Inelastic Neutron Scattering
on
Rare Earth Superlattices

- Spin Wave propagation along the surface normal -
- in a Gd/Y superlattice -

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Large **S**cale **S**tructures
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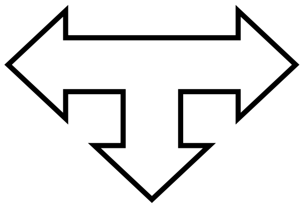

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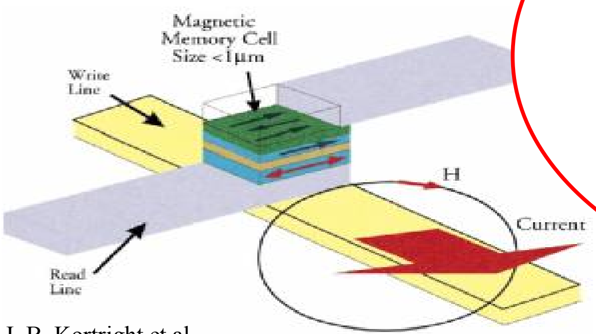
Motivation

Technical applications
- 'nanoscience', 'spintronics'
- tailor-made magnetism
- superparamegnetism
- hard drives, sensors, nonvolatile memories

Fundamental research
- new theories are required
- model Hamiltonian

- magnetism in confined structures
- magnetic exchange interactions across nonmagnetic layer
- proximity effects

"Why?"
↕
Dynamics
↕
- Spin Waves -



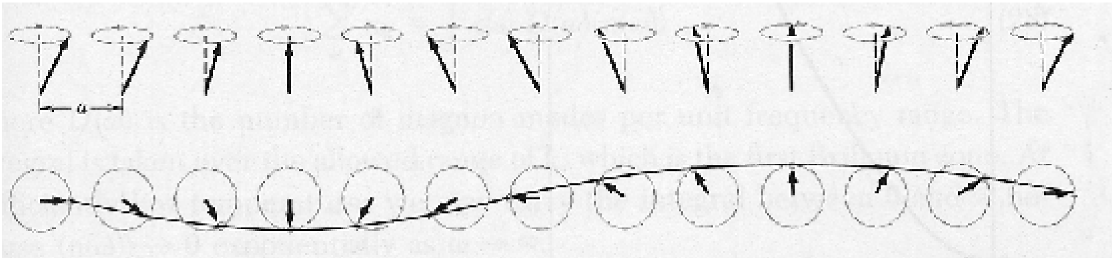
J. B. Kortright et al.,
Journal of Magnetism and Magnetic Materials 207, 7 (1999)

$$\hat{H} = -\sum_{<k,l>} J\hat{S}_k \cdot \hat{S}_l$$

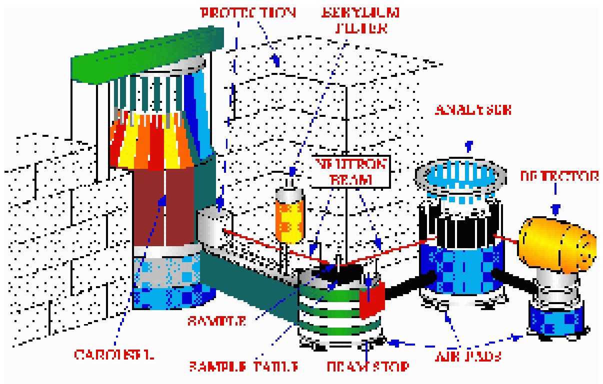
"Heisenberg model"

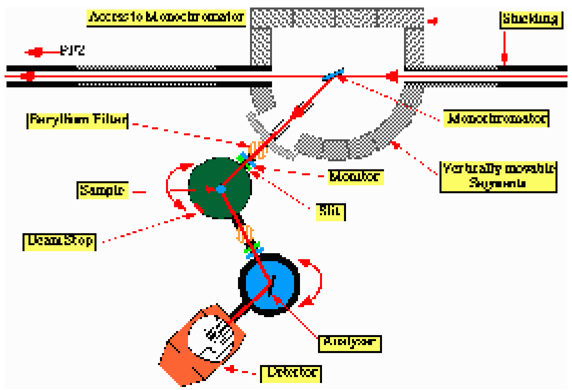
Spin Waves and Magnons

• Spin Waves are characterized by a frequency and a wavelength…



• … and they are measurable with
Inelastic Neutron Scattering (IN14, IN12)





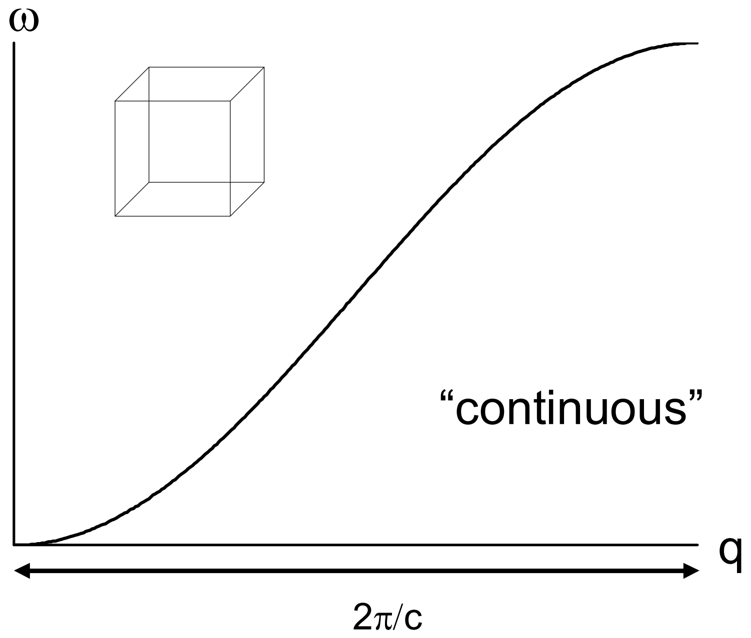
IN14 ← cold three axes spectrometer → IN12

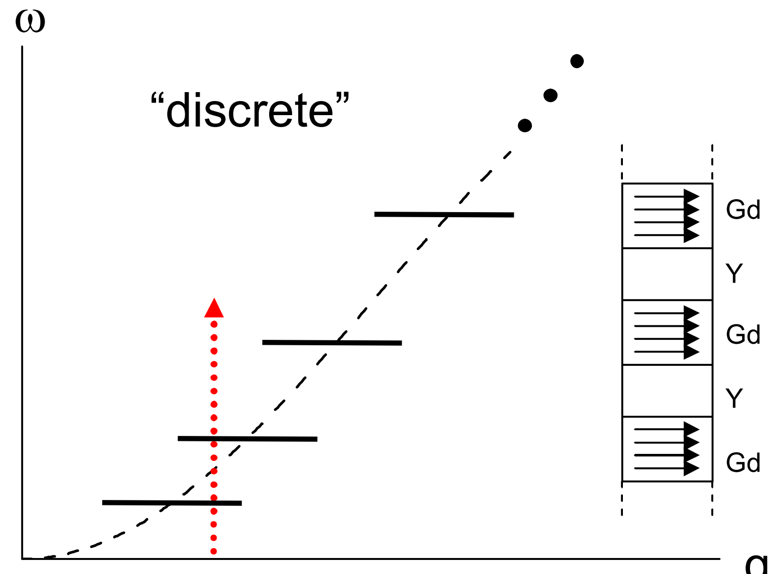
Spin wave dispersion

… in a bulk **… in a superlattice**

$$\hat{H} = -2J \sum_{i} \hat{S}_i \cdot \hat{S}_{i+1} \quad + \quad \textit{boundary conditions}$$

Hamiltonian of a one-dimensional chain of spins
(Heisenberg model)



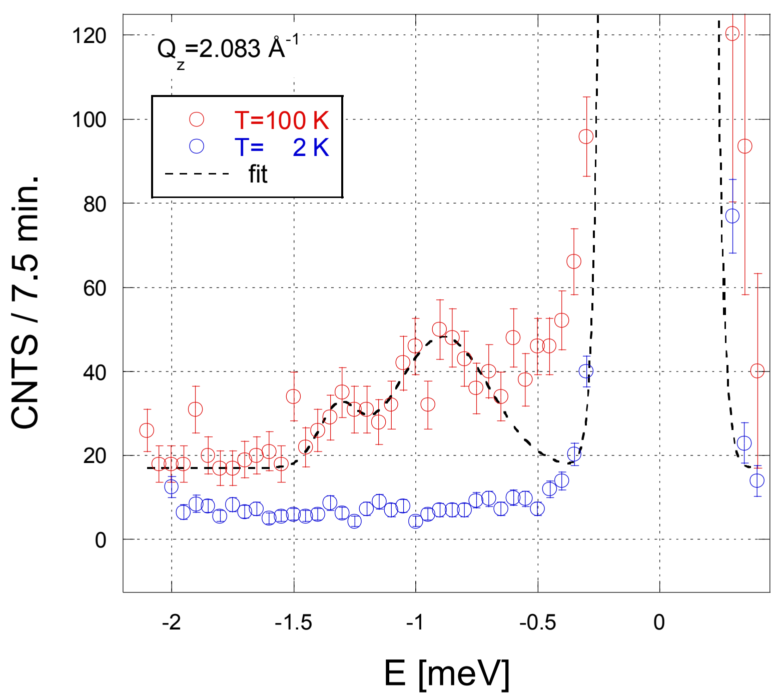


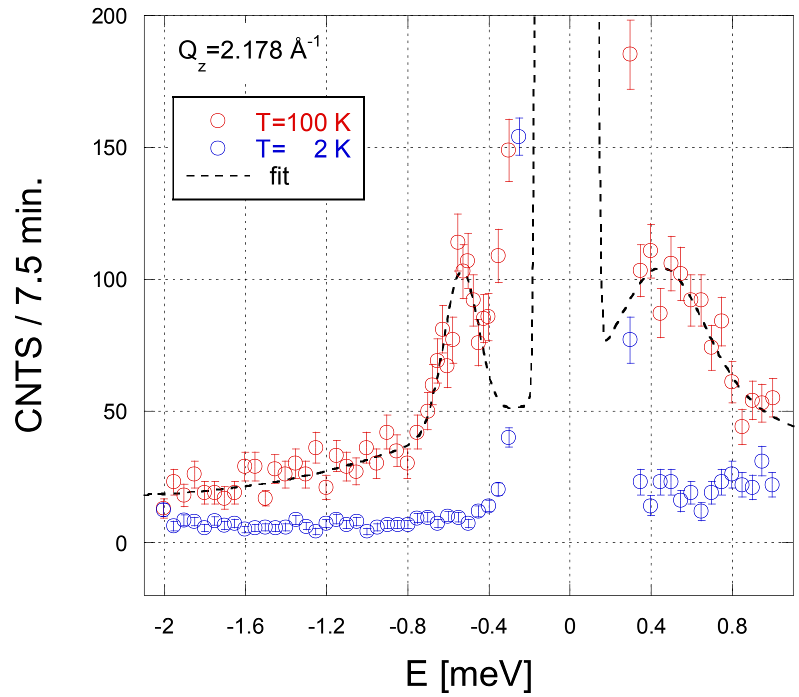
… due to
- Brillouin zone folding effects,
- discrete number of magnetic atomic planes in each bilayer

Experimental data

Nb_{5nm}/**[$Y_{1.8nm}$/Gd_{3nm}]$_{x100}$**/$Y_{1.8nm}$/$Gd_{6.7nm}$/Y_{40nm}/Nb_{50nm}/Al_2O_3 (substrate)

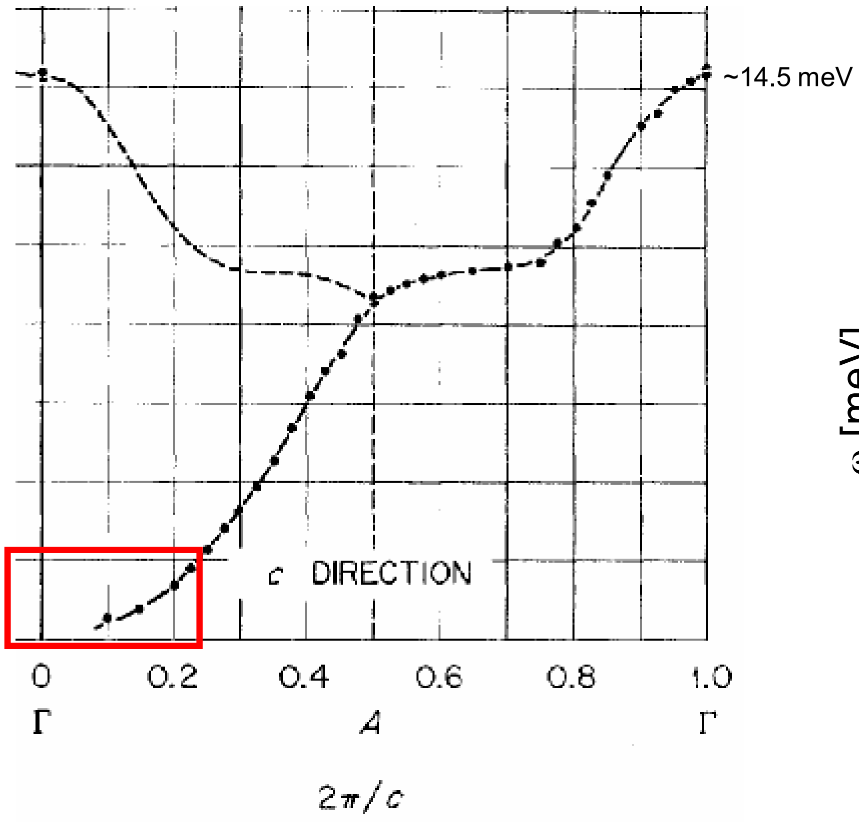
large magnetic moment (~8μ_B) / many bilayers (100) / ‘huge’ substrate (53x53mm²)



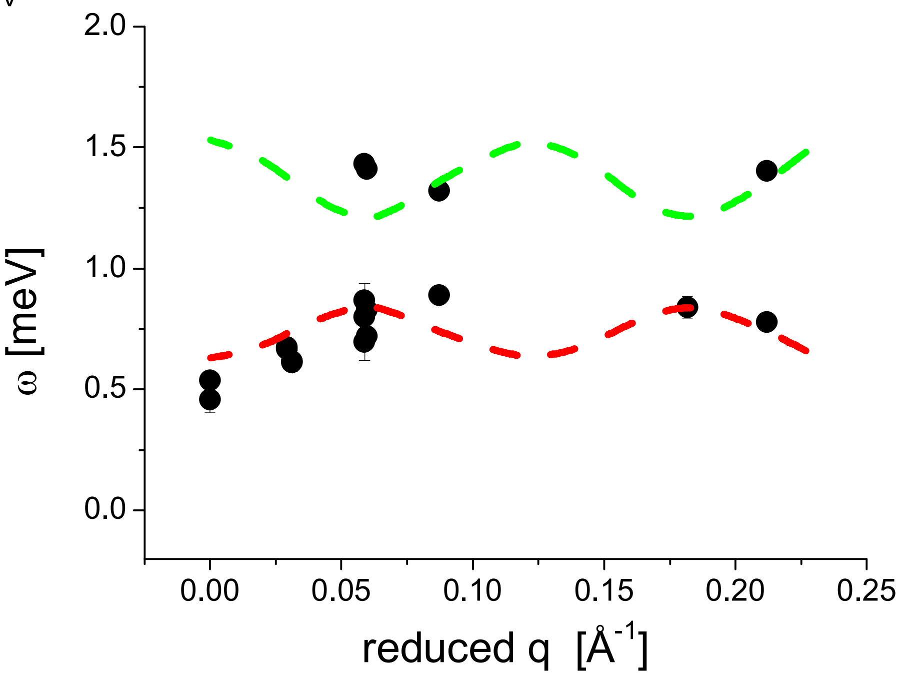


H=4 Tesla, IN14, k_f=fix=1.55 Å^{-1},
Coll: open-40’-40’-open, Be-filter (scattered beam),
monochromator & analyser: PG (002)

Bulk vs. superlattice



W.C. Koehler et al., Phys. Rev. Lett. 24, 16 (1970)



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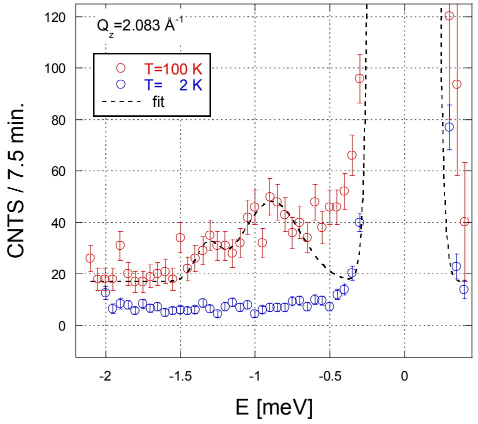
Summary…

- discrete energy levels for spin waves propagating along the surface normal have been observed at 4 Tesla, due to Brillouin zone folding effects and the periodicity of the sample
- similar results were found on a Dy/Y superlattice in zero field



… & Perspectives

- measurements as a function of the Gd and Y slab thicknesses, which changes the RKKY interaction;
- influence of interfacial roughness and interdiffusion;
- field dependence;
- better quantitative description;
- explore other superlattices to verify the ‘new’ model
- …

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