Temperature-induced stochastic resonance in non-linear modulated photonic cavities

Bertrand Braeckeveeld¹, Bjorn Maes⁰
¹ Micro- and Nanophotonic Materials Group, Research Institute for Materials Science and Engineering, University of Mons, 20 Place du Parc, Mons B-7000, Belgium

Abbreviated abstract: It is known that injected noise in a bistable modulated system can lead to stochastic resonance [1]. Recently, it has been shown both experimentally and numerically that such a phenomenon can, for example, enhance energy harvesting [2]. Here, for the first time, we present stochastic resonance resulting from temperature-induced noise studying thermal radiation and outgoing power. We show that such a system exhibits frequency conversion and paves the way for temporal control of radiative heat transfer.

Related publications:

Techniques and Methods

Non-linear cavity with mode amplitude a coupled to an external port. The cavity is driven by monochromatic pump \( s_p \) and noise \( \xi \).

System modelled with a stochastic differential equation: homemade solver.

\[
\begin{align*}
\frac{da}{dt} &= \left[j(\omega_0 - \alpha |a|^2) - \gamma a + \sqrt{2\gamma a} \langle s_p(t)e^{j\omega_0 t} + \xi \rangle + \sqrt{2\gamma} \xi a \right] \\
\frac{\partial a}{\partial t} &= -s_+ + \sqrt{2\gamma} a \\
\langle \xi(t)\xi^*(t') \rangle &= k_B T_0 \delta(t-t') \quad i \in \{e, d\}
\end{align*}
\]

Pump amplitude modulation such that the system stays in a bistable regime during all the cycle:

\[ s_p(t) = \left( \frac{\pi}{\gamma_0} \right) \left[ \lambda_0 + \frac{\xi_0 + \xi_1}{2} \cos(\Omega t) + \frac{\xi_2 + \xi_3}{2} \right] \]

Solver validation with a test case without modulation and known analytical solution.

Results and Conclusions

- If \( \Omega \) increases: higher temperatures are needed to achieve stochastic resonance.
- Stochastic resonance at temperature around 1000K for modulation 10^5 \( \omega_0 \).
- At stochastic resonance, output power for frequencies \( \omega_p/\Omega \) is orders of magnitude larger than input power: system exhibits frequency conversions

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Bertrand.BRAECKEVELDT@umons.ac.be