Generalized representation of noise in optical frequency combs by spectral correlation analysis

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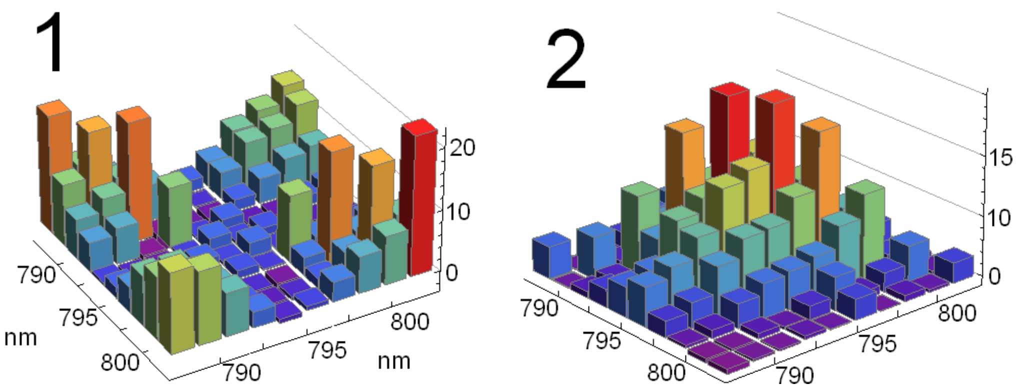
Amplitude and phase noise of optical frequency combs have been studied extensively for individual optical frequencies or for the mean field[1]. Repetition-rate and CEO-phase noise are examples of noise properties of the entire comb. Rather than observe noise for the mean field, the measurement may be spectral resolved and correlations can be considered. Phase noise can be measured down to the quantum limit by the interference of a frequency comb with a cavity filtered part of lower phase noise and recording the resulting intensity noise[2]. Using this technique and a pulse-shaped reference, we determine the entire noise covariance matrices of amplitude (Fig.1) and phase (Fig.2) of a 6nm FWHM Ti:Sapph frequency comb.



Both noise quadratures are correlated differently and all correlations vanish at the quantum limit at 3MHz detection frequency. The eigenvectors of both matrices correspond to spectral distributions of correlated noise. We term the underlying well-defined pulse shapes ***noise modes.*** Both noise quadratures are found to be a superposition of multiple orthogonal noise modes. Covariance matrices can be projected into any basis of such modes, permitting to calculate the noise levels of the comb in any possible mode. Repetition rate- and CEO-phase noise correspond to well defined noise modes[3]. They emerge canonically in this representation and we study their noise levels close to the quantum limit. In addition, the sensitivity of measurements with frequency combs could be improved if the mode of detection is chosen with regard to the noise modes of the comb.

1 D.V. Sutyrin, et. al., Frequency noise performances of a Ti: sapphire optical frequency comb stabilized to an optical reference, Optics Communications, (2012)

2 R. Schmeissner, V. Thiel, C. Jacquard, C. Fabre and N. Treps, “Analysis and filtering of phase noise in an optical frequency comb at the quantum limit, to improve timing measurements”, arXiv preprint arXiv:1401.3528 (2014)

3 B. Lamine, C. Fabre and N. Treps, “Quantum improvement of time transfer between remote clocks”, Physical review letters 101, 123601 (2008)