Linewidth Engineering of an Er:fiber Frequency Comb

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Frequency combs based on mode-locked Er:fiber oscillators exhibit several advantages over solid-state lasers based combs like compactness, alignment-free operation and robustness against environmental influences. State-of-the art systems have typical intrinsic tooth linewidths in the range of several tens of kHz. A reduction of the intrinsic linewidth below a few kHz without the need of locking to an optical stabilization cavity would simplify laser cooling experiments significantly. In this work we employ a recently demonstrated technique[1] aiming for intrinsically narrow linewidths in the wavelength range from 689 nm to 1550 nm.

The broadening of the linewidth is attributed to factors such as pump-power-induced noise, environmental effects as well as on quantum noise effects.[2] As the spectral position and the linewidth of a comb line is determined by the carrier-envelope offset frequency f_{ceo} and the repetition rate f_{rep} we examined their dependency on pump power independently. Using the elastic-tape model[3], we can manipulate the position of the pump-induced fix point of the comb by up to 600 THz through adjustments in the net-dispersion of the 80-MHz oscillator. Notably, the sensitivity of comb linewidth on the pump power experiences a marked decrease while the pump-induced fix point shifts to high frequencies. Consequently, this allows for sub-kHz-comb-tooth-linewidths in a very broad spectral range (e.g. 689 - 813 nm).

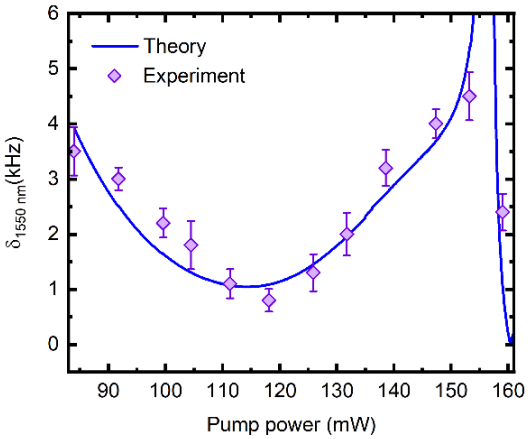

Fig. 1: Theoretical and measured comb tooth linewidth at 1550 nm vs. pump power of the Er:fiber-oscillator.

Fig. 1 shows the linewidth measured at 1550 nm vs. the pump power of the Er:fiber-oscillator. The minimum linewidth of a comb tooth at this wavelength is well below 1 kHz. The spectral position of the minimum linewidth varies with the oscillator pump-power.[1,2] The selected oscillator design facilitates the adjustment of the minimum linewidth's spectral position to desired wavelengths, reaching down to 689 nm as per experimental validation. These findings align well with theoretical projections, derived from pump-power dependency measurements of f_{ceo} and f_{rep} across the entire spectral range from 689 to 1550 nm.

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