Wavelength Tuning Characteristics of CW-Pulsed Laser

Overview:

Broadly tunable mid-IR external-cavity CW-PLS lasers can be operated in both continuous wave (CW) and pulsed (PLS) mode. In contrast to Continuous Wave Mode-Hop-Free (CW-MHF) lasers, the tuning range of CW-PLS lasers is not mode-hop free. Quasi mode-hop-free tuning behavior may be achieved with a combination of temperature and grating tuning to work around the mode hops.

For some applications, a suitably tuned CW-PLS laser may be a more practical or economical solution compared to a mode-hop-free CW-MHF laser. The CW-PLS laser may potentially be considered as an alternative to the CW-MHF after careful consideration of the application requirements.

The linewidth emitted from a CW-Pulsed laser during CW operation is < 100 MHz (<.003 cm-1) and is single-mode. Operation in pulsed mode will broaden the linewidth to < 30 GHz (< 1 cm-1) as multiple modes are emitted during the pulse. While pulsed operation offers great utility, it is not the subject of discussion for this application note – please refer to Tunable Pulsed Laser materials for performance details during pulsed operation.

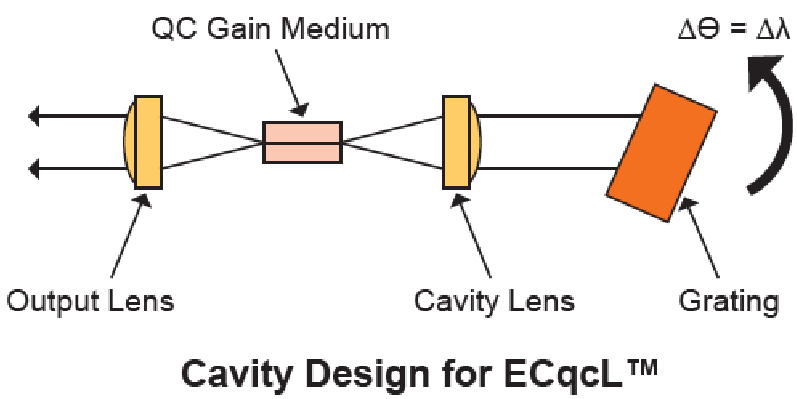

Figure 1: Conceptual drawing of an external cavity quantum cascade laser (ECqcL™) – wavelength tuning is achieved by rotation of diffraction grating.

Grating Tuning:

Unlike the CW-Mode-Hop-Free laser, the CW-Pulsed laser does not maintain a continuous cavity length of the laser as the grating is rotated to adjust wavelength. This results in micro-hops through the entire wavelength tuning range. The size of the mode hops are typically within 0.5 to 1.5 cm-1 (15 to 45 GHz). Just as mode-hops occur as a result of the rotating grating, parking or fixing the grating will yield stable, single-mode emission with no mode-hops. See Figure 2 for an illustration of the stepped wavelength emission curve as the grating angle is incremented to demonstrate several micro-hops.

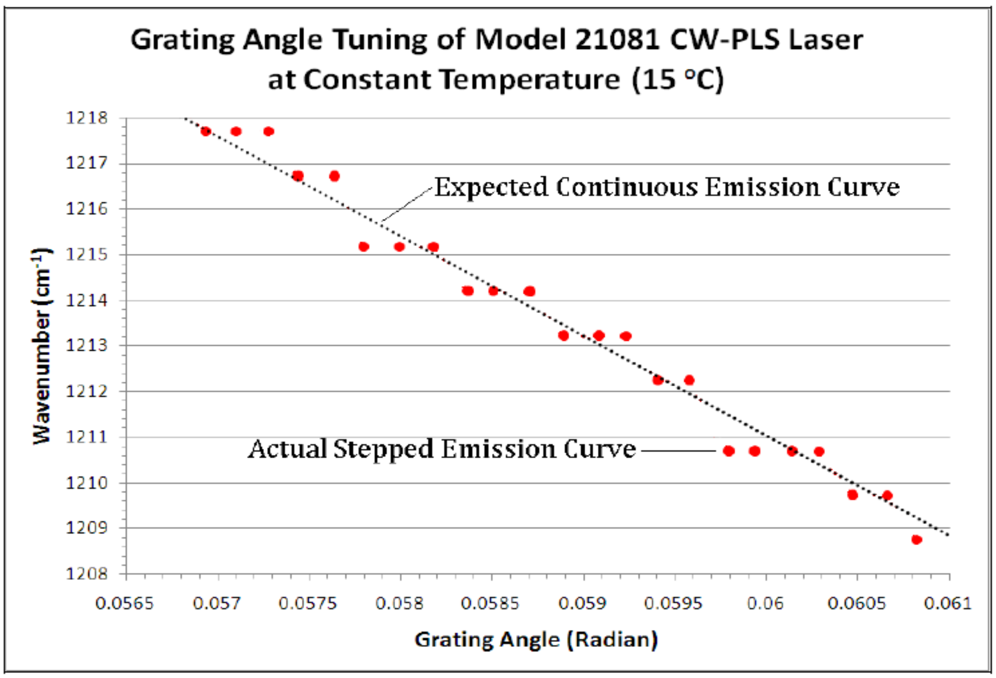

Figure 2: Example of a grating tuning experiment demonstrating that during tuning the optical field experiences“micro-hops” from mode to mode producing a stepped emission curve.

Temperature Tuning

The external cavity of the CW-PLS laser from Daylight Solutions is mounted on top of a thermoelectric cooler that maintains the temperature of the laser cavity to within ± 0.01 °C. Alternatively, the thermoelectric cooler allows for the precise heating or cooling of the laser cavity. Figure 3 shows how heating and cooling will change the length, and consequently the emission wavelength and mode structure of the cavity.

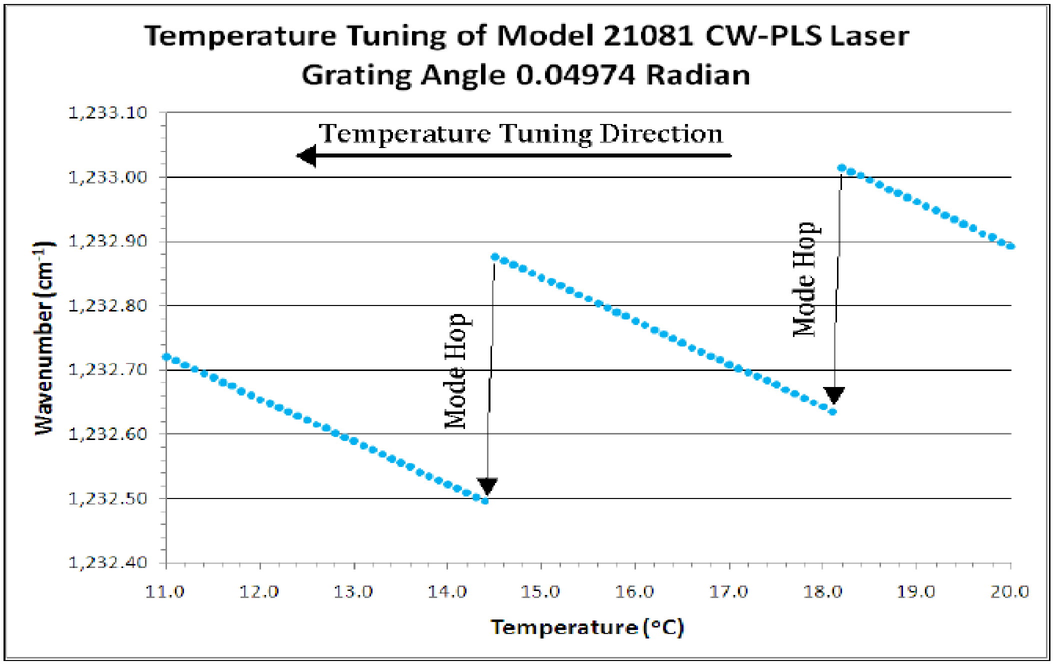

Figure 3: Results of a temperature tuning experiment (from high to low temperature) showing two mode hops.

Based on figure 3, we can calculate the frequency resolution for temperature tuning experiments. We can see that by changing the temperature by 3.5 °C, the wavenumber is shifted by 0.24 cm^{-1}. The minimum temperature increment for the laser head is 0.01 °C, corresponding to 350 temperature steps over the 3.5 °C interval. If we divide the wavenumber tuning range by the number of steps, we obtain a minimum wavenumber step of 0.0007 cm^{-1}. However, this does not take into account any effects due to thermal and mechanical instabilities, so the minimum wavelength increment would be larger. Therefore this technique is not recommended as a substitute for a CW-Mode-Hop-Free laser when the application is high resolution spectroscopy.

Grating and Temperature Tuning Combined

Combining temperature tuning with grating tuning, the total wavelength coverage may be maximized, as demonstrated by figure 4. By performing temperature tuning at several closely spaced grating positions, the quasi mode-hop-free tuning range was expanded from

0.46 to 0.59 cm^{-1}. We also see the formation of two additional quasi mode-hop-free tuning ranges. Continued grating tuning is expected to close the remaining gaps leading to a continuous quasi mode-hop-free tunable range spanning several wavenumbers.

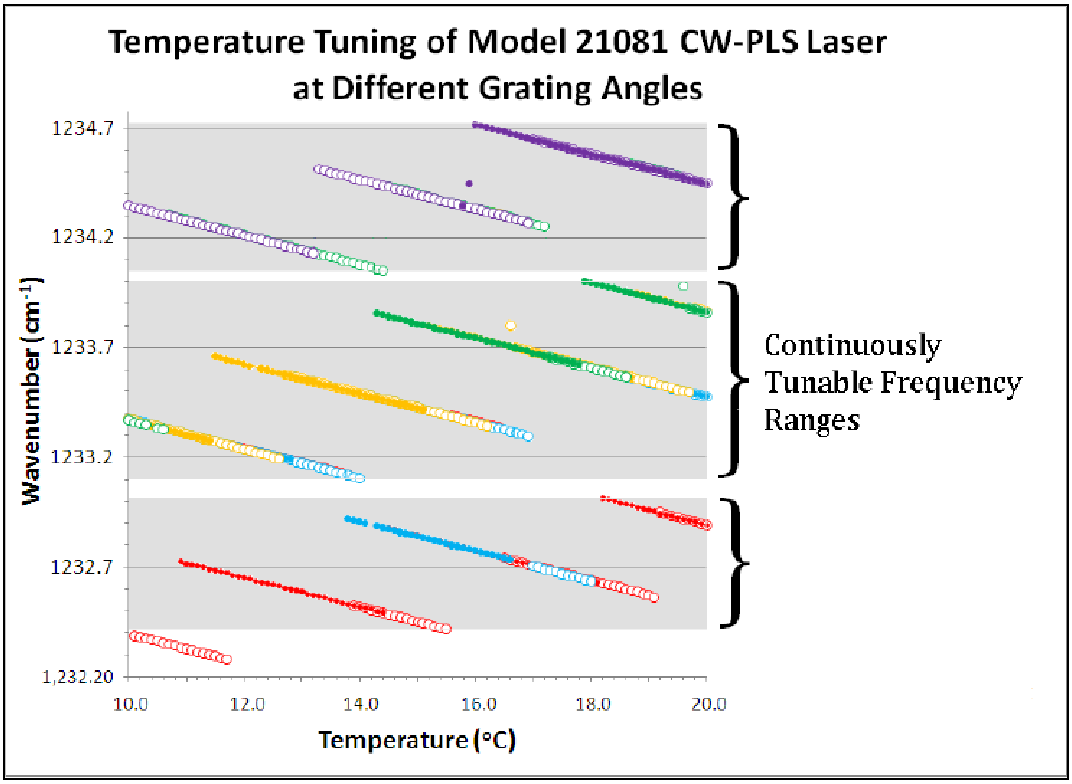

Figure 4: Example of a combined temperature and grating tuning experiment that leads to the expansion and eventual merging of adjacent quasi mode-hop-free frequency tuning ranges.

Use of mode-hopping or quasi mode-hop-free lasers may require a wavelength reference to make use off any data collected. A 621B-MIR Laser Wavelength Meter from Bristol Instruments was used to collect the above data and will work at all wavelengths currently offered with the CW-Pulsed Laser platform. Please contact a Daylight Solutions specialist with additional questions.