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A 12.6 – 15 µm Mid-IR Source Based on Difference Frequency Generation in Orientation-Patterned GaAs

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Tunable laser sources in the mid-infrared (mid-IR) spectral range have been of great interest for a variety of applications such as molecular spectroscopy and trace gas detection. Difference-frequency generation (DFG) based on nonlinear frequency conversion in nonlinear crystals has been an effective approach to realize tunable mid-IR laser sources [1]. Among nonlinear crystals, orientation-patterned (OP) GaAs has been highly attractive for mid-IR DFG laser sources due to its large nonlinear susceptibility, lack of birefringence, wide transparency range (0.9 – 17 µm), high thermal conductivity, and high laser-damage-threshold [2,3]. Here, we report the generation of broadly tunable mid-IR radiation across 12.65 – 15 µm based on the DFG approach using an OP-GaAs crystal.

Figure 1(a) shows a schematic of our OP-GaAs based DFG experimental setup. An external-cavity quantum cascade laser (EC-QCL), followed by an optical isolator (OI), was used as the pump source. The EC-QCL provides single-mode emission in the 5.49 – 5.71 µm spectral range. The EC-QCL was operated at 13 °C with an output power up to 70 mW. The inset of Fig. 1(b) shows the variation of the EC-QCL power as a function of wavelength, measured before the input facet of the OP-GaAs crystal, against the wavelength. A tunable CO_2 laser was used as the signal source. The CO_2 laser was operated at a repetition rate of 1 KHz with a duty cycle of 20%, resulting in an output power up to 10 W. Two sets of two concave mirrors (CMs) were used to optimize the beam waists of the pump and signal lasers inside the crystal for maximum DFG efficiency. Both the pump and signal laser beams were aligned through a beam combiner (BC) and focused onto the OP-GaAs crystal by a parabolic mirror (PM). After the OP-GaAs crystal, the idler signal was collected by a second PM and then focused onto a liquid-nitrogen-cooled HgCdTe detector using a KBr lens (L). A longpass filter (LF) was placed before the focusing lens to eliminate both the pump and signal lasers.

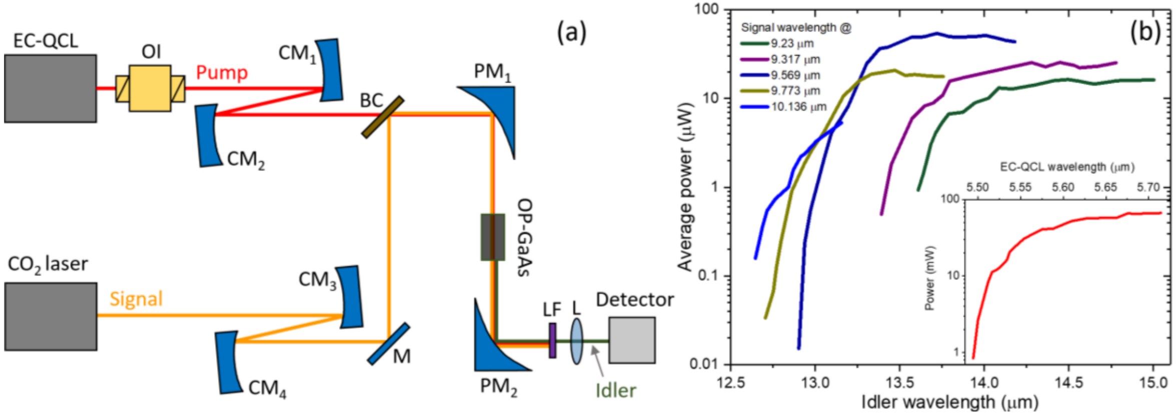

Fig. 1 (a) Schematic of the DFG experimental setup. (b) Average power of the idler (DFG) laser at different signal wavelengths (CO_2 laser lines). The inset shows the power of pump laser (EC-QCL) across its tuning range.

By combining the tunability of the pump and signal sources, we have obtained an idler wavelength range between 12.646 µm (790.76 cm^{-1}) and 15.002 µm (666.57 cm^{-1}). Fig. 1(b) shows a few representative traces of the average power curves of the idler (DFG) laser at different signal wavelengths (CO_2 laser lines with varied laser power). The shape of idler power curves reflects the shape of the signal (EC-QCL) power curve shown in the inset of Fig. 1(b). The highest idler output power of about 55 µW has been achieved at an idler wavelength of 13.72 µm. Benefiting from the wide, continuous tunability of the idler wavelength of our DFG system, we can perform high-resolution spectroscopic investigations of the fingerprint of important molecules (e.g., benzene, xylene, and acetylene) in the obtained mid-IR wavelength range not accessible by commercial laser sources.

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