Hydrodynamic steady states of phonons in insulator

S. Sokolovsky

Prydniprovs'ka State Academy of Civil Engineering and Architecture, Department of Physics, 24a Chernyshevsky St., 49005 Dnipropetrovs'k, Ukraine, E–mail: sersokol@list.ru

Hydrodynamic states of the phonon subsystem of insulator are discussed starting from kinetic equation for phonon distribution function (DF) $\mathrm{f}_{\alpha p}(x,t)$. Usual consideration of this problem is based on the local equilibrium assumption according to which the Planck DF $n_{\alpha p}(\xi(x,t))$

$$n_{\alpha p}(\xi) = [e^{(\varepsilon_{\alpha p} - p_n v_n)/T} - 1]^{-1} \qquad (\xi_\mu : \quad \xi_0 \equiv T, \xi_n \equiv v_n)$$

gives zero order in gradients of variables $\xi_\mu(x,t)$ (temperature and drift velocity) contribution $\mathrm{f}^{(0)}_{\alpha p}(x,\xi(t))$ to phonon DF $\mathrm{f}_{\alpha p}(x,\xi(t))$ [1,2]. Our investigation is based on the Chapman-Enskog method in which phonon DF $\mathrm{f}_{\alpha p}(x,t)$ is considered as a functional $\mathrm{f}_{\alpha p}(x,\xi(t))$ of variables $\xi_\mu(x,t)$. Contrary to standard theory we do not make local equilibrium assumption and *calculate* contribution $\mathrm{f}^{(0)}_{\alpha p}(x,\xi)$ to nonequilibrium DF $\mathrm{f}_{\alpha p}(x,\xi)$ in a perturbation theory in small drift velocity v_n. It has been shown that $\mathrm{f}^{(0)}_{\alpha p}(x,\xi) \neq n_{\alpha p}(\xi(x))$ and *the local equilibrium assumption is not valid*. The obtained results correct standard equations of phonon hydrodynamics [1,2]. The differences have been studied in detail. The analyze shows that at low temperatures $T \ll T_D$ the corrections to the standard theory are exponentially small. However, the developed theory allows discussing intermediate and high temperatures $T \gg T_D$ too. In the present work special attention is given to steady hydrodynamic states of phonon subsystem of insulator. The situation in this system is exceptional because *the steady states of insulator exist even for a closed one*: the Umklapp processes break conservation of the quasi-momentum. It has been shown that the Akhiezer expression for the heat conductivity of insulator in its steady states are true at low temperatures with exponential accuracy. Condition of stationarity of temperature distribution in a closed insulator is discussed.

[1] E.M. Lifshitz, L.P. Pitaevskii, Physical Kinetics.– Oxford: Pergamon Press, 1981.

[2] A.I. Akhiezer, V.F. Aleksin, V.D. Khodusov, Low Temp. Phys. 20, 939 (1994); 21, 1 (1995).