Optical conductivity of superconductors

Part I: Optical conductivity in the SC state

1. Kinetic theory for the normal state. F=ma works, why do we need this new-fangled quantum mechanics?

2. Historical: two approaches: the Russians and BCS

3. The basics of the quantum approach to electrodynamics

   3.1 It's all about the potentials
   3.2 Longitudinal and transverse response
   3.3 Definition of the optical conductivity (and contrast with Meissner diamagnetism)
   3.4 Linear response, paramagnetic and diamagnetic currents
   3.5 The optical conductivity ultimately is related to the two-particle Green function. This way lies madness.

4. Exemplars of optical conductivity: independent electrons
   4.1 Independent electrons with Galilean invariance
   4.2 Independent electrons on a lattice
   4.3 Interacting electrons on a lattice

5. Contrasting the perfect metal and the superconductor

6. Disordered metal: Lazy man's approach to recovering the Drude conductivity in quantum mechanics.

7. Disordered superconductor: "Anderson's Theorem"

8. Optical conductivity of a disordered superconductor: Mattis-Bardeen theory

9. Example of success of Mattis-Bardeen: MgB_2

10. Examples of spectacular failure: cuprates (with brief overview of possible explanations)

Part II: Optical conductivity, vortices, and phase fluctuations

1. Superconductivity as a broken symmetry as seen through the Anderson pseudospin model

2. The essence of the supercurrent: conjugate relationship between phase and number operators

3. Supercurrent is the product of the phase stiffness (helicity modulus) and the gradient of the gauge-invariant phase

4. Vortices as topological defects in phase. Conductivity of vortices.

5. Example of electrodynamics of vortices in cuprates as determined by THz spectroscopy

   5.1. Comparison with Bardeen-Stephen formula

   5.2 Implications for cuprates

6. Phase fluctuations in granular regime: Kosterlitz-Thouless

7. Determination of phase fluctuation regime in cuprates

8. Optical conductivity and the cuprate pseudogap

Part III: Nonlinear optics of superconductors

1. Considered as a collective mode effect within Anderson pseudospin model

2. But…is this correct? Quasiparticle absorption in Mattis-Bardeen limit