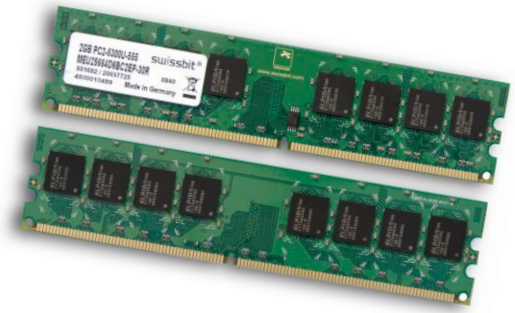
Magnetic Interface Coupling in Metal-Insulator Hybrid Structures

Alexander Grutter w/ special thanks to Patrick Quarterman

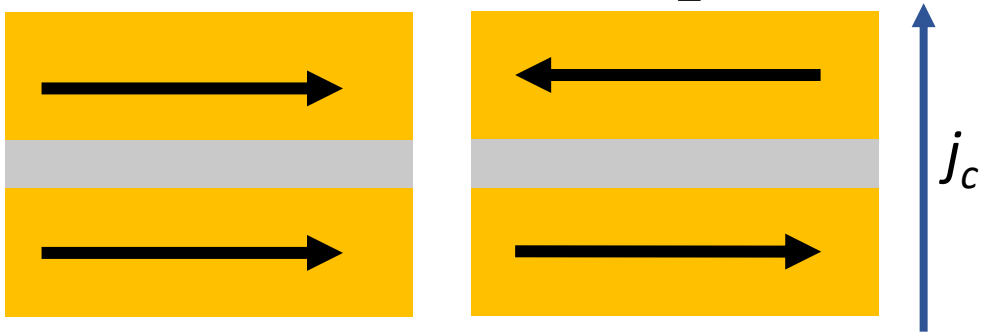
Why study magnetic thin films?

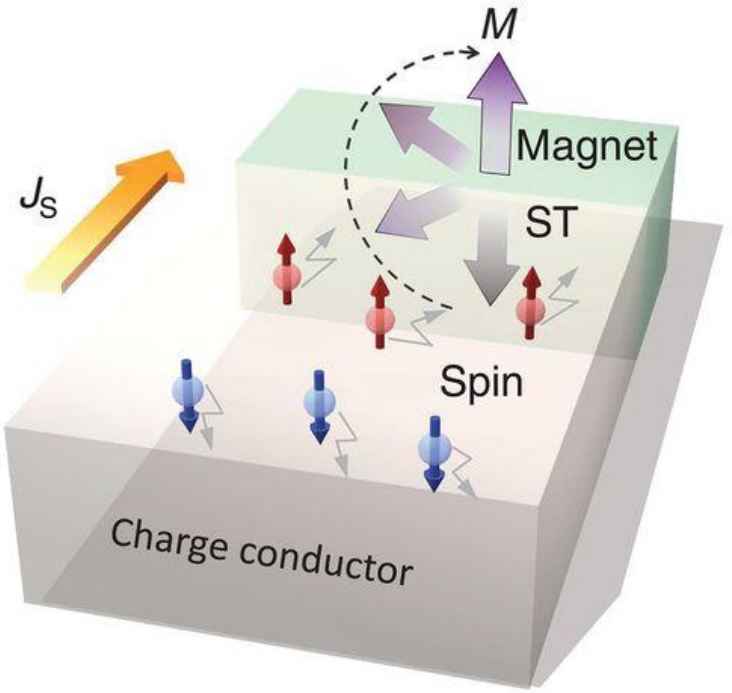
Magnetic materials are in all kinds of information technologies!



Parallel
Low resistance
"0"

Anti-parallel
High resistance
"1"





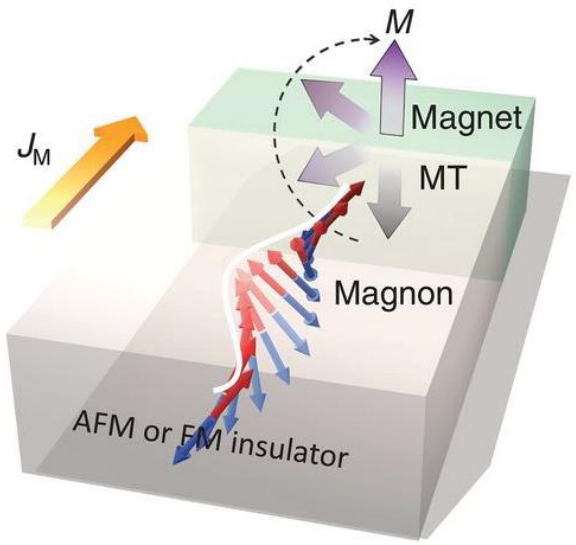
How do we change spin direction? Current-based spin-orbit torque is one way

Yi Wang, et al, Science 29 1125-1128 (2019)
Chumak et al, Nat. Phys. 11 452 (2015)

Spin-wave logic

Rotating magnetization with a spin-orbit torque requires moving electrons, which means heat!

What is we could do this without charge current?



Magnons or "Spin Waves" can transfer angular momentum between magnetic layers, but we need a special material

Yi Wang, et al, Science 29 1125-1128 (2019)
Chumak et al, Nat. Phys. 11 452 (2015)

What do we need for Spin-Wave Logic?

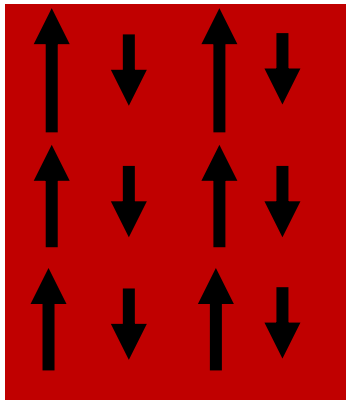
- No Joule heating → less energy dissipation
- Magnon current travel much further than spin current (not spin diffusion length)
- Wave interference and nonlinear wave interactions for quantum functionality?

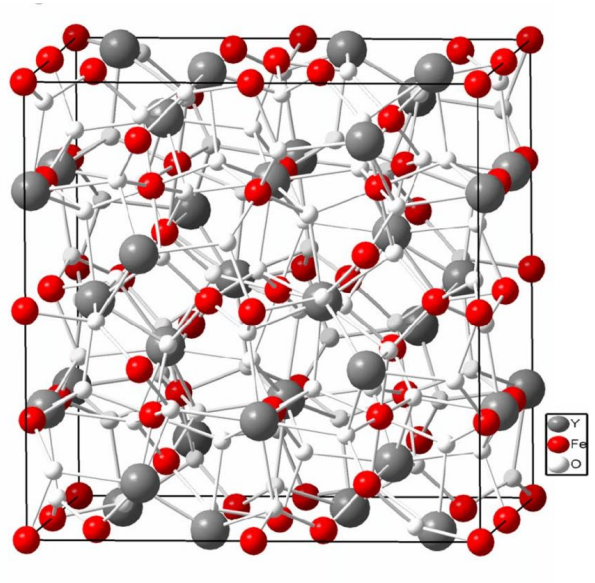
Material Requirements:

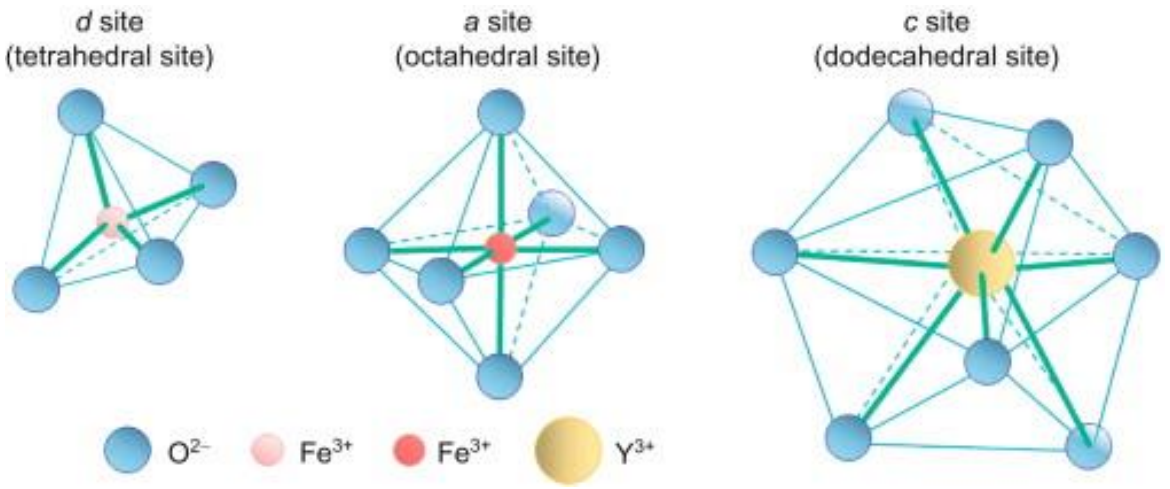
- Insulating (No charge current)
- Low Moment
- Low Magnetic Damping
- Magnetic at room temperature

This basically means $Y_3Fe_5O_{12}$ or $(Mg,Al,Fe)_3O_4$

Ferrimagnetic garnet system ($M_3Fe_5O_{12}$)



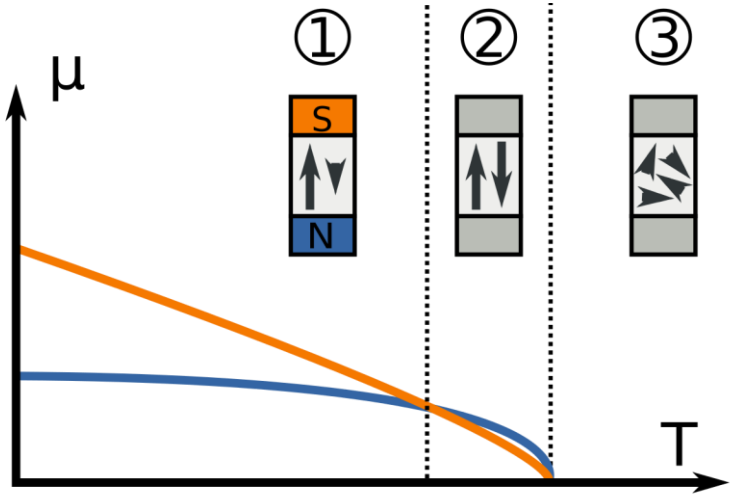




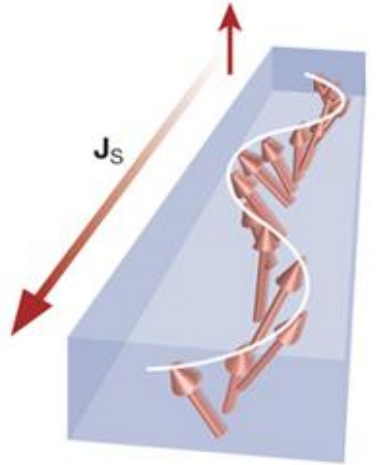
Strong magnetic interactions, both parallel and antiparallel

$Y_3Fe_5O_{12}$ (YIG)
$Tm_3Fe_5O_{12}$
$Tb_3Fe_5O_{12}$
$Dy_3Fe_5O_{12}$
$Eu_3Fe_5O_{12}$

Compensation effects



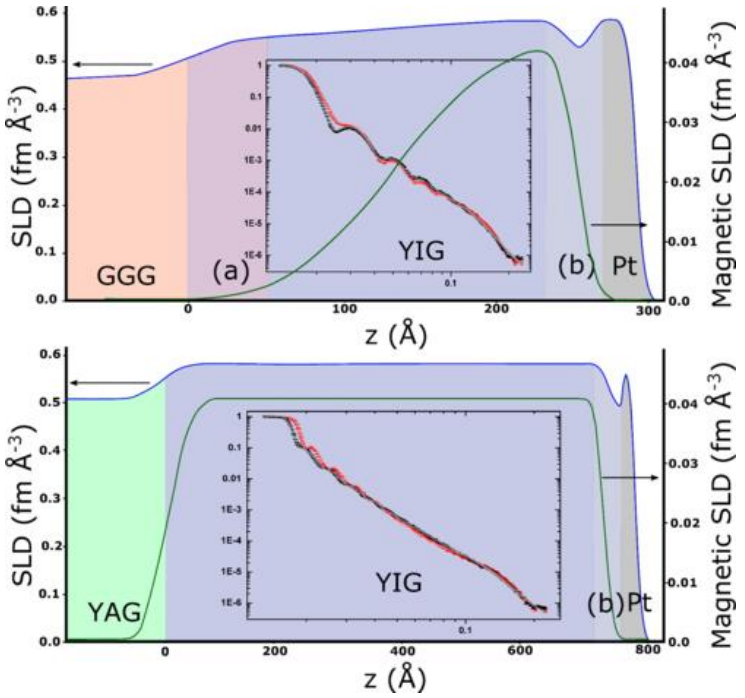
Magnons



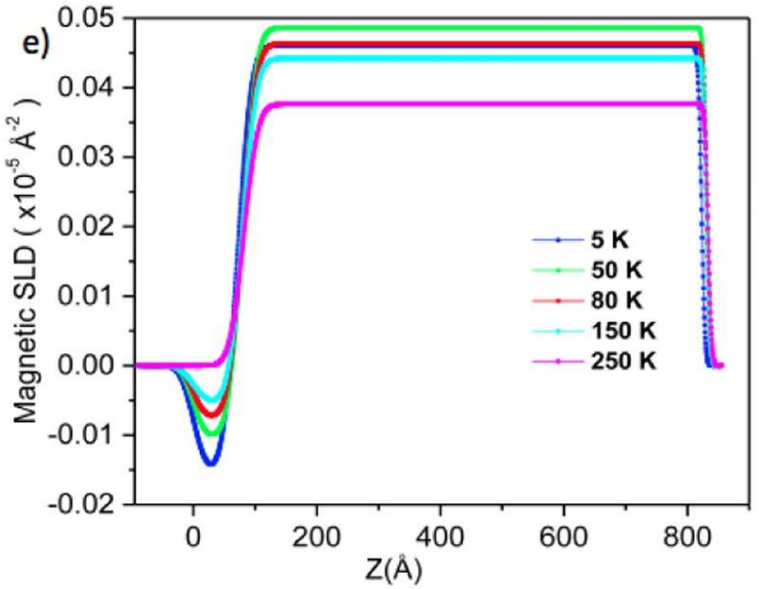
Garnets are a materials nightmare

Mostly grown on $Gd_3Ga_5O_{12}$ (GGG), where interfacial effects due to diffusion from GGG into garnets are reported extensively

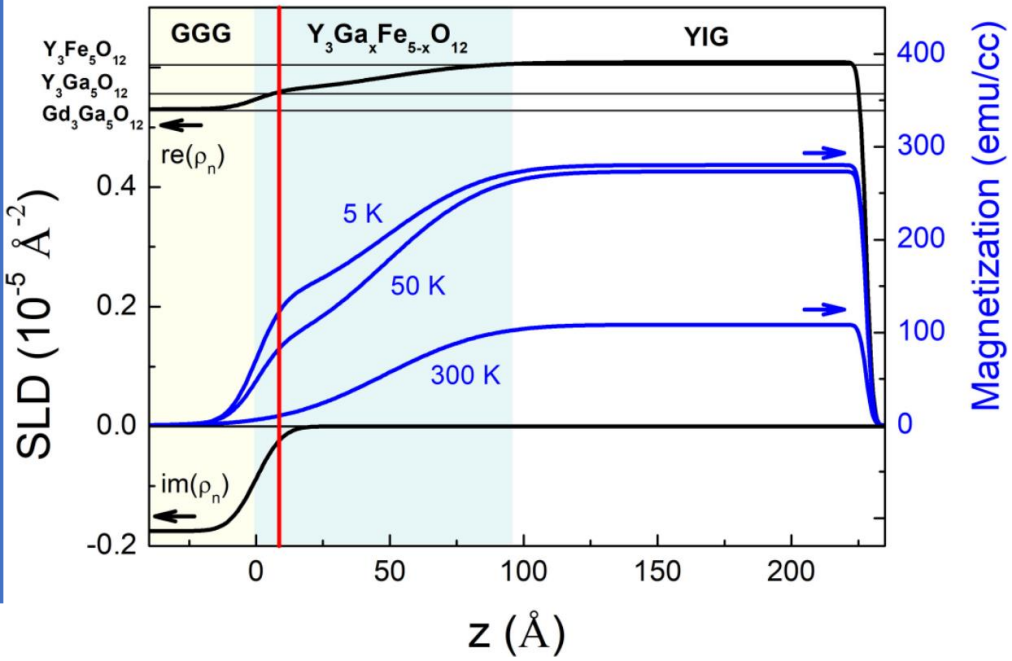
Cooper *et al*, PRB (2017) - ISIS



Mitra *et al*, Sci Reports (2017) - ISIS



Suturin *et al,* PRM (2018) - PSI



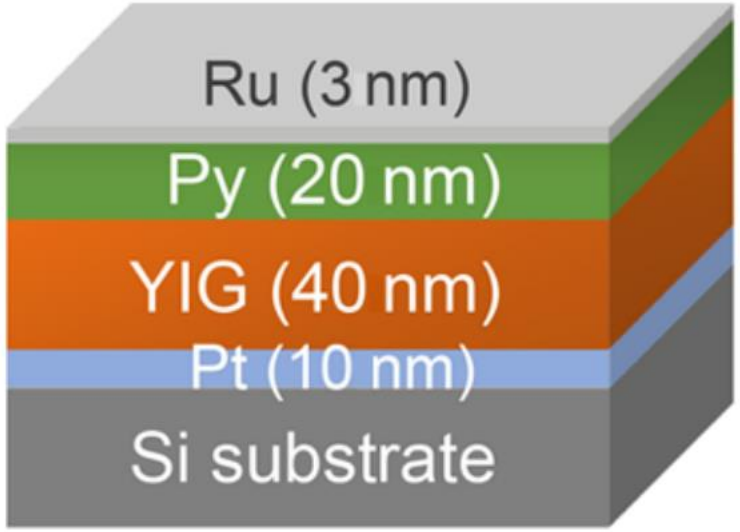
Reports agree that interdiffusion is there, but cause and effect vary

GGG → interdiffusion and industry compatibility issues

Si → cleaner interfaces and industry friendly, but not epitaxial

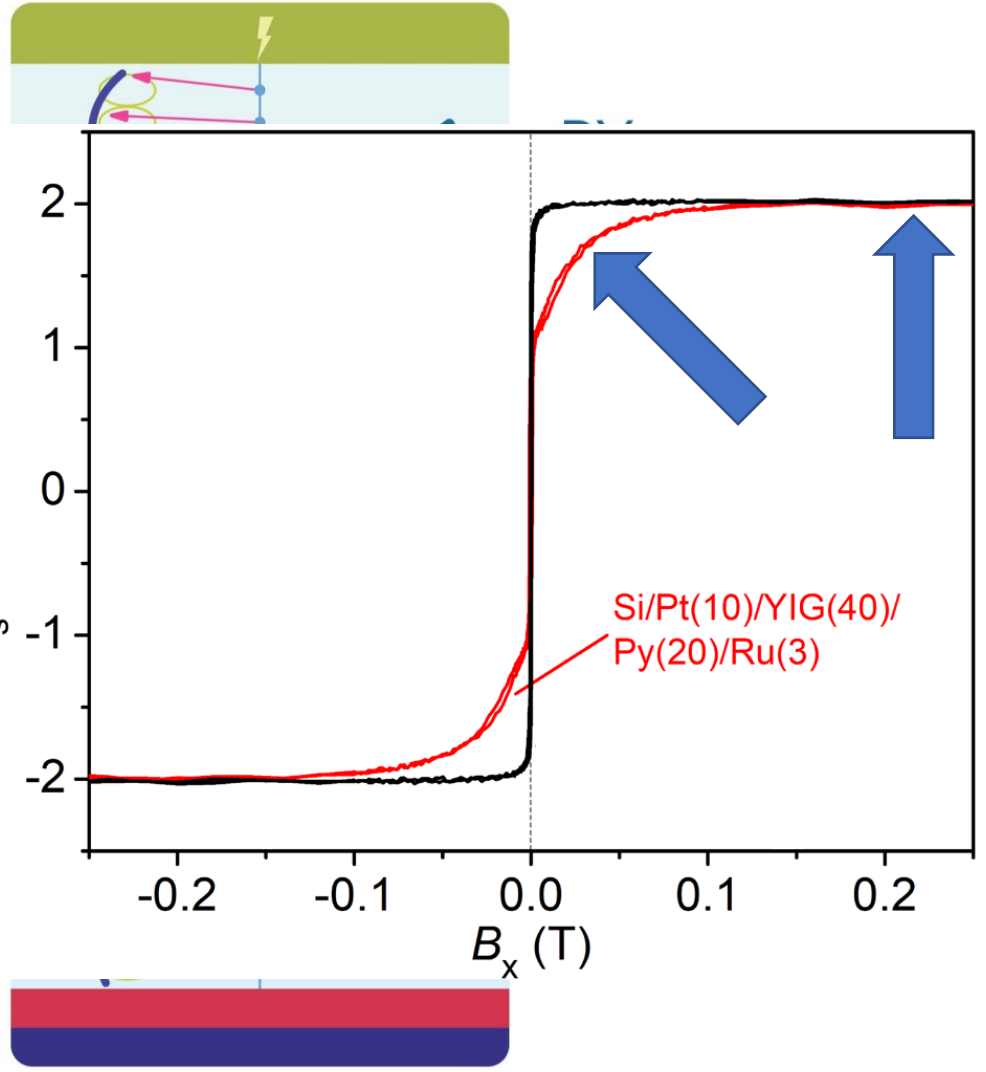
Phys. Rev. Applied 13, 061002 (2020)

Problems at Magnetic Interfaces



The Question: "My magnon transport is not very good. Can PNR look at my samples and see if something is wrong with the interface?"

Absolutely PNR can do that!



Start with High-Field Data