Light Transmission and Reflection from a Thin Metallic Film

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We consider the transmission of an electromagnetic wave through a thin (nanometer scale) metallic film. The thickness of the film is assumed to be much smaller than the electromagnetic wavelength and the mean free path of Fermi electrons. To solve this problem we treat the electrons in the metal as a charged degenerate Fermi liquid. Electronic motion inside the metal is governed by Boltzmann's kinetic equation [1]

$$\partial_t \delta f + (\mathbf{v}\nabla)\delta f - e(\mathbf{E}\nabla_{\mathbf{p}}) f_0 = -\frac{1}{\tau}\delta f, \tag{1}$$

where $f(\mathbf{r}, \mathrm{p}, t) = f_0 + \delta f$ is the perturbed distribution function and f_0 is the distribution function at equilibrium. We normalize the distribution function according to

$$\int d^3p \cdot f(\mathbf{r}, \mathbf{p}, t) = n(\mathbf{r}, t),$$

where $n(\mathbf{r}, t)$ is the local electronic density. Inside the film the electric field can be defined by a potential distribution: $\boldsymbol{E} = -\nabla\Phi$.
Let us also assume the temperature to be much lower than the Fermi energy ϵ_F. We introduce a new function $\chi(\mathbf{r},\mathbf{p},t)$, which describes the deviation of the distribution function from the equilibrium according to the equation $\delta f(\mathbf{r},\mathbf{p},t) = \epsilon_F \bullet \partial\epsilon \; f_0 \bullet \chi(\mathbf{r},\mathbf{p},t)$ The potential inside the film satisfies the equation

$$\Delta\Phi = -\frac{e p_F^3}{4\pi^2\hbar^3}\int \mathrm{d}o_p\, \chi. \tag{2}$$

Equations (1) and (2) form a self-consistent system that determines the amplitude of the electric field inside the film [2]. Together with boundary conditions it gives the complex Fresnel coefficients for transmission and reflection.

References

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