Optik - International Journal for Light and Electron Optics 193 (2019) 162916

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.com/locate/ijleo

Original research article

Demonstration of Q-factor enhancement in a mode splitting-based microdisk-coupled asymmetric Mach–Zehnder interferometer

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ARTICLE INFO

Keywords:
Integrated optics devices
Asymmetric Mach-Zehnder interferometer
Single planar microdisk
Mode-splitting

ABSTRACT

We demonstrate significant enhancement of an effective Q-factor in a silica planar waveguide-based asymmetric Mach–Zehnder interferometer (AMZI) coupled with a microdisk. To enhance the Q-factor, which is required to more effectively measure the signal changes occurring during biochemical events, the structure utilizes resonance mode splitting. This phenomenon is observed through power cancellation at the same amplitude and a 180° phase difference of each path in the AMZI. In this study, we experimentally showed the effective Q-factor enhancement by comparing resonance characteristics of a fabricated microdisk, AMZI, and the proposed structure at equal fabrication conditions. We measured an effective Q-factor of 9.15×10^4 with a 22 dB extinction ratio.

1. Introduction

High quality optical resonators have recently attracted considerable attention for several applications including sensors, nonlinear optics, quantum optics, and optical network [1–7]. One important requirement for sensing applications is the highly sensitive detection of molecules and nanoparticles in liquid and gaseous environments. This is enabled by a high quality-factor (Q-factor) of the resonator modes [2,3]. Specific detection can be obtained by functionalizing antibodies on the sensor surface that allow binding of distinctive target molecules [3]. The presence of particles is detected through a resonance wavelength shift proportional to the refractive index variation of the detected particle [8]. By measuring the intensity variation for a fixed wavelength or the shift in the resonance wavelength, the refractive index change can be measured. Thus, high sensitivity due to the steep slope and very high Q-factor in the resonance characteristics has always been required in biological and chemical sensing.

Microresonator structures, such as a microring [9,13], toroid [10], and disk [11,12,14–16], exhibit the characteristics of a whispering gallery mode. Although a ring resonator with easy fabrication has been studied for many applications, its Q-factor is relatively low compared with that of other resonator structures. A toroid resonator [10], which consists of a floating doughnut-shaped round waveguide in air, has an extremely high Q-factor of 10^8 because of low loss inside the resonator. However, it is difficult to regularly fabricate and measure the resonance characteristics because they are observed by coupling a tapered optical fiber in air [14]. Here, the coupling coefficient affects the Q-factor of the resonator, making it difficult to integrate with other devices. Floating microdisk resonators [15] also have similar disadvantages to the toroid resonator. In contrast, planar microdisk resonators are relatively easy to fabricate and integrate on a substrate. Because of that planar microdisk resonators can be utilized for the realization

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https://doi.org/10.1016/j.ijleo.2019.06.016
Received 28 March 2018; Received in revised form 19 April 2019; Accepted 9 June 2019