Experimental report

19/09/2019

Proposal: **4-01-1599** **Council:** 10/2018

Title: Spin-wave dispersion in the itinerant helimagnet FeP

Research area: Physics

This proposal is a new proposal

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Samples: FeP

Instrument	Requested days	Allocated days	From	To
IN8	7	7	23/07/2019	30/07/2019

Abstract:

FeP is a very unusual itinerant helimagnet, in which the spin spiral derives from a ferrimagnetic arrangement of spins ("double helix" structure). There are two magnetic sublattice with a different size of the magnetic moment, which are twisted into a helical spiral propagating along the orthorhombic c axis. As a consequence, two inequivalent pairs of incommensurate magnetic Bragg peaks (with associated helimagnon modes) form near the allowed and forbidden structural Bragg peaks (101) and (110), respectively. We performed overview TOF measurements that show rather sharp magnon modes at both positions, well localized in Q space. However, the signal intensity was insufficient to clearly see the details of the dispersion. Here we would like to use the high-flux spectrometer IN8 to follow the dispersion of these magnon branches in the thermal-neutron energy range.

Experimental report for proposal No. 4-01-1599

Introduction

FeP is a very unusual itinerant helimagnet, in which the spin spiral derives from a ferrimagnetic arrangement of spins (“double helix” structure). There are two magnetic sublattice with a different size of the magnetic moment, which are twisted into a helical spiral propagating along the orthorhombic c axis. As a consequence, two inequivalent pairs of incommensurate magnetic Bragg peaks (with associated helimagnon modes) form near the allowed and forbidden structural Bragg peaks (101) and (110), respectively. We performed overview TOF measurements that show rather sharp magnon modes at both positions, well localized in **Q** space. However, the signal intensity was insufficient to clearly see the details of the dispersion. Here we used the high-flux spectrometer IN8 to follow the dispersion of these magnon branches in the thermal-neutron energy range.

Experimental configuration and results

The experiment took place on 23–30.07.2019. We have used pre-aligned array of FeP single crystals with the total mass of ~ 1 g. The measurements were done with the sample mounted in the (HHL) scattering plane, which passes through the structurally forbidden (110) and structurally allowed (002) wave vectors and their magnetic satellites. The experimental configuration with PG filter and fixed $k_\mathrm{f} = 2.662$ or 4.1 Å^{-1} was used, and the measurements were done at the base temperature of 2 K. We have measured multiple momentum scans up to 35 meV and at a few energy scans to quantify the magnitude of the spin gap and the saddle point of the spin-wave dispersion near (110), as shown in Fig. 1 (left panel). Here, in addition to the magnon modes, one can also see an optical phonon in the range of 23–27 meV. The broadening of the features near the center is not intrinsic, but originates from the extremely steep magnon dispersion out of plane, where we start resolving the individual branches only above 30 meV.

As the next step, we repeated the same mapping measurements near the other nonequivalent pair of magnetic reflections around (002), as shown in Fig. 1 (right panel). The (002) reflection is equivalent to (101) and was chosen because it lies within the (HHL) scattering plane. However, its $|\mathbf{Q}|$ is much longer, and in addition, it lies in the proximity of the aluminium

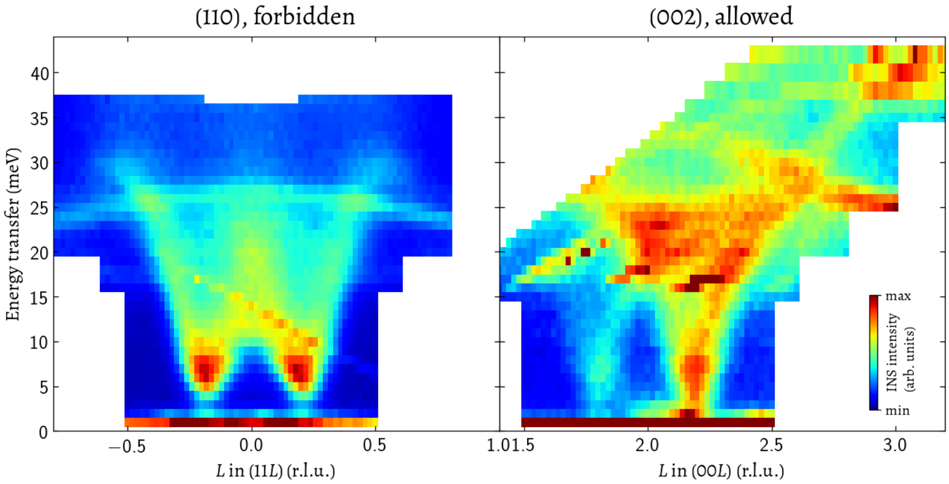

Fig. 1: Summary of the inelastic FeP color plots constructed from the IN8 data.

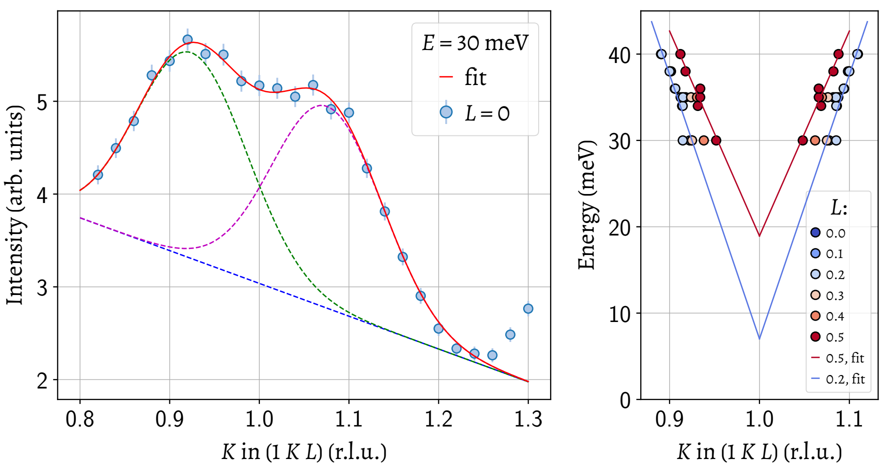

Fig. 2: The typical momentum scan in the $(0K0)$ direction (left) and the summary of energy-momentum plot for different $(00L)$ points.

powder line at a slightly larger $|\mathbf{Q}|$. This resulted in some considerably spurious contamination of the signal above ∼15 meV. On the other hand, long $\mathbf{Q}$ enabled us to track the dispersion to higher energies on one side of our color map. We can clearly see that the intensity of the low-energy parts of the dispersion is asymmetric, and the spin gap is similar to that near $(11L)$. Nevertheless, the dispersion near the saddle point remains unclear due to the contamination.

As the next step we were using goniometers in order to measure out-of-plane dispersion in the $(0K0)$ direction. We performed out-of-plane momentum scans around both points in reciprocal space and plotted the results in Fig. 2. The momentum resolution in this configuration is not optimal, but we could nevertheless resolve the two magnon branches at high energies. From the corresponding fits, summarized in the right panel, we can estimate the spin-wave velocity in this direction. It suggests that the spin waves shift from the commensurate position by only 0.1 r.l.u. at 40 meV energy transfer, which means that the magnon band width should be of the order of at least 200–300 meV.

Summary

While our measurement provided very useful and quantitative information about the low-energy spin wave dispersion that can be compared with spin-dynamical calculations (spin gap, saddle-point energy, spin-wave velocities), they still leave one important question unanswered. We could not convincingly demonstrate whether the dispersion near the allowed and forbidden Bragg satellites, which are strictly speaking nonequivalent in a compound with 4 spins per unit cell, are equivalent. To answer this question, an additional experiment in the $(H0K)$ scattering plane would be justified, where we could reach the (101) position with the shortest $\mathbf{Q}$ and perform scans along the $(10L)$ direction.