MSc projects 2019

Time frame: 6 months starting January 2019
Host: Ultrafast photonics laboratory at Chalmers University of Technology, Sweden. (www.vtc-lab.com)
Examiner: Victor Torres Company (Associate)
Main supervisor: Senior PhD student
Note: We have all the infrastructure required to successfully realize the tasks described below.

1*. High-performance dispersion measurements of high-Q silicon nitride microresonators*

Introduction & motivation
One of the main activities at the ultrafast photonics laboratory is the development and optimization of microresonator frequency combs for applications in fiber-optic communication systems [1] (see [2] for an introduction to the field of microresonators and [3] for an experiment that highlights the state of the art in the field). We have recently developed our own silicon nitride platform that features high-yield, low-loss, dispersion-engineered microresonators [4]. The dispersion profile of the microresonator is an essential parameter that dictates the performance of the resulting microresonator comb [5]. However, measuring precisely the dispersion of a microresonator is a challenging task. One very promising approach is described in [6]. This technique essentially leverages the high accuracy of a mode-locked laser frequency comb to calibrate precisely a tunable laser, and thus identify the exact location of the longitudinal modes of the microresonator. The objective of this project is to implement this technique with a newly acquired and commissioned ultra-low-noise frequency comb from MenloSystems [7] and establish a quantitative assessment against more standard techniques for dispersion measurement of microresonators (see e.g. [8]).

Concrete tasks:
1. Calibrate the tunable laser in the C + L band against a stabilized fs ultra-low-noise frequency comb
2. Establish a fully automated dispersion measurement setup based on the above technique
3. Establish a comparative assessment between measured dispersion up to fourth order with simulation results based on finite element modeling (i.e. comsol)
4. Establish a quantitative performance against measurements obtained using a standard Mach-Zehnder interferometer that is already established in the laboratory

2. Analysis of thermo-optic tunable passive components in silicon nitride

Introduction & motivation
It is possible to integrate thermo-optic heaters onto silicon nitride microresonators [9]. This feature essentially allows for tuning the longitudinal mode spectrum of the microresonators. In the context of microresonator combs, this allows to have a continuous-wave laser fixed in wavelength and tune the resonator to achieve mode-locking (low-noise) operation. We have implemented thermos-optic heaters on our microresonators (unpublished) but have not yet measured their tuning speed nor assessed whether they can be efficiently used to generate optical solitons. That would be the goal of this research project.

Concrete tasks:
1. Measure the speed of existing thermo-optic heater
2. Obtain thermo-optic coefficient of Chalmers material platform
3. Realize soliton comb generation with a fixed CW laser and a tunable microresonator

3. Inclusion of thermo-optic dynamics in nonlinear modeling of microresonator frequency combs

Introduction & motivation

The nonlinear dynamics of the formation of microresonator combs can be described in terms of a externally driven, damped nonlinear Schrödinger equation known as the Lugiato-Lefever equation [10]. This equation can be further supplemented with the thermo-optic dynamics of the microresonator [11]. Physically, the high-Q of the microresonators increases the intracavity power, which increases the temperature producing a shift in the position of the longitudinal modes. This effect has been largely explored in microresonators displaying anomalous dispersion (see e.g. [11]) but its contribution in high-Q cavities whose dispersion is normal is unknown. Notwithstanding, this is the regime of operation of the mode-locked dark-pulses in microresonators [1,12]. The goal of this project is to unravel the effects of the thermo-optic dynamics in the formation of low-noise mode-locked dark pulses in optical microresonators.

Concrete tasks:

1. Implement a numerical code solving the coupled differential equations in [11]
2. Provide a quantitative assessment of the experimental results corresponding to the dark pulse Kerr combs in [1], in terms of resonance shift and phase matching conditions

References

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