Entirely passive thin-disk dual-comb spectrometer operating in green

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Dual-comb spectroscopy (DCS) is an attractive tool for fast measurements with high sensitivity and high resolution [1]. One approach in dual-comb spectroscopy is to rely on fully passive dual-output (dual-comb) laser systems. The most powerful oscillator among these systems is a dual-comb thin-disk oscillator providing MW-peak power level directly. High output powers immensely simplify nonlinear frequency conversion and this ultimately paves a way towards dual-comb XUV spectroscopy.

Here, we present nonlinear frequency conversion into green spectral region and systematically compare it with the measurements at the fundamental wavelength of 1 µm. Real-time measurements simultaneously at both wavelengths are presented (see figure 1b). This is possible thanks to the excellent mutual stability of our dual-comb oscillator. The high output power of our laser source facilitates frequency doubling of our 1 µm and even further conversion UV. Simultaneous measurement of iodine (515 nm) and acetylene (1030) helps to evaluate the jitter and noise characteristics at both wavelengths.

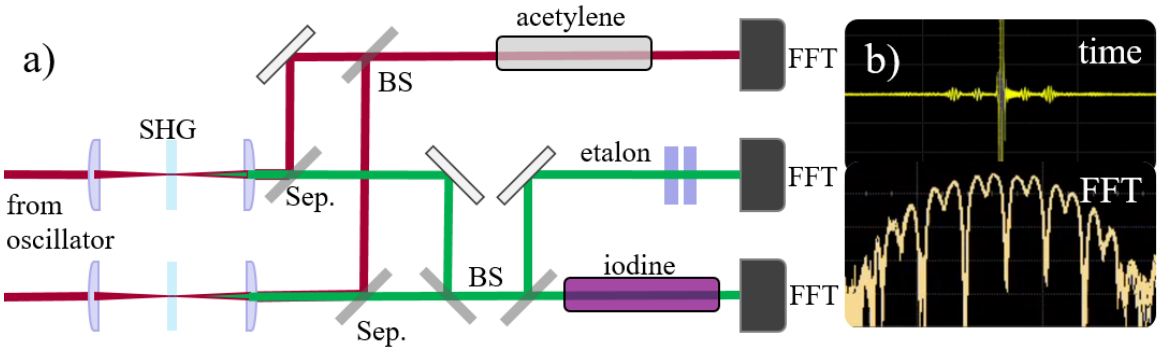

Fig. 1 a) Measurement setup. The 1030 nm IR-beams originated from the dual-comb thin-disk oscillator [2] enter the setup from the left. Both beams are passing identical SHG-stages before the 515 nm radiation is taken apart with separators (Sep.). Both, the IR and green beams are overlapped with beam splitters. The IR superimposed beam passes an acetylene cell and hits the photodiode (PD). The green superimposed beam passes an iodine cell and/or a Fabry-Pérot-etalon before beam measured with the oscilloscope b) A real-time measurement with oscilloscope Keysight DSOS254A. The yellow upper curve shows the time domain signal and the bottom curve the corresponding FFT with down-converted absorption dips induced by the R-branch of acetylene's $3\nu_3$band.

The dual-comb measurement setup is illustrated in figure 1a. The dual-comb laser sources are Yb:YAG based thin-disk 60 MHz-oscillators emitting 1.2 MW and 15 W average power pulses with 180 fs duration and 5.5 nm FWHM at 1030 nm [2]. Thin BBOs with 100 µm thickness are chosen. After separating green from IR and overlapping the beams, the spectrally separated dual-combs are guided through the acetylene and iodine cells. Afterwards the signal gets detected with photodiodes and oscilloscope. The dual-comb spectrometer stays within the necessary mutual stability range avoiding aliasing of the dual-comb spectra within two-hour measurement time. For a recorded 650 ms long oscilloscope trace, containing 143 acetylene and 143 iodine interferograms each, the difference of repetition rates is 217.14 Hz for both measurements. It's jitter was measured to be 26.4 mHz for acetylene and 26.5 mHz for iodine. These two values are nearly the same showing that there is no additional jitter accumulation due to the frequency doubling. The radio frequency jitter of the FFTs can easily be digitally corrected. Iodine has an extremely fine and complex absorption structure which makes it a perfect sample for high resolution spectroscopy studies. DCS of iodine with a frequency-doubled fiber laser has been reported before [3], however, with active, adaptive sampling technique and 3 mW average power. Our next step is the extension and first DCS measurements in UV spectral domain.

References

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