Thermal radiation in asymmetrically driven coupled non-linear Kerr photonic cavities

Bertrand Braeckeveldt[1], *Bjorn Maes*[1]
[1] Micro- and Nanophotonic Materials Group, Research Institute for Materials Science and Engineering, University of Mons, 20 Place du Parc, Mons B-7000, Belgium

Abstract: In this work, we investigate the influence of a coupled system on thermal radiation spectra in various regimes. We consider two photonic cavities with Kerr effect, coupled via a central waveguide and driven from one side. We demonstrate that the spectra can largely differ depending on the regime. Self-pulsing can, for example, lead to comb-like spectra with multiple super-narrow peaks. We combine an analytical study and numerical simulations to have a full understanding of the system, and predict the thermal radiation spectra in stable regimes.

Related publications:

– B. Braeckeveldt et al., J. Opt. Soc. Am. B (39), 2074 (2022)
– C. Khandekar et al., Appl. Phys. Lett. (106), 151109 (2015)

Previous work, challenge, and approach

Previous research was performed on thermal radiation of **single** Kerr non-linear cavities.

- When the non-linearity presents two photon absorptions (TPA), the **thermal radiation** can be **larger than the black body limit**. *C. Khandekar et al., Phys. Rev. B (91), 115406 (2015)*
- **When driven**, the thermal radiation can exhibit **super-narrow peaks** in certain regimes as well as Stokes and anti-Stokes like peaks, whose relative amplitudes depends on relative temperature of the cavity with respect to the external bath. *C. Khandekar et al., Appl. Phys. Lett. (106), 151109 (2015)*
- **When driven with a modulated pump**, temperature can be used as a noise source to induce **stochastic resonance** in the system. In this regime, periodic transitions between stable states are observed for a specific temperature. This regime can be used for **thermally tailored frequency conversion devices**. *B. Braeckeveldt et al, J. Opt. Soc. Am. B (39), 2074 (2022)*

In this work:

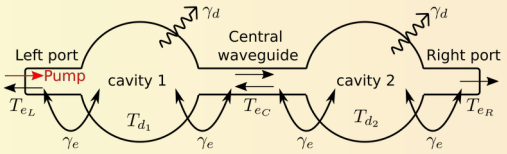
- Study influence of a **coupled system** on thermal radiation.
- Understand how the **stability of steady states influences thermal radiation**.
- Provide an **analytical description** of the linear and non-linear regime **combined with numerical simulations** for the prediction of thermal radiation spectra in stable regimes.

bePOM

Techniques and Methods

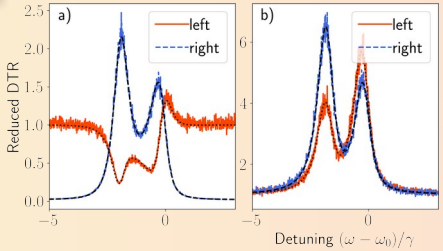
Coupled Kerr non-linear **cavities**:

- **No side coupling**, cavities are only coupled through the central port;
- **Same coupling and dissipation rates** in all the system;
- Single mode cavities with the **same resonant frequency**;
- The system is driven asymmetrically with a monochromatic **pump only on one side;**
- Different temperatures in the system.



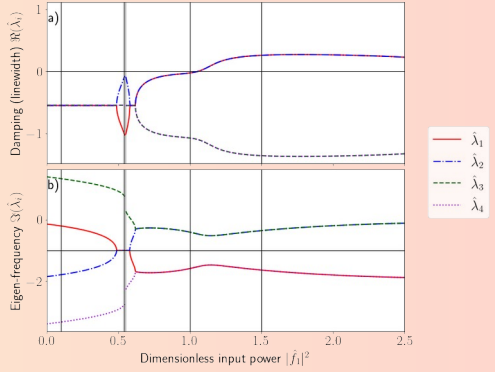
Coupled mode theory and Langevin frameworks:

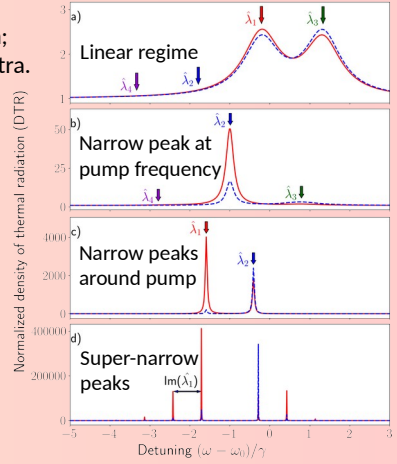
- **Numerical simulation** by solving 4 coupled stochastic differential equations;
- **Analytical approach** for steady states, stability analysis and thermal radiation spectra;
- Compute the spectral **density of thermal radiation** (DTR).



Results and Conclusions

- The analytical solution works in the stable regimes;
- Perturbed modes correspond to peaks of thermal radiation;
- Eigen-value analysis provides an understanding of the spectra.





This work was supported by FRIA and FNRS.
Computational resources have been provided by CÉCI.

UMONS Université de Mons

Bertrand.BRAECKEVELDT@umons.ac.be