INVESTIGATION OF FIBER LASER FOR LOW POWER APPLICATIONS

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Abstract

A fiber laser involving Fiber Bragg Grating designed and implemented to work at 1550 nm communication window has been proposed and demonstrated as an experiment. We are presenting the fiber laser for low power applications. These applications are based on Fiber Bragg Grating the Fiber Bragg Grating output is present in wavelength domain, so it requires sophisticated devices to measure wavelength. By measuring the output power corresponding to the measured wavelength, the system show low attenuation and high wavelength capabilities making fiber laser ideal for gigabit transmission and beyond. This technique is simple, low cost and potentially allows for very high sensitivity.

Keywords: Fiber Laser, Fiber Bragg Grating, Reflection, Transmission, Spectrum.

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1. INTRODUCTION

Optical fiber [1-7] is made possible by applying a phenomena of total internal reflection. This can be defined as a cylindrical dielectric wave guide. It consists of an inner core and outer cladding. It is made of material that has low loss such as silica class. Light enters the end of the fiber at a critical angle to the fiber axis follows a zigzag path through a chain of reflections down the length of the fiber. Two conditions are met to satisfy total reflection at the wall of the fiber. Firstly, the guided light inside a medium must have higher refractive index (n1) than surrounding medium (n2). Secondly, the light have an angle of incidence (φ) between the ray path and the normal of the fiber axis which is must be greater than a critical angle (φ_c) which is known as the incidence angle for which

$$\text{Sin}(\varphi_c) = n2 / n1 \qquad (1)$$

Fiber laser has attracted great attentions during the past few decades due to the advantages of high stability, high reliability, low total cost ownership, low jitter and amplitude noise, compact and immune to tough environment changes.

Fiber lasers [8] have demonstrated to span of light in range of 400 nm – 300 um. Many different applications used fiber laser technique such as laser cutting, welding of various materials, maximum precision of drilling and medical application in surgery. Low power ($p< 30$) watt continuous wave fiber lasers were wide use for marking integrated circuits.

Fiber Bragg Grating [9] can be described as a periodical perturbation of refractive index along the axis of the fiber. It is usually fabricated by phase mask method that is achieved by exposing the single mode fiber to intense optical interference pattern made with an ultraviolet 244 nm argon ion laser. A certain narrow band of the incident light is reflected by successive, coherent scattering on refractive index perturbations. Through strong interaction happens at incident light, the maximum reflected wavelength equal to wavelength (λ_B) is determined by phase matching condition [7]:

$$\lambda_B = 2\, n_{eff}\, \Lambda \qquad (2)$$

Where n_{eff} is refractive index that has the effect of the guided mode in the fiber core, and Λ is the grating pitch. The goal behind our work is to make the design and implementation of fiber laser for low power applications at lower cost based on standard telecommunication fiber amplifier that is doped with erbium. The power values were recorded and plotted to the change of corresponding values of fiber length and input pump power.

2. THEORY

The understanding of power increasing has required the construction of a fiber laser and the operation of it. In simple form there are three main components are used to implement a fiber laser (10): the pump source, the gain unit and the cavity. Light is pumped into cavity by the pump source. The gain unit, which is also known as the amplifier, is an optical fiber. It is simply a core that is coated by a layer of cladding. Total internal reflection moves the guided power inside the core. The pump power and the radiation of the laser are being guided in the erbium doped fiber amplifier. Inherent compactness and long term stability of the fiber laser are a result of the final combination of the laser process. The amplification process is defined by dividing the output optical energy to the input optical energy. A higher amplification ratio can be obtained by storing enough amount of light in the amplifier which leads to an efficient use of pump source (11).

3. Operation of Fiber laser

There are three phenomena that represent the driving process of the laser operation(12). These are; absorption, spontaneous emission and stimulated emission. Absorption is defined as the phenomena in which the material (or the electron in the material) absorbs the photon causing it to be in an excited state. The light at the pump wave length in the cavity is pumped by the pump source. Then the ions of the amplifier absorb this light and moves to a higher energy state after being in a ground energy state. When the ions get to the higher energy state, they emit the absorbed light in the form of photons, which are emitted at the laser wavelength. Spontaneous emission, in which the material or photons relaxes to an energy state that is lower and a photon that is emitted without the influence of another photon. The ions in higher energy state are stimulated by the reflected photons to emit more photons to produce the phenomena known as stimulated emission. The phenomena of stimulated emission are the actual cause of the lasing effect produced in the fiber laser.

4. Experimental work

The optoelectronic setup shown in Fig.1 depicts a schematic diagram of a fiber laser. Reducing the losses that result from using the connectors was the reason why all the components were spliced together. Reducing the loss achieves the enhancement of the output power. It comprises a broad-band super luminescent that has peak at 550nm with 200nm operating band width and 62 nm FWHM supplied by HAYATEK. A directional 3-dB coupler to collect the reflected spectrum from the Fiber

Bragg Grating, wave division multiplexing and OSA for spectral measurements at one of the two outputs 1 or 2. The Optical Spectrum Analyzer in our setup was supplied by Yokogawa model Ando AQ6370B. It included modifications to the monochromator in comparison with Ando AQ6317B and AQ6370. The OSA has a wavelength resolution of 0.02 nm. Ando AQ6370B was well suited for C-band and L-band measurements as it covers from 600 to 1700nm.

The broad band source is connected to port 1 of the circulator. In the port 2, Fiber Bragg Grating (FBG) with the bragg mode resonance dip location at 1546 nm is connected for transmission spectrum measurements. The coupler 50/50 is connected to port 3 for reflection spectrum measurements. The gain unit is erbium doped fiber which is most wide spread doping for active laser fiber cores in medical and telecommunication applications. Recording the reflected spectrum from the sensing grating carries out grating the measurements of the spectra. The core diameter of 10 mm single mode fiber is 8 um with 125 um cladding diameter where normal FBG was written using Argon ion laser 244 nm phase mask technique. The grating is pumped with 1550 nm laser diode.

5. Results and discussion

Table 1 shows how the length of the fiber amplifier is related to the fiber laser output power when the length of the fiber amplifier is Changed from 0.5 to 2.5 m. it is clear that the output power decreased with respect to the increasing fiber laser length.

Figures 2,3 and 4 show the reflection spectrum for different values of 1550 nm pump power (170 µw, 175 µw and 180 µw) respectively. All the data were stored and plotted by optical spectrum analyzer. The Wave Division Multiplexing (WDM) mixes the pump source light at 1550 with the light at lasing wavelength of 1550 nm. The light from the pump source is absorbed by the amplifier. This process excites the ions causing them to move to a higher energy state. The output light amplifier is sent through the circulator to the FBG. The circulator functions as sequential out ports. It is a combination of coupler and isolator that allow light to pass in one direction from amplifier to the FBG. The light that is reflected from the FBG can only pass to the coupler. The data are stored and plotted using OSA.

6. Conclusion

A simple high sensitivity and low cost fiber laser based on Fiber Bragg Grating has been presented. We conclude that the output power of the fiber laser was increased with an increase in the pump power successfully. The output of the power will be decreased when the length of the fiber amplifier is decreased due to the light being absorbed at the laser wavelength when the fiber is longer than 0.5m. When the length of the amplifier is increased beyond this point, the use of the amplifier and a lower output power is being wasted. The use of laser for high power applications needs double cladding fiber with ytterbium fiber amplifier.

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Table1. Thecorresponding output power to the change of fiber amplifier length

Amplifier length (m)	Output power (μw)
0.5	3.25
1	3.20
1.5	3.17
2	3.15
2.5	3.1

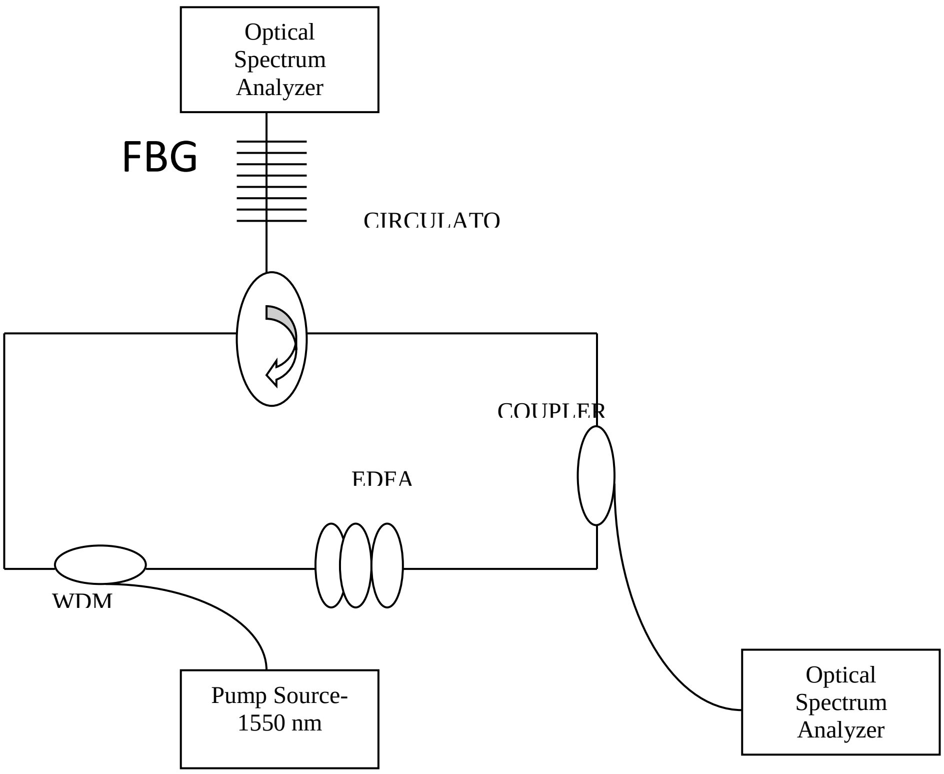

Fig.1 The setup of the fiber laser

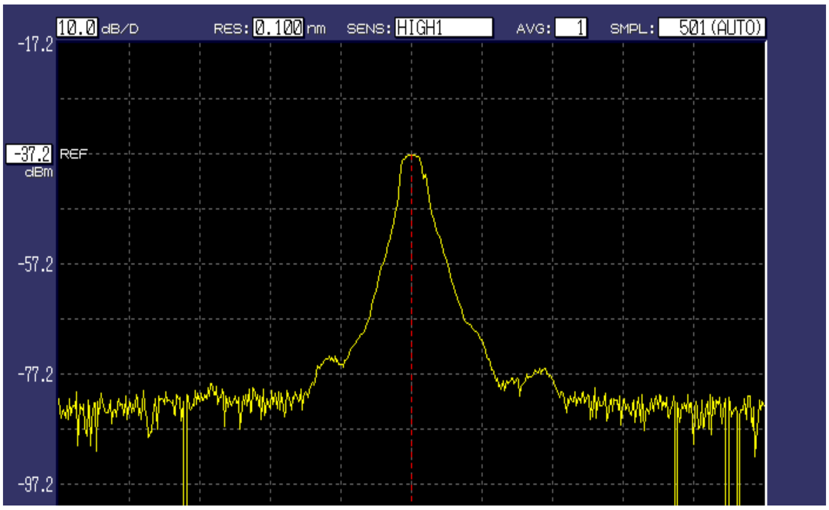

Fig.2 The output fiber laser for P_{pump}=170 μw

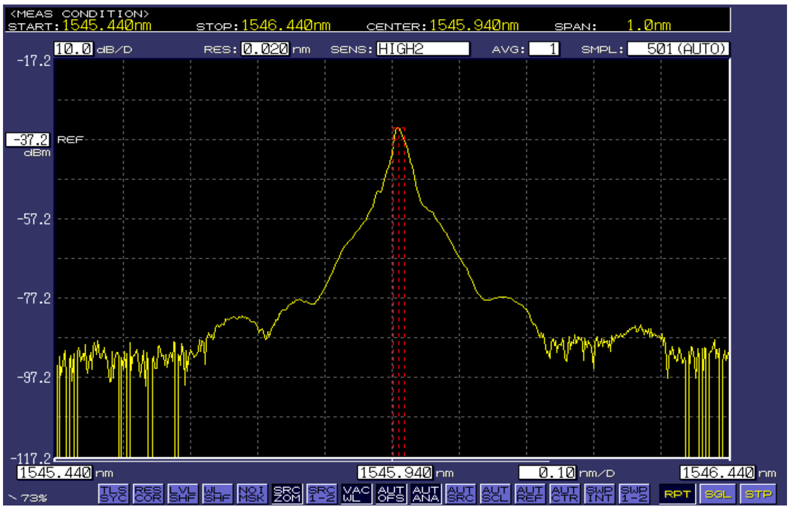

Fig.3 The output fiber laser for P_{pump}=175 μw

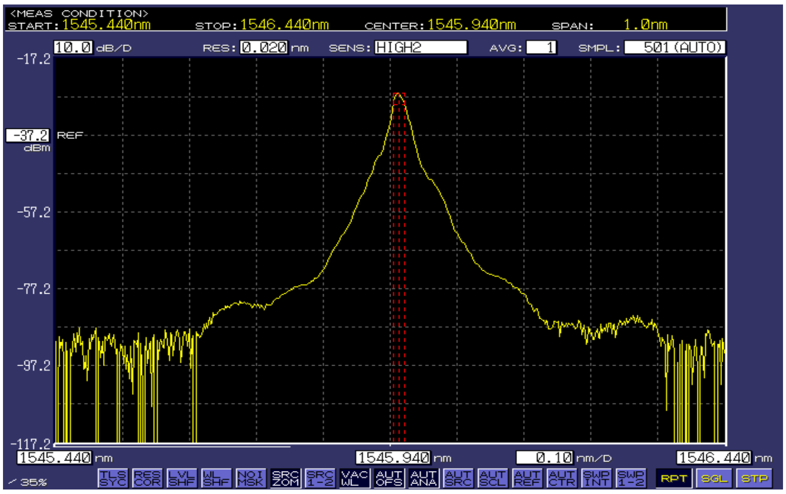

Fig.4 The output fiber laser for P_{pump}=180 μw

تحقيق ليزر ليفي لتطبيقات القدرة الواطئة

م.د. رياض خلف احمد

المستخلص

ان الليزر الليفي المتضمن محزز براغ ليفي المصمم والمنفذ للعمل ضمن نطاق حزمة الاتصالات 1550 نانومتر قد اقترح ومثل تجريبيا. في هذه البحث تم اظهارليزرليفي للتطبيقات ذات القدرة العالية مستندا على محزز براغ ليفي حيث ان اخراج المحزز براغ ليفي قد مثل على شكل اطوال موجية مما يتطلب اجهزة قيا س متطورة لقياسها. بقياس القدرة الخارجة ومناظرتها مع اطوال موجية مقاسه اظهر النظام توهين ضعيف وامكانيات عالية للاطوال الموجية جعلتة مثالي للارسال ونقل المعلومات بمعدل ارسال لاكثر من كيكا بت. هذه التقنية بسيطة التركيب و قليلة التركيب وتسمح باستشعارية عالية ميدانيا.

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