TUNABLE WIDEBAND WAVELENGTH CONVERTER IN A NONLINEAR FIBER FOR LIDAR APPLICATION

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Abstract: Remote sensing systems, such as Light Detection and Ranging (LIDAR), have benefited greatly from nonlinear sources capable of generating tunable mid-infrared wavelengths (300 – 500 nm). Much work has focused on increasing the energy output of these sources so as to improve the system's range. We present an approach that improves the range of a LIDAR system by employing nonlinear optical techniques in the receiver. In this paper, we demonstrate a novel tunable wideband wavelength conversion by using a dual-wavelength fiber laser in a highly nonlinear fiber. The widely tunable wavelength converter operates with only one external pump laser. By using this, a 180 nm wavelength conversion that range from 1460 nm to 1640 nm has been achieved. The relation between wavelength conversion efficiency and the converted signals indicates that the conversion efficiency reached a peak at about -20 dBm near the signal wavelength. The wavelength conversion efficiency has a variation smaller than 3dB over a 70 nm range.

INTRODUCTION

Optical LIDAR (Light Detection and Ranging) is widely used to measure properties of scattered light to acquire information about a distance target. LIDAR is used in a number of applications such as traffic enforcement [Fisher,1992], atmospheric science [Eberhard and Schotland, 1980], environment monitoring [Utkin, et. al., 2002], industrial testing, target detection [Pellen, et. al., 2001], imaging [Weibring, et. al., 2001] and range finding [Myneni, et. al. 2001.]. In remote sensing technology, LIDAR has some unique characteristics that make it an attractive and useful technology. Currently, much work has focused on increasing the energy output of these sources so as to improve the system's range. In this work, we present an approach that improves the range of a LIDAR system by employing optical technique in the receiver.

LIDARs, radars and sonar are active detection devices. They are used to measure the angular position, the range, the velocity and even the longitudinal shape (the profile) of targets [Chevalier, 2002] [Darricau, 1994] [Skolnik, 1990]. All these detection devices are based on the same principle, their performances depending on the nature (electromagnetic and acoustic) and the frequency domain (from radio to optical frequencies) of the emitted and received wave. Basically, the main interest of LIDAR is its short operating wavelength around 3 to 5 um range, which not allow to the eye safe region. An alternative to detection in the 3 to 5 um range is to frequency convert return signal to the near IR [Watson, 1990] [Midwinter, 1968]. Detection technology in the near IR can have a low noise equivalent power and have high speed. Therefore, in this paper, we report a tunable wideband wavelength conversion detector around IR region by using a dual-wavelength fiber laser in a highly nonlinear fiber for LIDAR systems

EXPERIMENTAL SETUP

Figure 1 shows the proposed ring cavity experimental setup which uses 11 m of Metrogain erbium doped fiber (EDF) (DL1500L, Fibercore Ltd.) as a medium source for amplified spontaneous emission (ASE) source as well as the gain medium. The EDF with Erbium ion concentration of 900 ppm has an absorption of 18.06 dB/m and 11.3 dB/m at 1530 nm and 980 nm respectively. In this experimental setup, we demonstrate a high-power erbium-doped fiber amplifier (EDFA) pumped with 980 nm wavelength light from two semiconductor laser diodes. Light outputs from the two 980 nm pump laser diode (LD) modules are 215 mW each. They are combined using a polarization beam combiner (PBC). The output is then connected to the ring cavity via a 980 /1550 nm wavelength division multiplexer (WDM) coupler and directed into the ring cavity. The combined pump power that travels in a clockwise direction is then absorbed by the EDF. The erbium ions will be excited and will then reemit an optical output at 1550nm in the form of ASE. From the measurement, the average ASE output power is 20.2 dBm with output emission in the C-band. The emission of C-band ASE output from the EDF will then travel through a 1x24 Arrayed Waveguide (AWG) which will be sliced into 24 individual output wavelengths coming from 24 channels. The 1x24 channels output covers a wavelength range of between 1530.473nm to 1548.613nm with an interchannel spacing of 100GHz. The channels are then connected to the variable optical coupler via a PC (polarization controller) as illustrated in Figure 1. A PC is used to optimize the matching of the polarization state of pump and signal powers. The dual-wavelength fiber laser, which is generated at the output port of the 2x1 variable optical coupler, then travels in the clockwise direction. This dual-wavelength output is then combined with the LIDAR return output using a 50/50 fused coupler. 1480 nm to 1640 nm of laser light to simulate the LIDAR return is generated from tunable laser source (TLS). The used output power of the TLS is 3.0 dBm. The LIDAR return and this dual-wavelength output will then be amplified by the EDFA and continue to travel towards the HNLF, where the interaction of the waves will result in the Four Wave Mixing (FWM) effect.

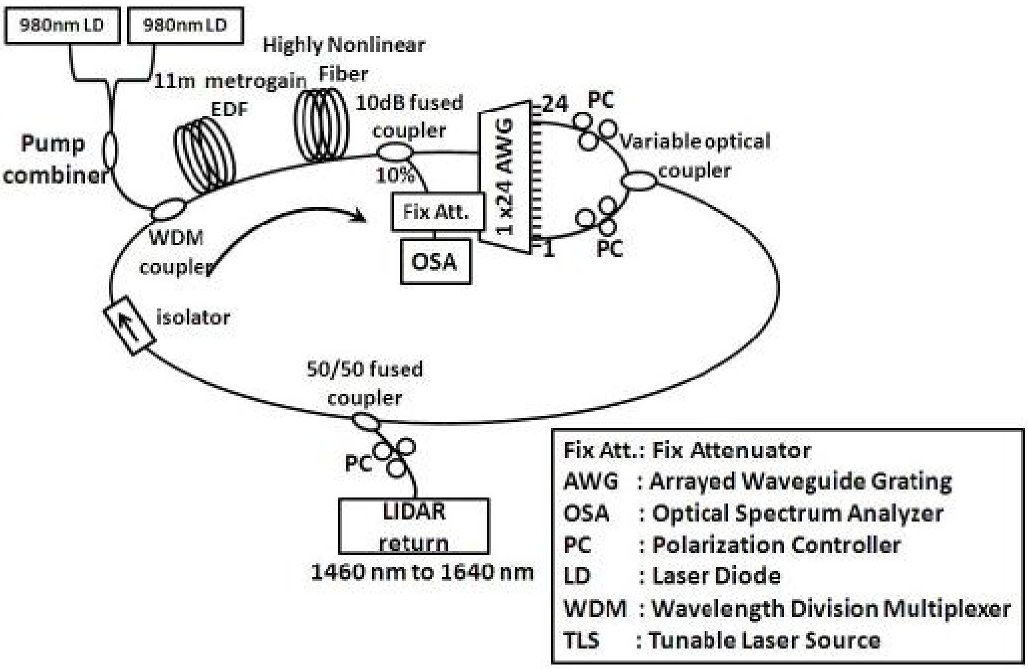

Figure 1: Schematic diagram for LIDAR system in a highly nonlinear fiber using dual wavelengths fiber laser incorporating AWG as a tuning element.

RESULTS AND DISCUSSION

In this experiment, the generated triple wavelength is a combination of the dual-wavelength fiber laser and LIDAR return that is shown in Figure 2 where it is marked as pump 1, pump 2 and signal (backscattering signal – LIDAR return), respectively. Due to the beating of pump 1, signal and pump 2, they experience an index-modulated grating within the highly nonlinear fiber. This process generates two sidebands C2 (a conjugate of signal) and S2 (a replica of signal) around pump 1 and pump 2, spaced by Δf and having the states of polarization of signal. This process occurred due to the nonlinear effect which is the FWM effect. In our experiment, the intensities of C2 and S2 are measured for every different wavelength of pump 2 over the entire wavelength range of between 1460 nm to 1640 nm with 100GHz of detuning depending on the spacing of the pump 1 and pump 2.

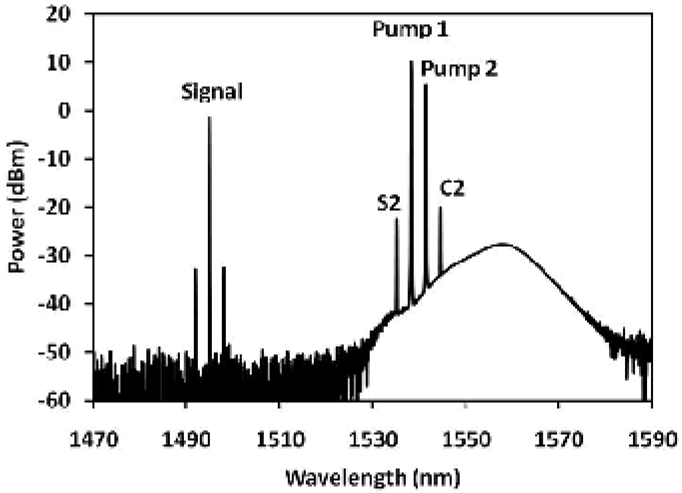

Figure 2: The typical output spectra at pump 1, signal and pump 2, as well as their converted signals (sideband fields) C2 and S2 when wavelength of pump 1, signal and pump 2 are 1538.3 nm, 1541.5 nm and 1530 nm.

To investigate the tunability of the proposed LIDAR detection, the input powers of pump 1 and pump 2 are fixed at 10.3 dBm and 5dBm, at wavelengths of 1538.3 nm and 1541.5 nm, respectively. The backscattering signal wavelength (signal) is then changed from 1460 nm to 1640 nm by using the different LIDAR wavelength transmitter, but in this experiment, the different wavelength is changed by using TLS. The converted signals C2 of LIDAR return is observed at 1548 nm. Therefore, the converted signal of the LIDAR return is focus at 1550 nm so as to take advantage of well developed telecommunications detector and system. Figure 4 (a), (b) and (c) show the output spectra of signal at different wavelength values. Results presented below clearly show that by using the proposed configuration the ultra-broadband tunable wavelength converter with a tunable range of over 180 nm can be achieved.

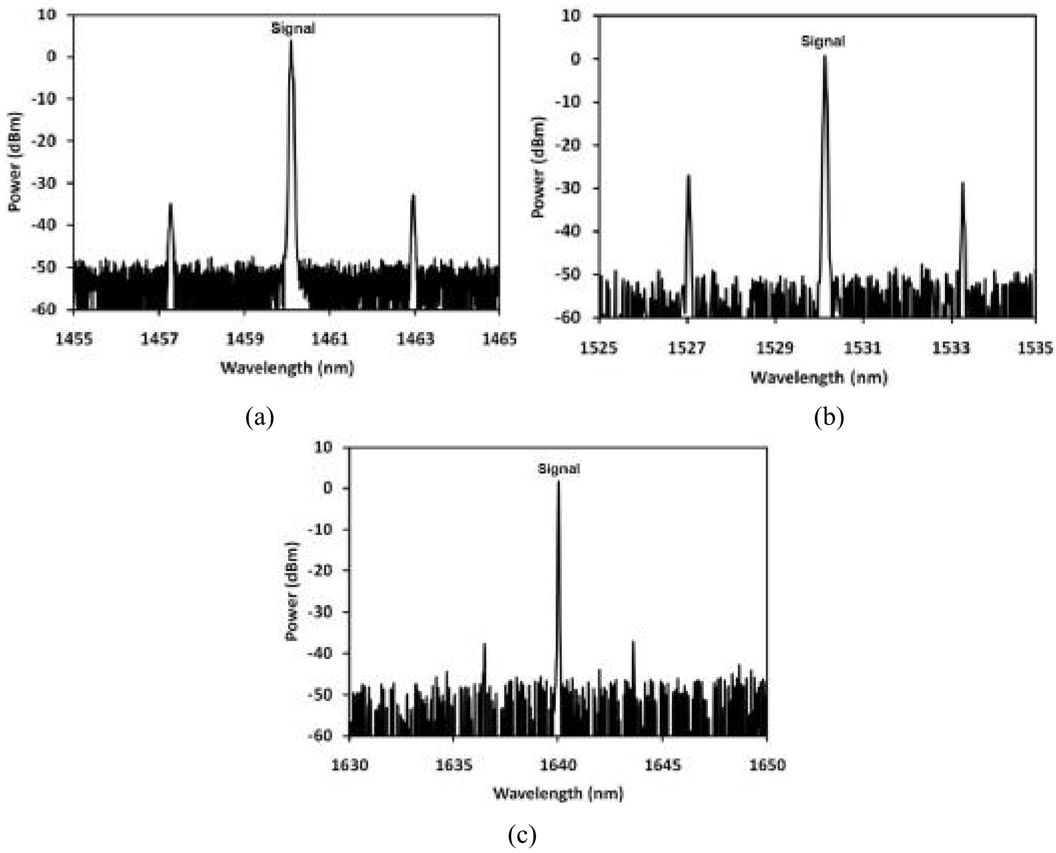

Figure 4 The output spectra of signal when the wavelength of Pump 1 and Pump 2 are 1538.3 nm and 1541.5 nm; (a) Signal is 1460 nm (b) Signal is 1530.2 nm (c) Signal is 1640 nm.

The efficiency of the proposed configuration, characterization of conversion efficiency and the OSNR are measured from results shown in Figure 3. The conversion efficiency is obtained by changing the wavelength of signal while fixing the input powers of pump1 of 10.3 dBm at 1538.3 nm and pump 2 of 5dBm at 1541.5 nm. During the measurement, the input pump power of signal is about 3 dBm and its wavelength changes from 1460 nm to 1640 nm. The maximum power of the converted wavelength is obtained by adjusting the three PCs as shown in Figure 1 for each measurement. When the polarization state of either Pump 1 or Pump 2 is changed, the output power of both S2 and C2 changes significantly. When the polarization state of pump 1 and pump 2 are both aligned and linear, the output powers of the converted signals are at maximum. Keeping this situation and by adjust the PC and signal a maximum output is achieved. The conversion efficiency is calculated as a ratio of the power of the converted signal C2 to the input signal. Results indicate that the FWM conversion efficiency is approximately -20 dB within 70 nm tuning range with 3.9dB fluctuation. However, as the converted wavelength is tuned over 70 nm tuning range, the conversion efficiency drops rapidly due to the effect of chromatic dispersion in the fiber as stated by K. Inoue [13]. The figure also shows the optical signal to noise ratio (OSNR) versus wavelength that shows the OSNR being maintained above 30 dB at around 70 nm tuning range. The OSNR is stable within wavelengths of 1470 nm to 1550 nm, and drops rapidly at longer wavelengths. This indicates that the data signal within this region can be converted efficiently. However, the application of conversion can still be realized at longer wavelengths with a higher degree of degradation. This can be improved by using higher pump and signal powers which cannot be realized at this moment due to the limitations of the high power laser.

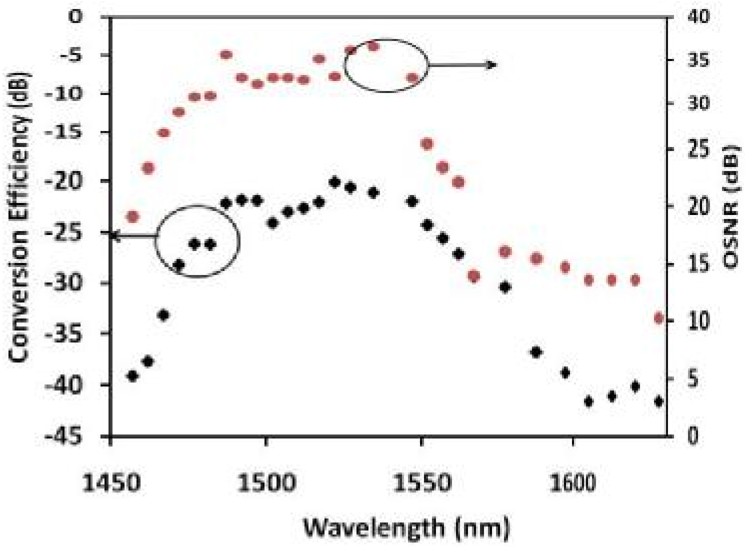

Figure 5 The conversion efficiency and the optical signal to noise ratio against the converted wavelength.

CONCLUSIONS

In conclusion, the tunability of LIDAR detection wavelength by dual-wavelength fiber laser and TLS which is acts as tunable receiver in a highly nonlinear fiber that operates has been successfully demonstrated. Using the proposed method, a wide band wavelength conversion has been achieved with a range of 1460 nm to 1640 nm, giving a bandwidth of 180 nm. A conversion efficiency of – 20 dB is achieved within a 70 nm tuning range within a 3.9 dB fluctuation. An optical signal to noise ratio of 30 dB is also realized within the same tuning range.

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