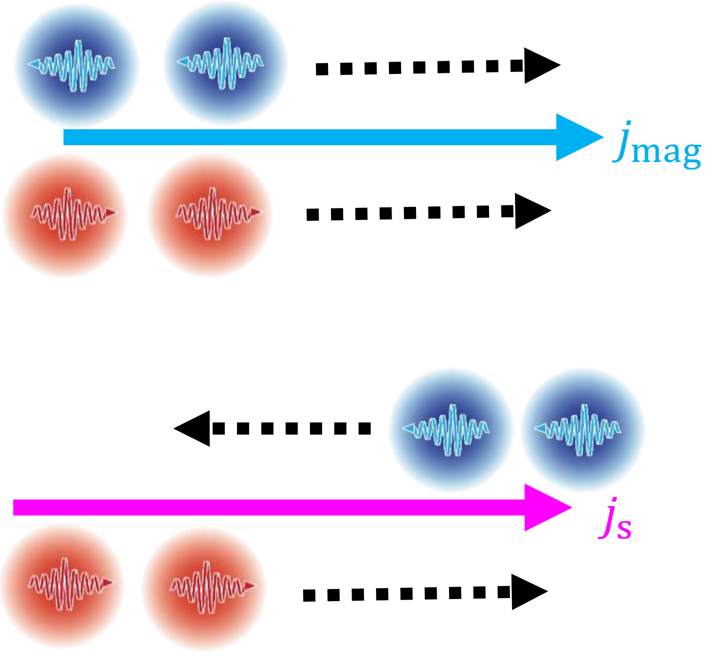
$|\tilde{\downarrow}\rangle$

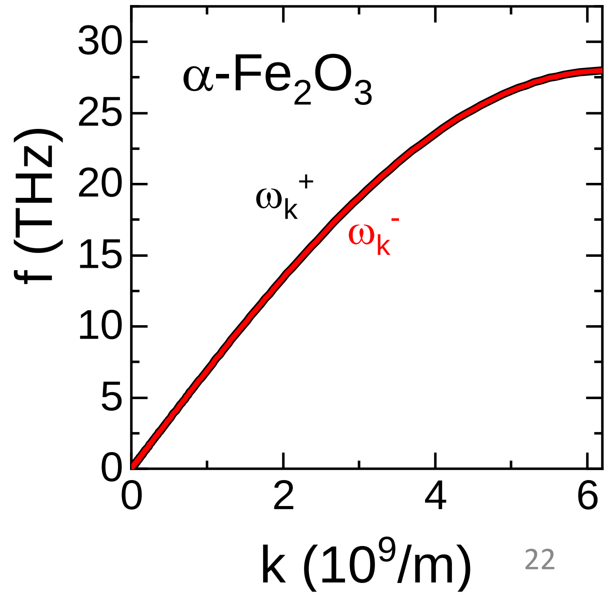


spin +1



$|\tilde{\uparrow}\rangle$



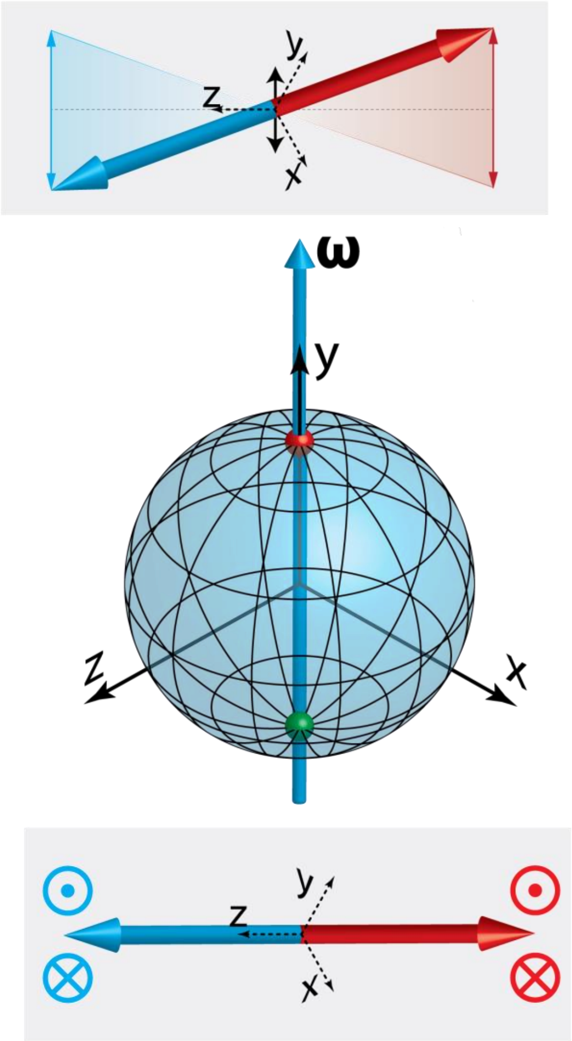


R. Cheng *et al.*, Sci. Rep. **6**, 24223 (2016).
Rezende *et al.*, JAP **126**, 151101 (2019).
K. Nakata *et al.*, J. Phys. D **50**, 114004 (2017).
M.W. Daniels *et al.*, Phys. Rev. B **98**, 134450 (2018).
K Shen, JAP **129**, 223906 (2021).
J. Han *et al.*, Nat. Mater. (2023).

Antiferromagnetic Magnons Described via Pseudospin

A. Kamra

Pseudospin **S**



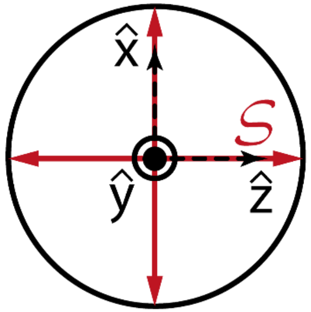
T. Wimmer *et al.*, Phys. Rev. Lett. **125** , 247204 (2020).
A. Kamra *et al.,* Phys. Rev. B **102**, 174445 (2020).

General concept also applicable to other bosonic systems, e.g. photons, phonons

Antiferromagnetic Magnons Described via Pseudospin

A. Kamra

Pseudospin S



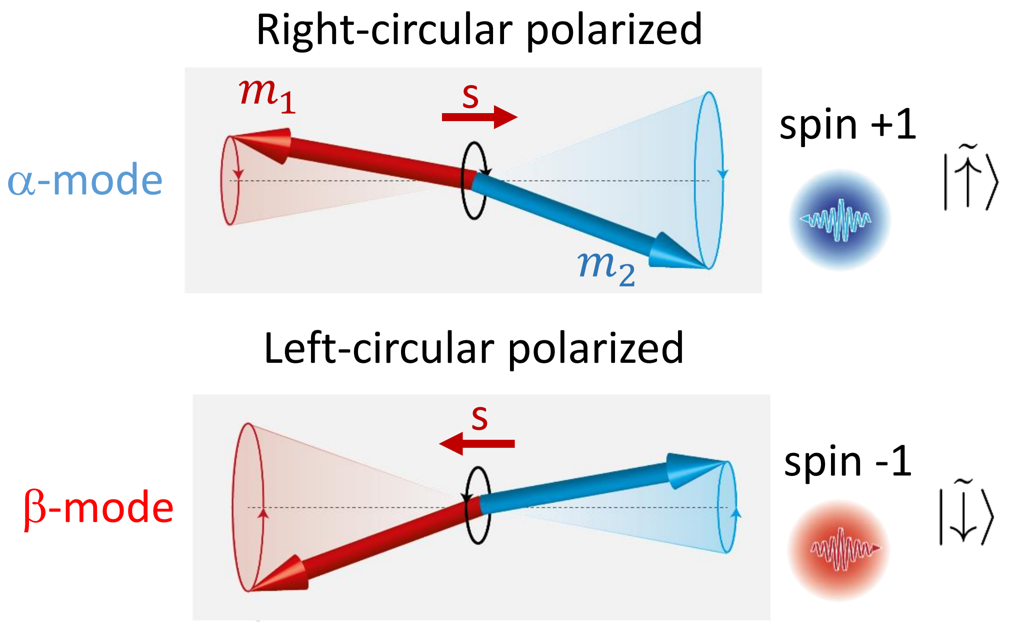
- Pseudospin S direction determines the polarization state of the magnon modes and their superpositions
- Finite magnon spin is given by z component of S
- Mapping of up- and down-spin states similar to Bloch sphere description of a two-level system

T. Wimmer *et al.*, Phys. Rev. Lett. **125** , 247204 (2020).
A. Kamra *et al.,* Phys. Rev. B **102**, 174445 (2020).

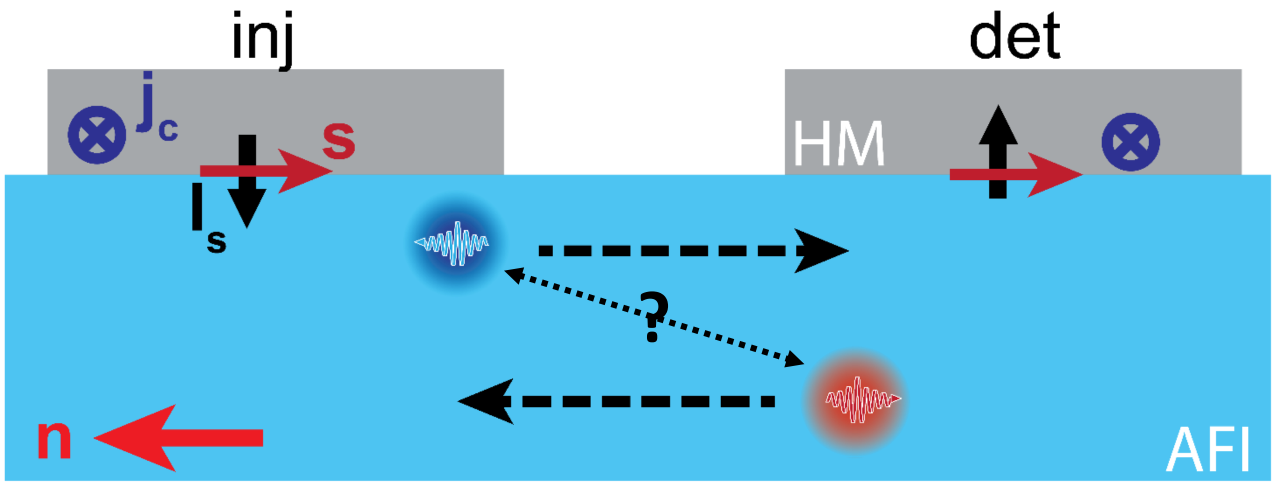
General concept also applicable to other bosonic systems, e.g. photons, phonons

Antiferromagnetic Magnons and Transport

Antiferromagnetic magnons come in pairs with opposite precession chiralities



Natural basis states of AFI

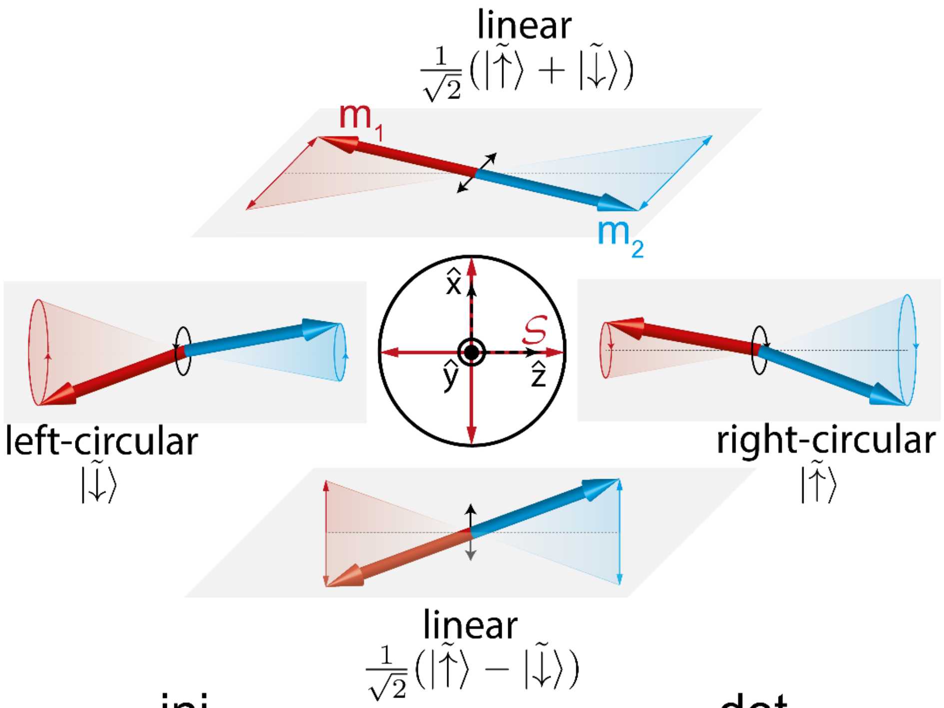


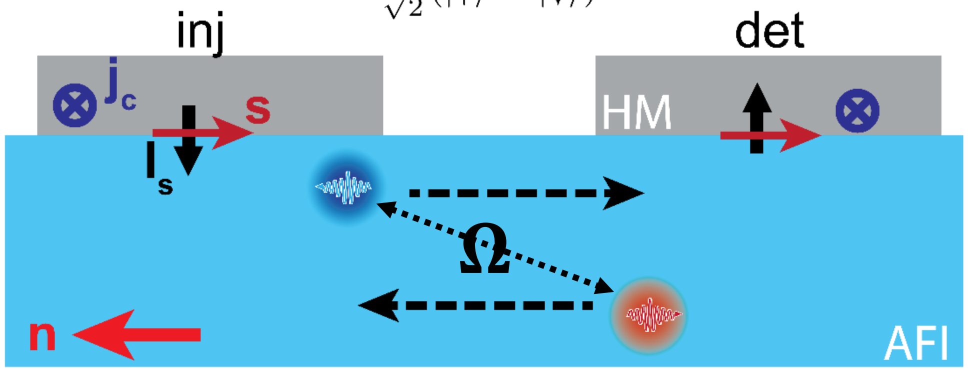
- SHE-induced spin current in HM leads to excitation/depletion of circularly polarized α- and β-modes
- Magnon excitation when $\boldsymbol{s} \parallel \boldsymbol{n}$

How do we describe coupled modes in the AFI?

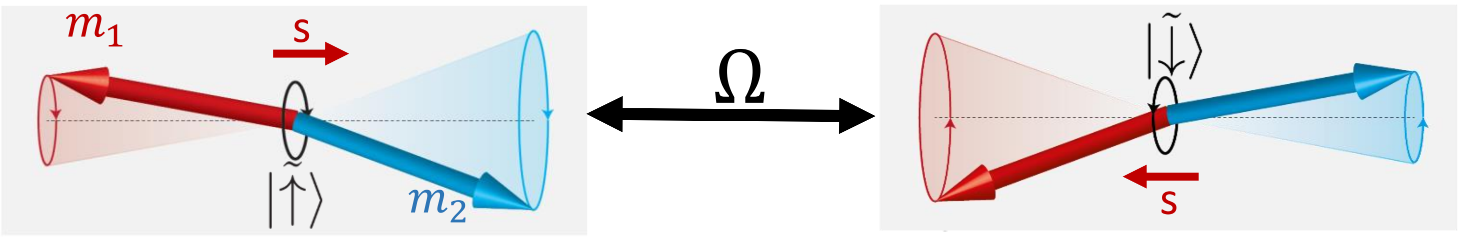
J. Han et al., Nature Nanotechnology **15**, 1748-3395 (2020)
S. M. Rezende, Journal of Applied Physics **126**, 151101 (2019)
R. Lebrun *et al., Nature* **561**, 222 (2018).
K Shen Physical Review B **100** , 094423 (2019).
L. Cornelissen *et al.*, Nature **11**, 1022-1026 (2015)
R. Lebrun et al., Nature Communications **11**, 6332 (2020).

Mode Coupling Ω and Pseudospin Diffusion Equation





What happens when they couple?



Mode coupling Ω induced via breaking of rotational symmetry about the Neel vector $\boldsymbol{n}$

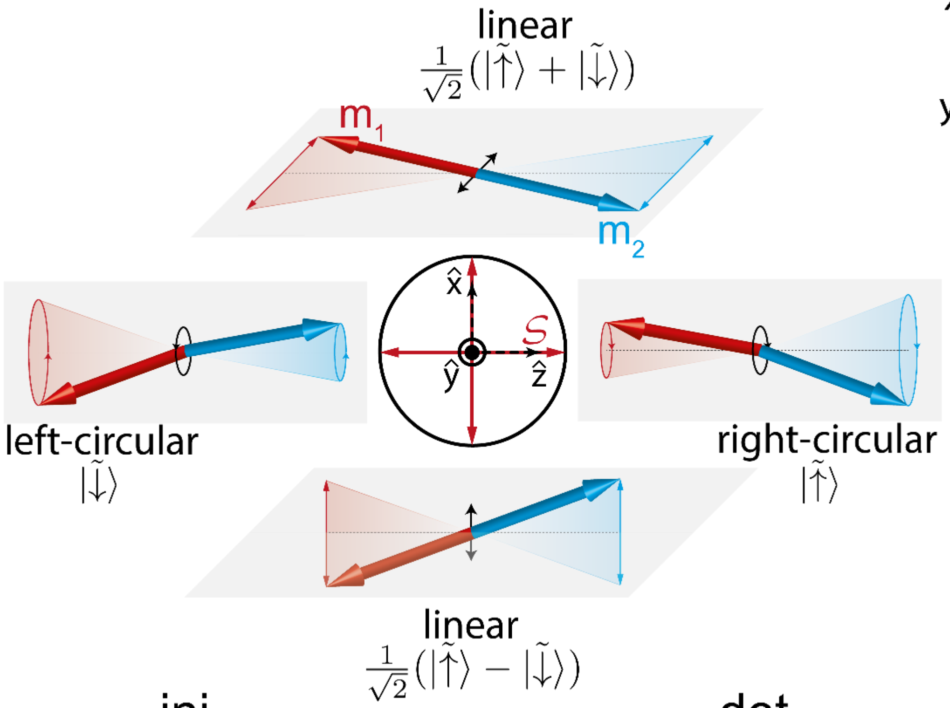
Diffusive pseudospin transport equation:

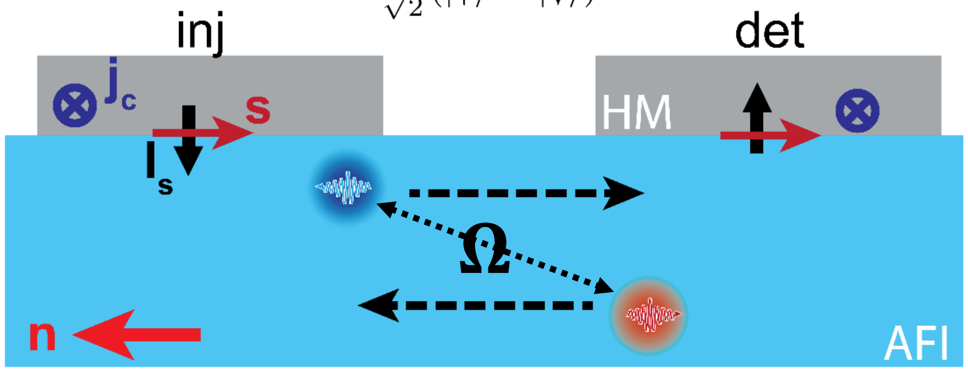
$$\frac{\partial \mathcal{S}}{\partial t} = D\nabla^2 \mathcal{S} - \frac{\mathcal{S}}{\tau_s} + \mathcal{S} \times \Omega\,\hat{\mathbf{y}}$$

S : pseudospin density vector
D: diffusion constant
τ_s: spin lifetime
Ω: coherent coupling between 'spin-up' and 'spin-down' modes → precession frequency of pseudospin

T. Wimmer *et al.*, Phys. Rev. Lett. **125** , 247204 (2020).
A. Kamra *et al.,* Phys. Rev. B **102**, 174445 (2020).

Mode Coupling Ω and Pseudospin Diffusion Equation





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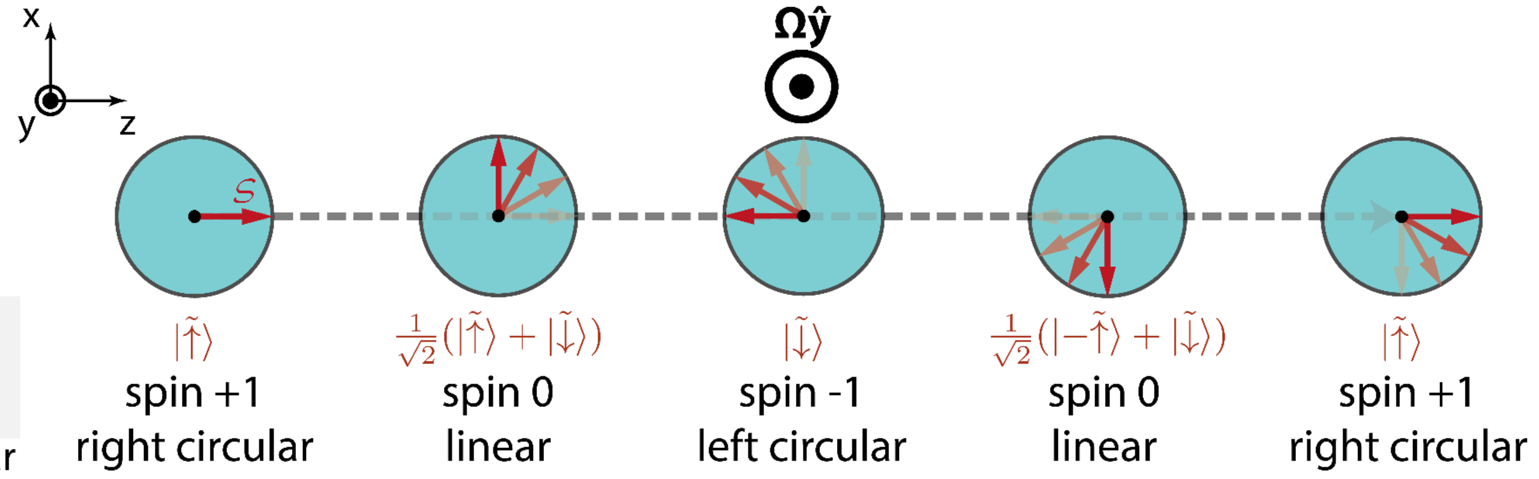

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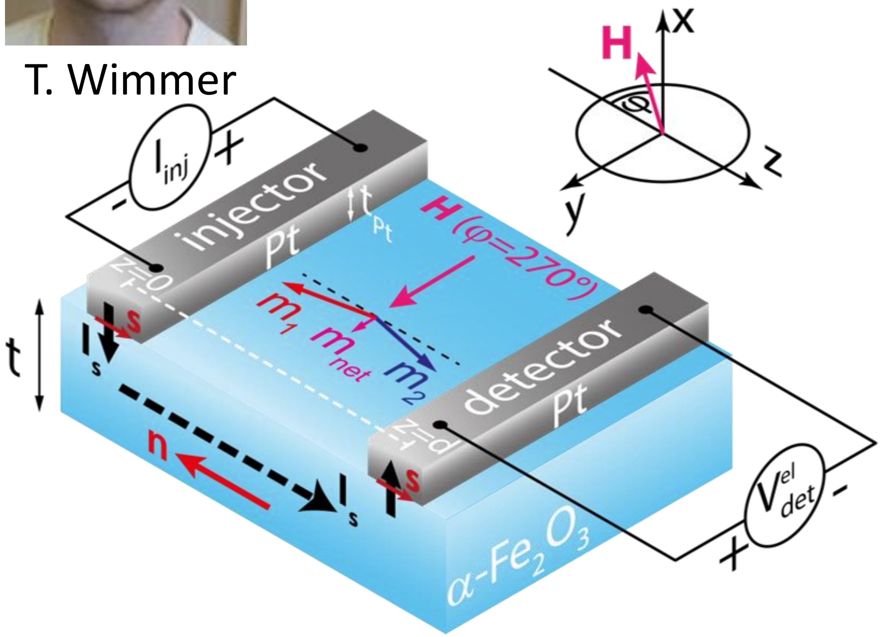
T. Wimmer *et al*., Phys. Rev. Lett. **125** , 247204 (2020).
A. Kamra *et al.,* Phys. Rev. B **102**, 174445 (2020).

Sample Layout and Properties: Pt/α-Fe_2O_3(hematite)

T. Wimmer

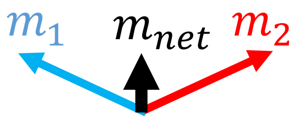
$$t_{\mathrm{Pt}} = 5\ \mathrm{nm}$$
$$t_{\mathrm{Fe_2O_3}} = 15\ \mathrm{nm}$$



$$V_{\mathrm{det}}^{\mathrm{el}} = \frac{V_{\mathrm{det}}(+I) - V_{\mathrm{det}}(-I)}{2}$$

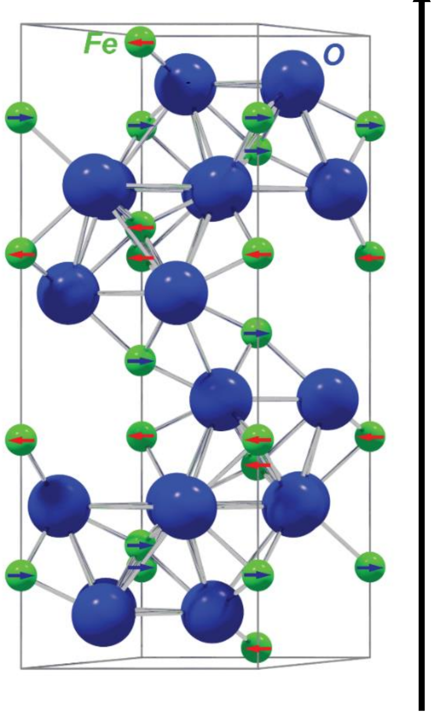
Normalization: $R_{\mathrm{det}}^{\mathrm{el}} = \frac{V_{\mathrm{det}}}{I_{\mathrm{inj}}} \cdot \frac{A_{\mathrm{inj}}}{A_{\mathrm{det}}}$

magnetic easy-plane (c-plane) with slight canting due to DMI



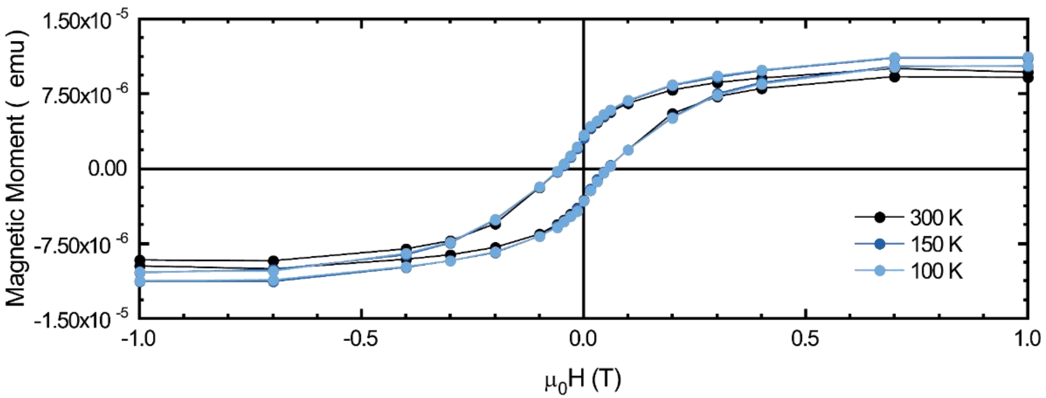
α-Fe_2O_3

c-axis (0001)



- hexagonal (0001) orientation
- grown via pulsed laser deposition (PLD) on sapphire Al_2O_3
- 15nm thick
- shows NO Morin transition

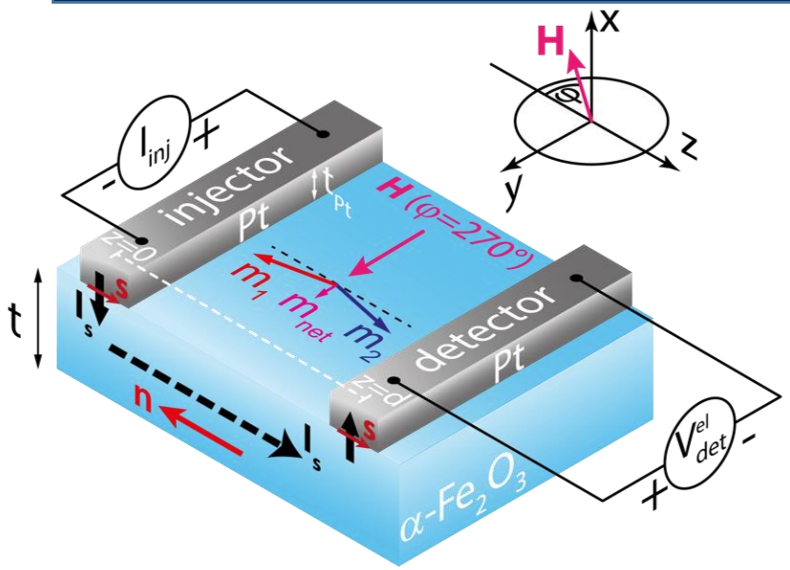
→ Spins oriented in-plane for all temperatures
→ magnetic easy-plane film



ferromagnetic behaviour due to canted moment and easy plane anisotropy

vanishing Morin transition observed for thin hematite also in:
J. Han *et al.*, Nature Nanotechnology **15**, 1748-3395 (2020).

Pseudospin Precession Frequency in Hematite and 1D Solution of Pseudospin Diffusion Equation



$$\frac{\partial \mathcal{S}}{\partial t} = D\nabla^2 \mathcal{S} - \frac{\mathcal{S}}{\tau_s} + \mathcal{S} \times \Omega\,\hat{\mathbf{y}}$$

Boundary condition at injector ($z = 0$): $-D\frac{\partial \mathcal{S}_z}{\partial z} = j_{s0}$

Steady state solution in 1-D:

$$s_z(z) = \frac{j_{s0}\lambda_s}{D(a^2+b^2)} e^{\frac{-az}{\lambda_s}} \left(b\cos\left(\frac{b\,z}{\lambda_s}\right) - a\sin\left(\frac{b\,z}{\lambda_s}\right)\right)$$

with $a = \frac{1}{\sqrt{2}}\sqrt{1+\sqrt{1+\Omega^2\tau_s^2}}$ and b $= \frac{1}{\sqrt{2}}\sqrt{-1+\sqrt{1+\Omega^2\tau_s^2}}$

and $\lambda_s = \sqrt{D\tau_s}$ spin Diffusion Length

In hematite: coupling Ω determined by easy-plane anisotropy and DMI induced canting

Pseudospin precession frequency:

$$\hbar\Omega = \hbar\tilde{\omega}_{an} - \mu_0 m_{net0} H$$

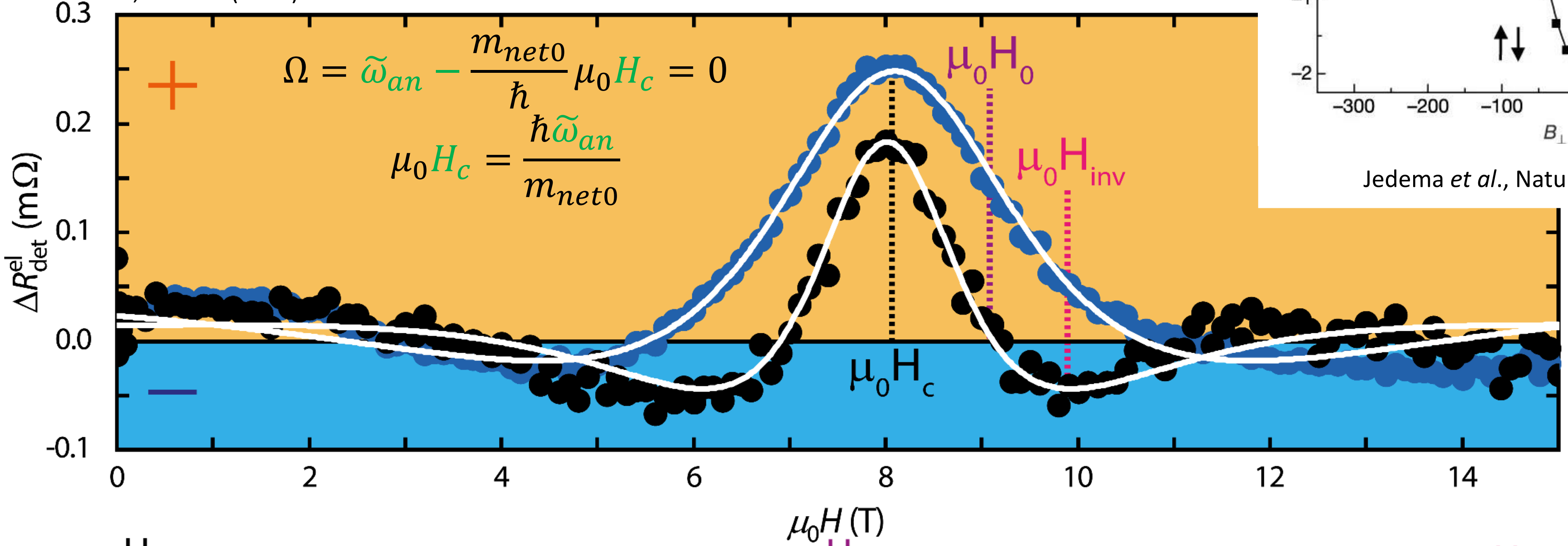
m_{net0}: canted magnetic moment at zero external field
→ DMI-induced canting
ω_{an}: easy-plane anisotropy energy

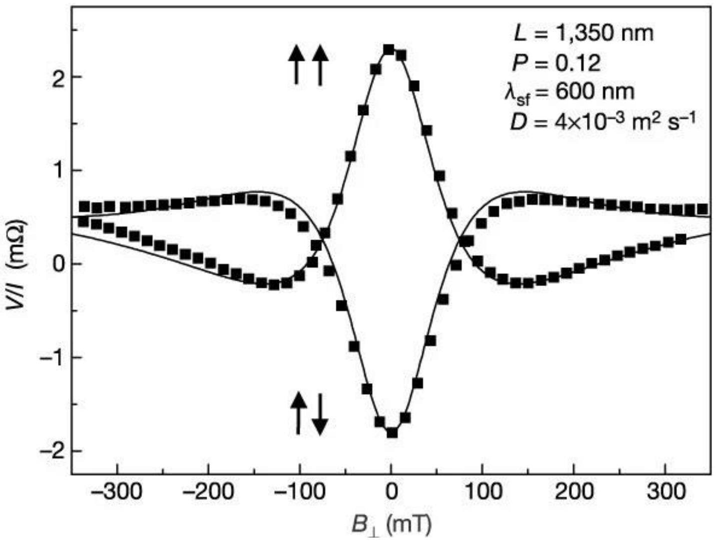
T. Wimmer *et al.*, Phys. Rev. Lett. **125** , 247204 (2020).
A. Kamra *et al.,* Phys. Rev. B **102**, 174445 (2020).

Antiferromagnetic Magnon Hanle Effect

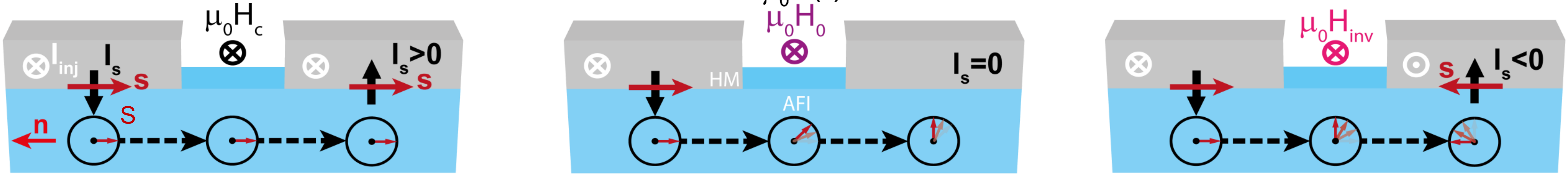
T. Wimmer *et al.*, Phys. Rev. Lett. **125** , 247204 (2020).
A. Kamra *et al.*, Phys. Rev. B **102**, 174445 (2020).
A. Ross *et al.*, Appl. Phys. Lett. **117**, 242405 (2020).
K. Shen, Journal of Applied Physics **129**, 223906 (2021).
V. Brehm *et al.*, Phys. Rev.. B **107**, 184404 (2023).

$$\Delta R^{\mathrm{el}}_{\mathrm{det}} \propto s_z(z)$$





Jedema *et al.*, Nature **416**, 713 (2002).



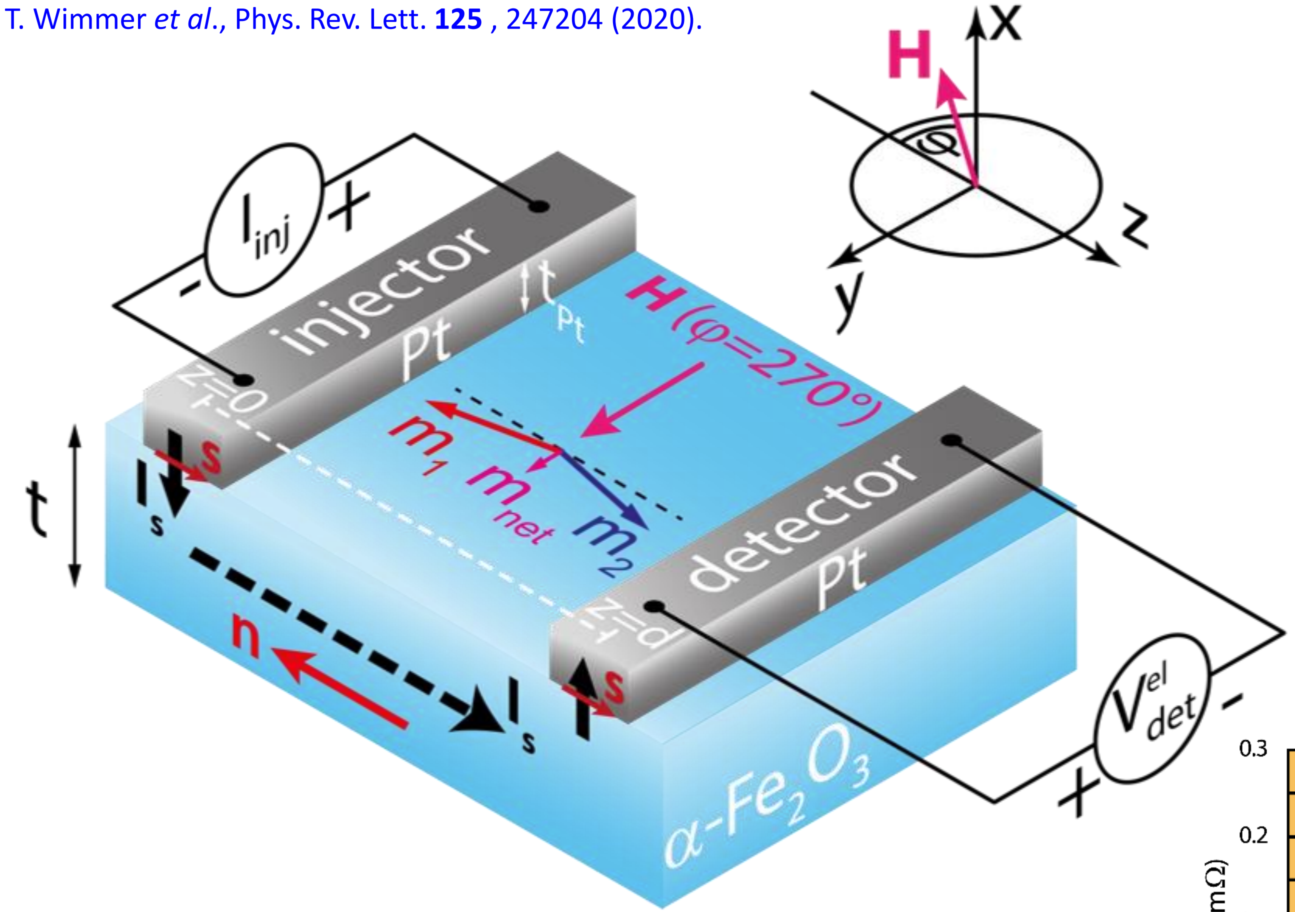
$\Omega = 0$
$s_z > 0$

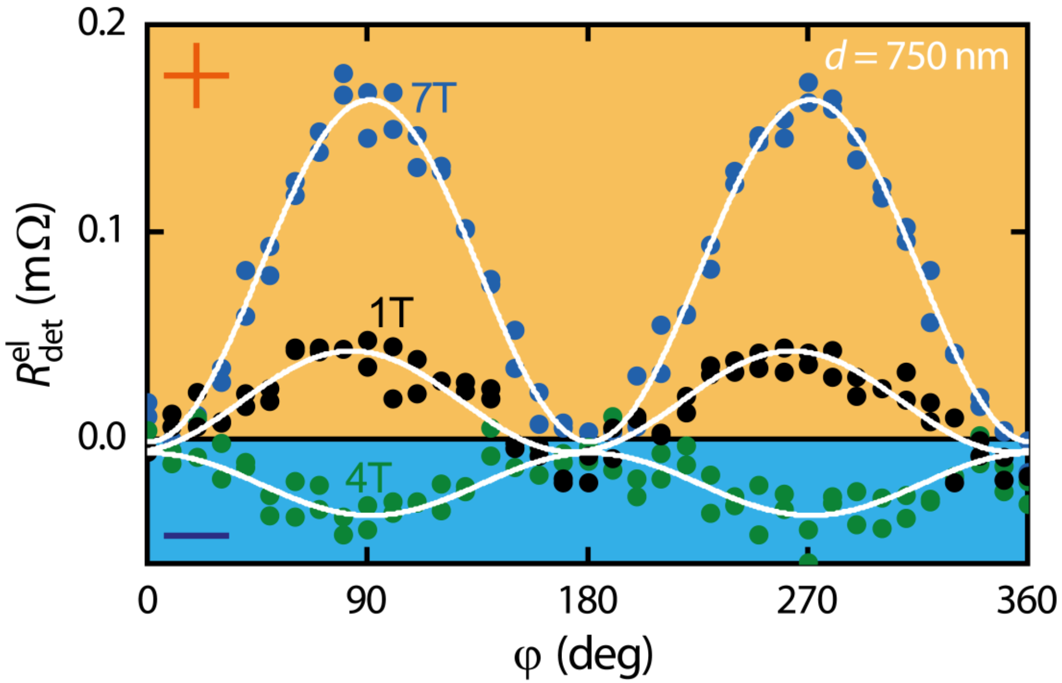
$\Omega_0 > 0$
$s_z = 0$

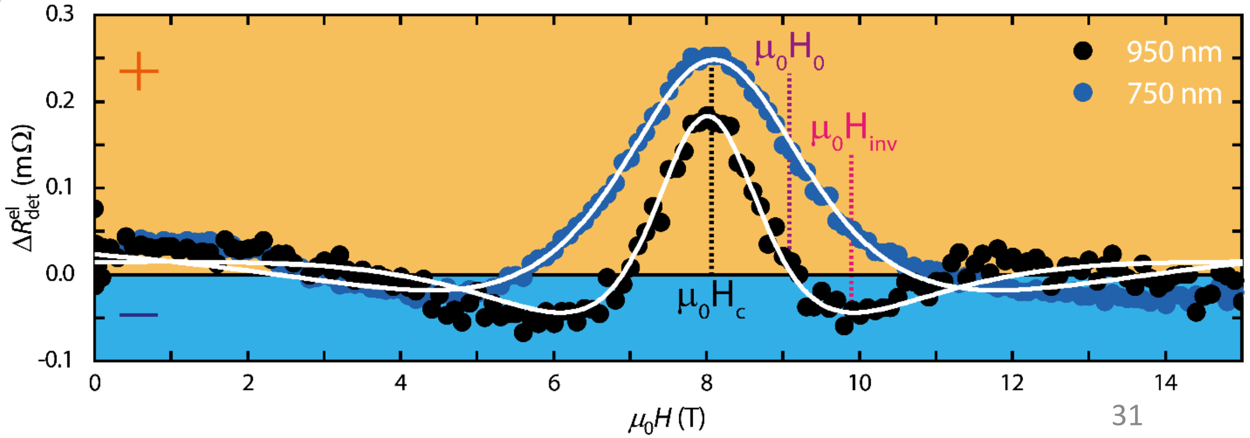
$\Omega > \Omega_0$
$s_z < 0$

Angle Dependent Magnon Transport Signals

T. Wimmer *et al.*, Phys. Rev. Lett. **125** , 247204 (2020).

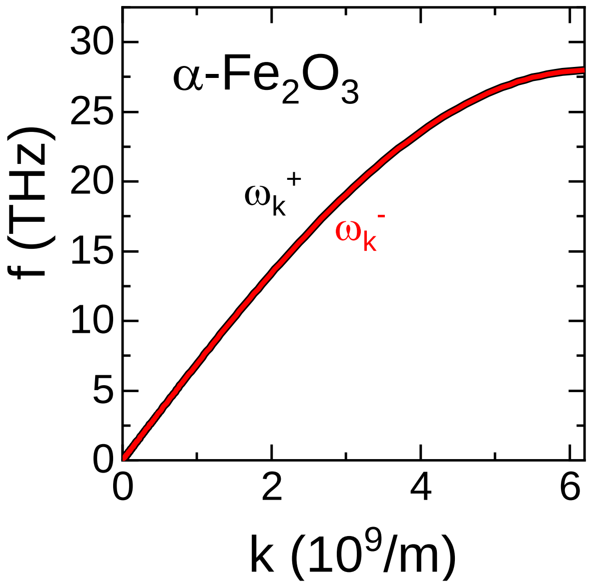






- Finite magnon transport for $\boldsymbol{n} \parallel \boldsymbol{s}$
- Clear sign change also in angle dependent measurements

Nonreciprocal Magnon Dispersion

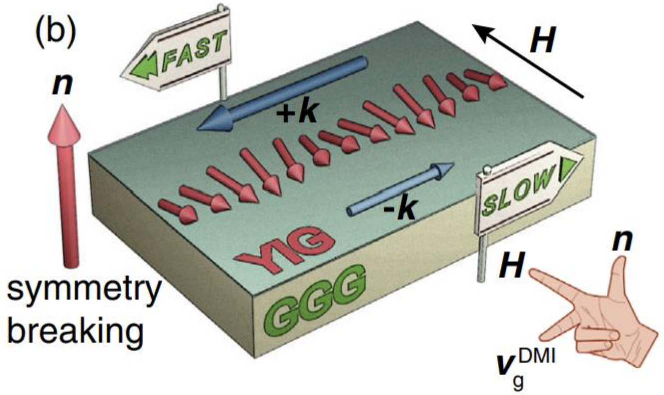


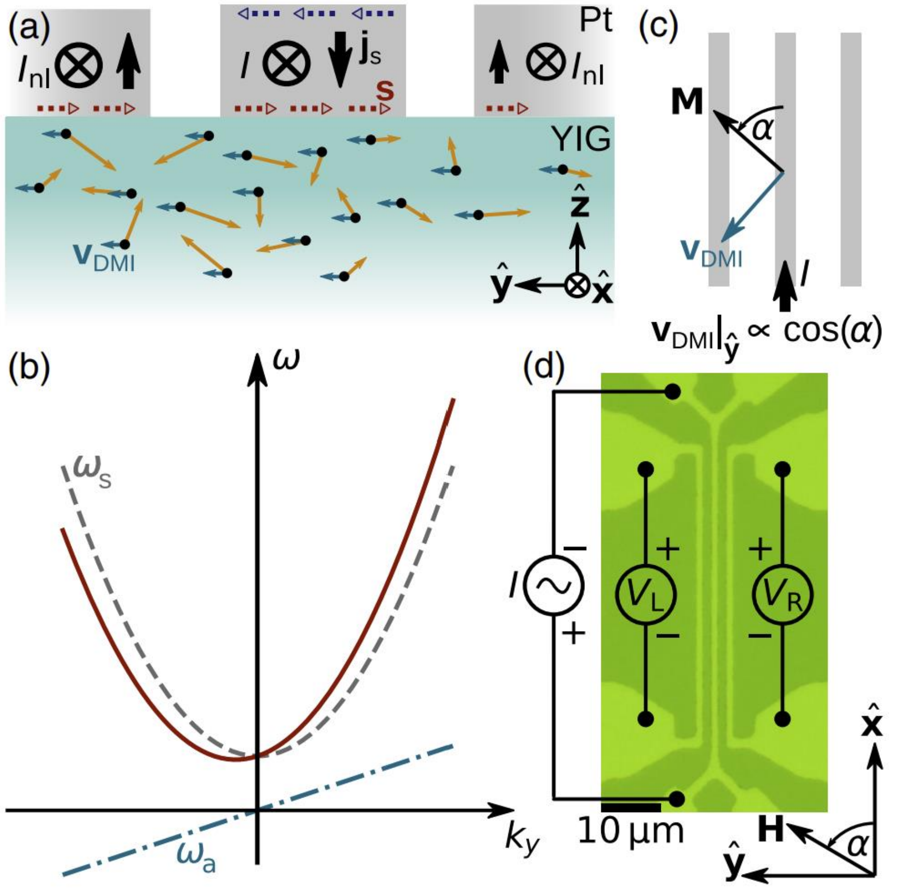
Previous assumption:

$$\omega(\boldsymbol{k}) = \omega(-\boldsymbol{k})$$

Inversion symmetry breaking due to substrate/film interface:

YIG/GGG interface:





What happens with pseudospin dynamics when inversion symmetry is broken?

H. Wang *et al.*, Phys. Rev. Lett. **124**, 027203 (2020).
R. Schlitz *et al.*, Phys. Rev. Lett. **126** , 257201 (2021).

Nonreciprocal Pseudospin Diffusion Equation

A. Kamra

Diffusive pseudospin transport equation:

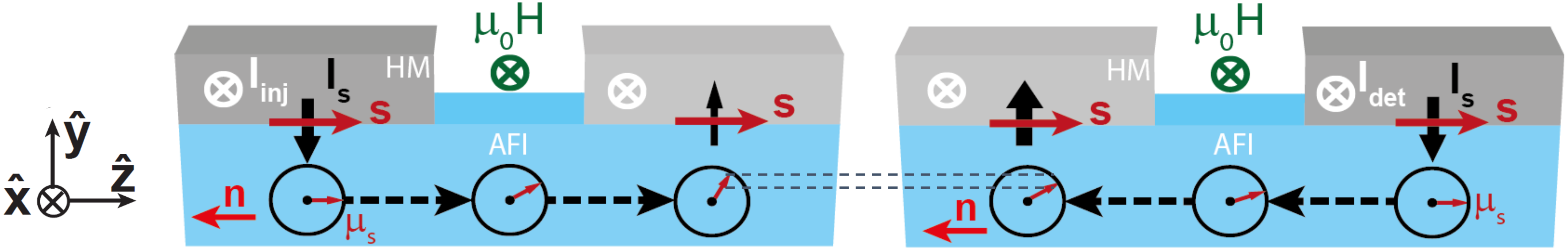
$$\frac{\partial \boldsymbol{\mu}_s}{\partial t} = D\nabla^2 \boldsymbol{\mu}_s - \frac{\boldsymbol{\mu}_s}{\tau_s} + \boldsymbol{\mu}_s \times \omega\hat{\boldsymbol{x}} - l\,\frac{\partial \boldsymbol{\mu}_s}{\partial z} \times \delta\omega\hat{\boldsymbol{x}}$$

Antisymmetric component of the k-resolved pseudofield $\boldsymbol{\omega}(\boldsymbol{k})$

$$\boldsymbol{\mu}_s(z) = \boldsymbol{\mu}_s^{\mathrm{sym}}(z) + \boldsymbol{\mu}_s^{\mathrm{asym}}(z)$$

$$\mu_{sz}(+d) = \mu_{sz}^{\mathrm{sym}}(d) + \mu_{sz}^{\mathrm{asym}}(d)$$

$$\mu_{sz}(-d) = \mu_{sz}^{\mathrm{sym}}(d) - \mu_{sz}^{\mathrm{asym}}(d)$$

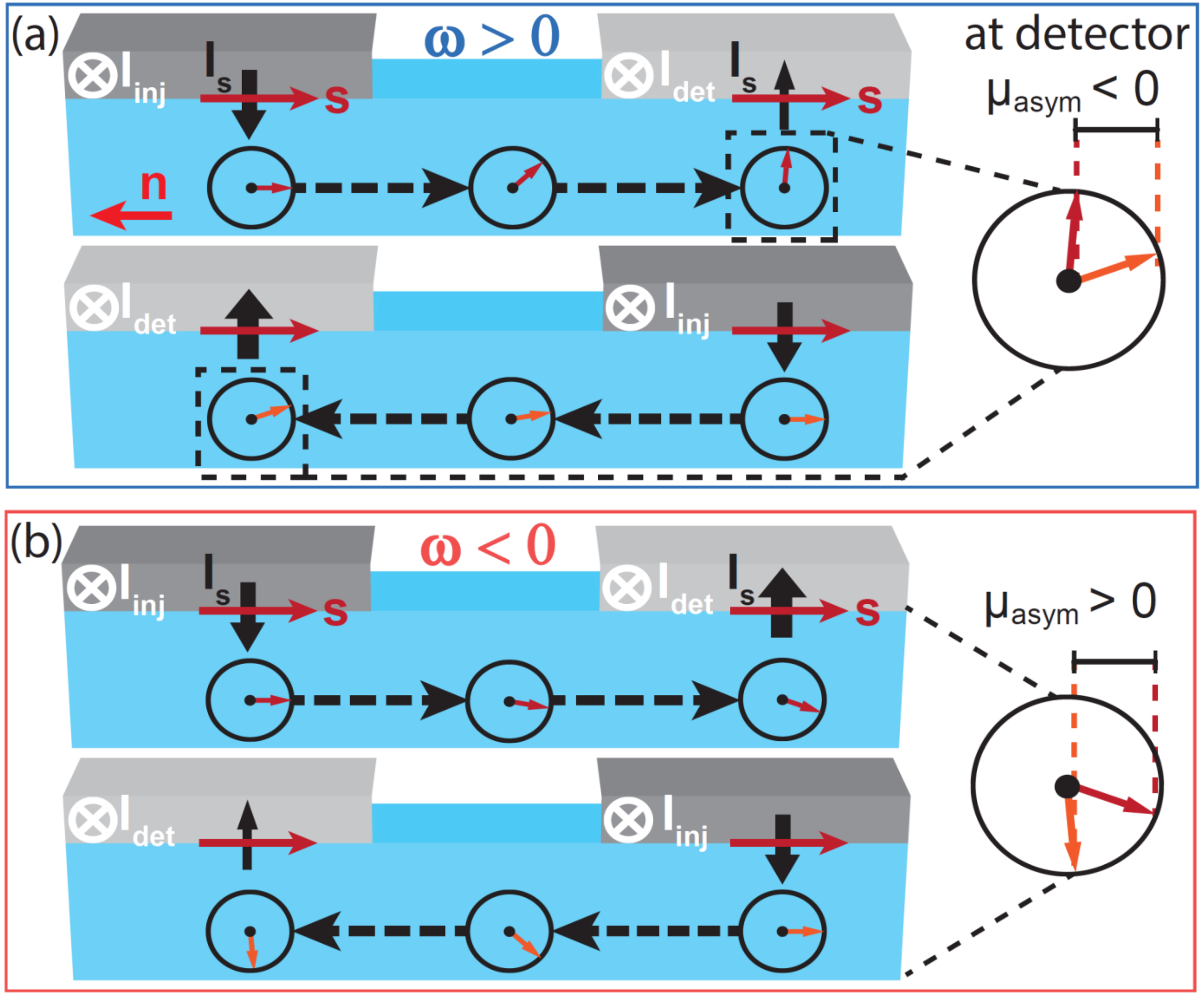


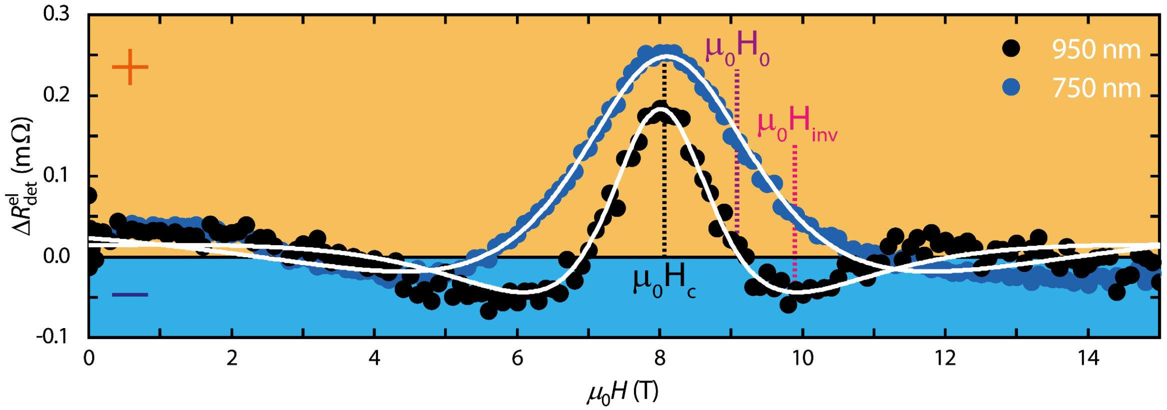
Inj → Det

Det → Inj

J. Gückelhorn, et al., PRL **130**, 216703 (2023).

Magnetic Field Dependence





$\mu_0 H < \mu_0 H_c$

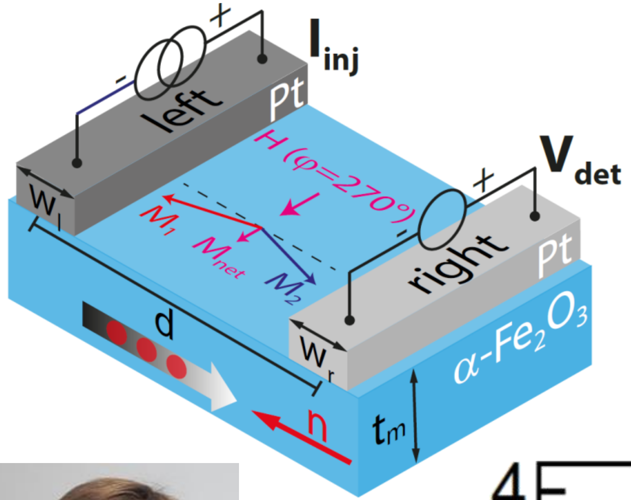
$$\boldsymbol{\mu}_s(z) = \boldsymbol{\mu}_s^{\text{sym}}(z) + \boldsymbol{\mu}_s^{\text{asym}}(z)$$

Symmetric signal has maximum at $\mu_0 H_c$
Antisymmetric signal changes sign at $\mu_0 H_c$

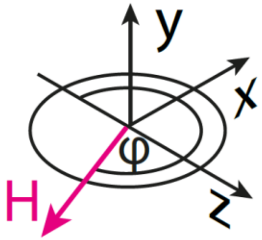
$\mu_0 H > \mu_0 H_c$

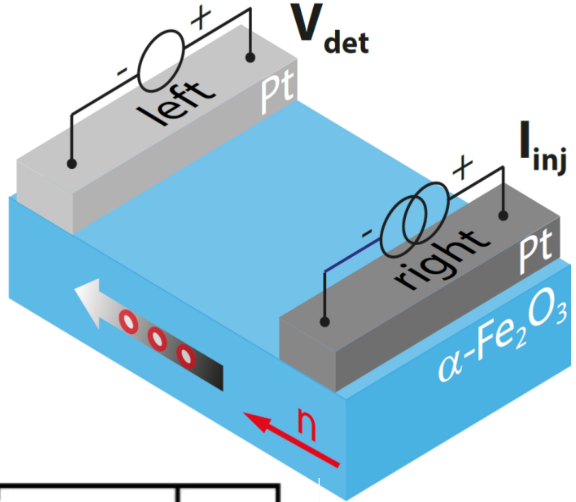
J. Gückelhorn, et al., PRL **130**, 216703 (2023).

Nonreciprocity in Magnon Transport Experiment



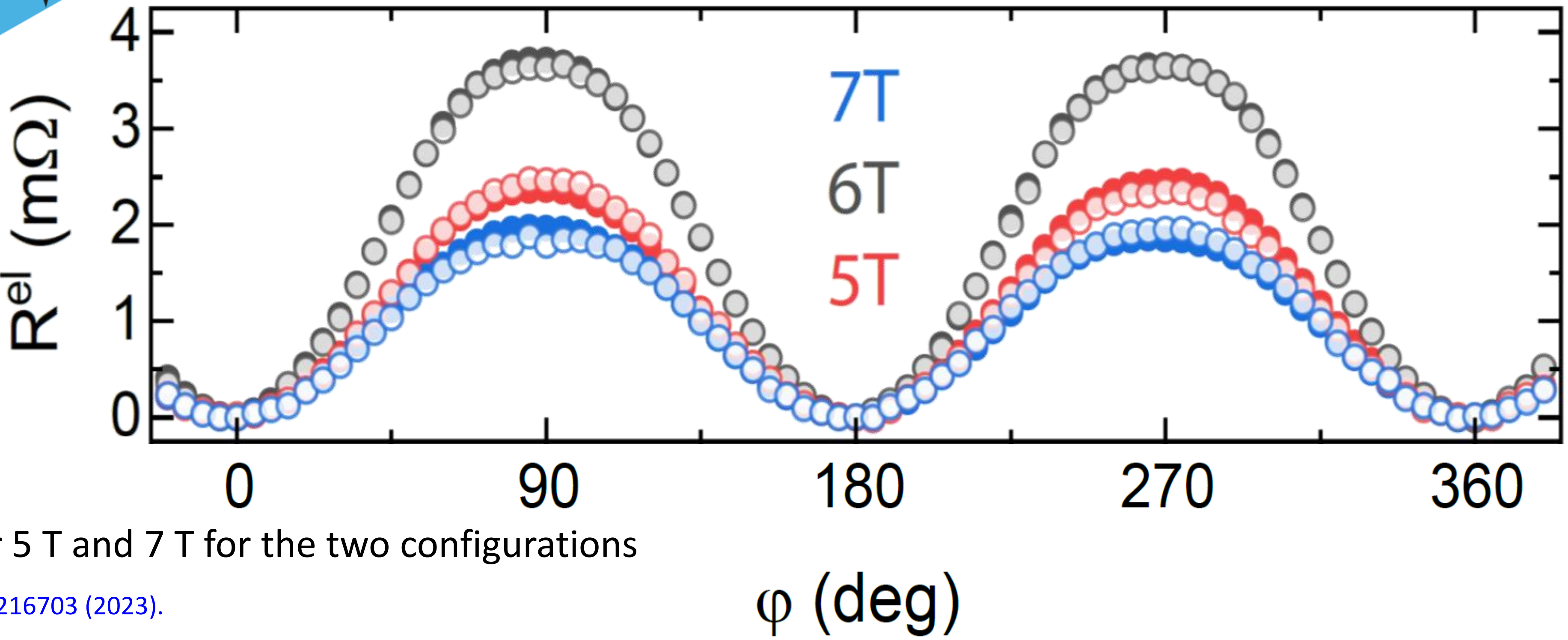
t_m = 89 nm
d = 1.2 µm
T = 250 K





$\mu_0 H_c \approx 6\ \mathrm{T}$

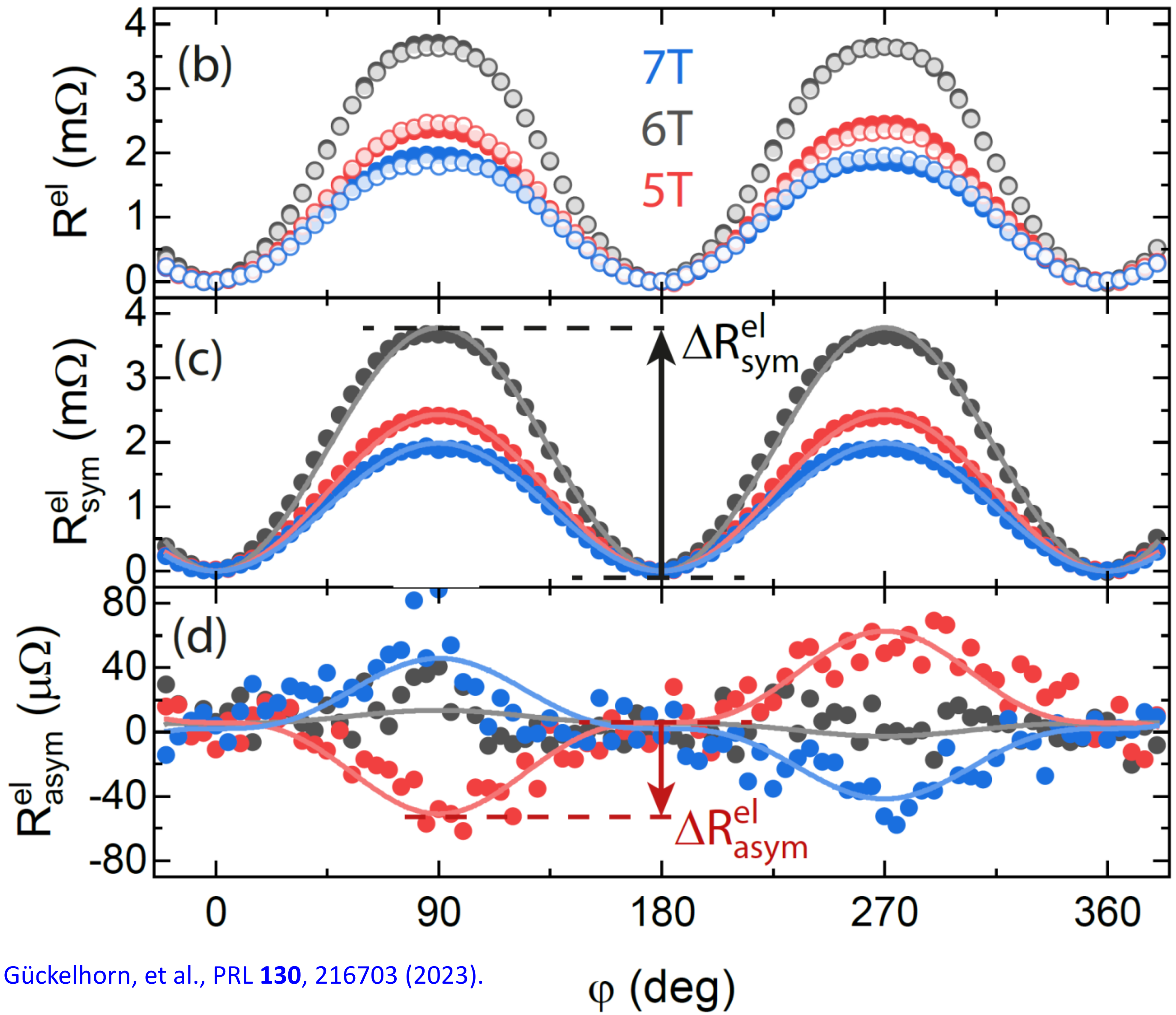
J. Gückelhorn

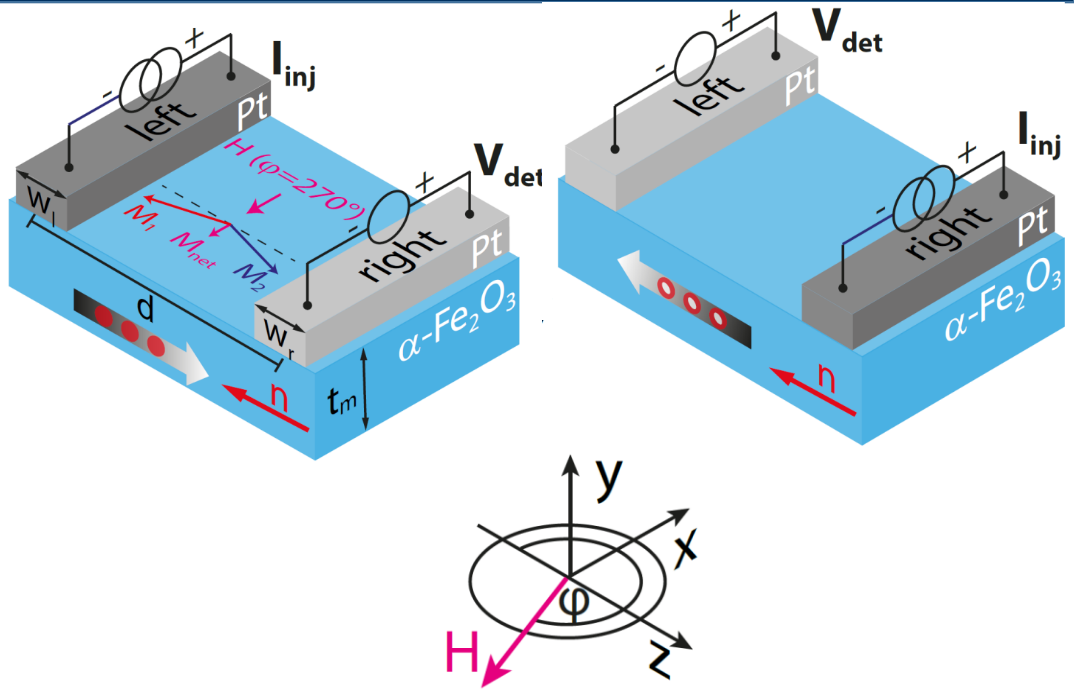


Finite differences for 5 T and 7 T for the two configurations

J. Gückelhorn, et al., PRL **130**, 216703 (2023).

Symmetric/Antisymmetric Spin Signal





$$R^{el}_{sym} = [R^{el}(+d) + R^{el}(-d)]/2$$

$$R^{el}_{asym} = [R^{el}(+d) - R^{el}(-d)]/2$$

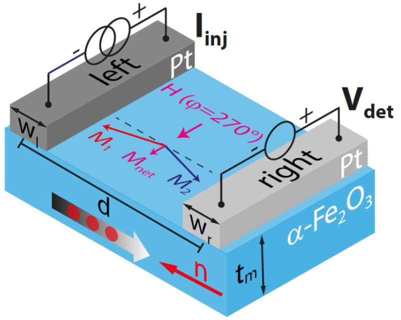
Extract amplitudes via fit:

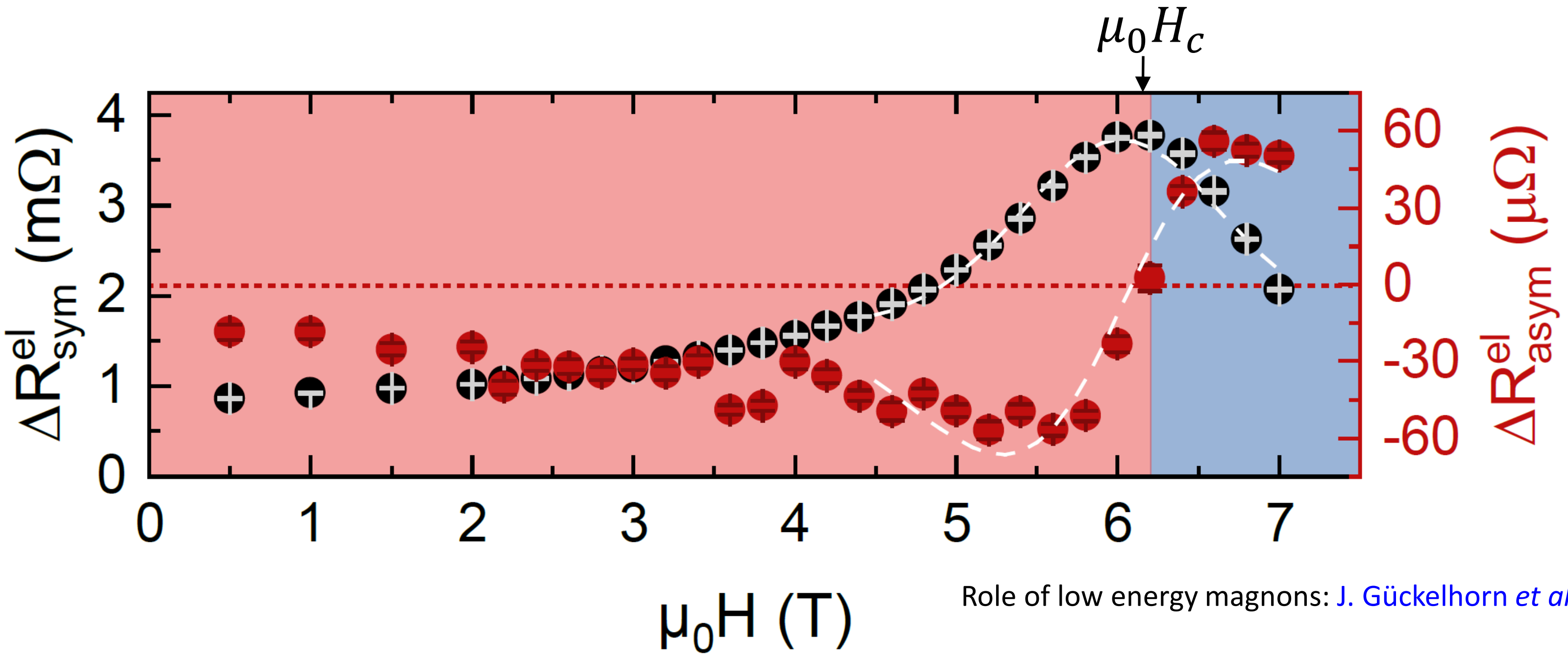
$$R^{el}_{sym} = \Delta R^{el}_{sym} \sin^2 \varphi$$

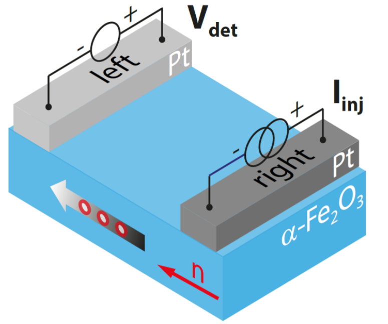
$$R^{el}_{asym} = \Delta R^{el}_{asym} \sin^3 \varphi$$

J. Gückelhorn, et al., PRL **130**, 216703 (2023).

Magnetic Field Dependence

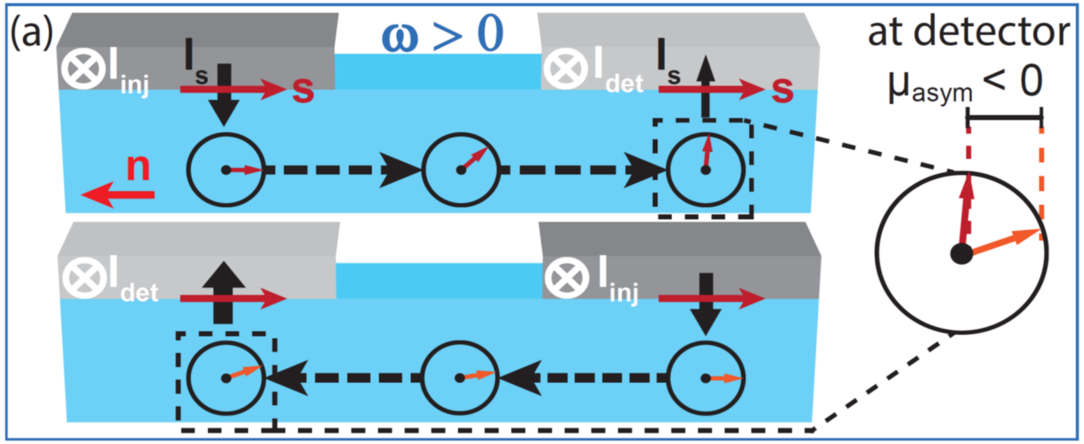




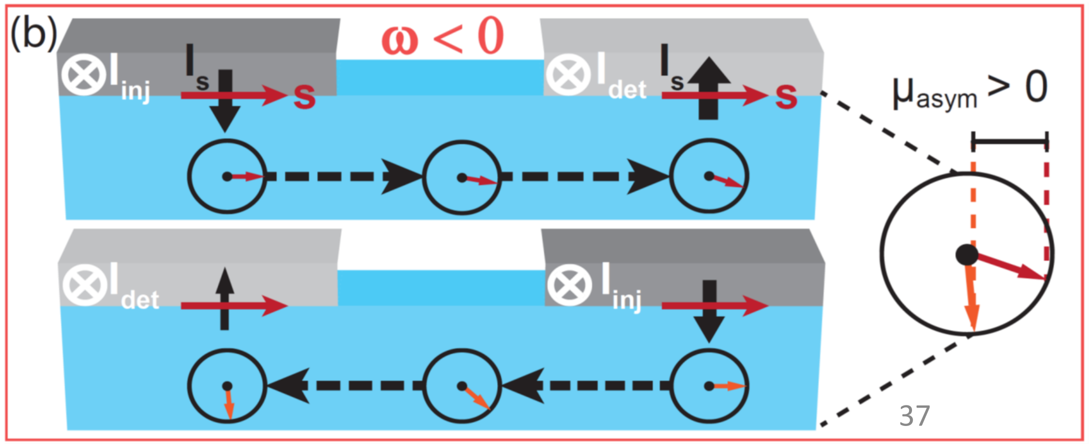


Role of low energy magnons: J. Gückelhorn *et al.*, Phys. Rev. B **105**, 094440 (2022).

$\mu_0 H < \mu_0 H_c$ Good agreement between theory and experiment $\mu_0 H > \mu_0 H_c$



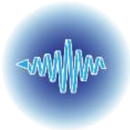
Microscopic Origin?

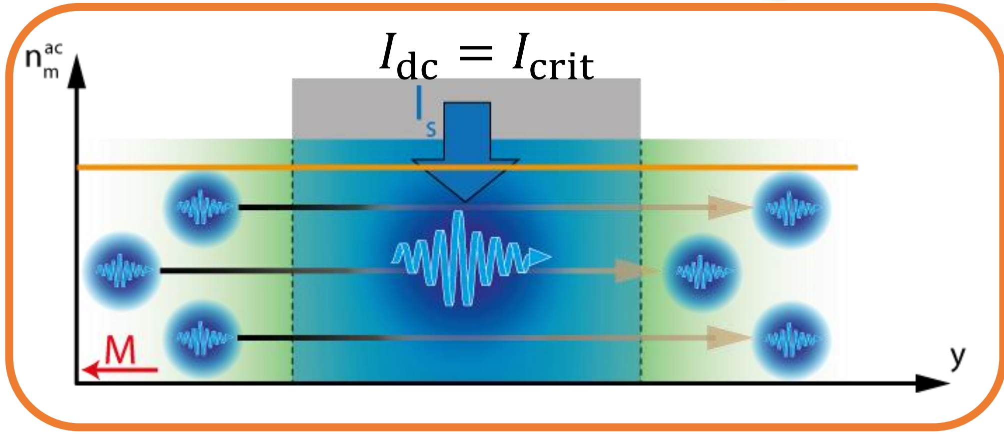


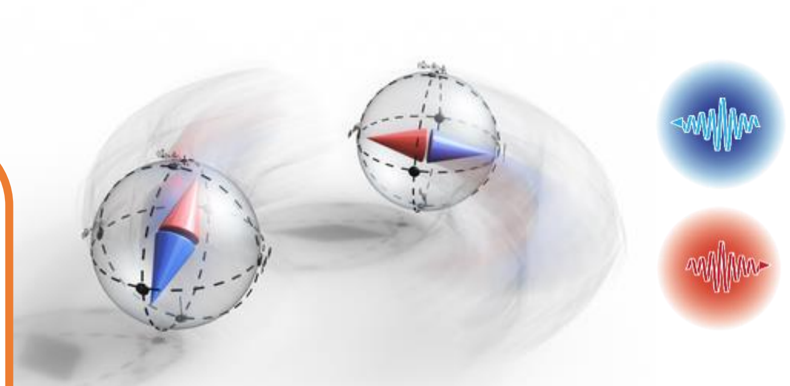
J. Gückelhorn, et al., PRL **130**, 216703 (2023).

Dances with magnons

Magnons in Ferromagnets







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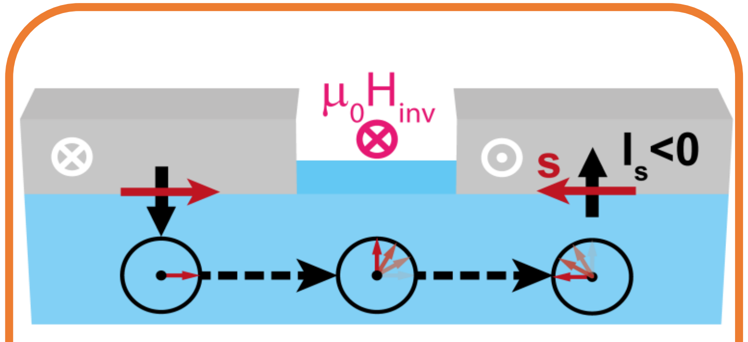
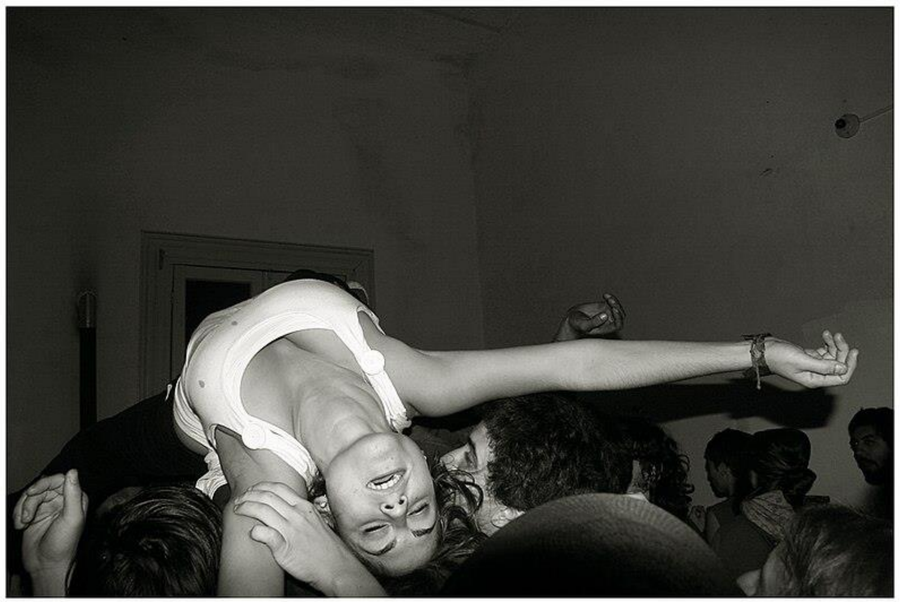
Magnons in Antiferromagnets



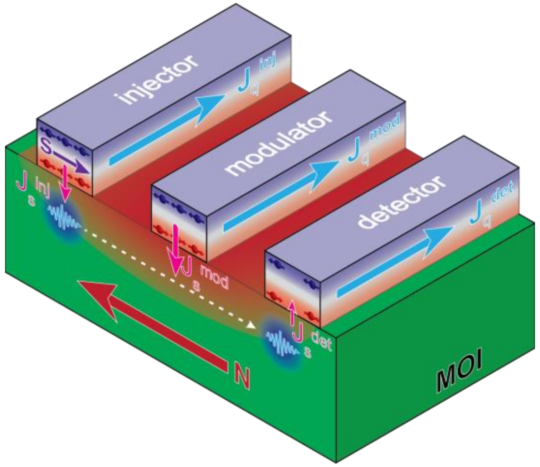


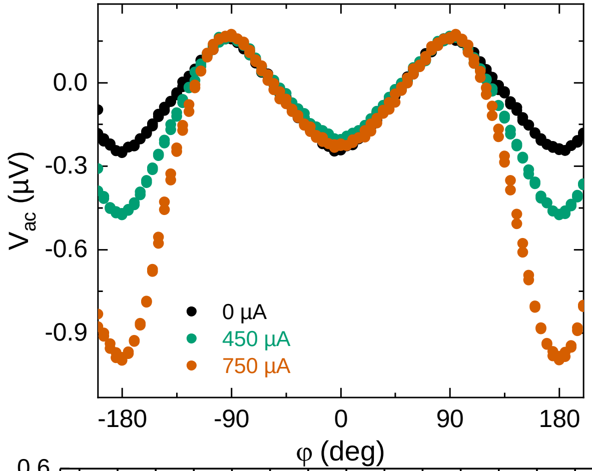
Getting higher.. by Libertinus Yomango / CC-BY-SA-2.0

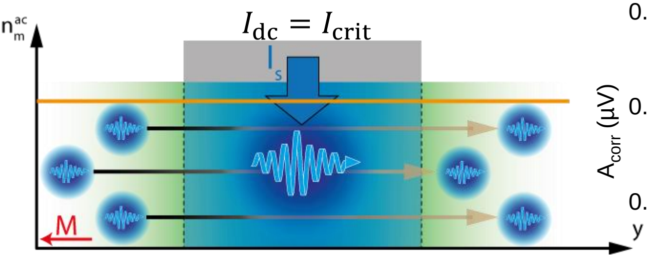
Vienna Opera Ball by Gryffindor / CC-BY-SA-4.0

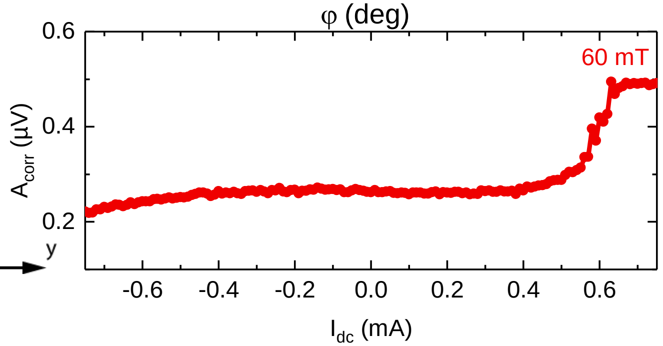
Summary

Ferrimagnet YIG ("prototype ferromagnet")





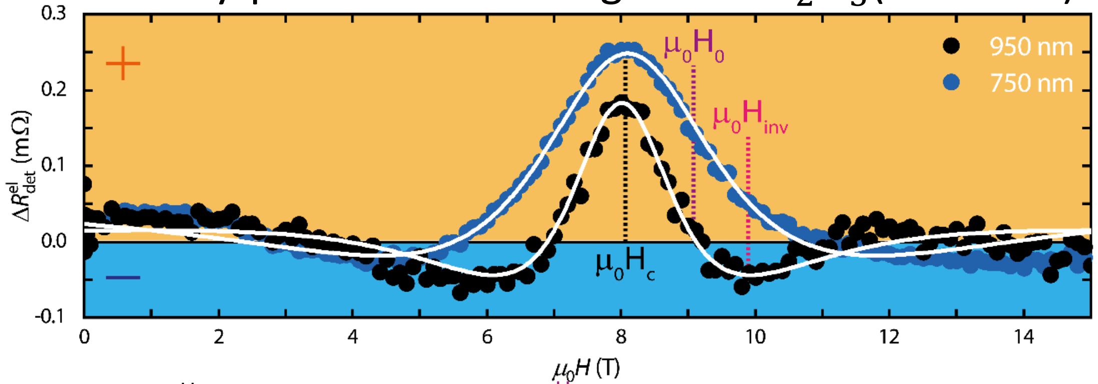


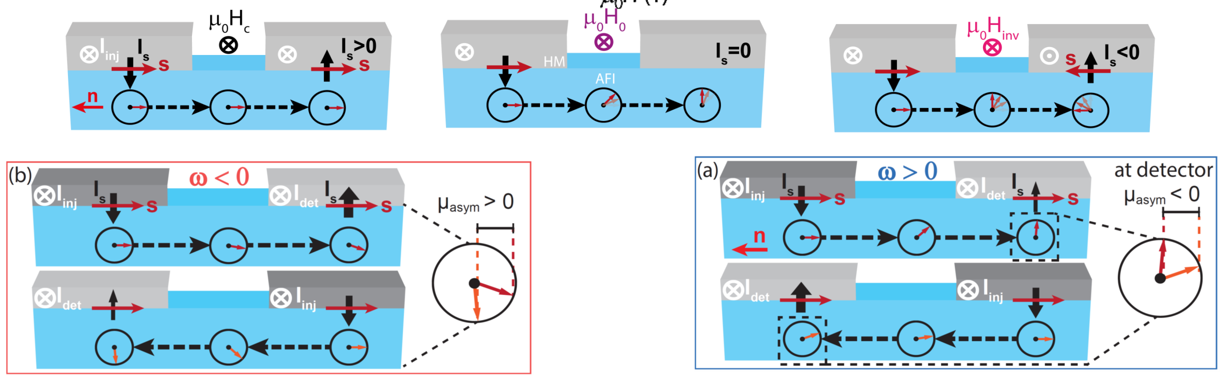


- Nonlinear modulation regime with pure spin currents
- Damping compensation state compatible with zero magnon spin resistance

T. Wimmer *et al.*, PRL **123** , 257201 (2019).
J. Gückelhorn *et al.*, APL **117** , 182401 (2020).
J. Gückelhorn *et al.*, PRB **104**, L180410 (2021).

Easy-plane antiferromagnet α-Fe_2O_3(hematite)





- Pseudospin dynamics and antiferromagnetic magnon Hanle effect
- First observation of nonreciprocal spin transport in an antiferromagnet
- Influence of nonreciprocity on magnon Hanle and Pseudospin dynamics

T. Wimmer *et al.*, Phys. Rev. Lett. **125** , 247204 (2020).
A. Kamra *et al.*, Phys. Rev. B **102**, 174445 (2020).
J. Gückelhorn *et al.*, Phys. Rev. B **105**, 094440 (2022).
J. Gückelhorn *et al.*, PRL **130**, 216703 (2023).

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