20W single-frequency fiber laser operating at 1.93 um

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Abstract: We have demonstrated a high power Tm-doped fiber laser system operating at 1.93um. The DFB fiber laser with 20mW output power is amplified in a Tm-doped all-fiber amplifier system to the output power of 20W.

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1. Introduction

Typical applications for single-frequency lasers are interferometric sensing, coherent LIDAR, spectroscopy and nonlinear conversions [1]. Today the DFB fiber laser technology is well developed in the 1.06 um wavelength region for Yb-lasers and 1.55 um wavelength region for ErYb lasers in terms of low noise, ultra-narrow linewidth and high power. Recently, the wavelength span around 2.0 um, using Tm-doped fiber as the amplifying medium, has received growing attention. A great progress was achieved in high power Tm-doped fiber lasers [2] and amplifiers [3].

Here, we report the development of a single-frequency fiber laser source at a wavelength of 1.93 um power scaled to the output power of 20 W.

2. Seed source

The seed source of the system is a Tm-doped DFB fiber laser at a wavelength of 1.93 um. The laser is constructed by writing a π-phase shifted Bragg grating into a 5 cm long thulium doped silica fiber. The phase shift position is displaced toward one of the ends of the grating in order to obtain single-sided emission. One particularly interesting feature of the DFB fiber laser is that the grating may be fabricated so strong that the background losses of the fiber become the dominating factor for the cavity Q-value. This allows for operation at extreme wavelengths within the gain bandwidth compared to other laser designs, particularly in the long wavelength end of the gain spectrum. We have thus achieved single-frequency emission at 1.74 [4], 1.76, 1.93, 1.98 and 2.09 um which covers more than 300 nm.

The DFB fiber laser is pumped in the forward direction using a diode pump source amplified by a single-clad L-band EDFA, as shown in figure 1. In this way, the pump system provides up to 230 mW of output power at a wavelength of 1595 nm. The laser terminates in a custom made 1.9 um isolator.

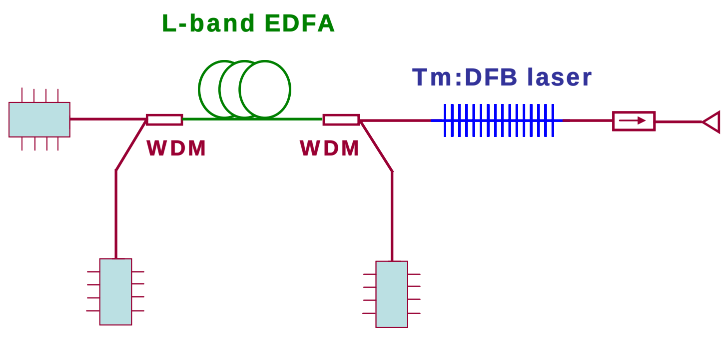

Figure.1. Configuration of the thulium DFB fiber laser seed source. The DFB laser is pumped by a single-clad L-band EDFA module giving up to 230 mW output power at a wavelength of 1595 nm

The slope efficiency of the DFB fiber laser is around 10 % with respect to launched pump power and a threshold of lasing of 14 mW. For optimum efficiency, the lasing wavelength should be between 1.85 and 1.9 um. Single-frequency operation is verified using a Fabry-Perot interferometer with a FSR of 15 GHz and a minimum resolvable bandwidth of 100 MHz. The linewidth can be estimated to be between 20-50 kHz [5].

The noise characteristics of the DFB fiber laser were also characterized. The RIN peak of the laser was in the range of 0.5 – 2 MHz depending on the pump power and the peak RIN value was below -130 dB/Hz throughout its operating range. Also long term stability of the laser was observed to be below 2 % over 12h operation.

The DFB fiber laser is thermally tunable with a tuning coefficient of 40 pm/K and for faster tuning applications it is also piezo-tunable with a coefficient 0.2 pm/V up to a maximum modulation bandwidth of 100 kHz.

3. Amplifier

The amplifier consists of two amplification stages. Each stage was pumped by an Er:Yb co-doped fiber laser at 1567 nm to get an amplification in a ~2 m long Tm-doped fiber. Fiber-to-fiber isolators with typical loss of less then 0.5 dB and more then 25 dB at 1900 nm were used to isolate the seed laser and amplification stage from each other. More than 30 dB of gain was achieved in this optical configuration of the thulium amplifier. 20mW input single-frequency signal at 1932 nm was amplified in the first stage up to 1 W. Maximum output power of 20 W after the second stage was limited by the pump power only. Short length of the active fiber did help to avoid any non-linear effects related to a single-frequency origin of the input signal.

Output power vs. total pump power (first and second stage pump lasers) is shown in fig.3. The slope efficiency of this Tm-doped fiber amplifier is around 65 % with respect to the total pump power. Such a combination of efficient pump diodes, Er:Yb fiber laser and Tm amplifier result in wall-plug efficiency of about 13 %.

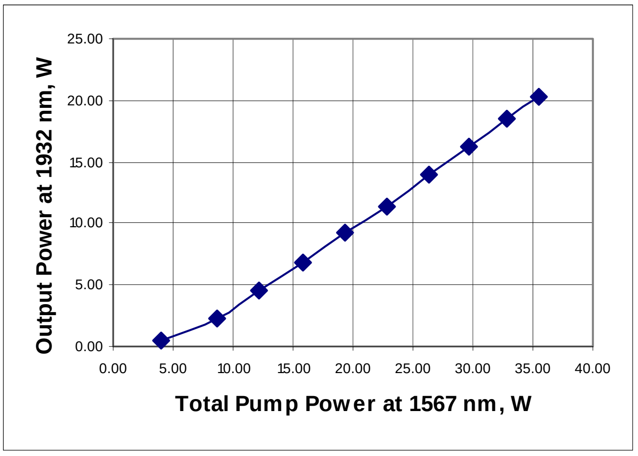

Figure.3. Output power vs. total pump power

This amplifier contributes to intensity noise of the single frequency signal. There are two visible peaks in RIN spectrum related to relaxation oscillation peaks of two Er:Yb co-doped pump lasers. Measured RIN peak of the amplifier is about –115 dB/Hz in the range of 0.2-0.5 MHz depending on the pump power. There are several ways though to reduce these peaks in RIN by suppressing relaxation oscillations in pump lasers so that low noise (RIN <-130 dB/Hz) of the seed laser can be preserved.

4. Conclusion

We have successfully demonstrated single-frequency lasing using a thulium doped DFB fiber laser at a wavelength of 1.93 um. The slope efficiency of the laser was 10 % with respect to launched pump power and the total output power was recorded to 22 mW.This seed laser was successfully amplified in the Tm-doped all-fiber amplifier up to 20W power. Optimized parameters of the fibers and optical configuration resulted in high efficiency (65% to the pump at 1567 nm and about 13 % wall-plug) of the amplifier.

5. References

[1] D.J. Hill, B. Hodder, J.De Freitas, D.D. Thomas and L. Hickey, "DFB fibre-laser sensor developments", Fonds voor Wetenschappelijk Onderzoek – Vlaanderen, FWO and proceedings of SPIE – The International Society for Optical Engineering, vol. 5855 PART II, pp. 904-907, 2005

[2] D. Gapontsev, N. Platonov, M. Meleshkevich, V. Gapontsev, Y. Barannikov, A. Unt, V. Sergeev, "High power Tm fiber lasers at 1.8 to 2.2 micron region", presented at Photonics West 2004

[3] M. Meleshkevich, A. Drozhzhin, N. Platonov, D. Gapontsev, D. Starodubov, "10W single-mode single frequency Tm-doped fiber amplifiers optimised for 1800-2020 nm band", presented at Photonics West 2005

[4] S. Agger, J. H. Povlsen, and P. Varming, "Single-frequency thulium-doped distributed-feedback fiber laser," Opt. Lett. **29**, 1503-1505 (2004)

[5] S. Agger, P. Varming and J. H. Povlsen, "Thulium DFB fibre lasers and applications", Session HPFL-2, 3rd International symposium on High-power fiber lasers and their applications, St. Petersburg, Russia, june 2006