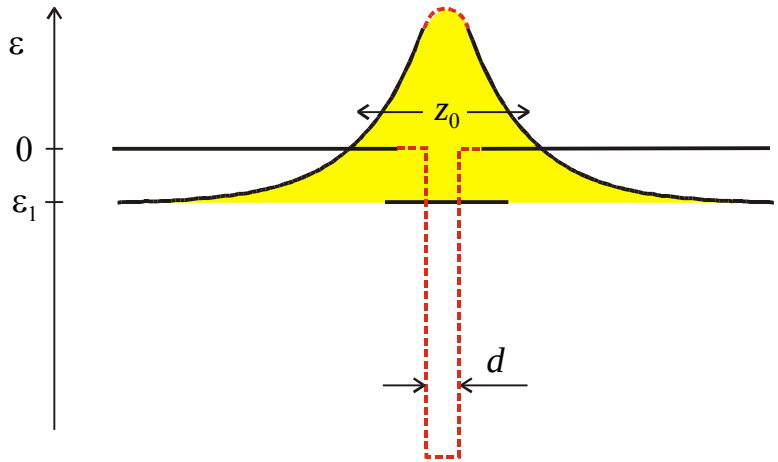
Ultrathin QW's

- Effective mass approximation

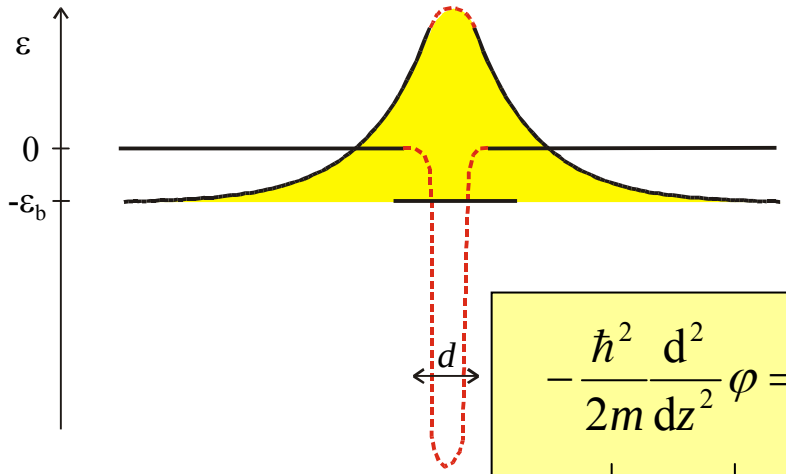


$$\varepsilon_1 = -\tfrac{\pi^2}{4}\delta^2 U$$

$$\varphi_1 = \sqrt{\alpha_1}\begin{cases} e^{\alpha_1 z}, & z<0 \\ e^{-\alpha_1 z}, & z>0 \end{cases}$$

$$\frac{z_0}{d} \sim \frac{1}{\delta^2} >> 1$$

- Zero-radius potential



$$\varepsilon_b = \frac{\hbar^2\alpha^2}{2m}$$

$$-\frac{\hbar^2}{2m}\frac{d^2}{dz^2}\varphi = \varepsilon\varphi$$

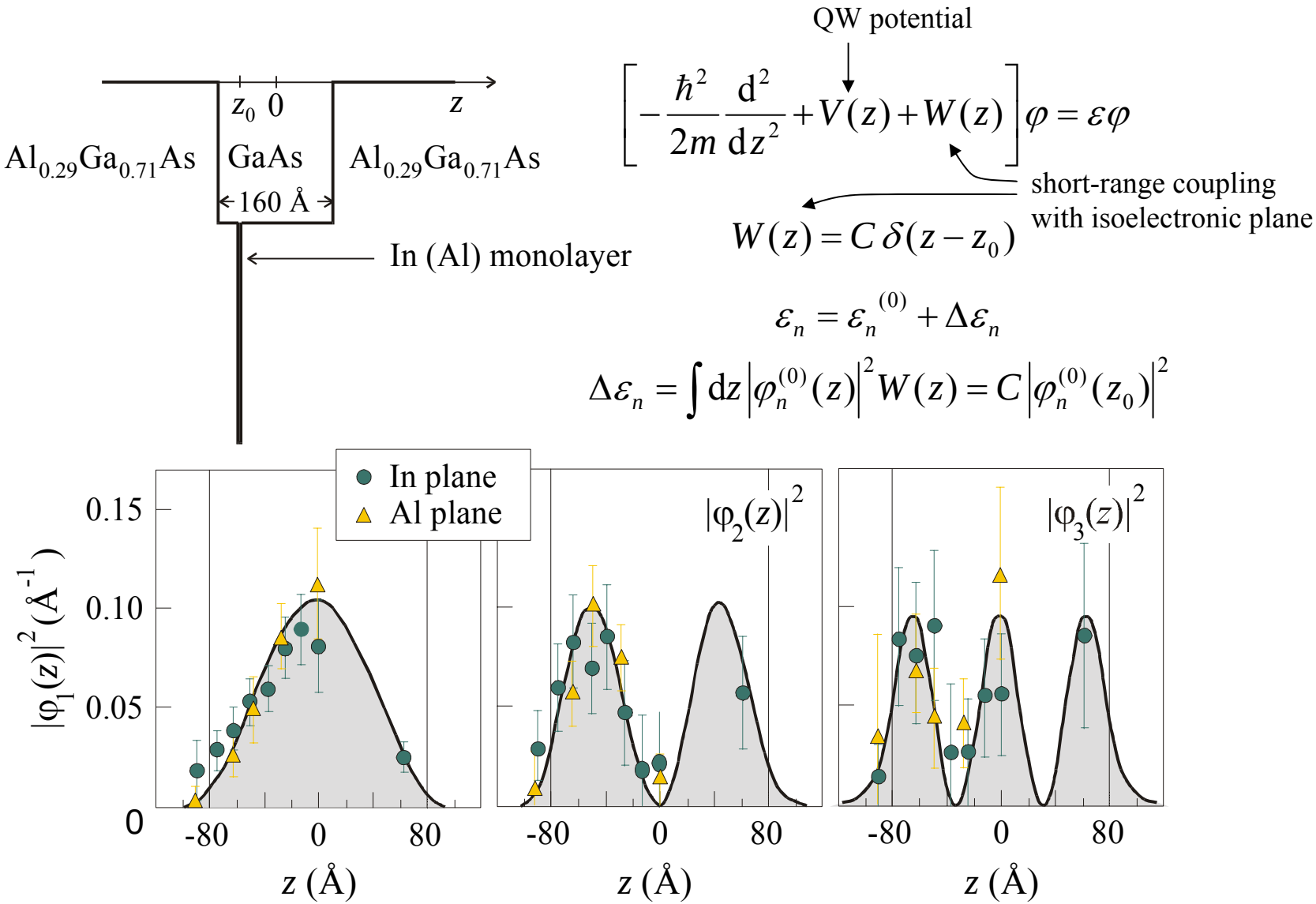
$$\varphi\big|_{-0} = \varphi\big|_{+0}$$

$$\frac{\varphi'}{\varphi}\bigg|_{+0} - \frac{\varphi'}{\varphi}\bigg|_{-0} = -2\alpha$$

parameter

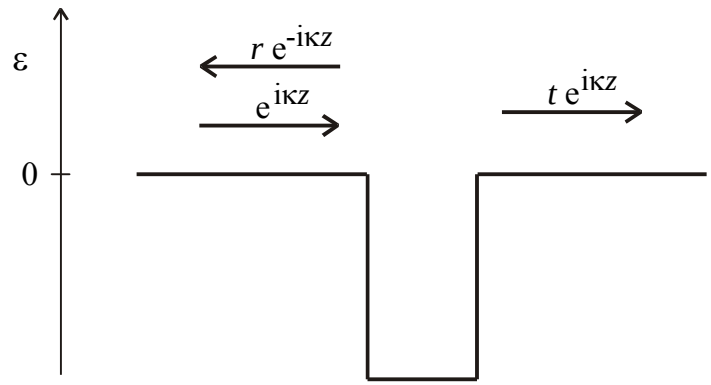
- The Dirac well

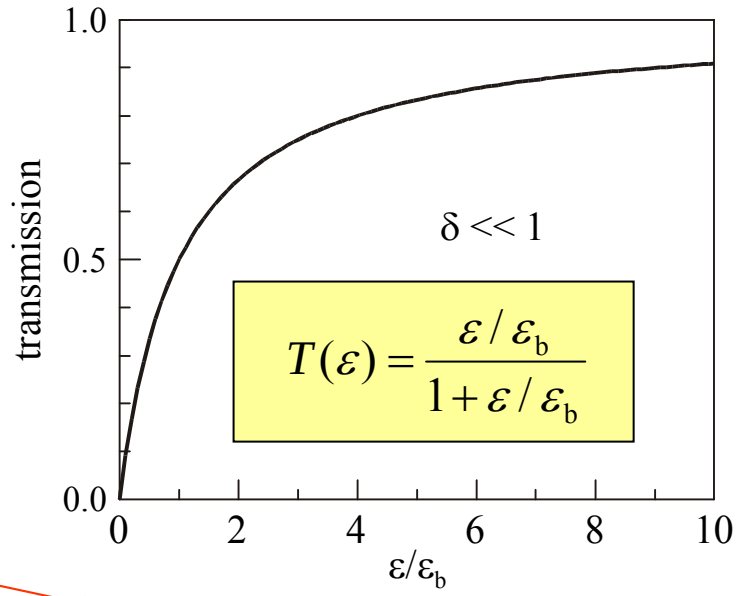
$$\left[-\frac{\hbar^2}{2m}\frac{d^2}{dz^2} - \frac{\hbar^2}{m}\alpha\,\delta(z)\right]\varphi = \varepsilon\varphi$$



[J.-Y. Marzin and J.-M. Gérard, *Phys. Rev. Lett.*, **62**, 2172 (1989)]

Electrons above QW

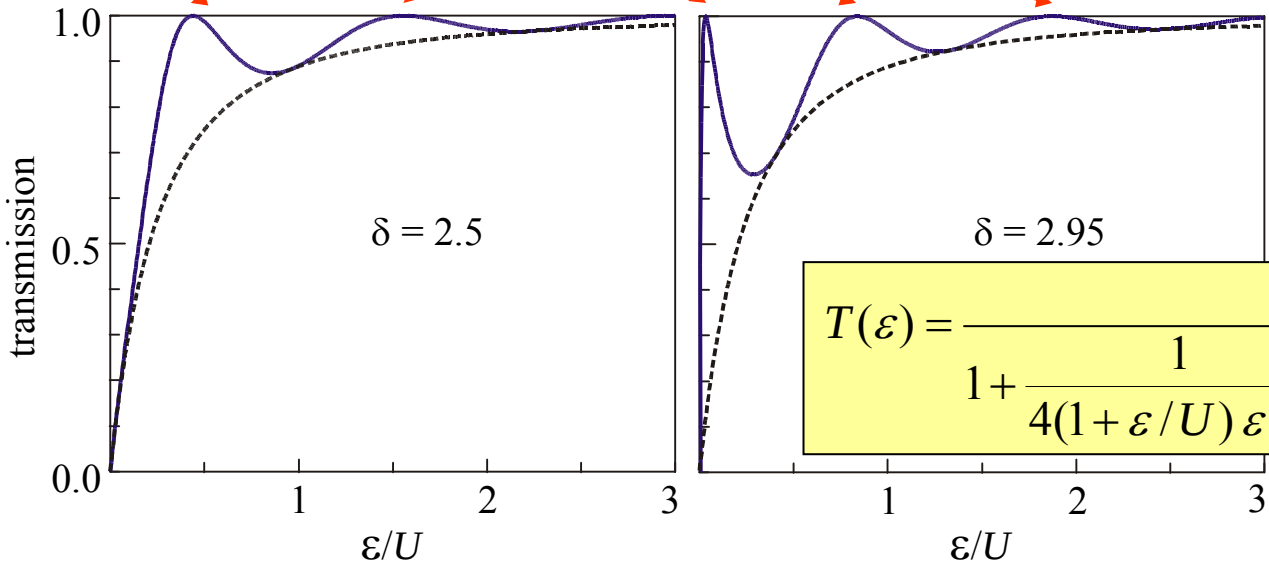




$$T(\varepsilon) = \frac{\varepsilon/\varepsilon_b}{1+\varepsilon/\varepsilon_b}$$

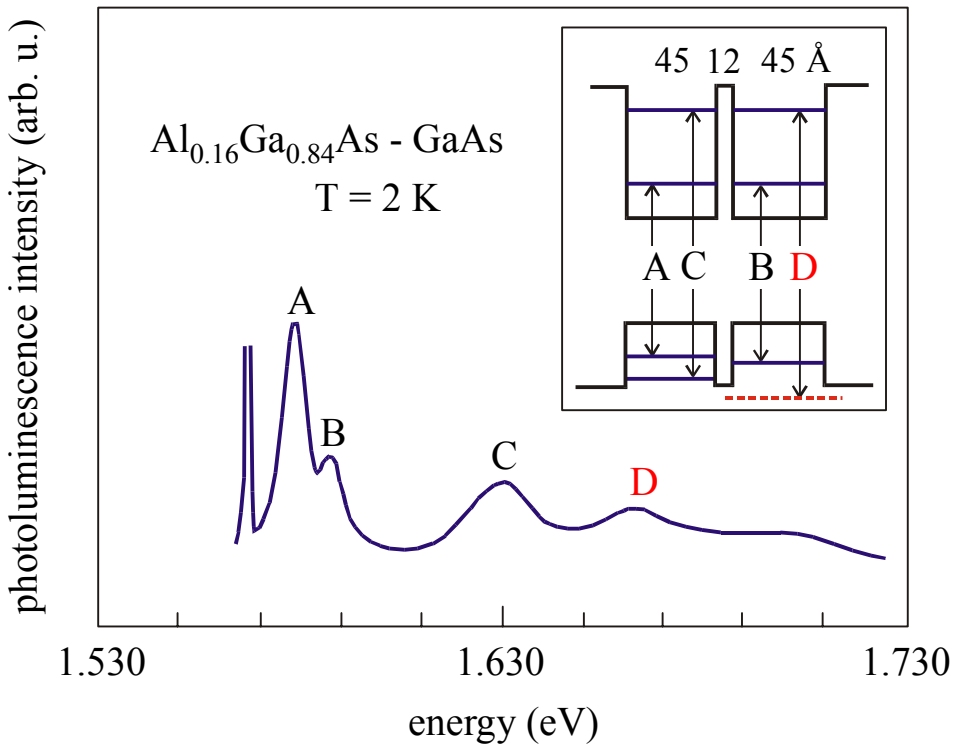
virtual levels

$\varepsilon + U = Wn^2$

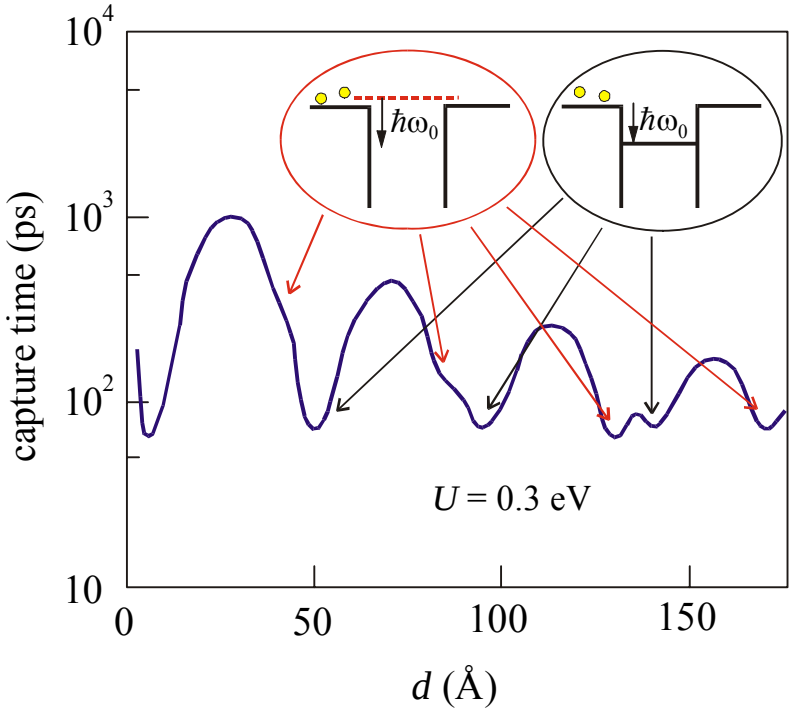


$$T(\varepsilon) = \frac{1}{1+\dfrac{1}{4(1+\varepsilon/U)\,\varepsilon/U}\sin^2(\pi\delta\sqrt{1+\varepsilon/U})}$$

Electrons above QW: Virtual levels

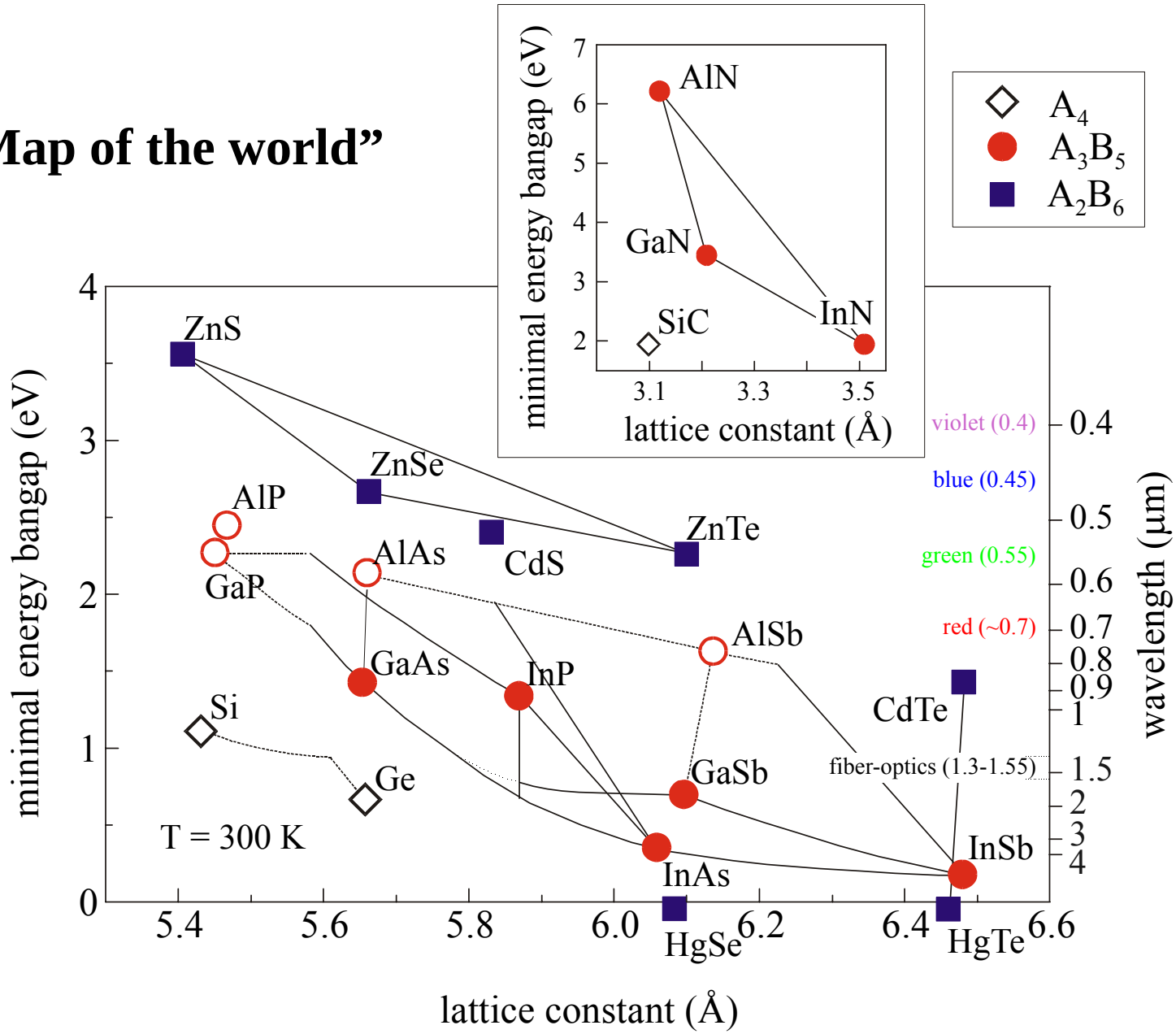


[G. Bastard *et al.*, *Solid State Commun.*, **49**, 671 (1984)]



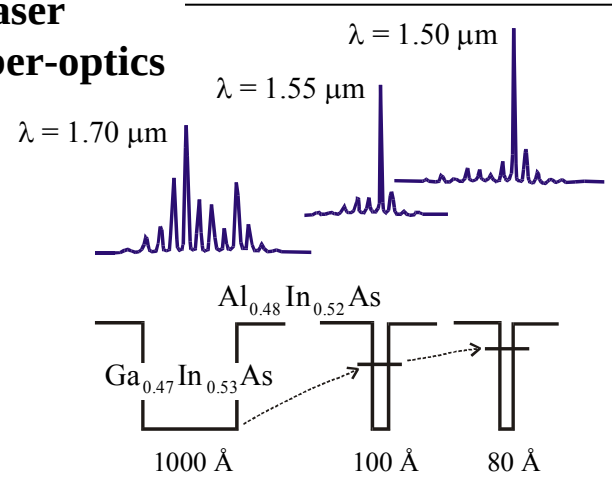
[J. A. Brum and G. Bastard, *Phys. Rev. B*, **33**, 1420 (1986)]

“Map of the world”



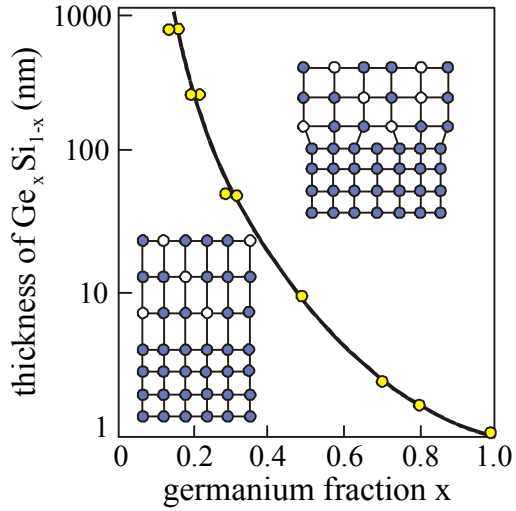
Band structure engineering

QW laser for fiber-optics



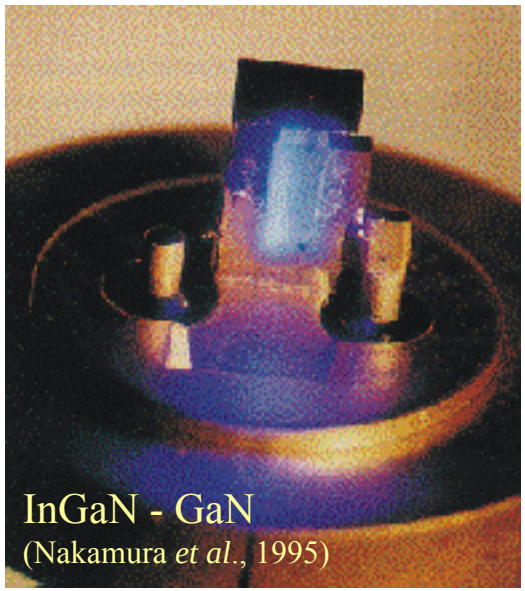
[H. Temkin *et al.*, *Appl. Phys. Lett.*, **42**, 845 (1983)]

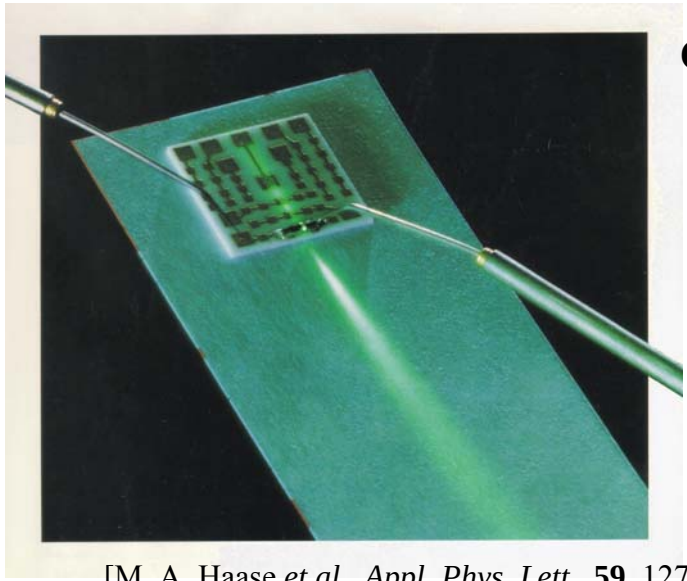
Strained heterostructures



GaInAs – GaAs (Osbourn *et al.*, ~ 1980)

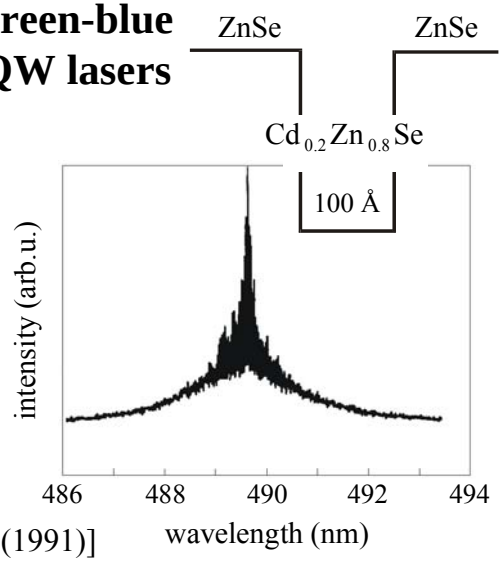
GeSi – Si (Bean *et al.*, ~ 1980)





[M. A. Haase *et al.*, *Appl. Phys. Lett.*, **59**, 1272 (1991)]

Green-blue QW lasers



Resumé

NB

- math:

$$\int_a^b \mathrm{d}x\, \delta(x - x_0)\, f(x) = f(x_0), \quad x_0 \in [a,b]$$

$$\delta(C\,x) = \frac{1}{|C|}\delta(x)$$

Glossary:

- ultrathin QW's
- reflection / transmission amplitudes r, t and coefficients R, T – atspindžio ir pralaidumo amplitudės ir koeficientai
- band structure engineering – juostinės struktūros inžinerija
- strained heterostructures – įtempti heterodariniai

Further reading:

- V. Narayanamurti, *Phys. Today* **37**(10), 24 (1984)
- S. Nakamura, *Phys. World* **11**(2), 31 (1998)
- (Karpus 2004, p. 41–78)

Problems to solve:

- 2.9.4: 0.8pt, 0.6pt
- 2.9.5: Kvantinė duobė ir stačiakampis barjeras 0.6pt, 0.6pt
- 2.9.6: 1pt, 0.2pt, 0.6pt