Spin Waves in fcc-cobalt

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STREAMLINE

Spin fluctuations in magnetic materials have been studied over many decades but are still of relevance today. Theory has advanced greatly in describing such phenomena but still needs to improve [1,2]. Studying simple ferromagnetic metals like iron, cobalt, nickel with inelastic neutron scattering allowed spin wave dispersion to be observed and the Landau damping resulting from the interaction with the Stoner continuum, to be studied. This has been a testing ground for theory and the methods are still improving with modern state of the art calculations, which can include the spin fluctuations [2]. Recently it has been shown that soft x-ray RIXs can be used for such studies and in particular with ultra-thin films [3,4]. Here we will show the application of soft x-ray RIXS to thin fcc-cobalt films and compare the spin-wave dispersion to TD-DFPT calculations.

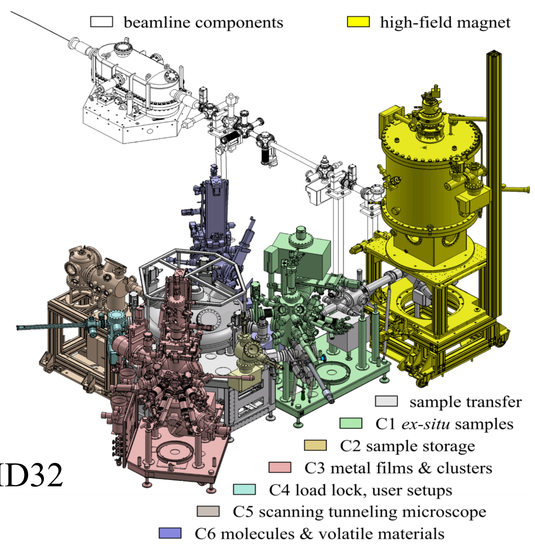
Sample preparation:

Thin films grown in the ID32 sample preparation facility [5].
Characterised using Auger, LEED and STM.

Samples transferred using a UHV vacuum suitcase to the RIXS chamber for measurements.

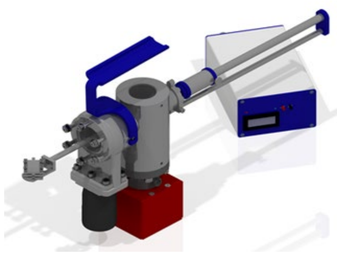
Characterised using XMCD and XAS.

fcc cobalt films grown on Cu(001) 8nm thick.
In-plane magnetization.



Sample preparation facility ID32

UHV suitcase



ID32 RIXS spectrometer

RIXS Measurements:

T= 25K
Energy resolution ~30meV (FWHM) at Cobalt edge (778eV)
2Θ range 50-150° ~ 0.3 - 0.8 Ang $^{-1}$
(001) Direction Chi = 0°
(111) Direction Chi = 54.7°

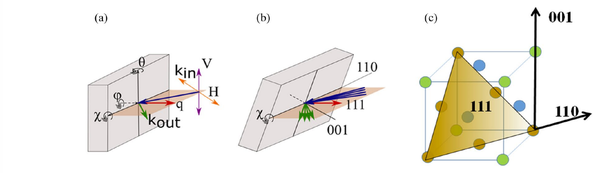
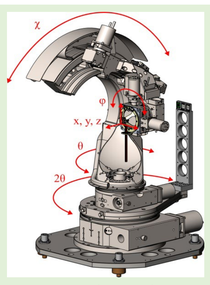


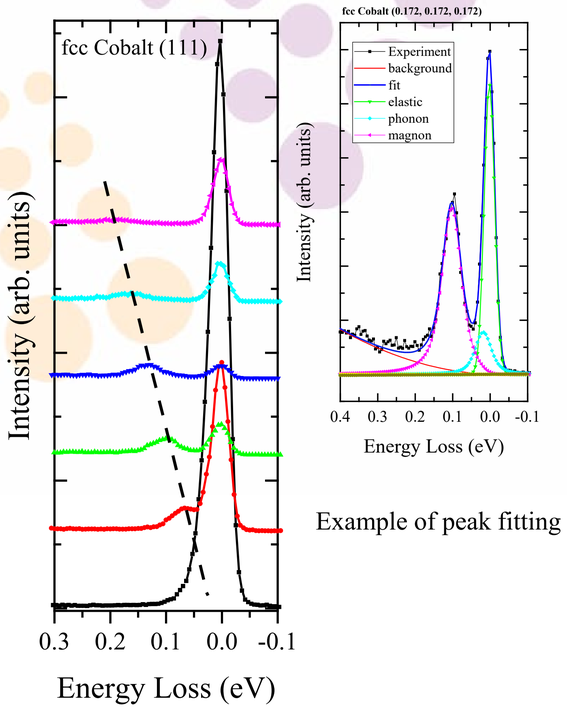
FIG. 1. (a) Generic RIXS measurement geometry, showing the rotation angles θ, ϕ, and χ. (b) Measurement geometry for the [111] dispersion, after rotation of the sample around χ. (c) The unit cell for fcc nickel showing the 111 plane.



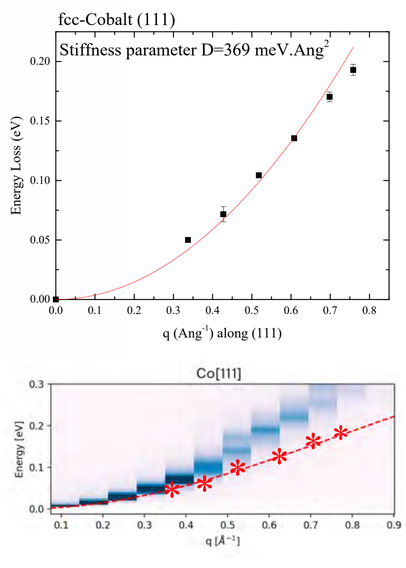
UHV sample goniometer
4 circle

https://www.esrf.fr/home/UsersAndScience/Experiments/EMD/ID32/RIXS.html

Results:



Example of peak fitting



Spin wave dispersion (111) direction:
Comparison to quadratic function (upper panel) and to TD-DFPT calculations (lower panel)

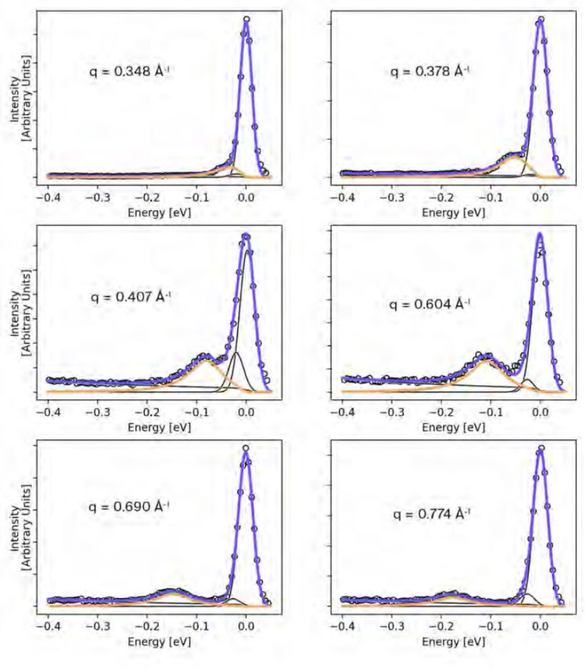


Figure 5.8: Cobalt [001] RIXS spectra at six different q. The spin wave contribution is shown in orange.

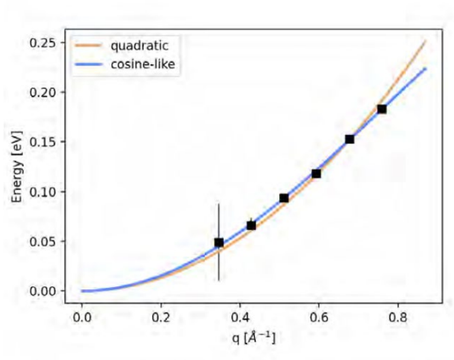
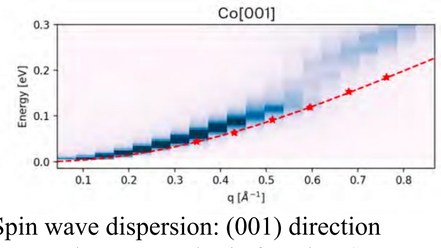


Figure 5.9: Fits for the cobalt [001] data. When not shown, error bars are smaller than marker size.



Spin wave dispersion: (001) direction
Comparison to quadratic function (upper panel) and to TD-DFPT calculations (lower panel) [6]

Conclusions:

The spin wave dispersion along the (001) and (111) directions of a 8nm thin fcc-cobalt film grown on Cu(001) were measured using soft x-ray RIXS. The results are compared to TD-DFPT calculations. The agreement is quite good, although the dispersion is smaller. Fitting the data to a quadratic spin-wave expression gives a stiffness parameter comparable to those determined by other methods.

References

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