PT symmetry breaking and transverse mode filtering in microring lasers

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Abstract: We show that the concept of parity-time (PT) symmetry breaking can be utilized to suppress higher order transverse modes in microring lasers.

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In this work, we report the first experimental demonstration of transverse mode filtering in PT-symmetric lasers. This goal is achieved by accompanying a multimode microring laser with an identical but lossy partner [1-3]. Depending on the amount of gain/loss contrast between the two cavities and also the coupling strength between each pair of modes, the corresponding supermodes can have complex (broken PT symmetry regime) or real (exact PT phase regime) eigenfrequencies. The key idea behind the mode selection property is the fact that different transverse modes exhibit different PT-symmetry breaking threshold: As it is predicted theoretically the lower order modes has lower PT-symmetry breaking threshold and are therefore more likely to be in the broken PT symmetry regime. Of our interest is to break the PT symmetry for modes with the fundamental transverse profile while keeping any other mode with higher order transverse distributions below their symmetry breaking threshold.

In the experiment, we utilize InGaAsP microrings partially buried in SiO_2. Each ring, having a width of 1μm and a height of 200nm, exhibits an external radius of 10μm and the separation between the two coupled resonators is 200nm. Active regions in the rings are achieved by relying on six InGaAsP quantum wells. The quantum well layer can provide gain in a large spectral window centered around 1550 nm and ranging from 1350 nm to 1600 nm, while the pump laser operates at 1064nm.

Figures 1 shows the experimental results of the spectrum measurements for a single lasing ring (left panel), as well as a PT-symmetric pair of rings (right panel). According to this figure a single ring resonator, within the gain bandwidth, exhibits several prominent longitudinal modes corresponding to two sets of transverse modes. In the PT-symmetric arrangement, the second transverse mode with all of its longitudinal variations is suppressed, this results in more gain to be available for the fundamental longitudinal modes.

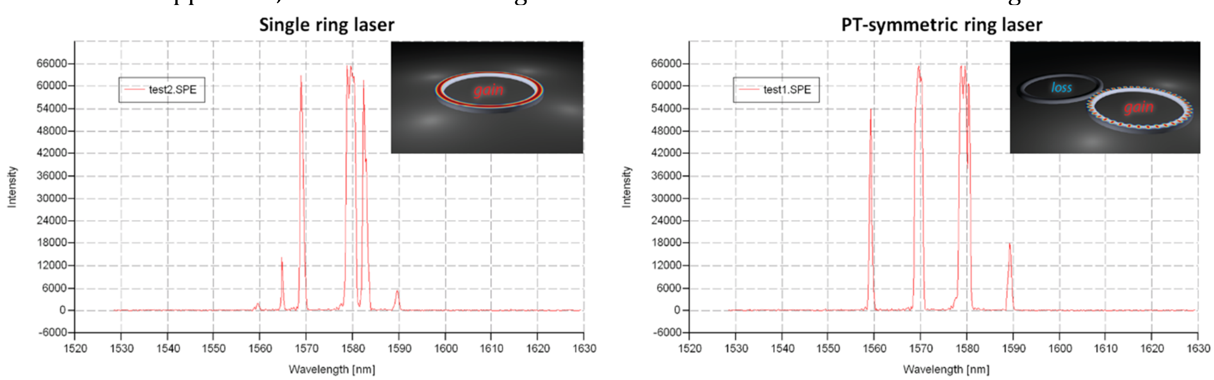

Fig. 1. Experimental demonstration of n transverse mode selection in PT-symmetric microring lasers. The lasing spectrum of a single microring laser (left panel), and PT-symmetric microring laser (right panel). The single microring laser exhibits two transverse modes and each transverse mode corresponds to several longitudinal resonances. In the PT-symmetric arrangement however all modes with a radial node are simultaneously suppressed.

References

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