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Electrically injected first-order gratings broken Parity-Time symmetry DFB lasers: insight on device design rules and experimental results

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Abstract: We address the problem of the optimal design of first-order Parity-Time symmetric Bragg grating for the distributed feedback laser diodes operation. It is shown that the optimal design grating is not that corresponding to the exceptional point where the perfect unidirectional reflectivity condition is met. It is rather that corresponding to the broken Parity-Time symmetry phase where the reflection asymmetry is still playing an important role. We also present experimental results on the electrically injected DFB lasers based on such design.

The advent of Parity-Time symmetry sparked an important interest to this topic with a plethora of experimental demonstration of related physical effects. This work represents an attempt to apply the concept of PT-symmetry to practical mature complex devices, in particular to the design and fabrication of an electrically injected single frequency DFB laser. The main interest of applying the concept of PT-symmetry to DFB lasers is to take advantage of two characteristics that improve the single-frequency behavior by the simultaneous presence of index modulation and losses. Fig. 1 represents the principle of complex coupling with gratings made up of physically separate contributions which are seen by the mode of the waveguide. The presence of the index-modulated grating ensures a lower threshold injection current, while the presence of losses improves the laser emission mode discrimination mechanism and makes single-frequency operation more robust [1,2]. Moreover, according to the theoretical works, the one-way reflection characteristic of the Parity-Time symmetry should make the laser more robust with respect to online optical feedback.

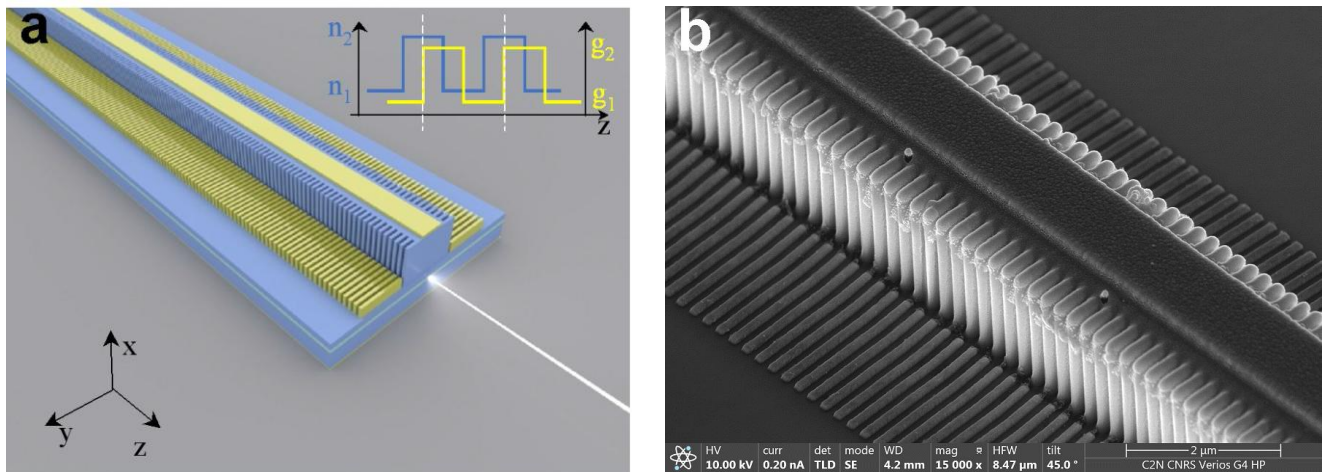


Fig.1. a) Sketch of PT-symmetric DFB laser, blue (dielectric) and yellow (metallic) gratings are shown; the inset depicts the condition for PT-symmetric potential. b) SEM side view of a fabricated first-order broken PT-symmetry DFB laser.

Our modeling results show that optimal operation of these complex coupled DFB lasers requires careful management of the imaginary part of the index profile to avoid excessive losses leading to increased threshold current and reduced power. It turns out that the modulation of the imaginary part of the index profile must be approximately three to four times lower compared to the modulation of the real part of the index profile. Such a complex index profile Bragg grating corresponds to the PT-symmetry broken condition. Nevertheless, the asymmetry in the reflection coefficient leading to the appearance of an additional narrow-band gain discrimination mechanism [1] still plays a beneficial role leading to more robust single-frequency operation. An additional improvement of this mechanism allowing to decrease even more the threshold current and to increase the emitted power could be obtained by using an AR/HR coating whose asymmetry is matched to that of the Bragg grating with a complex profile [2].

Experimental results for electrically injected uncoated DFB lasers with a first order PT-symmetry broken Bragg grating are shown in Fig. 2. As can be seen, the threshold current is less than 20mA while the output power at 100mA injection current is about 13mW. This presents a very noticeable improvement over the third-order PT-symmetry-broken DFB lasers we report earlier [1]. Further improvement in output power can be achieved by increasing the injection current up to 300mA, but this requires mounting the fabricated lasers on heat sink mounts. Work on this direction is ongoing.

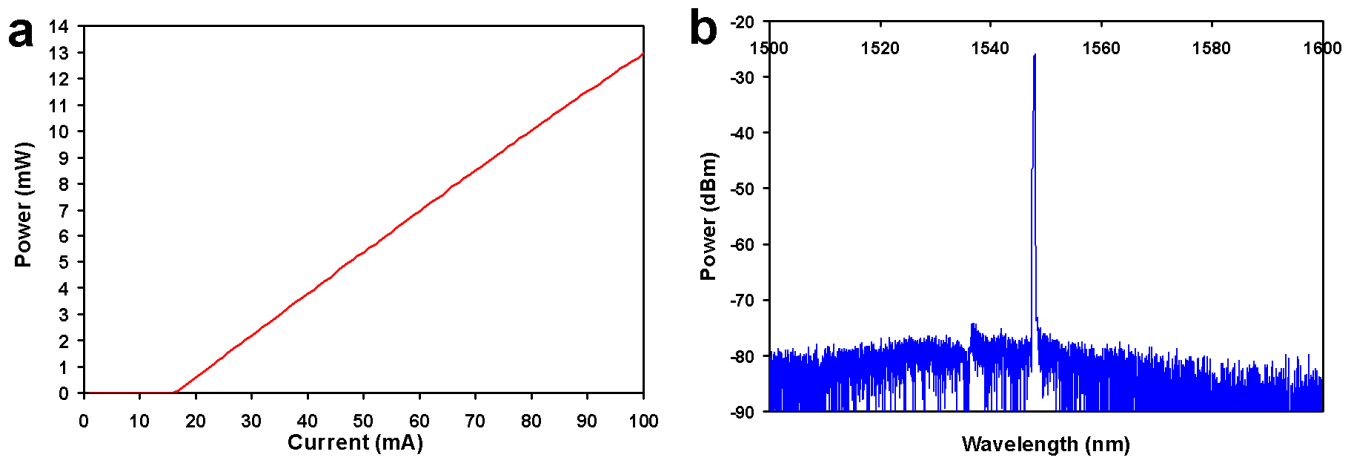


Fig. 2 Typical a) Light–current characteristic; b) Emission spectrum for first-order broken PT-symmetry DFB lasers.

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