Wavelength Conversion and All-Optical Switching in QCL's.

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Outline

*Device Design.

*Materials Considerations.

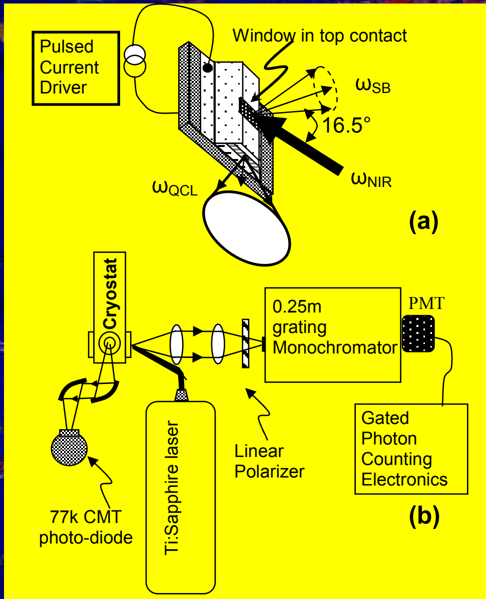
*Frequency mixing experiments.

* THz laser results.

*All-optical switching.

*Concluding Remarks.

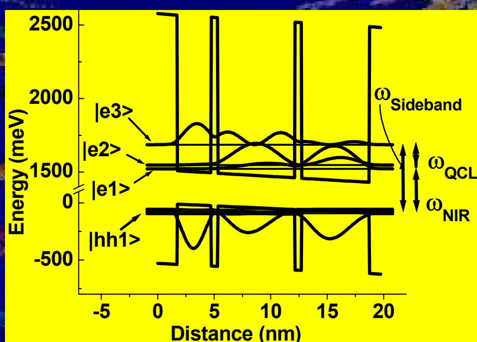
Device Design

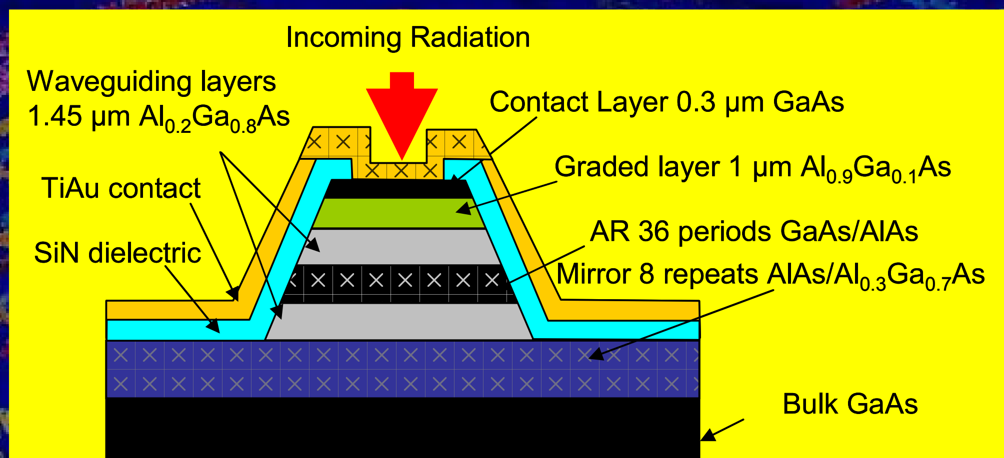


*Standard (-ish) QCL with window in top contact

* Needs cladding layers transparent to bandgap radiation

* Needs DBR for reflective mode experiments.





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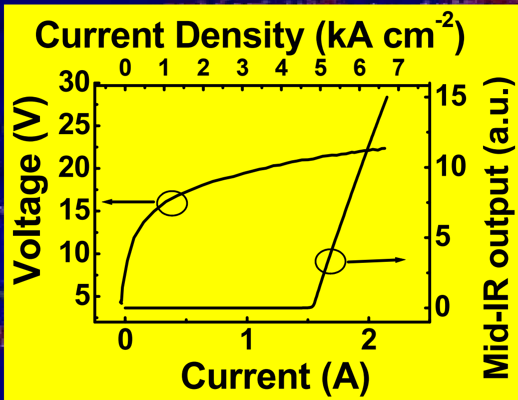
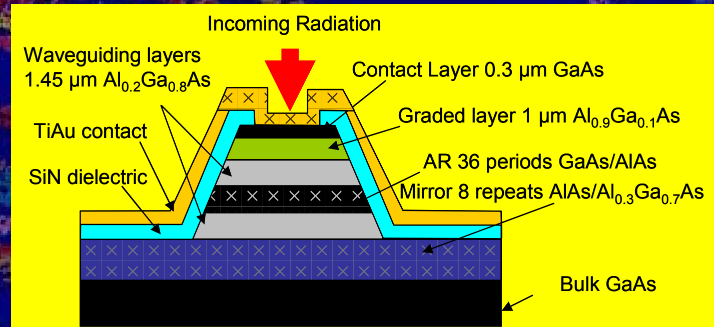
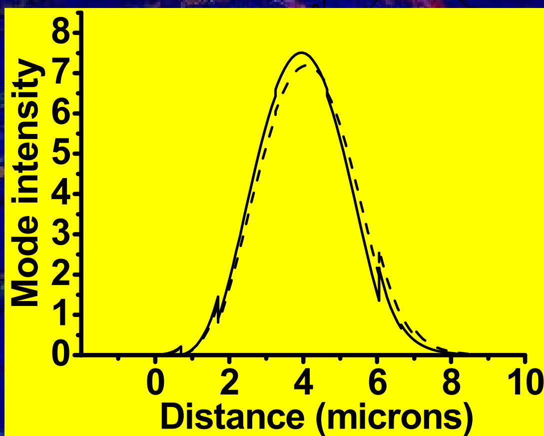
Materials Issues







*Lots of Al, but electrically stable.

* J_{Th} indistinguishable from devices without holes or DBR's

* DBR looks much like cladding to the QCL mode.

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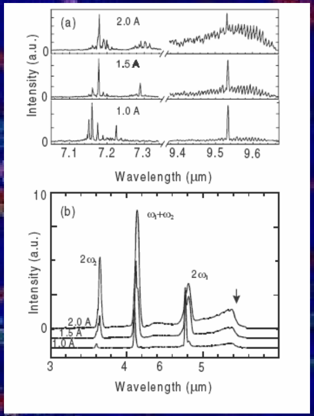
Non-linear optics for new wavelengths

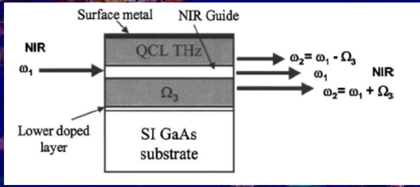
*QCL cavities have high radiation density and the intrinsic $\chi(2)$ of III-V's.

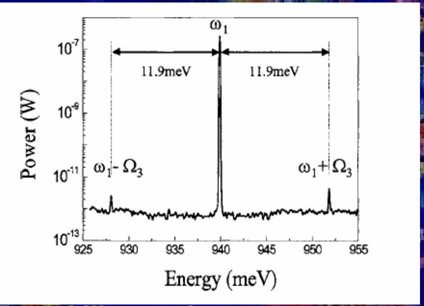
*Artificial resonances can be designed-in.

*Designable dispersion for phase matching.

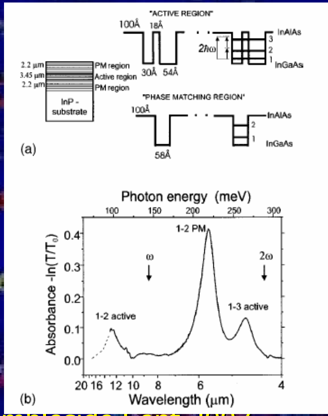


N Owschinikow et al. PRL, 90 (4), 043902-1 (2003).

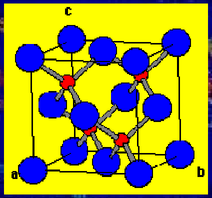


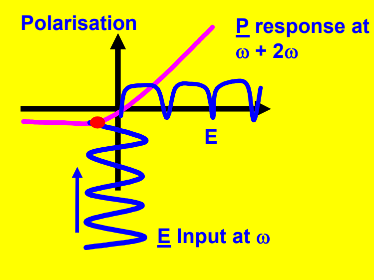


S S Dhillon et al. APL 87, 071101 (2005).



K L Vodopyanov et al. APL 72(21), 2654 (1998).





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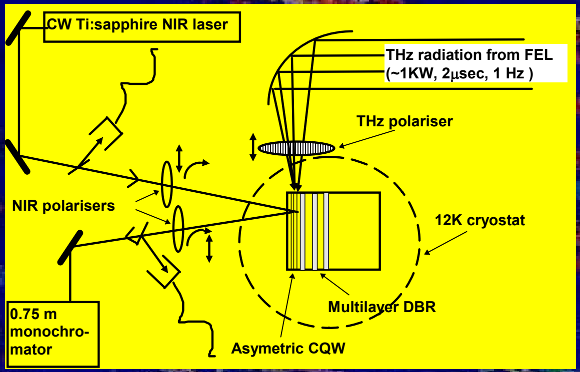
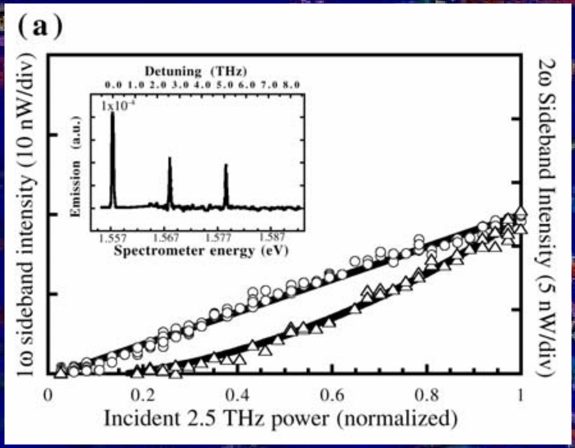
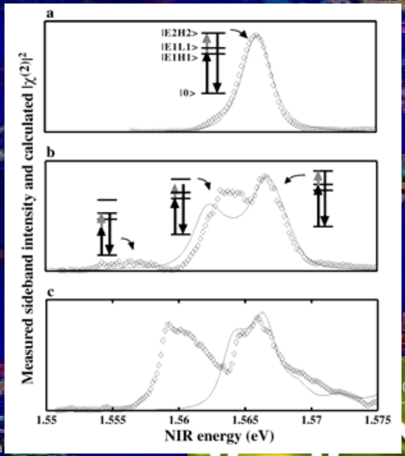
Earlier FEL Experiments.





- *Easy phase-matching.
- *Polarisation insensitive.
- *Broad bandwidth.
- *telecomms λ's



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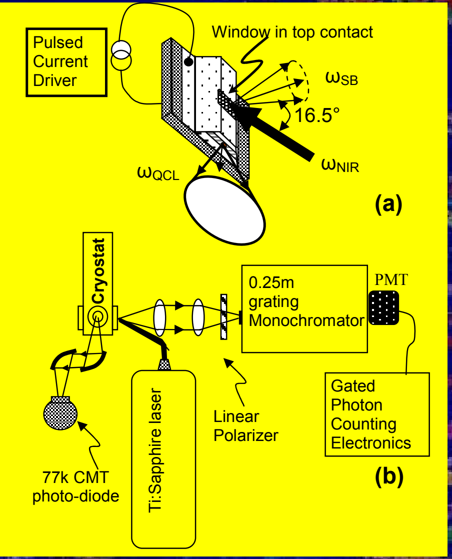
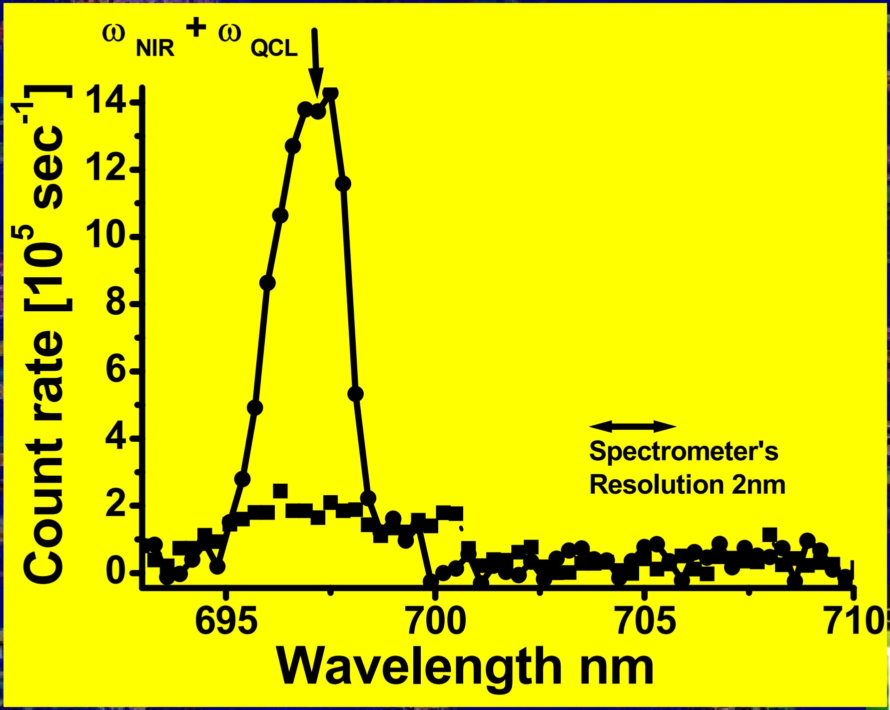
Sideband spectra.



*Gated measurement.



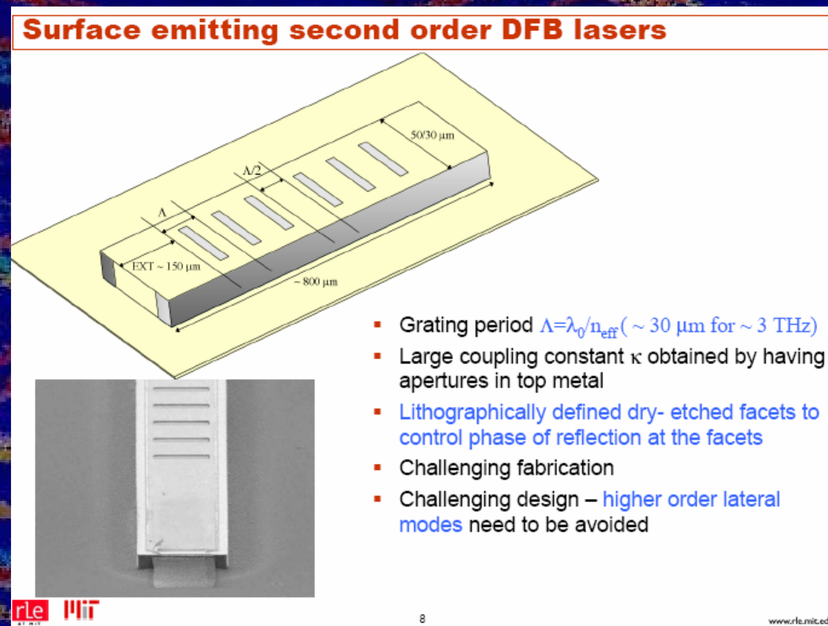
THz lasers

*$\Delta\lambda/\lambda$ ~ 1%

*Closer to DWFM applications.

*Tunes over wide frequency range.

*Polarisation insensitive.

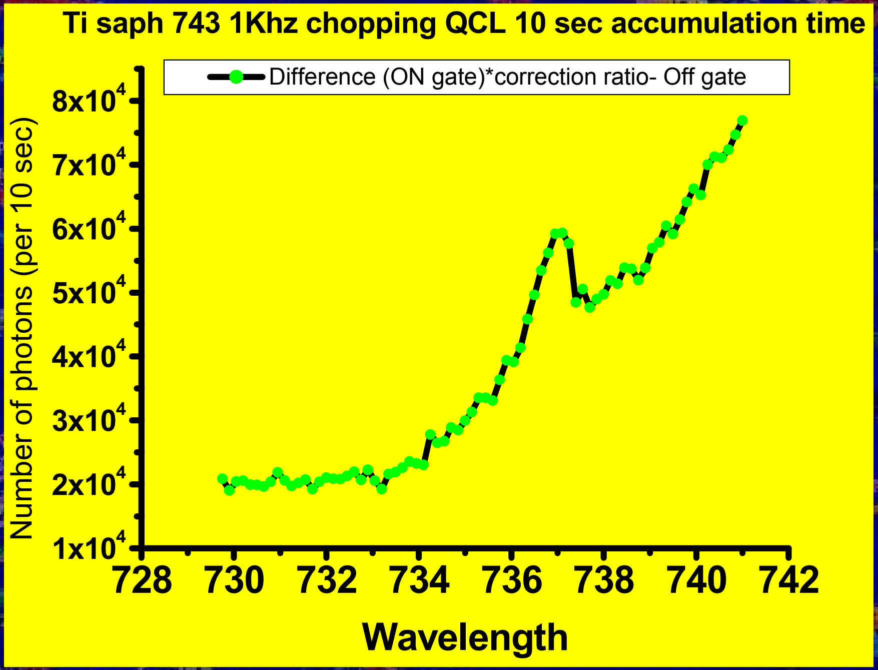


Sideband generation in THz lasers

*$\Delta\lambda/\lambda$ ~ 1%

*Sideband has right polarisation dependence

*Tunes over wide frequency range.

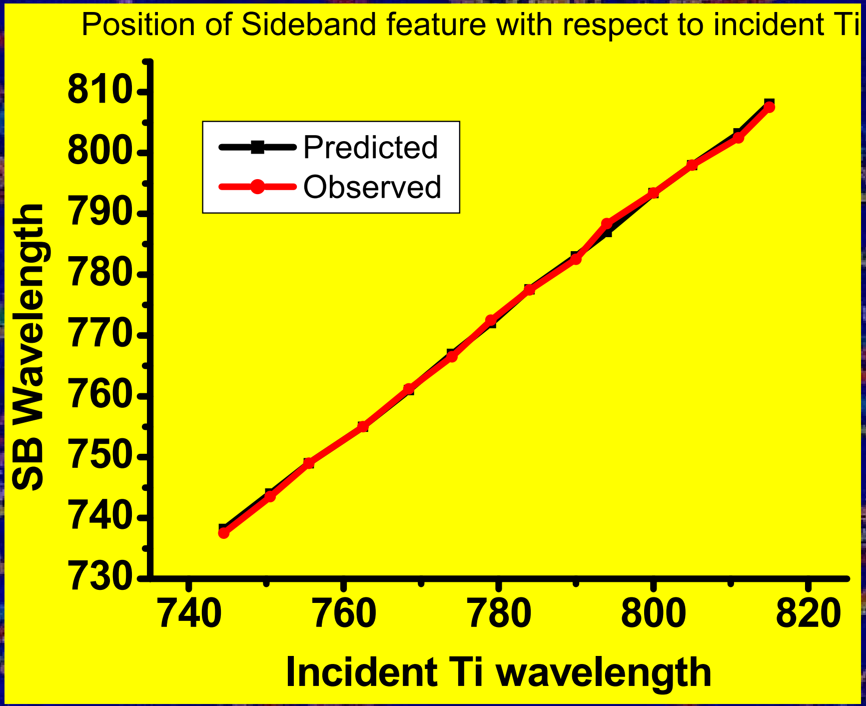


Sideband tracks with incident wavelength.

*$\Delta\lambda/\lambda \sim 1\%$

*Sideband has right energy dependence

*Tunes over wide frequency range.

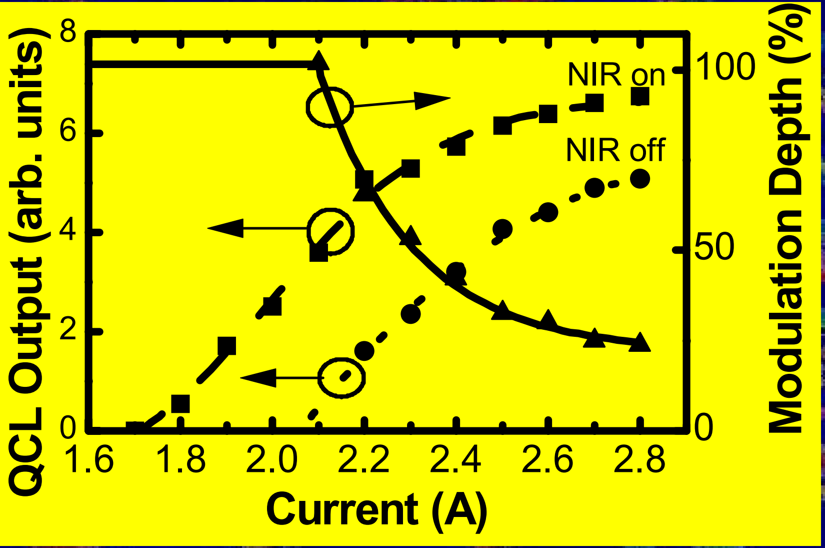


All-optical switching.

*Seen only in 25% Al samples.

*QCL J_{th} lowers when Bandgap radiation is applied.

*100% modulation depth possible @ ~ 50% of Max QCL o/p power.



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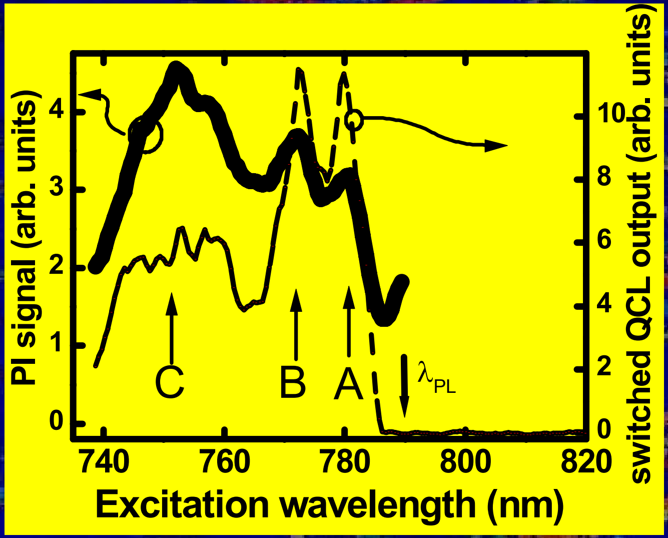
Spectral Dependence.

*Follows same spectral sensitivity as Active region PLE

*QCL J_{th} lowers when Bandgap radiation is applied.

*Implies switching effect originates with photoexcitation in AR.



Switching dynamics.

*Even with PRF down to 200Hz, switching intensity is independent of pulse timings (!)

* Applying 10 nsec / 120 mW asynchronous pulses, need 13 to switch device for PRF’s 10Hz-> 10kHz (!)

*Current pulse “resets” memory of NIR illumination.

*Re-timing function for telecomms.

Switching Mechanism?

*Switching fluence 6 x 10^{10} photons, i.e ~ 2 x electrons flowing in the 100 nsec J pulse.

* Could be J enhancement, but how come the long memory?

*Of 0, 10, 20, 25% Al clad devices , only 25% ones switched.

*Everything was below ~120K anyway

Two possibilities

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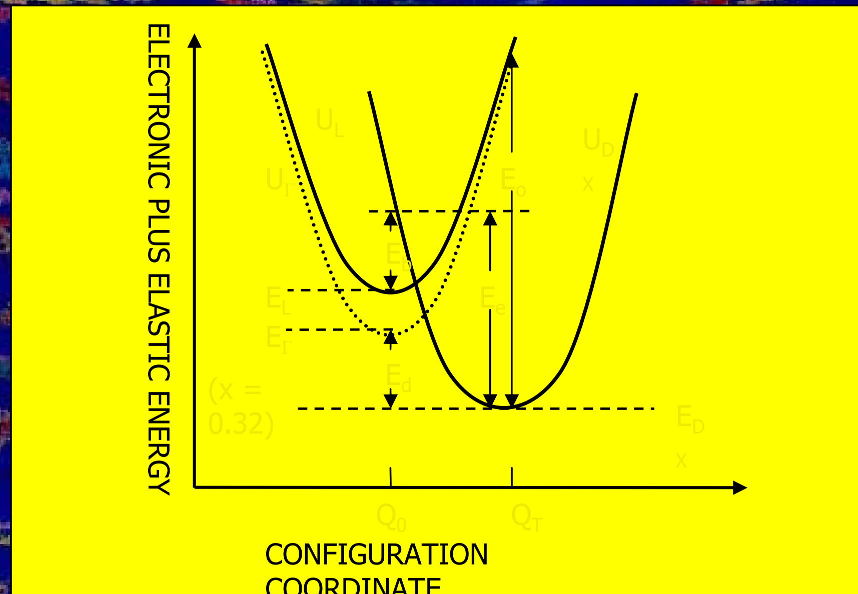
DX centres in AlGaAs

* $\sim 10^{9}$ donors under window

* Could hold ~ ½% of switching charge

* Would be field ionised by J pulse, with long recapture time?

* Known to appear only at low T and x > 22%



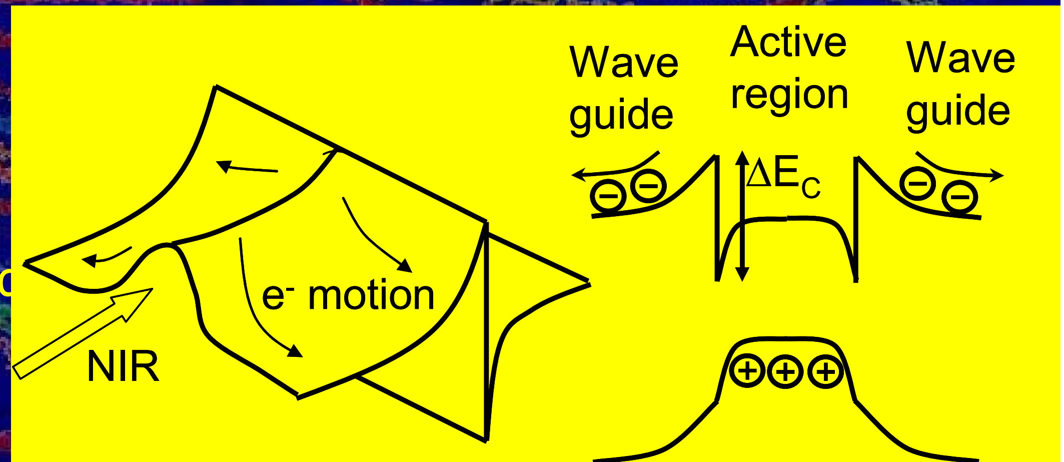
Charge separation at heterojunction

* Barrier only present for X~ 20% in clad

* Needs "giant ambipolar" diffusion mechanism* to spread charge.

* Would work at high T and in InGaAs.

* Watch this space….



* See K H Gulden et al. PRL 66, 373 (1991).

Concluding remarks

* NL frequency mixing demonstrated

*Electronically modulatable two-terminal device for a variety of telecoms functions. (add-drop, packet switching, high bandwidth, data transparent conversion etc.)

* Principles transferable to telecomms wavelengths.

* That elusive “killer application” for QCL’s?