Coupled waveguide arrays ring resonators

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1. INTRODUCTION

Optical ring resonators (RR) consist of a closed-loop waveguide which evanescently couple to one or to a set of waveguides [See Fig.1]. When the optical path length of the resonator is an integer number of wavelengths, the RR show a resonance. This is a result of the interference between the build-up intensity over multiple round-trips and the input beam.

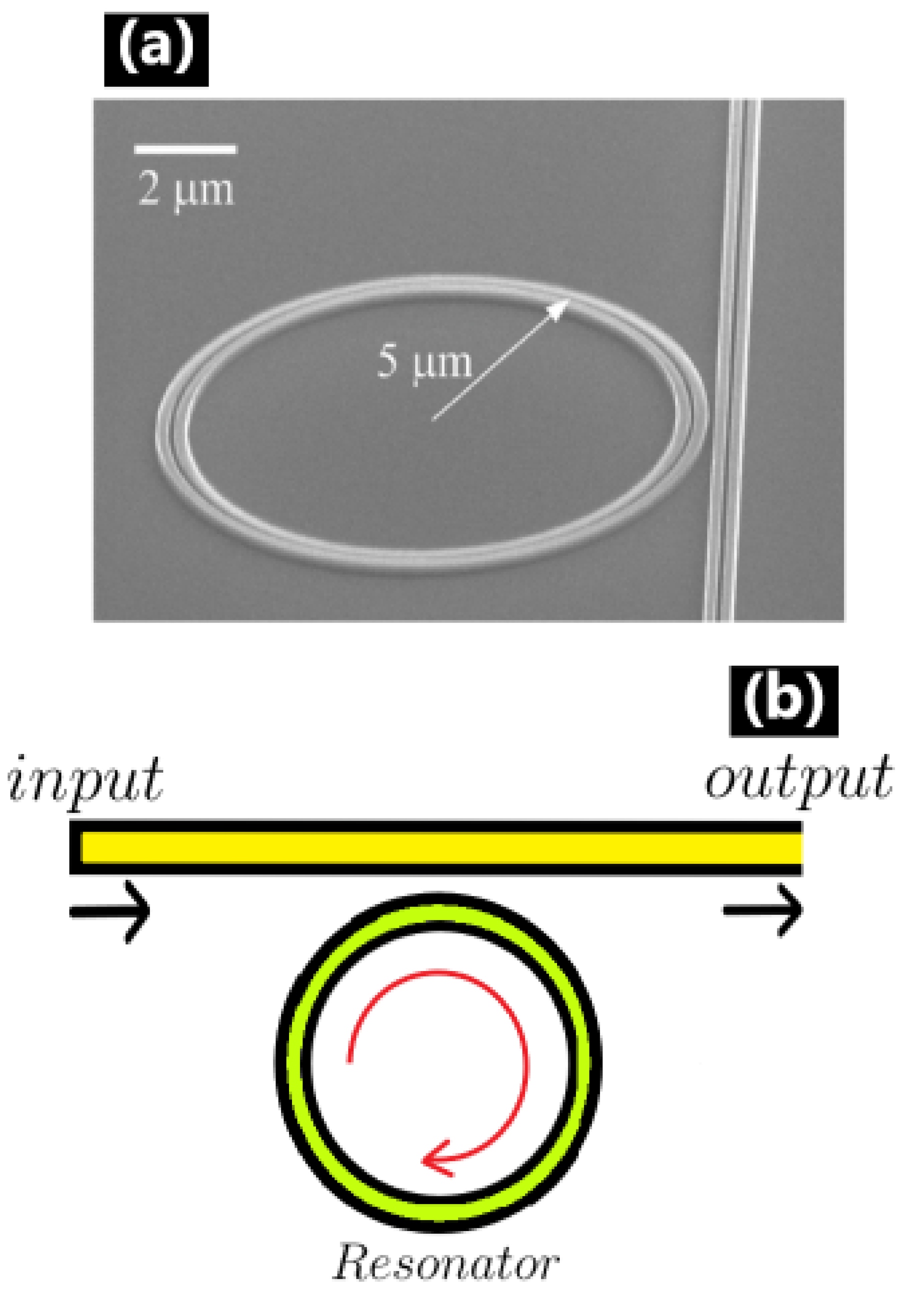

Figure 1: *General Model of RR. (a) SEM image of a slotted RR with radius of 5 m. [10] (b) The Red arrow shows the wave rotation.*

The study of this system has had a great deal of attention from the scientific community in the last years due to the amount of possible applications: in laser fabrication, interferometry, telecommunications, optical parametrical oscillators, among others [1]-[3]. Several works describe the dynamics in systems fabricated in Silicon [4]-[6] as well as in Photonic Crystal configurations [7]-[9]. However, RR using waveguide arrays configurations have not been still developed neither studied. Our aim is to explore this possibility. Interestingly, although the coupling mechanism in between the input straight waveguide and the ring resonator itself is based on an evanescent coupling, no relation or analogy with coupled waveguide arrays has been established up to now.

Furthermore, the shape of the mode in a waveguide depends directly on the wavelength of the light beam; i.e., for long wavelengths the excited mode is wider while for short wavelengths the mode becomes thinner. As a consequence, the tails of broader modes cover a larger area outside the waveguide and the coupling is stronger with neighboring waveguides. This indicates that the coupling is directly proportional to the wavelength used to excite the array; therefore, a RR model using waveguides could be directly used as an optical wavelength filter.

In this work, we propose to theoretically and numerically investigate a RR analog based on waveguide arrays (WARRs). We compare our main findings with standard RR results in terms of the transmission dependence concerning the coupling between the detection waveguide and the ring and, also, with respect to the wavelength.

2. MODEL

We propose a WARR composed of a single detector waveguide u_0 and a ring formed by N waveguides on a circular geometry [See Fig.2(a)]. The coupling constants are a function of the propagation coordinate z, as the unit cell shows in Fig.2(b). This is necessary to define a rotation direction, as it would happen in a standard RR configuration [See Fig.1(b)]. In order to produce a rotational power increment and a clear resonance spectrum, we study the repetition of unit cell (*cycle*) along the propagation coordinate z [See Fig.2(c)].

Therefore, by using coupled waveguide theory we obtain:

$$-i\frac{\partial u_n}{\partial z} = v_n(z)(u_{n+1}+u_{n-1}) \quad (1)$$

Where u_n is the amplitude of the electric field at the $n-th$ waveguide and $v_n(z)$ depends on the specific waveguide and the z coordinate. Waveguides inside the ring couple to each other with coupling v, while the detector waveguide couples to the ring with a coupling v_0.

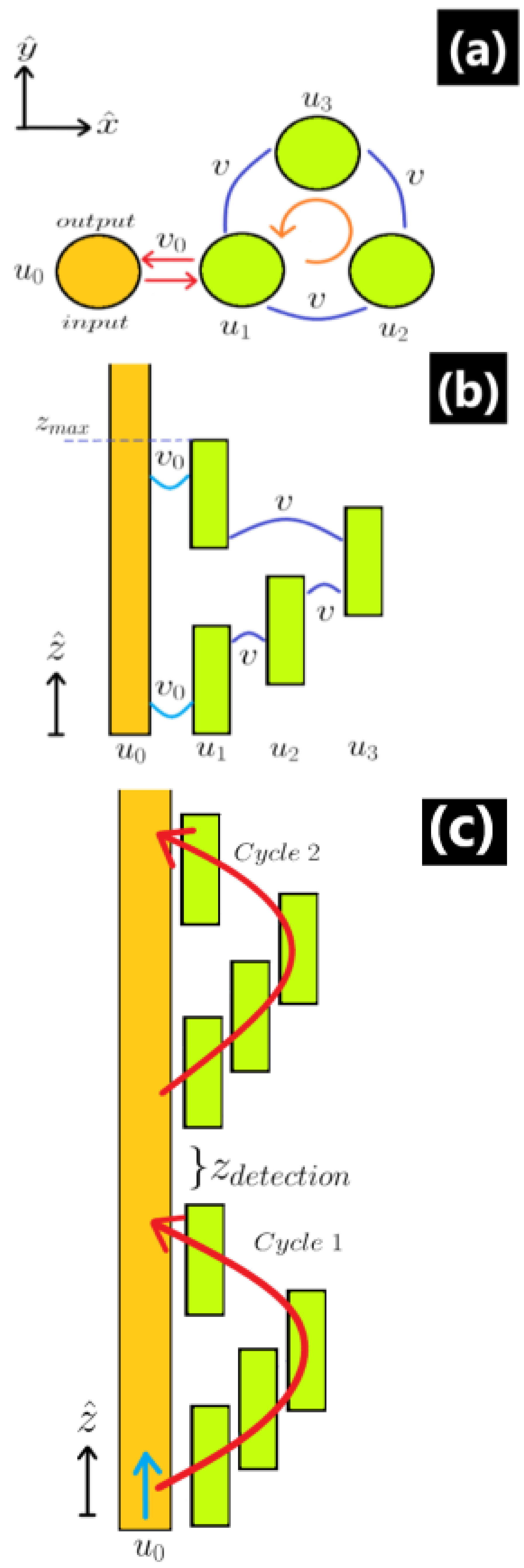

Figure 2: *Proposed schematic WARR model.(a) Frontal view: input-output waveguide u_0 couples to a ring formed by three waveguides. Top view of (b) the unit cell and (c) two concatenated cycles. In order to generate a rotational direction, waveguides are cut as shown in (b) and (c). To obtain multiple round-trips, we simply repeat the unit cell along z coordinate.*

3. NUMERICAL RESULTS

We define z_{max} [See Fig.2(b)] as the distance where the transmission is equal to one when $v_0 = pi/2$. We calculate numerically the transmission $T = |u_0(z_{max})|^2/|u_0(0)|^2$ for each cycle, as a function of the coupling v_0 [See Fig. 3(a)]. We observe that by increasing the number of cycles in our WARRs, the difference between the maximum and the minimum increases, producing pronounced and thinner resonant peaks. We find several maxima in the transmission diagram occurring at well defined values of coupling $v_0 = \frac{k\pi}{2}$, with k integer [See Fig. 3(b)].

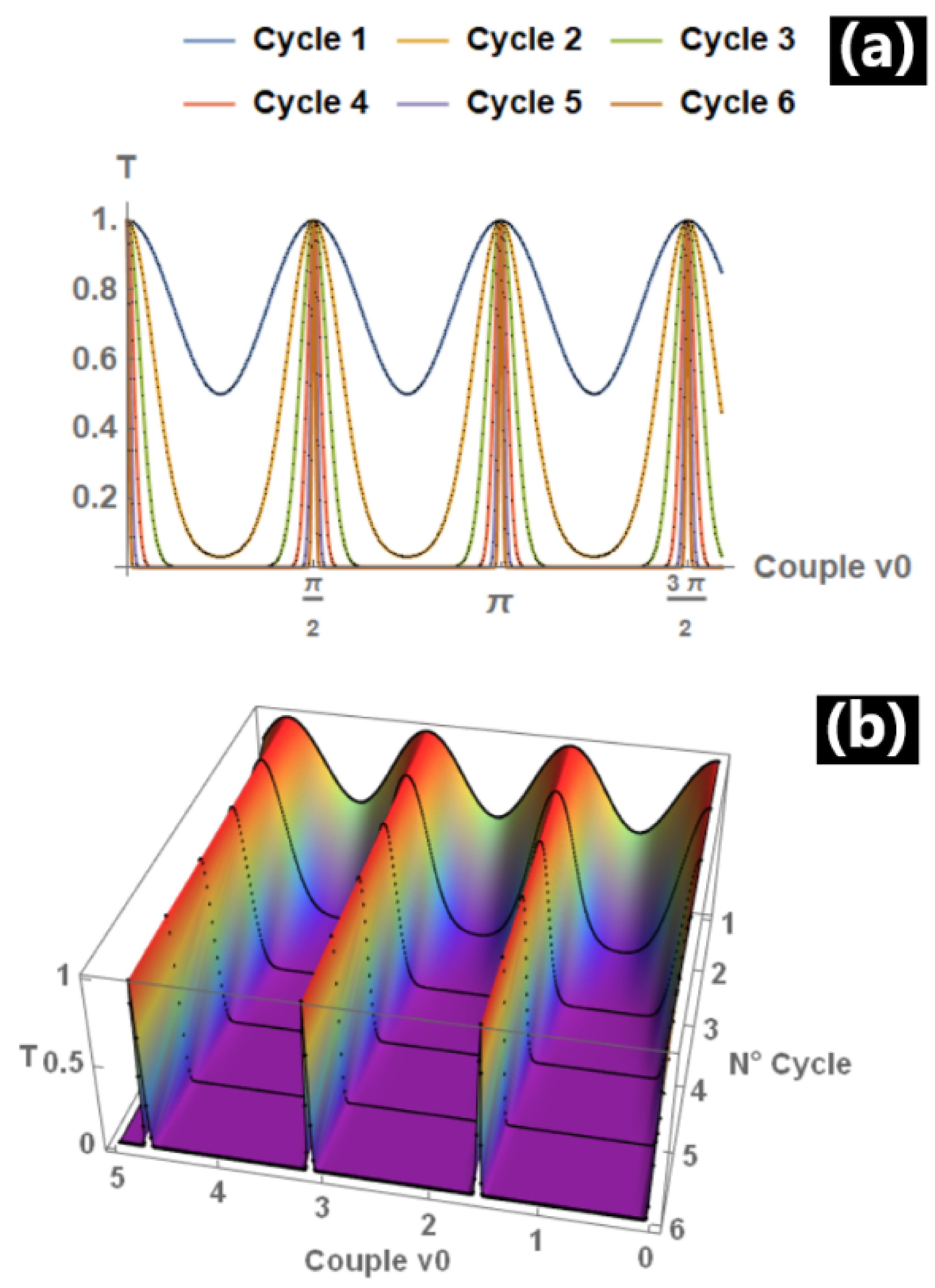

Figure 3: *Transmission T for each cycle (a) 2D view, (b) 3D view.*

4. CONCLUSION

Our results show that the proposed model is a good candidate for a RR analog using photonic lattices. We are still exploring other aspects of WARRs, such as studying the transmission by varying the distance between successive cycles or including an impurity waveguide inside the ring. The strong dependence of coupling constants with the wavelength makes our configuration a very good candidate for filtering colors, which could be of interest in concrete applications. We expect to observe this phenomena experimentally, work which is in progress at present.

5. Acknowledgment

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