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A ring-type polarization-maintaining λ/4-shifted distributed feedback fiber laser pumped by a 0.98 μm laser diode

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Abstract: We report a ring-type polarization-maintaining λ/4-shifted DFB fiber laser with 0.98 μm pumping. Such output characteristics as output power, linewidth, and relative intensity noise have been greatly improved.

Introduction

λ/4-shifted distributed feedback (DFB) fiber lasers [1], [2] are attractive for dense wavelength-division multiplexing (WDM) systems and sensing applications due to their robust single-mode operation, narrow linewidth, fiber compatibility, and ease of fabrication. A reduction in the threshold and an improvement in the linewidth have been reported by employing λ/4-shifted DFB fiber lasers with a ring configuration [3]. However this ring-type λ/4-shifted DFB Er-doped fiber laser suffers from self-pulsation, which is caused by ion pairs in a highly Er-doped fiber acting as saturable absorbers [4].

We have recently reported a ring-type polarization-maintaining λ/4-shifted DFB fiber laser using 1.48 μm pumping [5], in which the self-pulsation can be suppressed by adopting a ring configuration and co-doping erbium fiber with aluminum [6]. In addition, with the ring type configuration, we were able to achieve a narrow linewidth and low relative intensity noise (RIN) characteristics.

In this paper, we report a large improvement in the output characteristics of the ring-type polarization-maintaining λ/4-shifted DFB fiber laser by using 0.98 μm pumping. We achieved an output power of 0.6 mW with a pump power of 100 mW, a linewidth as narrow as 3 kHz, and low RIN of less than -130 dB/Hz for frequencies above 0.6 MHz.

PM λ/4-shifted DFB fiber laser using 0.98 μm pumping

A PM λ/4-shifted DFB fiber laser was fabricated in a PANDA-type Er-doped germanosilicate fiber. To reduce ion clustering, a large amount of aluminum was co-doped into the fiber. The λ/4-shifted FBG was inscribed by scanning a UV beam (266 nm). The UV laser consisted of the fourth-harmonic generation of a Q-switched YAG laser. The 140 mm FBG was fabricated by using a phase mask and the scanning beam technique [7]. A permanent λ/4-shift FBG was established by using a phase mask with a phase shift of π in the middle. From the measured reflection spectrum of the fabricated FBG, the 3 dB bandwidth of the stop-band was 4 GHz. In our calculation this corresponds to a grating strength of $\kappa L=8$.

With 0.98 μm pumping, the fabricated PM λ/4-shifted DFB fiber laser oscillated in a single longitudinal mode. However, the laser exhibited self-pulsation when the pump power was less than 60 mW, and CW operation was achieved when the pump power was increased to more than 60 mW. The linewidth measured by the delayed self-heterodyne technique with an 80 km delay line was 18 kHz. The RIN was less than -130 dB/Hz above 0.6 MHz and the peak RIN value was -90 dB/Hz at a relaxation oscillation frequency of 0.3 MHz with 100 mW pumping.

Ring-type PM λ/4-shifted DFB fiber laser using 0.98 μm pumping

Figure 1 shows the configuration of a ring-type PM λ/4-shifted DFB fiber laser using a 0.98 μm pump LD (laser diode). Pump light from the 0.98 μm LD was coupled to a λ/4-shifted EDF-FBG through a PM WDM coupler. We suppressed the self-pulsation by co-doping the EDF with a 0.4 wt% concentration of Er and a 12 wt% concentration of Al. With a 20/80 PM coupler, 80 % of the power was led to the laser output and 20 % was returned to the ring cavity to obtain a high output power. In this ring configuration, a linearly polarized light aligned with a slow axis propagated unidirectionally. The laser output from the PM coupler was coupled to a 2 nm optical band pass filter to eliminate the pump light.

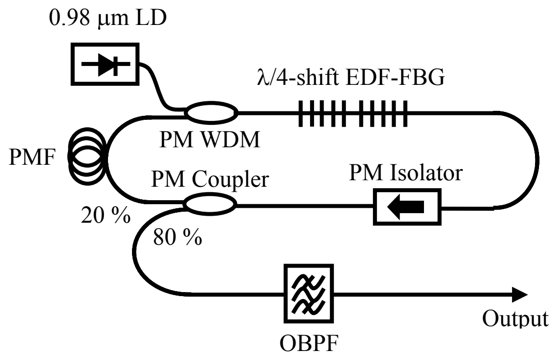

Fig. 1 Configuration of a PM ring-type λ/4-shifted DFB fiber laser using 0.98 μm pumping.

Because of the ring configuration, the signal passes repeatedly through the narrow passband filter at the lasing wavelength that is formed by the λ/4-shifted grating. The laser signal is stabilized as a result of the noise reduction realized by this ring cavity configuration.

Output characteristics

The oscillation wavelength of this laser was 1542.5 nm and the optical signal-to-noise ratio was 70 dB. Figure 2 shows the output power as a function of pump power with 0.98 and 1.48 μm pumping. The laser threshold was 10 mW in both cases. Heterodyne beat measurement with a single-mode semiconductor laser confirmed the CW operation of the laser. It is clearly seen that the output power was significantly increased by using 0.98 μm pumping. For example, for a pump power of 100 mW, the output power was 0.6 mW with 0.98 μm pumping, which was 2.5 times larger than that with 1.48 μm pumping.

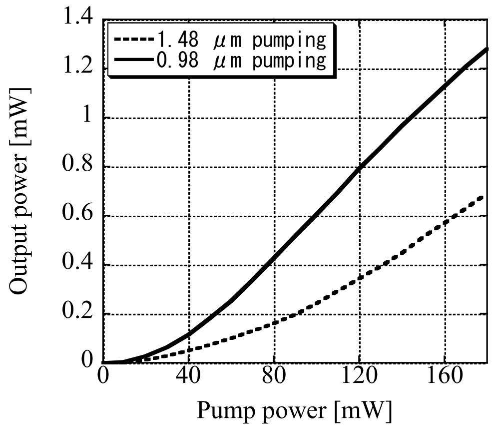

Fig. 2 Output power as a function of pump power.

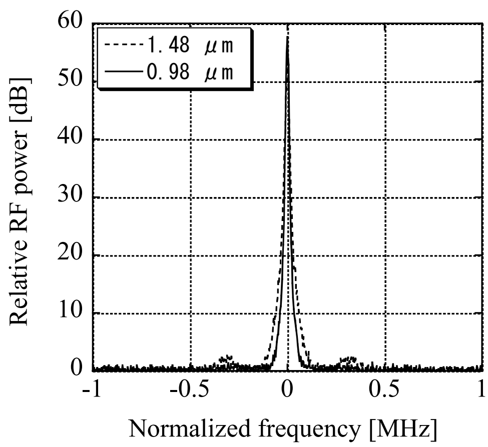

Fig. 3 Self-heterodyne beat spectrum for laser linewidth measurement.

The optical linewidth was measured using the delayed self-heterodyne technique with an 80 km delay line. The beat spectrum is shown in Fig. 3. With a Lorentzian fitting, the linewidth is estimated to be 3 kHz for pumping at 0.98 μm and 2 kHz for pumping at 1.48 μm. The small difference is due to the limited measurement resolution. With an 80 km fiber delay, the measurement resolution was limited to 1.3 kHz. In addition, as shown in Fig. 3, the tail of the spectrum is narrower with 0.98 μm pumping than with 1.48 μm pumping, and the relaxation oscillation peak at 0.25 MHz is suppressed.

Figure 4 compares RIN measurements with 0.98 and 1.48 μm pumping. The peak RIN value was -110 dB/Hz at a relaxation oscillation frequency of 0.25 MHz with 0.98 μm pumping and -108 dB/Hz at a relaxation oscillation frequency of 0.31 MHz with 1.48 μm pumping. For pumping at 0.98 μm, the measured RIN was less than -130 dB/Hz for frequencies above 0.6 MHz. For all frequencies, the RIN was below that obtained with 1.48 μm pumping. These improvements are attributed to the high population inversion and large absorption cross-section realized with 0.98 μm pumping.

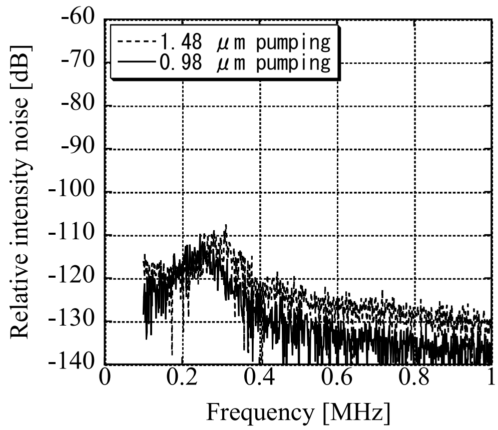

Fig. 4 Measured relative intensity noise (RIN) of the fiber laser.

Conclusion

By employing a previously proposed ring cavity configuration and using 0.98 μm pumping, we greatly improved the output power characteristics of a PM λ/4-shifted DFB fiber laser, where we took advantage of the noise reduction that resulted from 0.98 μm pumping. As a result, the output power was increased 2.5 times, and the linewidth and RIN characteristics were also improved.

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