Transport in Carbon Nanotubes

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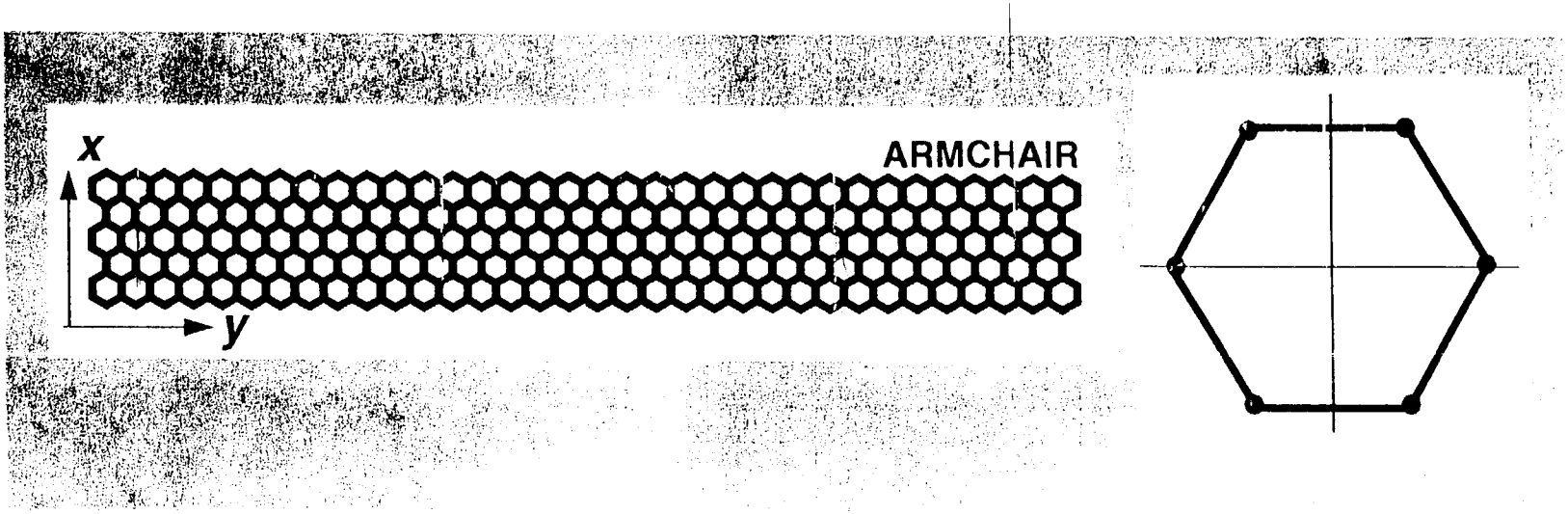
MOTIVATION & OUTLINE

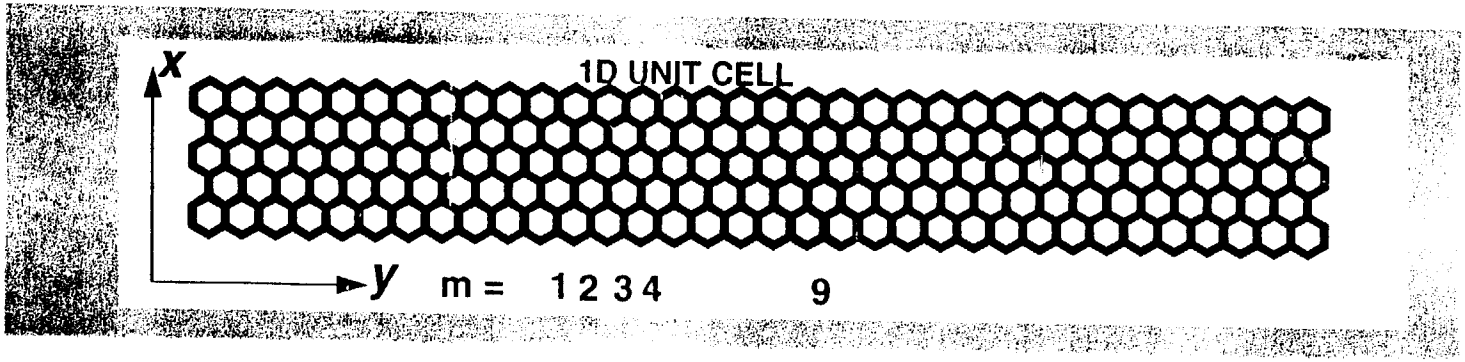
- Coupling between CNT and simple metals (FEG)
- Coupling between a graphene sheet and FEG
- What happens when the sheet----->strip (CNT)
- Dependence of coupling on width of strip and disorder

GRAPHENE STRIP IN UNIFORM CONTACT WITH METAL

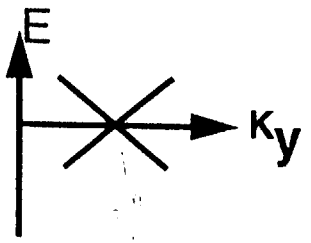


- K_Y is conserved
- K_X conservation is relaxed due to finite *width* of *contact area*
- FEG couples better to CNT than to graphene
- Cut-off K_{Fermi} of metal is smaller than $\frac{4\pi}{3a_0}$=1.7 Å^{-1}

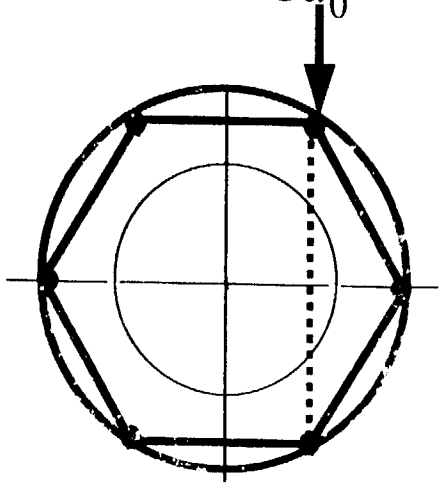
COUPLING TO ARMCHAIR TUBES



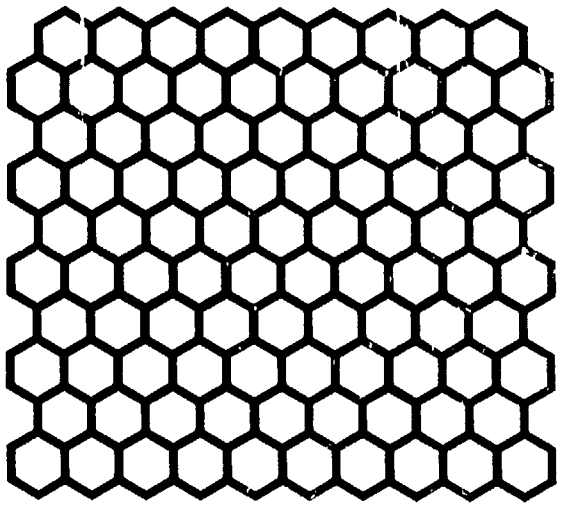
$\Psi = e^{imk_y a_0}\phi$ m = integer and ϕ is wave func. of atoms in 1D unit cell



- E=0 at $K_y = \frac{2\pi}{3a_0} = 0.85$ Å^{-1}
- Metal with $K_{Fermi} < \frac{2\pi}{3a_0}$ couples weakly



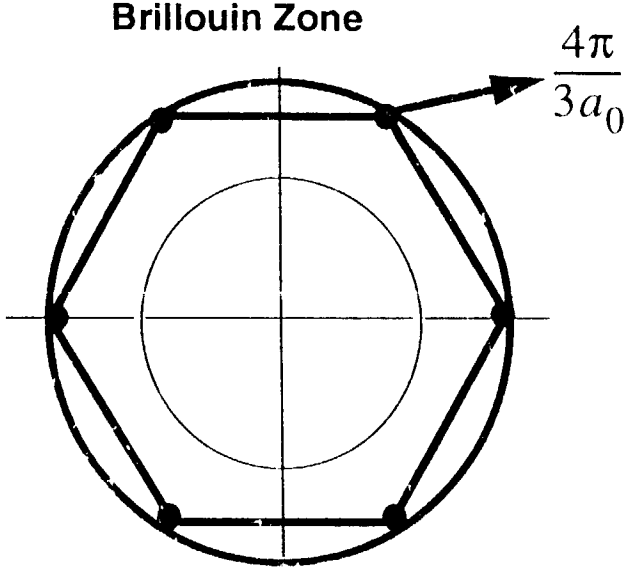
GRAPHENE SHEET IN UNIFORM CONTACT WITH METAL



FEG

(Free Electron Gas)

Brillouin Zone



For good coupling: Metal $K_{Fermi} > 4\pi/3a_0$

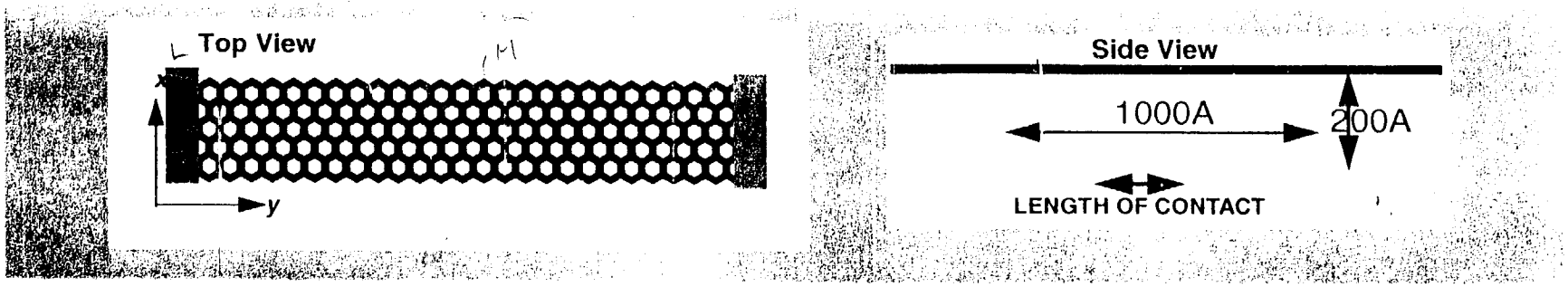
	K_{Fermi} Å^{-1}
Cs	0.65
Ag	1.20
Au	1.21
Hg	1.37
Al	1.75
⬡	1.7

K-vector along plane is not conserved for most metals
Poor coupling.

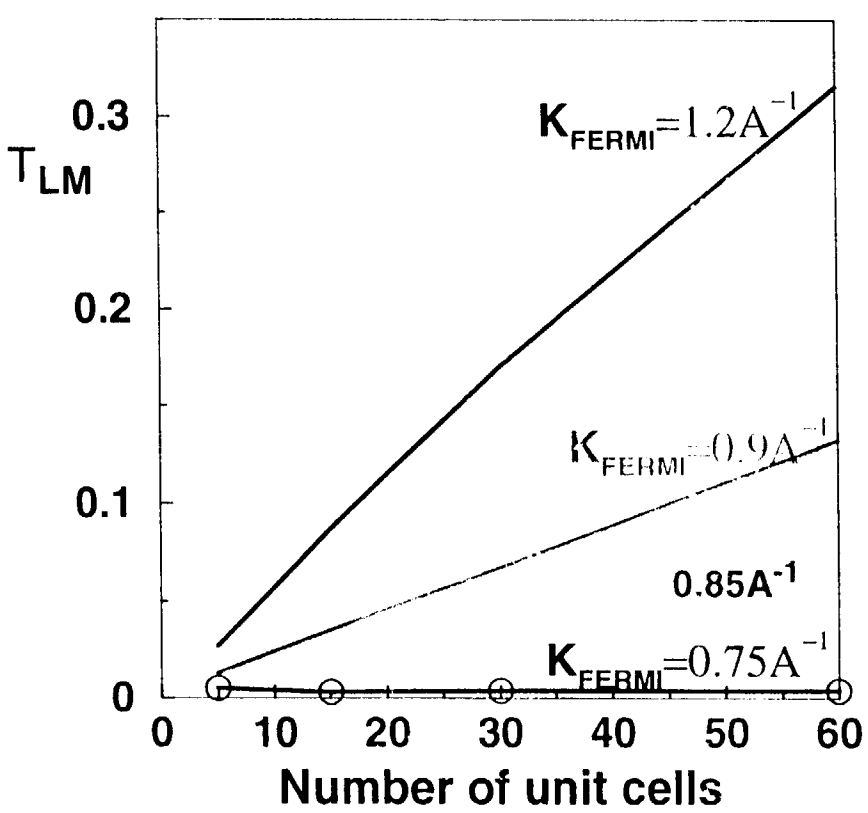
*** Ashcroft & Mermin, Solid State Physics**

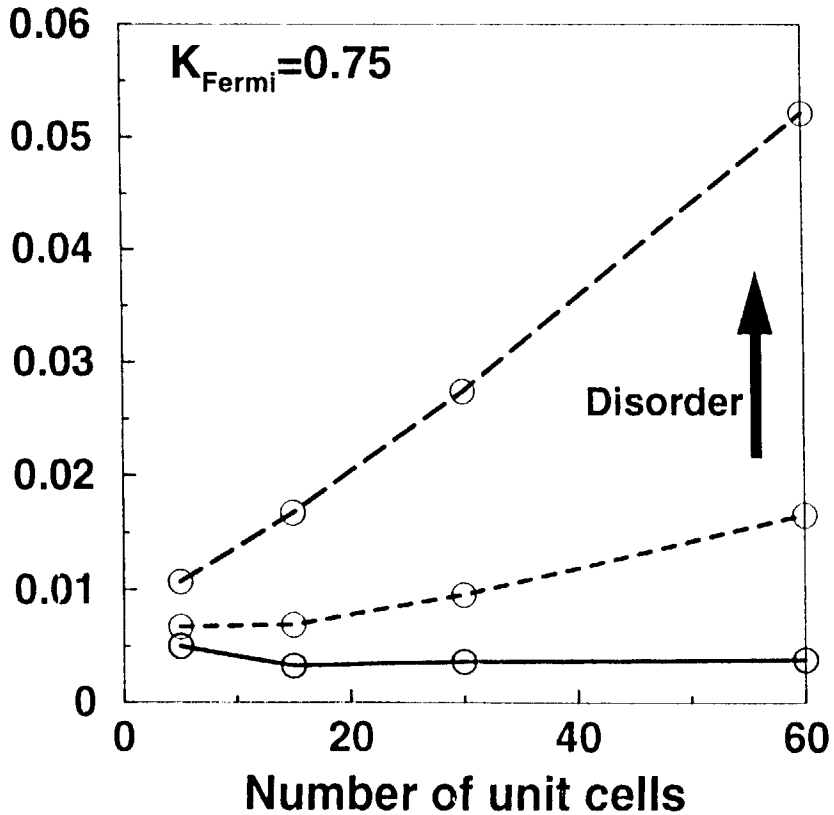
EFFECT OF HIGHER SUBBANDS ON dI/dV VERSUS V

- S. Frank, P. Poncharal, Z. L. Wang & W. A. de Heer, Science, v.280 (1998)]

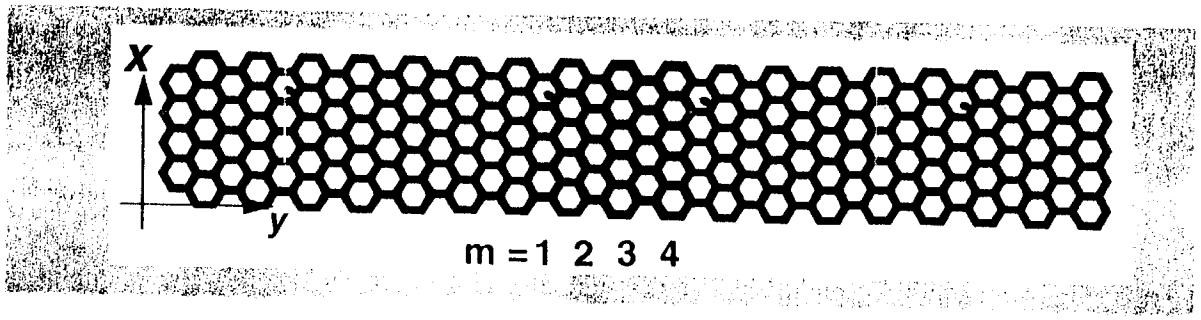


- Anantram & Govindan, Transport through carbon nanotubes with defects, Phys. Rev. B v.58 (1998);
- Compute self energy due to: (i) metal & (ii) semi-infinite CNT leads
- $T_{LM} = Tr\left[\Gamma_M G_d^r \Gamma_L G_d^a\right]$



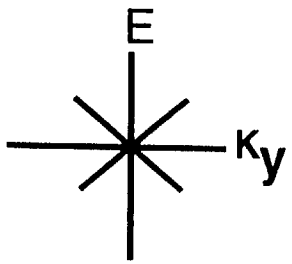


COUPLING TO ZIGZAG TUBES

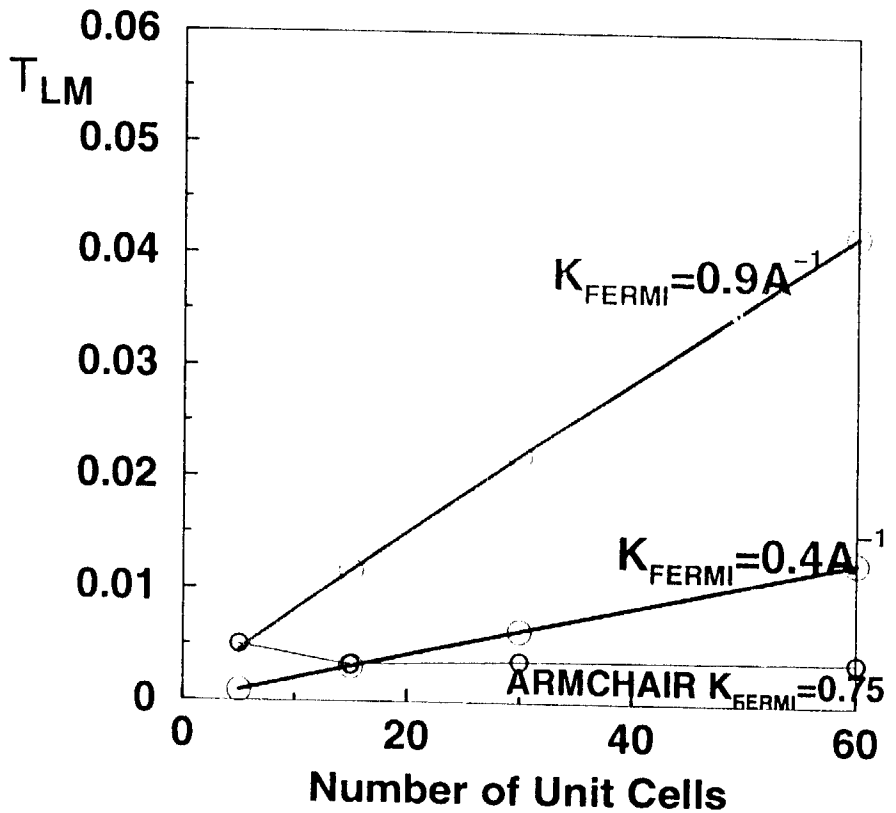


$$\Psi = e^{imK_y\sqrt{3}a_0}\phi$$

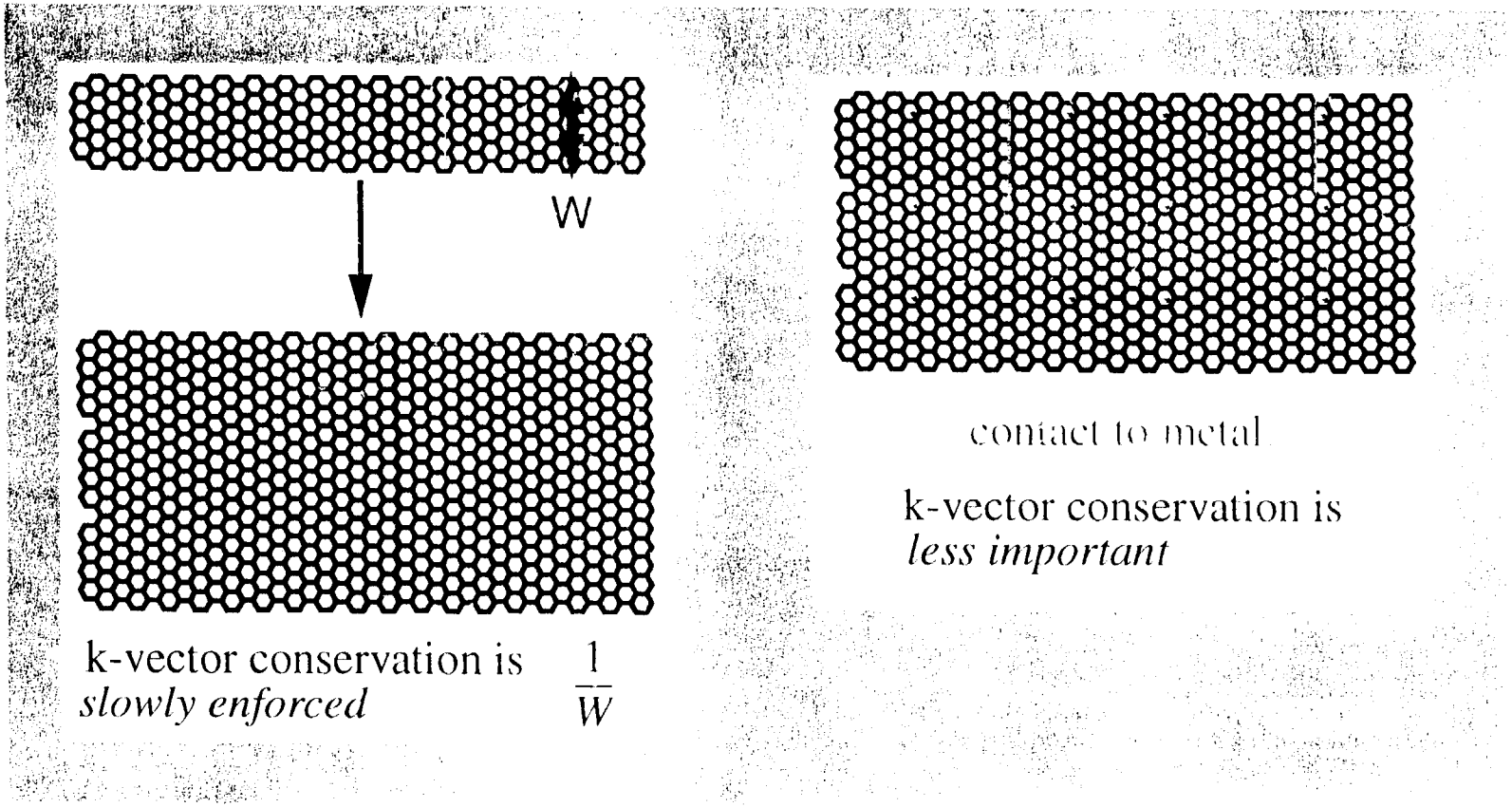
- E=0 at K_y=0.



- No cut-off value of metal K_{Fermi}



LARGE DIAMETER TUBES



- *Increase Transmission*: Small phase coherence length in metal / disorder in metal-CNT coupling [Frank et.al, Science, v.280 (1998)]

CONCLUSIONS

- Graphene sheet: does not couple well to most simple metals (K-vector conservation; $4\pi/3a_0$)

- CNT / graphene strip: couples much better to simple metals (need for k-vector conservation along width is relaxed)

- Axial k-vector conservation is still required. Causes non trivial difference in coupling of zigzag and armchair tubes to a FEG.

ARMCHAIR	ZIGZAG
cut-off $K_{Fermi} = 2\pi/3a_0 = 0.85 Å^{-1}$	cut-off $K_{Fermi} = 0$

- Transmission increases with length of contact

- Disorder / small phase coherence length will increase transmission