Gain, Noise Figure and Efficiency Characteristics of an L-Band Erbium Doped Fiber Amplifier

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ABSTRACT

In this work, the construction of a single stage L-band erbium-doped fiber amplifier which incorporates a short 5.1 m erbium doped fiber coil is described. Gain and noise figure measurements as a function of forward, backward and counter-propagating CW 1480 nm pumping schemes at different pump power levels are presented. Further, the Erbium Doped Fiber Amplifier (EDFA) power conversion efficiency (PCE) calculations as a function of pump power are provided.

Keywords: Erbium Doped Fiber Amplifier (EDFA), Gain, Noise Figure, Power Conversion Efficiency, Wavelength Division Multiplexers (WDMs)

1. INTRODUCTION

Erbium Doped Fiber Amplifiers (EDFAs) are widely incorporated into fiber-optic networks to boost the transmitted signals and to overcome insertion losses due to optical components inserted into the fiber optic communication link. Consequently, EDFAs extend the fiber-optic telecommunication link range by amplifying the transmitted signals. A single EDFA may be used to simultaneously amplify many channels when used with wavelength division multiplexers (WDMs).

Silica-based erbium-doped optical fibers are typically doped with germanium, aluminum and sometimes with lanthanum and phosphorus. Higher aluminum concentration results in a flatten gain shape in the L-band and reduces erbium pairing effects (Wang and Andrejco, 2005).
In comparison with C-band EDFAs (from approximately 1525 nm to 1565 nm), L-band EDFAs (from approximately 1571 nm to 1603 nm) have flatter gain curve and thus the design of the gain flattening filter used in the L-band EDFA is simpler (Flood, 2000a; Flood, 2000b; Yu-Hang, Yu-Bin, Tian-Shu, & Xue-Mei, 2006). Additionally, L-band EDFAs extend the transmission window for higher capacity wavelength division multiplexing systems. C and L band EDFAs can be operated in parallel in a communication network and thus increase the network bandwidth to more than 80 nm (Flood, 2000b; Yu-Hang, Yu-Bin, Tian-Shu, & Xue-Mei, 2006; Zhang, Du, Xi, & Zhao, 2006; Becker, Olsson, & Simpson, 1999).

Here, it is worth noting that optical fiber based amplifiers can be constructed using other rare earth doped fibers such as neodymium, ytterbium, thulium and praseodymium. Neodymium or ytterbium optical amplifiers which have many industrial applications in material processing are used for amplifying the output power of 1 µm lasers. Whereas thulium based fiber amplifiers are used for amplification in the telecom S-band between 1460–1530 nm and also around 1650 nm; and praseodymium fiber amplifiers are used for amplification in the 1300 nm telecom window (http://www.rp-photonics.com/fiber_amplifiers.html; Urquhart, 2011).

In comparison with Neodymium, ytterbium, thulium and praseodymium based fiber amplifiers, erbium-doped fiber amplifiers have lower noise figure, large dynamic range, high pump to signal transfer efficiency, wider spectral band amplification and provide a cost effective solution for long-haul communication networks (Becker, Olsson, & Simpson, 1999; Urquhart, 2011).

In this paper, the construction of a single stage L-Band EDFA which incorporates a novel erbium-doped fiber design is described. Signal gain and noise figure measurements as a function of wavelength collected at different forward and backward pump powers are presented. Finally, results obtained for the L-Band EDFA power conversion efficiency at different backward pump power settings are discussed.

2. L-BAND EDFA MEASUREMENT SYSTEM

The single coil L-band EDFA constructed for investigating the gain and noise figure characteristics of Er³⁺-doped fiber coil as function of 1480 nm pumping schemes and power levels is shown schematically in Figure 1. The Er³⁺-doped fiber coil key specifications are listed in Table 1.

Laser beams emitted from 38 distributed feedback (DFB) lasers operating in the L-band (1571.3 nm to 1603.3 nm) and spaced spectrally 0.8 nm from each other are launched into a 1xN tree coupler. The output end of the tree coupler is launched into an isolator, a variable optical attenuator (VOA) and 1x2 optical switch. The VOA is inserted into the optical bath to attenuate the laser beam launched into the EDFA and to control the power levels launched into the EDFA. Whereas, the 1x2 optical switch is used to switch between the EDFA signal and the measurement system reference channel. Laser beams emerging from the VOA are launched into a polarization scrambler which is used to generate a pseudo-random polarization output beams. The output of the polarization scrambler is considered to be the point at which different wavelengths are launched into the constructed EDFA.

The EDFA coil, 5.51 m in length, is pumped by a forward (P1) and backward (P2) 1480 nm laser pumps which are coupled to the Er-coil via WDM couplers. An isolator and 1480 nm cutoff filter are inserted into the optical path to prevent the 1480 nm excitation wavelength from reaching the optical spectrum analyzer (OSA).

Before collecting any measurements the laser pumps output power was calibrated against the pumps drive currents. Figure 2 depicts the 1480 nm laser pump drive currents as a function of the measured laser output power.
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