Optimal Design of Double-Clad Ytterbium-Doped Fiber Amplifiers Operating at 1020-1070 nm

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Abstract: We experimentally demonstrated a double-clad ytterbium-doped fiber amplifier operating at 1020 to 1070 nm. The measured gain is 27 dB and the gain variation is less than 2 dB.

Keywords: fiber amplifier, ytterbium-doped

1. INTRODUCTION

Ytterbium doped fibers (YDFs) have a broad emission range of around 1 to 1.1 μm which find applications in spectroscopy, frequency conversion and medical treatments. YDFs with double clad fiber (DCF) can provide high efficiency, compactness, and high reliability for lasers and amplifiers [1-3]. The ytterbium transition is three-level for short wavelength (<1040 nm). In general, three-level transitions are not favorable for cladding pumped operations because of significant reabsorption of signal in weakly pumped regions. Therefore, YDF amplifiers for short wavelength can be obtained by using single-clad fiber (SCF) instead of DCF. On the other hand, the ytterbium transition is predominately four-level for long wavelength (>1040 nm), which means the gain is proportional to the overall upper-state population and the reabsorption is weak [3,4]. Therefore, YDF amplifiers for long wavelength can be achieved by using DCF easily instead of SCF. As a result, it is difficult to design YDF amplifiers with a given gain and low gain variation which operates in the 1020-1070 nm range by using only either SCF or DCF YDFs. If we only use SCF, the amplifier configuration is complex, the efficiency is low, and the gain variation may be large [3]. In addition, amplifiers using DCF alone cannot cover the entire 1020-1070 nm range.

In this paper, we proposed and demonstrated an optimal design of a YDF amplifier in the 1020-1070 nm range by using both SCF and DCF.

2. DESIGN THE CONFIGURATION

Figure 1 shows the schematic of a YDF amplifier which utilizes both SCF and DCF YDFs. The amplifier

consists of two parts: a pre-amplifier stage and a booster stage. SCF is used in the pre-amplifier stage for the short wavelength range while DCF is used in the booster stage for the long wavelength range.

Fig.1. Configuration of the Amplifier

For the SCF YDF in the pre-amplifier stage, a 975 nm pump is used because 915 nm pumps have large amplified stimulated emission (ASE) noise at 975 nm which limits the gain available at the long wavelengths [3]. The pump power is 600 mW. The length of SCF YDF is 1.2 m which allows the gain at 1020 nm to reach above 27 dB.

For the booster stage, since the peak absorption of the DCF is 915 nm, two multimode pump diodes are used. The total maximum pump power is 16 W. A combiner is used for cladding pumping. The fiber length is 2.2 m, which is chosen carefully because the re-absorption at 1020 nm is related to the fiber length. The gain decreases as the length increases. On the other hand, the gain at 1070 nm drops if the fiber length is not long enough.

3. SIMULATION AND EXPERIMENTAL RESULTS

Figure 2 shows the simulated gain profiles of amplifiers by using only SCF and only DCF. It is found that the peak gain of SCF is around 1030 nm, while the peak

gain of DCF is around 1070 nm. In addition, only limited operation range can be obtained by using either SCF or DCF alone. Using different pump power or fiber length can modify the gain curves, however, the required operation range cannot be obtained.

Fig.2. Simulated gain spectra of SCF, DCF

Figure 3 shows the simulated results for both DCF and SCF and experimental measured gain points respectively. Simulation results show that the proposed amplifier design can give a 28 dB gain with around ± 1.5 dB gain variation in the wavelength range of 1020-1070 nm. The solid triangles in Fig. 3 represent the experimental measured gain spectrum. Although there are only limited number of measurements because of the limited available signal sources, the measured gain profile matches with the simulated results. The measured gain is 27 dB with a gain variation less than 1.83 dB.

Fig. 3. Simulated and experimental gain spectra

4. CONCLUSIONS

We proposed and demonstrated a ytterbium-doped fiber amplifier operating at 1020 to 1070 nm. Two-stage amplification utilizing both single clad and double clad

ytterbium-doped fiber are used. The amplifier gain is 27 dB with a gain variation of less than 2 dB.

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