Relaxation of populations in nonequilibrium many-body physics: Breakdown of Mathiessen's rule

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The lifetime of a quasiparticle of an equilibrium many-body system is determined by Mathiessen's rule, where the total scattering rate is given by the sum of the scattering rate for all different scattering processes. The relaxation time is then represented by 1/[-2Im $\Sigma(\omega)$], which determines both the lifetime of the quasiparticle spectral function and the linear-response dc resistivity. In a pump/probe experiment, a high intensity pump excites electrons into a nonequilibrium distribution, and those excited populations decay and relax back towards a new equilibrium, with a characteristic relaxation time, that depends on the energy of the excitation above the Fermi energy. It turns out that this relaxation time is often significantly different from the equilibrium relaxation time. In this talk, I will describe what determines this nonequilibrium relaxation time. It does not satisfy Mathiessen's rule, but instead depends in a complicated fashion on how energy is exchanged from electrons to phonons, as the populations relax. It also is often not given by the equilibrium relaxation time. One consequence of this analysis, is an explicit proof that a simple hot electron model is inconsistent with the exact equations of motion of a many-body system. We end with a discussion of some experiments that illustrate this behavior and some open challenges that remain in fully understanding nonequilibrium relaxation.

[1] Alexander Kemper and James Freericks, Relationship between Population Dynamics and the Self-Energy in Driven Non-Equilibrium Systems, Entropy 18, 180 (2016).

[2] A. F. Kemper, H. R. Krishnamurthy, and J. K. Freericks, The role of average time dependence on the relaxation of excited electron populations in nonequilibrium many-body physics,to appear in Fortschritte der Physik (2016).