MOCCA ESRs' Newsletter

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MOCCA ESR Francesco Talenti presents his project.

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ABOUT MY PROJECT AND ITS PROGRESSES

The title of my project is: "**Optical Microcombs Dynamics for Novel Microcomb Sources"**

Frequency combs are optical sources with many applications in fields such metrology, molecular spectroscopy, telecommunications, astronomy or atomic clocks. From year to year the technology behind their experimental set ups has been developed and improved, typical devices miniaturized and integrated. Nowadays is possible to generate frequency comb on-chip with input powers, at the state of the art, of few tens of μWs. In this project the dynamics of comb generation is studied and novel schemes for comb generation are proposed. We study the dynamics of comb formation in novel devices such as photonic crystal (PhC) cavities.

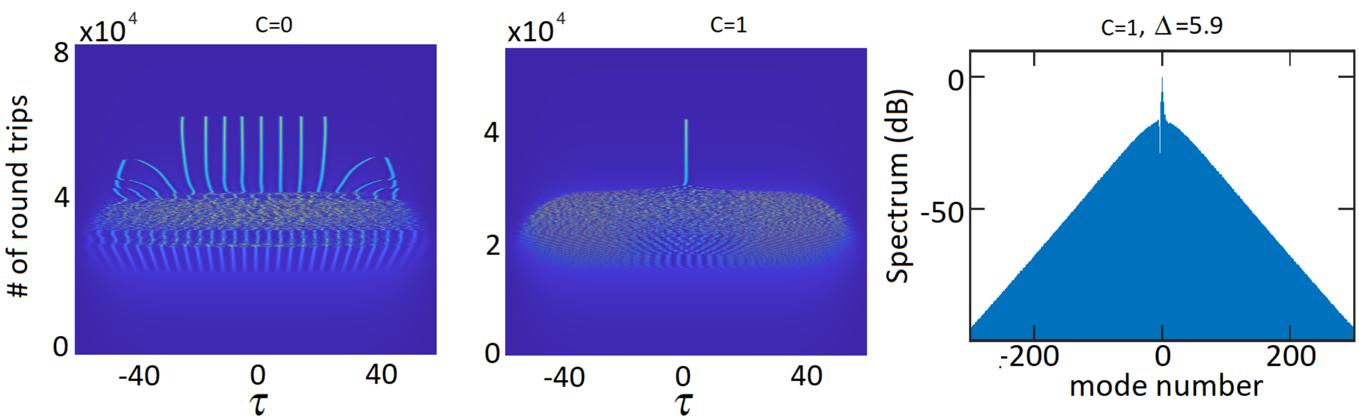

Image: Dynamical study of kerr cavity solitons frequency combs. From left: in the first two panels we report multi- and single solitons dynamics controlled by a chirped pulse driven field. On the right the comb spectrum of a single soliton state.

Solitons dynamics in passive cavities

Behind the wide range of applicability of frequency comb sources, we study the dynamics of light propagation in passive optical cavities. An optical cavity is a structure used to confine light in a small portion of the space. In its simplest configuration it is composed by two mirrors placed one in front of the other. Once light is coupled inside the cavity, it stays confined between the two mirrors. If we think to a photon, it bounces against the mirrors without having the possibility to escape. Once the photon comes back to its initial position, it completes a round trip of the cavity, starting a new identical one.

A simple bow-tie cavity is sketched in fig.1. This in particular was used for one of the first experimental demonstration of τ (2) frequency combs. When describing the temporal dynamics if light matter interaction in such structures, it is useful to consider two scales of time. Normally one refers to slow time and fast time, which we denote as t and τ, respectively. The reason we do that, beyond the math, it is quite intuitive: t represents the time over successive round trips, while τ its the actual physical time. The dynamics evolving on the t scale doesn't tell us anything about the rich physics inside the cavity, but it gives us information about how the physical parameters evolve over successive round trips. In contrast, the τ dynamics describes the fast light evolution inside the cavity.

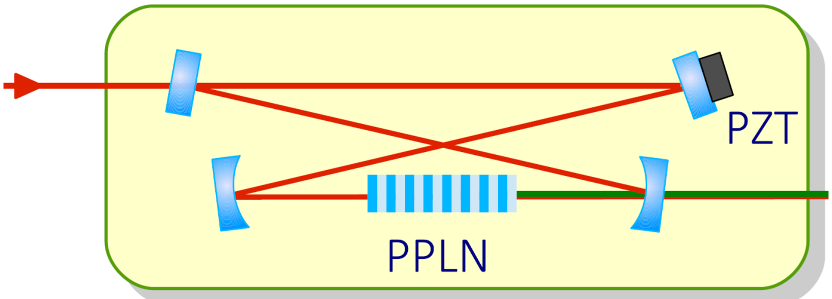

Figure 1: An optical cavity for frequency combs, from [1]. The mirrors are located in a "bow-tie" configuration, a crystal is placed inside (named "PPLN", for Periodically pooled nonlinear crystal). The nonlinear interaction of red light with the crystal convert the input radiation in a green output.

We can think to t and to τ as the passing of time outside and inside the cavity, respectively. Let's see how this helps us in the description of light evolution

in passive resonators. Referring to fig. (2), in each plots we report on the x-axis the fast time τ and on the y-axis the slow time t. The light colored regions of the plots represent higher optical intensity. Basically, we report 3-D plots, where the third dimension is described by the color, scaled from blue (low intensity) to red (high intensity). In this work, presented in [2], we describe how we can use the so-called chirp parameter C to control the solitons dynamics in nonlinear resonators. An optical soliton is very important in the context of frequency combs generation since, if coupled inside a cavity, its spectrum is a comb. Here we show how the C parameter is useful to control the fast dynamics of solitons within the cavities. You can visualized them as the lighter tracks arising from the center of each plots. The dynamics is the following: one starts to couple light inside the cavity which interacts with the medium.

After some time (look the y-axis then!), we observe a chaotic region, where it is quite difficult to understand what is going on. From chaos, the soliton born, eventually interacting with each other. This extremely rich dynamics last for just few micro-seconds and we can perfectly visualize it with the two-scale approach we presented.

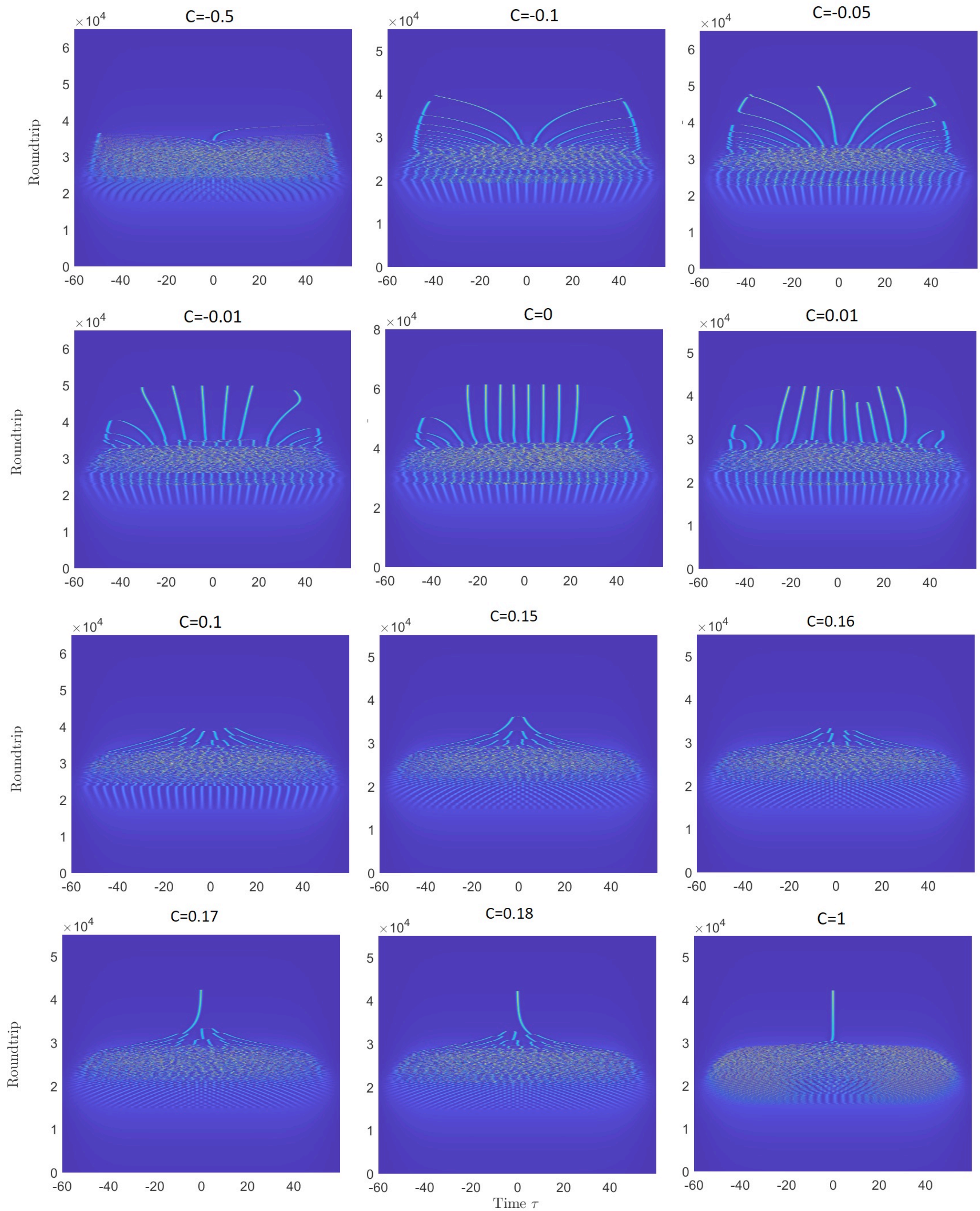

Figure 2: Solitons arising from chaos in optical passive resonators. C is the chirp parameter. If we tune it, we might be able to control the cavity dynamics.

References:

[1] Iolanda Ricciardi, Simona Mosca, Maria Parisi, Pasquale Maddaloni, Luigi Santamaria, Paolo De Natale, and Maurizio De Rosa. Frequency comb generation in quadratic nonlinear media. Phys. Rev. A, 91:063839, Jun 2015.

[2] Francesco Rinaldo Talenti, Tobias Hansson, and Stefan Wabnitz. Control of kerr cavity soliton combs by chirped pumping. In OSA Advanced Photonics Congress (AP) 2020 (IPR, NP, NOMA, Networks, PVLED, PSC, SPPCom, SOF), page JTu2D.4. Optical Society of America, 2020.

You can follow the progress of MOCCA ESR's research on our blogs and social media:

See https://mocca.astonphotonics.uk/blog/

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MOCCA's Partners:

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