Q-Switching with Phase-Coupled Nanolasers

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Non-Hermitian photonics represents a paradigm shift in optics, focusing on systems where dissipation is intentionally introduced [1]. By judiciously incorporating gain and loss within photonic structures, this field enables the realization of unique phenomena such as exceptional points and unidirectional light transport. These properties hold significant potential for applications in sensing, lasing, and quantum information processing. Recently, we have demonstrated how non-Hermitian coupling can be achieved in a pair of III-V semiconductor nanolasers integrated onto a unique SOI waveguide (see Fig. 1-a). The phase shift, ϕ, associated with light propagation between the cavities determines the nature of this coupling, $\gamma e^{i\phi}$, whether it be dispersive and lead to frequency-splitting between the quasi-normal modes (QNMs); or dissipative and lead to loss-splitting. In the case of dissipative splitting, a high-quality factor resonance can form as soon as proper frequency-detuning condition is set between the cavities [2].

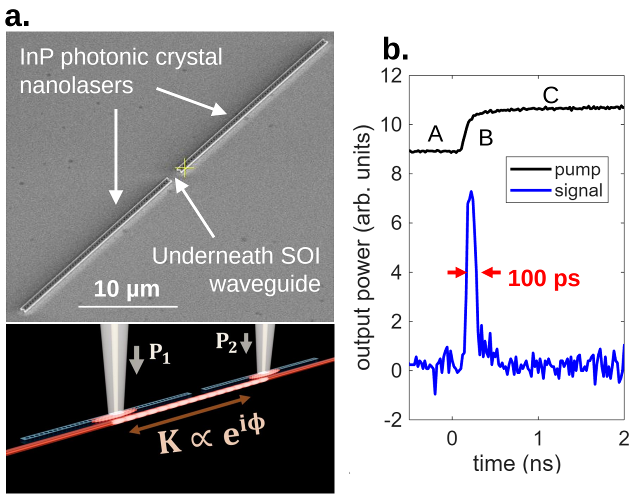

Figure 1: **a. Waveguide-coupled nanolasers** – top: SEM micrograph of a pair of indium phosphide photonic crystal nanolasers, integrated on a SOI waveguide. bottom: artistic view of the system evidencing the non-Hermitian coupling scheme resulting from distant waveguided interaction. **b. Q-switching process** – Under pulsed optical pumping (black trace), the waveguide outputs ~100 ps pulse responses (blue trace)

In the present work, we exploit this situation in highly damped nanolasers, incapable of lasing due to over-coupling to the waveguide. Yet when detuning is set to zero, the lasing threshold of the low-loss QNM is significantly reduced and single-mode operation can be produced. Configuring the system slightly out-of-tune with one strongly pumped nanolaser and one unpumped, we study the effect of abrupt optical pump pulses on the latter. Due to high alpha-factor, the pulse produces a frequency shifts in the cavity which momentarily restores the low-loss QNM. During this short lapse of time, the loaded carriers deplete into light pulses which can be collected at the waveguide output (see figure 1-b.). We report our experimental results where several control parameters are varied. The emitted pulse widths, energies, and the achievable repetition rates are discussed.

In this work, we exploited a non-Hermitian coupling scheme to produce Q-switching with coupled active nanocavities, contrary to the conventional approach using variable attenuator placed inside the cavity. More generally, the exploitation of non-Hermitian devices beyond their linear regime constitutes a promising avenue for the production of new optical functionalities.

References

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