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Dual-wavelength nano-engineered Thulium-doped fiber laser via bending of singlemode-multimode-singlemode fiber structure

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ABSTRACT

In this paper, a dual-wavelength fiber laser (DWFL) using nano-engineered Thulium-doped fiber as a gain medium with a bent singlemode-multimode-singlemode fiber structure (SMS) is demonstrated. The SMS structure is packaged systematically using Cr-39 polymer plates to provide linear bending via applied load. Experimental results have proved that the bent SMS is capable to provide highly effective wavelength filter and wavelengths stabilizer by balancing the net cavity gain between the two wavelengths. The DWFL provides very narrow spacing of 0.9 nm, narrow 3 dB spectral linewidth of ~0.07 nm and SNR of ~42 dB. Based on stability test, very small mode hopping is observed at the two wavelengths having deviations of ±0 nm and ±0.04 nm respectively. In conjunction, the DWFL provides very stable relative wavelength spacing with a deviation of ±0.04 nm.

1. Introduction

Recently, dual-wavelength fiber laser (DWFL) has been under extensive development due to its usefulness in many applications. For instance, the change of dual-wavelength spacing and wavelengths shifting can be used to probe the change in temperature and strain as demonstrated by Liu [1]. Whereas, in differential absorption measurements, one wavelength of the DWFL is used as a reference and other as a probe [2]. DWFL also finds applications in generation of soliton pulses [3], generation of microwave [4] and THz signals via the optical beatings [5]. In conjunction to this, the development of single-wavelength and multi-wavelengths lasers at the 2 μm region is even more desirable due to its eye-safe feature and bio-medical friendly [6,7] owing to its strong water absorption at this wavelength region. Lately, Thulium-doped fiber have drawn many researchers for developing fiber lasers operating at 1.9–2.1 μm due to its capability to produce high efficiency, high output power, and retina safe lasers for applications such as remote sensing and biomedical [8,9]. To date, many different glass host materials have been used to fabricate Tm^{3+}-doped optical fibers, including silica and nonsilica glass fibers such as germanate- and tellurite-based types [10,11].

In this paper, a nano-engineered Thulium-doped fiber (NTDF) will be used as gain medium to develop dual-wavelength fiber laser at 1.9 μm region via the bending of singlemode-multimode-singlemode fiber structure (SMS). The NTDF provides high efficiency 1.9 μm laser with low pump threshold at pump wavelength of 1552 nm [12]. Moreover, the main glass network of NTDF is silicon dioxide (SiO_2) which improves in mechanical strength and shows better compatibility with silica fiber than any other multi-component glass fibers. This allows the ease and robust fusion spliced between the NTDF with active fibers and the standard passive silica fibers. However, the fiber is developed to be having large core size of 13.43 μm. When the fiber is spliced with SMF-28 fibers an unstable multi-wavelength lasing is generated associated with the Mach-Zehnder interferometer effect.

To complement this issue, the SMS is utilized to filter the undesirable wavelengths and select only two narrow spaced dual-wavelengths for lasing. In the past, SMS has been investigated and proposed as a basis for a number of novel fiber-optic devices [13,14]. Optical devices based on SMS offers all-fiber solutions for optical communications and optical sensing with the advantages of ease of packaging and interconnection to other fiber optic components [14]. Recently, SMS structure along with fiber Bragg

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grating (FBG) [15] and multimode fiber (MMF) twined on a polarization controller (PC) were used to generate dual-wavelength fiber laser [16]. In our previous work, we have demonstrated the use of packaged SMS using Cr-39 plastic polymer plates for load sensing which provides linear and reliable sensitivity [17]. Here, similarly a SMS is systematically packaged and arrange in cantilever structure, but however to generate stable dual-wavelength NTDF laser via bending of the MMF when load is applied on the cantilever. The bending of the SMS balances the net cavity gain between the two oscillating wavelengths where mode competition can be suppressed and laser stability can be achieved.

2. SMS packaging method

The transmission characteristic of the SMS is highly depends on the multimode fiber (MMF) length, core size and its bending condition as mentioned in [18]. Therefore, in order to minimize highly non-linear spectral change, a custom made SMS packaging structure is built to assists on linear and flexible bending when load is applied on the package. The packaging method is illustrated in Fig. 1(a)–(d). A MMF having a step index profile, core size of 105 μm and length of 7.9 cm is spliced between two SMF-28 fibers to build the SMS. On the other hand, an elastic and flexible Cr-39 plastic polymer plate with a length of 17.5 cm, width of 4 cm and thickness of 0.05 cm is used to package the SMS. A pen marker is used to foot print the line on the plate for the SMS fiber to be laid as shown in Fig. 1(a). Tapes are used to fix the SMS fiber with the center of MMF coincides with that of the plate. To avoid unnecessary displacement during the whole packaging process, the plate is securely placed on a flat and solid surface. In Fig. 1(b), small amount of water-proof epoxy is spread thinly and evenly over the fiber using a mini spatula to permanently attach the fiber to the plate. Subsequently, a blow dryer is used to dry and harden

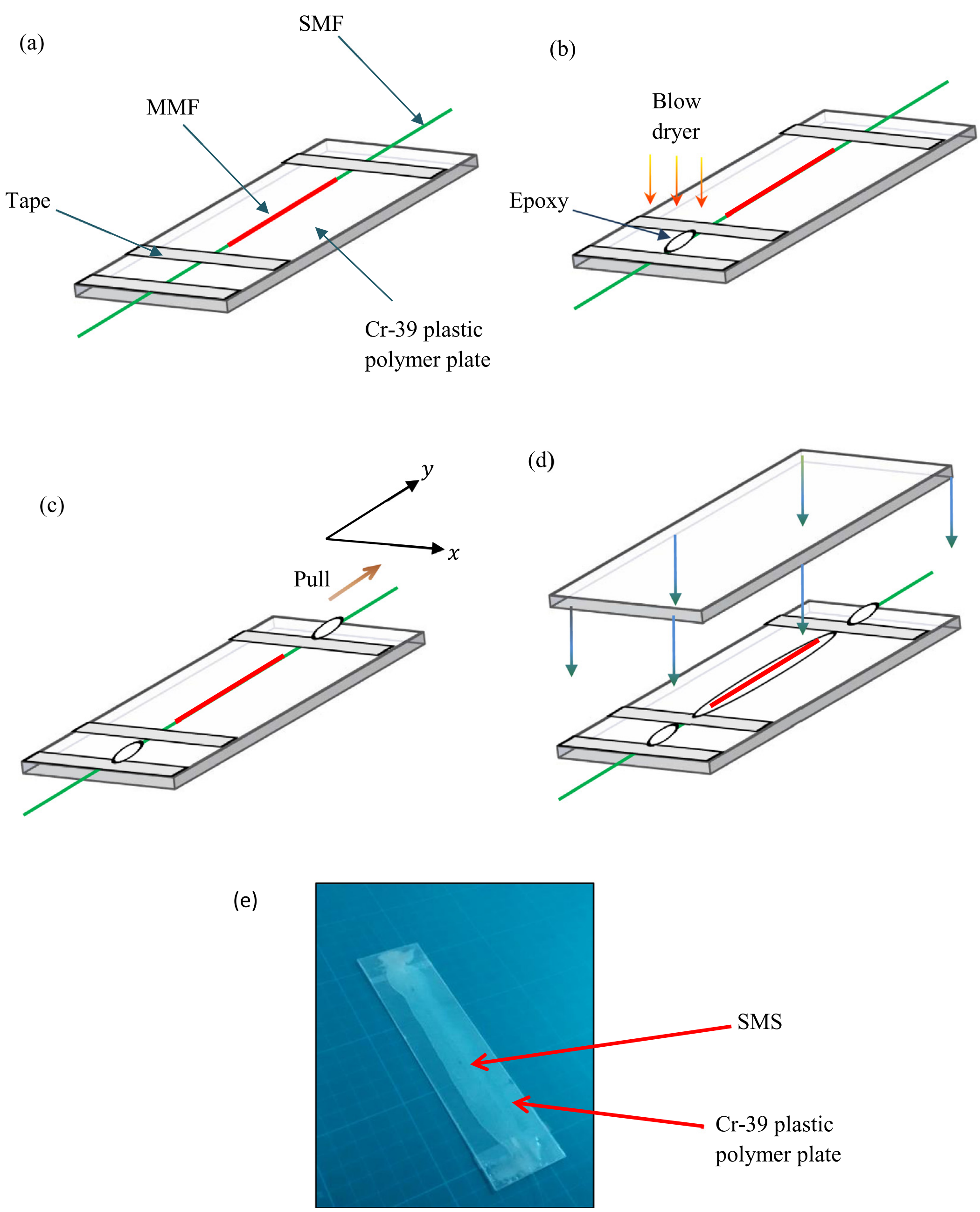

Fig. 1. Packaging of SMS structure.