Experimental report

12/04/2016

Proposal: **4-03-1710** **Council:** 10/2014

Title: Quasielastic intensity distribution in Ce0.5La0.5B6

Research area: Physics

This proposal is a new proposal

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Samples: Ce(0.5)La(0.5)B6

Instrument	Requested days	Allocated days	From	To
IN5	5	5	12/05/2015	18/05/2015

Abstract:

Experimental report No. 4-03-1710

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Experimental team: P. Portnichenko, M. Surmach (TU Dresden)
Date of experiment: 12-18 May, 2015

Reason for the sample replacement

In May 2015 we have scheduled experiment with the proposal number 4-03-1710 on the disk chopper time-of-flight spectrometer IN5. In a number of recent experiments on the pure CeB_6 compound, we have revealed strong quasielastic intensity in the normal (paramagnetic) state with a rich momentum-space structure. In the pure compound, the quasielatic intensity is uniformly distributed between the commensurate positions like R, X or Γ points, whereas in 23% doped sample we could see a suppression of the intensity at the R point and increase at the X point. To fully understand the influence of La doping on the suppression of the AFQ order, we initially planned to map out the full 4D energy-momentum space of $Ce_{0.5}La_{0.5}B_6$.

However, by the time the proposal was scheduled, we already accumulated preliminary data on the same sample. At the same time, we had already a large amount of triple-axis data on the pure CeB_6 compound in magnetic field that we would like to publish soon. What was missing was the data of the detailed magnetic field dependence of excitation spectra at low fields below 2.5 T, which would complete our dataset. Low background vertical magnet available at IN5 would certainly allow us to distinguish low-energy excitation at the zone center, therefore, with all this new information, we mapped out the full 4D energy-momentum space as a function of magnetic field for the pure CeB_6 and used beamtime more effectively. The results formed a major part of the paper [1] that has already been submitted and is currently under review.

Introduction

In our recent inelastic neutron scattering (INS) experiments, we have discovered several novel features in the magnetic excitation spectrum in the parent CeB_6. Strong quasielastic intensity with a rich momentum-space structure, which exists within the paramagnetic state [2], gave rise to sharp collective modes below the antiferromagnetic (AFM) transition temperature $T_N = 2.3$ K. According to neutron-diffraction measurements on CeB_6, phase III represents a double-**q** commensurate antiferromagnetic phase with the propagation vectors $\mathbf{q}=(\frac{1}{4} \pm \frac{1}{4}\ \frac{1}{2})$ and $\mathbf{q}'=(\frac{1}{4} \pm \frac{1}{4}\ 0)$ [3, 4]. The AFQ state in CeB_6 with propagation vector $\mathbf{q}_{AFQ}=(\frac{1}{2}\frac{1}{2}\frac{1}{2})$, which within the RB_6 family of hexaborides (R being a rare earth) is peculiar only to CeB_6, has been extensively studied as it represents an example of a magnetically hidden order, most commonly associated with the ordering of magnetic quadrupolar moments [5–7]. The strongest inelastic intensity can be observed in the AFM state at 0.25 meV near the zone center $\Gamma(110)$ which represents magnetic excitation centered at the FM wave vector. Previously, we were able to collect a preliminary data set covering the spectrum at the wave vector of the exciton mode at Γ in different magnetic fields. In this beam time we wanted to complement the data and to see how it gets suppressed together with the AFM phase in the magnetic field.

Experimental configuration

Measurements were performed on single-crystalline sample of CeB_6 with a mass of 4 grams, prepared from 99.6 % isotopically enriched ^{11}B to minimize neutron absorption. The sample was mounted in the 2.5 T "orange" cryostat-based magnet with its crystallographic ⟨110⟩ axis aligned vertically. Using the published lattice parameters $a = b = c = 4.14$ Å, $\alpha = \beta = \gamma = 90^\circ$ we aligned the sample on the most intense (110) and (001) reflections. The resulting scattering plane was (HHL). After aligning the crystal, we fixed the incident neutron wavelength to 5 Å (3.27 meV) and rotated the sample during the measurement in steps of 1° to map out the complete energy-momentum space.

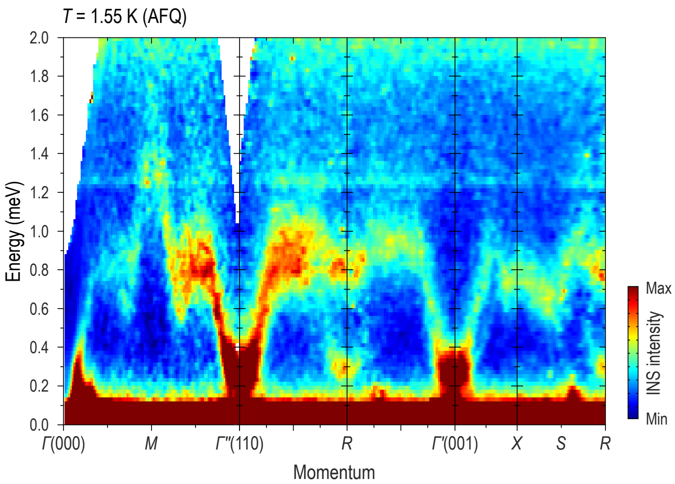

Fig. 1: Energy-momentum profiles along high-symmetry directions in the AFQ state measured at $B = 2.5$ T. Measurements were performed at 1.55 K (AFQ). The magnetic field was aligned along the $[1\bar{1}0]$ direction.

Results

In Fig. 1 we present a continuous dispersive magnon band connecting the local intensity maxima at the zone center (Γ) and zone corner (R) measured at 2.5 T. These data were obtained as two-dimensional cuts along high-symmetry directions from our four-dimensional TOF dataset by integrating within ±0.15 r.l.u. along the momentum direction perpendicular to the plane of the figure in the (HHL) scattering plane, and ±0.04 r.l.u. in the out-of-plane (vertical) direction parallel to the magnet axis. It is remarkable that the magnon is more intense around the $\Gamma''(110)$ point than at the equivalent $\Gamma'(001)$ or $\Gamma(000)$ positions, suggesting an anomalous non-monotonic behavior of the dynamic form factor that is characteristic of multipolar moments. A magnetic field of 2.5 T does not change the excitation energy at the zone center significantly but increases the magnon bandwidth twofold.

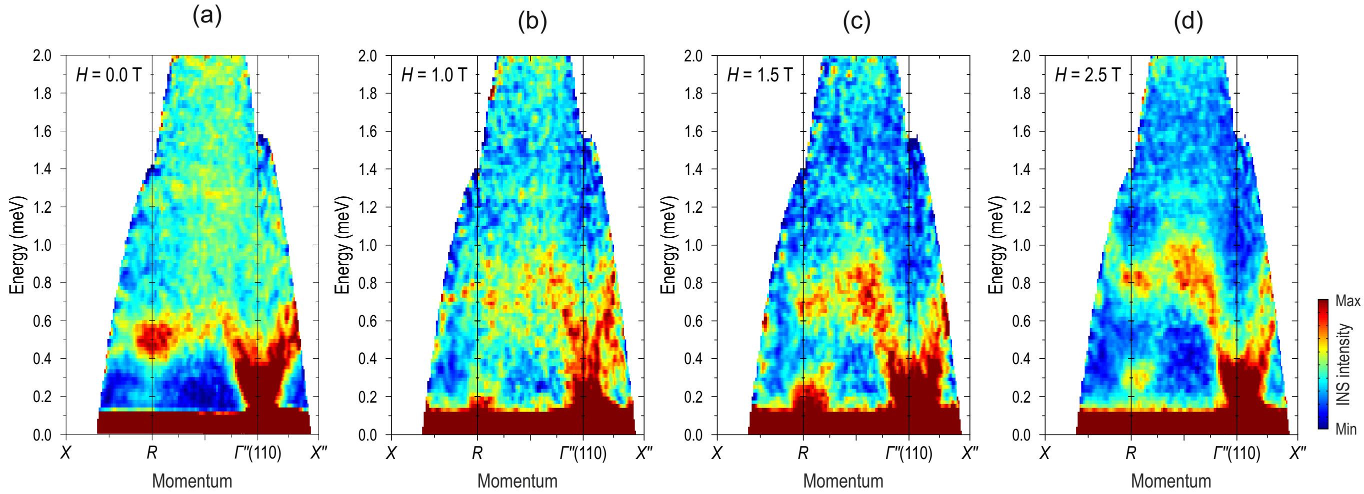

Fig. 2: Magnetic field dependence of the magnon spectrum along high-symmetry directions in CeB_6. Each panel (a-d) consists of color maps integrated along straight segments connecting $X(00\frac{1}{2})$, $R(\frac{1}{2}\frac{1}{2}\frac{1}{2})$, $\Gamma''(110)$, and $X''(11\frac{1}{2})$ points.

We measured in detail the field dependence across QCP for Γ and R points. This would reveal essential differences in the behavior of the resonances in comparison with other HF systems. Energy-momentum profiles for several fields are shown in Fig. 2 as well as each field scan along the ΓR direction can be found in our preprint [1] as an animation. We also present one-dimensional energy profiles obtained from the same data by integration within ± 0.15 r.l.u. around the Γ and R points as color maps in Fig. 3. The data in Fig. 3(a) illustrate the non-monotonic behavior of the zone-center excitation as it initially softens to zero upon entering the phase III′ and then reappears within phase II at an energy that continuously increases with the applied field. A qualitatively different picture is observed for the resonance peak at the R point in Fig. 3(b). Increasing the field within phase III keeps the resonance energy constant while it decreases in amplitude and broadens, transferring a significant part of its spectral weight to the second low-energy mode whose tail can be seen above the elastic line already above ~ 0.5 T. Upon crossing through the phase III–III′ transition, the amplitude of the low-energy mode is maximized, whereas the higher-energy mode shifts up in energy. Both excitations then follow a linear trend with the same slope and approximately equal amplitudes in phase II, in agreement with our earlier report [8]. This behavior is completely different from the field-induced splitting of the neutron resonance in the SC state of $CeCoIn_5$, where the second mode emerges from the resonance energy and then shifts down monotonically with increasing field [9].

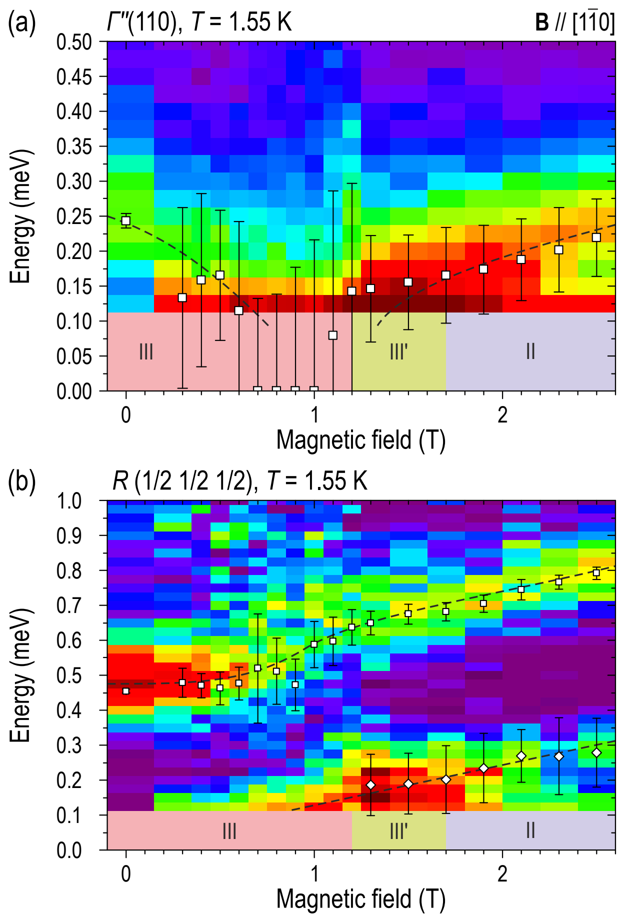

Fig. 3: Magnetic field dependence of the resonance peaks at (a) Γ and (b) R points. Markers in both panels were determined as peak maxima from the fits. Dashed lines are guides to the eyes, and the shaded areas below each panel mark the resolution cutoff and indicate the field regions corresponding to the AFM (III, III′) and AFQ (II) phases.

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