EXCITONS IN NANOSTRUCTURES

Introduction

Reasons for nano

It is desirable to control properties of devices

The decision is NANOSTRUCTURES

Kinds of nanostructures

- Single heterojunctions
- Quantum wells
- Quantum wires
- Quantum dots
- Superlattices

Types of nanostructures

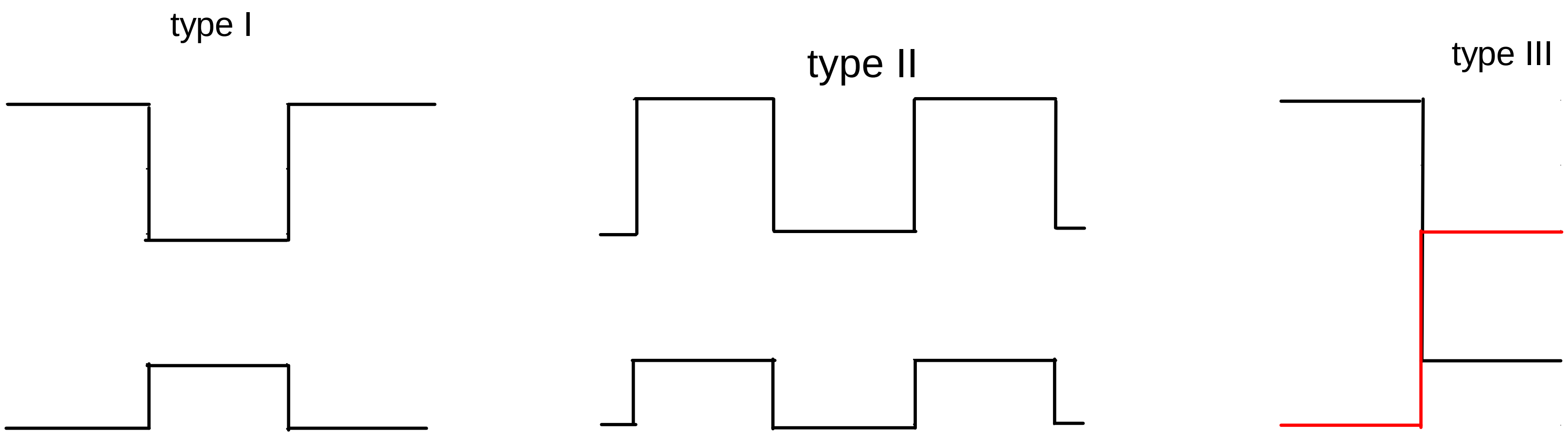
QWs can be of

Type I

Type II

Type III

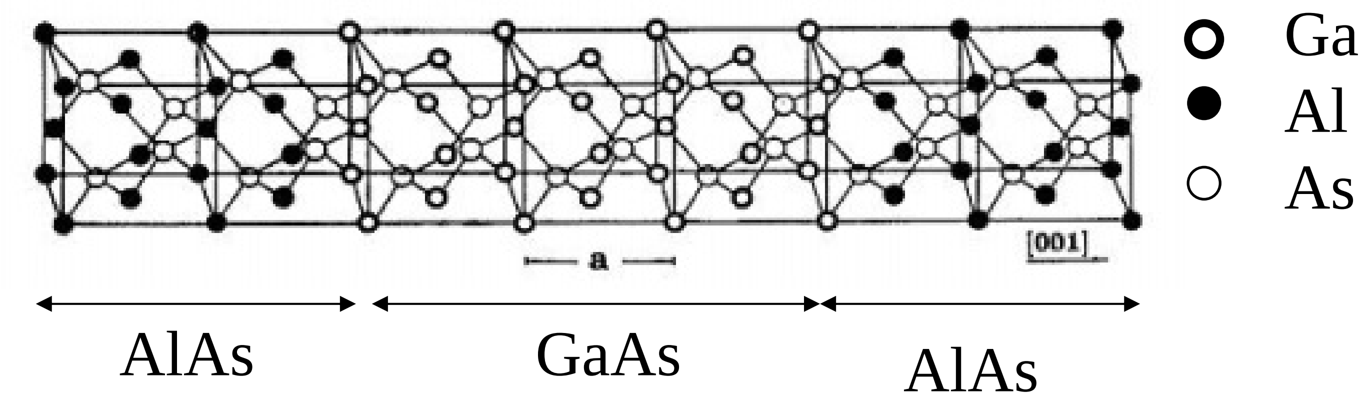
Types of heterostructures

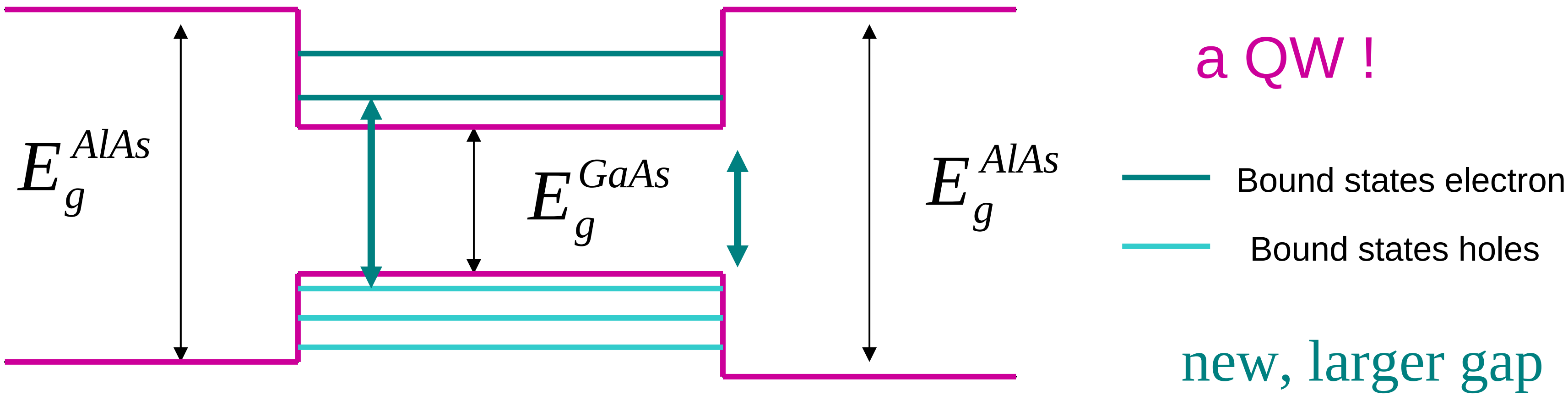


The main advantage of nanostructures arise from quantization

The principle of a semiconductor QW

New artificial material formed by thin layers of semiconductors with different energy gaps





semiconductor QW

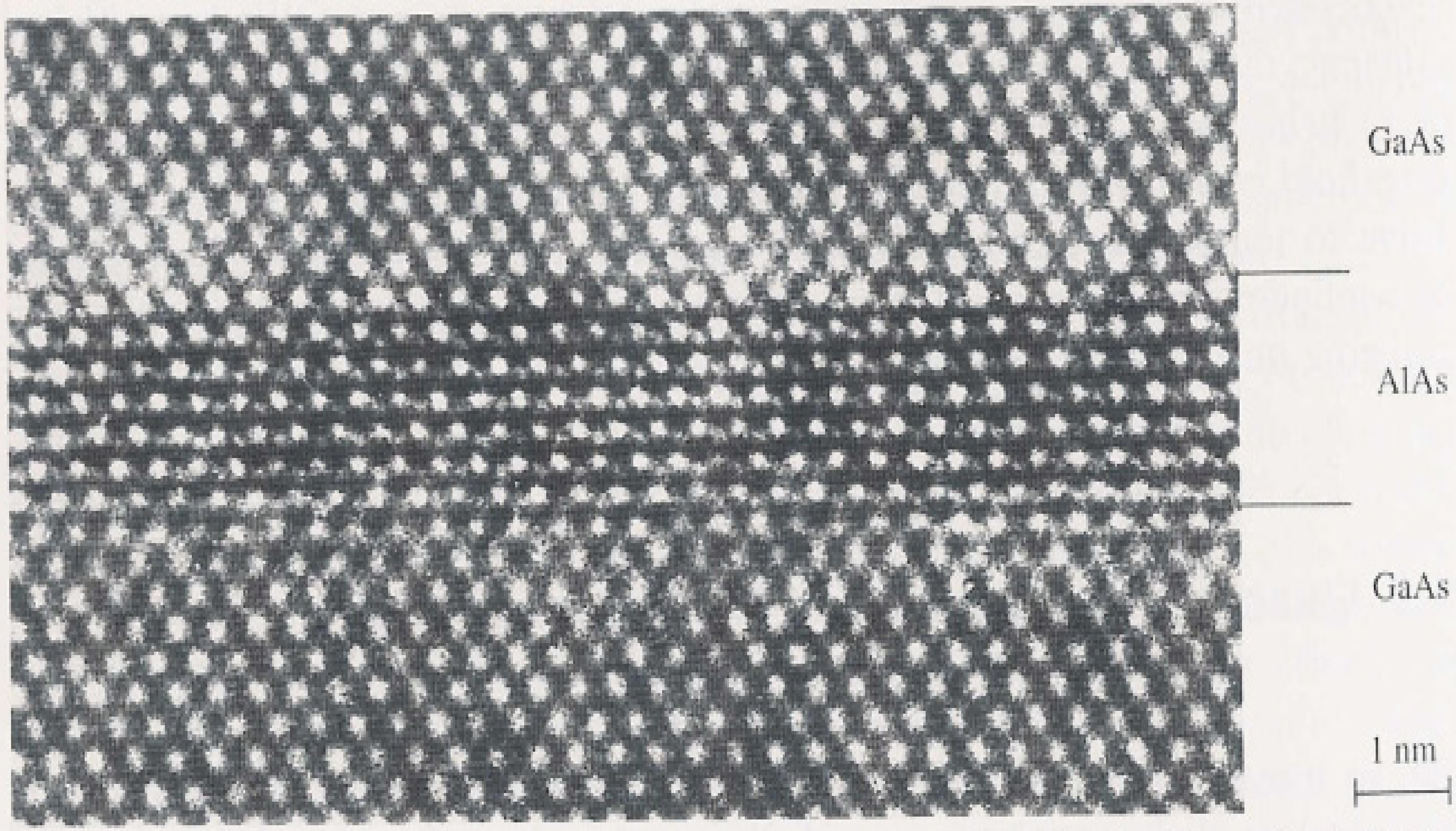


Fig. 9.1. High resolution transmission electron micrograph (TEM) showing a GaAs/AlAs superlattice for a [110] incident beam. (Courtesy of K. Ploog, Paul Drude Institute, Berlin.) In spite of the almost perfect interfaces, try to identify possible Al atoms in Ga sites and vice versa

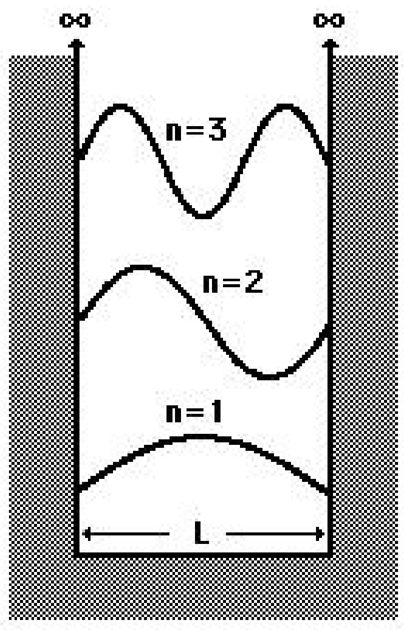
Quantum well (QW)

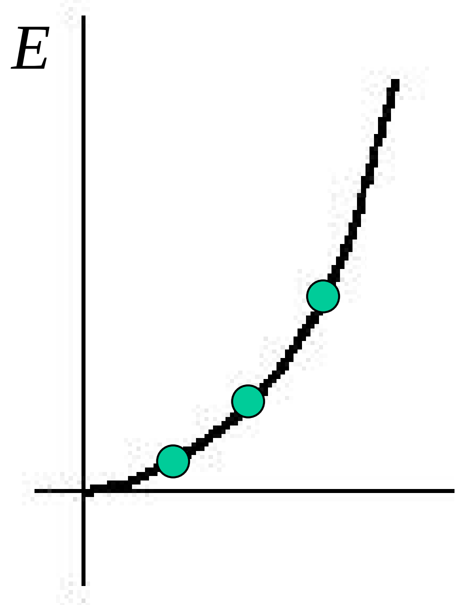
width L, infinite barriers

$$\psi(0) = \psi(L) = 0$$

$$\psi(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi}{L} x\right)$$

$$E_n = \frac{h^2}{8mL^2} n^2 = \frac{\hbar^2}{2m}\left(\frac{n\pi}{L}\right)^2 = \frac{\hbar^2}{2m} k^2$$





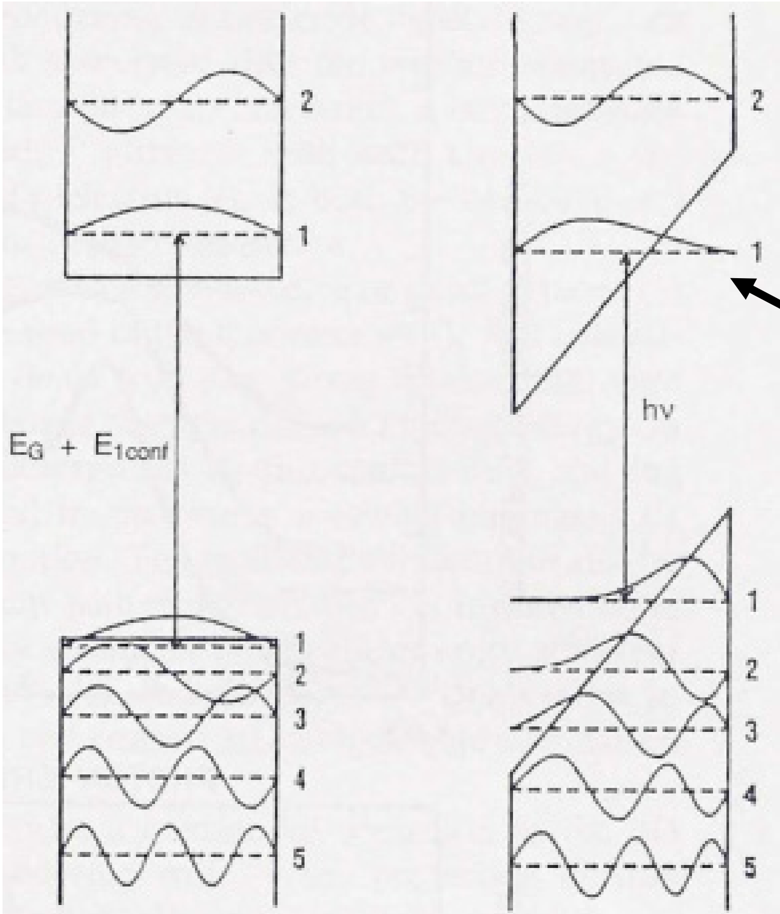
parabolic dependence

$$k = \frac{n\pi}{L}$$

Quantization in two, three dimensions = NW, QD

QW with applied electric field

$E=0$ $E\neq 0$



$U \Rightarrow U + eEx$

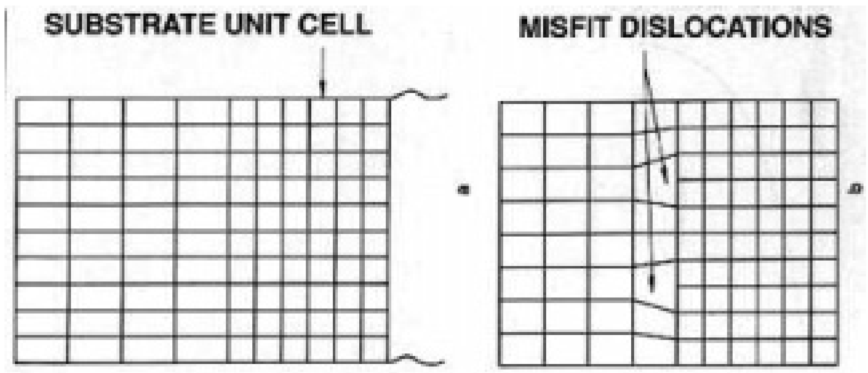
We can control the wavefunction not only due to quantization, but also by external fields

growth of sharp interfaces

Each material has an optimal lattice parameter a

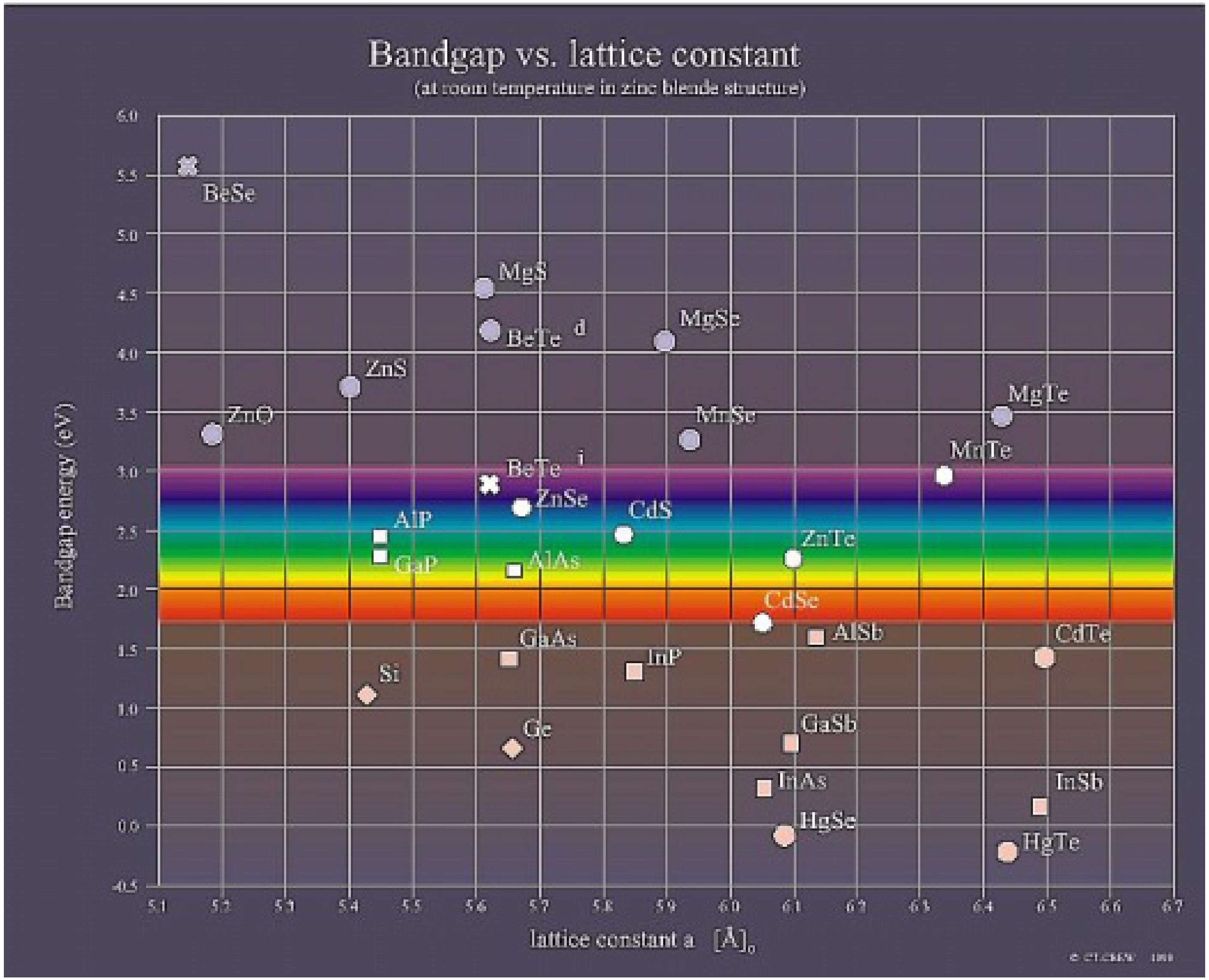
layer by layer growth proceeds nicely if the lattice parameters of the semiconductors used have almost the same lattice parameter (<1 % difference)

elastic deformation



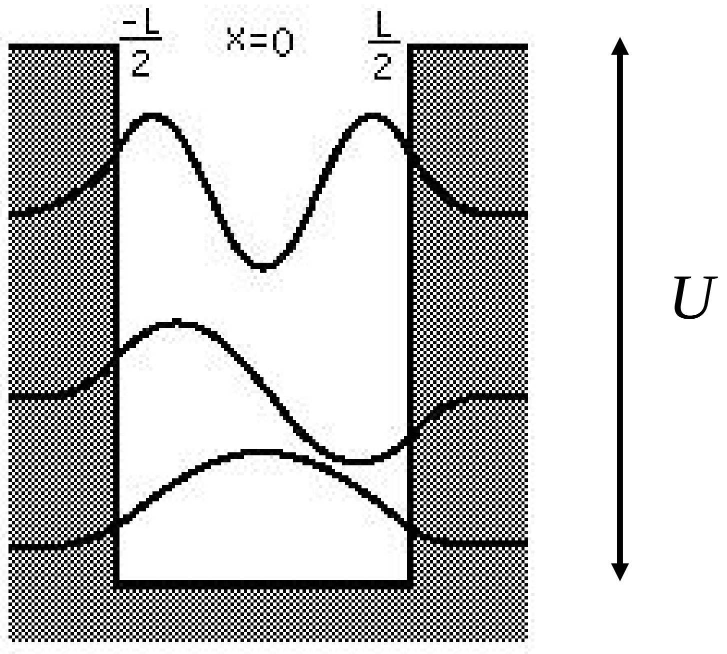
dislocations

Energy gaps and lattice parameters



Tunneling

QW with barriers of finite height U



In the barrier

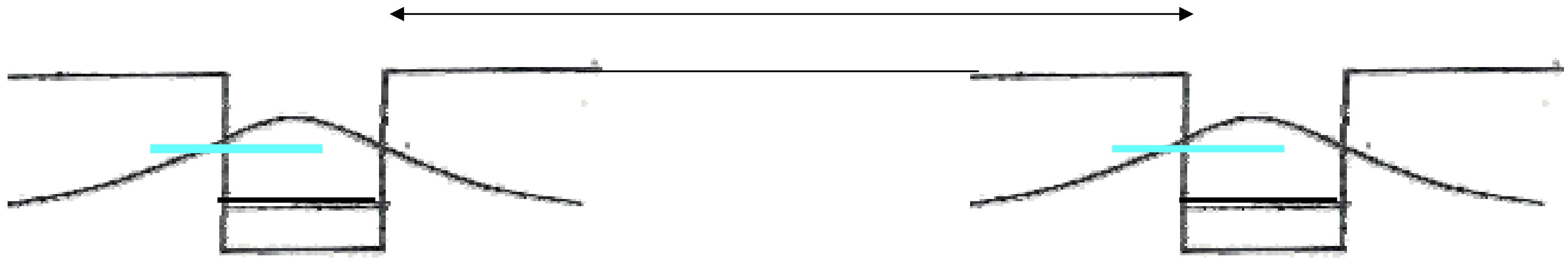
$$\psi \approx e^{-Cx} = e^{-x/l_d}$$

$$l_d = C^{-1} = \sqrt{\frac{\hbar^2}{2m(U-E)}}$$

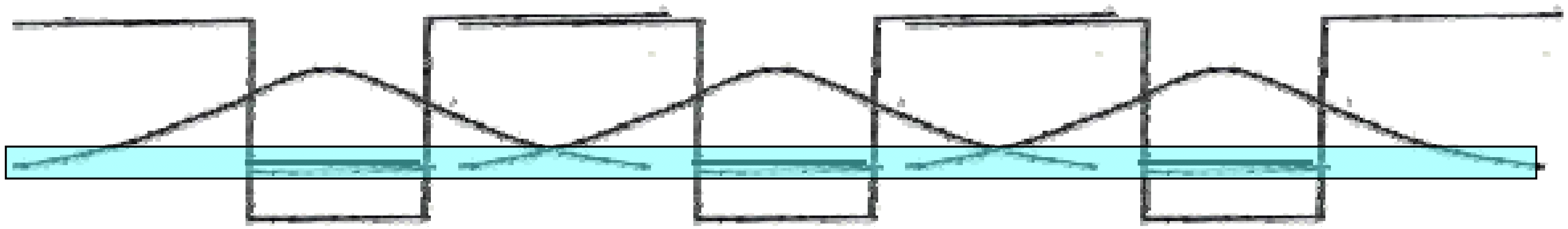
Wavefunction decays more slowly in the barrier when its energy gets closer to U

Multiple QW's versus superlattices (SL)

Multi QW $L_{barrier} >> l_D$ same energy level in each well enhances absorption/emission



Superlattice $L_{barrier} \sim l_D$ formation of minibands



A new 3D material with tunable energy bands !