Frequency comb stabilization and application as an optical ruler

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Motivation

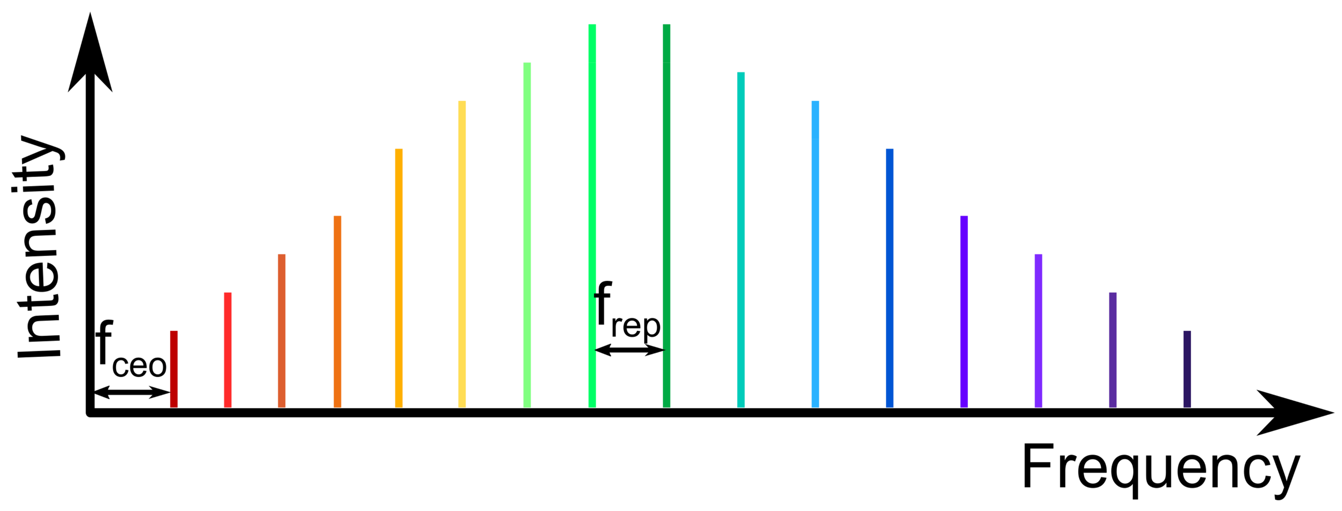
Our goal: spectrally expand a stabilised frequency comb via propagation through a highly nonlinear fiber and employing the generated supercontinuum as an optical ruler for precise frequency measurements and even frequency stabilisation of other cw laser sources.

Frequency comb

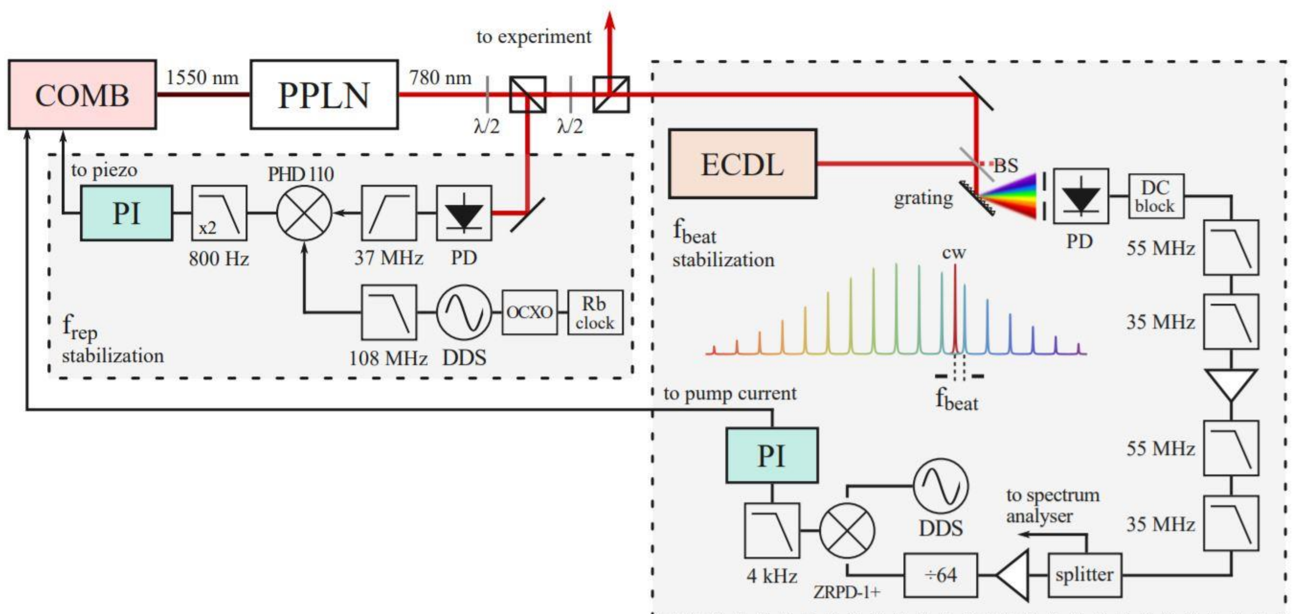
Frequency comb (FC) - spectrum consisting of discrete equidistant frequency lines
Lines are given as:

$$f_n = n \cdot frep + fceo$$

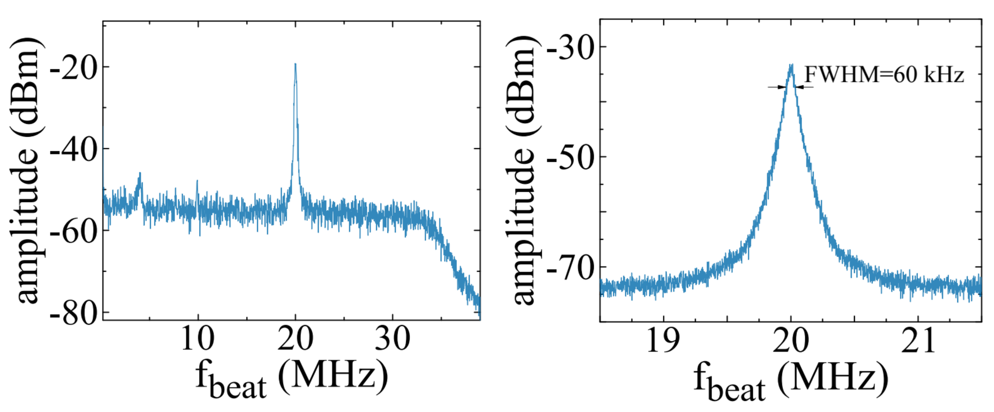
Optical frequencies (THz) RF frequencies (MHz)



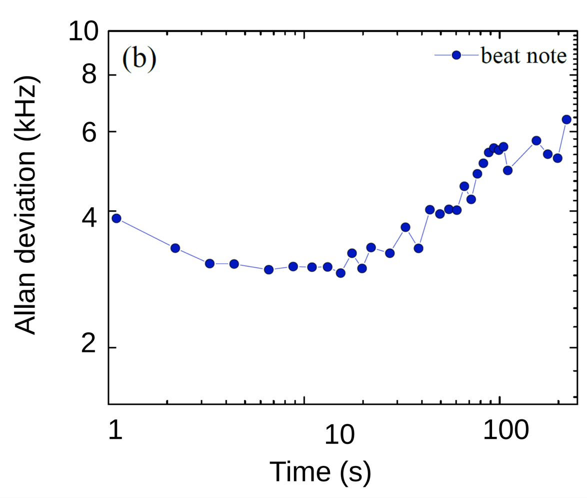
Frequency comb stabilisation setup



Repetition frequency is stabilised by referencing onto a Rb clock. Offset frequency is indirectly stabilised by optical heterodyne beats of an n^{th} tooth of FC to a stabilised cw laser source [1].



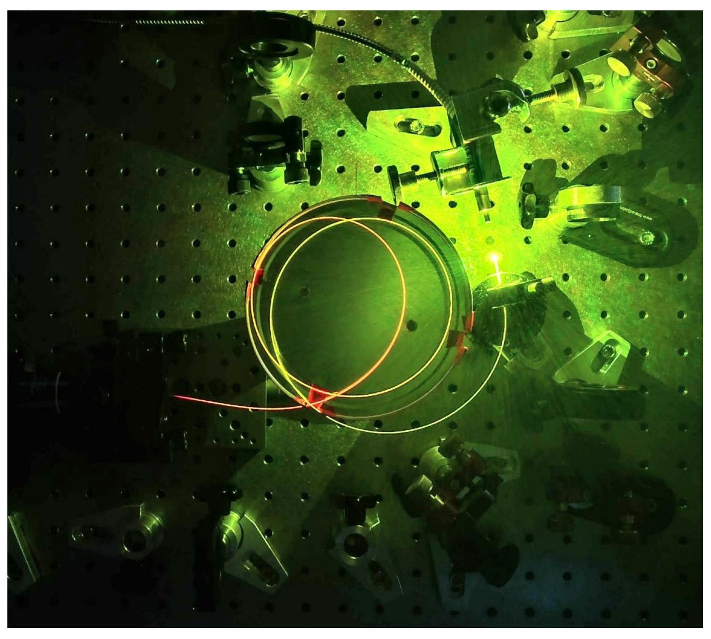
Optical heterodyne detection of beats between of an n^{th} comb tooth and stabilised cw laser source



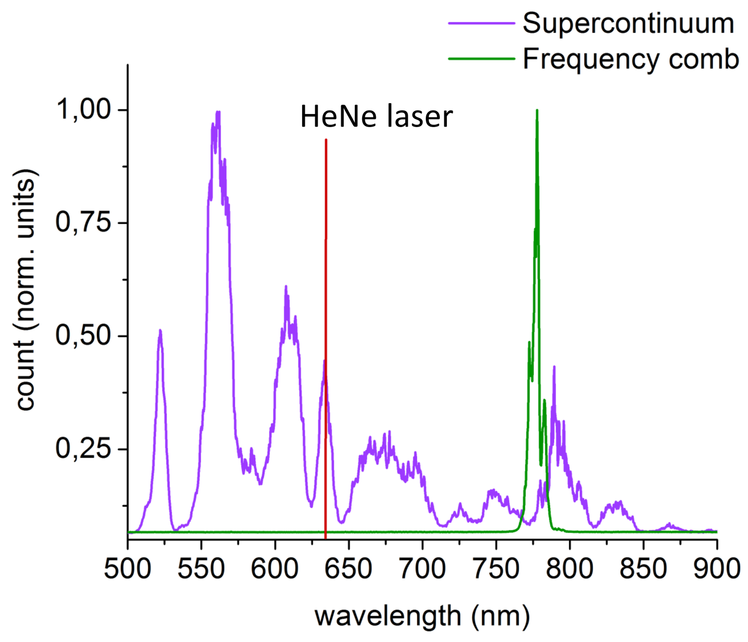
[2]

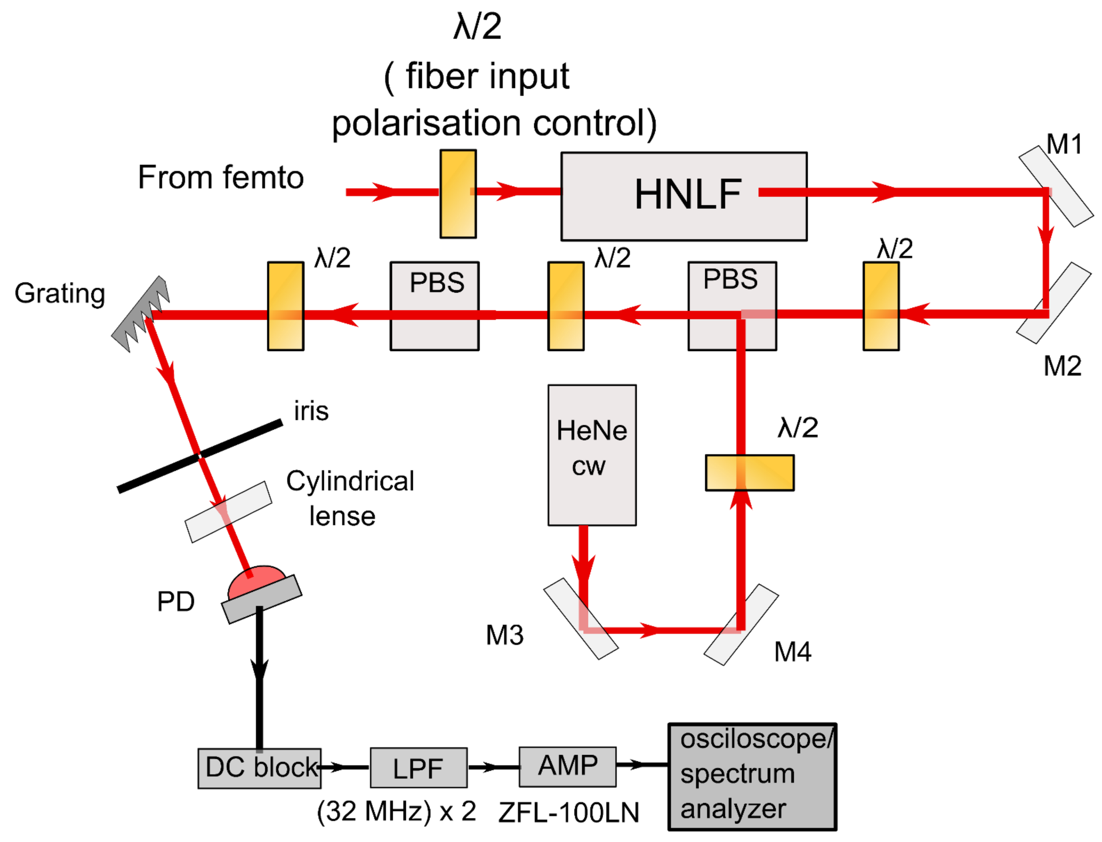
Frequency stability of FC by heterodyne beating with ECDL locked to a two-photon transition of Rb^{85}

Supercontinuum generation and optical heterodyne beat detection setup

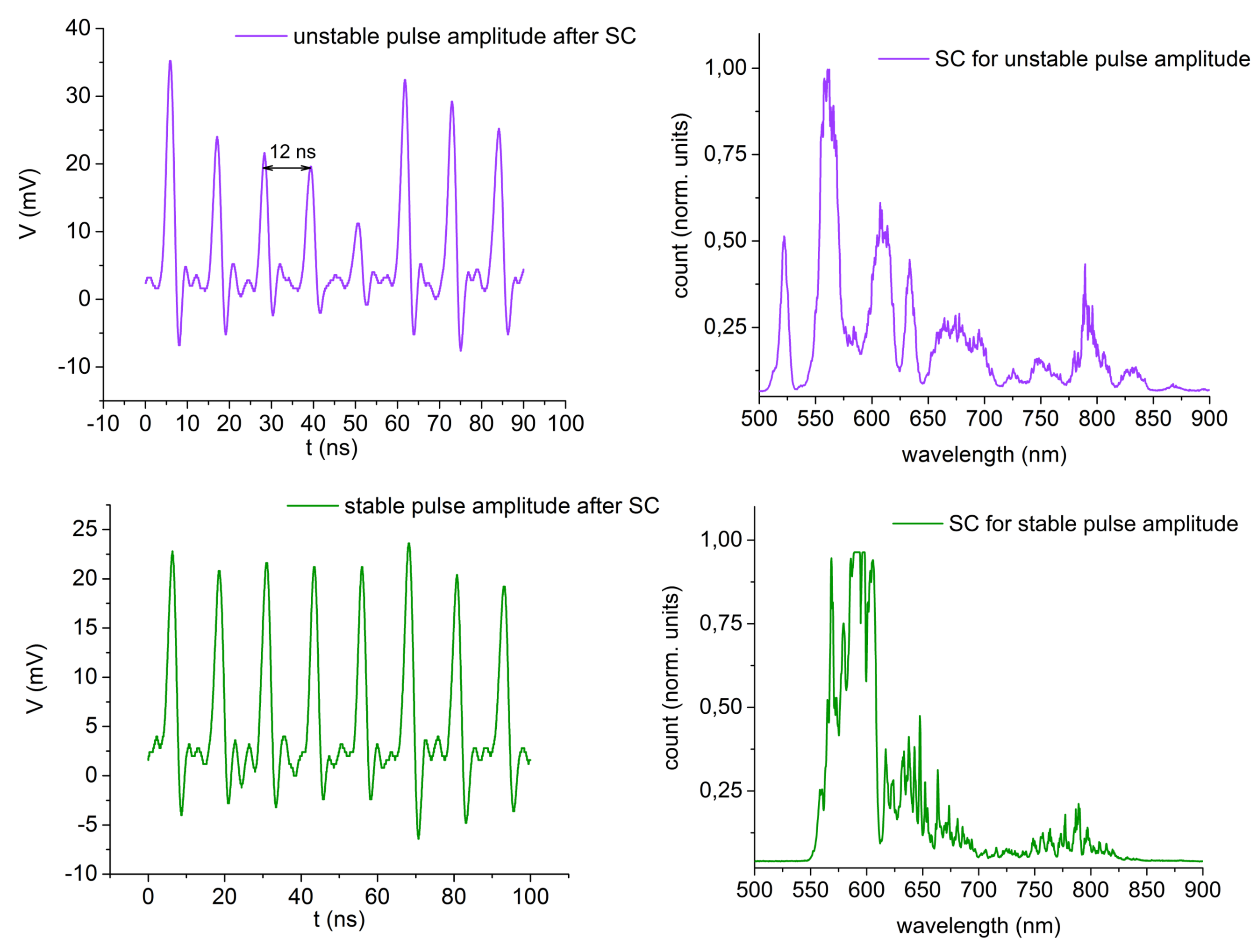


Femtosecond pulses are propagated through a highly nonlinear fiber. Higher order nonlinear effects broaden the FC into spectral supercontinuum. This broadened FC is then employed as an optical ruler for a HeNe laser source.





Modulation instability induced coherence degradation and pulse amplitude oscilations



During supercontinuum generation, modulation instability (MI) causes coherence degradation of the FC. Degradation manifests as random evolution of the pulse phase and strong oscilations of the pulse amplitude, preventing beat detection between the SC and HeNe laser source. Reduction of input power into the fiber will reduce the MI induced noise producing more stable pulses.

Outlook

A possible solution to coherence degradation presents itself in the form of pulse compression prior to SC generation as shorter pulses are less susceptible to modulation instability. Also, shorter pulses will cause faster expansion of the SC in the fiber, allowing a reduction in fiber length. This reduction in fiber length will decrease MI-induced noise in the SC and reduce coherence degradation which will allow us the use the FC as an optical ruler.

References:
[1] Synthetic Lorentz force for neutral cold atoms, N. Šantić, PhD thesis
[2] „Frequency comb stabilization without self-referencing for cold atom experiments", N. Santic, G. Kowzan, D. Kovacic, D. Aumiler, P Maslowski, and T. Ban