Nonequilibrium Superconductvity in Inhomogeneous Materials

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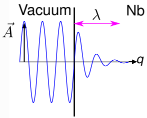
Northwestern University & Fermilab

- Electrodynamics of Superconductors
- Inhomogeneous Surface Structures
- Vortex Nucleation, Dynamics & Instabilities

NSF-PHY 01734332

Electrodynamics of Superconductor-Vacuum Interfaces

- Program: “Real Materials” Calculations of the Current Response & Local EM Fields near Superconducting-Vacuum Interfaces



$$\vec{J}(\mathbf{q},\omega) = -\frac{1}{c}\boxed{\overset{\leftrightarrow}{K}^{R}(\mathbf{q},\omega;\boxed{\vec{A}})}\cdot\boxed{\vec{A}(\mathbf{q},\omega)}$$

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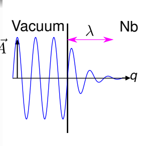

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- Material Inputs to Nonequilibrium SC Theory
  - Fermi Surfaces - DFT dHvA, dI/dV & APRPES
  - Pairing/Decoherence via Electron-Phonon Coupling

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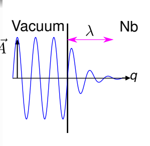

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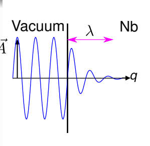

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  - Surface Scattering: $S_{\text{surf}}(\mathbf{p},\mathbf{p}')$

- surface structure factor
- mesoscopic roughnes
  - $\rightsquigarrow$ backscattering
  - $\rightsquigarrow$ Andreev scattering
  - $\rightsquigarrow$ sub-gap dissipation

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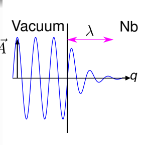

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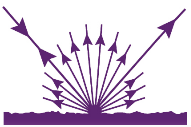

- surface structure factor
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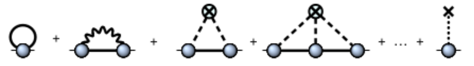
- Theoretical & Analytical Tools
  - QFT à la Matsubara, Abrikosov, Gorkov Eilenberger, Larkin & Ovchinnikov
  - Migdal-Eliashberg: electron-phonon
  - Asymptotic Expansions: $k_B T_c/E_f,\ \hbar/\tau E_f,\ \hbar/p_f\xi,\ \hbar\omega/E_f\ \ldots$



  - Symmetry, Selection Rules & Scattering Theory

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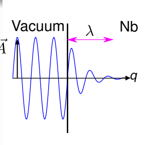

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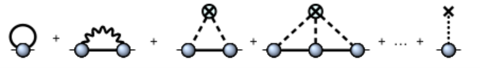

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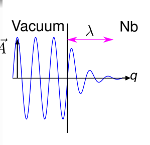

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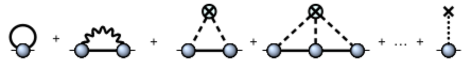

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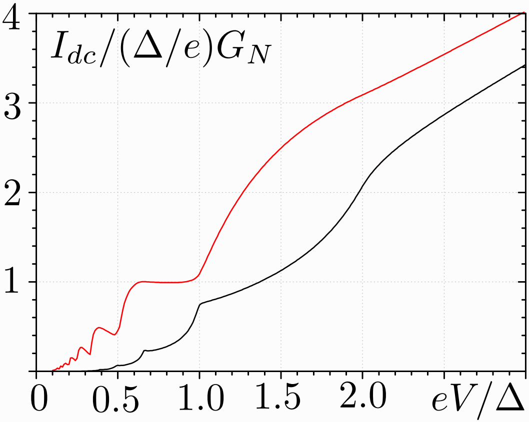
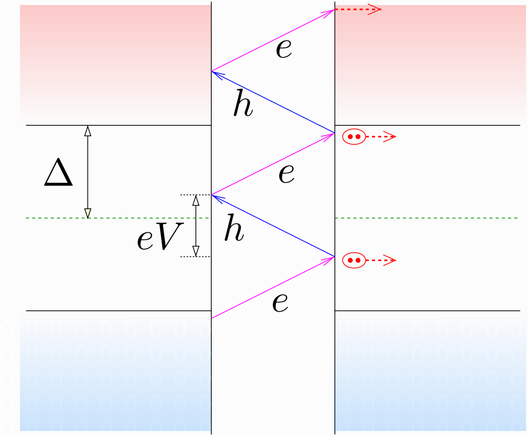
  - Nonequilibrium Quasiparticle, Cooper Pair & Vortex Dynamics

D. Rainer & J. A. Sauls, Strong-Coupling Theory of Superconductivity, World Scientific (1995)

Sub-Gap Dissipation in Weak Links under a.c. Excitation





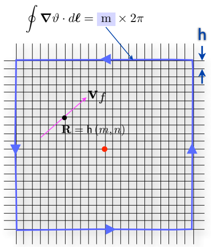
- Sub-Gap Dissipation
- Impurity & Branch Conversion Scattering

- Multiple Andreev Reflection ⇝ dissipation
- ⇝ Non-equilibrium QP distribution

T. Klapwijkz, G. Blonder and M. Tinkham, Physica BC 109, 1657 (1982). E. Zhao and JAS, Nonequilibrium Josephson Weak-Links, PRB 78, 174511 (2008).

Vortex Structure, Nucleation and Dynamics in Superconductors

Program: Computational Theory for Vortex Structure, Spectroscopy, & Non-Equilibrium Vortex Nucleation, Dissipation & Instabilities



$$\Psi(\mathbf{R},t) = |\Psi(\mathbf{R},t)|\, e^{i\vartheta(\mathbf{R},t)}$$

$$\oint_{\mathscr{C}} d\mathbf{R} \cdot \nabla\vartheta(\mathbf{R},t) = m_{\mathscr{C}}\, 2\pi$$

- ▶ Vortex Structures & Dynamics
  - Core Structure in Strong-Coupling SCs
  - Field & Current Distributions
  - NMR & SANS - Spectrosocpy
  - Electrodynamics of Vortex States
- ▶ Nucleation, Pinning & Catastrophes
  - Phase Fluctuations at Surfaces
  - Surface Nucleation Barriers
  - Disorder Fluctuations & Pinning
  - Critical Currents & Critical States

▶ Robert Regan & JAS, Northwestern & CAPST