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Absence of antiferromagnetic order in UBe_{13}

A. de Visser [a], N.H. van Dijk [a], J.J.M. Franse [a], A. Lacerda [b,1], J. Flouquet [b], Z. Fisk [c] and J.L. Smith [c]

[a] *Van der Waals–Zeeman Laboratorium, Universiteit van Amsterdam, Valckenierstraat 65, 1018 XE Amsterdam, The Netherlands*
[b] *Centre de Recherches sur les Très Basses Températures, BP 166X, 38042 Grenoble, France*
[c] *Los Alamos National Laboratory, Los Alamos, NM 87545, USA*

The linear magnetostriction ($\lambda_{\parallel}$ and $\lambda_{\perp}$) of a single-crystalline sample of the heavy-fermion compound UBe_{13} has been measured for fields $B < 8$ T ($B \parallel [100]$) in the temperature interval $0.3 < T < 12$ K. We find neither evidence for the antiferromagnetic order ($T_N = 8.8$ K) nor for the magnetostrictive oscillations, that were reported recently. Instead λ varies proportional to B^2 as expected for a normal paramagnetic metal.

In recent years antiferromagnetic (AF) order with extremely small moments ($|\mu| \sim 0.01\mu_B$/f-atom) has been detected for several heavy-fermion superconductors. In the case of URu_2Si_2 ($T_N = 17.5$ K) neutron diffraction [1] has revealed an ordered moment of $\sim 0.03\mu_B$/U-atom. For UPt_3 ($T_N = 5$ K) μSR-experiments [2] and neutron diffraction [3,4] point to an ordered moment of $0.02\mu_B$/U-atom. NMR-experiments [5] yield a Néel temperature of ~ 0.6 K for superconducting $CeCu_2Si_2$. In the case of the superconductor UBe_{13} microscopic techniques (in particular careful μSR-experiments [2]) have thus far been unsuccessful in demonstrating long-range magnetic order. Nevertheless, evidence for a transition to an AF state at $T_N = 8.8$ K has recently been put forward by Kleiman et al. [6], who measured the magnetostriction, $\lambda(B)$, of a single-crystalline sample using a field modulation technique and observed an additional contribution at low temperatures, that was ascribed to AF ordering. In the same paper a pronounced hysteretic behaviour and magnetostrictive oscillations, ascribed to de Haas–van Alphen oscillations due to an unusual aspect of the Fermi surface, were reported. However, our prior $\lambda(B)$ data [7], taken in the same field and temperature interval, did not reveal such anomalous behaviour. Therefore, we decided to reinvestigate the magnetostriction of our single-crystalline UBe_{13} sample. Hereto we performed an extensive magnetovolume study [8] in the temperature interval $0.3 < T < 12$ K and in magnetic fields up to 8 T.

A single-crystalline UBe_{13} sample was shaped into a rectangular bar with edges of ~ 2, 4 and 6 mm, along the crystallographic (cubic) [100] directions. The single-crystalline nature of the sample was confirmed by a neutron-scattering experiment. In order to measure the linear magnetostriction, $\lambda = (L(B) - L(0))/L(0)$, the sample was mounted in a parallel-plate capacitance cell, machined of oxygen free high conductivity copper (see ref. [8] for experimental details). The length changes were always measured along the 4 mm edge, either parallel to the field ($B \parallel [100]$), $\lambda_{\parallel}$, or perpendicular to the field, $\lambda_{\perp}$, by rotating the cell (with B along another [100] direction).

The magnetostriction of UBe_{13} has been measured up to 8 T at temperatures of 0.4, 0.5, 0.6, 1.25, 4.2, 6, 8 and 10 K [8]. In fig. 1 we show some typical as-measured curves in the normal phase ($T_c = 0.85$ K) at 1.25, 4.2 and 10 K. Within the experimental error no hysteresis is observed. The volume magnetostriction is calculated from $\lambda_v = \lambda_{\parallel} + 2\lambda_{\perp}$. In fig. 1 we show $\lambda_v/3$. The linear normal-state magnetostrictions, $\lambda_{\perp}$ and $\lambda_{\parallel}$,

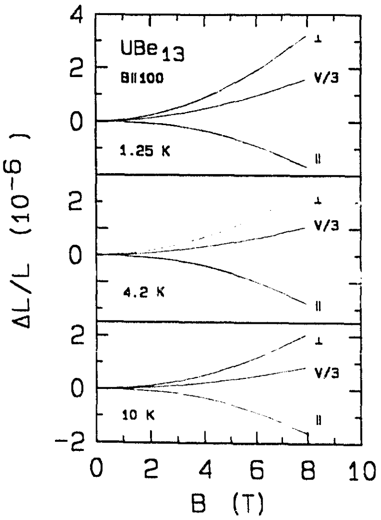

Fig. 1. The magnetostriction of single-crystalline UBe_{13} along (‖) and perpendicular (⊥) to the applied magnetic field ($B \parallel [100]$) at temperatures indicated. Data for field sweeps up and down coincide. The curves labeled v/3 represent $\lambda_v/3$.

[1] Present address: Los Alamos National Laboratory, Los Alamos, NM 87545.

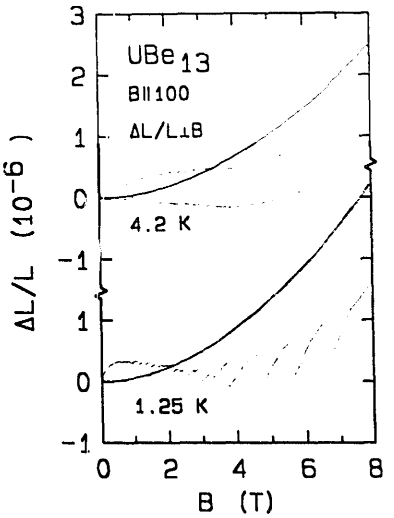

Fig. 2. Comparison of our magnetostriction results for $\lambda_\perp$ (solid lines) with the data of Kleiman et al. [6] (dotted lines) at 1.25 and 4.2 K (upper dotted line: field up; lower dotted line: field down).

are strongly anisotropic and follow a quadratic field dependence. Consequently, λ_v is proportional to B^2, as expected for a paramagnetic metal.

In fig. 2 we compare our results at 1.25 and 4.2 K with the data of Kleiman et al. [6]. The different data sets are obviously at large variance with each other. Clearly hysteretic and oscillatory behaviour are absent in our data. In order to search for the occurrence of long-range AF order, we have plotted in fig. 3 the temperature variation of the slope of the λ vs B curve in fields of 3, 5 and 7 T. For $\lambda_\perp$ (upper frame) the slope smoothly decreases with increasing temperature, while it remains roughly constant for $\lambda_\parallel$ (lower frame).

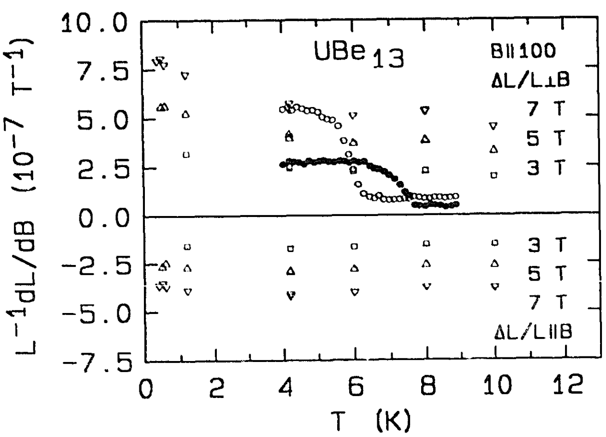

Fig. 3. $L^{-1}\mathrm{d}L/\mathrm{d}B$ versus temperature in fields of 3, 5 and 7 T. In the lower frame we show $\lambda'_\parallel$ and in the upper frame $\lambda'_\perp$. Dotted lines serve as a guide to the eye. The closed and open circles represent data for $L^{-1}\mathrm{d}L/\mathrm{d}B$ by Kleiman et al. [6] in fields of 3 and 7 T, respectively.

We also compare in fig. 3 our data with the data of ref. [6], obtained with the field modulation technique in fields of 3 and 7 T. The abrupt increase in $\lambda'_\perp$ (with decreasing temperature) observed in ref. [6] at 7.7 K in 3 T and at 6.2 K in 7 T has been put forward as evidence for an AF transition. However, the interpretation of these experimental data is by no means clear-cut. The slope was measured using a field modulation technique with an amplitude of 0.1 T. It is likely that the reported unusually field-induced hysteretic and oscillatory behaviour, which is moreover strongly varying with temperature, influences in a non trivial way the obtained slope. From fig. 3 it is obvious that our data do not confirm the transition to a long-range ordered AF state.

It is unlikely that the large discrepancy between our data and the data in ref. [6] must be ascribed to a sample quality dependence. The published data on the thermodynamic and the magnetic properties of various UBe_{13} samples yield in general consistent results, indicating a proper sample quality. Specific-heat data [8] on our sample reveal that we have a sample of sufficient quality. It is remarkable that the magnetostrictive oscillations, reported in ref. [6], have the largest amplitude at a temperature of 1.25 K, where also the maximum in the thermal expansion is found ($\alpha_{max} = 1.7 \times 10^{-6}$ K^{-1}) [7,8]. A temperature oscillation of, for instance, 0.1 K would induce an oscillation in $\Delta L/L$ with amplitude $\sim 1.7 \times 10^{-7}$, which is of the order of the reported values. Therefore, we suggest that an unusual temperature instability, possibly induced by eddy current heating, might have caused the unusual λ vs B curves reported in ref. [6]. Concurrently, one cannot exclude that the "evidence" for antiferromagnetism (fig. 3) is an artifact of the experiment.

In summary, our magnetostriction data are in sharp contrast with the data of Kleiman et al. [6] and do not confirm a transition to the long-range ordered state at $T_N = 8.8$ K in zero field for our UBe_{13} sample. Of course the present investigation cannot exclude the occurrence of antiferromagnetism above 12 K, or at very low temperatures. For a thorough analysis of the magnetovolume effects in UBe_{13} we refer to ref. [8].

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