Student Paper

Widely Tunable Integrated Quantum Cascade Lasers

Dingkai Guo[a] Jiun-Yun Li[b] and Fow-Sen Choa[a]

[a] *Department of CSEE, UMBC, USA, choa@umbc.edu,* [b] *Department of Electrical Engineering, National Taiwan University, Taiwan, Republic of China*

Mid-infrared (IR) lasers are very important for chemical sensing , explosive detections, and spectroscopy applications. A widely tunable mid-IR laser has the potential to perform like a Fourier transform infrared (FTIR) spectrometer and at the same time provide much higher resolution and measurement sensitivity due the narrower linewidth and higher power output of a laser compared with an IR lamp.

In the past, we have demonstrated multi-section distributed Bragg reflector (DBR) type tunable quantum cascade lasers (QCLs) with a tuning range of 30cm^{-1} in the 4.6 um range [1]. The wavelength tuning is achieved by using a tiny thermal electric (TE) cooler under the grating section and tuning the laser thermally. In this work we report an improved version of tunable QCLs with a tuning range of >90 cm^{-1}. To achieve wide tuning range we have changed from a simple grating reflector to a pair of sampling gratings with slightly different sampling pitches. Using Vernier effect the tuning range can be extend beyond index change only.

Tunable QCLs based on binary sampling grating have recently been reported [2,3]. The binary sampling grating is simply a grating with part of it being periodically removed. It has the advantage of easy fabrication. However, as shown in Fig. 1, its Fourier spectrum has a round top profile and will limit its tuning range to the small high reflectivity region. Using super structure grating (SSG) as shown in Fig. 2 the Fourier spectrum of it reflectivity can achieve a flat and rectangular profile, which can extend the tuning range to it full sampling spectrum. A tuning range of 90 cm^{-1} was achieved even with a low gain QC material and a non-ideal grating etching depth (too shallow). In the work the SSG ITQCL tuning is achieved by current heating. The front mirror injection is red shifted and the rear mirror is blue shifted following the design.

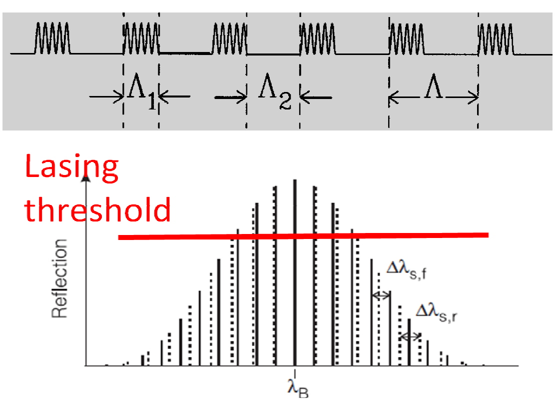

Fig. 1. Binary sampling grating and it's reflectivity spectrum

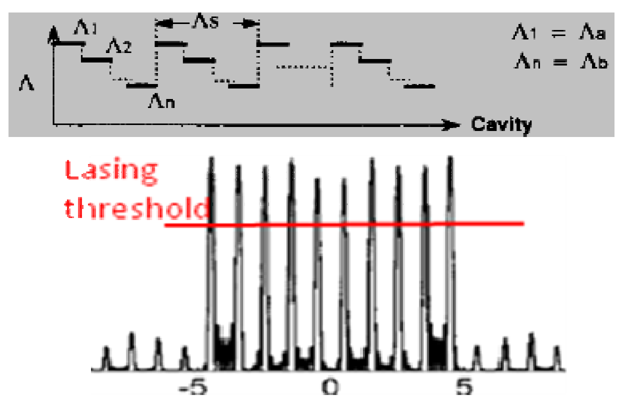

Fig. 2 Superstructure grating and it's reflectivity spectrum

The sampling grating can be achieved by using either a chirped pitch profile or a chirped phase shift profile in real space. However, to obtain a flat sampling grating profile in the Fourier domain is actually a nontrivial problem. Through transfer matrix calculation we have designed pairs of sampling gratings based on chirped pitch profiling design. The different period numbers for different pitches are employed to modify the sampling grating profile in Fourier domain so that their satellite peaks can have about equal heights in the desired tuning range of

>500nm centered at the 4.8 um. Fig. 2 (a) shows a fabricated uniform grating with grating yes/no patterning made by using a holography system. Fig. 2(b) shows the super-structure grating made by using their E-beam system. Fig. 3 shows the output wavelength of the QCL. A total tuning range of more than 90cm^{-1} is achieved, which is limited by the gain material. The design shall be able to achieve 350cm^{-1} tuning range.

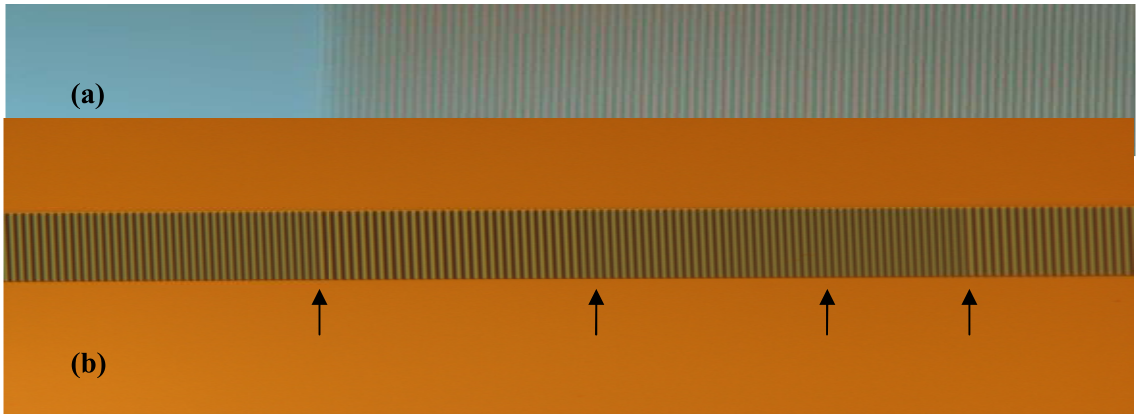

Fig. 2 Fabricated gratings (a) A typical holographic grating with grating yes/no pattern. (b) A super structure grating with 5 different piecewise variable grating periods.

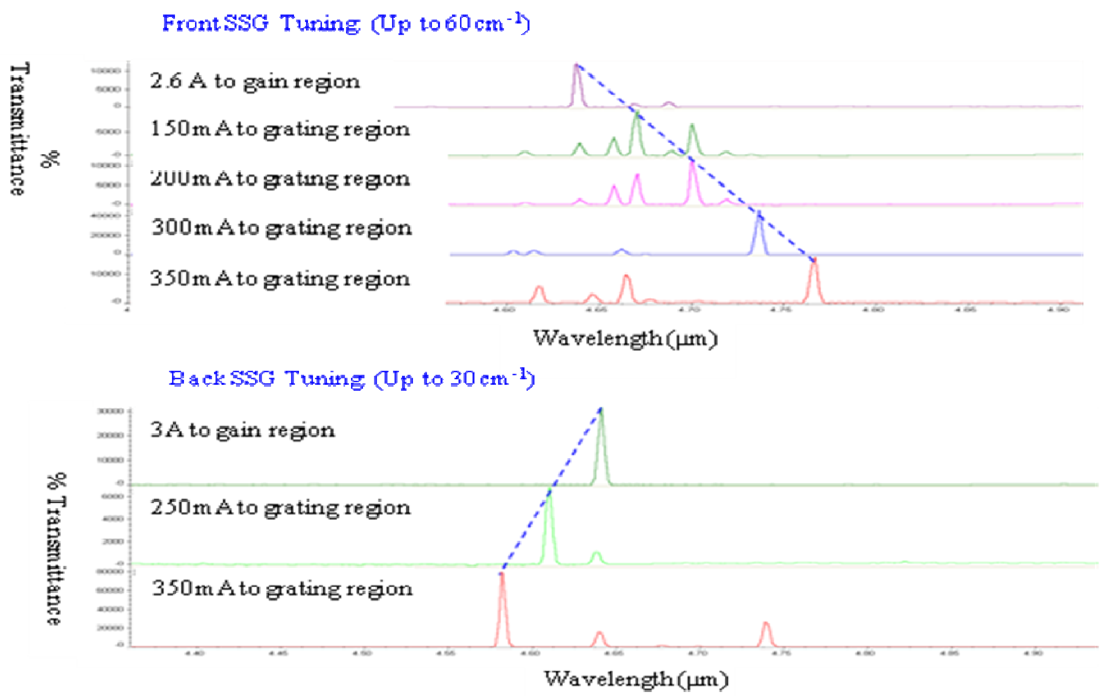

Fig. 3 Tuning spectra of the widely tunable laser with both front and back grating mirror tuning

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