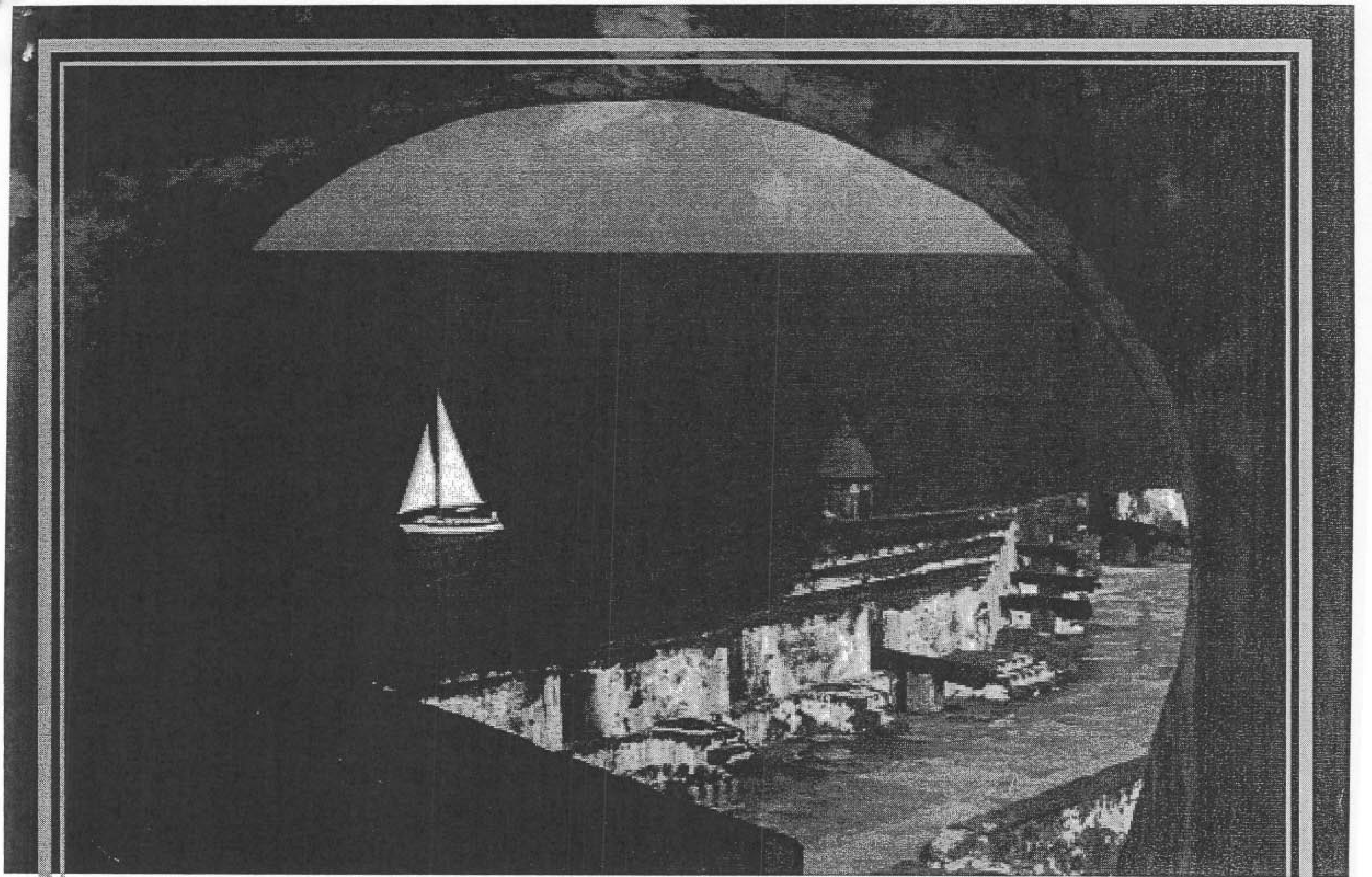

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Multimode Interference Coupled Ring Cavity Resonator with Total Internal Reflection Mirrors and Semiconductor Optical Amplifier

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Abstract: We investigate the properties of the multimode interference coupled ring resonator with total internal reflection mirrors and semiconductor optical amplifier. A free spectral range of approximately 97 GHz with good extinction ratio is observed.

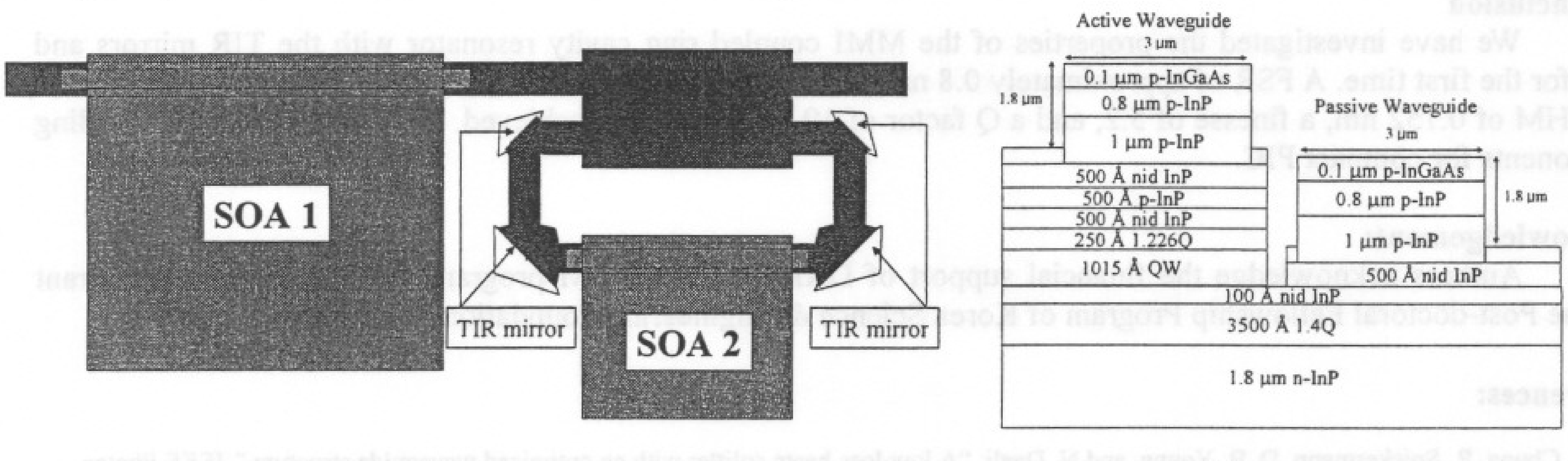
1. Introduction

Wavelength division multiplexing (WDM) is a common way of increasing the capacity of fiber optic communication networks. Compact photonic integrated circuits (PIC) have been a very active research area ever since the inception of integrated optics for the application of the WDM networks. One of the main size limitations to regular integrated optics based circuits is the weak optical confinement. This makes it very difficult to change the direction of optical waveguides in a very short distance with low loss. Photonic band gap based approaches offer promise of compact waveguide size that can be bent over very rapidly. However, wavelength dependence and the fabrication difficulty remain to be the challenges. Another approach is TIR based mirrors [1]. Such mirrors can be combined with regular optical waveguides and can reduce the size of PIC drastically.

In this paper, we investigate the properties of the multimode interference (MMI) coupled ring cavity resonator with the total internal reflection (TIR) mirrors and the semiconductor optical amplifier (SOA). To the best of our knowledge, the fabrication and measurement of MMI coupled ring cavity resonator with TIR mirrors and SOA have not been performed before.

2. Device Description

Figure 1 (a) depicts the schematic of MMI coupled ring cavity resonator with TIR mirrors and SOA. The left part is SOA 1 of length 2 mm which is used as an internal broadband light source. A standard ridge waveguide laser structure is used for the SOA part. The SOA waveguide width is 3 µm. The right section is the MMI coupled ring cavity resonator. The resonator cavity is formed by employing MMI, TIR mirrors, SOA region in a rectangular geometry. The MMI length and width used in the experiment are 390 µm and 15 µm, respectively. There are significant advantages of ring cavity resonators with TIR mirrors. First, the resonator cavity itself is a low-loss optical guiding structure with high confinement. Second, the active and passive sections of the cavity have excellent overlap. Third, MMI sections can be designed independently out of passive waveguides with significant power coupling into the resonator. Except for the TIR mirrors, the optical mode is guided by regular semiconductor rib waveguides, which minimizes the effect of side wall roughness.



(a) (b)

Figure 1. (a) Schematic diagram of MMI coupler micro ring cavity resonator with TIR mirrors and SOA, (b) Cross sectional profile of the active and the passive waveguide structure used in the experiments. Only active areas are SOA1 and SOA2.

TIR mirror fabrication requires a deep etch to create TIR at the semiconductor air interface. The most important part of micro ring cavity resonator with TIR mirrors is the realization of low loss and efficient turning mirrors. In our previous work we demonstrated very low loss TIR mirrors [2]. In the design we considered the effects of vertical

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and lateral misalignment of the mirror position, effect of the etch depth, effect of the variations of the mirror position from vertical and the effect of mirror index. The SOA 2 in the resonator is used to compensate the internal waveguide and the mirror loss [3]. The length and width of the SOA 2 are 365 μm and 3 μm, respectively.
Figure 1 (b) shows the cross sectional profile of the active and the passive waveguide structure used in the experiments. It should be noted that this approach requires only one regrowth and no wafer bonding for vertical coupling is needed. By deep etching the MMI region the width and the length of the MMI can be reduced significantly. The required fabrication steps are exactly the same with laser fabrication except for one deep etching step. Therefore these resonators can be directly integrated with tunable lasers, wavelength converters and detectors. As a matter of fact SOA1 and resonator filter combination is a XGM based wavelength converter.

3. Results and discussion

Figure 2 (a) shows the transmission of MMI coupled ring cavity resonator when the bias current of the SOA 1 is 130 mA. The SOA 2 in the resonator is biased by 40 mA to compensate the internal waveguide and the mirror loss. Figure 2 (b) shows the transmission of MMI coupled ring cavity resonator at the wavelength from 1567.5 nm to 1572.5 nm. The bias current of the SOA 1 is 130 mA. The bias current of the SOA 2 is changed from 0 mA to 40 mA. A free spectral range (FSR) of approximately 0.8 nm (97 GHz) is observed near 1569 nm. The on-off ratio and the full-width at half-maximum (FWHM) are 8 dB and 0.152 nm corresponding to a finesse of 5.2, and a Q factor of 10,322.

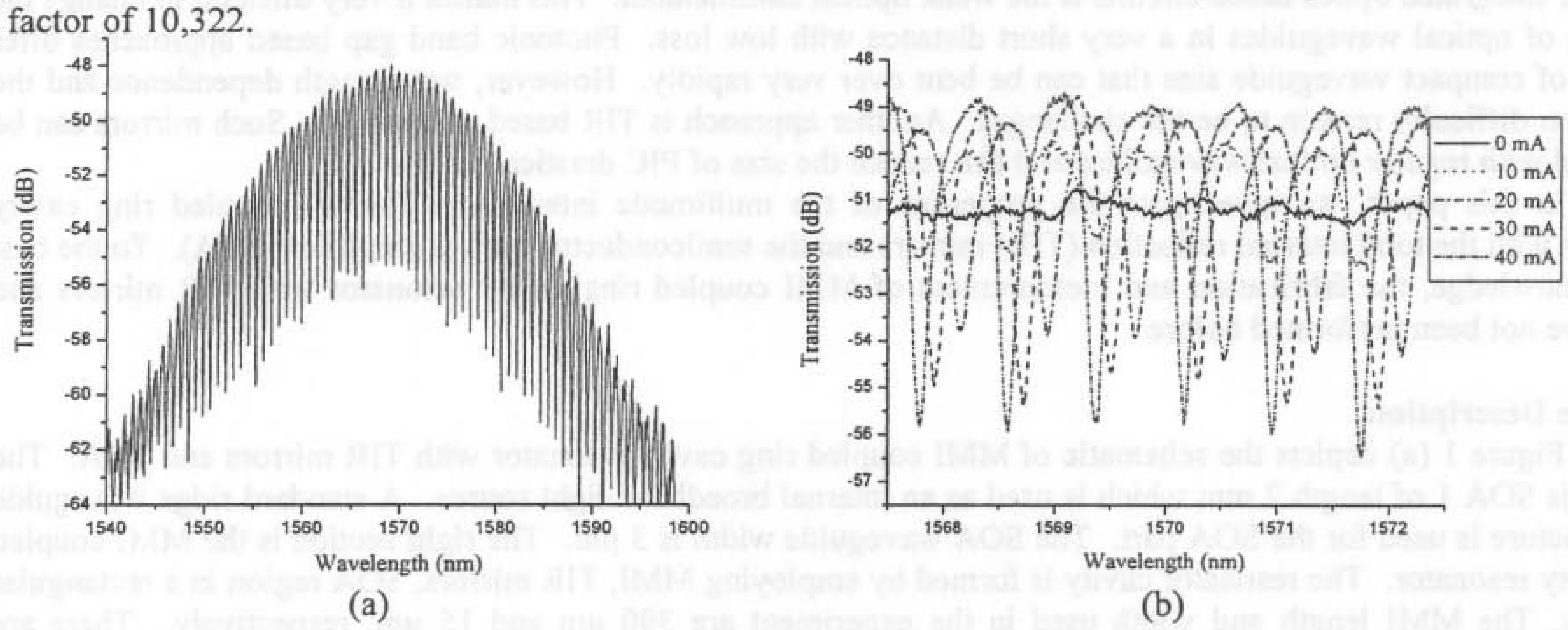

Figure 2. (a) Transmission of MMI coupler micro ring cavity resonator when the SOA 1 is biased at 130 mA and the SOA 2 in the resonator is biased by 40 mA. This figure is not corrected for the spectral variation of the SOA 1 output. (b) Transmission of MMI coupled ring cavity resonator from 1567.5 nm to 1572.5 nm when the SOA 1 is biased at 130 mA and the SOA 2 bias current in the resonator is changed from 0 mA to 40 mA.

4. Conclusion

We have investigated the properties of the MMI coupled ring cavity resonator with the TIR mirrors and SOA for the first time. A FSR of approximately 0.8 nm (97 GHz) is observed near 1569 nm. An on-off ratio of 8 dB, a FWHM of 0.152 nm, a finesse of 5.2, and a Q factor of 10,322 have been achieved. Such resonators are enabling components for compact PIC.

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