Over 200 mW single-frequency Tm-doped fiber ring laser at 2.05 μm

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Single-frequency fiber laser sources operating in the wavelength region of 2.05 μm are widely used in coherent Doppler lidars and differential absorption lidars. Compared with the short linear-cavity scheme, the ring-cavity fiber laser allows the optimization of the active fiber length to improve the pump absorption, which are more suitable for single-frequency power scaling. By further incorporating a piece of rare earth doped fiber based saturable absorber (SA) and a high-reflectivity mirror, a narrow bandwidth dynamic Bragg grating would be established inside the SA based on the standing-wave interference effect, forcing the intracavity laser to operate in single longitudinal mode scheme. It has been demonstrated that using a highly absorptive fiber SA would enhance the strength of the dynamic grating, benefiting strong mode selection capability [1]. However, for the previously demonstrations of single-frequency fiber lasers above 2 μm with such scheme, all the SA used are Tm-doped fibers. Limited by the weak mode selection resulted from the low absorption of Tm^{3+} ions in this wavelength region, the maximum single-frequency power is only 40 mW.

Here, we propose a novel idea that using Ho-doped fiber and Tm/Ho-codoped fiber as the SA for the first time. The absorption cross section (@ 2050 nm) of Ho^{3+} ions is around 0.6×10^{-25} m^2, and is much larger than that of the Tm^{3+} ions ($<0.1\times10^{-25}$ m^2). Therefore, compared with the singly Tm-doped fiber SA, the introduction of Ho^{3+} ions would enhance the saturable absorption process and lead to a stronger dynamic grating. By optimizing the length of Tm/Ho-codoped fiber SA, 215 mW stable single-frequency laser at 2.05 μm is obtained under 2 W 1570 nm pump power, with the slope efficiency being 22%. To the best of our knowledge, this is the highest single-frequency all-fiber laser oscillator output power above 2 μm. Furthermore, a control experiment that using singly Tm-doped fiber as the SA is also conducted and the results are summarized in Table. 1. It is noticed that the single-frequency output power using Tm-doped fiber exhibits an obvious drop. This comparison verifies that the Tm/Ho-codoped fiber or Ho-doped fiber is a more preferable choice of SA to enhance the output power for single-frequency fiber laser above 2 μm.

Table 1. 2.05 μm single-frequency laser power with different SA length

	2 m	4 m	6 m
Tm-doped fiber	/	60 mW	93 mW
Tm/Ho-codoped fiber	160 mW	215 mW	180 mW

[1] S. Stepanov, *J. Phys. D Appl. Phys.* **41**, 22 (2008).