Polarization Independent, Figure-Eight Birefringent Sagnac Variable Comb-Filter/Attenuator

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Abstract

We propose and theoretically analyze multi-functional integrated optical device based on figure-eight shaped birefringent Sagnac loops. Our analysis shows that the propose device exhibit many unique features which allows it to operate as a tunable high-Q comb filter with a good channel isolation, and the intensity transmission of the filter can be varied from zero to 100 percent.

I. INTRODUCTION

Recently, a variable channel spacing dual-segmented Sagnac-Lyot filter has been demonstrated[1],[2]. and multiple segmented Sagnac-Lyot filter which produces higher order filtering function and a tunable dual-wavelength fiber laser based on this 2nd-order Sagnac-Lyot filters have been successfully demonstrated[3]. The proposed device in this paper is a figure-eight shaped loop device that can perform multiple functions such as an optical router, an optical attenuator and an optical filter. By adjusting the angles of the polarization in different parts of the loops, the device can work as an optical attenuator which the transmission can vary from 100 percent to zero, and unique filtering functions that include comb filter function with a large channel isolation.

II. THEORY

The figure-eight shaped birefringent Sagnac loop consists of two 2×2 directional couplers, three PM waveguides or fiber sections and four polarization rotators as schematically shown in Figure. The input wave is splitted at each coupler and the device effectively acts as a cascaded loops with a double pass. The polarization before each PM section is rotated by using a polarization rotator.

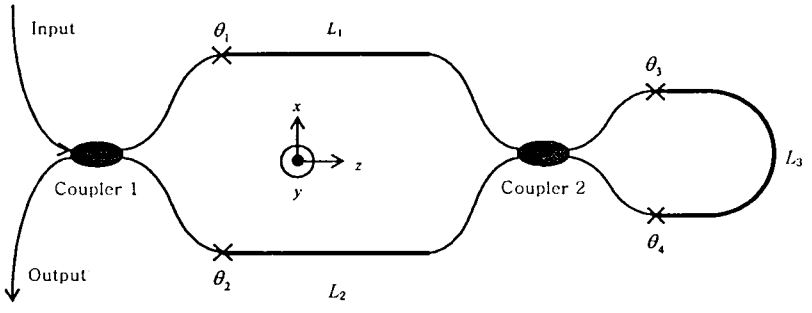

Figure. The figure-eight shaped birefringent Sagnac loops device.

In this paper, we consider that all three PM fibers have same length, the lossless couplers are independent of the polarization of the lightwave and the power coupling ratio is 50/50. In that case, the optical intensity transmission can be written as

$$T = \cos^2(\theta_1 - \theta_2) + \sin^2(\theta_1 - \theta_2)\left[\cos\theta_3\cos\theta_4\cos\left(\frac{3\pi}{\lambda}\Delta nL\right) + \sin\theta_3\sin\theta_4\cos\left(\frac{\pi}{\lambda}\Delta nL\right)\right]^2$$

The first term on the right-hand side is a DC term that is a function of θ_1 and θ_2 and determines the DC off-set of the device. The second term is the modulation term. The sine squared term determines the overall amplitude of the modulation. The two terms in the bracket are the actual modulation terms and determines the modulation frequency and the shape of the modulation. The transmission is independent of the polarization of the input wave.

If θ_3 and θ_4 are set to 90° and zero, the modulation term disappears and transmission function becomes $T = \cos^2(\theta_1 - \theta_2)$ and the device works as an attenuator which the transmission can vary from 100 percent to zero with controlling the angles θ_1 and θ_2.

When $|\theta_1 - \theta_2| = 90°$ and $\theta_3 = \theta_4$, then the transmission function can be rewritten as

$$T = \left[\cos^2\theta_3\cos\left(\frac{3\pi}{\lambda}\Delta nL\right) + \sin^2\theta_3\cos\left(\frac{\pi}{\lambda}\Delta nL\right)\right]^2$$

Based on analysis of the filter function, the side lobes between the main transmission peaks are minimum when $\theta_3 = 57°$ and this corresponds to more than -30 dB suppression of the side lobes.

When $\theta_1 \neq \theta_2$ and $|\theta_1 - \theta_2| \neq 90°$, the DC offset in the transmission function occurs. The larger amplitude of the DC term, the smaller amplitude of the modulation terms, thus the visibility of the transmission function is decreased. While providing comb filter function, the proposed device can be simultaneously functioned as a variable attenuator.

III. CONCLUSION

We proposed and analyzed the performance of a novel, multi-purpose figure-eight shape Sagnac filter that can function as an optical router, variable optical attenuator and optical filter. The device can be tuned by controlling the polarization states in the loops and this allows tuning of the filter channel spacing, amplitude, DC off-set, visibility, channel isolation and shape of the filter function. The device is insensitive to input polarization and can be made to have low insertion loss.

References

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