Analysis of Chaos Synchronization of Microresonator Frequency Combs

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With ever-increasing computing power in almost every device, there is an emerging need for secure data communication, which could be realized by chaos synchronization [1, 2].

In this work, we studied the behavior of chaos synchronization in two cascaded microresonator frequency combs [3] numerically using the modified Lugiato-Levefer-Equations (LLEs). The simulation incorporates two cavities which are pumped by continuous-wave lasers. After we generate a modulation instability (MI) comb in both cavities, we inject the output from the first resonator into the input of the second resonator to synchronize the two cavity fields. To implement such chaos synchronization in communication systems, we analyze the degree of synchronization and feasibility of secure communication over the chaotic channel.

We employ differential binary phase shift keying (DPSK), as shown in Fig. 1(a), where the data is encoded for DPSK to modulate on the chaos (MI comb) output from the first cavity. Then the phase-shifted chaos from the second cavity is added to the received modulated chaos to recover the signal data. A Mach-Zehnder Interferometer (MZI) is used to detect the phase shifts to decode the received signal to obtain the transmitted bits. The better the synchronization is, the smaller the bit-error rate (BER) is.

Figure 1(b) shows the simulation results, with which we can distinguish “0” and “1” bits, which results in a BER of 0. We repeated the analysis and confirmed that the first and second resonators are always uncorrelated, which should result in a high BER. However, the extracted bit sequence is yet distinguishable. It indicates that while both signals are uncorrelated, each signal is correlated on its own, i.e., periodic to some extent and that the chaos is changing slower than expected.

Figure 1(c) shows the temporal phase at different roundtrips in the cavity, where one cavity roundtrip is 5 ps. Because the temporal field changes slowly, where the DPSK modulation is at a much higher frequency, we need to adjust the cavity parameters to increase the chaos frequency to let it overlap with the signal frequency.

In summary, we studied the chaotic properties of the microresonator frequency comb (MI comb) and discussed the challenges if we want to use them for secure communication.

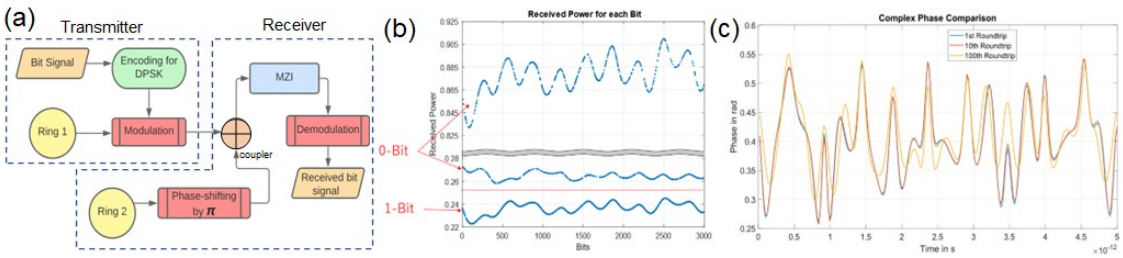

Figure 1: (a) Model. (b) Received power after the MZI. (c) Waveforms in a cavity for different roundtrips.

References:

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