Polariton lasing from fluorescent proteins

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There is an increasing interest in using biologically produced materials for photonic applications. Recent research impressively illustrates the broad potential of biological materials for providing optical gain [1]. In particular, fluorescent proteins like eGFP retain a special position within the quickly growing family of biologically produced laser materials. Fluorescent proteins have a barrel-like molecular structure that prevents concentration-induced quenching of the fluorescence by suppressing Förster and Dexter energy transfer [2] and drastically reduces singlet-singlet annihilation (SSA) at high excitation densities (outperforming common synthetic laser materials). Thus, fluorescent proteins are perfectly suitable for application as optical gain material in microcavities.

By using suitably designed resonators and increasing the concentration of fluorophores, we are able to observe polariton lasing at room temperature. Beyond this, we demonstrate the first two-threshold behavior of the microcavity emission indicating the onset of polariton condensation as well as photon lasing for an active organic material because of the high molecular photon stability of fluorescent proteins. This second threshold has previously not been within reach due to pronounced SSA at high excitation densities.

We further present different approaches capable of tailoring the in-plane confinement in planar optical microcavities filled with an active protein layer and thus creating three-dimensionally confined micro- and nanostructures. The respective confinement affects both the photonic and excitonic part of the microcavity and has therefore direct influence on weak [3] and strong light-matter interactions [4]. The approaches include: (i) organic imprint lithography, (ii) direct lasing writing above bleaching threshold and (iii) hemispherical mirrors in open microcavities. For all different techniques, we achieve confinement potentials on the order of several meV up to several tens of meV.

The variety, versatility and moreover the compatibility of the applied techniques gives us the opportunity to tailor the photonic and excitonic part of organic cavities jointly and individually and paves the way towards PT-symmetric systems or complex photonic structures such as photonic chains and lattices.

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