



HAL
open science

ULTRASONIC ATTENUATION NEAR THE LAMBDA LINE OF 4He UNDER PRESSURE

A. Ikushima, K. Okamoto

► **To cite this version:**

A. Ikushima, K. Okamoto. ULTRASONIC ATTENUATION NEAR THE LAMBDA LINE OF 4He UNDER PRESSURE. *Journal de Physique Colloques*, 1978, 39 (C6), pp.C6-188-C6-189. 10.1051/jphyscol:1978683 . jpa-00218363

HAL Id: jpa-00218363

<https://hal.science/jpa-00218363>

Submitted on 4 Feb 2008

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

ULTRASONIC ATTENUATION NEAR THE LAMBDA LINE OF ^4He UNDER PRESSURE

A. Ikushima and K. Okamoto†

The Institute for Solid State Physics, The University of Tokyo, Roppongi, Minato-ku, Tokyo 106, Japan.† *Tokyo Institute of Technology, Ookayama, Meguro-ku, Tokyo 152, Japan.*

Résumé.- L'atténuation ultrasonore a été mesurée au voisinage du point lambda de ^4He sous pression, en étendant les travaux de Carey et al., dans le domaine de la fréquence plus haute jusqu'à 90 MHz. Les comportements du temps de relaxation qui donnent le sommet de l'atténuation sont inexplicables par la théorie de Pokrovskii-Khalatnikov. Il semble que l'hypothèse de la similarité dynamique s'applique aussi sous la pression.

Abstract.- Ultrasonic attenuation was measured near the lambda line of ^4He under pressure, extending the work of Carey et al. below 1 MHz to higher frequencies up to 90 MHz. The behaviours of the relaxation time for the attenuation peak cannot be explained by the Pokrovskii-Khalatnikov theory. The dynamic scaling hypothesis seems to work also well under pressure.

This paper is to report an experimental work on the ultrasonic attenuation near the lambda line of ^4He under pressure. This is an extension of the work of Carey et al. /1/ below 1 MHz to higher frequencies up to 90 MHz.

First-sound attenuation and dispersion have been employed as useful to study dynamic aspects of the lambda transition, and many works have been done /1-10/. However, as fundamental problems, are still remaining ; what the mechanism of the profound attenuation peak and the corresponding dispersion near T_λ , whether the dynamic scaling hypothesis holds well, and, whether the universality concept holds well.

A method of analysing the attenuation data has been a model /2/ applied first to pure ^4He under the saturated vapour pressure, in which two separate mechanisms contribute to the critical attenuation. The first mechanism is caused by a relaxation process attributed to coupling between first and second sounds, and occurs only below T_λ . The second one comes from the critical order parameter fluctuation, and was assumed to have equal strength above and below T_λ . The analysis seemed to succeed at lower frequencies yielding the relaxation time for α_{rel} approximately equal to $\tau' = \xi'/u_2$ as the Pokrovskii-Khalatnikov theory /11/ has given, where ξ' is the correlation length and u_2 the second-sound speed. However, this model was later on found not to work properly at least at higher frequencies /4/, and the mechanism for the attenuation peak has again been a problem.

On the other hand, α_{f1} above T_λ was recognized /5/ to be useful to get directly the characteristic parameter z in the expression of the dynamic scaling /12/,

$$\Omega(\kappa, k) = \kappa^z F(k/\kappa), \quad (1)$$

where Ω is the characteristic frequency of the order parameter fluctuation, $F(x)$ a scaling function, and κ and k the inverse correlation length and the wave number respectively.

The universality seems to hold rather well in the attenuation in mixtures with respect to the addition of ^3He , although some minor discrepancies would still exist in experimental results /8-10/.

Whether the time $\tau' = \xi'/u_2$ is really the characteristic time for the attenuation peak can be checked by looking at the pressure dependence of the peak position, since u_2 as a function of pressure has been determined, and the correlation length as a function of pressure can also be deduced from the well known expression,

$$\xi' = \pi \cdot m^2 k_B T / (h^2 \rho_s), \quad (2)$$

where m is the helium atom mass, ρ_s the superfluid density, and $k_B T$ and h have usual meanings.

Figure 1 is the plot of ϵ_{max} , the reduced temperature corresponding to the maximum attenuation, versus sound frequency at various pressures. This type of plot should be a straight line of slope unity if the relaxation time of the peak is given by the above-mentioned τ' and $\omega\tau' = 1$ at $\epsilon_{\text{max}}^{(1)}$.

(1) See reference /7/. $\omega\tau'$ is not exactly equal to unity at the maximum attenuation but depends somewhat on the frequency.

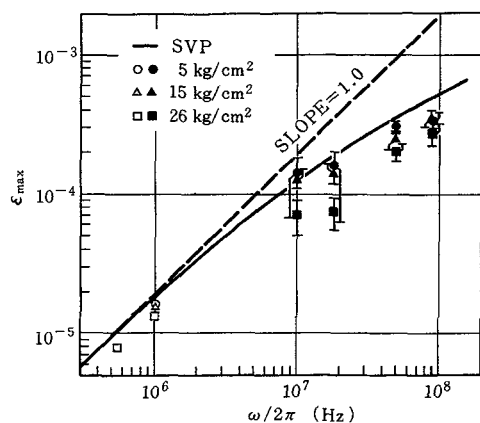


Fig. 1 : Plot of ϵ_{\max} , the reduced temperature corresponding to the maximum attenuation, versus frequency at various pressures. Closed marks are the present data, and open marks are from reference/1/.

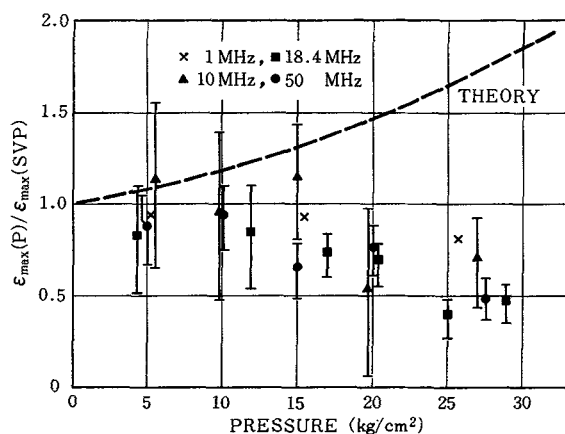


Fig. 2 : Plot of $\epsilon_{\max}(P)/\epsilon_{\max}(SVP)$ versus pressure at various frequencies. Crosses are from reference /1/. The theoretical curve corresponds to $\tau' = \xi'/u_2$.

Figure 2 is then showing $\epsilon_{\max}/\epsilon_{\max}(SVP)$ vs. pressure at some frequencies together with τ' calculated from the experimental u_2 and eq. (2). General trends of the experimental points and the calculated curve do not agree at all with each other. This trend has also been recognized even at lower frequencies /1/. One may think that direct experimental determination of ξ' is required instead of using eq. (2). However, the mechanism proposed by the theory seems to be in a more serious doubt.

For the fluctuation attenuation α_{fl} above T_λ , a scaling representation of the form /13/,

$$\alpha_{fl}(\omega, \epsilon) = \omega^{1+y} G(\omega\tau) \quad (3)$$

has usually been adopted, where $\tau = \tau_0 \epsilon^{-x}$ is the characteristic time constant of the fluctuation. Experiment then gives the parameter x , and the exponent z in eq. (1) can be obtained by $z = x/\nu$, where ν is the critical exponent for the correlation length. The values of z deduced in this way in the present study are listed in table I.

Table I

The dynamic scaling parameter z as a function of pressure.

Pressure (bar)	0	5	15	25
z	1.53±0.05	1.35±0.14	1.56±0.10	1.53±0.10

The value of ν was here assumed to be 0.667 irrespective of the pressure. z seems to be universal with respect to pressure.

The extension of this work to higher frequencies is being made, and will be reported in the near future.

ACKNOWLEDGEMENTS.- The present authors acknowledge Dr. K. Tozaki and Dr. Y. Hiki for their assistances.

References

- /1/ Carey, R., Buchal, C. and Pobell, F., Phys. Rev. 16 (1977) 3133
- /2/ Williams, R.D. and Rudnick, I., Phys. Rev. Lett. 25 (1970) 276
- /3/ Thomlinson, W.C. and Pobell, F., Phys. Rev. Lett. 31 (1973) 283
- /4/ Ikushima, A. and Tozaki, K., Proc. LT 14 (1975) Vol. 1
- /5/ Tozaki, K. and Ikushima, A., Phys. Lett. 59A (1977) 458
- /6/ Tozaki, K. and Ikushima, A., J. Low Temp. Phys. 33 (1978) in press
- /7/ Buchal, C. and Pobell, F., Phys. Rev. B14 (1976) 1103
- /8/ Ikushima, A., Roe, D.B. and Meyer, H., Proc. 2nd Int. Conf. on "Phonon Scattering in Solids" (Nottingham) 1975
- /9/ Ikushima, A., Roe, D.B. and Meyer, H., Proc. ICIFUAS-6 (Tokyo) 1977
- /10/ Roe, D.B., Meyer, H. and Ikushima, A., J. Low Temp. Phys. (1978) in press
- /11/ Pokrovskii, V. and Khalatnikov, JETP Lett. 9 (1969) 149
- /12/ Halperin, B.I. and Hohenberg, P.C., Phys. Rev. 177 (1969) 952
- /13/ Kawasaki, K., Int. J. Magn. 1 (1971) 171