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Chaotic micro-comb based parallel ranging

The transition to chaos is ubiquitous in nonlinear systems ranging from fluid dynamics and superconducting circuits to biological organisms [1]. Optical systems driven out of equilibrium such as lasers and supercontinuum generation exhibit chaotic states of light with fluctuations of both amplitude and phase and can give rise to Levy statistics, turbulence, and rogue waves. Spatio-temporal chaos also occurs in continuous-wave driven photonic chip based Kerr micro-resonators [2], where it is referred to as chaotic modulation instability. Such modulation instability states have generally been considered impractical for applications, in contrast to their coherent light state counterparts, which include soliton or dark-pulse states. Here we demonstrate that incoherent and chaotic states of light in an optical microresonator can be harnessed to implement unambiguous [3] and interference-immune massively parallel coherent laser ranging by using the intrinsic random amplitude and phase modulation of the chaotic comb lines. We utilize 40 distinct lines of a microresonator frequency comb operated in the modulation instability regime. Each line carries >1 GHz noise bandwidth, which greatly surpasses the cavity linewidth [4], and enables to retrieve the distance of objects with cm-scale resolution. Our approach utilizes one of the most widely accessible microcomb states, and offers - in contrast to dissipative Kerr soliton states - high conversion efficiency, as well as flat optical spectra, and alleviates the need for complex laser initiation routines. Moreover the approach generates wideband signal modulation without requiring any electro-optical modulator or microwave synthesizer. Viewed more broadly, similar optical systems capable of chaotic dynamics could be applied to random modulation optical ranging as well as spread spectrum communication, optical cryptography and random number generation.

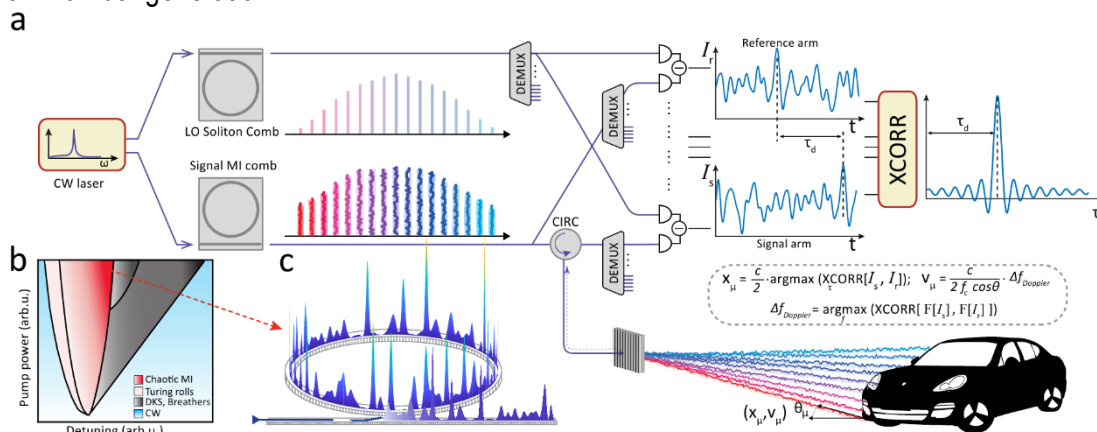


Figure 1: Concept of Chaotic microcomb coherent LiDAR. **a)** Schematic of experimental setup. **b)** Microcomb stability chart illustration. Chaotic modulation instability (MI) area represents the microcomb state of interest. Gradient fill towards top right highlights the preferred region of operation. **c)** Simulation of chaotic MI waveform in the microresonator.

References

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