QWIP related processes and novel directions

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A few points from this workshop (Multicolor…)

FIR & THz

Photovoltaic

Dark current reduction

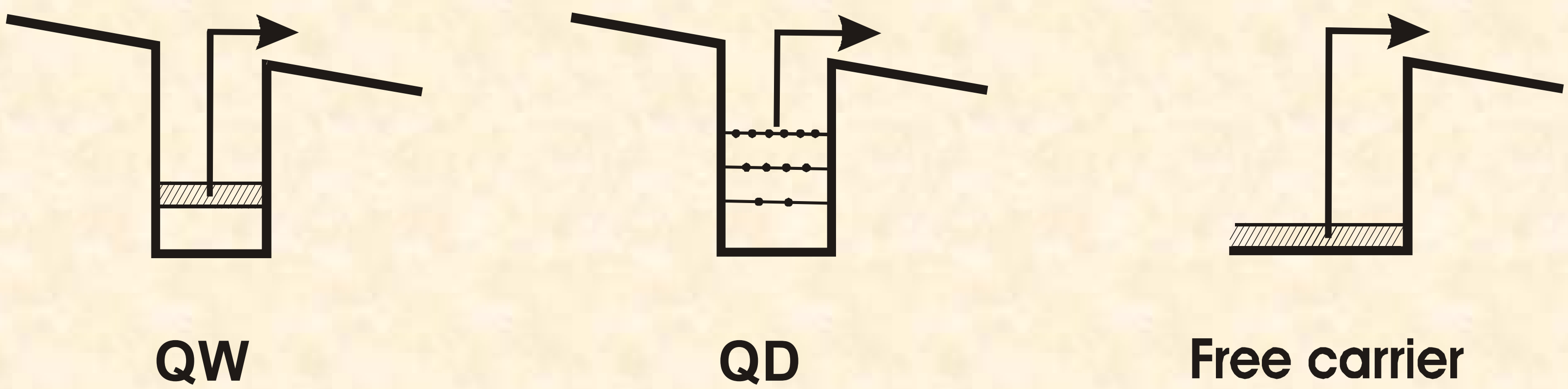
Quantum dots

Basic/simple points

THz QWIPs & arrays?

Low temperature & low doping required, absorption is a problem

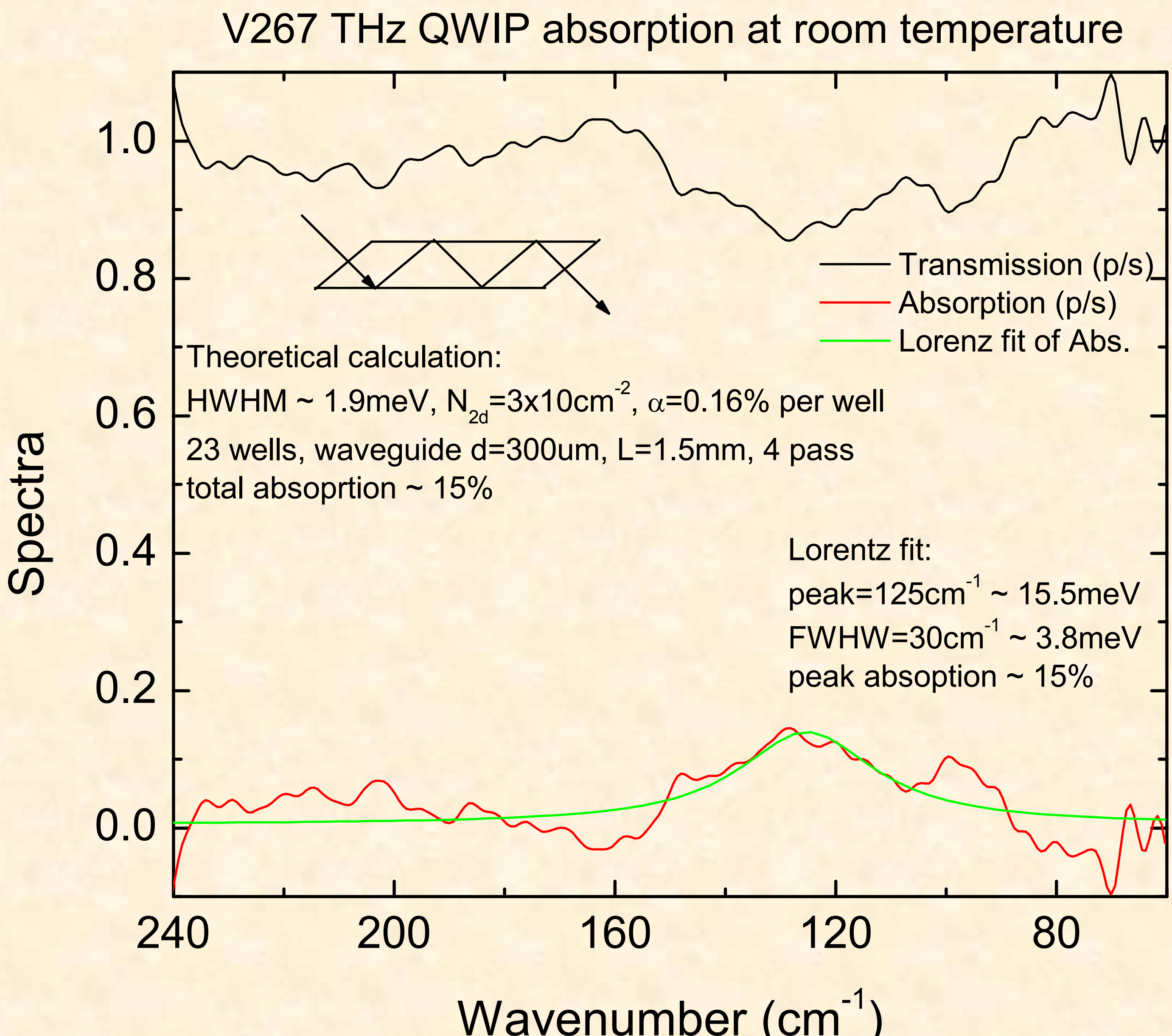
Free carrier absorption based detectors may be better here



Free carrier absorption physics:

Talk of Y.-C. Chang

Absorption needs to be improved



Absorption in our detector:

~7.5% for polarized light

On-going:

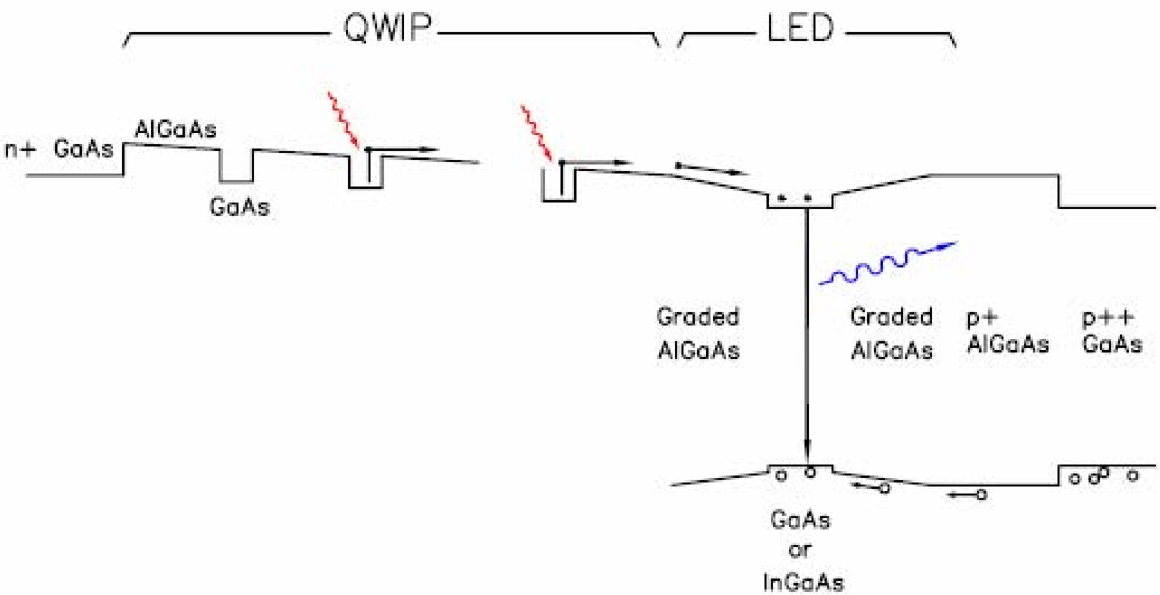
Improve absorption by

- Higher doping
- More wells

Free carrier absorption is very interesting for FIR/THz

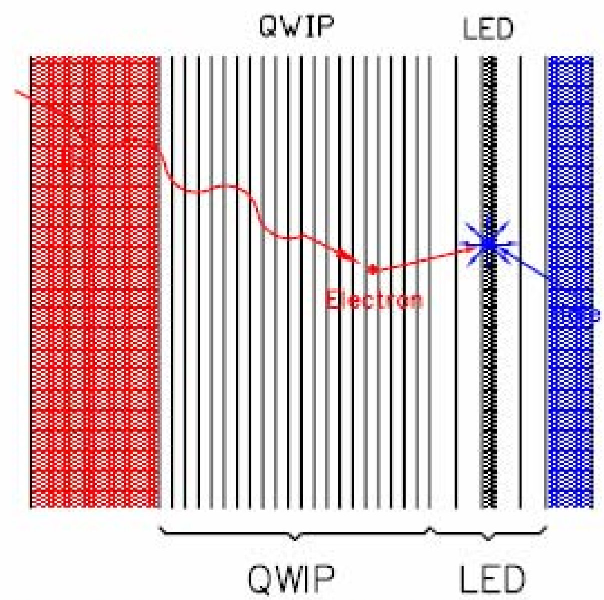
THz imaging is a hot area

Long wavelength to near IR converter



Electron. Lett. 31, 832 (95)

QWIP–LED stack is thin pixellation may not be necessary



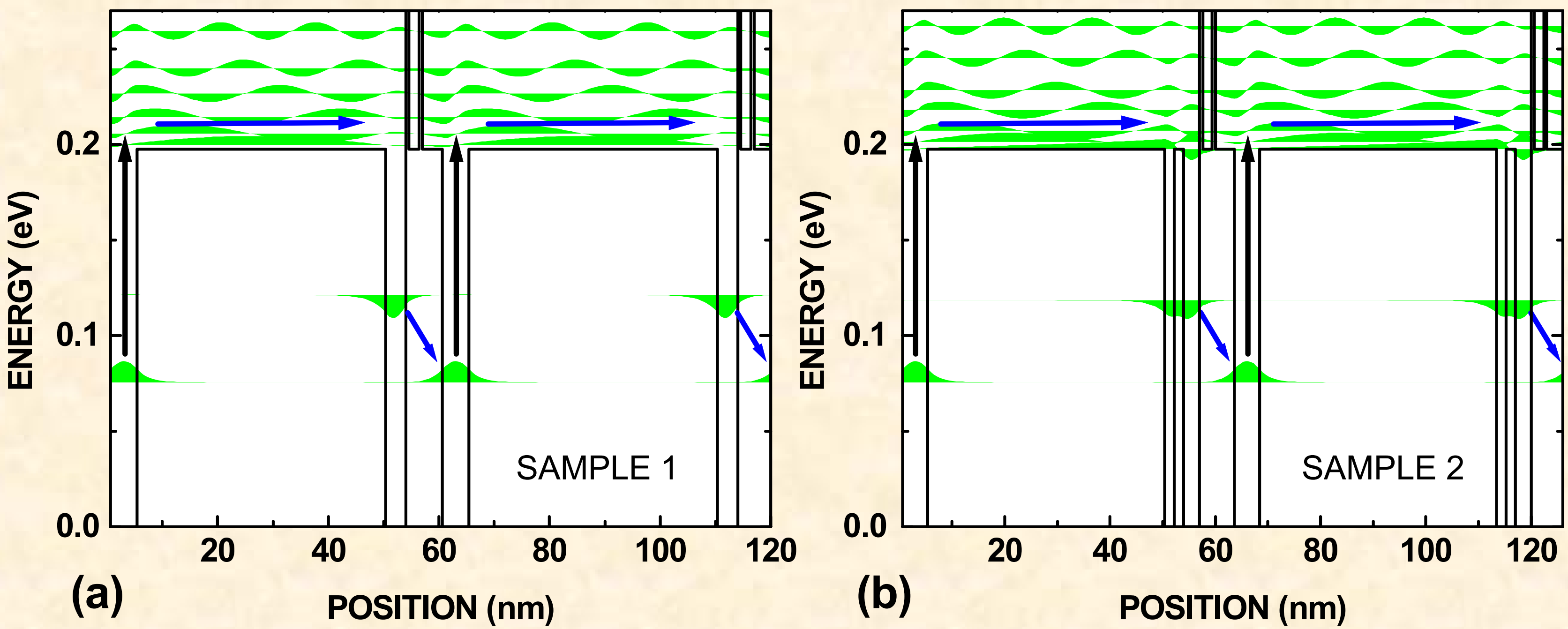
Key feature: thin active layer

Electron. Lett. 33, 378 (97)

Photovoltaic QWIP?

Schneider's "low noise" QWIP

Berger's QCD



Key point: making sure p_c=1 and p_e=1 at the same time

Final improvement: root 2 higher in blip D*

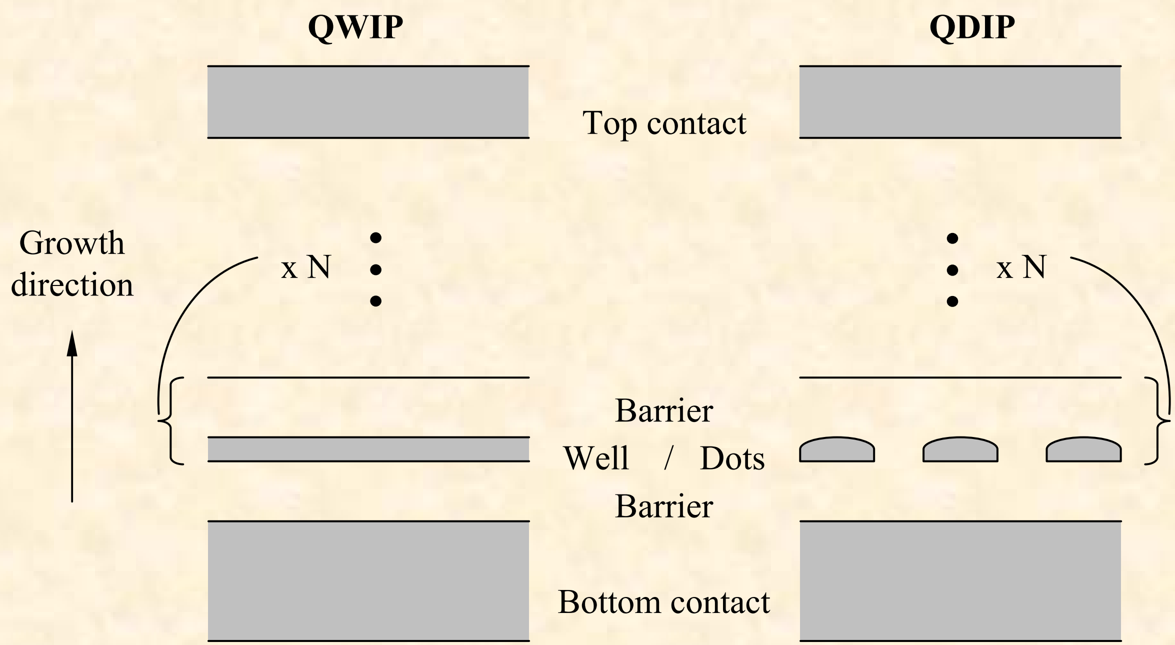
Reducing dark current?

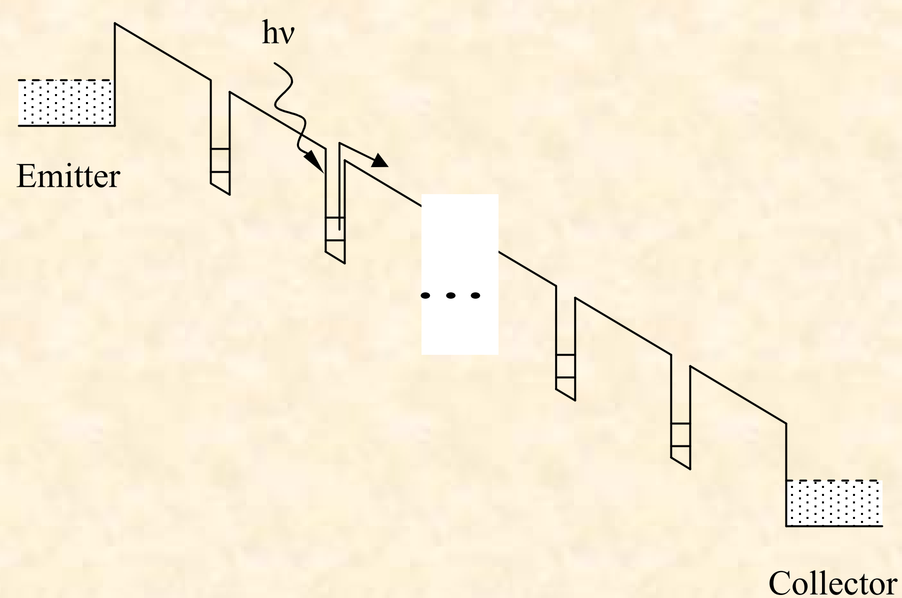
QWIPs with different contacts

JAP 82, 889 (1997)

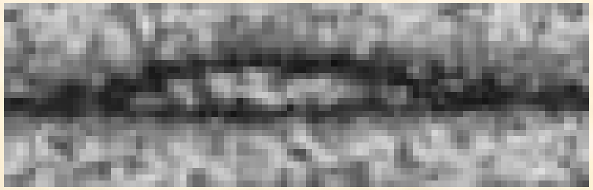
But all devices behaved just about the same!

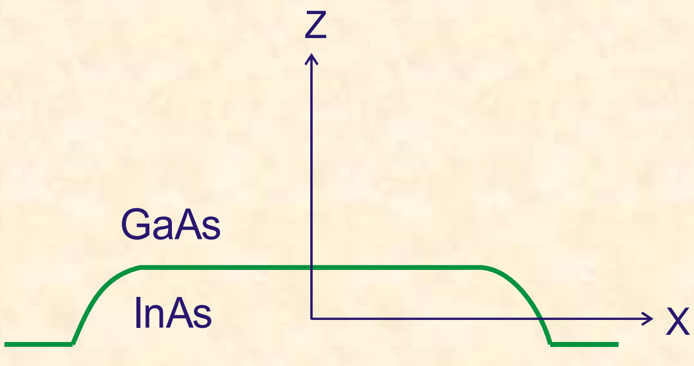
QWIP vs. QDIP

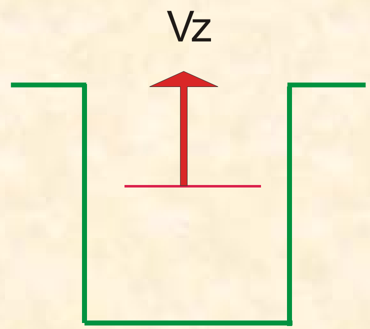

QWIP
QDIP
Top contact
Growth direction
x N
x N
Barrier
Well / Dots
Barrier
Bottom contact


hν
Emitter
Collector

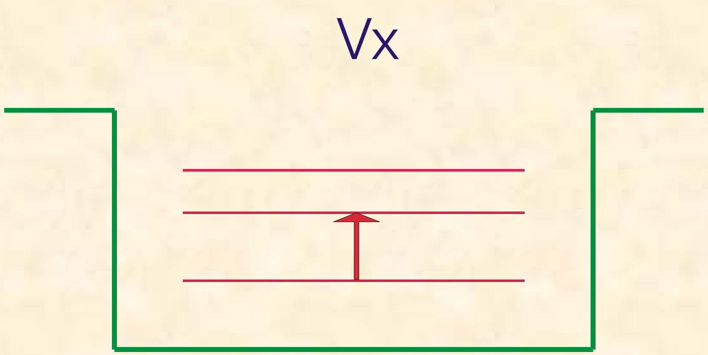
QDIP







~ 3 nm
Only 1 level confined



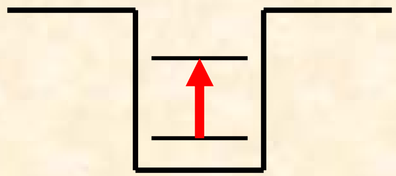
~20 nm
At least 3 levels confined

Need to

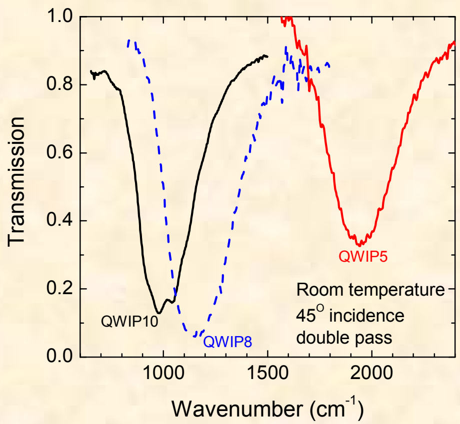
- Control dot shape for normal incidence
- High density for absorption
- Doping is unclear

Growth study: talk of W.Q. Ma

The absorption issue



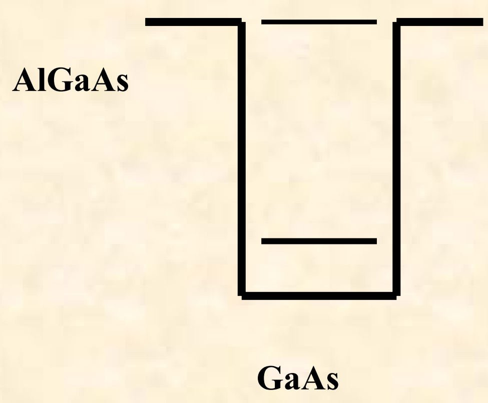
- Every electron has 1x1 nm^2 or 10x10 A^2 absorption cross-section in a quantum well/dot
- 1x1 nm^2 -> 10^{14} cm^{-2} -> 10^{12} cm^{-2} doped 100 wells give high absorption
- For QDIP, if ~10^{11} cm^{-2} dot density, needs ~1000 layers!

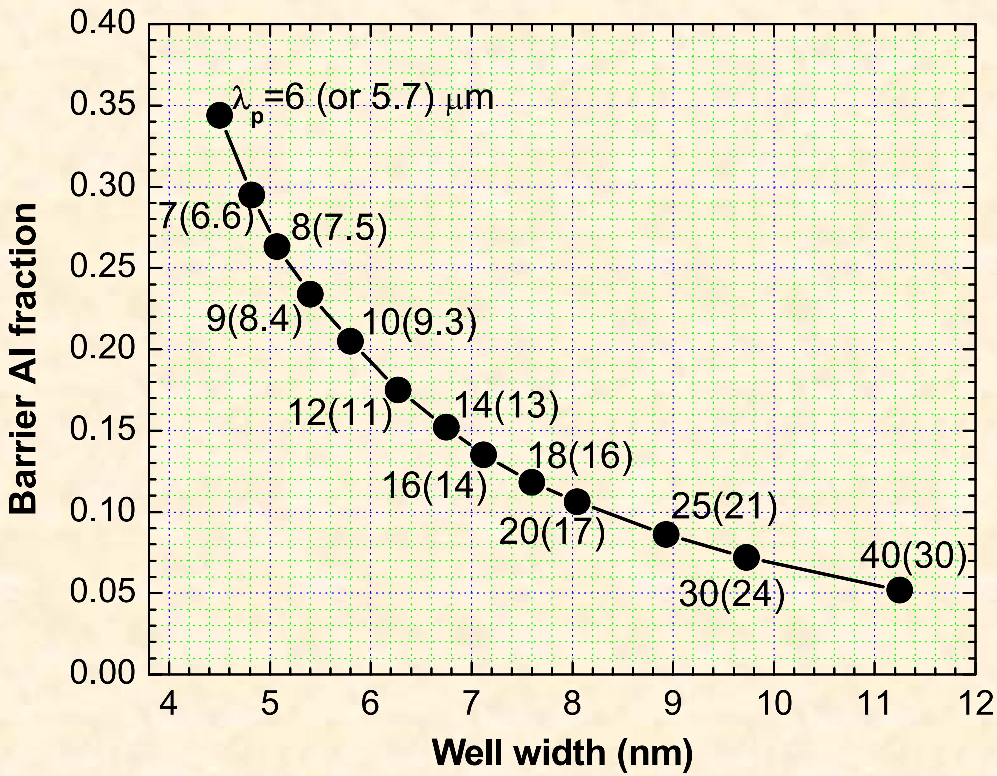


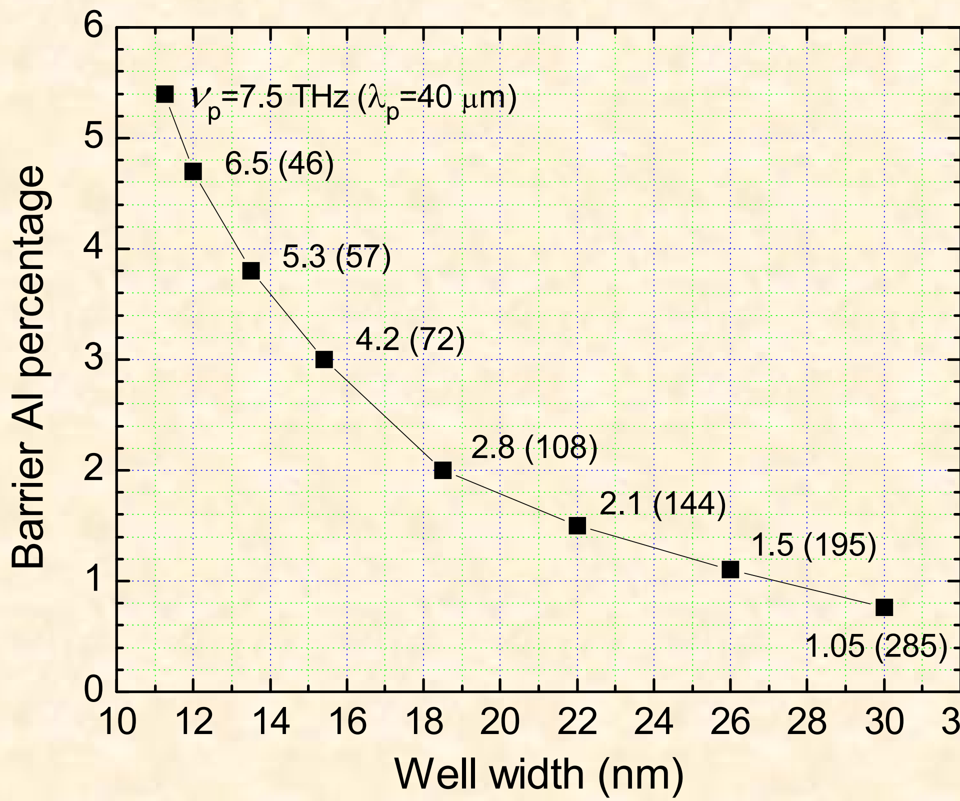
Peak cross-section ~ $(1/n_r m^*)$ $(1/\Delta E)$, for oscillator strength f~1

Basic: QW well design

"Optimal Design"







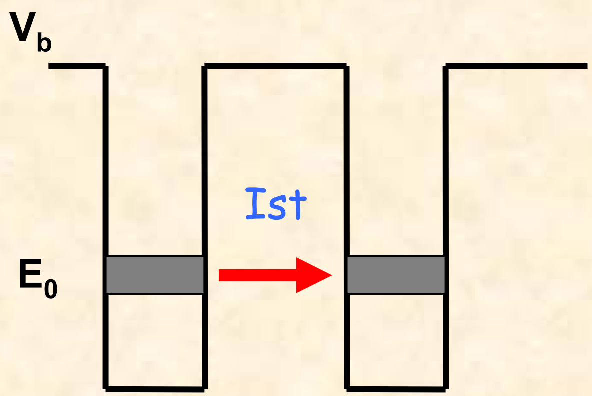
With many body correction:

6.5 -> 8.7 (30%)

3.8 -> 5.7 (40%)

1.9 -> 2.9 (40%)

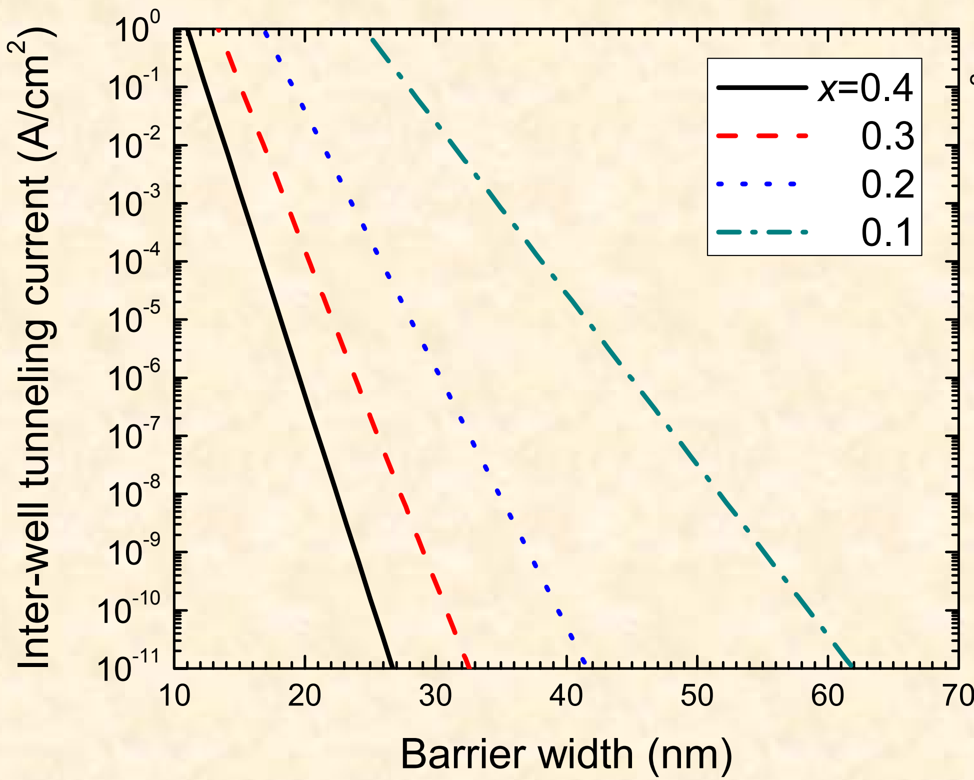
Basic: barrier width determination

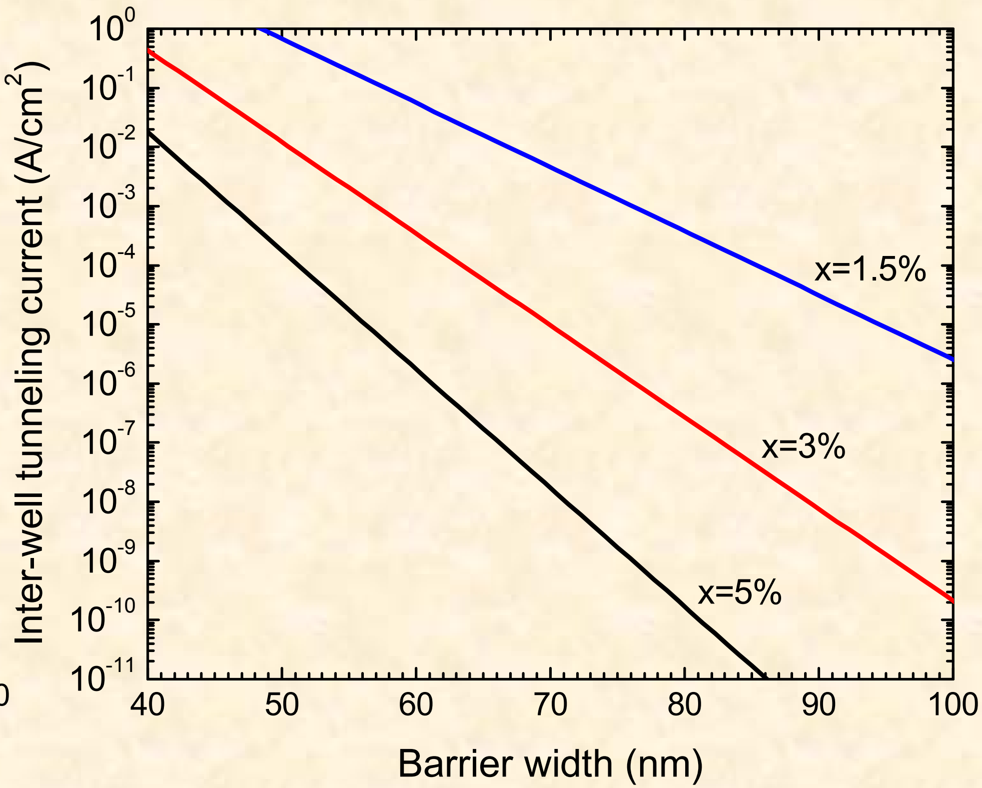


$$j_{st} \sim \frac{qn_{2d}}{\tau_{st}}$$

$$= \frac{qn_{2d}v_0}{L_w}\exp\left\{-\frac{2\sqrt{2m^*(V_b - E_0)}}{\hbar}L_b\right\}$$

$$v_0 = \sqrt{\frac{2E_0}{m^*}}$$

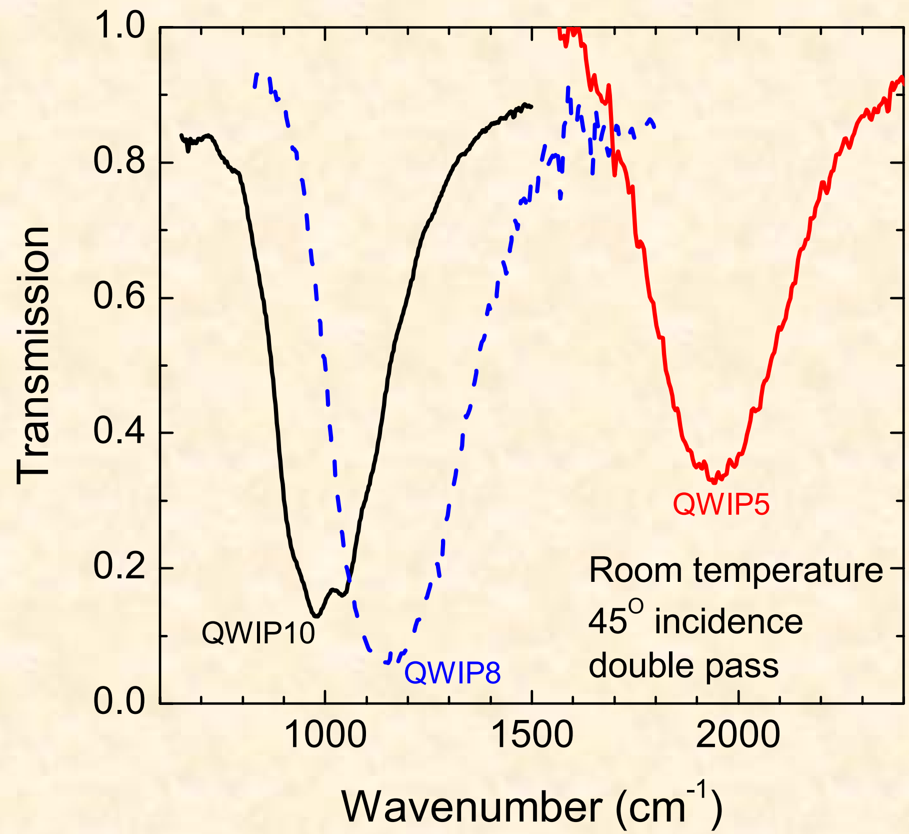




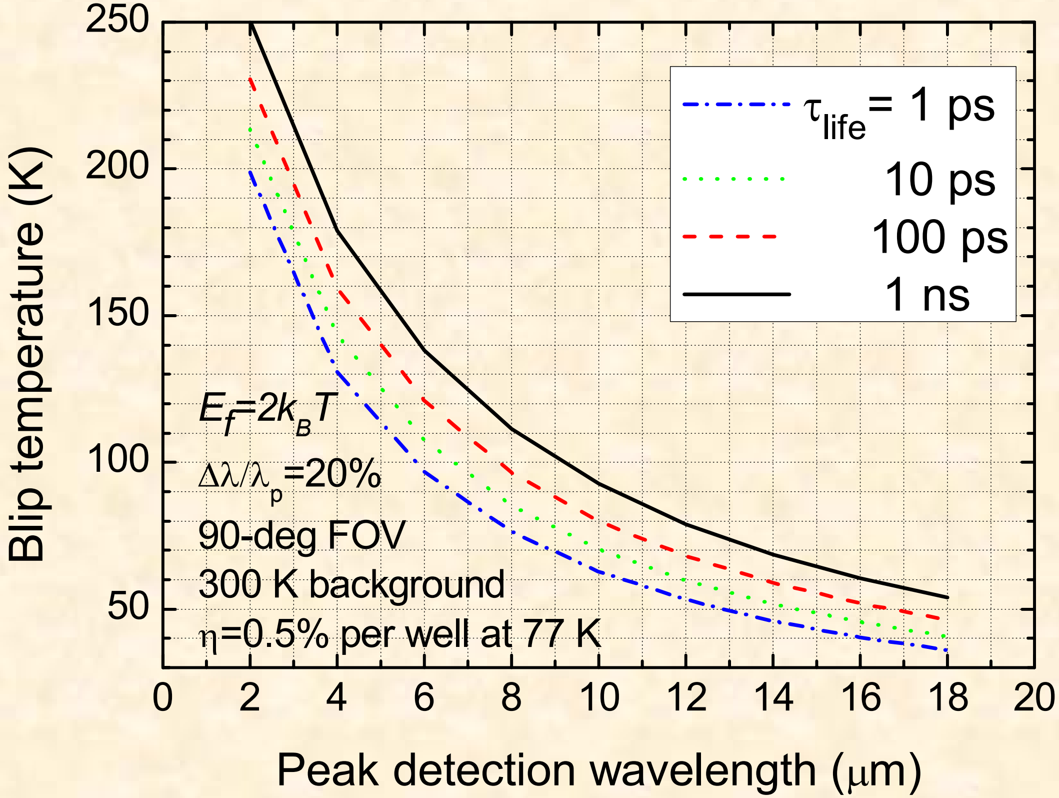
Basic: doping determination

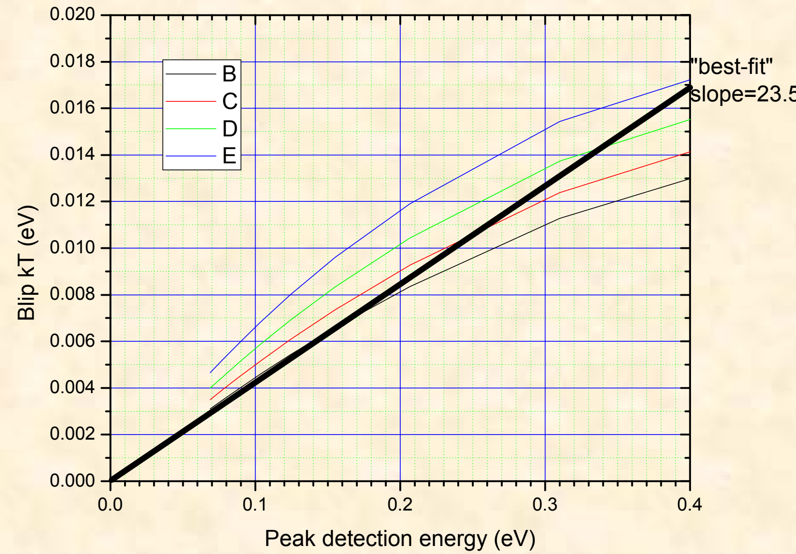
$E_f = 2k_BT$ and $n_{2D} = (m^*/\pi\leftarrow^2)E_f$, where E_f is the Fermi energy, m^* is the effective mass in the well, and T is the operating temperature

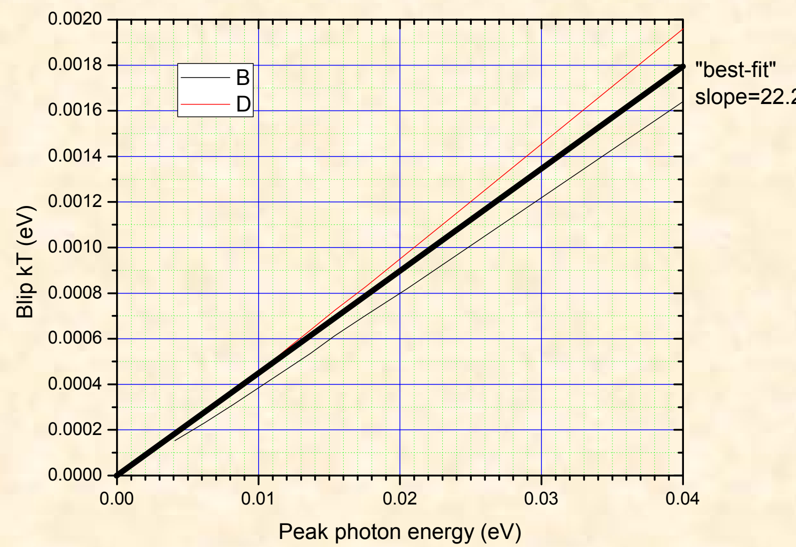
Note: extra cooling capacity buys higher absorption, an example is shown below, 10-μm peaked QWIP with 1E12 cm^{-2} doping and 100 wells gives high absorption, but a 10 K more cooling is needed (Tblip=60 K vs. the typical 70 K).



Basic: temperature







$h\nu_p$ is about 5 times $k_B T$

Basic: number of wells

- The more the better

  But …, see Alexandru