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Thresholdless THz Lasing from a Semiconductor Nanostructure in a Strongly-Coupled Plasmonic Microcavity.

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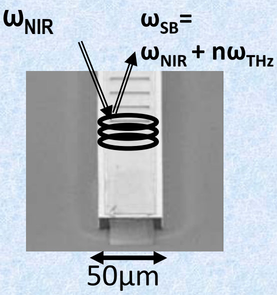
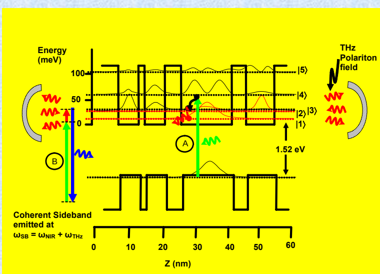
Introduction

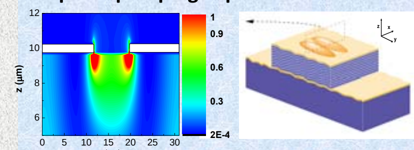
- ~3THz/λ~100μm QCL MQW heterostructure.
- "Plasmonic" metal-semiconductor-metal (MSM) waveguide.
- Slots in upper surface were originally designed to outcouple THz radiation but also support highly localised THz modes

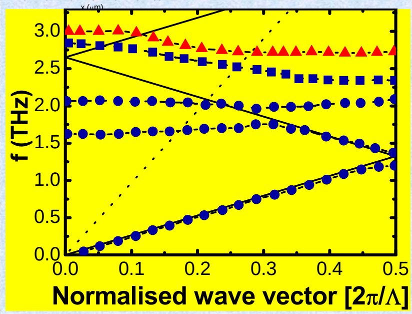




- $|2\rangle \Rightarrow |1\rangle$ *ISBT* is resonant with tightly coupled THz mode.
- Tiny mode volume (~ $\lambda^3/50$) gives coupling energy $\hbar\Omega_{VR} = 2Ee\, z_{12}\, N^{1/2} \sim 1.0$ meV .
- Electron-photon coupling energy gets us into "Strong-Coupling" regime, excitations are "polaritons", i.e. hybridised light-matter states.
- When polaritons are excited, energy can *Only* leave system as light. ("Inversionless Laser")

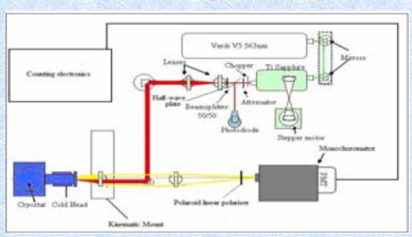
- Radiating mode (blue squares) has low Q~57.
- Localised mode (red triangles) has almost same energy, but Q~1100.
- Shallow "depth" of localised mode (~1μm) is well suited to interband optical pumping experiments.



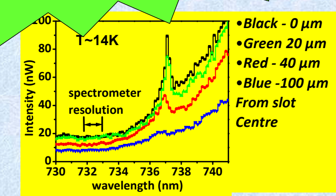


Experiment: Illuminate Slot at near normal incidence with tightly focused and frequency stable (but tuneable) beam from Ti:sapphire laser. Analyse the backscattered spectrum using a spectrometer with gated photon-counting

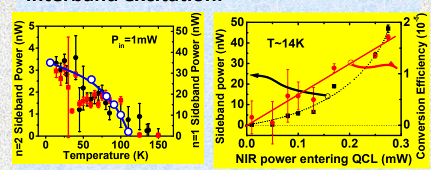
Experimental Set Up



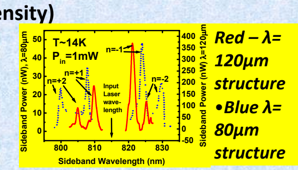
Backscattered spectra contain astonishingly sharp coherent "Sidebands" [SB's] at $\omega_{SB} = \omega_{NIR} + n\omega_{THz}$ (n=-2,-1,0,+1+2)!

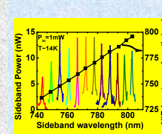


- SB's appear only when the laser spot hits slot opening and when TI:saph photon energy is high enough to create ISBT polaritons by interband excitation.

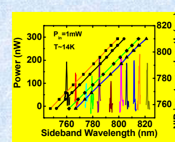


- SB's disappear at T ~120K, [like in THz QCL's] and the conversion efficiency is ∝ (ISBT polariton density)





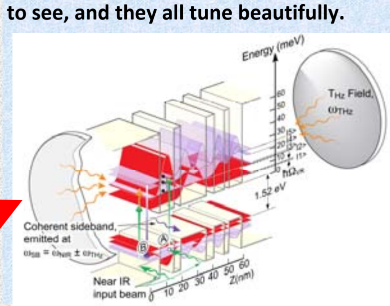
Tuning the n=1 SB on the λ= 120μm structure



n=2 spectra and tuning curves for all 4 SB's λ= 80μm structure

Higher (n = ± 2) order processes are easy to see, and they all tune beautifully.

- Summary.
- Plasmonic" cavity give strong Thz Mode compression, and SC polaritonic system
  - Unique geometry allows polaritons to be created by incoherent interband optical excitation
  - Radiative component of polariton state coherently mixes, (via the $X^{(2)}$ and $X^{(3)}$ GaAs optical non-linearity) with the same near-IR input beam, to generate "optical-heterodyne" SB's with unprecedently high efficiency
  - Could be used as a passive wavelength converter for telecoms (in InGaAs/AlInAs materials system]
  - Probably/possibly an instance of "thresholdless lasing", but v. weak out-coupling of THz and poor detectors makes it extremely difficult to verify directly just yet.



Johannes Gambari, Antonio I Fernandez-Dominguez, Stefan A Maier, Ben S Williams, Sushil Kumar, John L Reno, Qing Hu and Chris C Phillips "Thresholdless Coherent Light Scattering from Subband-polaritons in a Strongly-Coupled Microcavity."Phys. Rev B. (Rapid Comms). 121303-1 [2010]

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