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2.0 mW Er- DOPED 1550nm SUPER FLUORESCENT FIBER SOURCE FOR SINGLE AXIS MISSILE FIBER OPTIC GYROSCOPE

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Abstract: A 2-mW Single Pass Backward Signal (SPBS) Superfluorescent Fiber source (SFS) having a spectral width of 25.667nm was developed at a pump wavelength of 980.5 nm and presented the experimental results along with non-flattened ASE spectrum. The SFS has been packed into a small volume space of 100mm X 100mm X 15mm. The Fibre Source has application in single axis fibre gyroscope for missile. The fiber source was developed using all commercially available components.

Keywords: Single Pass Backward Signal Super-fluorescent Source, erbium doped fibre, missile fiber optic gyroscope.



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INTRODUCTION

Edge Emitting light emitting diodes (ELEDs) and super luminescent diodes (SLDs) were light sources for FOG for a decade in the past. But their wavelength stability with temperature is very poor. The change to fibre sources was motivated mainly by the high mean wavelength stability and high output power. The change to N_d doped fibre sources was motivated but these sources are sensitive to proton and gamma radiation. The change to Er-doped super fluorescent fibre source is motivated mainly by the reduced sensitivity to proton and gamma radiation at 1550nm and secondly, by the higher gain obtainable in Er: Silica. The Er-doped SFS was developed to elevate these problems.

High power, broad bandwidth, long lifetime, immune to proton and gamma radiation are the main advantages of 1550nm SFS to be the best light source for fiber optics gyroscope[1]. The broad spectrum of the SFS output (15-20nm FWHM) helps to reduce RIN and gyro bias stability. An SFS exhibits smaller random wavelength fluctuations and smaller more predictable wavelength versus temperature behavior. This makes it a easier for the FOG to achieve part per million wavelength stability than with the use of semiconductor light sources like laser diodes, LEDs, ELEDs and SLDs[1].

This paper presents a single pass backward signal SFS having a band width of 25.66nm operating at 1550nm wavelength using MP980 erbium doped fiber pumped at 980nm. The SFS used minimum number of fiber components. The SFS has been developed and packaged with Erbium doped fiber coiled to 35mm diameter and pigtails of other fiber components coiled to 60mm diameter. The SFS is package into a volume space of 100mm X100mm X15mm.

Basics Configurations Of SFS

There are five basic configurations of super fluorescent fibre source. These are Single – Pass Forward Signal(SPFS) SFS, Single – Pass Backward Signal(SPBS) SFS, Double – Pass Forward Signal (DPFS)SFS, Double –Pass Backward Signal (DPBS) SFS And Fibre Amplified Source (FAS)[2]. The SPBS configuration has been widely used in an FOG because of its simple configuration and stable performance [3]. In all other SFS configurations, accidental resonant lasing is a constant threat because optical components and FOG itself create feedback to the SFS. For this reason, this article presents solely on the SPBS super fluorescent fibre source configuration. Although various SFS configurations have been proposed and utilized [4], single pass backward signal proved most useful.

Single Pass Backward Signal (Spbs) Super Fluorescent Fibre Sources.

The figure 1 shows the configuration of SPBS super fluorescent fibre source.

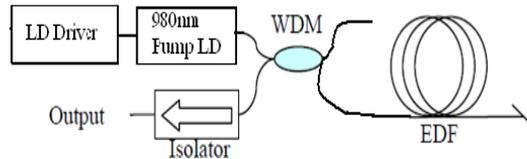


Fig.1: Single pass backward signal SFS configuration.

This configuration uses pigtailed pump laser diode, wavelength division multiplexing (WDM) coupler, erbium doped fibre (EDF) and fibre isolator.

The fluorescent rare earth doped fibre source (SFS) output is simply amplified spontaneous emission (ASE) generated by the inverted Er^{3+} ions ${}^4I_{13/2} - {}^4I_{15/2}$ transition as the three level laser system. These two states are separated by an energy difference ($\Delta E \approx 0.8\text{eV}$) at or below room temperature. Thus generated forward and backward ASEs in the erbium doped fibre, are confined by the EDF core in both the forward and backward directions, are amplified as they travel along the fibre. The SFS does not have a resonator; the spectral emission covers a broad spectral band because of stark splitting of erbium manifolds, typically a few tens of nanometers.

Measurements, Experimental Setup And Results

The mean wavelength of the pigtailed pump laser diode was measured using the Optical Spectrum Analyzer (OSA, ANDO model AQ6317C). The results of the measurements were shown in figure 2.

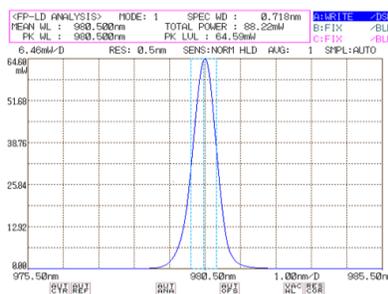


Fig.2: Mean wavelength of pump laser diode measured using Optical Spectrum Analyzer (OSA, ANDO model AQ6317C).

The erbium doped fibre procured from M/s OFS, USA has the Absorption and gain characteristics as shown in figure 3.

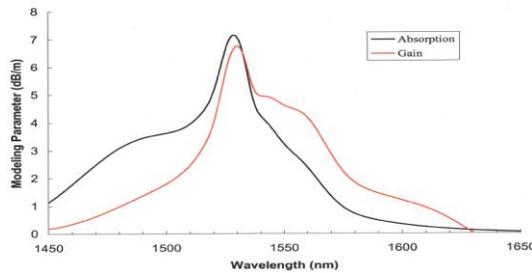


Fig. 3: Absorption and Gain characteristics of MP980 erbium doped fibre from M/s OFS, USA

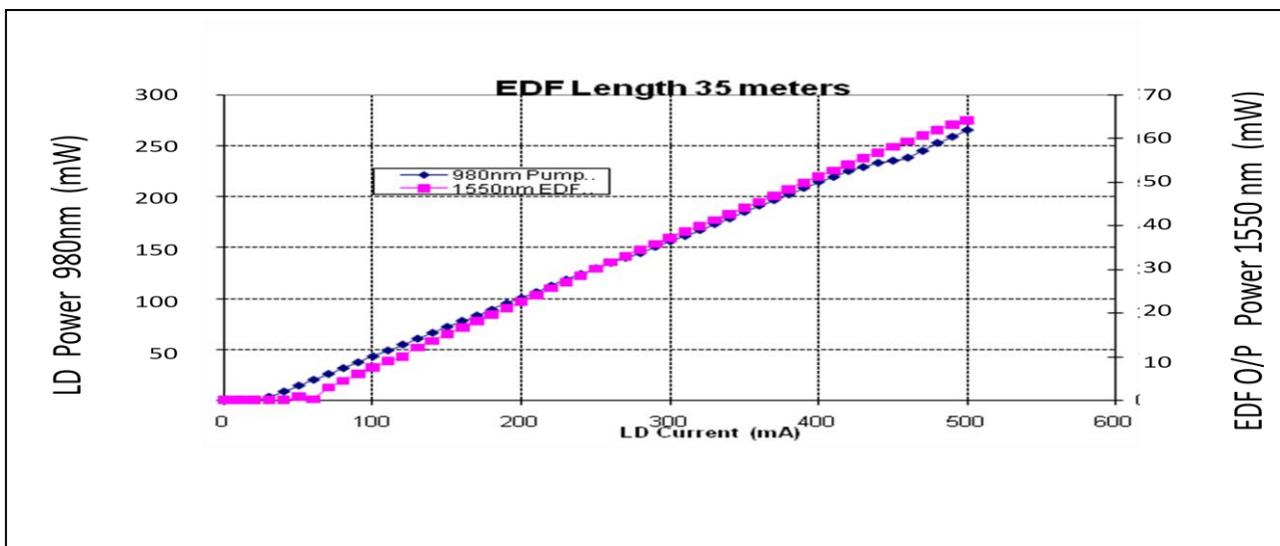


Fig. 4 : EDF output power as a function of input pump power at 980nm pump wavelength for EDF length of 35 meters.

The EDF had a 1.55µm core radius and numerical aperture of 0.223 with an erbium concentration of $10.62 \times 10^{24} \text{ m}^{-3}$

We measured ASE power as a function of pump powers in terms of pump current levels for erbium doped fibre of length 35 meters. The experimental results of these measurements are shown in figure 4.

The Experimental Setup Of SPBS Super Fluorescent Fibre Source.

The figure 5 shows the experimental setup of SPBS super fluorescent fibre source. In the experimental configuration, fibre pigtail of pump laser diode, fibre pigtails at 4 ports of WDM

coupler and input and output fibre pigtailed were coiled to a diameter of 60mm. The MP980 erbium doped fibre was coiled to the diameter of 35mm. This results the actual placement of SFS components in SFS package leading to physical size of the device.

Presently, the commercial FOGs weigh 200-250gms with a physical size of 100mmX100mmX50mm. The experimental configuration was realized with minimum optical components for SFS so that the weight is restricted to below 100 grams and the size to 100mmX100mmX15mm. We understand this weight and size of SFS attract considerations as an optical source for applications like FOG and other fibre optic sensors.

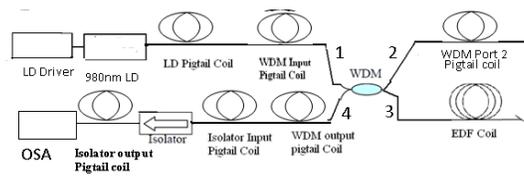


Fig.5: The experimental setup of SPBS super fluorescent fibre source

The experimental SPBS super fluorescent fibre source was implemented by using the procured components. The EDF is from M/s OFS, USA, (EDF-MP980, Lot No: MP2A4201), the 980nm pump laser diode is from M/s Powernetix, USA (9000 series, 5A), the WDM coupler (M/s Oplink Communications, Inc., USA, 980/1550 nm, FWDM59 Series), fiber isolator (M/s Oplink, 1550nm Single Stage Fiber Optical Isolator, 250 μ m, Item # OISS511111).

The MP980 erbium doped fibre was doped with erbium and co doped with aluminum. We made several measurements on different lengths of erbium doped fibre. At a length of 35 meters of EDF, the mean wavelength of backward signal ASE varied only less than one nano meter. This is the length we finalized for EDF in the SPBS super fluorescent fibre source. The 35 meters length EDF was longer than optimum for generating backward ASE power for a pump powers considered. This extended length served three main purposes. First, the length of EDF beyond optimal produced forward ASE absorption that reduced round – trip gain and prevented resonant lasing. Second, this EDF length guaranteed the absorption of more than 99% of the pump power across most of the pump band around 980nm. Finally, since the backward ASE signal was the desired output, reduction of the forward ASE signal was actually an advantage. Any photon emitted in the forward direction of the EDF was not available for emission in the backward direction EDF. One end of the EDF was polished at a 15^oangle to reduce reflections to an estimated level of -60dB.

The pigtailed pump laser diode, WDM coupler, Erbium doped fibre and fibre isolator were carefully spliced to a splice loss of less than 0.02dBm. The fibre isolator was introduced in the SPBS SFS to avoid the presence of pump wavelength in the backward ASE spectrum of fibre source.

A 980nm pigtailed laser diode was used as a pump source. The pump light was launched into the EDF through WDM fiber coupler. The pumped EDF produces ASE in both the forward and backward directions. The backward ASE is directed by a WDM coupler to a fiber pigtailed isolator. The spectrum of the source output was measured using an Optical Spectrum Analyzer (OSA).

In this work the super fluorescent output signal was measured in backward direction using Optical Spectrum Analyzer (OSA, ANDO model AQ6317C). The output power in the forward direction was about one nano watt.

The output amplified spontaneous emission from the SPBS super fluorescent fibre source (figure 2) was measured using Optical Spectrum Analyzer (OSA, ANDO model AQ6317C) at 30mA, 100mA, 200mA and 300mA. The results are shown in figure 6. The ASE power in the forward direction at port 2 of WDM coupler was about 1 nW. Since the source is SPBF SFS, the forward ASE output power and spectrum have hardly any relevance. This 1 nW power indicates that most of the forward ASE power in the EDF was converted to backward ASE which appeared at output port of fibre isolator.

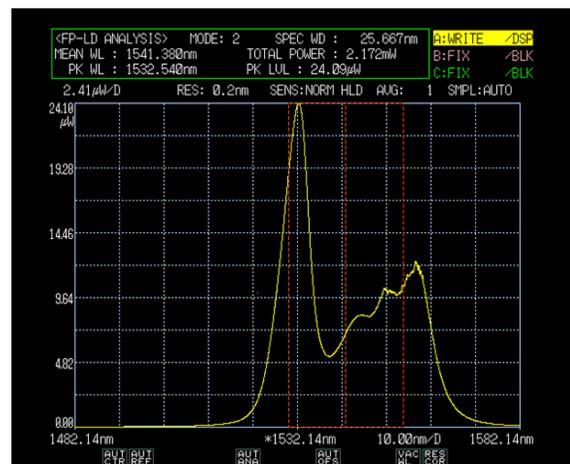


Fig. 6 The ASE spectrum of SPBS super fluorescent fibre source at 300mA LD input current or 37.2136mW input pump power measured using optical spectral analyses(OSA,ANDO model AQ6317C). The ASE output power is 2.172Mw and the spectral width is 25.667 nm.

CONCLUSIONS

In conclusion, this publication describes the single pass backward signal Superfluorescent fiber source having an output power of 2mW and a spectral width of 25.667nm at 980.5nm pump wave length. This represent a broad band width SFS over the previously developed fiber source having 12nm bandwidth at 1060nm for fiber optics gyroscope application[5]. For the first time to our knowledge the publication reports the SFS that was developed and packaged in a volume space of 100mm X 100mm X15mm using MP 980 erbium doped fiber coiled to the diameter of 35mm and pigtails of other SFS fiber components coiled to the diameter of 60mm for the fiber optics gyroscope. This SFS meets the basics requirements of single axis fiber optics gyroscope which requires a power of 1 to 2mW at 1550nm wavelength with a minimum spectral width of 10nm.

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