Pump to Signal Transfer of Modulation Index in Ytterbium Doped Fiber

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Pump modulation is a method to modulate signal via modulating the pump in a gain fiber amplifier system. This method can also be applied for active mode locking in a fiber laser, as has been demonstrated in thulium-doped fiber laser [1] and erbium doped fiber laser [2]. For the understanding of transfer characteristics of pump to signal and signal to signal transfer, an analytic model for gain modulation in erbium-doped fiber amplifier (EDFA) was theoretically investigated previously [3]. It showed that the pump to signal transfer of modulation index exhibited a low pass filter response. Pump to signal transfer was also investigated in thulium doped fiber experimentally previously [4]. Here, we present the pump to signal transfer of modulation index in ytterbium-doped fiber (YDF) experimentally.

Fig. 1 shows the schematic of a YDF pump modulation system. Pump power is modulated by a laser diode driver with sinusoidal waveform.

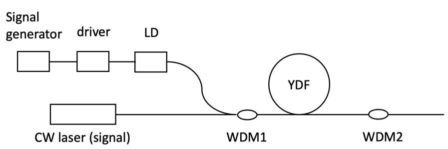

Fig. 1 Schematic of a YDF pump modulation system

Assume the pump power and modulated output signal to be described by:

$$P_p = P_p^0(1 + m_p \cos \omega t)$$
$$P_s = P_s^0\{1 + m_s \cos(\omega t + \phi)\}$$

where P_p and P_p^0 are pump power and its average value respectively. m_p is the modulation index of pump power. P_s and P_s^0 are signal power and its average value respectively. m_s is the modulation index of signal. ω is the pump modulation frequency. ϕ is the phase difference between signal and pump. Here, we define the pump to signal transfer of modulation index to be:

$$T = m_s / m_p$$

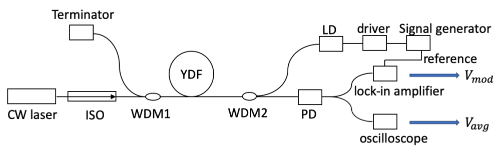

Fig. 2 Experimental setup for measuring pump to signal transfer T

In the experiment, the transfer T as a function of modulation frequency ω was measured. Fig. 2 shows the experimental setup for measuring the transfer T for a YDF amplifier system. Here, we employed backward pumping so that residual pump did not interfere with our measurement. Modulated signal power and average power are measured as V_{mod} and V_{avg} with lock-in amplifier and oscilloscope respectively. Thus, modulation index of signal m_s can be calculated by:

$$m_s = (V_{mod} * C) \,/\, V_{avg}$$

where C is the calibration coefficient between the lock-in amplifier and oscilloscope.

Fig. 3 shows the measurement results (dotted line) of pump to signal transfer and simulation results (solid line) according to the theory in ref. [3]. Fig. 3 (a) shows the transfer at three different saturation level A, B and C with the same pump power (68mW), where A is less saturated and C is highly saturated. Result shows that higher saturation leads to lower transfer at low frequency. Fig. 3 (b) shows the transfer at three different pumping level (45mW, 68mW and 81mW respectively) with the same signal power (2mW). Result shows that higher pump power leads to higher transfer.

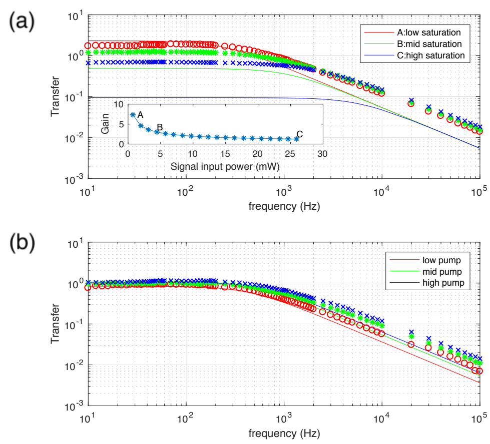

Fig. 3 Transfer at different saturation level (a) and pumping level (b). Dotted line: experiment results; solid line: simulations.

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