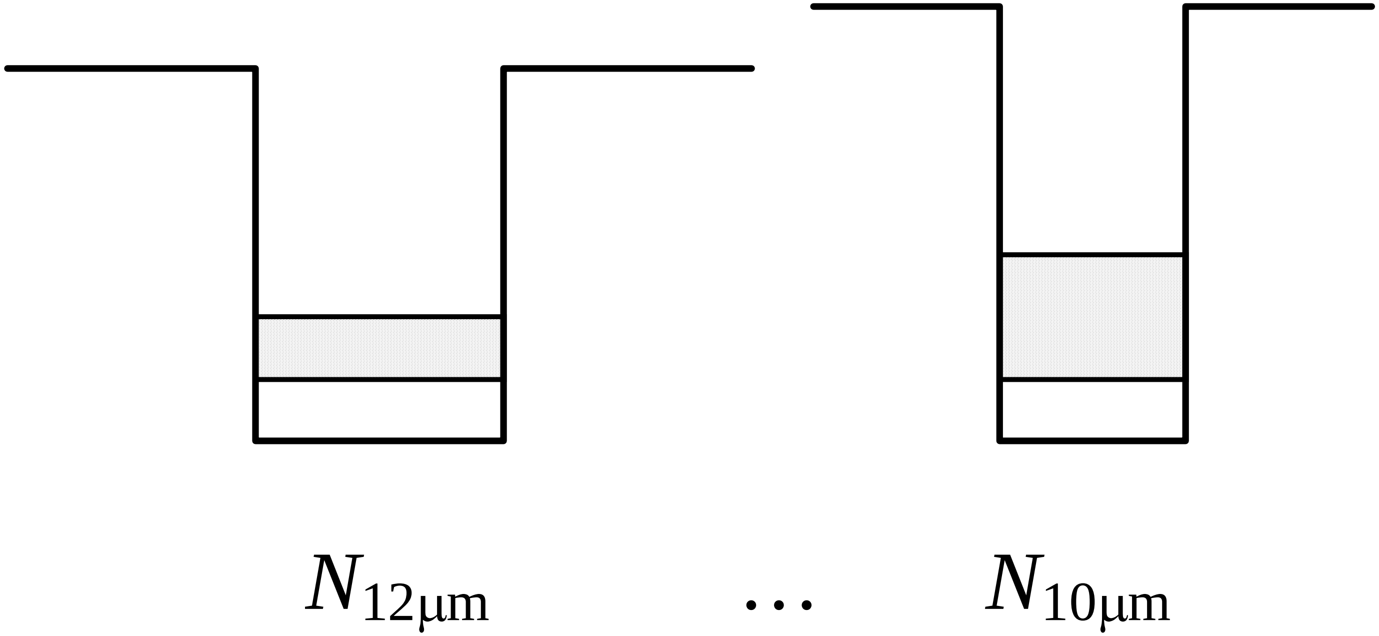
Broadband QWIP Designs

Goals:
Cover wavelength range of 8 – 12 μm (40% $\Delta\lambda/\lambda$)
Tblip >= 50 K (the best predicted case 65 K)
Absorption >= 15%

For maximizing dark current limited D*:
Using $E_f=2k_BT$ and $n_{2D}=(m^*/\pi\leftarrow^2)E_f$, where E_f is the Fermi energy, and m^* is the effective mass in the well.
For GaAs wells, we get: $E_f=8.625$ meV, and $n_{2D}=2.43\text{x}10^{11}$ cm^{-2}.

Design 1: Stacked Design

Two stacks of MQWs separated by 100-nm n^+ GaAs



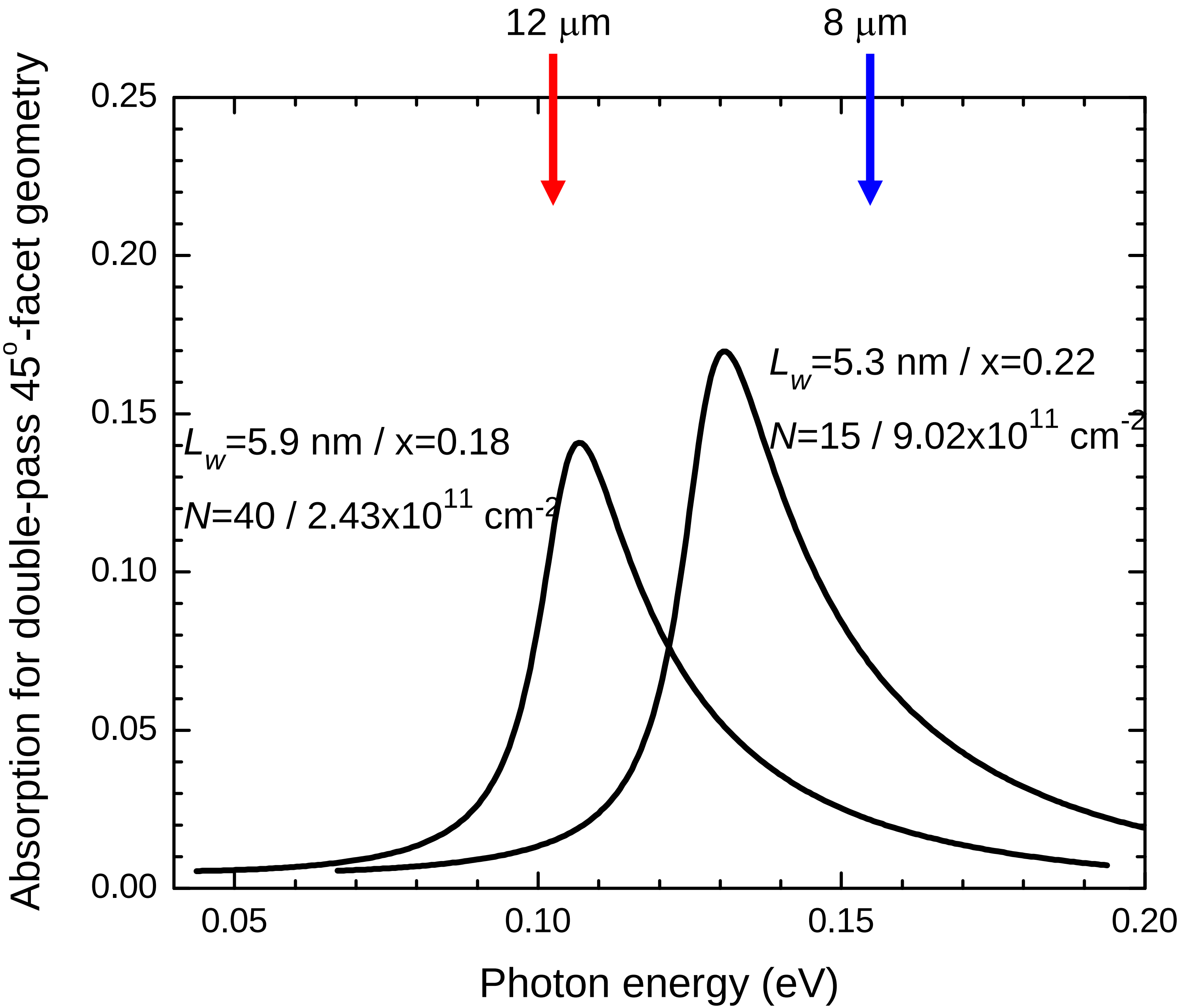
The design is essentially two standard QWIPs in series.
Advantage: responsivity should be similar to standard QWIPs.
Disadvantage: thick structure.

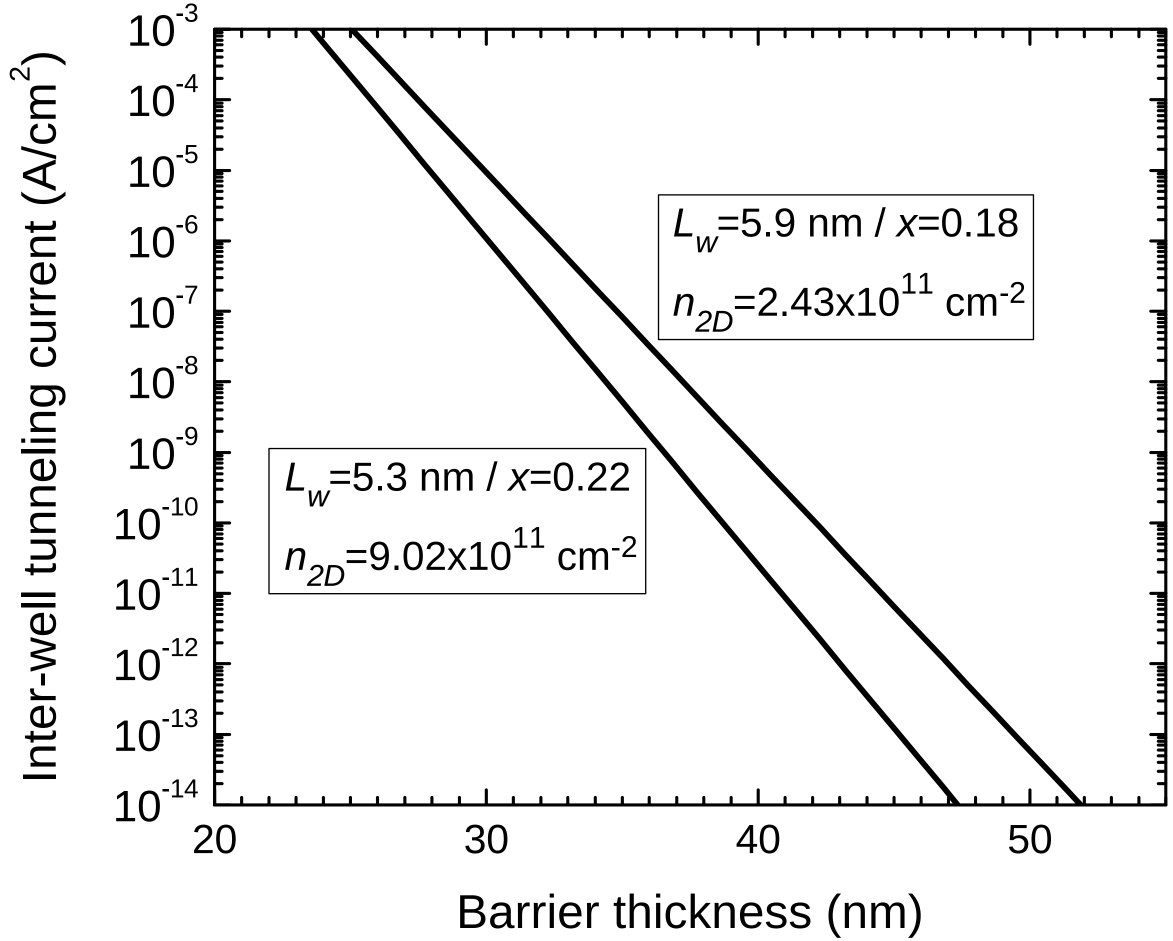
For the 12-μm QWIP,
the GaAs well width is Lw=5.9 nm with AlGaAs barrier Al fraction x=0.18.
As given before, the n-type doping in the well is $n_{2D}=2.43\times10^{11}$ cm^{-2} (Ef=8.625 meV).
For the 10-μm QWIP, Lw=53 nm and x=0.22.

To ensure the same device resistance, the doping in the 10-μm QWIP is increased to 9.02×10^{11} cm^{-2} so that the activation energy is the same.
ΔEf is 23.4 meV. This leads to Ef=8.625+23.4=32.0 meV

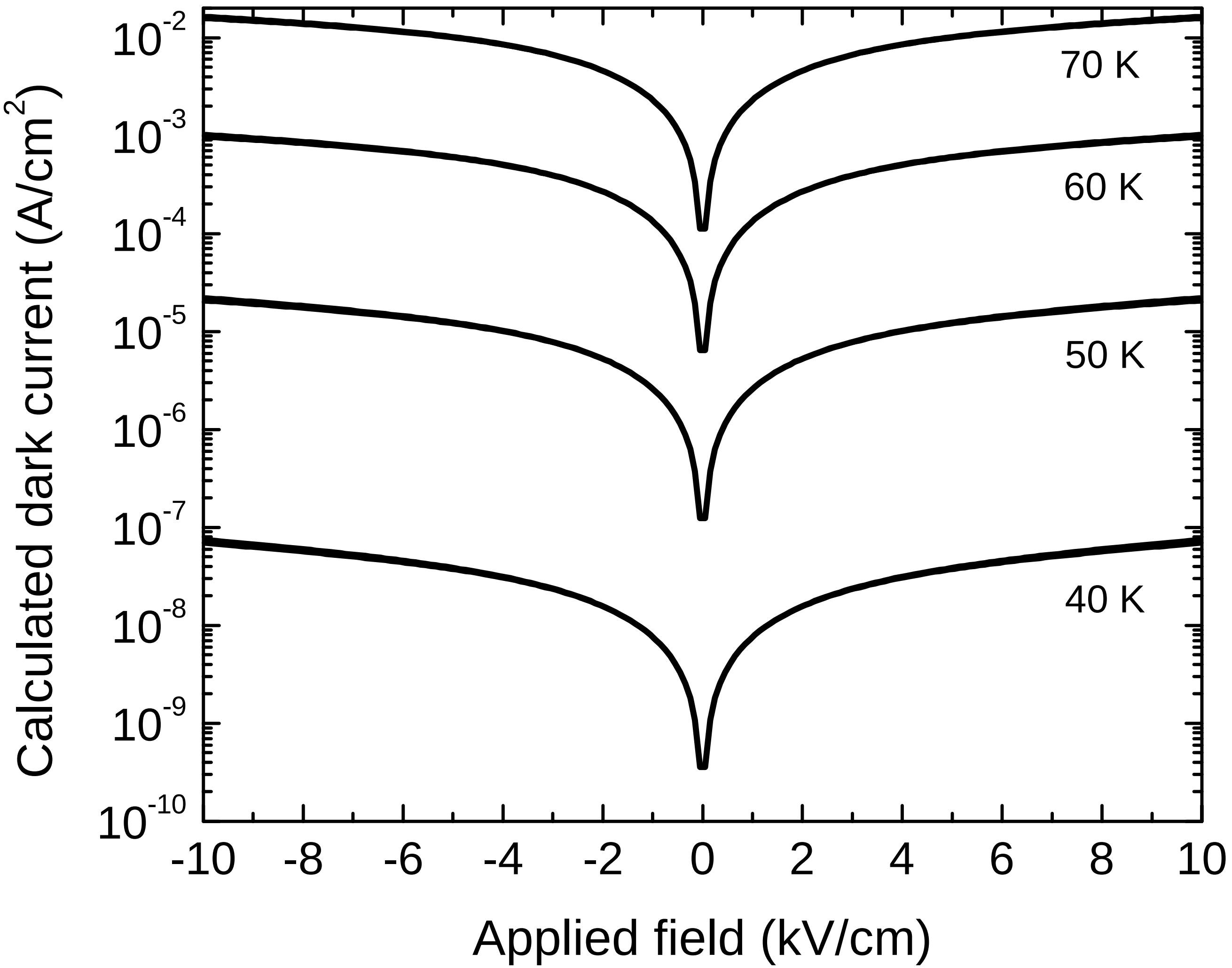
Now since the doping is almost four times higher, more wells are required for the 12-μm QWIP to have an equal absorption, perhaps not as much as 4 times since 12-μm QWIP will have a tail absorption into the 8 – 10 μm region.

Let us take the numbers of wells to be $N_{12\mu m}=40$ and $N_{10\mu m}=15$.

12 μm
8 μm
L_w=5.3 nm / x=0.22
N=15 / 9.02x10^{11} cm^{-2}
L_w=5.9 nm / x=0.18
N=40 / 2.43x10^{11} cm^{-2}
Absorption for double-pass 45^{o}-facet geometry
0.00
0.05
0.10
0.15
0.20
0.25
0.05
0.10
0.15
0.20
Photon energy (eV)



The last parameter is the barrier thickness: A simple estimate can be made of the direct inter-well tunneling current. The background photocurrent for a usual environment (~300 K) is no more than 10^{-5} A/cm^2. To be well on the safe side, we choose the barrier widths Lb=40 and 37 nm for the 12-μm and 10-μm QWIPs, respectively.



Calculated dark currents for both 10 and 12-μm QWIPs, they are identical.

Design 2: Interlaced Design

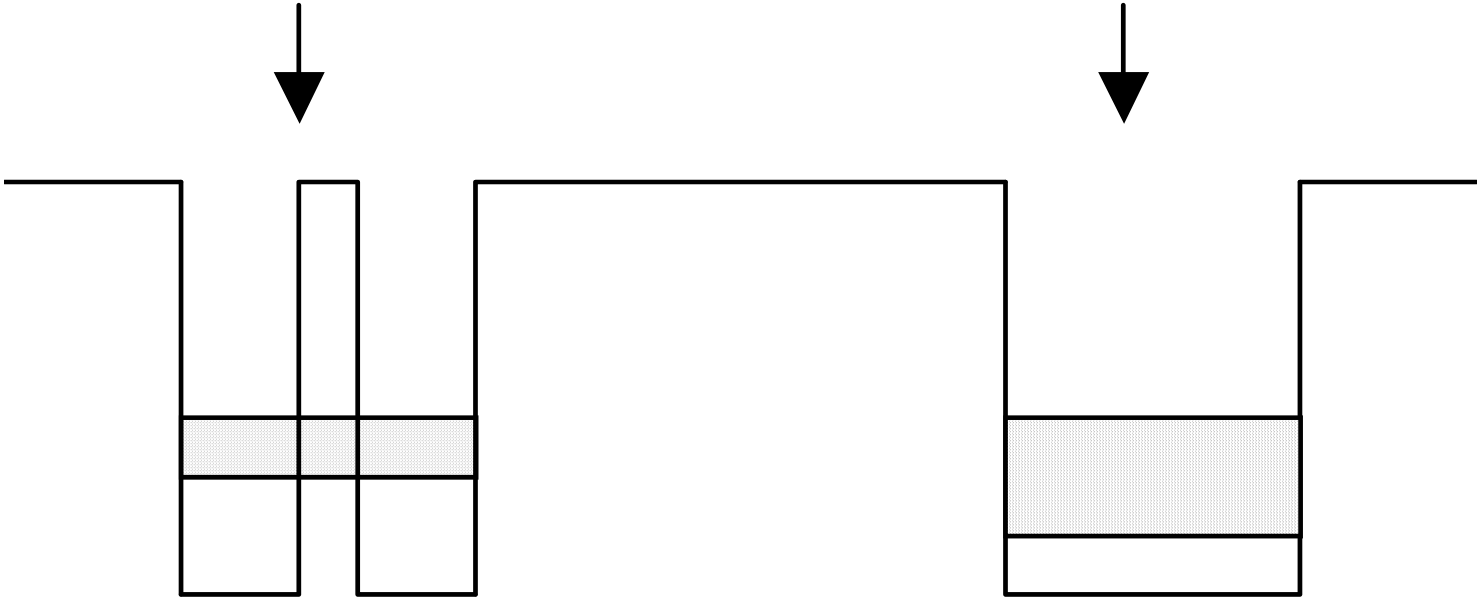
20 10 10 nm

graded x=0.18 – 0.22

This unit is repeated N times

with a few more 12 μm wells throughout

Design 3: Potential inserted Design



12-µm QW

40 nm *x*=0.22

10-µm QW

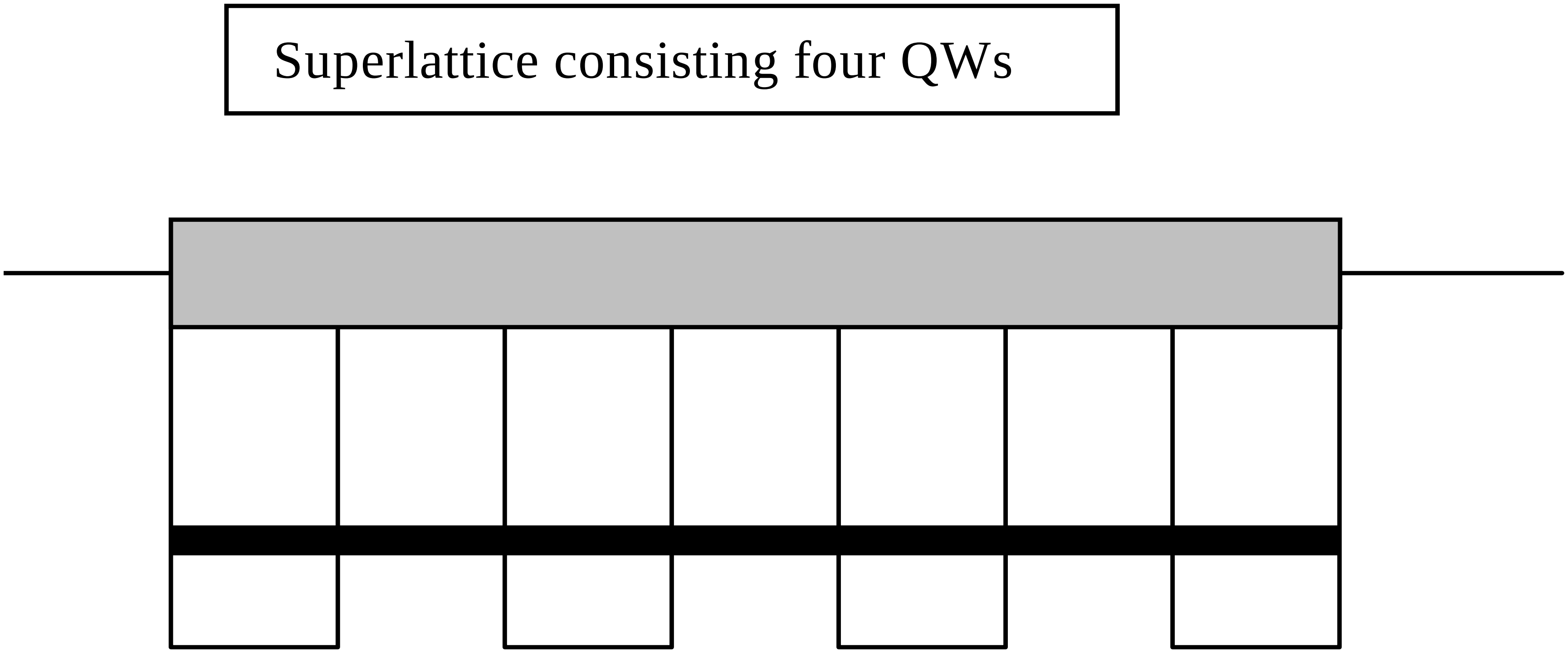
2.3 0.7 2.3 nm

5.3 nm

This unit is repeated N times

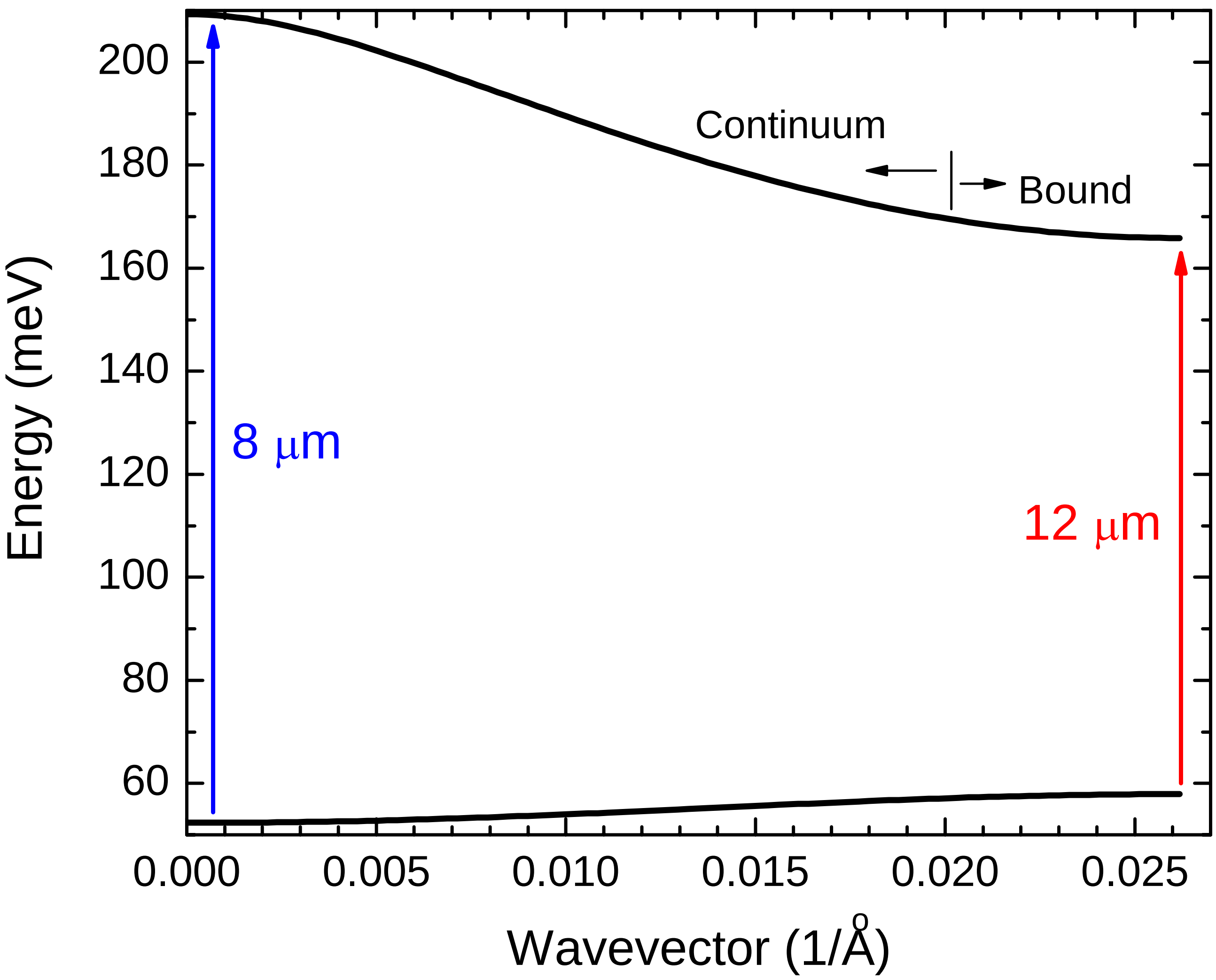
with a few more 12-µm wells throughout

Design 4: Few-period Superlattice Design

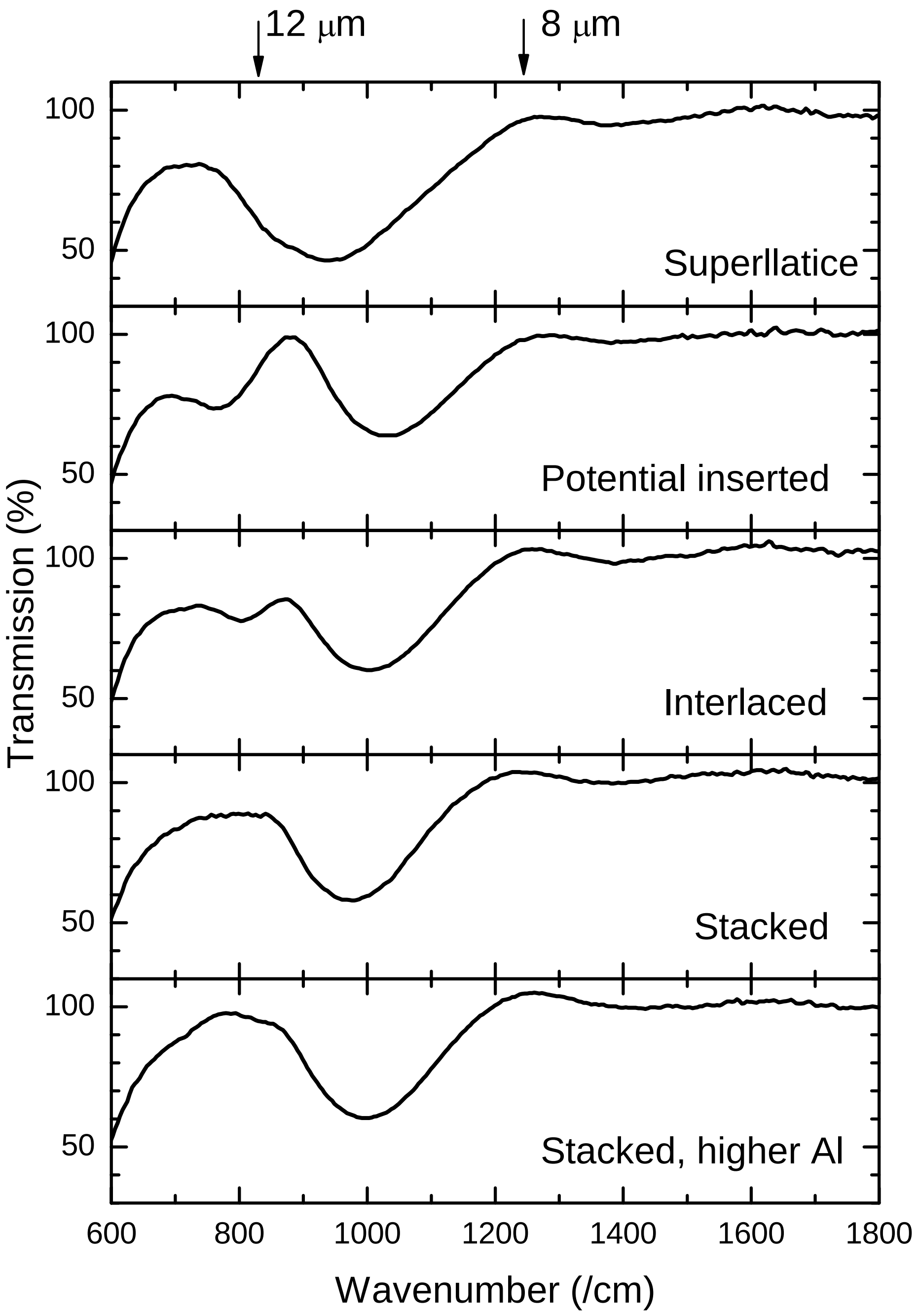


Superlattice consisting four QWs

32 repeats of this unit



Lw/Lb = 5.8/6.2 nm and *x*=0.19



Room temperature, zigzag, 3 bounces

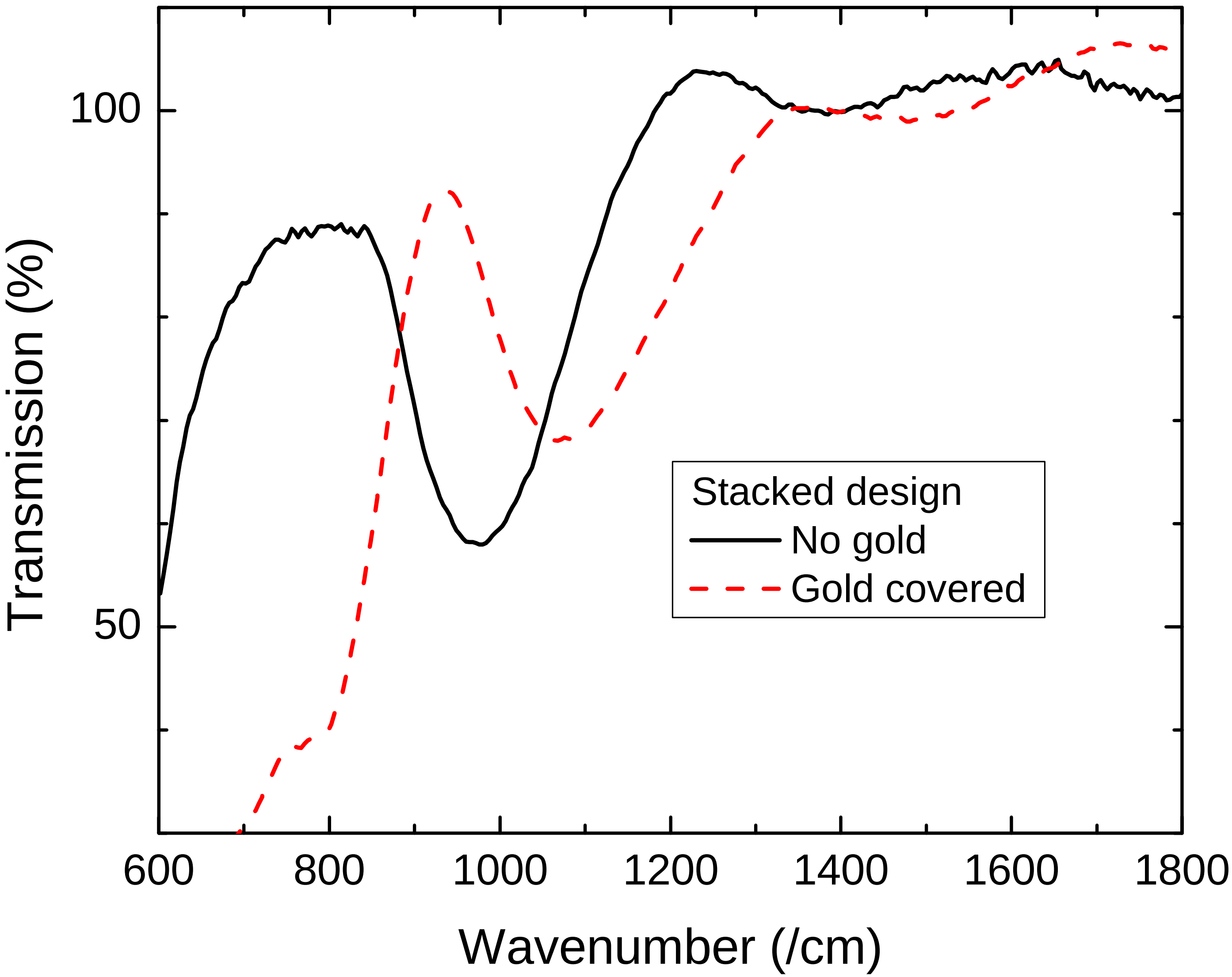
Superlattice: OK, a little broader to 8um side would have been better

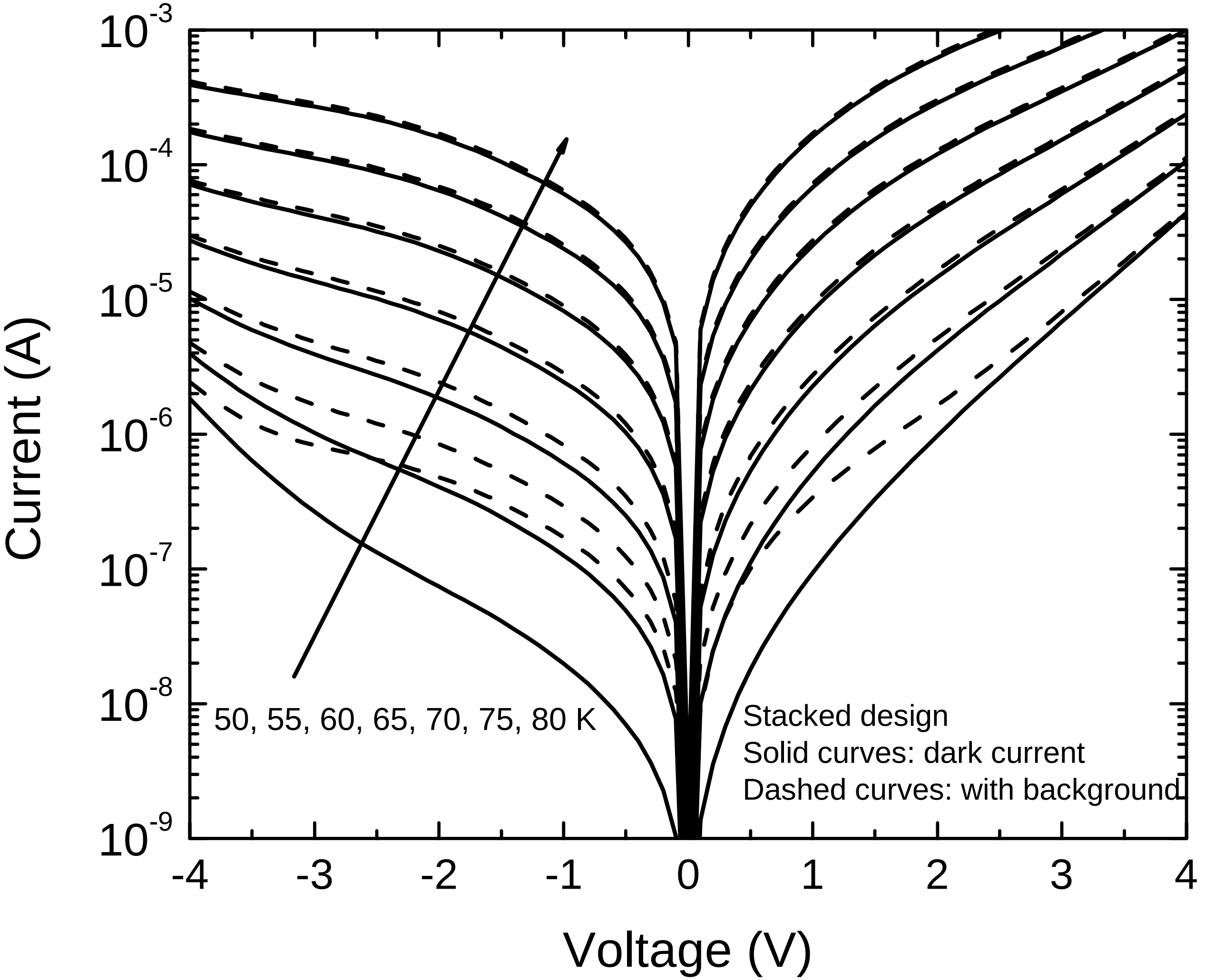
Potential inserted: moving the 12um feature higher would be better, 10um feature is broader due to higher doping

Interlaced: similar to above

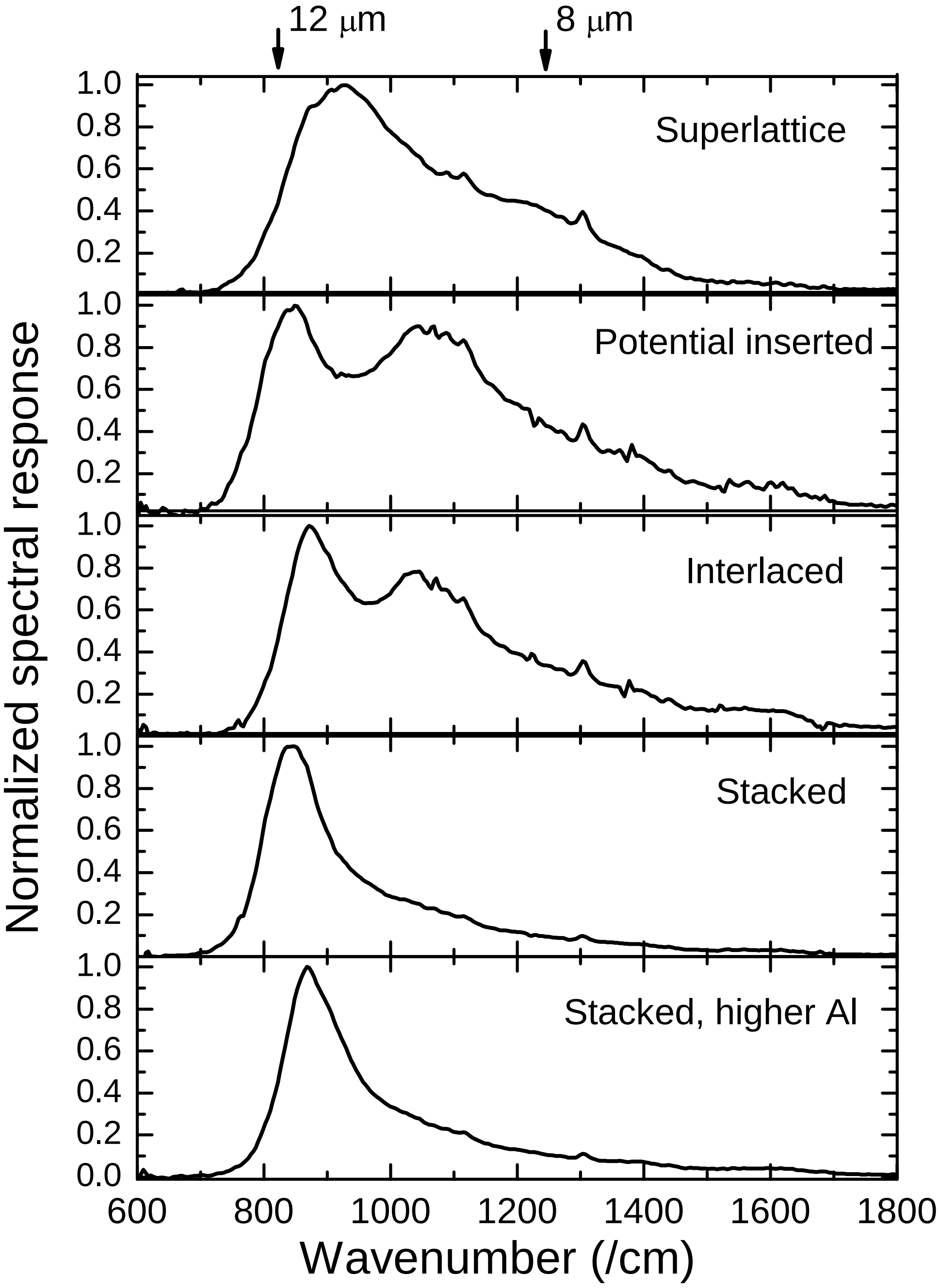
Stacked: grew an extra one with higher Al,
missing 12um absorption !?

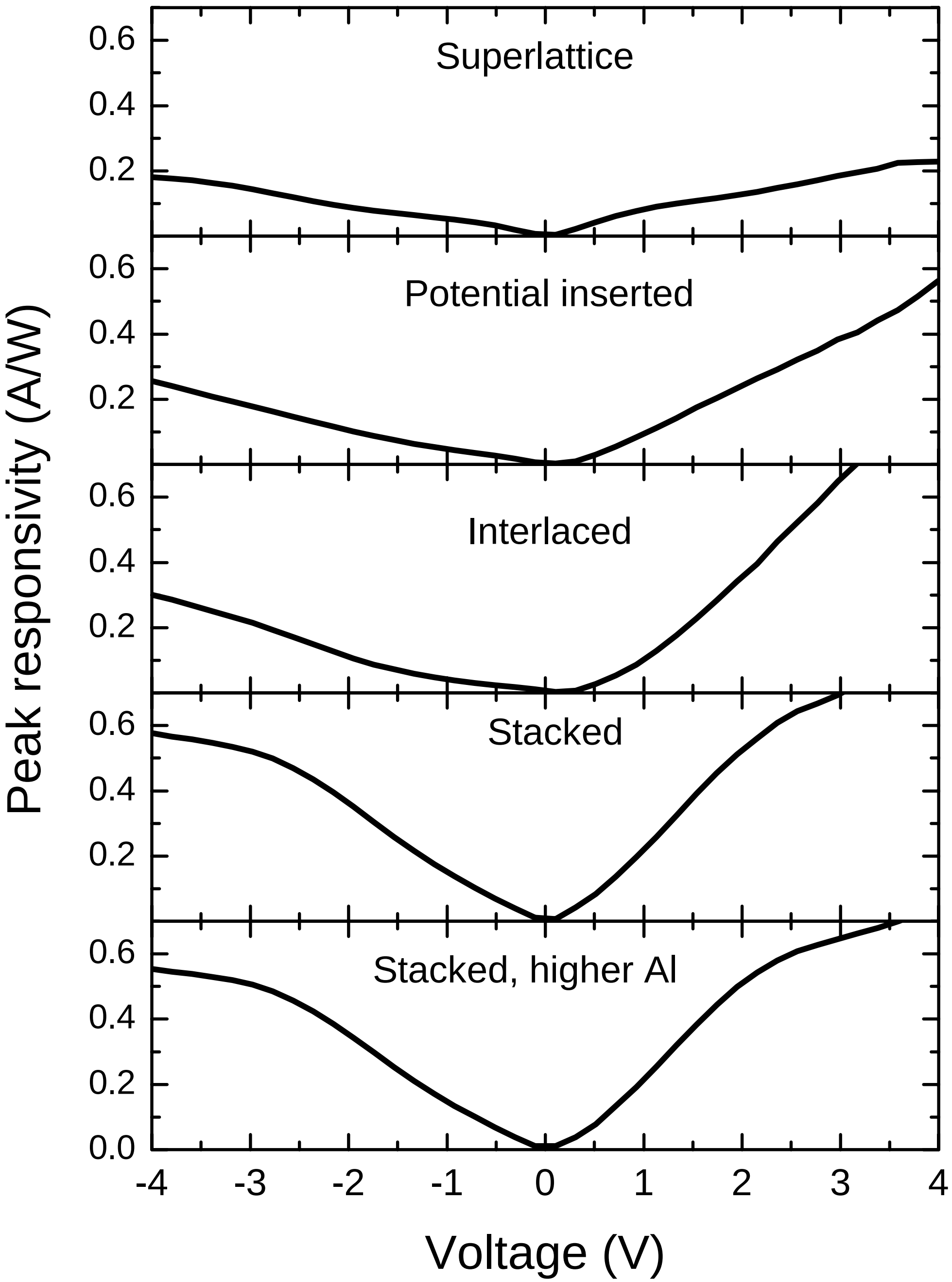
Standing wave effect?





V0280, stacked high Al, -0.5 to -2 V,	58 K
V0281, stacked, -0.5 to -2 V,	55 K (curves above)
V0284, interlaced, -0.5 to -1 V,	60 K
V0286, potential inserted, -0.5 to -1 V,	57 K
V0285, superlattice, -0.5 to -1.5 V,	60 K


12 μm
8 μm
Superlattice
Potential inserted
Interlaced
Stacked
Stacked, higher Al
Normalized spectral response
0.0
0.2
0.4
0.6
0.8
1.0
600
800
1000
1200
1400
1600
1800
Wavenumber (/cm)


Superlattice
Potential inserted
Interlaced
Stacked
Stacked, higher Al
Peak responsivity (A/W)
0.0
0.2
0.4
0.6
Voltage (V)
-4
-3
-2
-1
0
1
2
3
4

Conclusion

- Superlattice, potential inserted, and interlaced designs met expectation
- Stacked design has difficulties