Experimental report

13/10/2020

Proposal: **4-04-500** **Council:** 10/2019

Title: Magnetic Bloch Oscillations and domain wall dynamics in a near-Ising ferromagnetic chain

Research area: Physics

This proposal is a new proposal

Main proposer: **Ursula Bengaard HANSEN**

Experimental team: Ursula Bengaard HANSEN
Kim LEFMANN
Niels Bech CHRISTENSEN

Local contacts: Martin BOEHM

Samples: CoCl2 2D2O

Instrument	Requested days	Allocated days	From	To
IN3	2	2	01/09/2020	03/09/2020
THALES	4	3	07/09/2020	10/09/2020

Abstract:

The possible existence of Magnetic Bloch Oscillations (MBOs) in the near-Ising ferromagnetic chain CoCl2*2D2O have since a long time been discussed from a theoretical point of view, however no real experimental proof have been found to this day. Combining new analytical calculations, simulations based on the random phase approximation and recent results from the MACS neutron scattering spectrometer, we have obtained evidence for a field dependent signal that we believe is to be caused by MBOs. However, the experimental configuration chosen at MACS limited the accessible energy transfer range, which in turn limited the field range over which we could probe the MBO signal. Here we propose an experiment at Thales, to study the magnetic excitations in CoCl2*2D2O between 0-3 meV at 22 K as a function of magnetic field, in order to finalise our study of Magnetic Bloch Oscillations.

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no. 4-04-500

Experimental team: U. B. Hansen

Local contact: M. Boehm

Introduction

The notion of Bloch Oscillations was first introduced in 1929 and describe the somewhat counter intuitive oscillatory motion of Bloch state electrons in a constant electric field [1]. Experimental evidence of Bloch Oscillations did however had to to await the development of ultra pure GaAs-GaAlAs multilayers [2] and Bose-Einstein condensates [3].

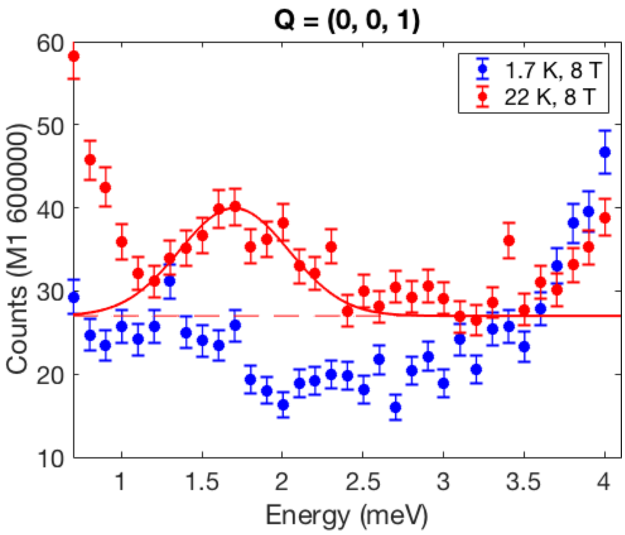
In 1998 Kyriakidis and Loss predicted that in exchange-anisotropic ferromagnetic chain compounds with dominant Ising character, single domain walls could play the role of particles performing MBOs in response to a constant magnetic field [4]. They in particular predicted the existence of MBOs in the antiferromagnet $CoCl_2{\cdot}2D_2O$. In $CoCl_2{\cdot}2D_2O$ the dominant interactions are ferromagnetic and couple nearest neighbour spins lying on chains. Weaker inter-chain interactions gives rise to an antiferromagnetic ordering of the chains below $T_N = 17.2$ K. Experimental searches for MBOs in $CoCl_2{\cdot}2D_2O$ have, however, been unsuccessful [5,6] and MBOs are yet to be observed experimentally. New theoretical predictions have however more recently highlighted that it would be possible to observe MBOs in $CoCl_2{\cdot}2D_2O$ at higher temperatures [7]. In this experiment we would like to test these predictions by extending the field range that we have already covered in our recent experiment at MACS, NCNR, NIST[8]

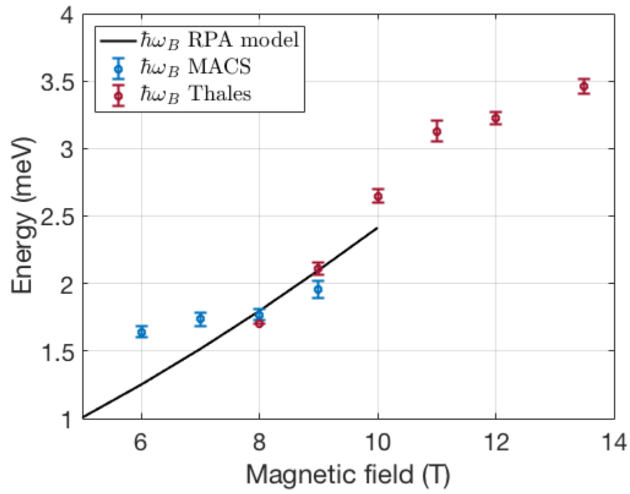
Experimental setup

The Thales instrument was used unpolarised with PG monochromator+velocity selector and PG analyser. We had k_f fixed to 1.55 Å^{-1}. We had a beryllium filter in k_f and no collimation was used. Two crystals of $CoCl_2{\cdot}2D_2O$ (total mass ~1.6 g) were co-aligned in the (H0K) plane and mounted on an aluminium sample holder. The magnetic field and temperature was controlled by the 15 T vertical cryomagnet.

Results

In this experiment we studied the magnetic MBO excitations primarily at the Q=(0,0,1) reflection at 22 K, while varying the external magnetic field. In the figure below we have shown examples of the inelastic neutron scattering data at 8 T at 1.7 K and 22 K along with the resulting energy of the MBO signal.





In the following table an overview of the different Q- and energy ranges covered in this experiment are summarised. Following this experiment we would like to extend our theoretical analysis of the excitations up to 13.5 T. In the future, it would be interesting to study the temperature dependence as well of the MBO signal, but this was not feasible within the 3 days of beam time we had available.

Q	Energy range	Monitor pr point	Time pr point	H (T)	T (K)
(0 0 1)	0.3 - 6.0 meV	3600000	~ 5.7 minutes	0.0	22.0
(0 0 1)	0.8 - 5.0 meV	4200000	~ 6.6 minutes	7.0	22.0
(0 0 1)	0.8 - 6.1 meV	4800000	~ 7.6 minutes	8.0	22.0
(0 0 1)	0.3 - 4.0 meV	4200000	~ 6.6 minutes	9.0	22.0
(0 0 1)	0.8 - 4.0 meV	4200000	~ 6.6 minutes	10.0	22.0
(0 0 1)	0.8 - 4.4 meV	4200000	~ 6.6 minutes	11.0	22.0
(0 0 1)	0.3 - 4.5 meV	4200000	~ 6.6 minutes	12.0	22.0
(0 0 1)	0.8 - 4.5 meV	4200000	~ 6.6 minutes	13.5	22.0
(0 0 1)	0.3 - 6.1 meV	4200000	~ 6.6 minutes	8.0	1.7
(0 0 1)	0.8 - 3.0 meV	2200000	~ 3.5 minutes	8.0	30.0
(0 0 0.5)	0.3 - 4.0 meV	3600000	~ 5.7 minutes	9.0	22.0
(0 0 0.5)	0.3 - 4.5 meV	4200000	~ 6.6 minutes	12.0	22.0

[1] F. Bloch, Zeitschrift für Physik **52**, 555 (1929). [2] E. E. Mendez et al, PRL **60**, 2426 (1988). [3] M. Ben Dahan et al, PRL 76, 4508 (1996). [4] J. Kyriakidis and D. Loss, PRB **58**, 5568 (1998). [5] N. B. Christensen et al, Physica B **276**, 784 (2000). [6] W. Montfrooij et al, PRB **64**, 134426 (2001). [7] S. Shinkevich and O. Syljuåsen, PRB **85**, 104408 (2012). [8] U. B. Hansen, arXiv preprint arXiv:1906.11554, 2019.