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UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

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SMR. 628 - 3

Research Workshop in Condensed Matter, Atomic and Molecular Physics
(22 June - 11 September 1992)

Working Party on "NOISES IN MESOSCOPIC SYSTEMS"
(27 July - 7 August 1992)

"A Short Cuted Tunnel Junction"

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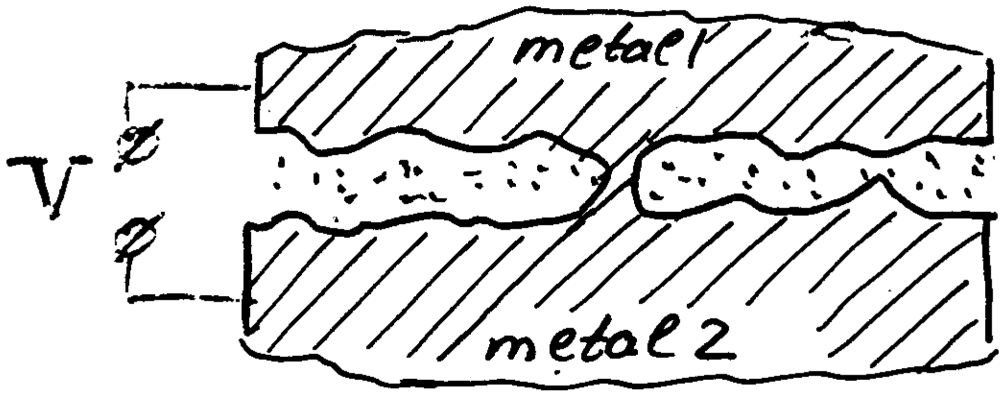
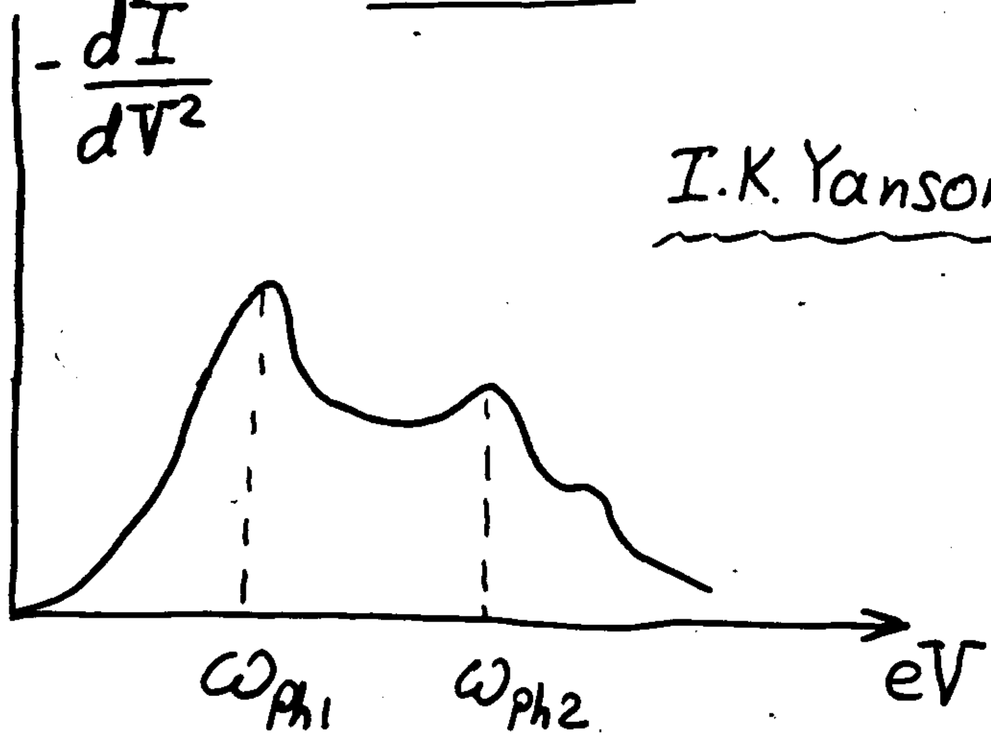
Sweden

A short cuted tunnel junction



Nonlinear I-V curve

(≈ 10%)



I.K. Yanson 1974

Transport Spectroscopy in Metals is Impossible

Necessary current values

$$j = ne\vartheta$$

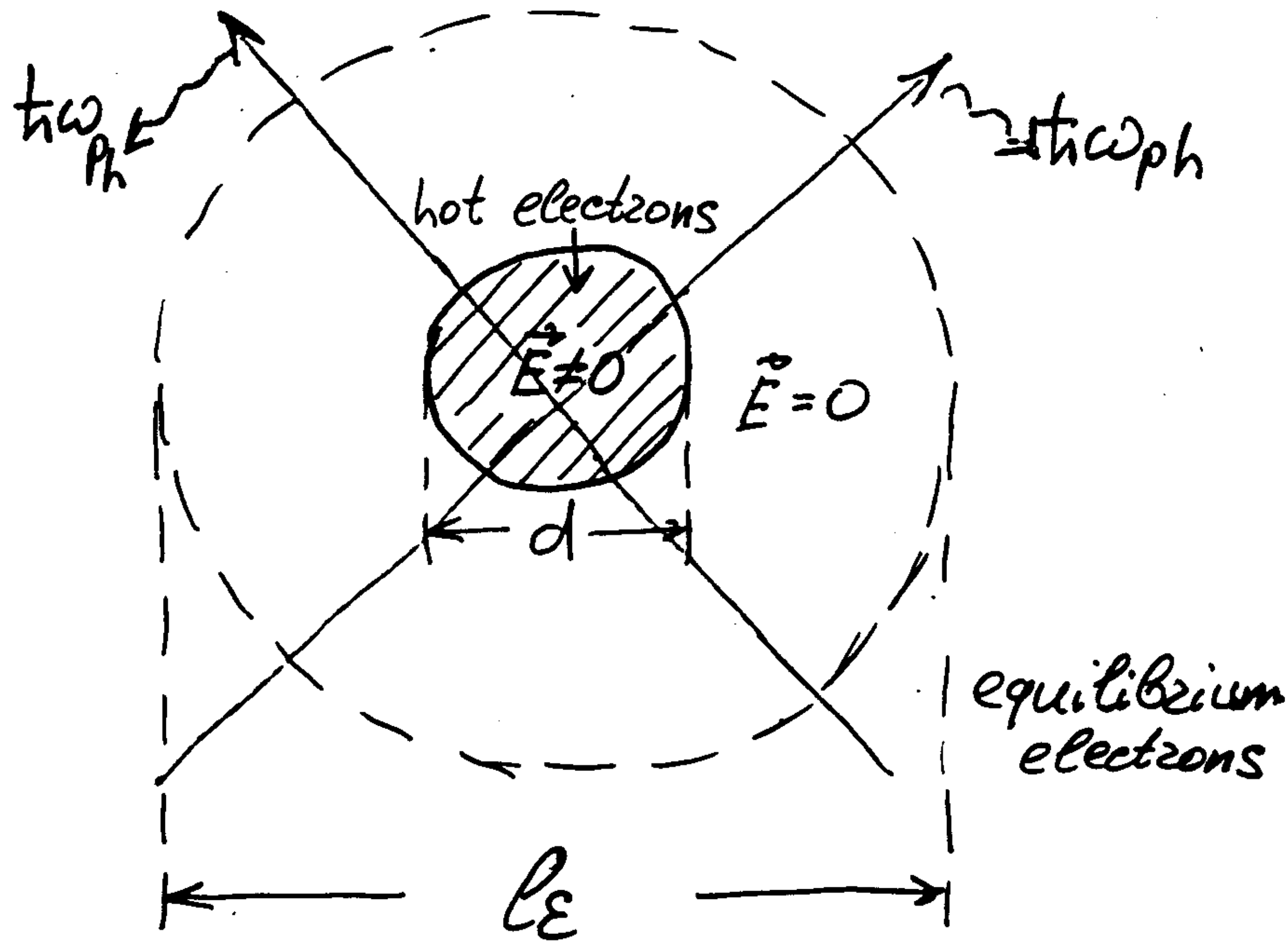
$$\vartheta \simeq \Delta\mathcal{E}/p_F \simeq \frac{\hbar\omega_D}{p_F} \simeq S$$

$$j \simeq 10^9 A/cm^2 \xRightarrow{\text{heating}} \underline{\underline{Q \simeq \sigma^{-1} \cdot j^2}}$$

Such heating results in melting of the metal!!

Metal is an essentially linear transport system. The Ohm law is a very good approximation.

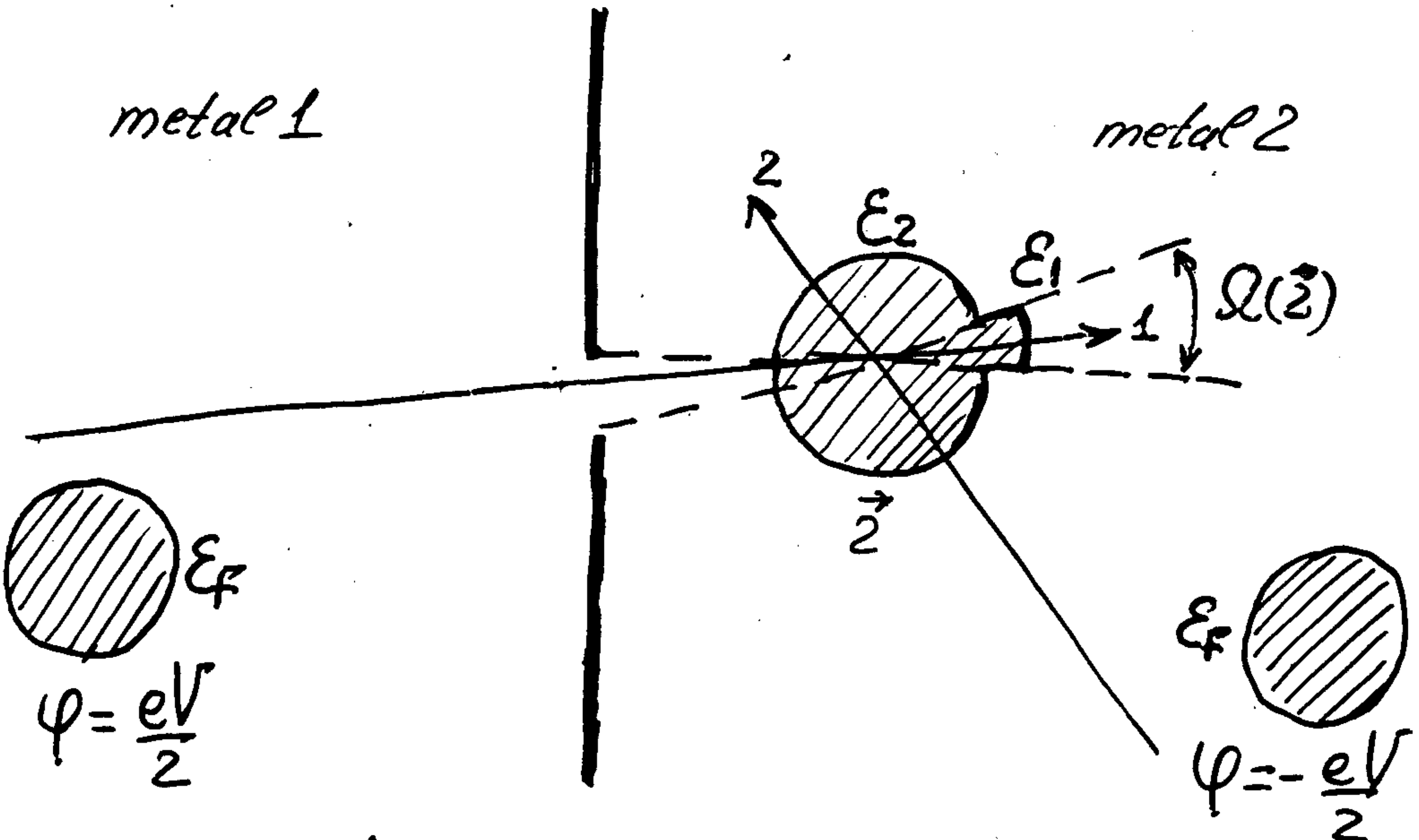
Spatialy localized nonequilibrium state.



$$l_\varepsilon \gg d$$

$$n_{hot}(\vec{r}) \simeq n_{hot}(d) \cdot \left(\frac{d}{r}\right)^2 \qquad r \gg d$$

Ballistic Point Contact.



$$d \ll l \,; \quad d \gg \lambda_F$$

$$eV \ll \mathcal{E}_F$$

$$\mathcal{E}_1 = \mathcal{E}_F + e\varphi(\vec{z}) + \frac{eV}{2}$$

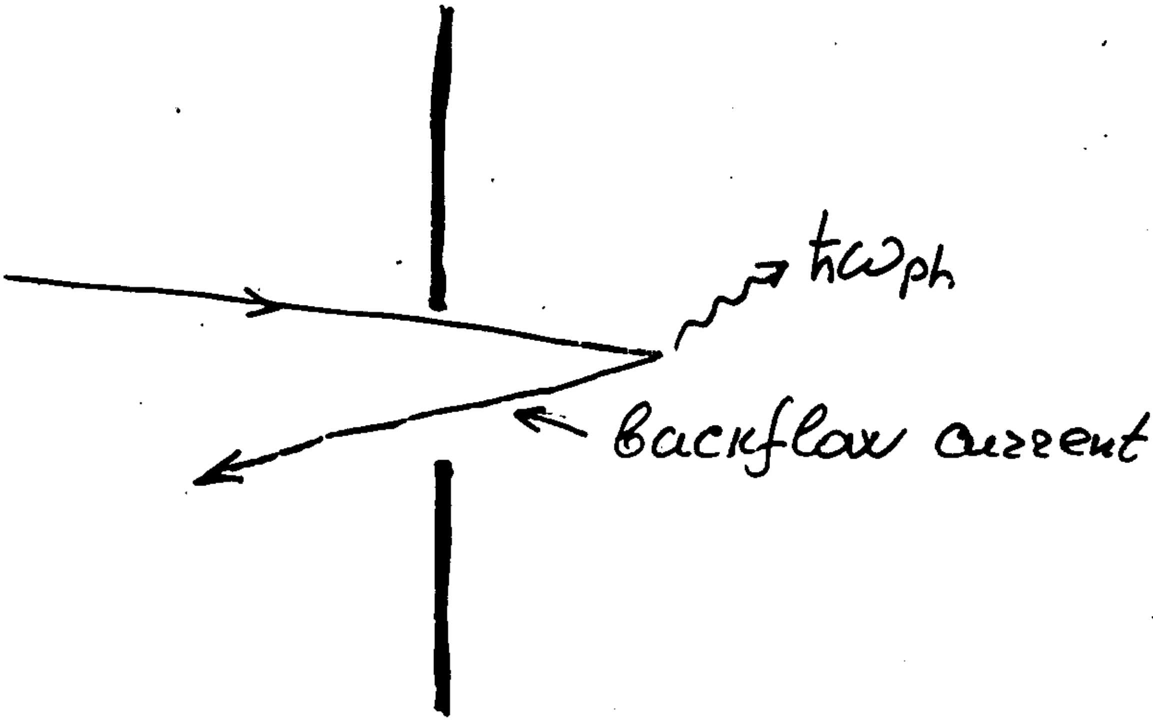
$$\mathcal{E}_2 = \mathcal{E}_F + e\varphi(\vec{z}) - \frac{eV}{2}$$

$\mathcal{E}_1 - \mathcal{E}_2 = eV$ – Does not depend on $\vec{z}$

$$\varphi(\vec{z}) = \frac{V}{2}\left[1 - \frac{1}{2\pi}\Omega(\vec{z})\right]; \quad \Omega(\vec{z}) \simeq \left(\frac{d}{z}\right)^2$$

I.O. Kulik, A.N. Omelyanchouk, R.I. Shekhter 1977

Electron-phonon relaxation in a point contact



$$P_{scat.} \simeq \int_0^{\varepsilon} d\omega\, g(\omega)$$

$$g(\omega) = \langle\langle |V_{\bar{p}-\bar{p}'}|^2 \delta(\omega - \omega_{ph}(\bar{p}-\bar{p}')) \rangle\rangle$$

$$g(\omega) \simeq \alpha^2(\omega) F(\omega)$$

$$I_{backflow} \simeq \int_0^{eV} d\varepsilon \int_0^{\varepsilon} d\omega\, g(\omega)$$

Point Contact Spectroscopy of Metals

$$\boxed{\frac{1}{R}\frac{dR}{dV} = \frac{16}{3\pi}\frac{ed}{v_F}G(\omega = eV)}$$

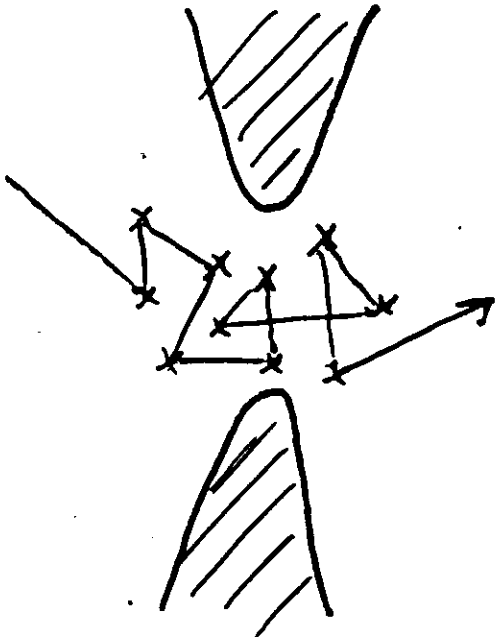
$$G(\omega) = \langle\langle |V_{\vec{p}-\vec{p}'}|^2 K(\vec{p},\vec{p}')\,\delta(\omega-\omega_{ph}(\vec{p}-\vec{p}'))\rangle\rangle$$

$$K(\vec{p},\vec{p}') = \frac{|n_z n_z'|}{|n_z\vec{n}' - n_z'\vec{n}|}$$

$$\vec{n} = \frac{\vec{p}}{p_F};$$

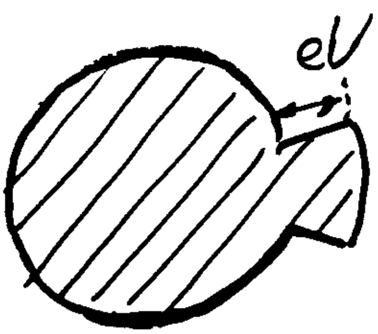
I.O. Kulik, A.N. Omelyanchouk, R.I. Shekhter
1977

Impurity scattering of Electrons in a Point Contact

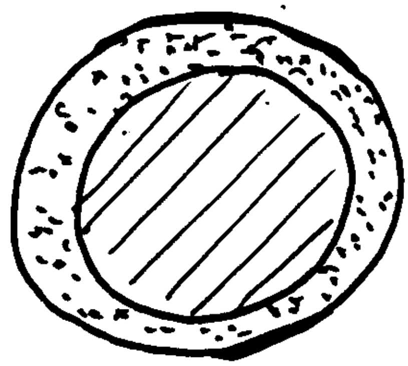


$d \ll \sqrt{l_i l_\varepsilon}$

Electron motion is stil conservative;



Ballistic Point Contact
$l_i \gg d$



Diffusive Point Contact
$l_i \ll d$

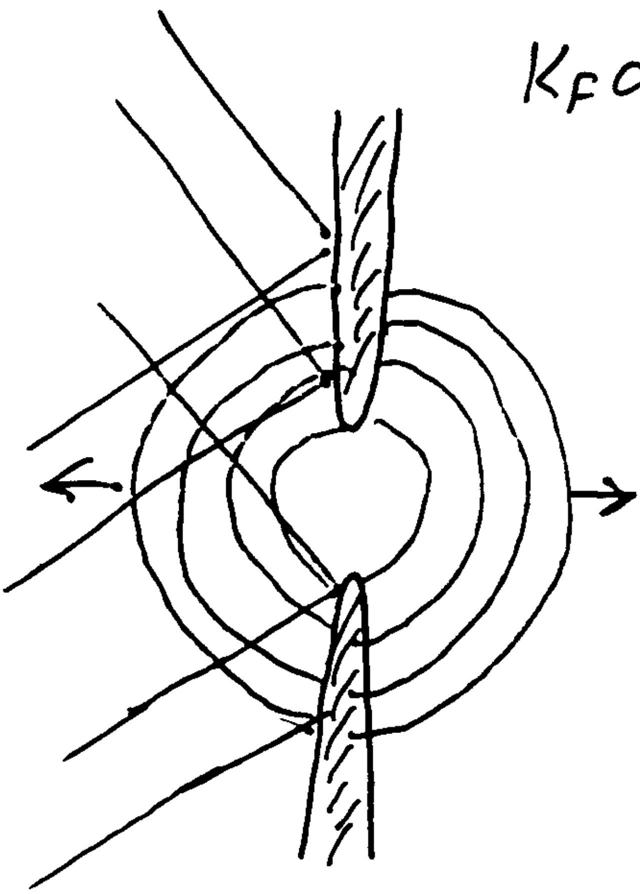
$$\sigma_{imp}(\omega) \simeq \frac{l_i}{d}\sigma_{bal}(\omega)$$

Point Contact Conductance

$$G = \frac{1}{2}\frac{e^2}{h}(k_F d)^2$$ Sharvin 1969

Quantum Point Contacts

$k_F d \lesssim 1$

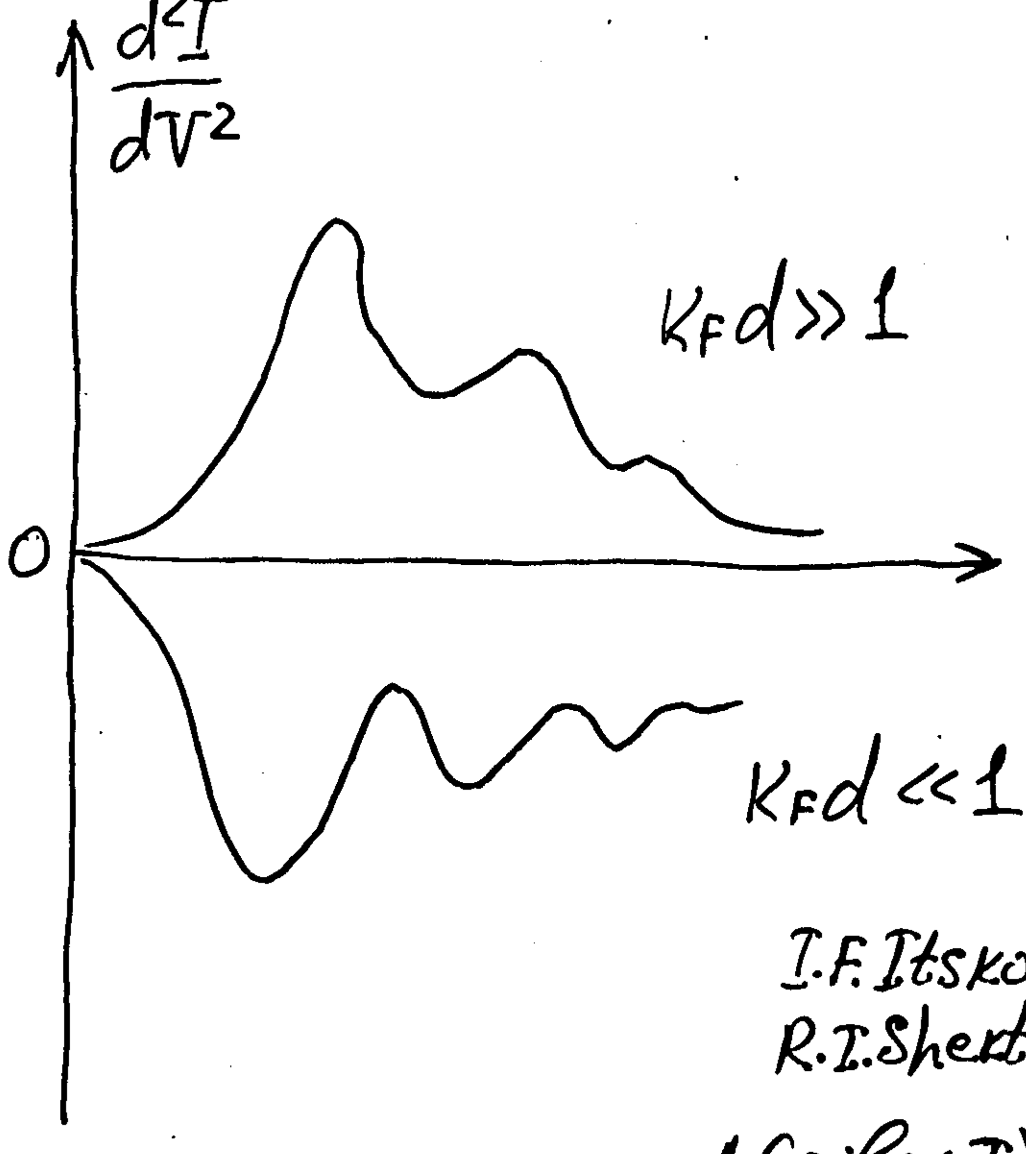


Transport is blocked by quantum interference

$$G_{quant.} \simeq G_{clas} \cdot (k_F d)^4$$

$$G = \frac{e^2}{h}\sum_{\alpha,\beta}^{N} |t_{\alpha\beta}|^2$$ Landauer

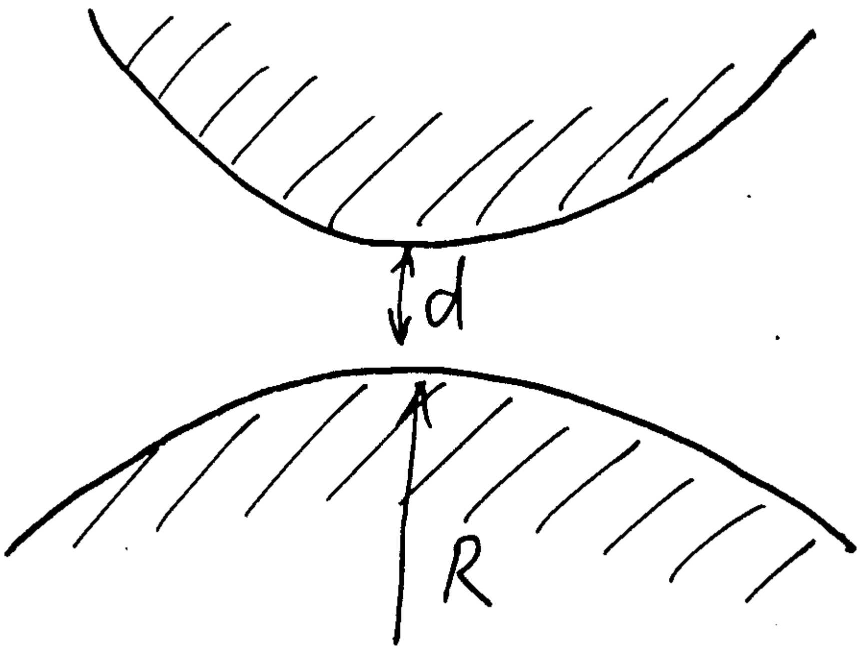
Point Contact Spectrum in Quantum Point Contacts.



I.F. Itskovich
R.I. Shekhter 1985

A. Gribov, I. Yanson
P. Wyder 1989

Adiabatic Point Contacts



$$\underline{R \gg d}$$

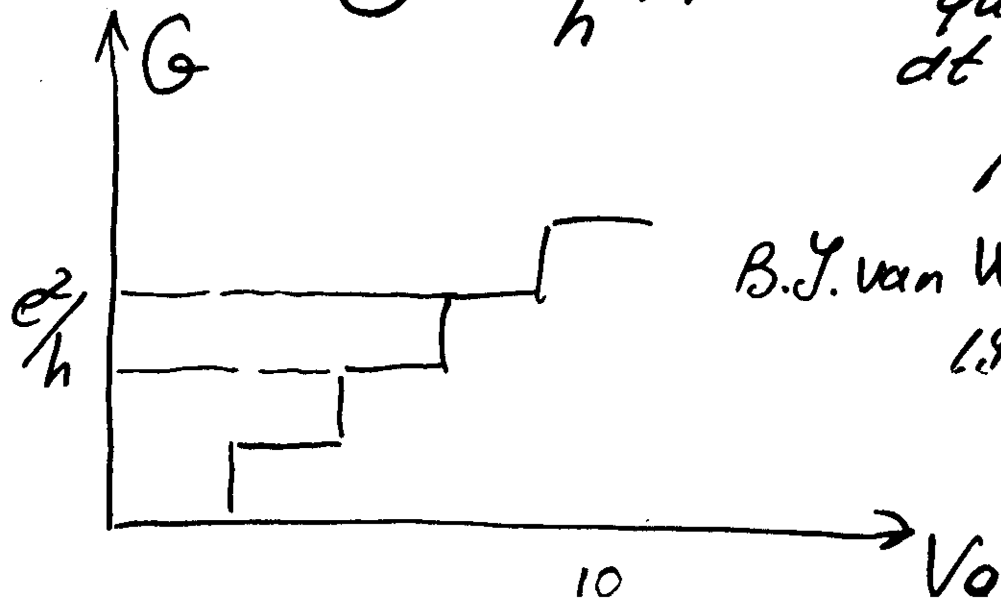
$$\sqrt{Rd} \gg \lambda_F$$

$$t_{\alpha\beta} = \begin{cases} 1 & \text{for transport modes} \\ 0 & \text{for reflected modes} \end{cases}$$

$$G = \frac{e^2}{h} N$$

N – Number of quantized modes at Fermi Surface

$$N = N(V_G)$$



B.J. van Weiss at.all
1988

Gate-controlled 2-D electrons

Poole, M.Pepper, K.F. Berggren, G. Hill, H.W. Myrron, J.Phys. C15, L21, (1982)

J. Thornton, M.Pepper, H.Ahmed, D.Andrews, G.J. Davies., PRL, 56, 1198, (1986).

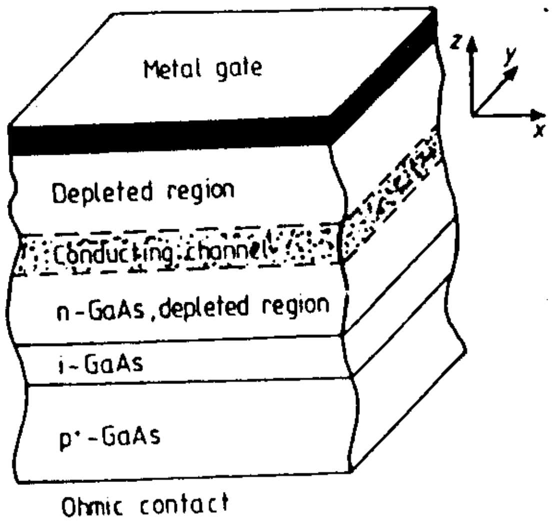


Figure 1. A schematic cross sectional diagram of the special GaAs MESFET structure (Poole *et al* 1982). The broken lines show the depletion region edges which locate the conducting channel (shaded area). The n region is doped in excess of the Mott critical concentration. The behaviour of the channel is therefore 'metallic'.

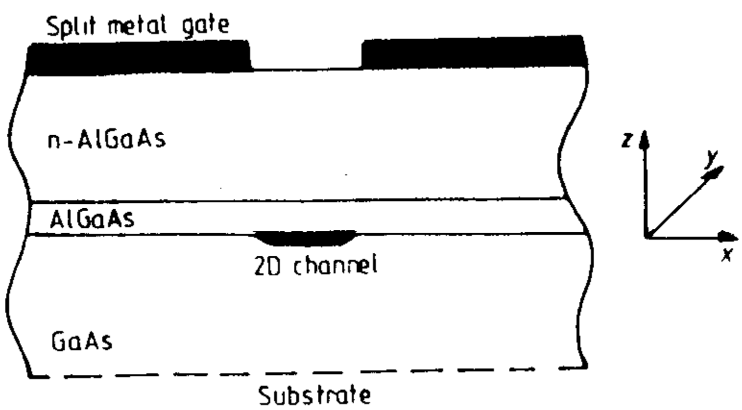


Figure 2. A schematic cross sectional diagram of the split gate GaAs/AlGaAs heterojunction FET (Thornton *et al* 1986) used to define a narrow channel in a 2D electron gas. The distance between the gates is typically 1 μm.

Fundamental steps of the Ballistic conductance

$$\lambda_F \simeq d \ll \ell$$

J. van Wees, H. van Houten, C.W.J. Beenakker, J.G. Williamson, L.P. Kouwenhoven
D. van der Marel, C.T. Foxon Phys. Rev. Lett. 60, 848, (1988)

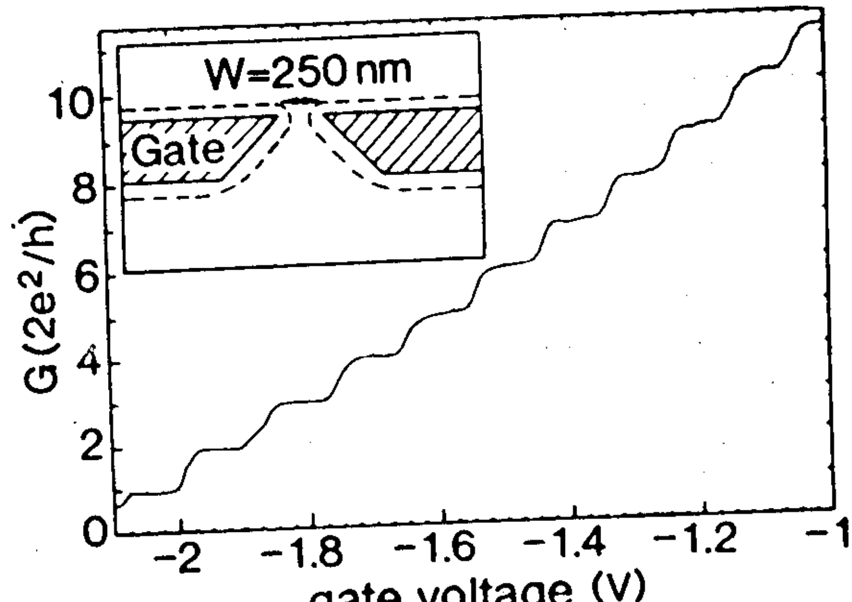


FIG. 44. Point contact conductance as a function of gate voltage at 0.6 K, demonstrating the conductance quantization in units of $2e^2/h$. The data are obtained from the two-terminal resistance after subtraction of a background resistance. The constriction width increases with increasing voltage on the gate (see inset). Taken from B. J. van Wees *et al.*, *Phys. Rev. Lett.* **60**, 848 (1988).

Adiabatic transport of quantized electron modes.

$L \gg \lambda_F$, L-Channel length

$$G = \frac{2e^2}{h}\left[\frac{k_F d}{\pi}\right]$$

L.I. Glazman, G.B. Lesovik, D.E. Khmelnitskii, R.I. Shekhter
JETP Lett., 48, 238 (1988)