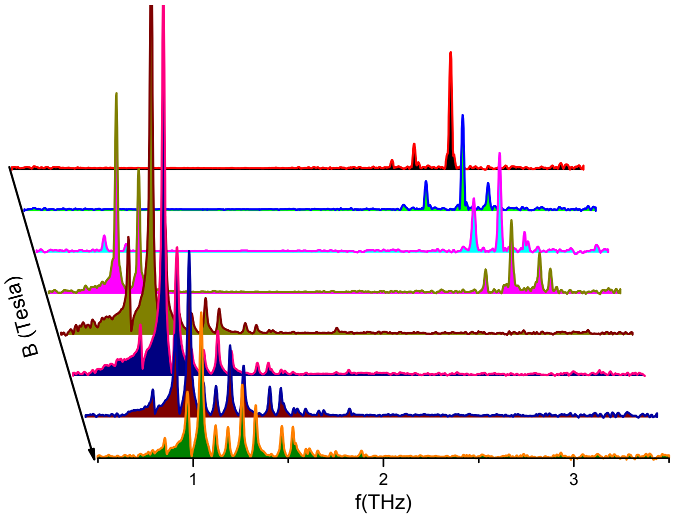
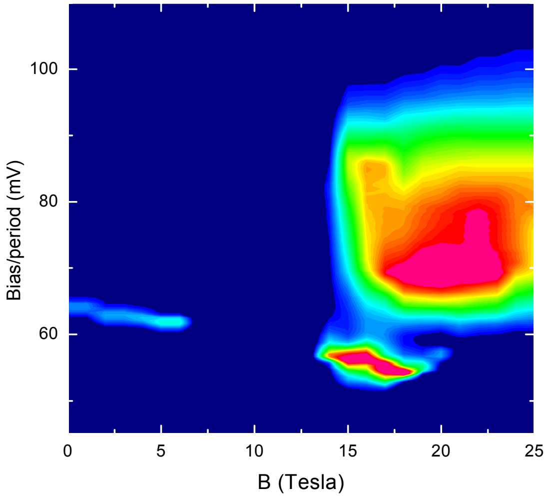
Strong, magnetic field controlled sub-THz multi-wavelength emission in a Quantum Cascade Laser

Aaron Wade





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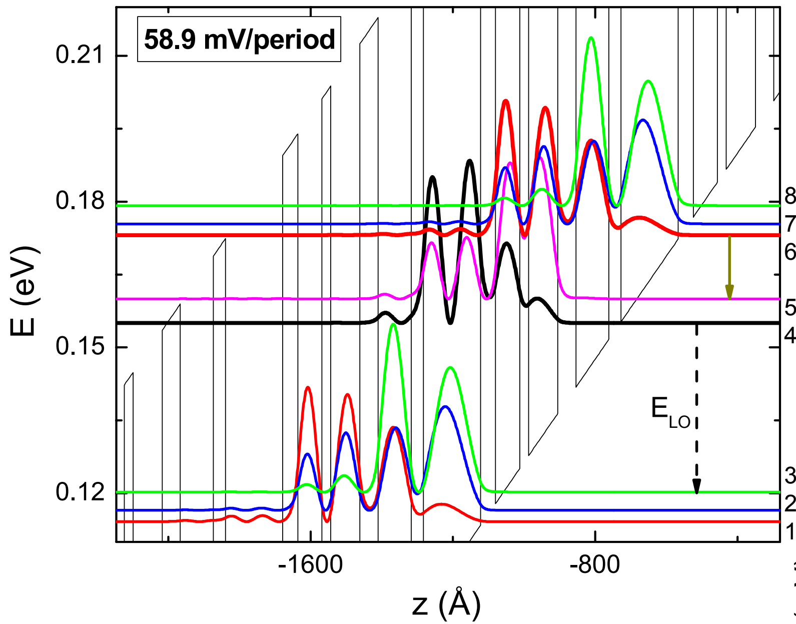
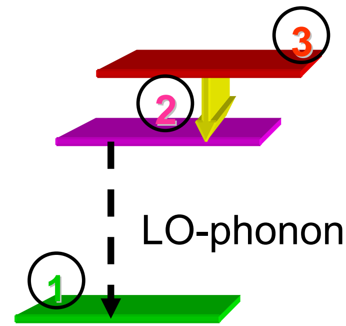
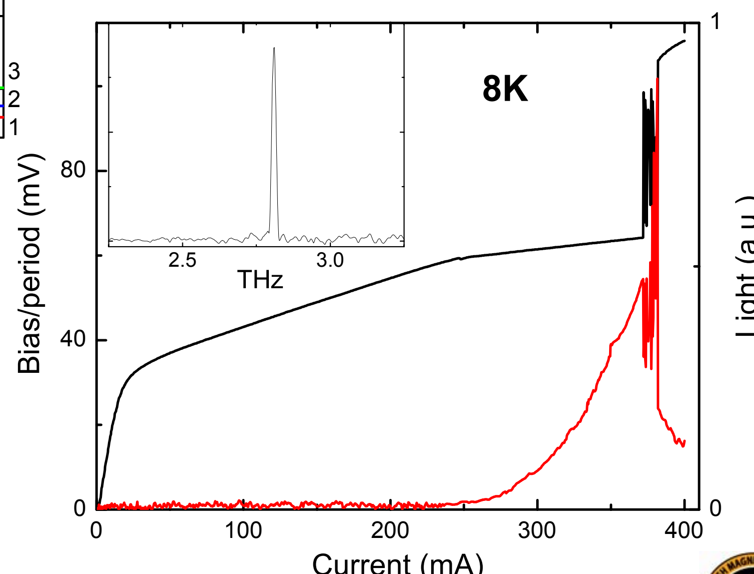
B.S. Williams, Sushil Kumar, Q. Hu (MIT)

Massachusetts
Institute of
Technology

Samples







178 period GaAs/Al$_{.15}$Ga$_{.85}$As THz QCL

Designed by: MIT

B. S. Williams et al. APL **82**, 1015 (2003)

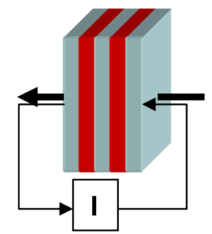
Why Magnetic Fields?

B-field breaks the continuum in discrete Landau Levels

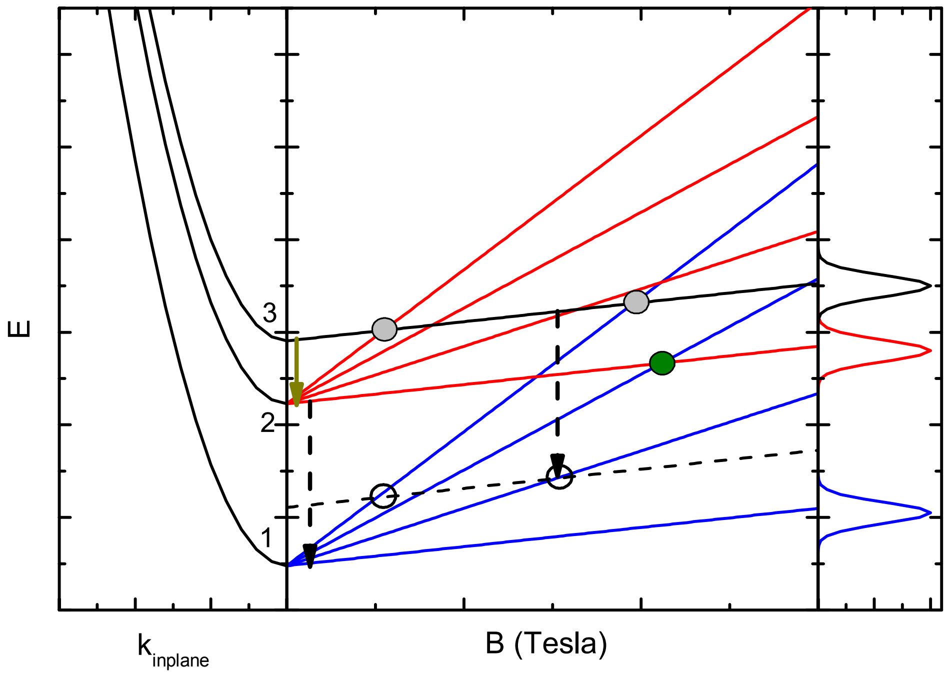
$$E_{n,p} = E_n + \left(p + \frac{1}{2} \right) \hbar \omega_c$$

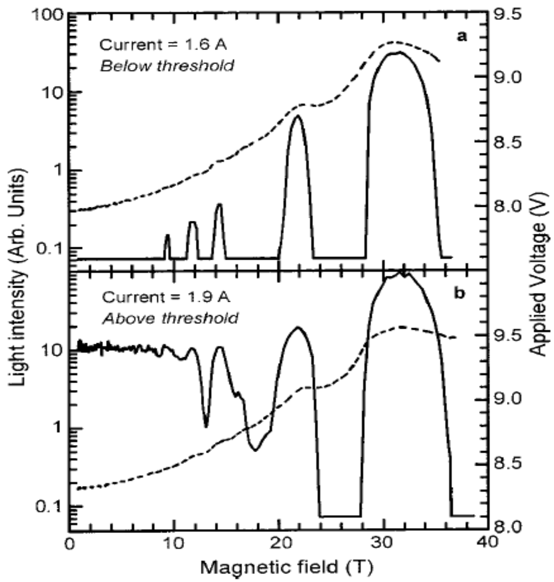
$$\omega_c = eB / m^*(\varepsilon)$$

$$\delta = \sigma_0 \sqrt{B}$$



$B \mathbin{//} I \perp$ 2DEG

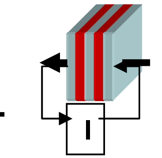


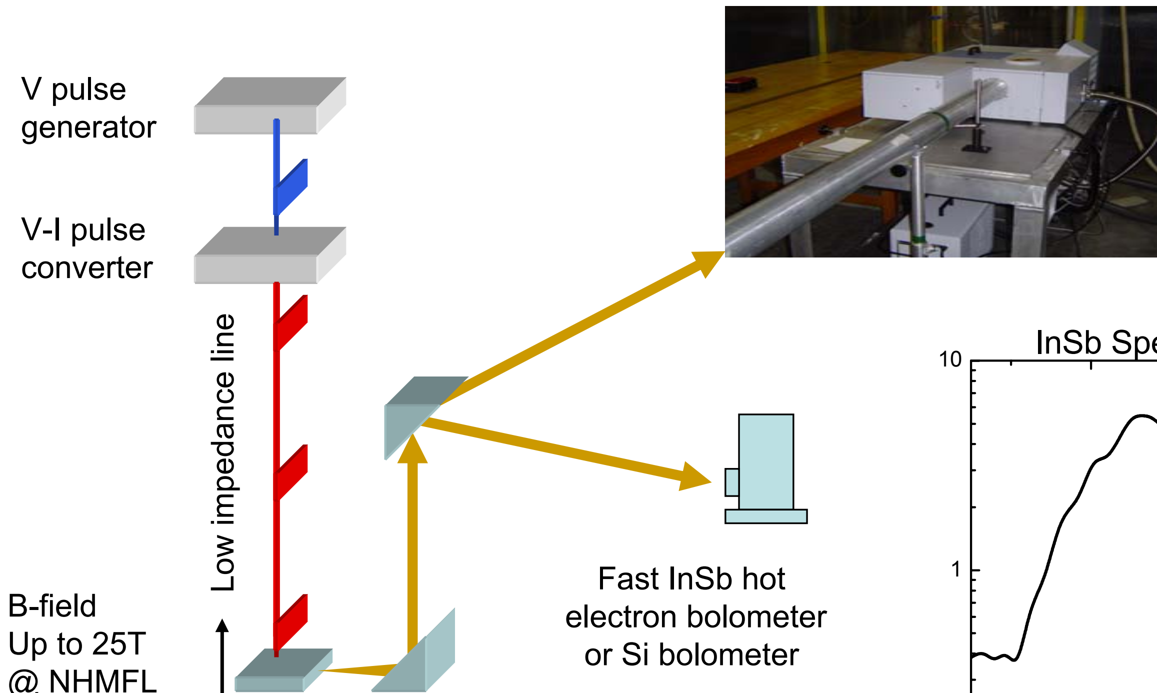


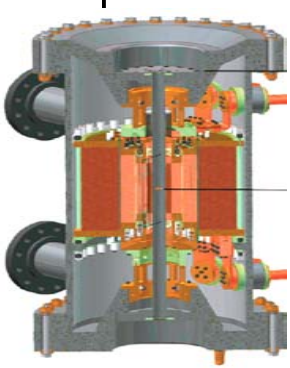
MIR QCL: Smirnov et al. PRB (2002)

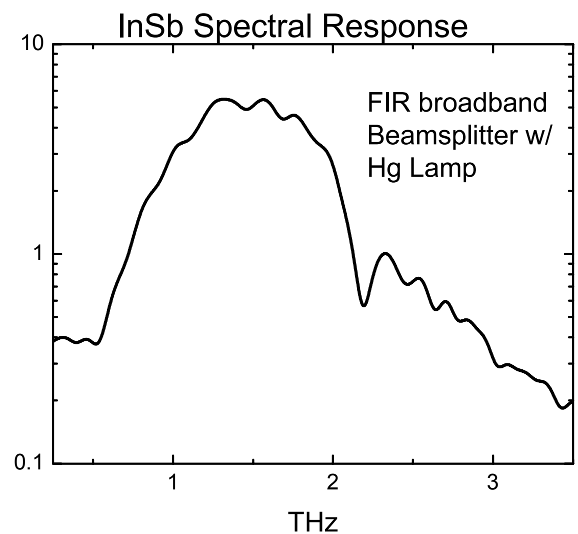
THz QCL: Scalari et al. APL (2003)

The Experiment



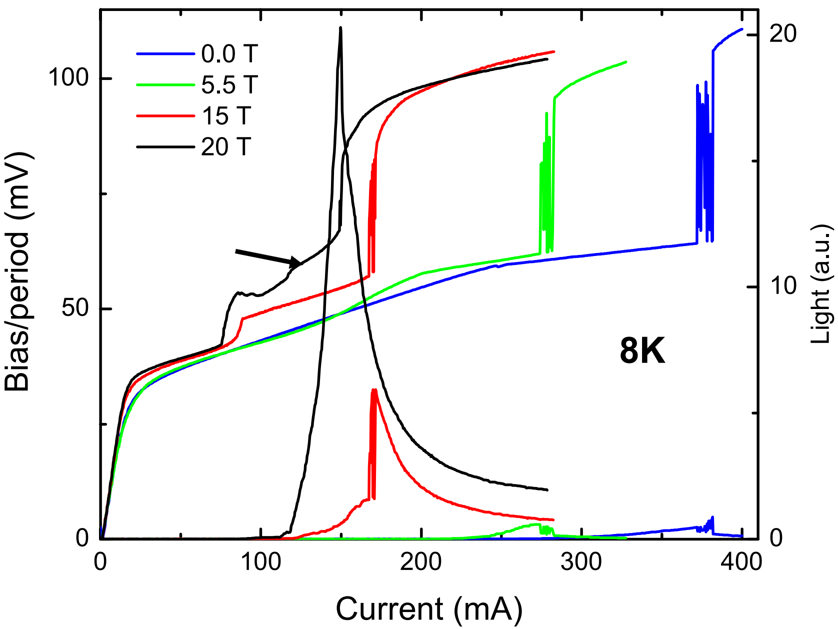


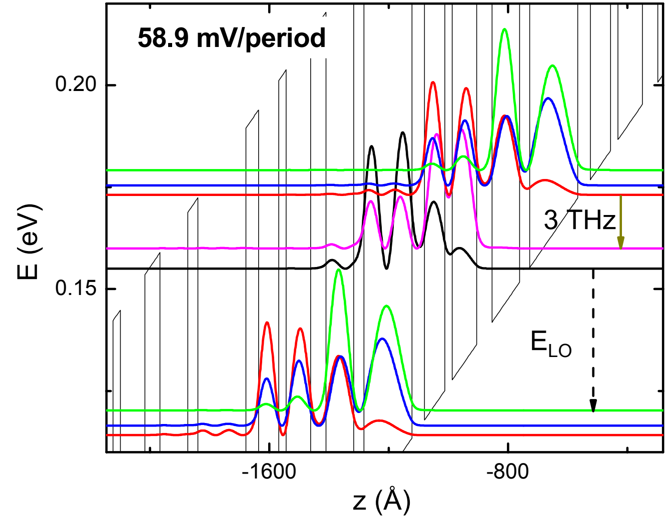


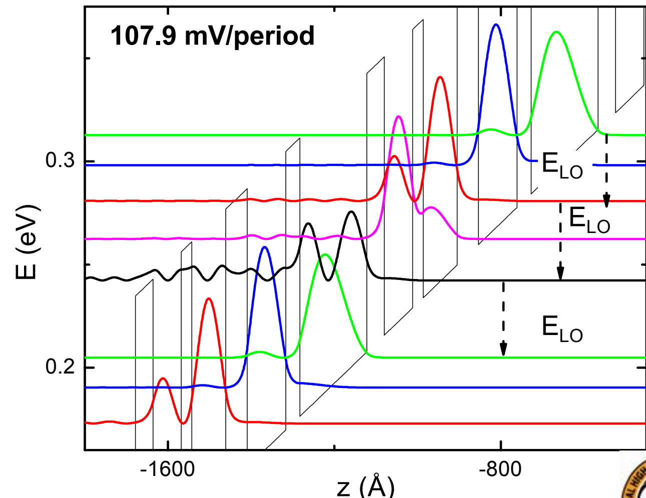


- Pulsed Current Injection ~1 μs, I < 400 mA, T ~ 8 K
- P(B), V(B) @ I = constant
- P(I), V(I) @ B = constant
- Spectra: 5 – 125 cm^{-1}

The PVI curves

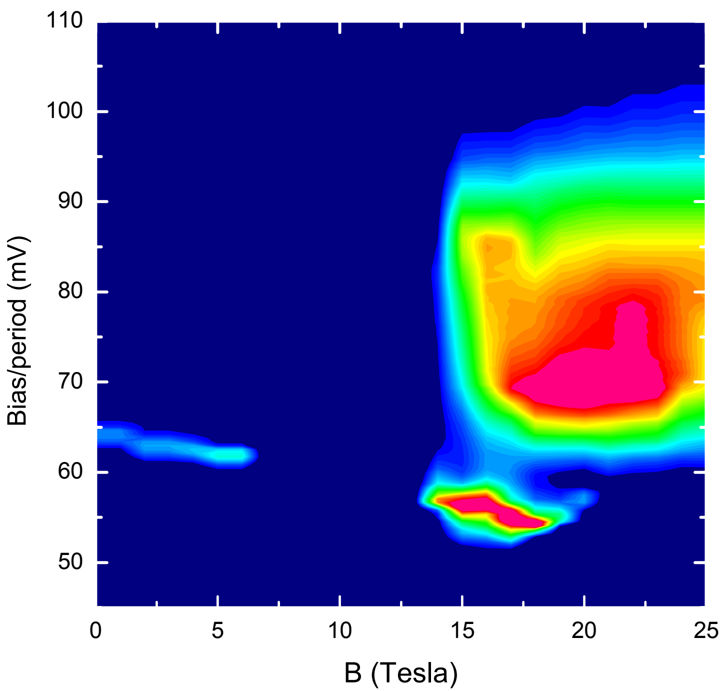


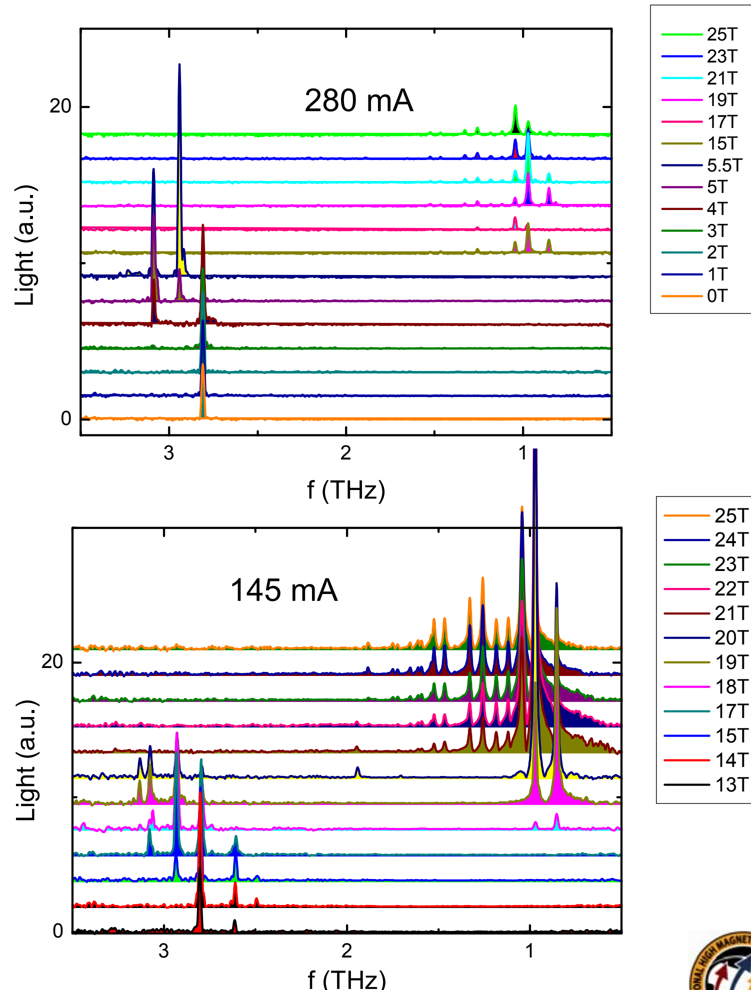




New alignment at ~61 mV/period
and a large increase of light

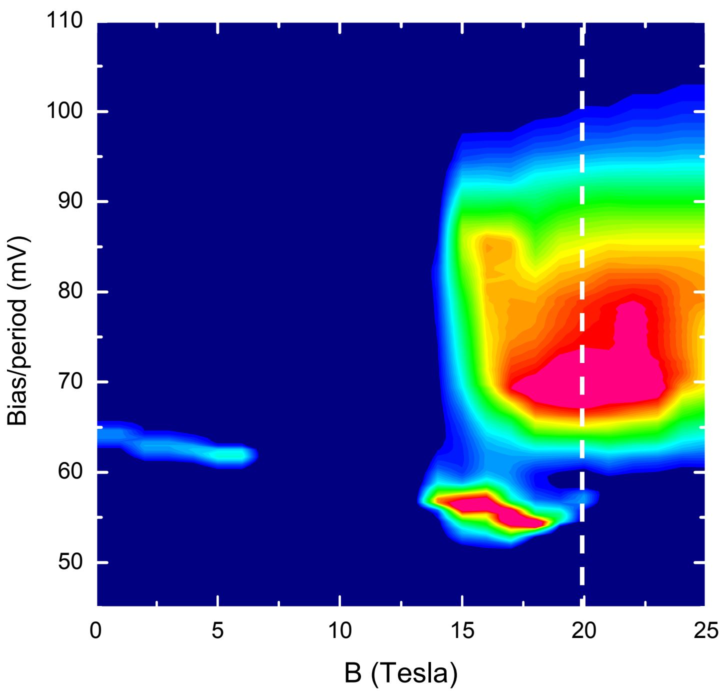
B and V range

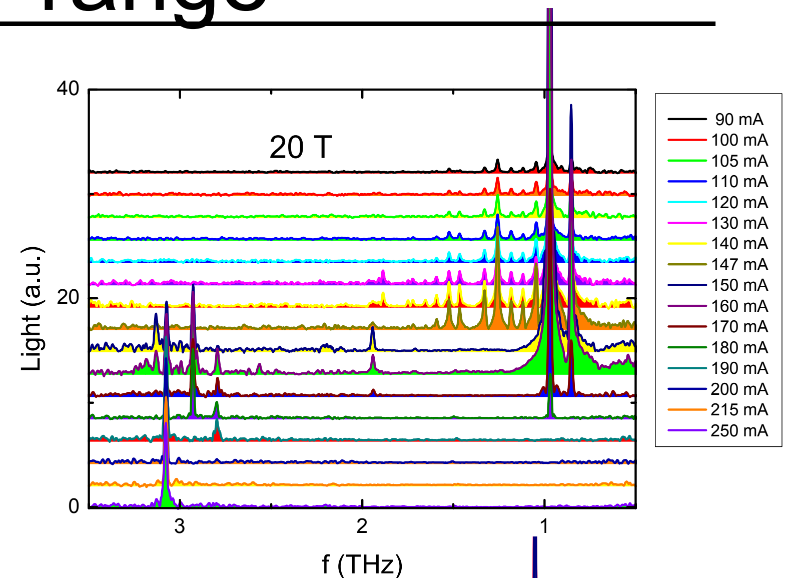


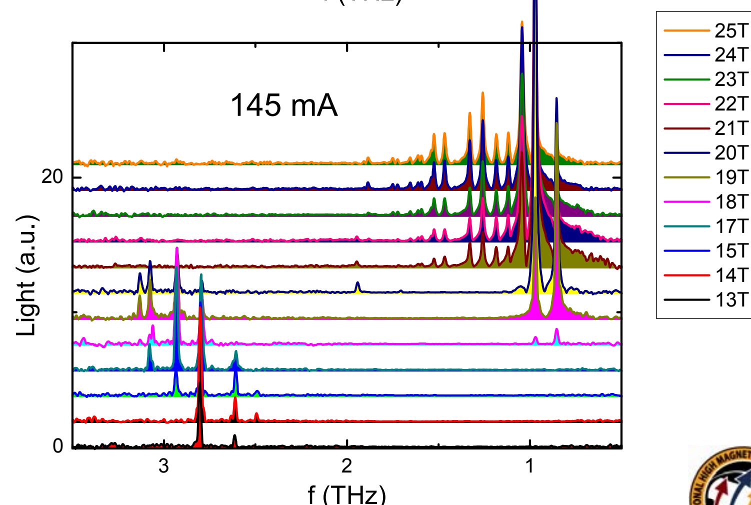


- •Contour plot from slices of Light vs. Field
- •Light normalized to account for spectral response of detector
- •P(3THz) multiplied by 2

B and V range

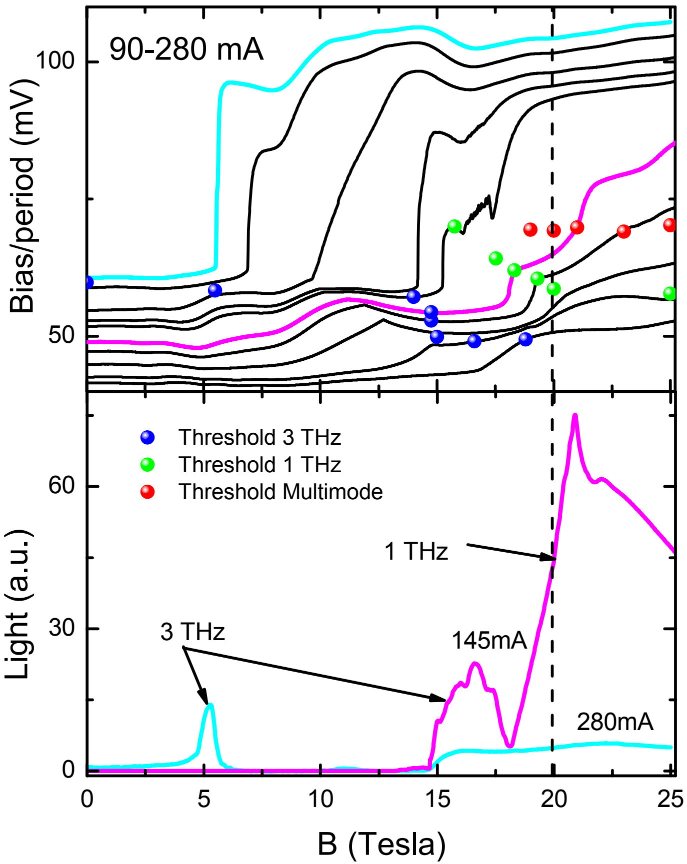


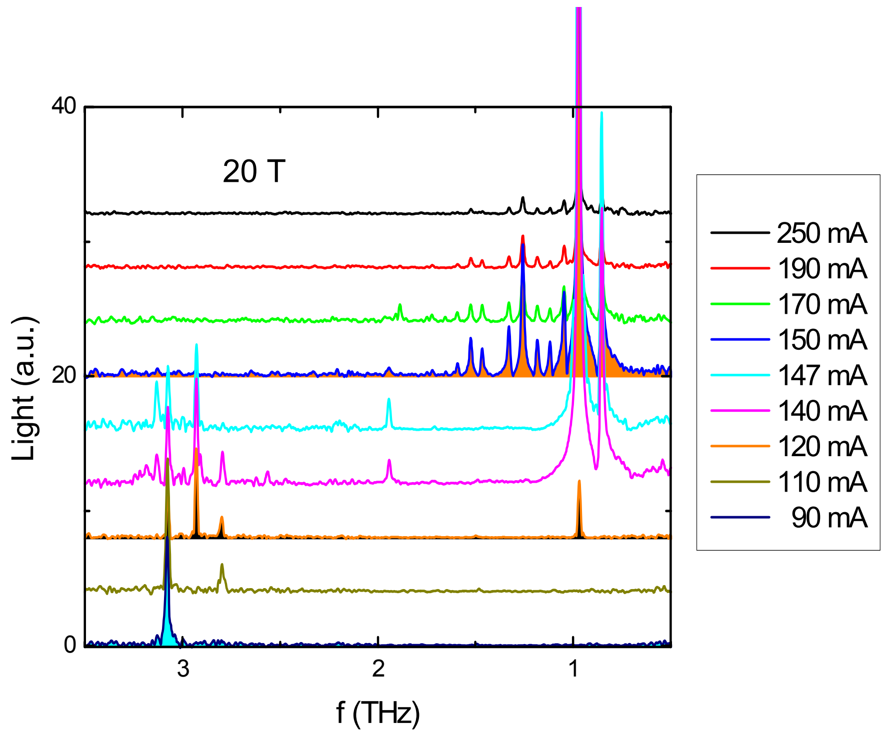




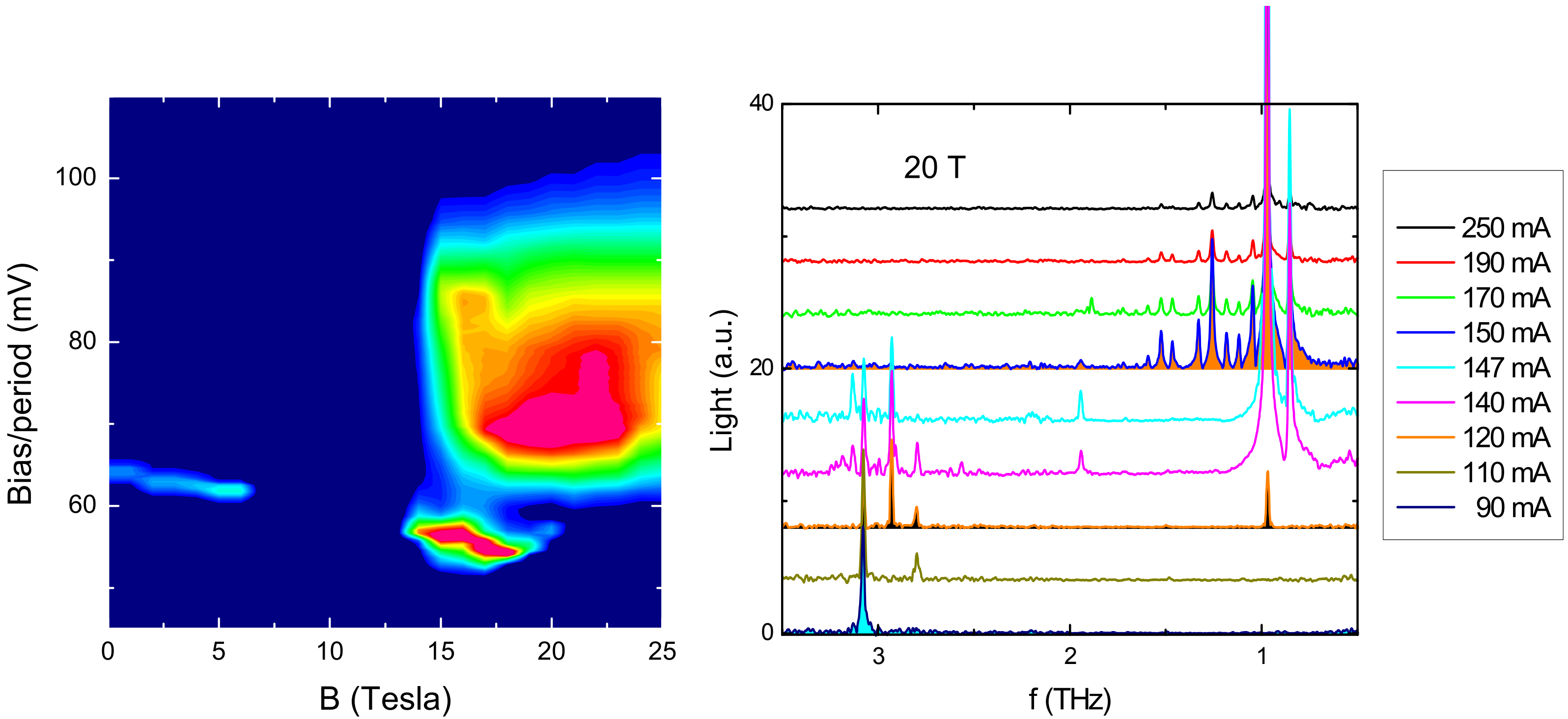
- Contour plot from slices of Light vs. Field
- Light normalized to account for spectral response of detector
- P(3THz) multiplied by 2

Light & Voltage vs. Field



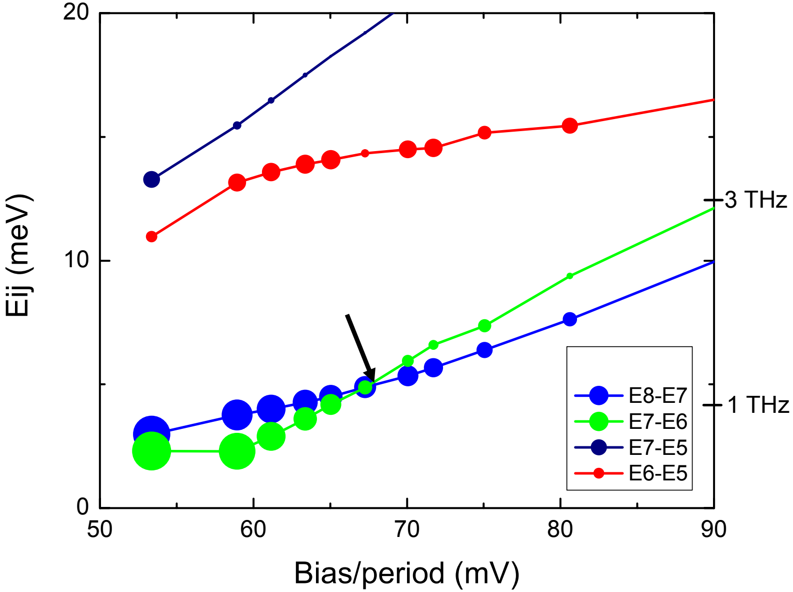


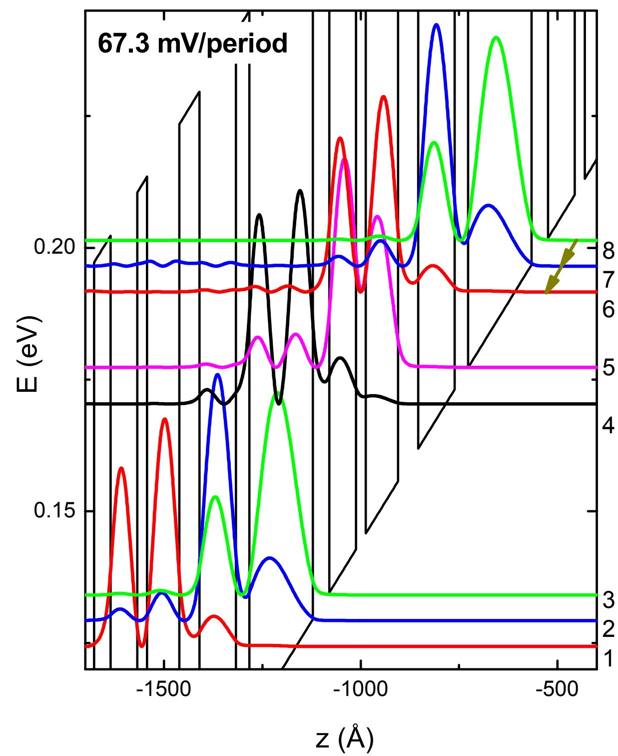
Summary of Exp Results



- Very strong < 1 THz at 20 T and ~67-72 mV/period
- Broadband lasing .85 - 1.6 THz
- Offset of strong lasing at ~22T
- Bright 3 THz light at 16 T
- Region of suppressed emission from 7 – 12 T

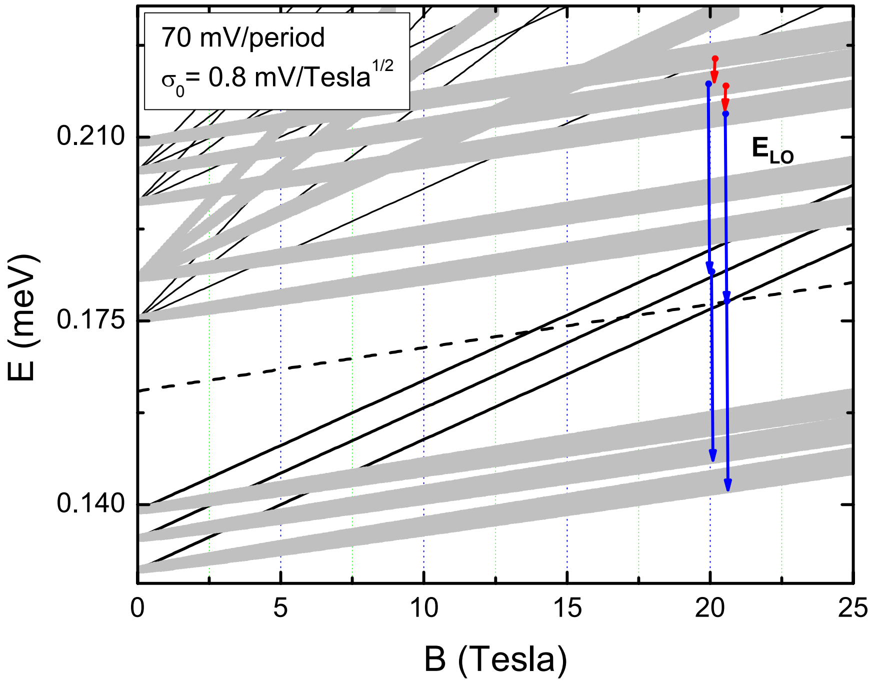
Why 1 THz?

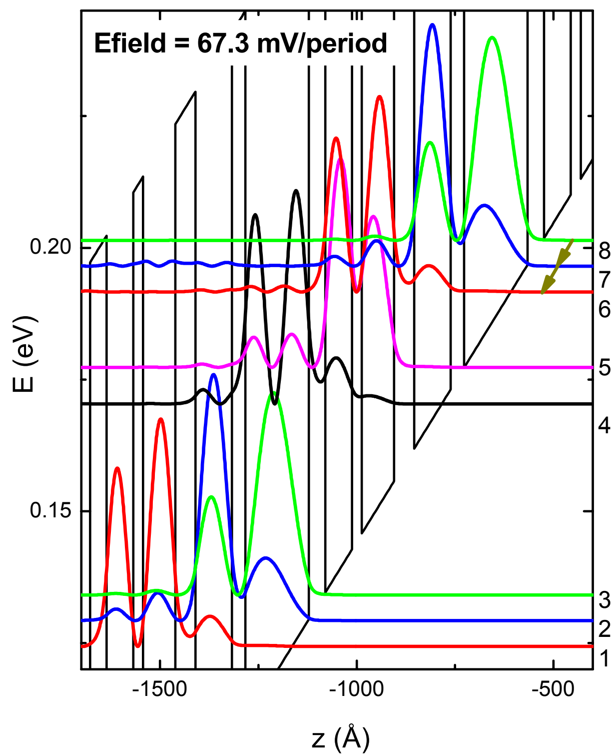




•Size of dots proportional to Matrix Elements

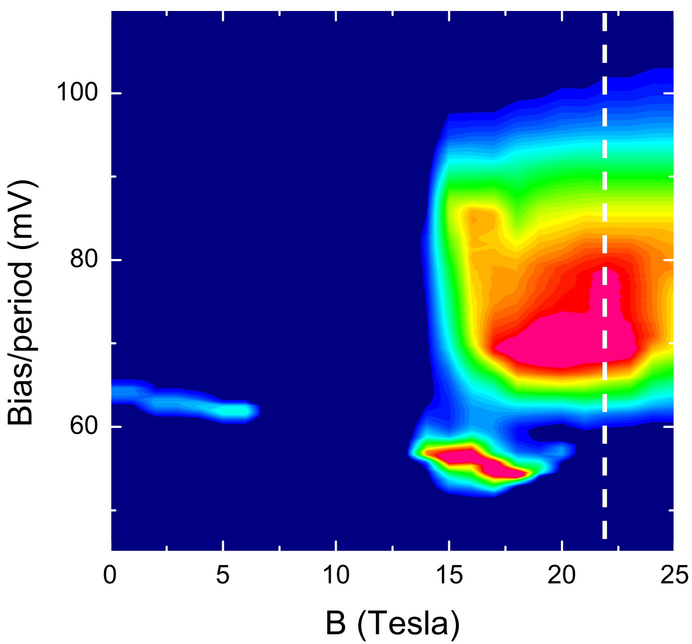
Strong 1 THz light around 70 mV and B~20T

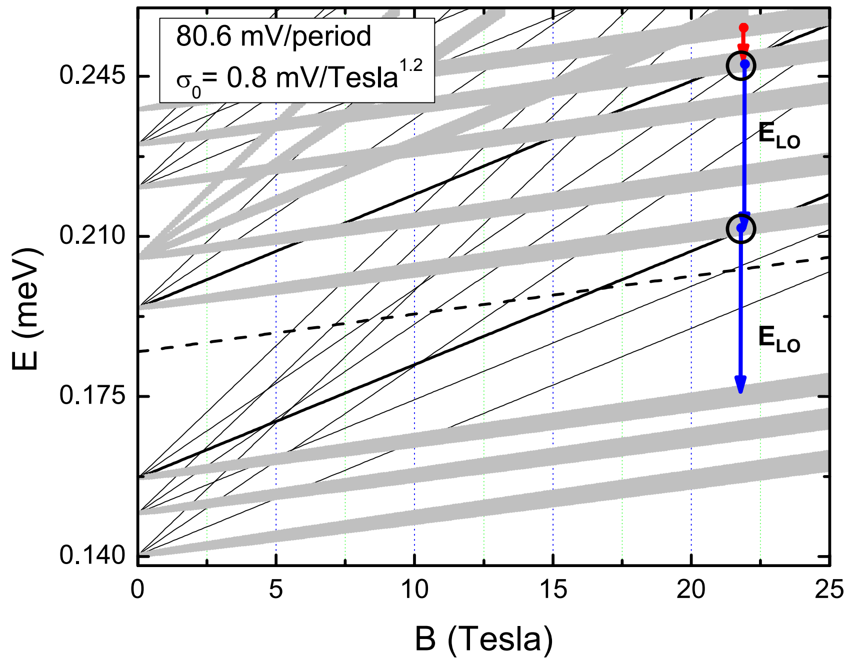




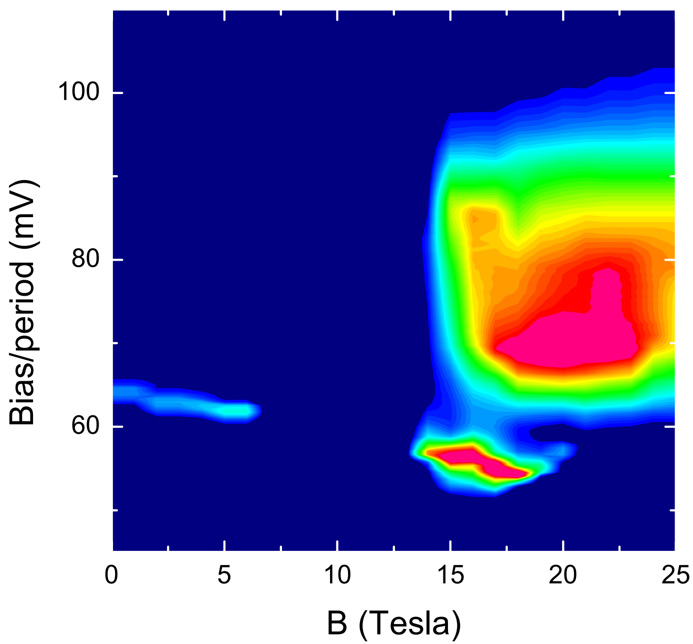
Strong Emission at 22 T

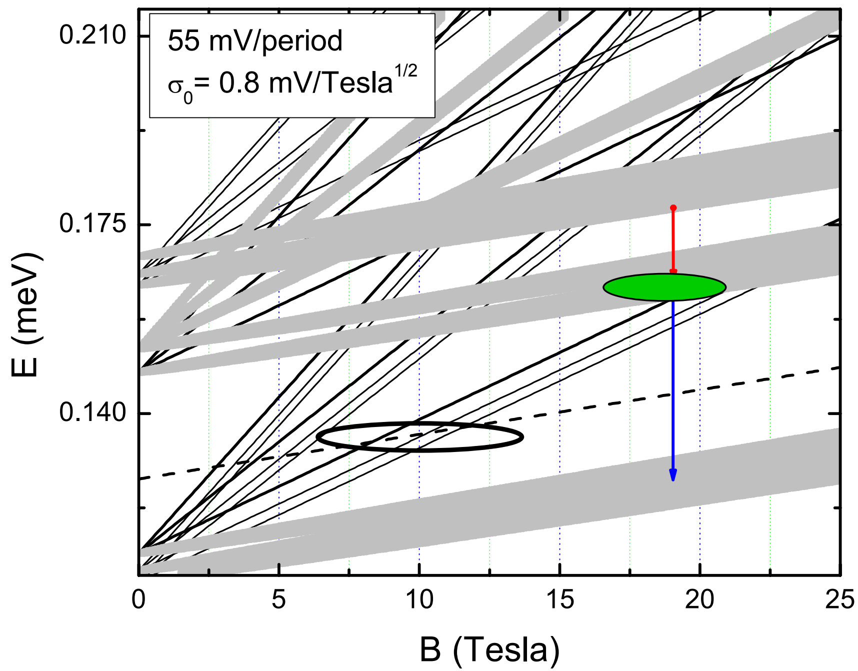
$E_{LO} = E_{cyc}(\sim 22T)$





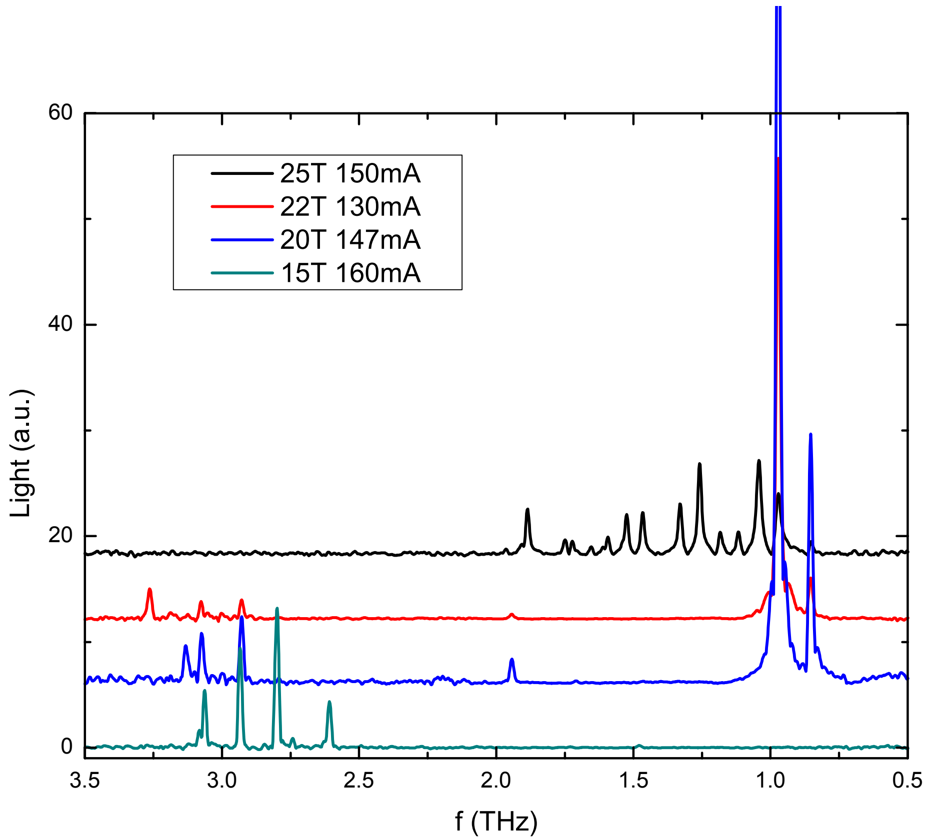
3 THz emission





•Above the MPR limit
•Elastic scattering helps depopulate the lower state
Scalari et al. APL (2003)

Spectral Range



3.27 to 2.61 THz and 1.53 to 0.85 THz

Summary

- We observe strong sub-THz radiation for a QCL.
- Applying the appropriate bias and magnetic field, the laser emission from a single device can be tuned to a wide range of frequencies: 3.27 to 2.61 THz and 1.53 to 0.85 THz.
- The ability of the magnetic field to control the carrier path to the final state of the QCL's LO-phonon scheme