Condensed Matter Physics II
SS 2015

Wednesday 9:30-12:30

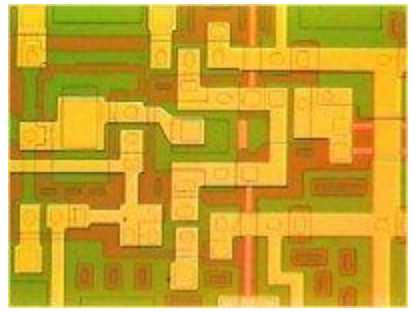
Seminar Room Physics 2

Prof. Paul H.M. van Loosdrecht

pvl@ph2.uni-koeln.de

www.loosdrecht.net

Last time:
Superconductors: Main properties



- Macroscopic quantum phenomenon

- Vanishing resistance → Kamerlingh Onnes
- Perfect diamagnet → Meissner-Ochsenfeld effect
  - Type I and type II superconductors
- 2^{nd} order phase transition → Thermodynamics (Heat cap.)
- Electronically gapped state → Tunneling spectroscopy, optics
- Isotope effect: Role of phonons? → Isotope experiments
- Unit of charge ‘responsible particle’ is 2e → Flux quantization

One more experiment showing 'pairing'

SOVIET PHYSICS JETP VOLUME 19, NUMBER 5 NOVEMBER, 1964

THE THERMAL CONDUCTIVITY OF THE INTERMEDIATE STATE IN SUPERCONDUCTORS

A. F. ANDREEV

Institute for Physics Problems, U.S.S.R. Academy of Sciences

Submitted to JETP editor November 27, 1963

J. Exptl. Theoret. Phys. (U.S.S.R.) **46**, 1823-1828 (May, 1964)

It is shown that, owing to over-the-barrier reflection of electron excitations at the boundary of the normal and superconducting phases, a temperature drop occurs when there is a flow of heat. The additional thermal resistance of a superconductor in the intermediate state is calculated. It is shown that it increases exponentially as the temperature is lowered and does not depend on the electron mean free path.

Transport through a N-S interface

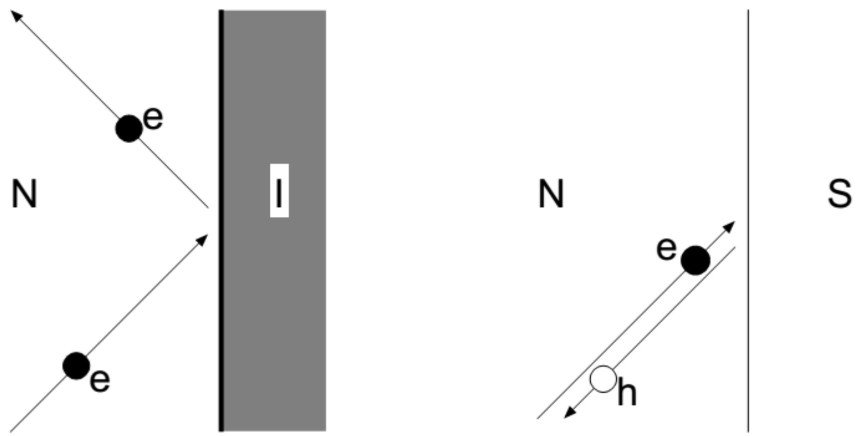
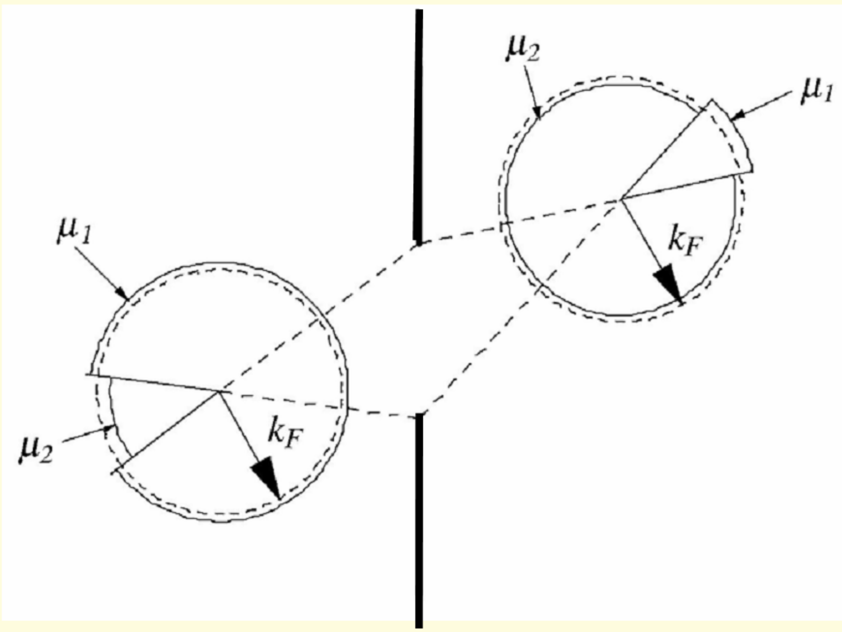


Figure 1: Normal reflection by an insulator (I) versus Andreev reflection by a superconductor (S) of an electron excitation in a normal metal (N) near the Fermi level. Normal reflection (left) conserves charge but does not conserve momentum. Andreev reflection (right) conserves momentum but does not conserve charge: The electron (e) is reflected as a hole (h) with the same momentum and opposite velocity. The missing charge of $2e$ is absorbed as a Cooper pair by the superconducting condensate.

From Beenakker, ArXiv 9909293

Point contact conductance

Semiclassical ballistic contact $\lambda_F << L << l, l_\varphi$



Current density

$$\mathbf{j}(\mathbf{r}) = \frac{2e}{L^3} \sum_{\mathbf{k}} \mathbf{v}_{\mathbf{k}} f_{\mathbf{k}}(\mathbf{r})$$

potential difference imposed at far left and far right

$$V(-\infty) = -\tfrac{1}{2} V_0, \quad V(+\infty) = +\tfrac{1}{2} V_0$$

total current by integrating over the contact area

$$\boxed{G_S = \frac{2e^2}{h} \left(\tfrac{1}{2} k_F a\right)^2}$$

Voltage drops over a length $\sim a$

NB. For monovalent metals and one atom $k_F a \approx 1.7$

Yu.V. Sharvin, Sov. Phys.-JETP **21** (1965) 655

Point contact & tunneling

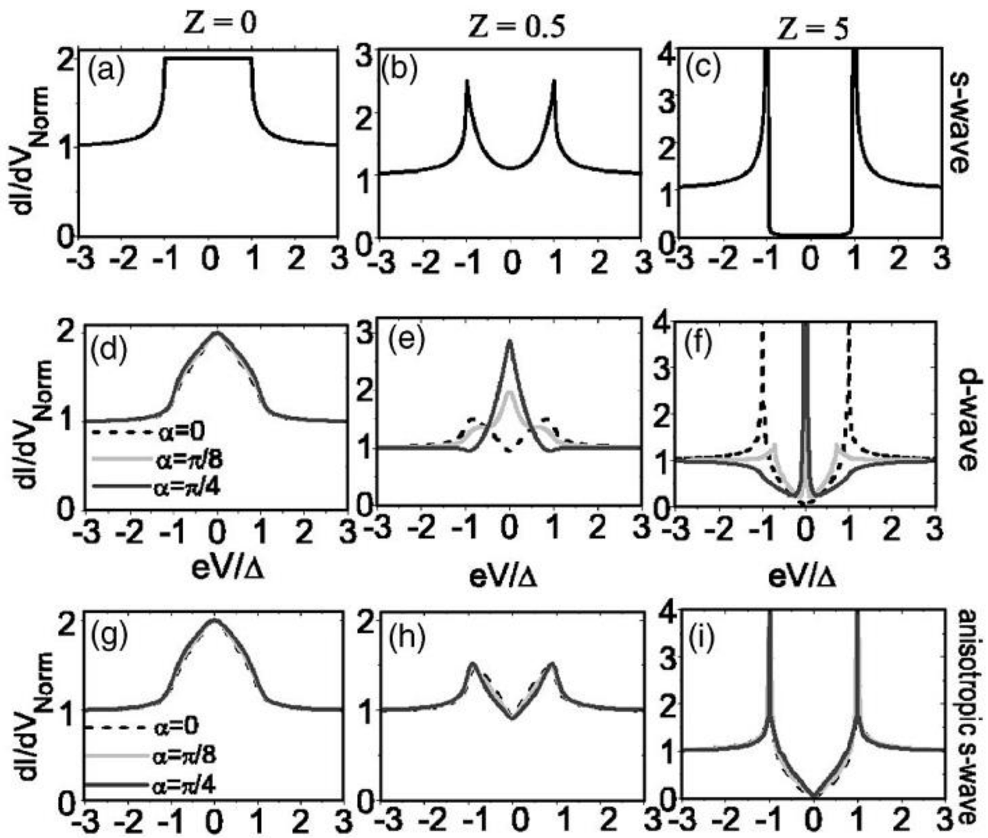


FIG. 1. Conductance characteristics, at low temperatures, for different barriers Z as obtained by the BTK model for a point contact junction between a normal metal and a *s-wave* [(a),(b),(c)], a *d-swave* [(d),(e),(f)] and an anisotropic *s-wave* superconductor [(g),(h),(i)].

From Piano et al. PRB 2006

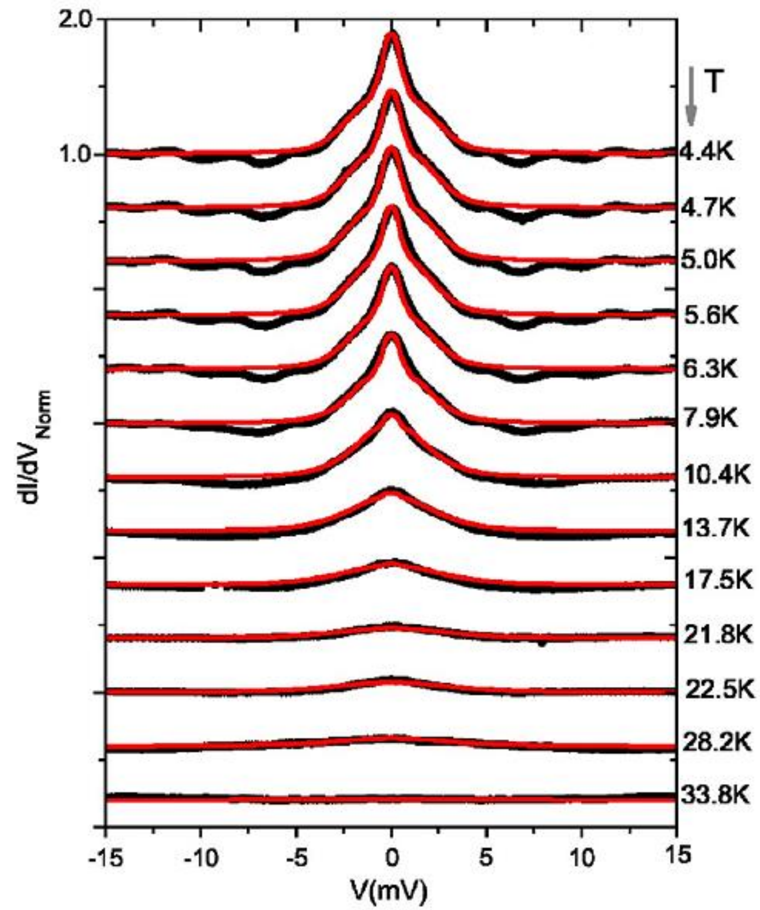


FIG. 4. (Color online) Temperature evolution of the conductance spectrum of Fig. 2(c) from T=4.2 K to up the critical temperature (dots). The solid lines are the theoretical fittings obtained by a modified *d-wave* BTK model with the energy gap as only free parameter.

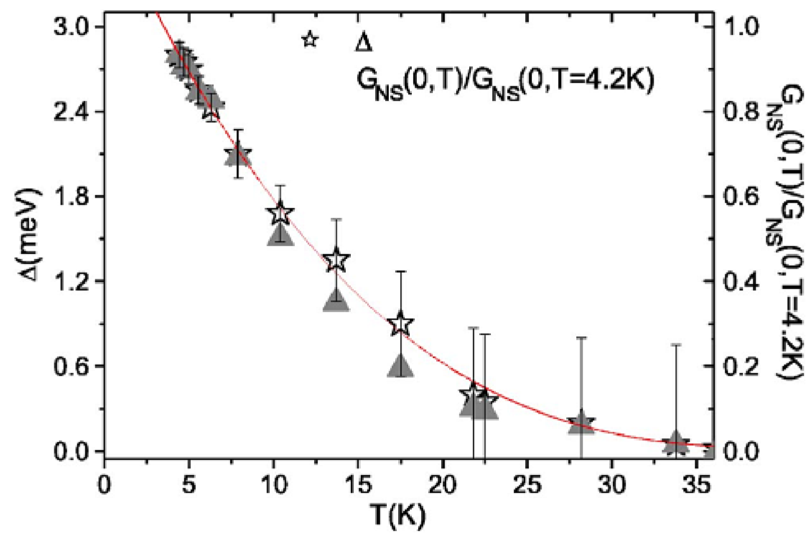


FIG. 5. (Color online) Temperature dependence of the superconducting energy gap as inferred from the theoretical fittings shown in Fig. 4. The solid line is a guide for the eyes. The right hand scale refers to the temperature evolution of the measured height of the ZBCP normalized to the 4.2 K value.

PHYSICAL REVIEW B **73**, 064514 (2006)

Pairing state in the ruthenocuprate superconductor $RuSr_2GdCu_2O_8$: A point-contact Andreev reflection spectroscopy study

Samanta Piano, Fabrizio Bobba, Filippo Giubileo, Anna Maria Cucolo, Marcello Gombos, and Antonio Vecchione

Quasi-particles