Flexible all-PM NALM Yb:fiber laser design for low-noise frequency comb applications and single-cavity dual-comb generation

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Dual-comb systems traditionally consist of two mode-locked lasers actively stabilized to each other, leading to expensive and complex systems [1]. A very promising simplification is the single-cavity approach, where two pulse trains are generated within a single laser cavity [2]. Here, we present dual-comb generation from a single all-polarization-maintaining Ytterbium (Yb)-fiber laser via spectral subdivision. The laser is mode-locked using a nonlinear amplifying loop mirror (NALM) with a non-reciprocal phase bias. This versatile architecture allows for both single- and dual-comb operation in various intracavity group delay dispersion regimes.

In the single-comb operation mode, we have characterized the intensity noise, timing jitter and the free-running linewidth of the carrier-envelope-offset (CEO) frequency of five representative mode-locking states ranging from anomalous (-0.035 ps^2) to normal (+0.015 ps^2) intracavity dispersion [3]. We show that operation points far from the spontaneous emission peak of Yb (~1030 nm), but close to zero intracavity dispersion can be found, where the influence of pump noise is suppressed so strongly that the CEO-linewidth can be reduced to the single-digit kHz level at 1s integration time without any active stabilization.

Dual-color operation in such a laser is achieved by adding a thin blade-shaped beam block in the grating compressor where the light is spatially dispersed, see Fig. 1(a). The laser emits two pulse trains centered around 1030 nm and 1060 nm, respectively. By tuning the cavity dispersion, we can vary the difference in repetition rates from ~1 kHz to 10 kHz around a nominal repetition rate of 77 MHz, which corresponds to a maximum non-aliasing bandwidth of ~2.5 THz. The spectral overlap necessary for dual-comb operation is realized outside of the laser cavity by amplification and subsequent nonlinear broadening. The usability of this dual-comb setup is demonstrated by measuring the transmission of a Zinc Selenide (ZnSe) etalon.

The single-cavity dual-color/dual-comb all-PM Yb:fiber laser platform [4] presented here can easily be combined with power scaling stages and subsequent nonlinear wavelength conversion to expand its spectral operation range. Hence, such lasers show great potential as a versatile tool for many applications in spectroscopy and beyond.

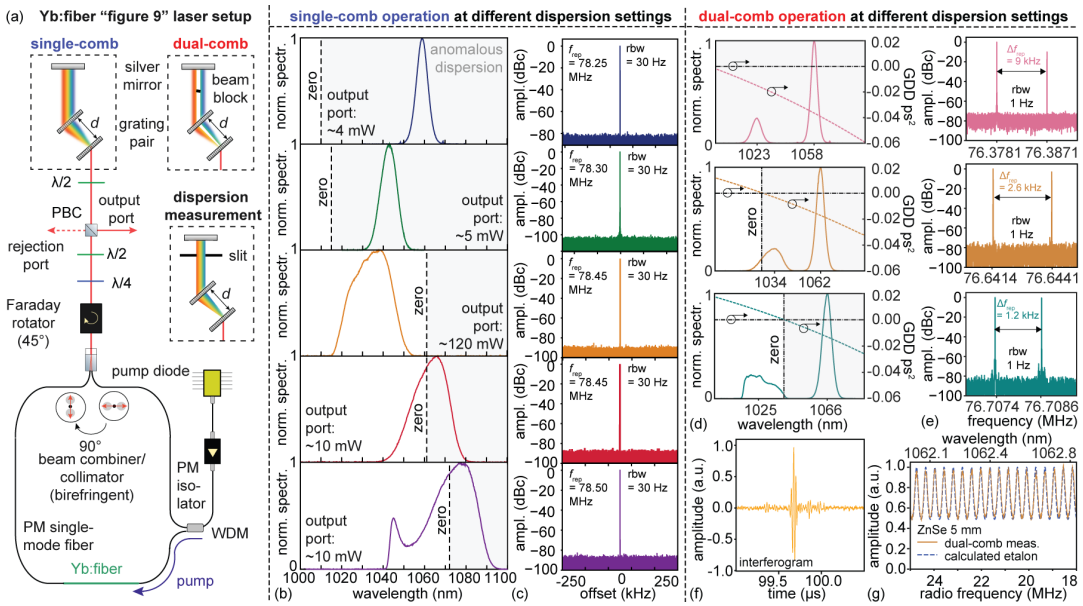

Figure 1: (a) Laser setup depicting the single- and dual-comb operation mode as well as the slit-method used for intra-cavity dispersion measurements. (b) Optical spectra of modelocking states obtained in single-comb operation at 5 different grating separations d and (c) corresponding measurement of the repetition rate frequency f_{rep}. (d) Optical spectra in dual-comb operation at 3 different grating separations and (e) corresponding measurement of the repetition rate frequencies $f_{rep,1}$ an $f_{rep,2}$. (f) Single-shot time domain interferogram of the configuration with Δf_{rep} =2.6 kHz corresponding to (g) transmission measurement of a 5-mm thick ZnSe (orange) and simulation (blue)

References:

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