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Abstract:	A compact mid-infrared diode-pumped optical parametric oscillator has been developed. Single longitudinal mode output tunable over 9 GHz is produced with amplitude stability <1%. Use of the device in absorption spectroscopy has been demonstrated in carbon monoxide. (1 refs.)
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Chemical:	CO; C; O
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Carbon Monoxide absorption spectroscopy using a diode-pumped continuous wave optical parametric oscillator

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Summary

We have demonstrated for the first time long-term stable operation of a continuous wave optical parametric oscillator (CW OPO) pumped by a distributed bragg reflector (DBR) diode laser. We have also demonstrated the first use of a diode-pumped OPO in spectroscopic measurements. Continuous frequency scans through absorption features of Carbon Monoxide have been performed using the 2.3-μm OPO output. The OPO operates on a single longitudinal mode, with a bandwidth of 5MHz and an output power over 1mW in both signal and idler wavelengths. Continuous frequency scans of 9GHz have been demonstrated. Extension of the operating range of the OPO throughout the 1.1 to 3.6μm range will make such devices highly promising as room-temperature, low-cost, compact mid-infrared sources for numerous detection and spectroscopic applications.

The OPO uses an inexpensive, low-power (150-mW) DBR diode laser as a pump source. This source has several characteristics which make it suitable as a pump for a CW OPO. First, it operates stably on a single longitudinal mode with a measured bandwidth of less than 5MHz. Second, the diode frequency can be continuously tuned by as much as 50GHz without a mode hop, enabling continuous tuning of the OPO. Finally, the diode frequency can be rapidly modulated, allowing modulation of the OPO frequency and locking of the OPO frequency to absorption features. The diode output beam is focused through a Faraday isolator into a linear cavity OPO using periodically-poled lithium niobate (PPLN) as the nonlinear material. The OPO cavity is resonant at both signal and idler wavelengths, and the pump wave is double passed through the nonlinear crystal.

Output coupling of ~1% at signal and idler allows total OPO output of 18 mW to be obtained for 89 mW input power. OPO oscillation threshold is around 17mW. The PPLN is poled at 23.1-µm period to allow operation centered at 1.3 and 2.3 µm. Stable OPO operation requires precise control of OPO cavity length to maintain oscillation on the same signal and idler mode pair. This is achieved by implementing a dither-lock scheme, such that the diode current is modulated at up to 500kHz, and feedback is applied both to diode current and OPO cavity piezoelectric transducer (PZT). The high frequency component is fed back to the current and the low frequency component to the PZT. In this way the diode frequency is the frequency reference in the system. The diode frequency is significantly more passively stable than the frequency determined by the OPO cavity. Single-frequency operation has been observed without mode-hops for periods over one hour. OPO amplitude has been measured (at 1.3 µm) over a period of 15 minutes with a calculated standard deviation in amplitude <0.3% (figure 1). The linewidth of the OPO has been shown to be less than 60MHz using a confocal interferometer. According to previous investigations [1] , it is expected that the linewidth should match that of the pump source (<5MHz).

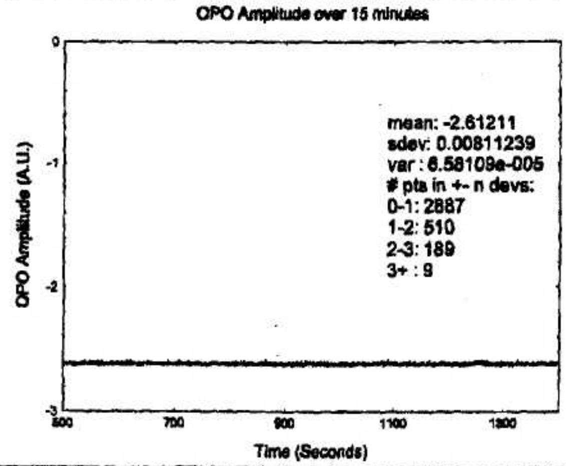

Figure 1 : OPO amplitude(negative) over a 15 minute period under 125kHz current dither / cavity stabilization. Standard deviation in amplitude is < 0.3%.

Continuous tuning of the OPO is obtained by applying an additional ramp voltage to the external input of the diode current supply while maintaining OPO cavity servo-lock. For a diode frequency scan of 14GHz, OPO signal frequency scanning of 9GHz and idler frequency scanning of 5GHz has been demonstrated. The OPO frequency has been scanned through carbon monoxide absorption features at 2.3 µm in a simple single-pass spectroscopy experiment (figure 2). OPO frequency scanning of up to 30GHz should be achievable using a cavity PZT with a greater travel range. We have also investigated rapid modulation of the OPO frequency. Frequency modulation is achieved by applying a rapid modulation of the diode current, while the cavity servo-control maintains locking of the OPO to the same cavity mode. Modulation at frequencies up to 800Hz with a range of 300MHz at the idler frequency has been demonstrated. Greater frequency range can be obtained at lower modulation frequency. This capability will allow frequency modulation spectroscopy and locking of the OPO frequency to absorption lines to be performed. We intend to extend both modulation frequency and range.

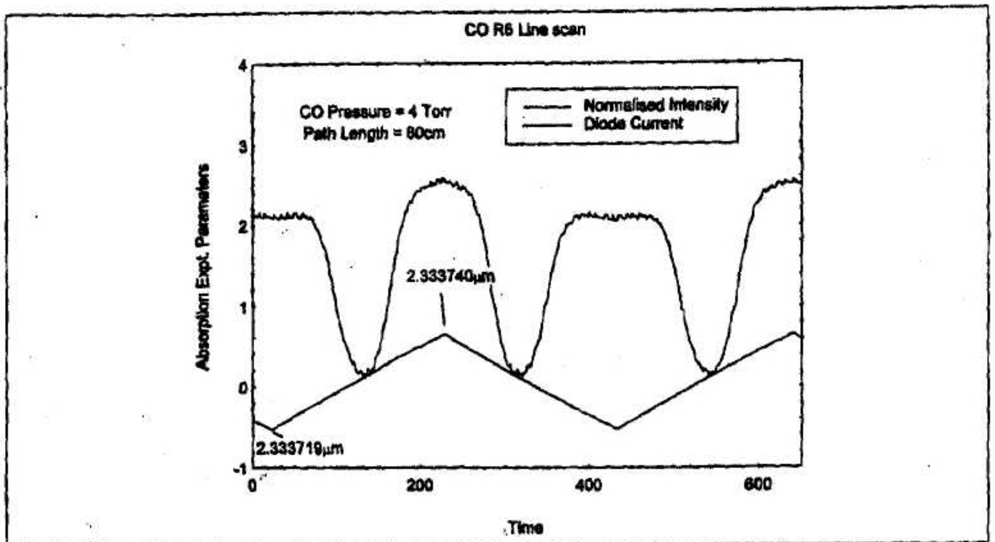

Figure 2 : 20pm wavelength scan of OPO idler wavelength through R6 absorption line in Carbon Monoxide, showing normalized transmitted amplitude through cell.

We are currently developing further OPO systems with idler wavelengths of 2.8μm, 3.2μm and 3.6μm. Such wavelength coverage will allow the OPO to be used in spectroscopic investigations of numerous species including N_2O, NO, CO and CO_2. These devices are compact, versatile, single-frequency sources, potentially tunable anywhere between 1.1 and 3.6 μm. Operating at room temperature or above, they offer significant advantages over current mid-infrared sources such as lead-salt diode lasers.

[1] C.D. Nabors, S.T. Yang, T. Day, and R.L. Byer, "Coherence properties of a doubly resonant monolithic optical parametric oscillator", J. Opt. Soc. Am. B. 7, 815-820 (1990).