Magnetic excitations

spin waves, acoustic and optical magnons



inelastic neutron scattering



magnonics



ig University

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Spin waves

Ferromagnet

Image credit: S. Hunklinger

Spin waves

Ferromagnet



Antiferromagnet

Image credit: S. Hunklinger, mpg.de

Spin-wave dispersion



J. Appl. Phys. 39, 383 (1968)

Phys. Rev. Lett. 23, 1394 (1969)

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Experiment

inelastic neutron scattering

Inelastic neutron scattering: powder



2D data:
$$I = I(Q, E)$$

look featureless,
but can be compared to theory

Z0 mm 20 mm 50 mm M. Skoulatos (PhD thesis)

Inelastic neutron scattering: crystal



Fundamentals of Magnetism, WS 24/25

Magnetic excitations

Complexity of spin waves



More than two sublattices: both acoustic and (many) optical magnons



$\begin{array}{l} \textbf{Charge scattering}\\ 10^5-10^9\,\text{cts/s} \end{array}$

 $\begin{array}{l} \text{Magnetic scattering} \\ 10^0 - 10^2\,\text{cts/s} \end{array}$





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Resonant scattering $10^3 - 10^5$ cts/s



Resonant x-ray scattering (RXS)



Ba₂IrO₄, Ir L_2 edge (E = 12.83 keV) reflections with half-integer h and k

 \longrightarrow antiferromagnetic order, $\mathbf{k} = (\frac{1}{2}, \frac{1}{2}, 0)$

- small crystals (100 μ m size)
- no absorption issues

but: size of magnetic moment hard to determine



Resonant inelastic x-ray scattering (RIXS)



- minuscule crystals (100 μ m size) can be investigated
- no absorption issues

but: limited energy resolution (15 meV)



Material / Technology

magnonics

Magnonics



B. Rana and Y.C. Otani, Nature Comm. Phys. 2, 90 (2019)

Magnons:

can be excited with electric field (spin Hall effect), light pulse (microwave, THz), temperature pulses, acoustic waves... no charge motion \longrightarrow almost no energy loss

Garnets



$\mathsf{Ca}_3\mathsf{Al}_2(\mathsf{SiO}_4)_3$

Garnets





$\mathsf{Ca}_3\mathsf{Al}_2(\mathsf{SiO}_4)_3 \qquad \qquad \mathsf{Y}_3\mathsf{Fe}_2(\mathsf{FeO}_4)_3 \text{ aka } \mathsf{Y}_3\mathsf{Fe}_5\mathsf{O}_{12}$

Yttrium iron garnet (YIG): $T_C = 560$ K, band gap = 2.85 eV soft ferrimagnet, large Faraday rotation (strong coupling to light), low losses at microwave frequencies...

Intricacies of YIG

