The fractional thermal factor in LD-pumped Yb^{3+}/Er^{3+} codoped phosphate glass*

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Abstract: The fractional thermal in LD-pumped Yb^{3+}/Er^{3+} codped phosphate glass have been investigated base on the measurement of edge temperatures of glass. The temperatures of pump sopt at differernt pump power are calculated. The results indicate that upconversion processes have an important contribution to heat of LD pumped phosphate glass.

Keywords: LD-pumped Er:Yb:glass;; Thermal load; Upconversion processes

1. Introduction

As an eye-safe wavelength laser, 1.54 μm Yb^{3+}/Er^{3+} codoped phosphate glass lasers have attracted much attention for their compactness and low cost [1-3]. However, little attention is paid on the thermal loading in Yb^{3+}/Er^{3+} codoped phosphate glass.

Thermal effects greatly influence on the laser performance if the heat deposited in the glass is not removed efficiently. The net result is beam distortion due to thermal lensing, stress induced birefringence and ultimately catastrophic failure of the glass, if the thermally induced stress exceed the tensile strength of the glass. It is essential and useful to determine the fractional thermal loading factor (denoted as η in this paper) which is defined as a fraction of absorbed pump power deposited as heat in the phosphate laser glass.

In this paper, the loading factor η is determined under no laser condition. The temperatures of edge and pump spot are calculated at different pump power. The role of upconversion processes in thermal loading of glass is analyzed and fraction of heat generated by upconversion processes is also calculated.

2. Determination of thermal loading

A. Experimental

The Yb^{3+}/Er^{3+} codoped phosphate glass with a thickness of 2 mm is mounted in a adiabatic fixture, and just cooled by natural convection of air. The concentrations of Yb^{3+} and Er^{3+} ions are 18 wt% and 0.27 wt%, respectively. The pumped source is a fiber-coupled laser diode at wavelength 980nm. The pump beam from the laser diode is shaped and focused with spot size is about 175 μm inside the phosphate glass by means of a suitable optical system. The temperature of glass is measured by an infrared thermometer. The output power is measured by a power meter.

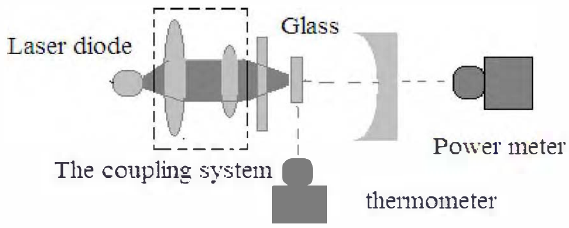

Fig. 1 Schematic diagram of experimental setup

B. Determination of fraction thermal loading

We measure the edge temperature of phosphate glass at different pump power with an infrared thermometer. The results are shown in Fig. 1. The temperatures of edge have a approximate linear relation with pump power. Then, we simulated temperatures of edge with η=0.68 through general steady-stated heat equation given by [4]. The simulated results are also plotted in Fig. 1. The good agreement indicates that the thermal loading factor in our phosphate is about 0.68 under no laser condition. Fig. 3 shows the temperatures of pump spot at different pump power. The temperatures of pump spot are very high even at low pump power.

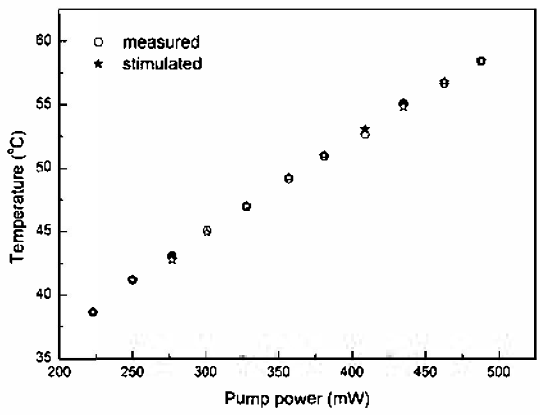

Fig. 2 The measured edge temperatures and the simulated temperatures with η=0.68

* International Cooperation Project of Shanghai Municipal Science and Technology Commission under Grant No. 05S207103

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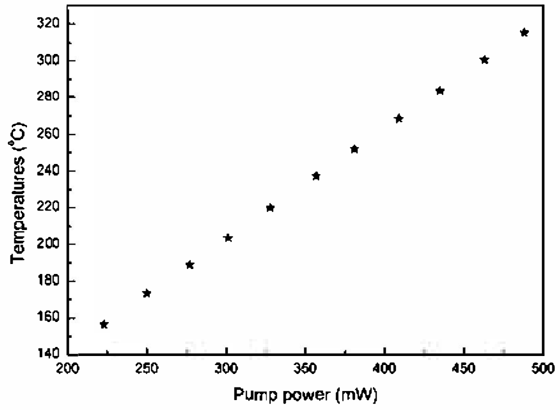

Fig. 3 The temperatures of pump spot at different pump power

The upconversion processes deplete the population at upper laser level, which cause the ions to jump to the higher levels, then drop down owing to the multiphonon relaxation and thus generate extra thermal loading in phosphate glass. Nonradiative transition rate is bigger than total spontaneous radiative transition rate at the upconversion energy levels from Ref. [5-6]. Therefore, it is reasonable that most of the pump energy absorbed by upconversion processes transform to heat via multiphonon radiation. We define the fractional influence of upconversion as ξ, and the rest of the fraction is induced by quantum defect $(1-\nu_e/\nu_p)$. Hence the fractional thermal loading η can be expressed as[7]:

$$\eta = \xi + (1-\xi)(1-\nu_e/\nu_p) \quad (1)$$

From the (1), we can calculated the thermal loading factor ξ=0.49. It means that the heat induced by upconversion processes accounts for 73% of total heat deposited in the glass.

The output characteristic is investigated under same conditions. The thickness of glass is 2mm and absorption coefficient is 11.5/cm. The output powers depend on pump power are shown in Fig 4. The glass is just cooled by air at laser operation.

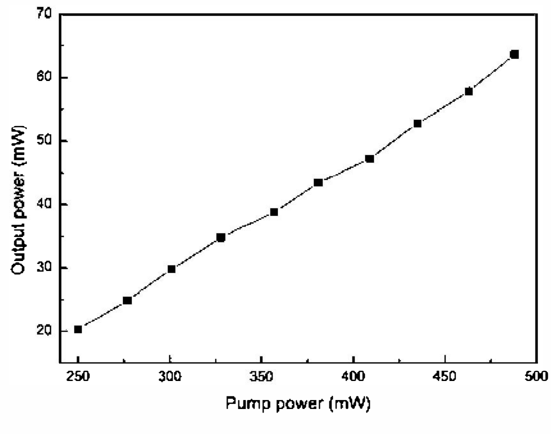

Fig 4 The output powers depend on pump power.

the energy transfer efficiency is relatively high which about 19%. At 488 mW, the output power reaches to 64 mW, even Te fractional heat loading is relatively high, and the glass just cooled by air. This result shows that the characteristic of glass is good.

3. Conclusions

In this paper we investigated thermal effects depends on the pump power in longitudinally LD pumped Yb^{3+}/Er^{3+} codoped phosphate glass. The fractional thermal loading is about 0.68 of the glass used in our experiment. It was found out that the maximum temperature could be very high even at low pump power. As discussed above, it is very important to cool Yb^{3+}/Er^{3+} codoped phosphate effectively, especially in short cavity lengths lasers. The heat induced by upconversion processes probably accounts for 73% of total heat in the glass. The fractional thermal loading can be decreased by lower upconversion transfer rate in phosphate glass. The energy transfer efficiency at same conditions is about 19% and shows that the characteristic of glass is good.

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