# Phonon line-widths in UPt3

**Alois Loidl, B. Renker, H. Rietschel, P. Frings, E. Bucher, M.-Ch. Lux-Steiner**

**Angaben zur Veröffentlichung / Publication details:**

Loidl, Alois, B. Renker, H. Rietschel, P. Frings, E. Bucher, and M.-Ch. Lux-Steiner. 1988. "Phonon line-widths in UPt3." *Journal of Magnetism and Magnetic Materials* 76-77: 441–43. https://doi.org/10.1016/0304-8853(88)90450-7.

# PHONON LINE-WIDTHS IN $UPt_3$

A. LOIDL

*Institut für Physik, Universität Mainz, 6500 Mainz, Fed. Rep. Germany*

B. RENKER, H. RIETSCHEL

*Institut für Nukleare Festkörperphysik, Kernforschungszentrum Karlsruhe, 7500 Karlsruhe, Fed. Rep. Germany*

P. FRINGS

*Institut Laue Langevin, 38042 Grenoble, France*

E. BUCHER and M.-Ch. LUX-STEINER

*Fakultät für Physik, Universität Konstanz, 7750 Konstanz, Fed. Rep. Germany*

Inelastic neutron scattering results on phonon line-widths of long wavelength longitudinal and transverse modes are reported for $UPt_3$. Contrary to the findings in ultrasonic experiments, no pronounced temperature dependent damping effects were detected in the longitudinal branches. However, an anisotropic attenuation occured for transverse modes at low temperatures.

$UPt_3$ is a heavy-fermion system (HFS) with a superconducting groundstate [1]. Recently antiferromagnetic order has been detected with a Néel temperature of 5 K and an ordered moment of $0.02\mu_B$ [2]. In this brief report we focus on the temperature dependence of sound propagation and on attenuation effects in $UPt_3$. Due to the large electronic Grüneisen parameters [3] and due to hydrodynamic fluctuations in heavy-fermion compounds [4] pronounced anomalies in the elastic properties are expected. It has been pointed out that in HFS the Landau–Placzek ratio (LPR) is enhanced by a factor of $10^4$–$10^6$ as compared with ordinary metals [4]. The LPR measures the ratio of the intensities of the central peak due to heat conduction and of the two phonon side bands due to sound propagation. Within the framework of a hydrodynamic theory it was shown that in HFS two quasielastic lines exist, a narrow one due to heat diffusion and a broad one due to electron diffusion. The electron density fluctuations dominate the attenuation of longitudinal sound waves. Experimentally a pronounced longitudinal absorption peak was observed in $UPt_3$ near 12 K [5] which is well below the characteristic Kondo temperature of the system ($T_K \approx 26$ K [5]). It was shown that for the frequencies investigated (30 MHz $\leq f \leq$ 600 MHz) the attenuation increased proportional to $\omega^2$ which was taken as evidence that the measuring frequencies were always smaller than the inverse life time of the heavy quasiparticles ($(\omega t)^2 \ll 1$).

It seems worthwhile to study the characteristic features of sound propagation and attenuation of HFS in the high frequency regime utilizing inelastic neutron scattering techniques. We investigated long wave length longitudinal and transverse phonons along the $\boldsymbol{a}$- and the $\boldsymbol{c}$-directions and analyzed especially the temperature dependent shift and line width effects of the scattered neutron groups. The measurements were performed on the triple axis spectrometer IN12 located on a cold source of the high flux reactor at the Institut Laue Langevin. A fixed incident neutron energy of 5.1 meV and a collimation (neutron-guide)–30′–60′–60′ was chosen yielding an energy resolution of 0.034 THz full width at half maximum (FWHM). A high quality single crystal with a diameter of 5 mm and 20 mm hight was mounted with the $(h0l)$ plane coinciding with the horizontal scattering plane of the spectrometer.

*Phonon line widths and phonon shifts.* We performed a detailed investigation of longitudinal and transverse phonons in $UPt_3$ with sound velocities proportional to the elastic constants $c_{33}$ and $c_{44}$. Representative results are shown in fig. 1. Here we plotted the neutron intensities versus frequency as observed in constant-$Q$ scans for transverse phonon modes propagating along the $c$-direction with a polarization along the $a$-direction ($q \parallel c$ and $u \parallel a$) for various temperatures. These modes are characterized by a sound velocity proportional to $c_{44}$. A significant increase of the line width with decreasing temperatures is clearly demonstrated. At zero energy transfers a quasielastic line dominates which is predominately due to elastic incoherent scattering processes. The observed scattered neutron intensities were fitted using Gaussian line shapes for the quasielastic peak and for the phonon sidebands. The width of the quasielastic peak was limited by the experimental resolution at all temperatures. The results of the fits for the phonon energies and for the phonon widths as determined for the longitudinal and transverse modes can be summarized as follows: – within the experimental uncertainties of the present measurements no temperature dependent shifts of the neutron groups could be detected. The anomalous temperature dependence of $c_{11}$ and $c_{33}$, that has been determined by ultrasonic techniques [3], is far inside the estimated errors of this inelastic neutron scattering study.

– no anomalous damping effects were detected for longitudinal waves, contrary to the experimental findings in ultrasonic experiments [5]. This might be due to the fact, that the neutron scattering data are characteristic for a collision dominated regime ($\omega\tau \gg 1$). However, these neutron results put severe constraints to any theory explaining the damping effects as measured at much lower frequencies by ultrasonic techniques.

– the most unexpected and exciting result is the highly anisotropic damping as measured for transverse sound waves propagating with a velocity proportional to $c_{44}$. While the modes which propagate within the hexagonal planes along the $a$-direction exhibit a significant increase of the life time below 20 K, the modes propagating along the $c$-direction exhibit no anomalous damping effects.

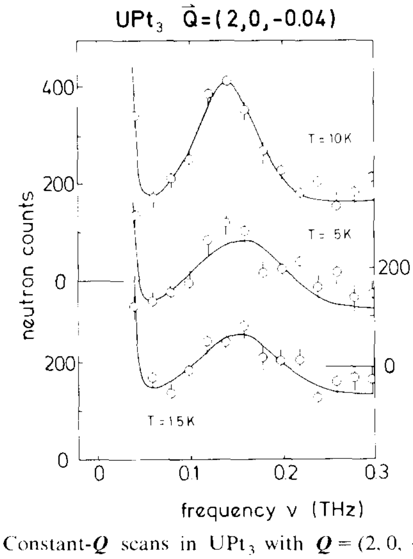

Fig. 1. Constant-$Q$ scans in $UPt_3$ with $Q = (2, 0, -0.04)$ at various temperatures. The scattered neutron groups correspond to transverse phonons which propagate with a velocity proportional to $c_{44}$. The solid lines represent the results of Gaussian fits.

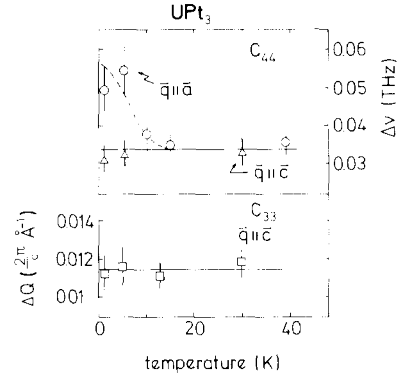

Fig. 2. Temperature dependence of the widths (fwhm) of neutron groups as measured in longitudinal and in transverse scans (the solid lines are drawn to guide the eye). Upper frame: energy width as measured in constant-$Q$ scans for $c_{44}$ modes propagating along $a$ and along $c$; lower frame: width in momentum space as measured in constant-energy scans for longitudinal modes propagating along $c$ with a sound velocity proportional to $c_{33}$.

A summary of these results on the phonon life times is shown in fig. 2. The lower frame documents the absence of anomalous damping effects for longitudinal waves. The upper frame shows the anisotropy of the attenuation in the transverse modes. At the moment we only can speculate about the origin of this observed anisotropy, which might be due to the coupling of the transverse acoustic waves to spin fluctuations. But clearly, further measurements are needed.

*Landau–Placzek ratio.* In order to detect the onset of a central peak intensity that develops below the characteristic temperature we performed a series of constant-$\boldsymbol{Q}$ scans at $(0, 0, 2-\xi)$ for reduced wave vector components $0.05 \leq \xi \leq 0.1$, where $\xi$ is given in units of $2\pi/c$, and for temperatures $1.5\ \mathrm{K} \leq T \leq 30\ \mathrm{K}$. Theoretically one expects a narrow central line due to heat diffusion and, in addition, a broad quasielastic line due to electron density fluctuations [4]. Experimentally the central peak intensities have to be separated from the large elastic incoherent scattering and from the phonon side bands. Although we achieved relatively high counting statistics we were unable to detect any clear evidence of a central line. However, due to the intensity of the incoherent peak, a LPR $\leq 0.2$ would have been hardly detectable, which is still much larger than the theoretically expected estimates.

This work was supported by the Bundesministerium für Forschung und Technologie under the contract number 03-LO1MAI-0 and by the Sonderforschungsbereich 252, Darmstadt/Frankfurt/Mainz/Stuttgart.

## References

[1] G.R. Stewart, Z. Fisk, J.O. Willis and J.I. Smith, Phys. Rev. Lett. 52 (1984) 679.
[2] G. Aeppli, E. Bucher, C. Broholm, J.K. Kjems, J. Baumann and J. Hufnagel, Phys. Rev. Lett. 60 (1988) 615.
[3] M. Yoshizawa, B. Lüthi and K.D. Schotte, Z. Physik B64 (1986) 169.
[4] K.W. Becker and P. Fulde, Z. Physik B65 (1987) 313.
[5] V. Müller, D. Maurer, K. de Groot, E. Bucher and H.E. Bömmel, Phys. Rev. Lett. 56 (1986) 248.