Spectral Properties and Frequency Control of Optical Parametric Oscillators for Applications in Metrology

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Abstract: We characterize a cw OPO featuring narrow linewidth and the possibility of phase locking to optical frequency standards. We present a novel scheme for transferring frequency stability between the IR and visible.

The mid-IR spectral range around 3 µm is of great interest to high-resolution spectroscopy and metrology since it contains fundamental vibrational modes of molecular bonds including hydrogen. Accessing these transitions provides vast opportunities for fundamental research and industrial applications. Their spectroscopic investigation, however, is hindered by the lack of appropriate tunable laser sources operating in this spectral region. Continuous-wave optical parametric oscillators (cw OPOs) are one of the few viable options.

We present a practical cw OPO device that offers several advantages over analogous systems. Its detailed description and the first application for Doppler-free spectroscopy of methane are reported in [1]. The singly resonant OPO with resonated pump is based on a periodically-poled lithium niobate (PPLN) crystal pumped by a monolithic Nd-YAG laser. The OPO contains a specially designed intracavity etalon, which allows controlled access to any desired frequency in a wide emission range: 1.5-1.9 µm (signal) and 2.4-3.7 µm (idler). The output radiation has a linewidth less than 15 kHz and power levels of 10-50 mW. We have shown that the OPO output frequencies can be easily phase locked to independent laser sources in the visible and IR ranges.

These features of the OPO combined with the recently developed optical frequency combs based on femtosecond mode-locked lasers [2] open up a series of new opportunities in optical metrology. We propose a scheme that allows to phase lock the OPO output frequencies and a femtosecond laser frequency comb to each other. Our idea is based on the fact that our OPO emits not only the signal (S) and idler (I) waves (with pump frequency P=S+I), but also a variety of (not necessarily phase-matched) linear combinations of the two frequencies. Some of these frequencies (P+S, P+I, 2S) are located in the emission range of a mode-locked femtosecond Ti:Sapphire laser and can be used for the mutual frequency stabilization of the two sources. In this arrangement the OPO serves as a bridge that transfers the stability of frequency standards operating in the near- and mid-IR into the visible and vice versa.

This paves the way for developing a precise frequency synthesizer for the entire optical range. One can also use the OPO – frequency comb tandem to compare frequency standards of different physical nature and thus carry out fundamental tests of physics.

References

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