Linewidth Enhancement Factor

Origins
- Linewidth beyond Schawlow-Townes limit in lasers
- Broadening of $1+\alpha^2$ [1]
- Change of refractive index accompanying carrier density fluctuation

Influence of LEF
- Linewidth
- Frequency chirp during modulation in QCL [2]
- Optical frequency comb formation in QCL

\[
\alpha = \frac{\partial \chi'/\partial \delta n}{\partial \chi''/\partial \delta n} = -2 \frac{\partial \beta/\partial I}{\partial g/\partial I}
\]

Measurement technique

QCL fast modulation
- DC current + RF modulation at 3 GHz
- RF modulation -> Intensity modulation (IM) and Frequency Modulation (FM)
- Side bands generation:

\[
E_n = E_0 \exp(-i(\delta + \Phi_{1M})) (J_n(\beta) + \frac{m}{4} J_{n-1}(\beta) \exp(i\delta) + J_{n+1}(\beta) \exp(-i\delta))
\]

Spectrally resolved measurement [4]
- SWIFTS Spectroscopy [3]

Results

Nonequilibrium Green’s function simulations [5]

- EV2016: single stack
  - Negative to positive LEF
  - NEFG - Right range / low fidelity
- EV2548: dual stack
  - Negative LEF - DFB Blueshifted

NEGF formalism
- Intracavity intensity as function of DC bias
  - Gain clamping condition
  - Photo-driven current
  - Output power of the laser
- Missing contributions: self-heating, spatial mode distributions

References