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Experimental demonstration of induced-transparency based on a novel resonator system

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ABSTRACT

We experimentally demonstrate that coupled-resonator-induced-transparency (CRIT) phenomenon results from classical destructive interference whose spectrum has a narrow transparency peak with low group velocity. In this work, a CRIT resonance with a quality factor of 0.72×10^5 is demonstrated with the same cavity sizes. The through and drop transmission spectra are reconciled well with each other which are in good agreement with the theoretical analysis. Simultaneously, the resonant wavelength can be controlled by changing the temperature.

1. Introduction

Structures composed of coupled optical resonators due to classical destructive interference have been predicted to display photonic coherence effects such as coupled-resonator induced transparency (CRIT) [1] in direct analogy with electromagnetically-induced transparency [2] (EIT). The spectral characteristics of CRIT can be seen from the steep and positive linear increase of the phase response, which renders transparency over a narrow spectral range within an absorption line [3]. In practice, it is challenging to detune optical cavity for controlling the resonant interaction between the two optical pathways. For instance, the cascade of two coupled resonators [4] requires ~8 nm perimeter difference between the two rings, which normally is very challenging to control experimentally. Other existing configuration based on other coupled resonators [5,6] proposed two almost identical resonators but with different coupling strengths and cavity losses which added complexity in device design and fabrication.

In the current work, we theoretically proposed that CRIT transmission can be generated in a new structure which consists of four-ring resonator with the same cavity size. The uniqueness of the proposed geometry compared to other systems is that the structure does not need precise calculation in the difference between resonators' and perimeters, which can lead to the simplicity of the design and fabrication. In addition, the structure also can obtain high Q factor and delay the time of light traveling. It is therefore promising for applications such as optical all-optical switches [7,8], delay lines [9,10], buffers [11,12], gyroscopy [13–16], modulators [17], optical computing schemes [18], and so on.

2. Theoretical analysis

All four microring resonators are identical in geometry and have center resonance wavelengths represented by λ_1,λ_2, λ_3 and λ_4, respectively. Ideally, we should have $\lambda_1=\lambda_4<\lambda_2=\lambda_3$ due to symmetry and coupling induced resonance wavelength shift. The phase matching in each resonator is very sensitive to even a very small amount of change in dimension or index distribution. Thus, it is conservative to assume $\lambda_1\neq\lambda_2\neq\lambda_3\neq\lambda_4$.

To deduce the theory of four-ring CRIT, the double ring cascade structure as shown in Fig. 1 is set as an example.

For ring 1, the reflection and transmission electric field intensity through coupler C1 are

$$E_2=\sqrt{1-\gamma}(r_1E_0+it_1E_1) \quad (1)$$

$$E_3=\sqrt{1-\gamma}(it_1E_0+r_1E_1) \quad (2)$$

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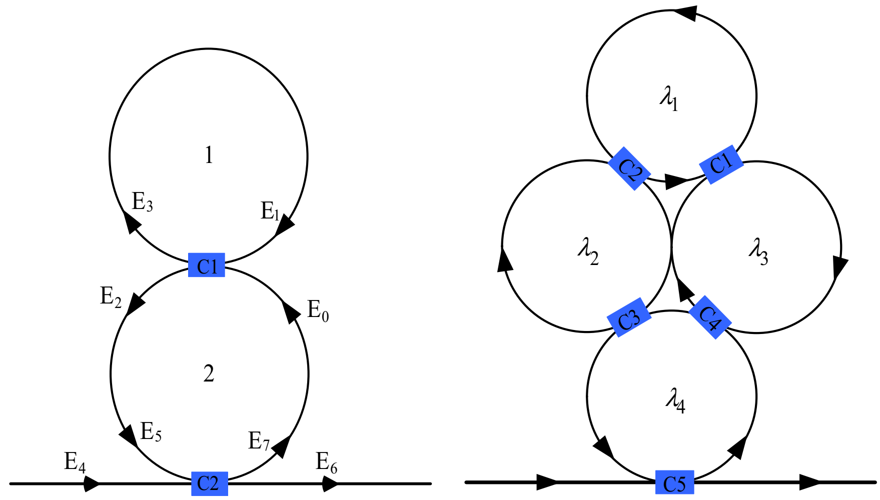

Fig. 1. Schematic drawing of double-ring and four-ring resonators.

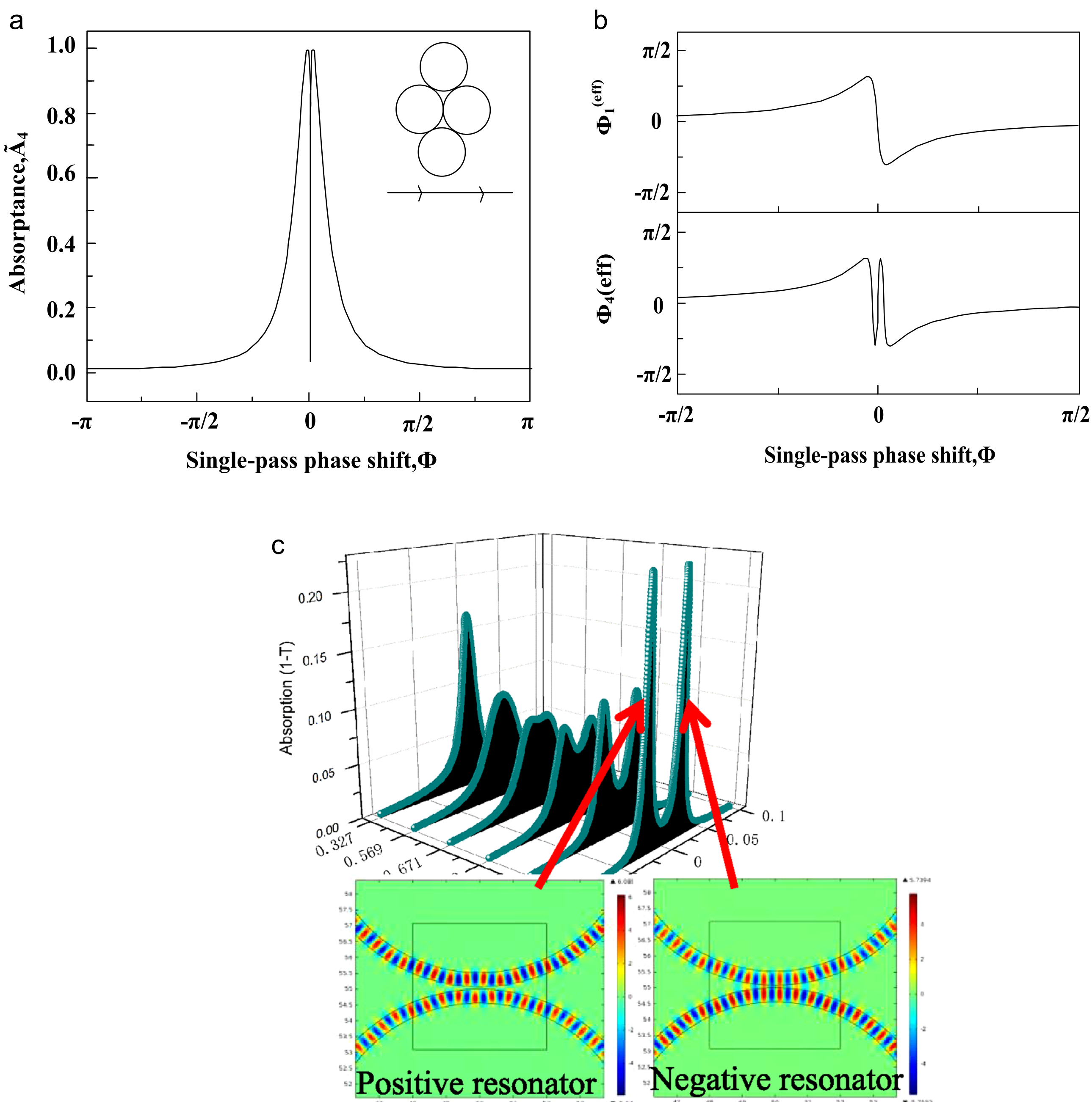

Fig. 2. (a) Absorption versus single-pass phase shift for four coupled ring resonators, (b) effective phase shift for a single ring resonator and for four-ring resonator, and (c) two split peaks of four-ring resonator.