External Cavity for QCL installed in Mid-Infrared Laser Heterodyne Instrument

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Abstract

We have developed the external cavity system for quantum cascade laser at mid-infrred wavelengths for use as a local oscillator in a heterodyne receiver. Tunability over 20 cm-1 at 1145 cm-1 was demonstrated using a grating spectrometer. It was shown that the spectral stability, side mode suppression, and narrow linewidth are excellent.

Introduction ~ Quantum Cascade Laser and External Cavity

- Qautum cascade laser became available as local oscillator for IR heterodyne spectroscopy.
- Tuneable (a room temperature) quantum cascade laser great expands accessible molecules of atmospheric and astronomical interest.
- Very Recent study presents an excellent broad gain quantum cascade laser with a tuning of over 400 cm-1 from 7 to 11 micron wavelength with a averaged outout power of 15 mW at room-tempearture [Hugi et al., 2009].
- Single-frequency operation of the source by use of external cavity potentially provides a great powerful tool for spectroscopicapplications.
- The purpose of this study is to develop the external cavity setup for QCL at Mid-IR heterodyne.

Tuneability of the DFB-QCL

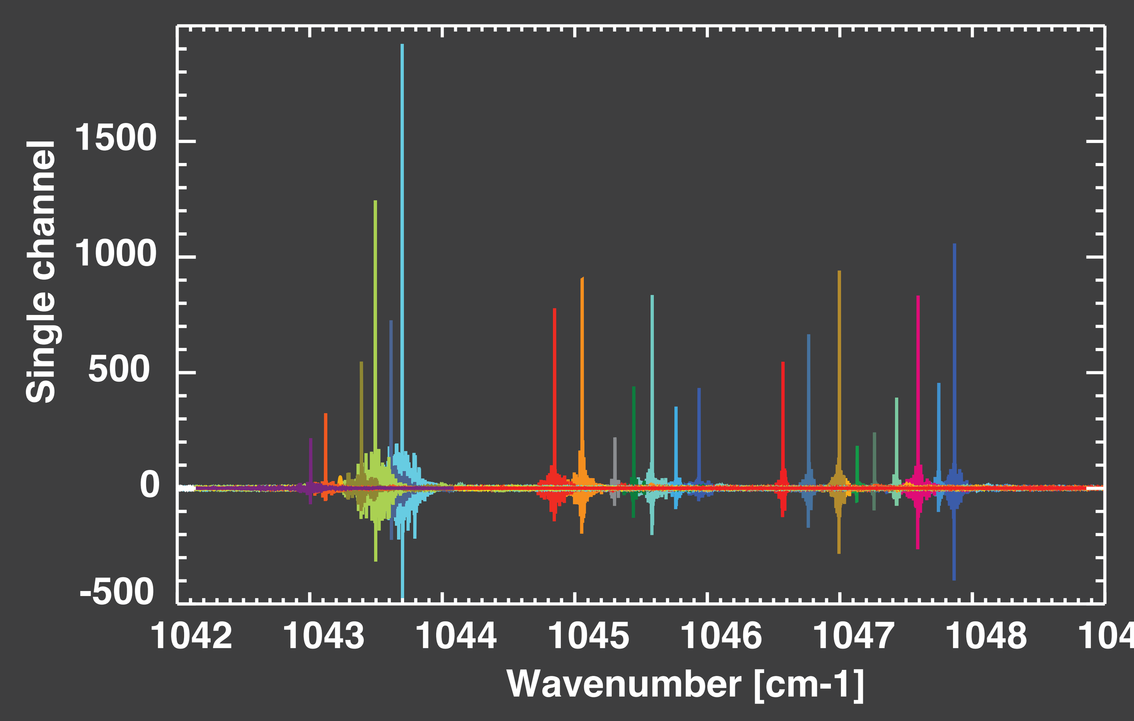

Fig. 1. Variation of the output spectra of a room-temperature DFB-QCL.

Experiment Setup and Results

Grating angles and Littrow configuration

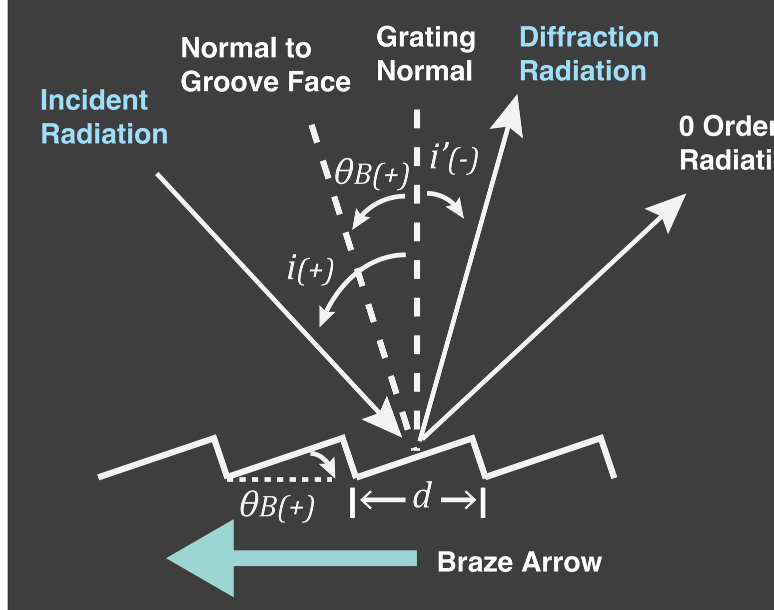

Fig. 2. Grating angle and terms

$$N m\lambda=(\sin i + i')$$
$$(m\lambda=d(\sin i + i'))$$
$$\theta_B=(i+i')/2$$
$$\lambda_{B(Litt)}=(2/N)\sin\theta_B$$

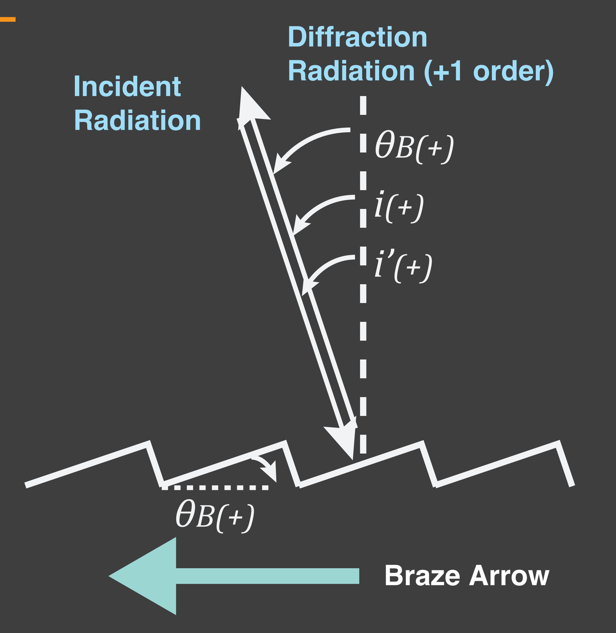

Fig. 3. Blazed grating and Littrow configuration.

N: Blaze number
d: Blaze distance (1/N)
m: Diffraction order
i: Incident angle
i': Diffraction angle
θB: Blaze angle
λB(Litt): Blaze wavelength at Littrow conf.

- Frequency selective feedback is achieved using a diffraction grating in a Littrow configuration.
- The multi-mode emissions are suppressed to be single-mode by optical feedback using external cavity.

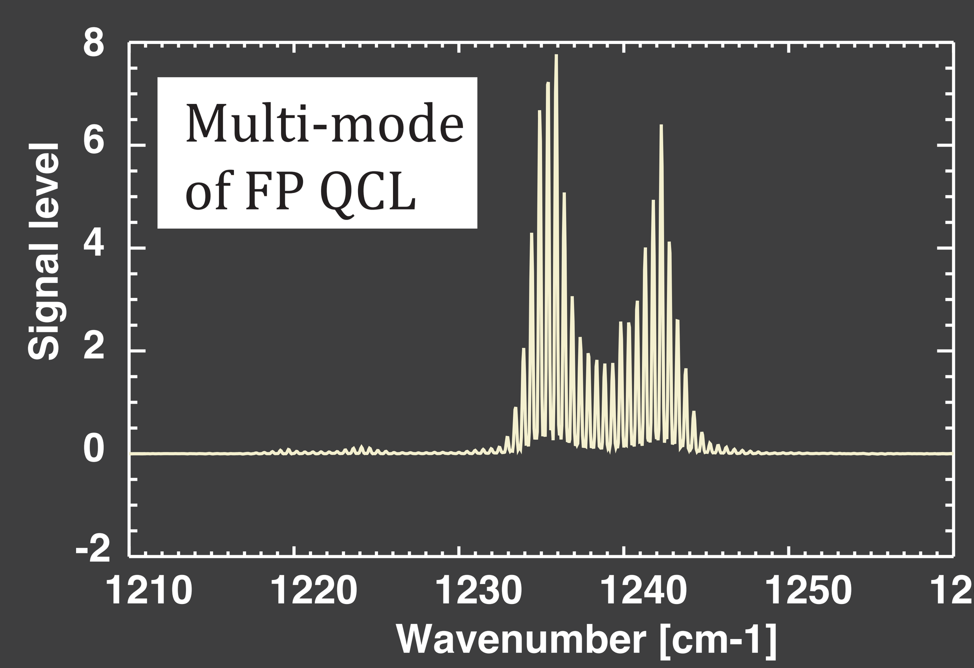

Fig. 4. Emission spectra of multi-mode FP-QCL without EC feedback.

Setup of the EC

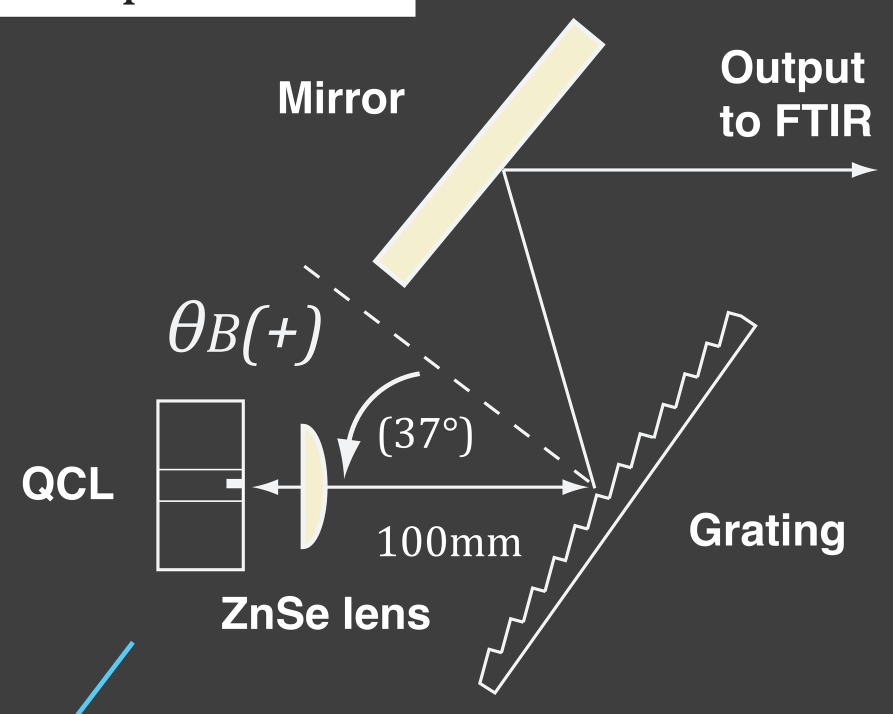

Fig. 5. Setup of the experiment.

- An essential requirement for maximum efficiency of the EC is precise mode matching between laser and EC, i.e., the positioning accuracy of the collimating optics.
- Using FTIR, we adjusted the grating vertical and horizontal angles to select a wavelength, maximize the feedback, and achieve single-mode operation.

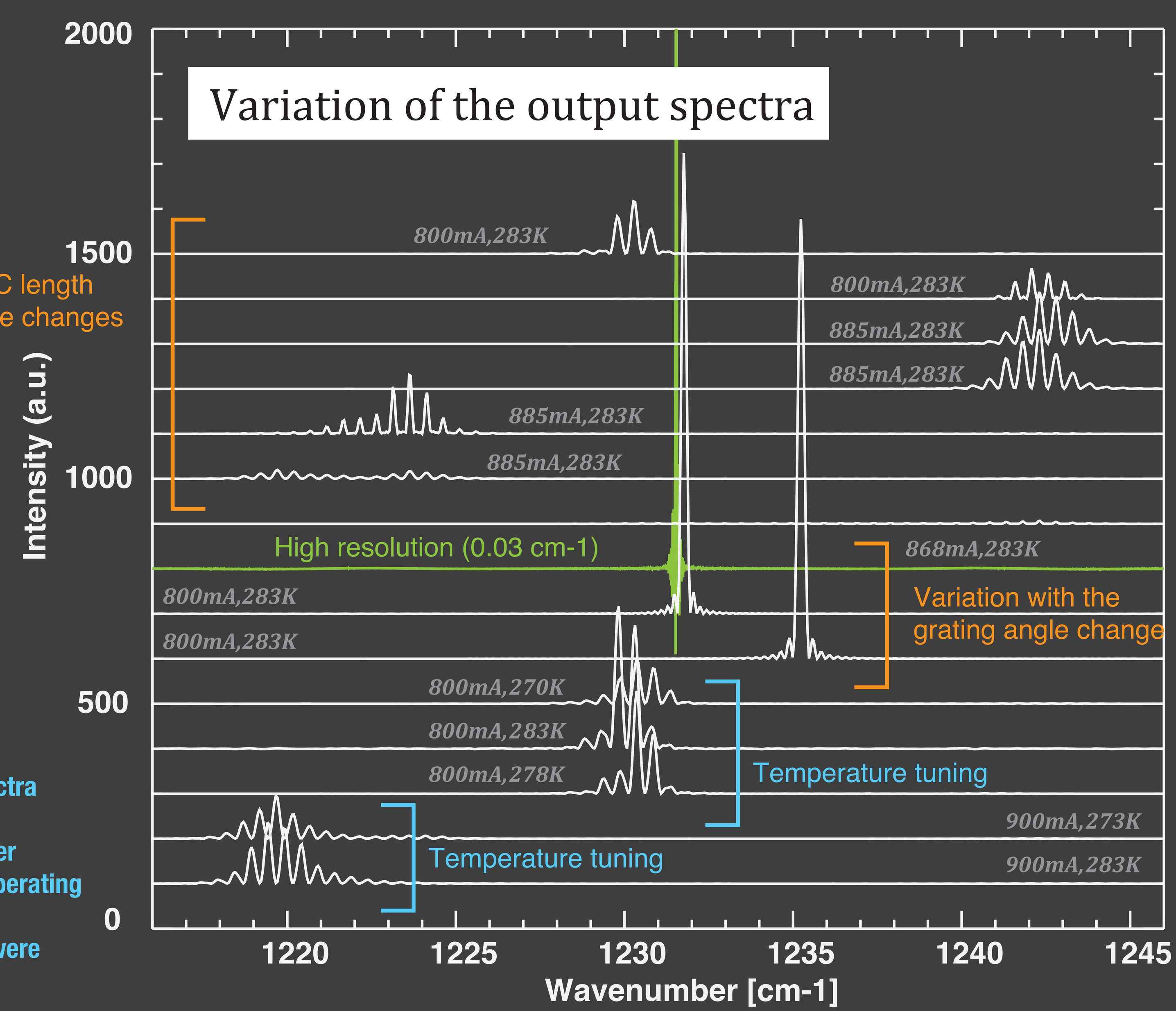

Fig. 6. Variation of the output spectra with/without EC feedback. The laser was operated at the laser current of 800~900mA, and the operating temperature of 270~283K. The grating angle and EC length were adjusted.

- The side mode suppression is due mainly to the higher selectivity of the QCL cavity without an AR coating, which suppresses oscillations of nearby EC modes.
- The position of each mode does not vary with the laser current. Temperature tuning is able to shift each mode frequencies and allow a complete frequency range to be covered with the EC QCL.

Key Device

FP-QCL cw 8.0 micron, no antireflection (AR) coating on the output facet) on a peltier temperature controler with 0.01K
Grating 150 grooves/mm blazed for 10.6 micron on a 25 mm x 25 mm reflects the first-order diffraction with polarization of the E vector perpendicular to the grooves of the grating that is diffracted into the first-order of 95%
Aspheric ZnSe lens f = 25.4 mm and a diameter of 25.4 mm
FTIR 0.125 cm-1 resolution with triangular-apodization

Summary and Future prospectives

Our result demonstrated that a compact external-cavity quantum cascade laser system was well suited to be used as a local oscillator in Mid-Infrared Laser Heterodyne Instrument (MILAHI), greatly expanding accessible wavelength. External cavity installed in MILAHI is widely usable for second-generation instrument for the airborne observatory, etc. For coarse frequency selection among the internal modes, one has to change the grating angle to shift the gain curve by free-spectral-range. To allow fine frequency tuning without mode hopes, both the laser current and the EC length have to be changed at the same time. Decreasing the length of the laser chip would result in increased side-mode separation and therefore in improved selectivity of the gragin feedback. Good AR coating of the laser output facet would suppress oscillation of the QCL without grating feedback and would extend the tuning range. First light of the instrument would be performed in the end of 2013 on board our dedicated telescope at the top of Mt. Haleakala, Hawaii.