Compact and wide-band bismuth-based erbium-doped fibre amplifier based on two-stage and double-pass approaches

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Abstract: In this study, a wide-band erbium-doped fibre amplifier (EDFA) operating in both C- and L-band wavelength regions is demonstrated based on two-stage and double-pass approaches. The amplifier employs two pieces of 21 and 46 cm long bismuth-based EDFs (Bi-EDFs) optimised for C- and L-band operations, respectively, which are pumped by 1480 nm laser diode and its performances are investigated in both parallel and linear configurations. Wide-band operation is achieved in both configurations that covers from 1525 to 1620 nm. Compared with the linear Bi-EDFA, the parallel Bi-EDFA provides a higher attainable gain especially for small input signal. At input signal power of $-30$ dBm, the average gains of the parallel Bi-EDFA are obtained at approximately $20$ dB with gain variation of $\pm 2.5$ dB within the wavelength region from 1530 to 1605 nm. At the input signal power of $0$ dBm, the average gains of approximately $10$ dB with a gain variation of $\pm 2$ dB within 1540 to 1620 nm region are obtained by both parallel and linear Bi-EDFAs. The noise figures for both configurations are maintained below $10$ dB in the wavelength region from 1535 to 1620 nm. The noise figures are mainly because of spurious reflection in the cavity and high reflection of amplified spontaneous emission (ASE) from the end face.

1 Introduction

The tremendous growth of the internet and data traffic has created an enormous demand for transmission bandwidth of dense wavelength-division-multiplexed (DWDM) optical communication systems. This has spurred the development of compact fibre amplifiers with a very short gain medium length [1–3]. To compensate for the short gain medium length, the active fibre needs to be doped with very high erbium ion concentration. However, the consequence of using high concentration erbium ion is a pair-induced quenching effect, which potentially reduces the pump power conversion efficiency and increase the noise figure for an erbium-doped fibre amplifier (EDFA) [4, 5]. In order to increase the limit of erbium-doping concentration while maintaining the transmission capacity, several techniques such as using different glass hosts like tellurite [6, 7], bismuthate [8] and co-doping the EDF with ytterbium [9, 10] have been proposed and demonstrated. Another method uses phosphate-modified tellurite glass in which the phosphate component allows higher doping levels, whereas the tellurite part maintains the bandwidth of a waveguide amplifier [11].

Recently, bismuth-based optical fibres have gained increasing interest for fibre laser and optical amplifier applications [12–14]. Bismuthate glass host has the ability to be highly doped with erbium ions to realise an ultra-compact fibre lasers and amplifiers. The Bi-EDF also has other excellent features such as wideband emission spectrum, easy refractive index control and high reliability. To date, many approaches have been used to improve the gain of an EDFA such as using double-pass and two-stage configurations [5, 15]. In the double-pass configuration, the same gain can be achieved with less pump power and a shorter length EDF. More recently, an optical gain improvement was achieved by inserting an optical isolator and filter within the amplifier length to stop the build-up of the backward amplified spontaneous emission [16]. In this paper, a compact, wide-band and flat-gain EDFA is demonstrated using a Bi-EDF as a gain medium in conjunction with two-stage double-pass configuration. The performance of the amplifier is investigated in two different architectures; parallel and linear configurations. It is found that the latter configuration provides a higher attainable gain of about $3–4$ dB ranging from 1525 to 1620 nm. The noise figures for both configurations are maintained below $10$ dB in wavelength region from 1535 to 1620 nm.

2 Experiment

Figs. 1a and b show the proposed compact two-stage double-pass Bi-EDFA in parallel and linear architectures, respectively. The components used are similar in both configurations where 21 and 46 cm long Bi-EDFs are used in the first and second stages to provide C- and L-band...