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Microresonator soliton frequency combs

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Optical frequency combs1,2 provide equidistant markers in the IR, visible and UV and have become a pivotal tool for frequency metrology and are the underlying principle of optical atomic clocks, but are also finding use in other areas, such as broadband spectroscopy or low noise microwave generation. In 2007 a new method to generate optical combs was discovered based on high Q optical microresonators3,4. Such microresonator frequency combs have since then emerged as a new and widely investigated method with which combs can be generated via parametric frequency conversion of a continuous wave (CW) laser inside a high Q resonator via the Kerr nonlinearity. Over the past years the a detailed understanding of the comb formation process has been gained, and regimes identified in which dissipative temporal solitons (DKS) can be generated, that not only provide low noise optical frequency combs but moreover give access to femtosecond pulses. Such DKS have unlocked the full potential of soliton micro-combs by providing access to fully coherent and broadband combs and soliton broadening effects. Dissipative Kerr solitons have now been generated in a wide variety of resonators, including those compatible with photonic integration based on silicon nitride (Si3N4). We will discuss the DKS regime, first discovered in crystalline resonators, and our current understanding including the observation of the breather soliton regime, the influence of avoided mode crossings on breather and the repetition rate, as well as methods to deterministically access the single soliton regime. Taken together this has enabled to reliably access single soliton states in photonic chip based resonators, in particular those utilizing the photonic damascene process. Dissipative Kerr solitons enable to obtain combs that can span more than a full octave using soliton induced Cherenkov radiation, which extends the combs bandwidth and power in the spectral wings via dispersive waves. Such DKS have been enabled to count the cycles of light, allow 2f-3f self referencing. Using such soliton Kerr optical frequency combs in a SiN microresonator we have recently demonstrated with the group of C. Koos (KIT) massively parallel coherent communication, with dual combs for both the source and as massively parallel LO for the coherent receiver. Moreover, we have demonstrated using a pair of photonic chip based frequency combs dual comb distance measurements, with record acquisition rates due to the combs large mode spacing (100 GHz). Recent work moreover has shown that DKS can be extended to the biological imaging window at 1 micron, relevant for e.g. Raman spectral imaging or OCT. Soliton microcombs have the potential to advance timekeeping, metrology or telecommunication by providing a technology amenable to full photonic integration, low power consumption and large comb bandwidth and repetition rate.

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