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Cross Phase Modulation by Pump Pulses Emitted from High-Power YAG Laser on Fiber Grating Couplers

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Abstract

The optical-switch due to cross-phase modulation (XPM) that intense high power YAG pump laser induces on the signal light propagating through the Bragg grating coupler is experimentally and theoretically investigated.

1 Introduction

The capacity of optical transmission systems has been recently increased significantly by using high-speed wavelength division multiplexing (WDM). Fiber grating couplers (FGC) is a novel key component in optical add/drop multiplexers. The FGC can be fabricated by writing the Bragg grating in the tapered waist of fiber coupler. Recently, all-optical switch of fiber Bragg gratings and FGCs has been proposed and demonstrated experimentally [1-3]. In this paper, we develop the nonlinear optical fiber switching using the so-called Kerr nonlinearity in fiber grating coupler [4]. The switching is based on the cross-phase modulation (XPM) when the intense high power pump copropagates in the grating region simultaneously with the signal light [5]. The fact will lead to the change in reflection spectra of Bragg grating and the resultant output intensity at the signal wavelength will be decreased when the power of high pump pulses increases.

2 Experimental set of all-optical switching

The experimental setup for all-optical switching is shown in Fig. 1. A narrow linewidth tunable laser, nearly centered in the reflection spectra of the FGC, is used as a low probe (signal) light. This CW probe is coupled at the fused portion of the FGC to high pump pulses of a Nd:YAG laser. The output frequency of YAG laser is used as a reference signal of a lock-in amp. This frequency is equal to the laser output

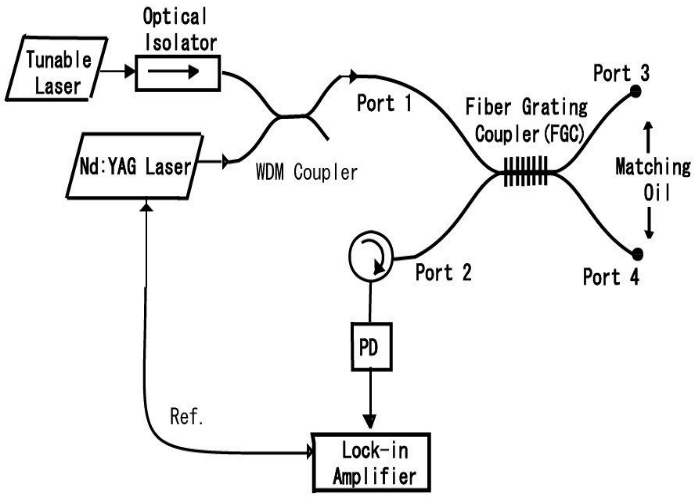

Fig. 1 Experimental setup for all-optical switching using fiber grating coupler

pump pulse repetition. The pump pulse source emits its spectra around 1064nm. The repetition rate of the pump pulse is 1kHz and the pulse width is approximately 70ns. Minimum YAG laser peak power is around 4kW at input end of WDM coupler. The grating used in the FGC is 10mm long and the index profile is Gaussian apodized. The insertion loss of the grating coupler fabricated in our laboratory is 0.89dB. The splitting ratio of the coupler is 1: 32.4 as a through-port power versus a coupled-port power. In our experiment, a drop efficiency of 58% at maximum is obtained at the Bragg wavelength λ_B =1538.26nm. The reflected signal light from FGC taken out of an optical circulator is detected with photo-diode (PD). The pump pulse, propagating in the grating of the FGC, induces a nonlinear variation of the refractive index that shifts the whole reflection spectra toward longer wavelength that is red-shifted

[5]. The operation of all-optical switching has been confirmed by means of coherent detection using a lock-in amp. [6].

3 Results

By detecting the change of output from the lock-in amp. in the presence and absence of pump light, the output is plotted as a function of signal wavelength (Fig. 2).

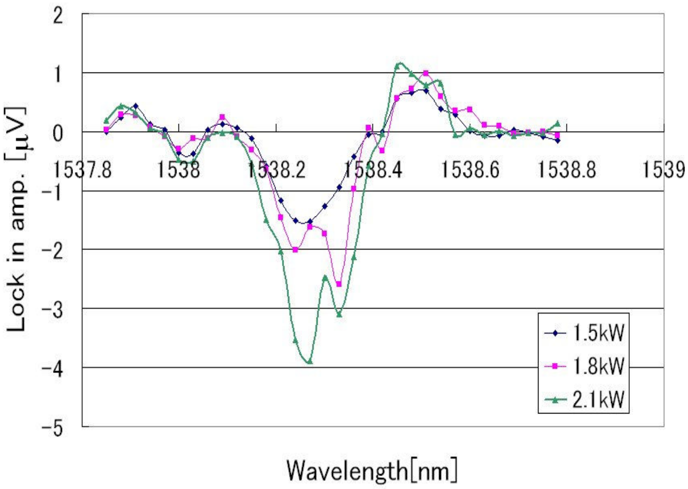

Fig.2 Experimental results of lock-in amplifier output vs. wavelength for a variety of pump peak powers using YAG pump pulse.

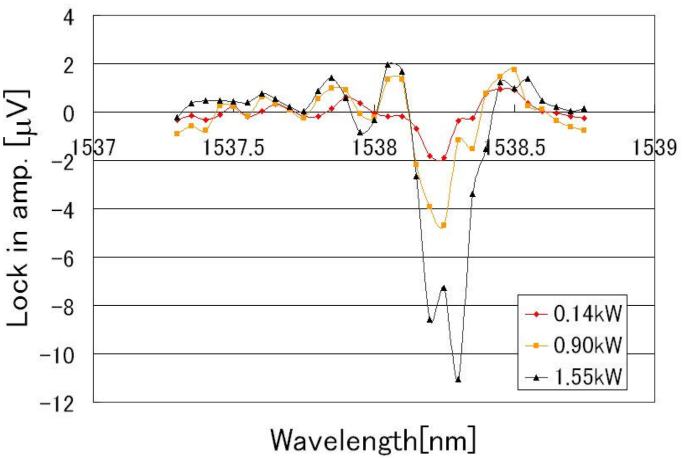

Fig.3 Experimental results of lock-in amplifier output vs. wavelength for a variety of pump peak powers using EDFA pump pulse.

The lock-in amp. output corresponding to the dropped signal power from port 2 decreases as the pump peak power increases. This is due to the fact that as the pump peak power increases, reflection spectra shift to a longer wavelength according to the formula of red-shifted Bragg wavelength $\lambda'_B = 2n\Lambda$ where Λ is the grating period and n is modulated refractive index. Modulated refractive index is a function of pump peak power, polarization coefficient and effective core area. By comparing the experimental curve (Fig. 2) with theoretical ones for outputs from a lock-in amplifier, we can estimate the red-shift of Bragg wavelength of FGC. This wavelength shift is comparable to the results of Fig.3, where we used an EDFA pulse laser as the pump source [6]. The pump pulse from an EDFA emits its spectra around 1534.2nm-1561.1nm with a peak power of 3.55kW at maximum. The repetition rate of the pump pulse is 20.6MHz and the pulse width is approximately less than 1ps. Using EDFA pump cause the mixture of pump pulse components into signal light problem. To overcome this problem in this experiment we perform an efficient switching using high power YAG laser (λ_p =1064nm) because its duration of pump pulse is longer than the grating within a FGC. We estimate the red-shift of Bragg wavelength 0.06nm at maximum pump power of 2.1kW.

4 Conclusions

Using the fabricated FGC in our laboratory, we experimentally demonstrated a relatively low-power, all-optical switching induced by intense pump light at 1064nm in a fiber optic-grating coupler. It was confirmed that the dropped signal power decreases as the pump peak power increases at the wavelength $\lambda < \lambda_B$ and the red-shift of the Bragg wavelength is 0.04-0.06nm/1.8-2.1kW.

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