Experimental report

19/09/2018

Proposal: **5-41-954**

Council: 4/2018

Title: Study of field-induced magnetic structures in the 2% Rh-doped URu2Si2in pulsed fields up to 40 T

Research area: Physics

This proposal is a new proposal

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Samples: U(Ru0.98Rh0.02)2Si2

Instrument	Requested days	Allocated days	From	To
IN3	0	3	09/07/2018	12/07/2018
IN22	10	7	04/09/2018	12/09/2018

Abstract:

Recent high-field neutron experiments in pulsed and static fields on the pure and 4% and 8 % Rh-doped URu2Si2 revealed that the first field-induced state (phase II) in the pristine system has propagation vector q1 = (0.6 0 0) in contrast to Rh-doped systems wuth propagation vector q2 = (2/3 0 0). Immediate question arises whether the change in q is connected with the disappearance of the so-called hidden order (HO) in the latter systems. With this proposal we suggest to determine the magnetic structures of the high field phases of 2% Rh-doped URu2Si2, which exhibits a re-entrant behavior of the HO. For this concentration, depending on temperature, either an AF state (with q0 = (1 0 0)) or the HO-rich state exists. This feature offers a possibility to test whether the appearance of the q0 phase in high fields above ~32 T is indeed linked to existence of the HO state at lower fields. The determination of other field-induced phases (the phase III, between 35.5 T and 37 T and the field-polarized state above 37 T) around the quantum critical point suggested at ~35 T should help to solve the mystery regarding the nature of HO in URu2Si2 and its relation to magnetism in this material.

The subject of this proposal was 2%Rh-doped URu_2Si_2. The pristine system, URu_2Si_2, has been examined intensively over last three decades. The rich phase diagram includes superconductivity, non-Fermi liquid behavior, unknown Hidden Order (HO) and multiple high magnetic field phases appearing at high magnetic fields [1-3]. Thanks to a new cryomagnet (developed by the LNCMI-Toulouse, the CEA-Grenoble, and the ILL-Grenoble) allowing neutron diffraction up to 40 T, the magnetic structure of URu_2Si_2 in fields between 35 and 39 T has been determined [4]. Former similar studies, albeit using much shorter magnetic field pulses allowed the study of the 4% doped system. In the pristine system the field-induced phase has propagation vector k_1 = (0.6 0 0) in contrast to Rh-doped system where propagation vector k_2 = (2/3 0 0) is found [5]. Recent high-field neutron experiments in static fields up to 26 T on the 8 % Rh-doped URu2Si2, where the first critical field is pushed below 22 T, lead the same results [6].Immediate question arises whether the change in k is connected with the disappearance of the so-called hidden order (HO) in the pure systems.

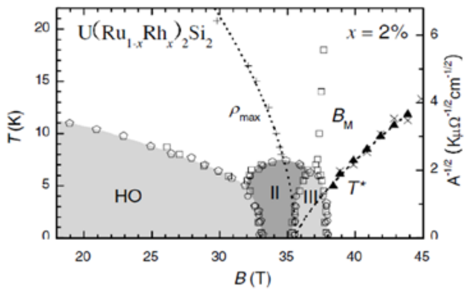

Fig. 1: Detail of the high-magnetic-field phase diagram for the 2% Rh-doped URu_2Si_2.

In the experiment 5-41-954, 0.7g heavy 2%Rh-doped URu_2Si_2 single crystal was studied in pulsed high fields up to ~ 40 T. The complicated H-T phase diagram [1] of the pristine compound is modified (Fig. 1) to show three field-induced phases. Critical fields of metamagnetic transitions are found at μ_0H_1 = 31.95/31.55 T, μ_0H_2 = 35.45 / 35.30 T (rising / falling fields), and μ_0H_3 = 37.1 T, respectively (Fig. 2). The state above is polarized paramagnetic state.

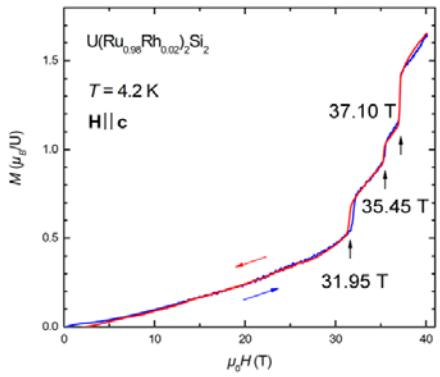

Fig. 2: Field dependence of the magnetization of the 2% Rh-doped URu_2Si_2 measured with field applied along the c axis (top) along with their field derivative.

The neutron diffraction experiment was carried out on the triple-axis spectrometer IN22 (CRG-CEA at the ILL) operated in a double-axis mode. Incident neutrons of wavelength λ = 1.10 Å were selected using a pyrolytic graphite (PG) monochromator. The field pulses were produced every ~ 7-8 minutes by discharging ~ 1 MJ capacitor banks to a nitrogen cooled conical solenoid magnet that allowed to observe few nuclear reflections. The crystal has been glued to a sapphire holder in the (h 0 l) plane, with field nearly along the tetragonal axis of the sample. UB matrix has been deduced using (200), (100) and (-10-1) nuclear reflections.

During the experiment we have concentrated mainly on measurements at base temperature of 2.3 K. We have performed an excessive search for magnetic, field-induced diffracted signal at (Q_h 0 Q_l) , positions (0.58 ≤ Q_h ≤ 0.68 and -0.0075 ≤ Q_l ≤ 0.0075). After testing several such positions and collecting up to 155 shots at a given momentum transfer, it became clear that the largest signal found between μ_0H_1 and μ_0H_2 is neither at k_1 = (0.6 0 0) as in the pure system, nor at k_2 = (2/3 0 0) as reported for 4% and 8% doped systems. It is found to be at k_3 = (0.63 0 0) (Fig. 3). The time profile of the field pulse along with the detected diffracted signal at k_3 is shown for 60 pulses in Fig. 4. The signal disappears at high temperatures, indicating its magnetic origin. The incommensurate position is somewhat surprising as it shows that the existence of the HO

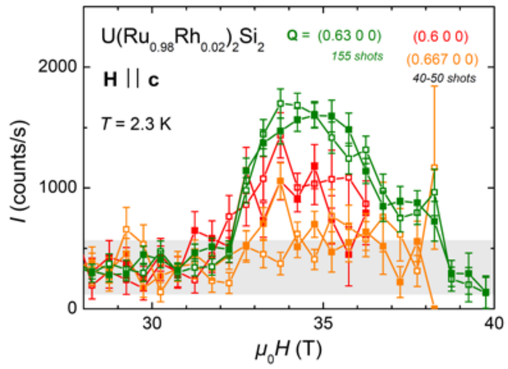

Fig. 3: Field dependence of the neutron diffracted intensities in fields up to 39.5 T at three representative Q positions for the 2% Rh-doped URu_2Si_2.

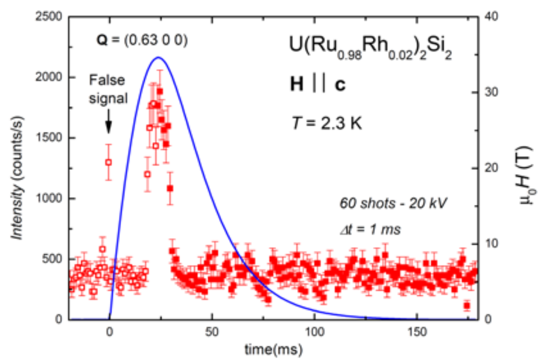

Fig. 4: Example of the time spectrum at (0.63 0 0) Q position at 2.3 K. The blue signal is the time dependent field profile and the red points (open, filled) are neutron counts (increasing, decreasing field).

state in both, pure and 2% doped systems does not impose that the field-induced phase has the same propagation vector and points to a Fermi-surface reconstruction.

In contrast to previous study in pulse fields we do observe an increase of the (-10-1) reflection in the polarized paramagnetic state. This is in agreement with expected field-induced ferromagnetic component. It should be noted that the (200) reflection in contrast decreases pointing to extinction effects.

Another surprising result is a clear decrease of the diffracted intensity at Q = (0.63 0 0) for fields between μ_0H_2 and μ_0H_3. In this region we observe a shift of the maximal intensity to position having non-zero Q_l and speculate that the magnetic structure has a wavevector k'_3 = (0.63 0 δ), with a small transverse component δ. This would suggest that field-induced phases in the 2% Rh-doped system and possibly also in the pristine system are of a multi-k nature. Then the intensity decrease would be connected with a loss of one of the k components and a change "dimensionality" of the multi-k structure (e.g. from 3k to 2k or 2k to 1k). A depopulation of one of the magnetic 1k-Bragg peaks above H_2 is also possible. In this case, the magnetic structure would be most probably of the 1k type. This, however, needs a bit better resolution of the instrument (achievable by e.g. increasing the wavelength) and would require further study

References

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