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Externally Coupled Bragg Grating 5-μm Quantum Cascade Lasers*

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Abstract: Narrow-bandwidth AlGaAs/GaAs Bragg grating was externally coupled with InP semiconductor based quantum cascade laser to yield stable wavelength operation with 1 nm linewidth, compared to unstable, multi-line spectra with 30 nm span of the free-running device. Isolated DBR segment allowed wavelength tuning of a few nm independently from the gain element.

Key words: semiconductor tunable laser; distributed Bragg grating; optical waveguide

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Mid-IR semiconductor lasers are often operated over a wide temperature range. For devices with monolithically integrated wavelength control such as DBR[1] or DFB[2], both the gain and the wavelength control element are affected simultaneously by any temperature variation. A large thermal load during a high power pulse, for example can cause a significant wavelength shift. An alternative is to have the elements isolated from each other. External planar grating, for example, allowes broad and accurate wavelength tuning of mid-infrared quantum cascade (QC) lasers over a wide temperature range[3,4]. This letter reports the use of external AlGaAs/GaAs Bragg grating (BG) waveguide to control the wavelength of a 5.1 μm QC laser. This configuration, which is similar to the commercial practice of coupling silica fiber BG to 1.5 μm diode lasers, also promises the possibility of using inexpensive, wavelength-pre-selected DBR for wavelength control of QC lasers, rather than monolithic DBR fabrication where yield and waste of expensive lasing materials can be an issue.

The coupled laser configuration was shown in the inset of Fig. 1(a). The extended cavity used lenses for coupling, and an intra-cavity beam splitter was inserted to monitor the output. The BG-side output was also monitored, but it was weaker owing to its high reflectivity. The spectra of all outputs were identical, ensuring that it was operated as a single cavity. In general, the butt-coupling configuration of inset Fig. 1(b) is more efficient and desirable, but it was not used because the other facet of the gain element was not accessible here. The BG was fabricated from an MBE-grown Al0.25Ga0.75As/GaAs/ Al0.4Ga0.6As slab waveguide of thickness of 2/1.5/3 μm, respectively. The grating was subsequently patterned on the waveguide with holographic exposure, and the AlGaAs cladding was etched 0.3-0.4 μm with BCi3 reactive ion etching. An image of the grating is

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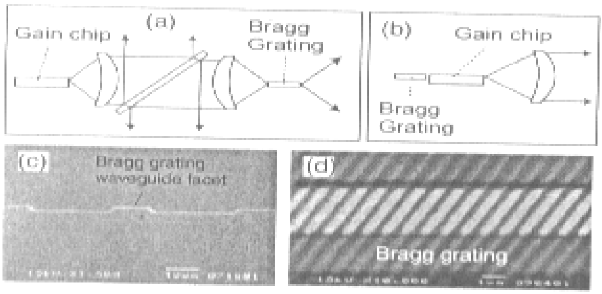
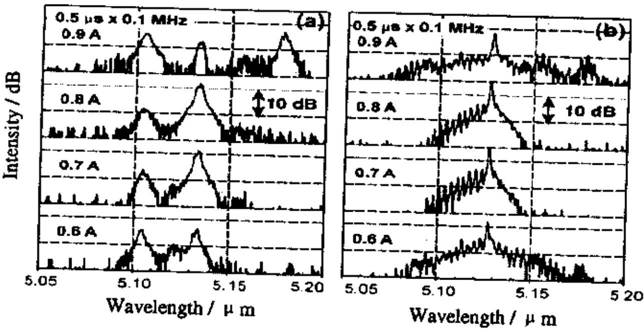
shown in Fig. 1(d). The grating period was 0. 8 μm, designed for first-order reflection at 5. 1 μm; and the index modulation was designed for the semiconductor/air interface without any passivation. Single-mode ridge waveguide were then fabricated, and a facet image is shown in Fig. 1(c). The DBR has no phase segment, and there was no AR coating on any facet of the gain chip or the DBR. The QC laser was mounted in a cryogenic Dewar, and the DBR segment was mounted at room temperature.



(a) Configuration for External Bragg Grating (BG)-Coupled Laser; (b) Alternative Butt-Coupling Configuration; (c) The BG Waveguide Facet View; (d) The BG Waveguide Top View

Fig. 1 Bragg Grating

Results and discussion: The coupling of the DBR led to a much more stable output spectrum, as shown in Fig. 2. As the peak drive current was increased from 0. 6 to 0. 9 A, the FP device spectrum in Fig. 2 (a) changed significantly, including the appearance of multiple bands. With DBR-coupling, the laser output spectrum in Fig. 2(b) was much more stable and had a narrower linewidth. For the corresponding light-current property, the DBR laser also exhibited a lower threshold, and smoother, kink-free output compared with the FP device. The wavelength stability of DBR laser was also evidenced as the gain element temperature was varied from 80 to 170K while the BG was maintained at room temperature. As shown in Fig. 3, the FP device spectra (dashed curves) exhibited red shifts and multiple lines; but the DBR laser spectra (solid curves) remained stable. A remarkable observation in both Fig. 2 and Fig. 3 is that the DBR laser lased at its wavelength, even as it was not within any spectral band of the FP device, and suppressed other far-away FP spectral features. This result suggests that the device again band is likely homogenous in spite of the multiband features.



(a) Spectra of Fabry-Perot Device for Pulse Peak Currents from 0. 6 to 0. 9 A; (b) Spectra of DBG Laser for Same Conditions

Fig. 2 Currents Spectra

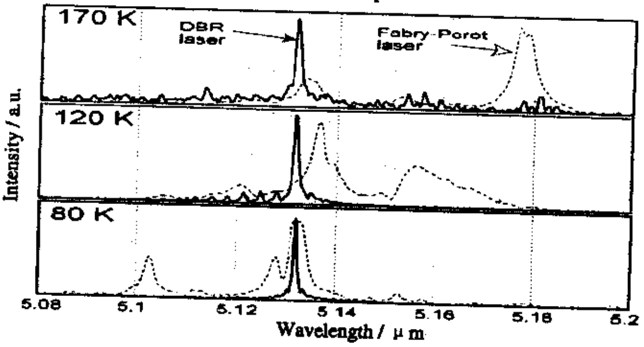


Fig. 3 Comparison of Normalized Spectra of Fabry-Perot Device (Dashed) and DBR Laser(solid) for Gain Chip Temperature From 80 to 170 K.

With physical separation, the thermal load on the gain element did not affect the DBR, and vice versa, the DBR could be electro-optically or thermally tuned without affecting the gain element. An example is shown in Fig. 4, where the wavelength shifted 2 nm as the DBR temperature rose 35-40℃. With facets uncoated, the DBR reflection as calculated in the inset of Fig. 4 has strong fringes, resulting in side lobes seen in Fig. 2,Fig. 3. Also, because of the long extended cavity[5], the central peak contains 2-3 longitudinal modes, but the net linewidth was only 1 nm, consistent with its design.

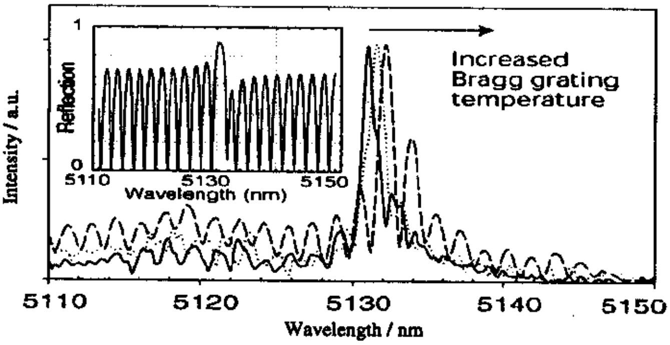


Fig. 4 Wavelength Tuning of the DBR Laser by Heating the Bragg Grating. Inset: Calculated Reflection Spectrum of the Entire DBR Segment.

External Bragg grating coupled with QC laser yielded narrow linewidth and highly stable wavelength against temperature and current variation. Calculation shows that with proper facet AR coating, shorter butt-coupling cavity, and an additional phase segment would give single mode with precise wavelength control and modulation.

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外耦合布拉格光栅5 μm量子级联激光器

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摘　要:窄带宽的 AlGaAs/GaAs**布拉格光栅耦合到**InP**的半导体量子级联激光器从而产生稳定的激光频谱,其激光谱线宽度在**1**纳米左右。如果不加光栅,非稳定的自由激射的激光器的谱线宽度有**30 nm**左右。隔离的分布式布拉格光栅可以独立调谐几个纳米。**

关键词:半导体调谐激光器;分布式布拉格光栅;光波导

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