Single-frequency single-polarization fiber ring laser at 1053 nm

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Abstract – We demonstrated experimentally a stable single-frequency single-polarization fiber ring laser at 1053 nm. The measured linewidth is less than 10 kHz.

Introduction

Single frequency fiber lasers can be used for many applications, such as coherent communications, wavelength division multiplexing (WDM) system, high-resolution atomic and molecular spectroscopy and laser interferometer gravitational wave detector [1-4]. In many of these applications, narrow linewidth and linearly polarized output from the lasers are essential [5]. Stable single frequency operation of a fiber laser is difficult to realize because of mode competition among different longitudinal modes and polarization modes which result in the mode hopping. In this paper, we proposed and demonstrated experimentally a single-frequency single-polarization Ytterbium doped fiber ring laser operating at 1053 nm without mode hopping.

Experiment Setup

Figure 1 shows the schematic of the proposed single-frequency single-polarization fiber ring laser at 1053 nm. A 10-m polarization maintaining (PM) Yb3+ doped fibers (YDF) is used as the gain medium of the laser. For narrow linewidth operation, a 2-m un-pumped PM YDF is used as the saturable absorber (SA). A 500 mW pump laser operating at 975nm is used as the pump source for the Ytterbium doped fiber. In addition to the SA, two cascaded FBGs are used to provide the filtering function. The reflection coefficients of FBG1 (r1) and FBG2 (r2) are set at 0.8. The length between the two FBGs (L) is 0.01 m. The total cavity length is ~15 m corresponding to a mode spacing of ~13 MHz.

At wavelength of 1053 nm, a grating with 0.2 nm is about 54 GHz wide. Therefore a single FBG would not be enough to isolate a single cavity mode. Cascading two FBGs will result in etalon effect thus enhance the filtering action required for the fibre laser [3]. The reflection coefficient of two cascaded FBGs are given by [4]

\[ R = r_1 + r_2 + 2(r_1 r_2)^{1/2} \cos \phi \]  

where \( \cos \phi = 4mL / \lambda \). Figure 2 shows the reflection caused by the cascaded FBG filters. The cascaded filters can restrict the number of modes in the ring laser and suppress mode competition.

To realize single mode operation, further filtering is achieved by using an un-pumped YDF as a saturable absorber. The unpumped YDF can act as a narrow bandpass filter [1-2]. Since the bandwidth of the YDF decreases when the length of the fiber increases, to optimize the filtering effect as well as balancing the gain in the cavity, an optimum length of the SA and the pump power should be selected [6]. Furthermore, if non-PM YDF is used, the polarization variation will result in SHB [5]. Note that the pump power will also affect the bandwidth of the filter [5]. To eliminate the effect of polarization, PM fiber is used for the cavity and the SA. Although alternative methods to suppress SHB by using a polarization controller or using a PM SA together with a polarizer have been proposed, these methods can only provide short term stability because the birefringence of non-PM fibers can be easily perturbed by changes in ambient conditions.

Experimental Results

Figure 3 shows the RF spectrum measured by using an electrical spectrum analysis (ESA). The results confirmed that only one single mode exists within the cavity. This laser is under single frequency operation. The optimised pump power is 100 mW. If the pump power is increased, mode competition between the two polarization modes will occur.
Figure 4 shows the spectrum measured using an optical spectrum analyzer (OSA), which is measured after a 1:99 taper (the 1% output). The center wavelength is about 1053.78 nm and the total output power is about 10 dBm. Figure 5 shows the self-heterodyne measurement of the linewidth. By considering the full width at −20 dB, the linewidth of the laser is estimated to be less than 10 kHz.

Conclusions

We have demonstrated experimentally a stable single-frequency single-polarization fiber ring laser operating at 1053 nm. The measured linewidth is less than 10 kHz.

References