Mode instability in Yb^{3+}-doped fiber amplifiers of continuous and pulsed signal

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***Abstract*—Spatio-temporal instability of fundamental mode in Yb^{3+}-doped large mode area polarization-maintaining fiber amplifiers was analyzed. Limitations of the amplifier output power and gain were investigated depending on the input signal parameters: spectral width, power level and polarization. The influence of backward reflection of the optical waves on the mode-instability threshold was also examined. The traveling electronic and thermal refractive index gratings following the optically-induced population gratings were found to provide the energy transfer from the main mode to the higher-order modes.**

Keywords—Mode instability, LMA fibers, Yb3+

Large mode area (LMA) Yb^{3+}-doped fiber amplifiers are used to obtain high power single-mode optical beam. However some fraction of the radiation is always converted in the LMA fibers to spurious higher order modes, and the fundamental mode power can transfer to higher modes. This threshold-like effect referred as mode instability is significantly limits average output power of single-mode radiation in the fiber amplifiers [1]. Physical mechanism of the induced mode coupling and mode instability was discussed to cause by nonlinear formation of refractive index grating [2]. Mode beating produces inversion and temperature gratings [3] with perfectly matched period for resonant energy transfer between fundamental and higher order mode.

In our work, origin of mode instability and methods for increasing its threshold were studied. Yb-doped fibers with 7 um MFD were used in the experiments as an amplifier of CW or pulsed signal (Fig. 1). It was found that instability threshold grows with increasing of the input-signal power and linewidth (Fig. 2a). Strong drop of mode instability threshold was observed in the presence of backward reflection of the amplified radiation (Fig 2b). Influence of wavelength difference of forward and backward propagating waves on the mode instability threshold in the fiber amplifiers was also investigated.

Numerical simulation of the mode instability was performed taking into consideration the electronic and thermal refractive index changes in the fiber amplifiers (Fig. 3). The electronic index grating (caused by polarizability difference of the excited and nonexcited Yb^{3+}-ions) was found to be strongly predominating over the thermal grating in condition of our experiments. Amplifying of fundamental LP_{01} and higher-order stocks, anti-stocks LP_{11} modes was calculated to confirm significant grating-assisted energy transfer.

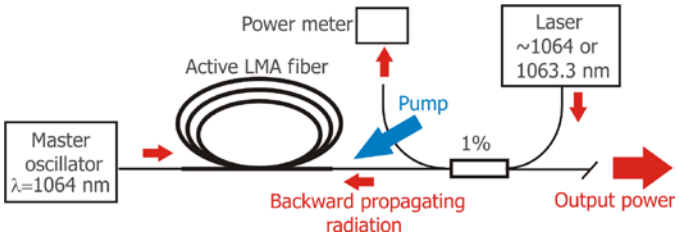

Fig. 1. Experimental setup.

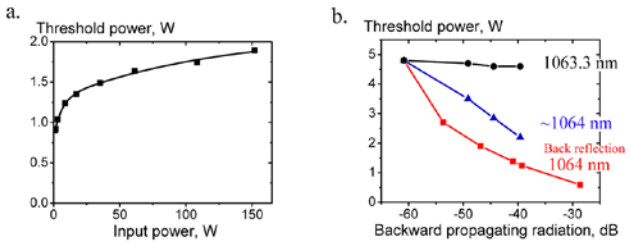

Fig. 2. Mode instability threshold dependence on input power and backward propagating power.

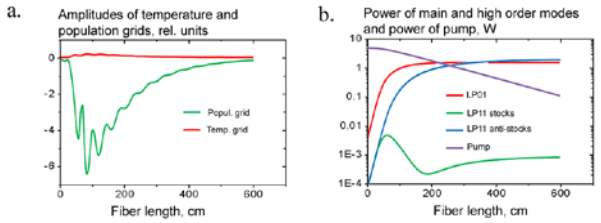

Fig. 3. Electronic and thermal refractive index gratings and amplifications of fundamental LP_{01} and stocks, anti-stocks LP_{11} modes.

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