Sliced fiber Bragg grating used as a laser diode external cavity

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ABSTRACT

A new type of fiber Bragg grating is proposed, which is called sliced fiber Bragg grating. Unlike the regular fiber Bragg grating which is a fiber based working device, the new sliced fiber Bragg grating can be used as a free space component. For example, a sliced fiber Bragg grating can be used as a laser diode external cavity. A multimode fiber Bragg grating written on a 100um core size is cut into small segments of 1 to 2mm. Each end surface of the fiber Bragg grating segment is polished and then coated with an anti-reflection coating. The fiber Bragg grating segment, or sliced fiber Bragg grating, is used to manufacture an external cavity laser diode. The sliced FBG external cavity laser diode bandwidth is reduced from 0.19nm to 0.06nm.

1. INTRODUCTION

Narrow bandwidth laser sources are important for optical fiber telecommunication applications. The core technology of DWDM is to increase the capacity of single mode fiber by using multiple wavelengths to carry the information. The center wavelength stability of the laser source is very critical for DWDM optical systems. Narrow bandwidth laser sources are also useful devices for instrumentation, sensor, metrology, and biomedical applications. To reduce the bandwidth of a laser diode, we can use technologies like volume holographic gratings, [1-3] and fiber Bragg gratings, [4-7].

Fiber Bragg gratings were used by Pezeshki et al [4] to stabilize the intensity and frequency fluctuations of a laser diode. There are some disadvantages to use fiber Bragg gratings as external cavities to suppress longitude and lateral mode hops: first the light from laser diodes, solid state lasers, or gain mediums must be coupled into the optical fiber with high energy loss; Second, the fiber Bragg grating is usually not located at the fiber end, but at some distance from the fiber end, therefore the length of the optical cavity is longer. Long external cavities makes it difficult to modulate the laser diode at a high frequency; third, there are many applications that need free space laser diodes and do not need light to be coupled into an optical fiber, which limits the use of Fiber Bragg gratings as external cavities.

Others have used volume holographic gratings as external cavities to reduce laser bandwidth and to stabilize laser center wavelength operation, [1-3]. Volume holographic gratings are of small size (around 1mm cubic) and they can be packaged inside a TO-Can laser diode. A laser diode with a volume holographic grating external cavity still has a free space beam. Several companies now manufacture laser diodes with volume holographic external cavities. There are also some drawbacks for volume holographic gratings as laser diodes external cavities: first, the high manufacturing cost and complex manufacturing process of the volume holographic gratings are the main obstacles to the widely use of volume holographic gratings; secondly Volume holographic gratings can not stand high power applications; third, long and short period volume holographic gratings are difficult to manufactured.

In this paper, we have used a new method, called sliced fiber Bragg grating technology, as a laser diode external cavity to reduce the laser diode bandwidth. For the purpose of easy alignment with a laser diode emission facet, a fiber

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Bragg grating written on a multimode fiber of 100um core size is cut into small segments of 1 to 2 mm in length, which we called sliced fiber Bragg grating. The sliced fiber Bragg grating is used as a laser diode external cavity to reduce the laser diode bandwidth and to stabilize the laser diode center wavelength.

2. EXPERIMENTS

As shown in Fig. 1, a standard Bragg grating is written on a multimode fiber with a core size of 100um by using the two interference beam method. The two interference beams can be produce by a phase mask or by using a beam splitter to build a two beam interferometer configuration.

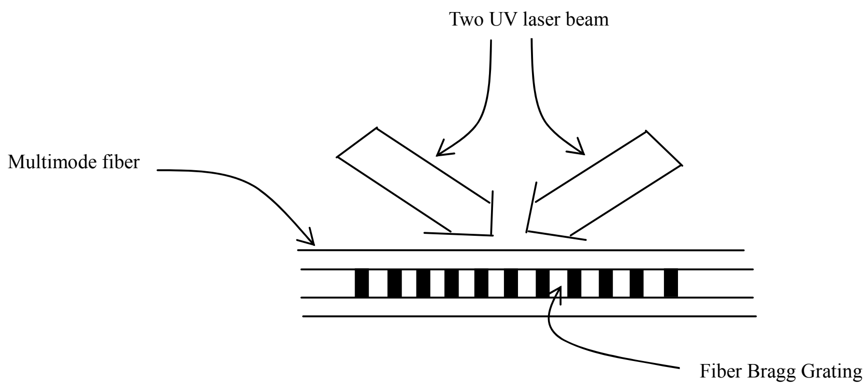


Figure 1. Fiber Bragg grating is written on a Multimode Fiber with a Core Size of 100um

After the fiber Bragg grating is annealed at a temperature of 120 degree C. the fiber Bragg grating is inserted into a ceramic ferrule filled with epoxy. Then the ferrule with the fiber Bragg grating is placed in an oven for two hours at a 100 degree C to cure the epoxy, as shown in Fig. 2. The fiber Bragg grating within the ferrule is then cut into small slices with a length of 1 to 2 mm as shown in Fig. 3.

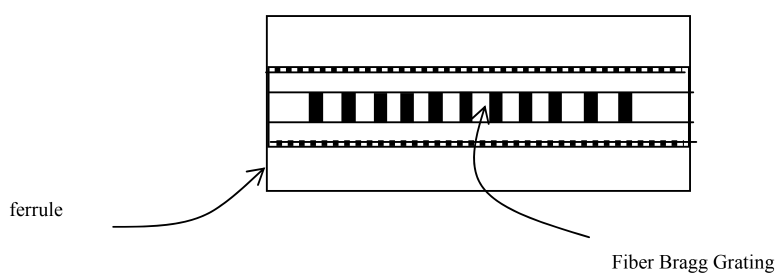


Figure 2. Fiber Bragg grating in a Ferrule

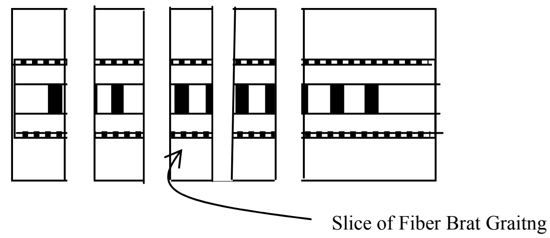


Figure 3. Fiber Bragg grating cut into small segments

Then both sides of the sliced fiber Bragg grating are polished and coated with an anti-reflection coating. A sliced fiber Bragg grating is placed in front of the laser diode emission area as an external cavity shown in Fig. 4. The laser diode used is single mode with a center wavelength of 785nm and an optical output power of 100mW. The fiber Bragg grating is written on a 100um multimode fiber with a center wavelength of 784.75nm, and a bandwidth of 0.45nm as shown in Fig. 5.

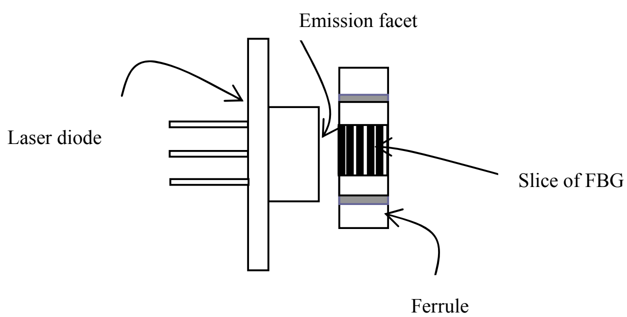


Figure 4. Sliced fiber Bragg grating used as a laser diode external cavity

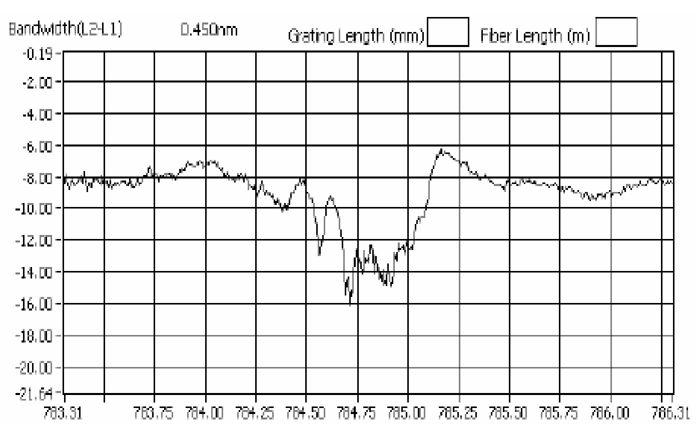


Figure 5. Sliced fiber Bragg grating spectrum

The sliced fiber Bragg grating is attached at the emission facet of the laser diode after its cap is removed. The bandwidth of the laser diode is reduced from 0.19nm to 0.06nm as shown in Fig. 6 and Fig. 7 respectively. The optical output power of the sliced fiber Bragg grating laser diode is slightly reduced from 100mW to 80mW, the S/N ratio is increased from 40dB to more than 50dB. Due to the optical spectrum analyzer resolution limitation of 0.01nm, the real bandwidth of the sliced fiber Bragg grating external cavity laser diode could not be verified. We believe it could be less than 0.06nm.

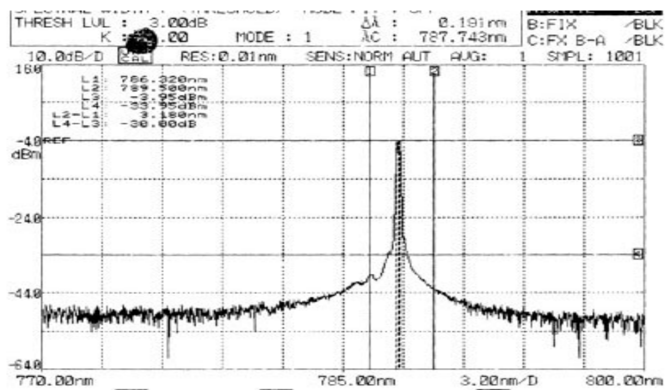


Figure 6. Laser diode spectrum

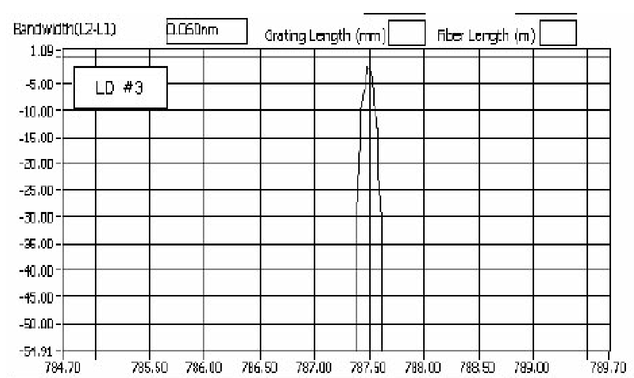


Figure 7. Sliced fiber Bragg grating external cavity laser diode spectrum

3. CONCLUSIONS AND DISCCUSSIONS

We have demonstrated a new type of fiber Bragg grating called sliced fiber Bragg grating, it can be used as laser diode external cavity to reduce laser diode bandwidths. Unlike the standard fiber Bragg grating which is a fiber based component, the new type of fiber Bragg grating can be used as a free space device. The experiments have shown that the sliced fiber Bragg grating is working well as a laser diode external cavity. For the purpose of easy alignment with a laser diode emission facet, a fiber Bragg grating written on a multimode fiber of a 100um core size is cut into small segments of 1 to 2 mm in length. Both ends of the fiber Bragg grating segment are polished and coated with anti-reflection coating, which we call sliced fiber Bragg grating. The sliced fiber Bragg grating is used as a laser diode external cavity to reduce the laser diode bandwidth from 0.18nm to 0.06nm and to stabilize the laser diode center wavelength. The new sliced fiber Bragg grating has many advantages over the regular fiber Bragg grating: first the light don't need to be coupled into a fiber, the new sliced fiber Bragg grating can be used as a free space working device to avoid huge power loss from coupling into a fiber. Second the alignment between sliced fiber Bragg grating and laser diode becomes easy. The sliced fiber Bragg grating can be written on a multimode fiber with a large core size. Alignment of a single mode laser diode with a multimode sliced fiber Bragg grating is fast and easy. Third the sliced fiber Bragg grating is of a small size, only a few mm long or less than 1 mm long, the working device can be very small.

4. DISCCUSSIONS

Several new applications of the sliced fiber Bragg grating have been discussed. One of the potential applications is the sliced fiber Bragg grating array as a band stop filter as shown in Fig. 8 to Fig. 10. The sliced fiber Bragg grating array is made by sticking many sliced fiber Bragg gratings together as shown in Fig. 8. The reason of sticking many sliced fiber Bragg grating together is to increase the effective working area of the fiber Bragg grating. As we know, the fiber face plate is made of a bundle of single mode fiber to transmit the image. The sliced fiber Bragg grating array can work as a fiber face plate but with additional function to block the bandwidth spectrum of the image transmitted. Having a large effective aperture, the sliced fiber Bragg grating array can handle more optical power and can reduce the insertion loss. Fig. 9 shows the working principle of the sliced fiber Bragg grating array. Fig. 10 shows the input spectrum, output spectrum and reflection spectrum for the sliced fiber Bragg grating array as a band stop filter.

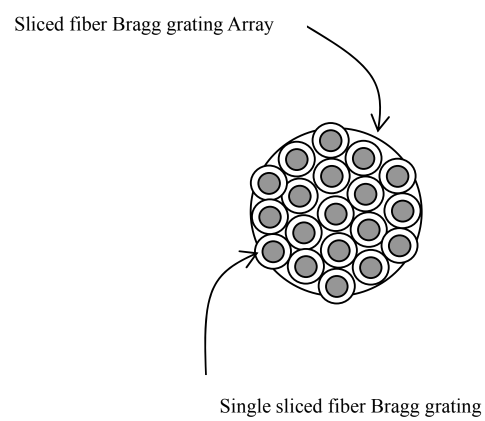


Figure 8. Sliced fiber Bragg grating array structure

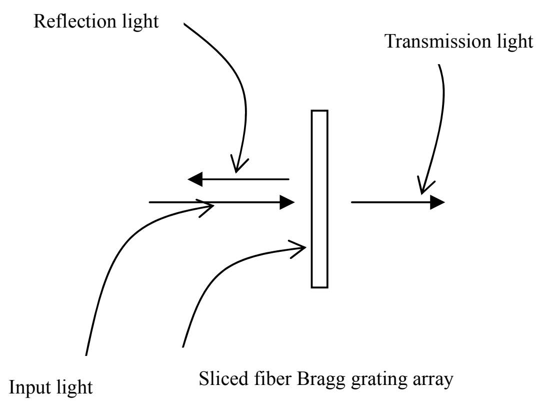
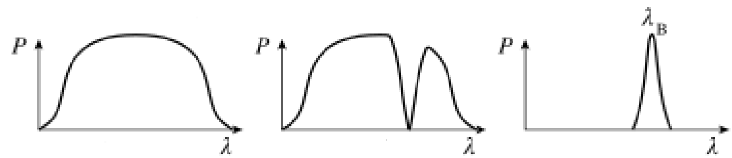


Figure 9. Sliced fiber Bragg grating array used as a band stop filter



(a) Input spectrum (b) output spectrum (c) reflection spectrum

Figure 10. Spectrum of the sliced fiber Bragg grating array used as a band stop filter

A second example of the sliced fiber Bragg grating application is for a free space optical temperature sensor. Standard fiber Bragg grating temperature sensor is well known to us. When the temperature changes, the center wavelength of a standard fiber Bragg grating will shift. To interrogate the wavelength shift of the standard fiber Bragg grating temperature sensor, the fiber needs to connect to an optical spectrum analyzer or fiber optical spectrum meter. The sliced fiber Bragg grating has the same function as a standard fiber Bragg grating temperature sensor. The sliced fiber Bragg grating can be mounted at any surface of an object. When the object has a temperature change, the sliced fiber Bragg grating attached to it will have is center wavelength shift. If we use a light beam to illuminate the sliced fiber Bragg grating, we can determine the temperature change of the object.

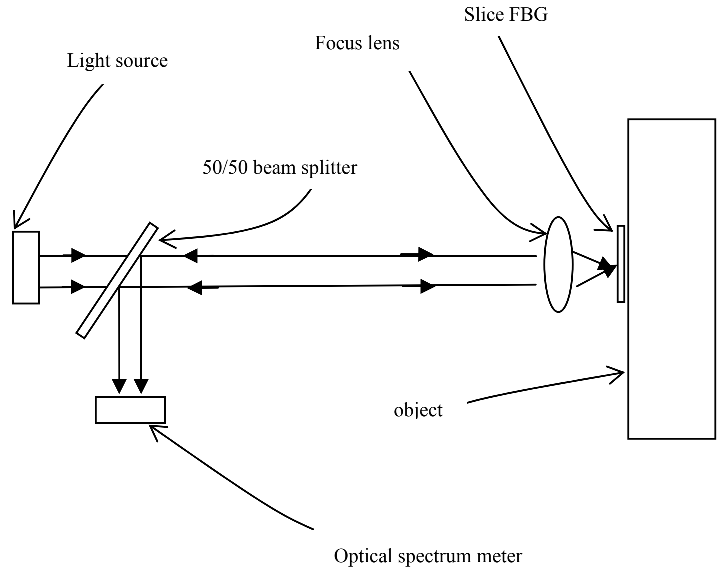


Figure 11. Optical configuration of a sliced fiber Bragg grating temperature sensor

As shown in Fig. 11. a collimated light source is passing through a 50/50 beam splitter and then focused on a sliced fiber Bragg grating via an optical lens. The light coming back from the sliced fiber Bragg grating, after collimation by the same optical lens, is reflected back to the 50/50 beam splitter into an optical spectrum meter to obtain the center wavelength measurement. When the object is exposed to a temperature change, the sliced fiber Bragg grating attached to the object will reflect the light with a different center wavelength. In this way, the object temperature can be known. Since this optical setup uses free space beam to sense temperature, the object can be a rotational or moving object like an engine or an airplane turbine.

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