Abstract of Dissertation
論文の内容の要旨

High-performance Optical Filters based on Fiber Bragg Gratings with Arbitrary Phase Shifts

（任意位相シフト光ファイバブラッグ回折格子に基づいた

高性能光フィルタ）

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Abstract

As optical communication systems have been developed for larger capacity (>10 Tb/s per filber) and bandwidth efficiency (>1 bit/s/Hz), optical filters play more and more important roles that perform functions of multiplexing different wavelength channels and demultiplexing them, background noise suppression, spectral filtering, dispersion compensation and optical signal processing. Among various optical filter techniques, fiber Bragg grating (FBG) has attracted much interest due to its all-fiber geometry, low insertion loss, potentially low cost, and easy fabrication. But the most distinguishing feature is the flexibility they offer for achieving desired spectral characteristics.

Although FBG technologies have been developed well in recently years, making FBG with arbitrary phase shifts by using general phase masks is unavailable, which limits the possibility to obtain more high performance FBG based optical filters. This project focuses on solving this problem to make high performance FBG based optical

filters with arbitrary phase shifts.

Multilevel phase-shifts phase sampling has been shown numerically to have higher diffraction efficiency than binary phase-shifts phase sampling. In order to fabricate grating structures with arbitrary phase shifts, displacing phase mask method has been proposed. Two kinds of phase sampling functions have been designed and corresponding FBG reflection spectra have been calculated numerically. Then, two kinds of phase sampled-FBGs (PSFBGs) have been fabricated to show the flexibility of displacing phase mask method for inducing phase change. The first has several binary phase shifts either 0 or π within a sampling period. The second has continuous phase variation between 0 to 2π within a desired sampling period. Experimental results verify that the developed fabrication method is suitable for making complex grating structures.

Multi-channel optical filters are cost effective for processing and manipulating optical signal in optical communication systems. Among various available technologies, phase-sampled FBGs have many advantages such as low insertion loss, all fiber geometry, compact and typically low cost. With the improved FBG fabrication method, two kinds of multilevel phase-sampled FBG (PSFBG) have been made with general uniform or chirped phase masks. Two applications based on fabricated multilevel phase-shifts PSFBGs are demonstrated. One is an 8-channel tunable dispersion compensator. The other is pulse repetition rate multiplier from 40 GHz to 160 GHz.

Conventionally, FBG-based optical filters are bandstop filters and need to be used conjunctionally with optical circulators, thus increasing the cost of devices. Although FBG-based tunneling filters with a flat passband have been demonstrated by inducing multiple π-phase-shifts along a uniform FBG, the stopband of uniform FBGs is generally narrower than 2 nm and such filters are still not suitable for many applications. We propose and demonstrate that direct-coupled resonators could be fabricated on LCFBGs, and that desired transmission characteristics could be designed by the amount and position of phase shifts. Since the stopband of LCFBGs can be very wide, bandpass filters based on LCFBGs are suitable for practical applications. In addition, center

wavelengths of bandpass filters can easily be controlled inside the wide stopband.

In high-speed optical communication systems, relative timing drift between signal pulses and clock pulses severely affects the performance of optical switching. By shaping the signal pulse waveform into rectangular shape, this issue can be solved. Rectangular short pulse generation by using strong unchirped FBG has been demonstrated. The grating structure is synthesized by using inverse-scattering algorithm. With this improved FBG fabrication method, the FBG is fabricated and the measured reflection spectrum coincides with target reflection spectrum very well. From experimental results, it can be seen that ~18 ps rectangular pulses are generated successfully. We also propose a scheme to generate rectangular short pulses by using two linearly chirped FBGs (LCFBGs): one is used for pulse reshaping and the other is for dispersion compensation. As an example, the grating structure of the pulse reshaping LCFBG has been designed to generate 4-ps rectangular output pulses, and numerical calculations confirm the feasibility of the proposed scheme.

The current emphasis on optical communication systems is on increasing the spectral efficiency. One of the techniques that is used for achieving high spectral efficiency in WDM systems is vestigial sideband (VSB) filtering. VSB filtering increases spectral efficiency (the number of bits per unit bandwidth) and improves fiber dispersion tolerance. FBG based optical VSB filters for 40 Gb/s bit rate application have been studied. The principle of VSB optical filters and available techniques for realizing VSB optical filters are introduced. A FBG based VSB filter with a 3-dB bandwidth of 0.32 nm has been designed and fabricated. The fabricated VSB filter has been used in 40 Gb/s optical transmission system and experiment results have been analyzed in detail.

Several high-performance FBG based optical filters with arbitrary phase shifts have been realized by using developed fabrication method with just general phase masks. It is anticipated that these high performance optical filters will play important roles in contemporary optical communication systems.