

# Квантовые провода и точки

1. Электронные свойства 1D системы.
2. Нелокализованные состояния в КЭХ.
3. Туннелирование через квантовую точку.

## Квантовый провод

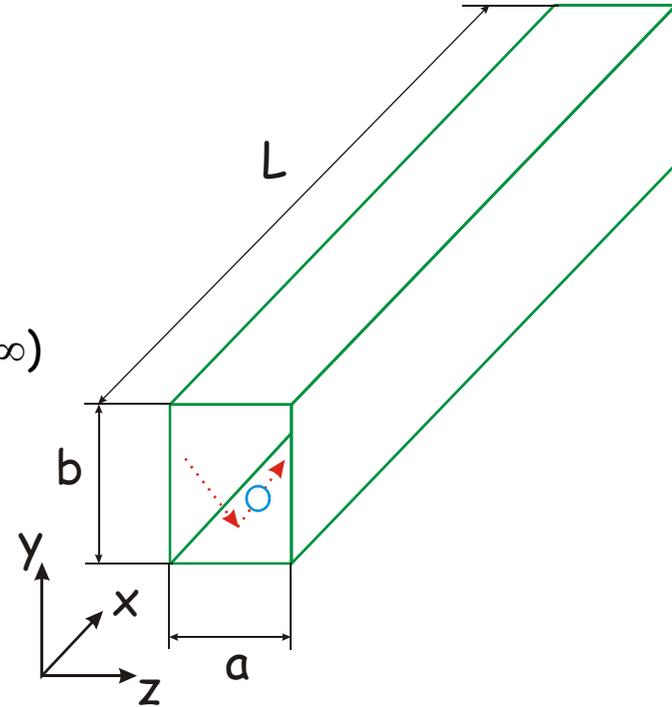
$$-\frac{\hbar^2}{2m}\Delta\varphi(r) + V(r)\varphi(r) = E\varphi(r)$$

$$\begin{cases} V(z, y) = \infty & z \in (-\infty; 0) \cup (a; +\infty) & y \in (-\infty; 0) \cup (b; +\infty) \\ V(z, y) = 0 & z \in (0; a) & y \in (0; b) \end{cases}$$

$$\varphi(r) = \psi_k(z)\chi_n(y)\exp\left(\frac{ip_x x}{\hbar}\right)$$

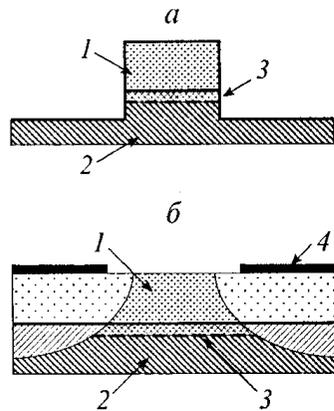
$$\psi_k(z) = \sqrt{2/a} \sin\left(\frac{\pi k}{a} z\right) \quad \chi_n(y) = \sqrt{2/b} \sin\left(\frac{\pi n}{b} y\right)$$

$$E_{kn} = \frac{\hbar^2 \pi^2}{2m} \left( \frac{k^2}{a^2} + \frac{n^2}{b^2} \right) \quad E = E_{kn} + \frac{p_x^2}{2m}$$

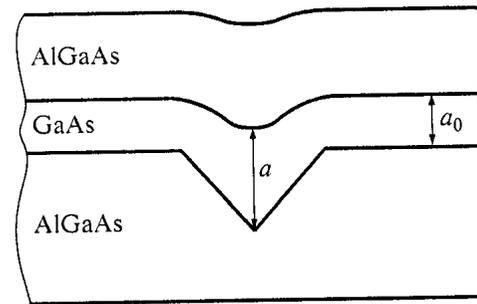


# Структуры с квантовыми проводами

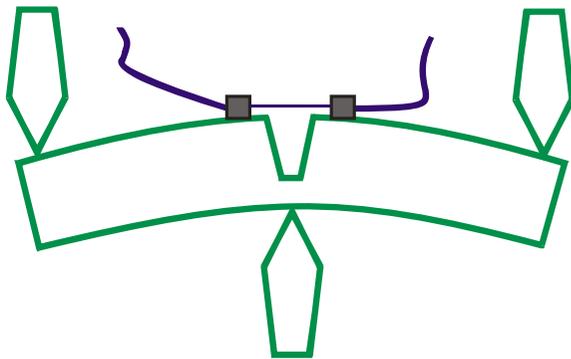
Квантовый провод из 2D системы



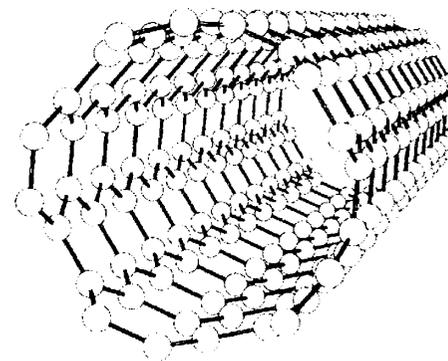
Квантовая канавка



Разрывной контакт



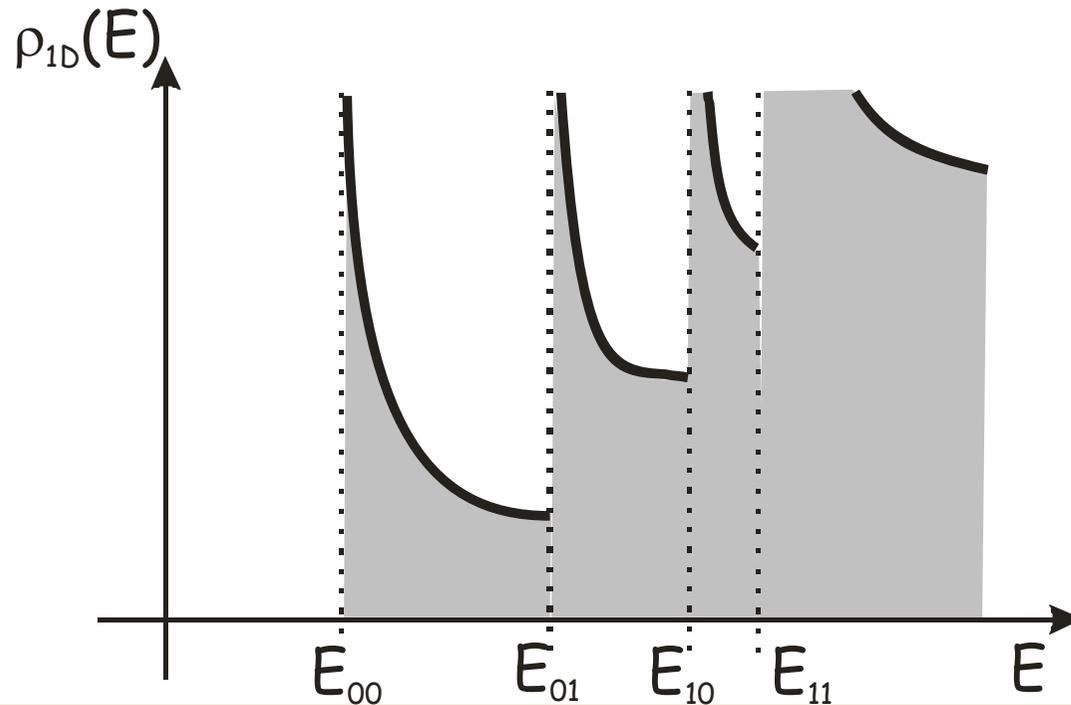
Нанотрубки



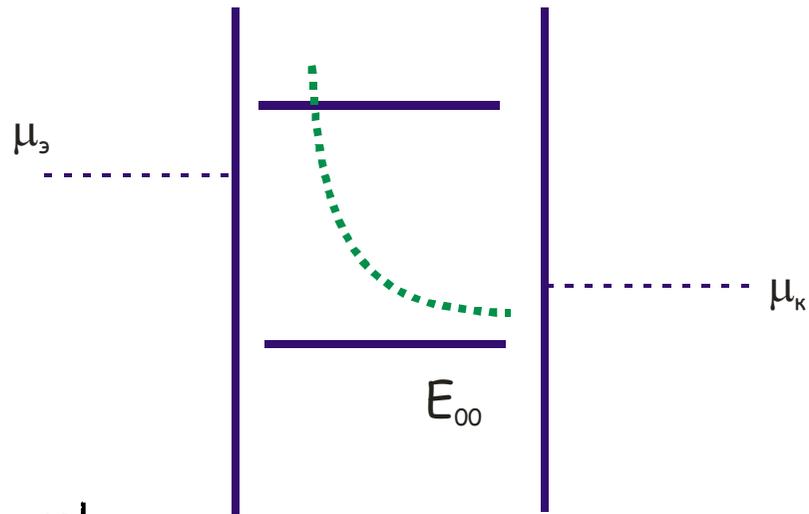
## Плотность состояний в квантовой нити

$$E_{1D} = E - E_{kn} = \frac{p_x^2}{2m} \quad dN_c(E_{1D}) = \frac{2dp_x L}{2\pi\hbar} = \frac{L}{\pi\hbar} \sqrt{\frac{m}{2E_{1D}}} dE_{1D}$$

$$\rho_{1D}(E_{1D}) = \frac{dN_c}{LdE_{1D}} = \frac{1}{\pi\hbar} \sqrt{\frac{m}{2E_{1D}}}$$

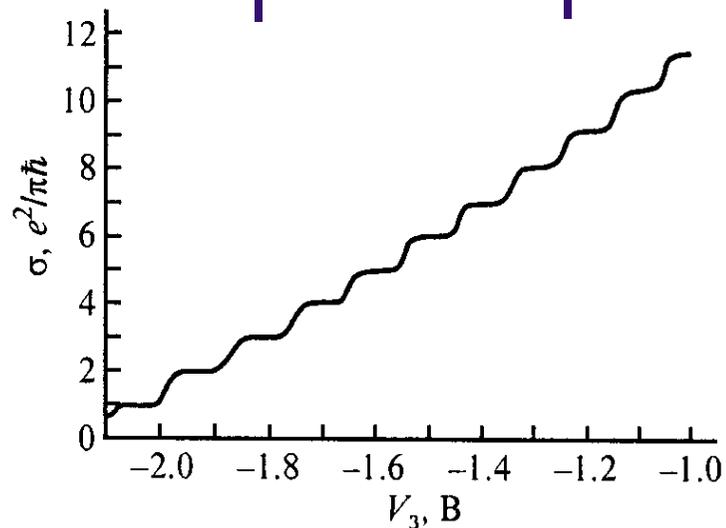


# Баллистическая проводимость квантовой нити



$$J = \int_{\mu_k}^{\mu_3} e v_x dn_c \quad v_x = \frac{dE_{1D}}{dp_x}$$

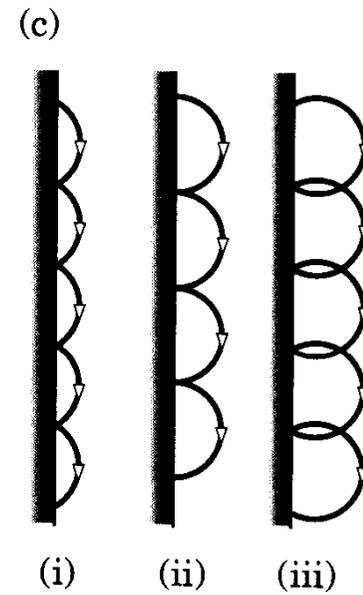
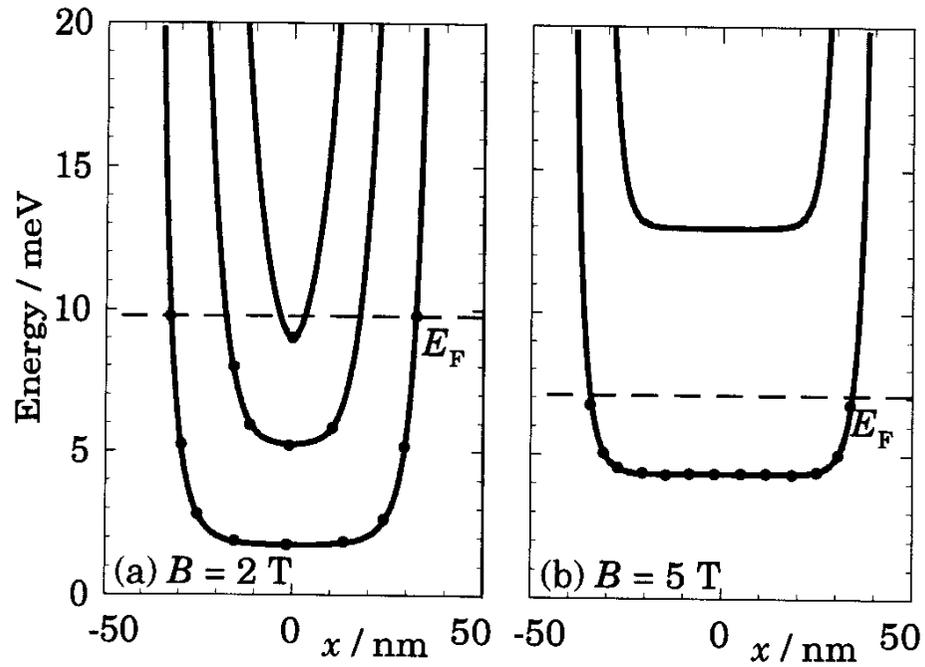
$$J = \int_{\mu_k}^{\mu_3} e \frac{\partial E_{1D}}{\partial p_x} \frac{2dp_x}{2\pi\hbar} = \frac{2e}{h} (\mu_3 - \mu_k) = \frac{2e^2}{h} V$$



$$J = \frac{2e^2}{h} N(V - V_n)$$

$$\sigma = \frac{dJ}{dV} = \frac{2e^2}{h} N$$

# Краевые состояния



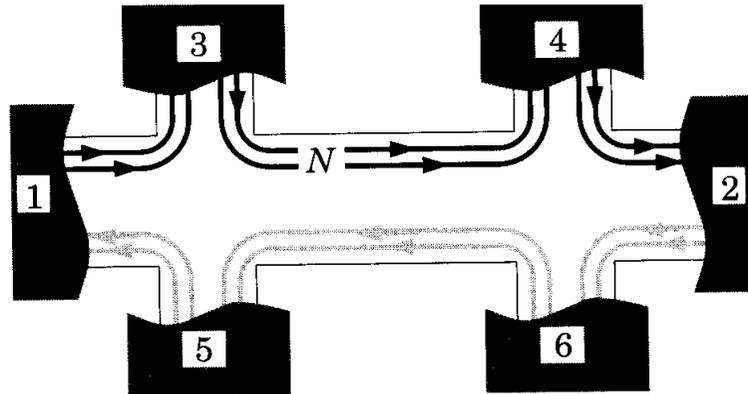
# Квантовый эффект Холла

$$\varphi_1 = \varphi_3 = \varphi_4 = -V_1$$

$$\varphi_2 = \varphi_6 = \varphi_5 = 0$$

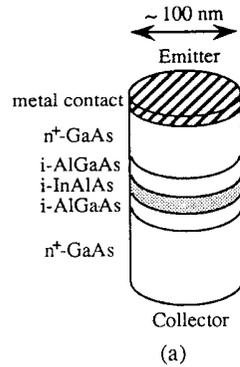
$$J_1 = -\frac{e^2}{h} V_1$$

$$J = \sum_1^N J_i = -\frac{e^2}{h} N V_1 = \frac{e^2}{h} N (\varphi_6 - \varphi_4)$$

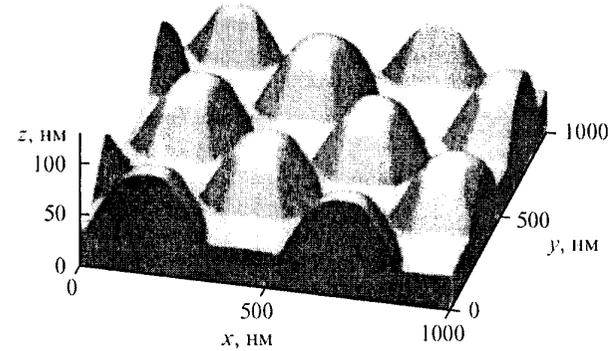


# Структуры с квантовыми точками

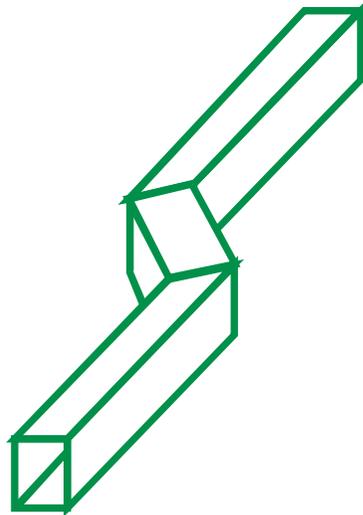
## 2D системы малых размеров



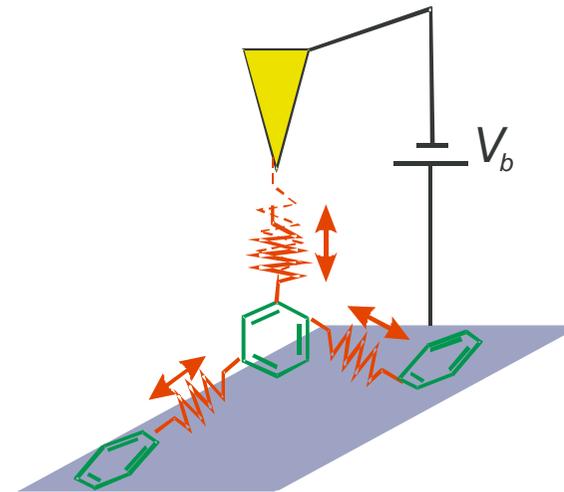
## Кристаллические кластеры



## 1D системы с дефектами



## Атомы и молекулы на поверхности



# НанорТД

## Асимметричный РТД

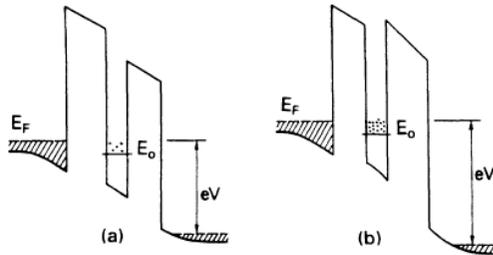


FIG. 1. Schematic energy diagrams of a large asymmetric DBRTS device under (a) positive and (b) negative bias. Hatching represents electron population of the emitter (left) and the collector (right) electrodes; dots represent the electron population in the well.  $E_0$  is measured from the bottom of the well to the bottom of the subband of the 2D resonant states.

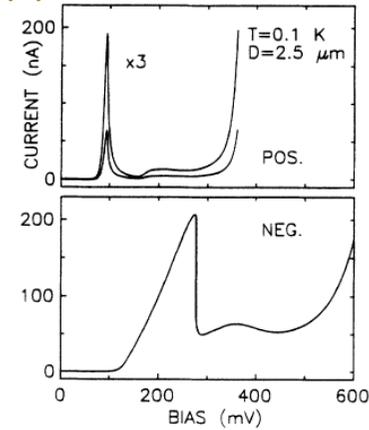
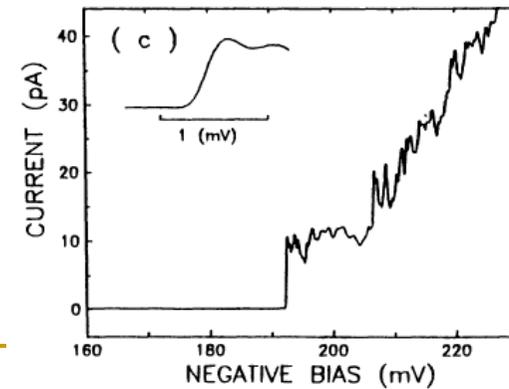
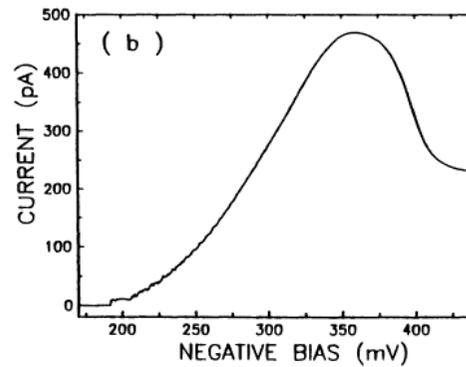
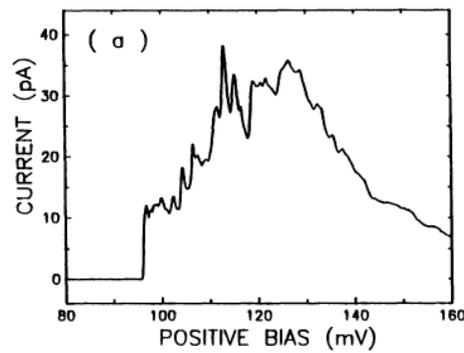


FIG. 2.  $I$ - $V$  curve of a large-area device. The asymmetry of the  $I$ - $V$  curve for positive/negative bias is due to the asymmetry of the barriers. Positive PTV ratio is 54.

## Асимметричный нанорТД



# Кулоновская блокада

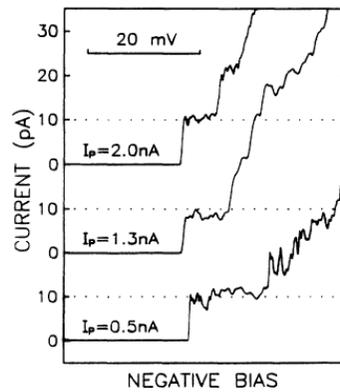


FIG. 5.  $I$ - $V$  curves of several devices made from the same DBRTS wafer.  $I_p$  gives the peak current; it is a measure of the “electrical size” of a device at  $V_p$  (Ref. 30). The first current step height  $I^{(1)}$  is independent of  $I_p$ .

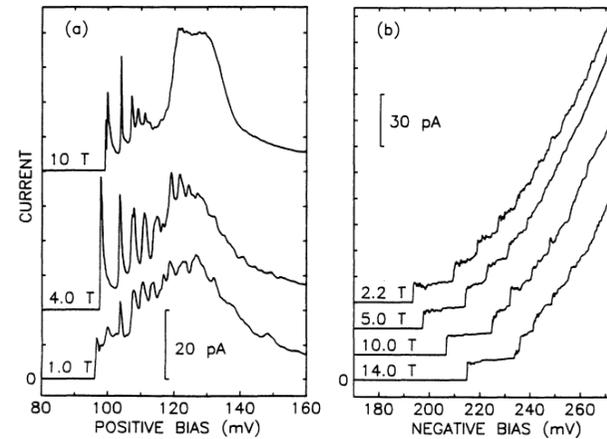


FIG. 6. Representative magnetotunneling data at 20 mK ( $B$  perpendicular to the barriers). Note the striking difference in the character of the data (peaks vs steps) in the two bias polarities.