Experimental report

10/11/2019

Proposal:	**5-42-463**	**Council:**	4/2017
Title:	Vortex lattice of the heavy fermion superconductor CeCu2Si2		
Research area:	Physics		

This proposal is a resubmission of 5-42-446

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Samples: CeCu2Si2

Instrument	Requested days	Allocated days	From	To
D33	5	3	28/05/2018	31/05/2018

Abstract:

The first heavy-fermion superconductor CeCu2Si2 was discovered in 1979. Even after extensive transport and thermodynamic studies the mechanism and the symmetry of its superconducting order parameter are still under debate. We have successfully observed the vortex lattice in this material (Experiment 5-42-404), and shown clearly that this material is Pauli-limited. We are asking for additional time to complete our data collection and to extend to the study of a sample showing both antiferromagnetic and superconductivity at the same time.

Vortex lattice study of the possible Pauli-limited heavy fermion superconductor $CeCu_2Si_2$

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$CeCu_2Si_2$ was the first heavy fermion superconductor to be discovered [1]. It crystallises in the body-centered tetragonal structure, with $a = b = 4.1$ Å, and $c = 9.9$ Å. The low temperature physical properties are very sensitive to extremely small changes in stoichiometry, such that one can prepare antiferromagnetic (A-type), superconducting (S-type), or antiferromagnetic and superconducting (A/S-type) samples [2]. The mechanism and symmetry of the superconducting order parameter are still open questions. Here, we have looked at a high-quality S-type sample that was previously measured at SANS-I, SINQ, as a test [3], and at D33, ILL [4].

The main purpose of the experiment was studying the vortex lattice in an A/S-type sample of $CeCu_2Si_2$. We performed a field scan and five different temperature scans but we did not observe any features or Bragg peaks corresponding to the flux line lattice. We spent 2 days on this sample, finally concluding with a search for magnetic critical scattering close the T_N for this compound. This searches were inconclusive. We then proceeded to change to a S-type sample.

The sample was aligned with the **c** axis parallel the field and the neutron beam, and a [110] direction in the horizontal scattering plane. It was installed in the BlueCharly magnet with a dilution insert (T_c = 670 mK). In this experiment, we concentrated on field dependences at higher temperatures reported in our previous experiment at ILL [4], as the vortex lattice form factor decreases with increasing temperature, as it was already observed in $CeCoIn_5$ [5-6]. To ensure a high quality vortex lattice, whenever changing field or sample orientation, the sample was field cooled from 750 mK to 40 mK with an oscillation of 1% of the applied field.

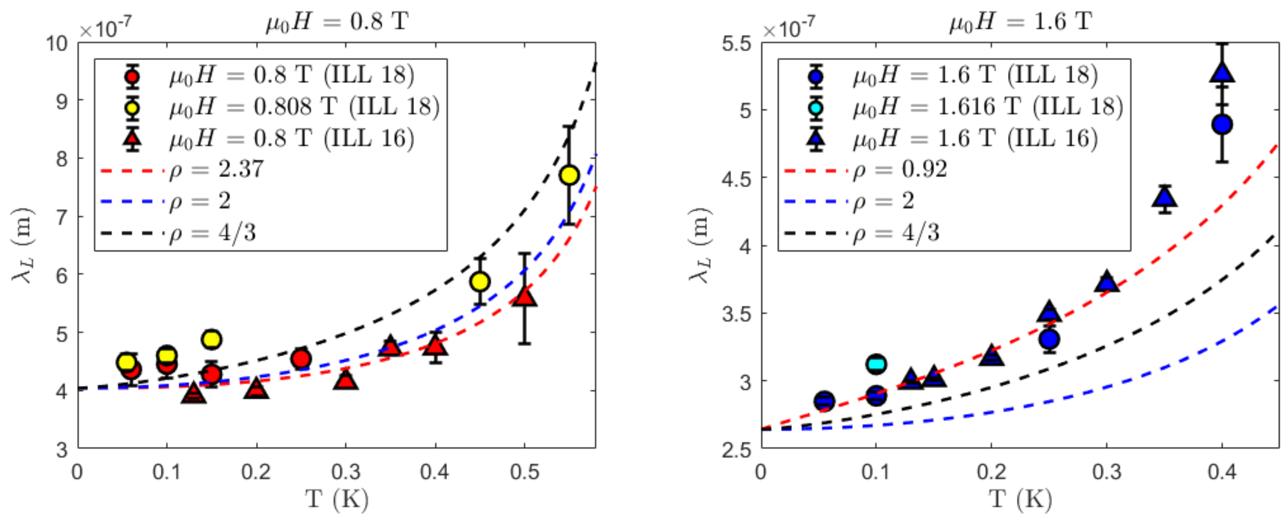

Figure 1: Temperature dependence of the form factor at different fields (data from this experiment and Ref. 4). Blue dashed lines correspond to the temperature dependence of London penetration depth for s-wave superconductors, black dashed lines correspond to d-wave and red dashed line correspond to the actual data.

We first measured the temperatures dependence of the form factor at 0.8T and 1.6T from. In **Figure 1,** assuming the London theory, we could calculate the temperature dependence of the London penetration depth. At 0.8 T the London penetration depth is close to the behaviour corresponding to a s-wave superconductor, meanwhile at 1.6 T, where the London penetration depth deviates to an unphysical result, suggesting that the London approximation cannot be used for studying the temperature dependence of the penetration depth once the Pauli paramagnetic effect appears in the sample.

Field dependence of the FLL was measured at 250 mK and 350 mK, by rocking through Bragg peaks. The resulting integrated intensity has been converted to the vortex lattice form factor, using the Christen formula [7]. **Figure 2** shows the data, as well as data obtained at ILL at 130 mK [4]. We can see from the graph that the form factor at 130mK is higher than the one at higher temperatures as we expected from the results in $CeCoIn_5$ [6]. We can see that the Pauli paramagnetic effect is much more evident from 1.5 T. Once the form factor reaches its maximum, it decreases rapidly to H_{c2}.

We also reported some problems at the beginning of the experiment with the LakeShore thermometer readings, as when the temperature went below 50 mK, the calibration curve stopped abruptly, leading to the Lakeshore failing to read, breaking the temperature control loop.

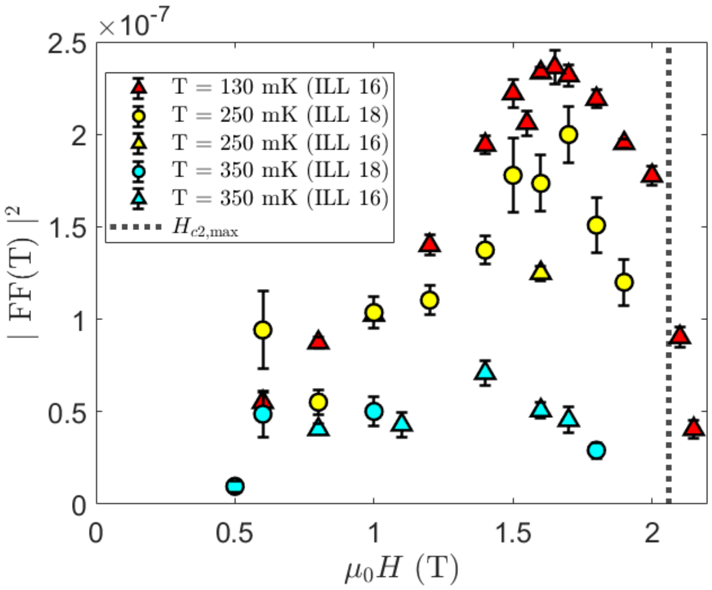

Figure 2: Field dependence of the form factor at different temperatures (data from this experiment and Ref. 4).

References

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