The Science of Optical Microresonators: Chipscale Optical Frequency Combs

Optical frequency combs[1,2] 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. Frequency combs are conventionally generated by using the periodic train of pulses from a modelocked laser. In 2007 a new method to generate optical combs was discoverer based on high Q optical microresonators[3,4]. Microresonator frequency combs have since then emerged as a new and widely investigated technology 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 can be generated, that not only provide low noise optical frequency combs but moreover give access to femtosecond pulses. Micro-resonator frequency combs offer high repetition rates in the technologically relevant GHz regime. Moreover the parametric gain is broadband enabling frequency combs that can extend over a full octave[5] without external broadening. In addition, micro-resonators are amenable to planar integration allowing further electronic and optical integration on a chip. The developments at EPFL will be reviewed, and results using SiN planar microring resonators[6] and ultra high Q crystalline MgF2[7] resonators presented. In particular low noise broadband comb operation will be discussed, their use in coherent telecommunications[8] for terabit/second coherent datacommunication and the extension of these Kerr frequency combs to the mid-IR[9]. Moreover the formation of dissipative temporal solitons discovered in microresonators will be discussed[10]. Using time domain broadening and 2f-3f self referencing, these temporal soliton states have allowed counting the optical cycles of light using a microresonator[1]. In addition we demonstrate higher order soliton based broadening phenomena in a SiN microresonator, allowing the direct generation of a fully coherent optical frequency comb that spans 2/3 of an octave using a continuous laser pumped SiN microresonator[2].

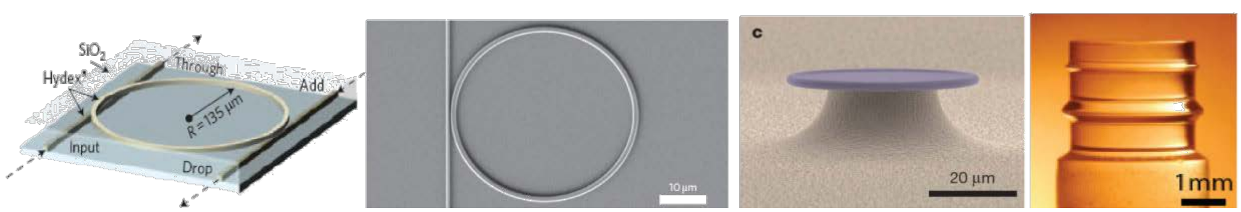

Figure 1 : Microresonator frequency comb platforms[4].

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