Fundamental Evaluation of Semiconductor Waveguide-type In-line Wavelength Selective Filters with Fabry-Perot Etalon Resonator

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1. Introduction

Dense Wavelength Division Multiplexing (DWDM) networks have been intensively investigated on the basis of ITU-T Recommendation G.692. To increase the channel numbers, the interval of adjacent two wavelengths is made extremely narrow, and the center wavelength should be properly defined in the systems. Wavelength selective filters that are highly stable and accurately locked at allocated wavelengths are essential to realize these systems. In addition, these filters should also be easy for tuning of the interval and the center wavelength, easy for integration with other optical devices such as a light source, a detector and a channel waveguide, and independent of polarization of light. To satisfy these requirements semiconductor waveguide-type in-line wavelength selective filters are quite promising. In this paper, we present the structure, fabrication process and fundamental filtering characteristics of an InGaAsP semiconductor waveguide-type in-line wavelength selective filter with a Fabry-Perot etalon resonator operating at the 1550nm wavelength range.

2. Fabrication

The structure of the device we fabricated is shown in Fig.1. The device was fabricated by liquid phase epitaxial (LPE) growth method on an InP substrate. These layers were not doped intentionally. After the growth, SiO_2 was deposited on the surface as a mask before photo-resist coating. In the photolithography, line patterns were first exposed as waveguide patterning, and then isolation patterns of resonator regions from waveguides were exposed by Laser Beam Direct Drawing (LBDD), because of the difficulty in the individual exposure and development processes and the simultaneous photolithography of waveguides and resonators. Furthermore, waveguides and resonators were inclined up to 8 degrees from the [011] direction to suppress spurious resonant modes generated between the cleaved facets [1]. The width of the grooves, that is, the spacing between the waveguide and the resonator became about 1μm after the development process. After the photolithography process, an InGaAsP cap layer, an upper InP buffer layer and an InGaAsP waveguide layer were etched down by the combination of Reactive Ion Etching (RIE)[2] and wet chemical etching methods in order to eliminate introduced damages and to suppress roughness of the etched surface (see in Fig.2). As a channel waveguide, a high mesa structure with a width of 5μm was adopted. In order to attain a desired wavelength interval $\Delta\lambda$, the length of the resonator (L) is determined as $L=\lambda^2/2n_{eff}\Delta\lambda$, where λ is the input wavelength and n_{eff} the effective refractive index of the resonator. Here, L is designed to be 469.2μm for $\Delta\lambda$=0.8nm using n_{eff}=3.20 at 1550nm wavelength. The spacing between a waveguide and a resonator was designed to be less than 1.0μm for low-loss coupling.

3. Evaluation

The fundamental filtering characteristics of the fabricated device with a total device length of 5-6mm were measured. As an input light source, amplified spontaneous emission of Erbium Doped Fiber Amplifier whose emission wavelength range was from 1.3μm to 1.6μm was used. The output spectrum of the device is shown in Fig.3. Fabry-Perot resonant characteristics were observed with a designed equal wavelength interval of 0.8nm (100GHz) and a pass-stop contrast ratio of 1.5dB. The low contrast ratio is considered to be due to rather poor facet flatness, as shown in Fig.2, as well as a transmission loss in the resonator, which came from a residual absorption loss and a side-wall scattering loss of about 2.7dB/mm. This facet roughness led to the reduction of the reflection coefficient. To flatten the resonator facets, the etching processes and conditions should be optimized. The fabrication process optimization will also lead to the realization of a narrow spacing between a waveguide and a resonator, which leads to a lower coupling loss between the waveguide and the resonator than the present value of about 6.7dB[3]. In addition to the facet flatness, high reflection coating on the resonator facets with thin metal or dielectric films is considered to improve the reflectivity on the facets. It is noted that spurious ripples were successfully suppressed by introducing the angled facet relative to the waveguide.

4. Conclusion

We reported the structure, fabrication process and fundamental filtering characteristics of a semiconductor waveguide-type in-line wavelength selective filter with a Fabry-Perot etalon resonator. We achieved designed 0.8nm wavelength interval and 1.5dB contrast ratio. Low contrast ratio can be improved by optimizing the fabrication process and the waveguide structure, and adjustment to the ITU-T recommendation wavelength allocation be attained by introducing a tuning mechanism.

References

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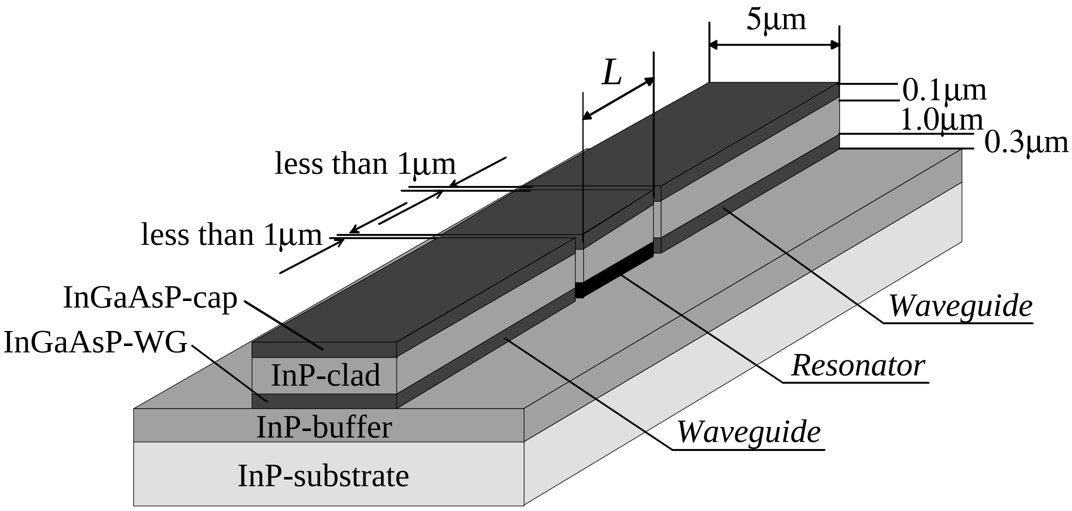

Fig.1: Schematic device structure

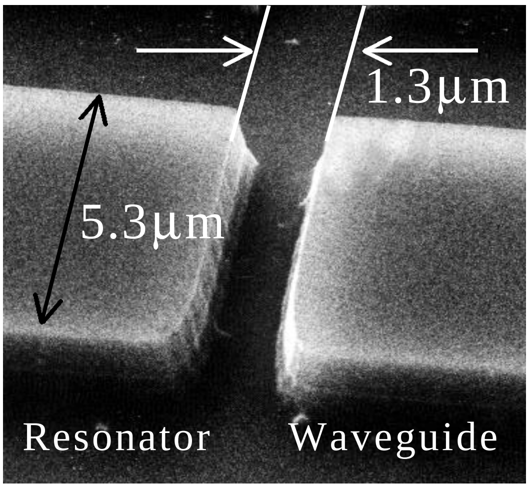

Fig.2 Surface of the device

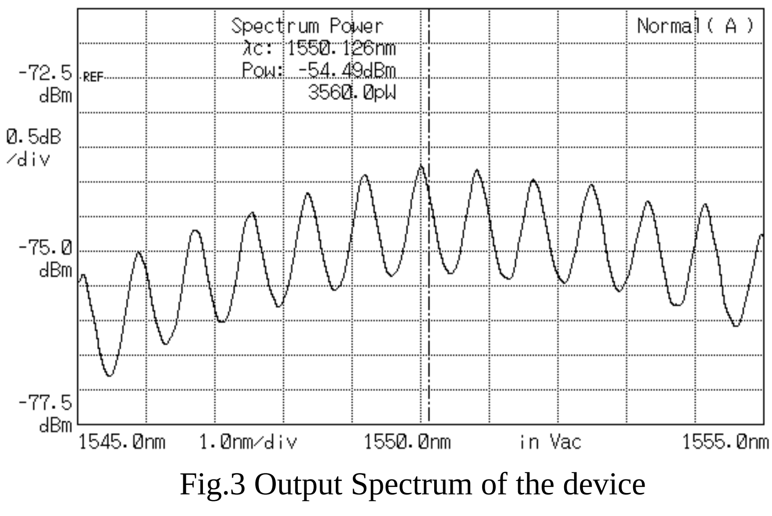

Fig.3 Output Spectrum of the device