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Investigation of red-shift of an Er:Yb:Kigre phosphate glass microchip laser at 1535 nm due to pump thermal loading

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Er:Yb doped phosphate glass microlasers have received attractive interests, and significant progress has been achieved in the past decade, as described in a recent review[1]. Although a lot of papers have been published on such type lasers, most of them concern merely on the laser performance such as threshold, slope efficiency as well as cavity designs. In this paper, emission cross section spectrum of the transition from $^4I_{13/2}$ to $^4I_{15/2}$ was experimentally measured in an Er:Yb codoped Kigre phosphate glass microchip, and the absorption cross section spectrum was derived using the McCumber theory. Based on these absolute cross section spectra, the gain spectrum was calculated in terms of different pumping ratios, which allows to determine the maximum lasing wavelength around 1535 nm and the total cavity loss being equal to 0.151 cm^{-1}. Both values are in good agreement with direct measurements. Under pumping with a Ti:sapphire laser at 975 nm, a high performance microchip laser at 1535 nm was realized with a low threshold of 5 mW and a high slope efficiency of 22% as well as a maximum output power of 22 mW operating in single frequency at 130 mW incident pump power. Red-shift effect of the 1535 nm microchip laser was also experimentally observed as the pump power was increased, as shown in Fig.1, and this is believed to originate from a compromise between the thermally induced expansion of the cavity and the change of refractive index due to temperature variation. The resonant laser wavelength is given by

$$m\lambda = 2nd\left(1+\frac{1}{n}\frac{\partial n}{\partial T}\cdot\Delta T\right)\cdot\left(1+\frac{1}{d}\frac{\partial d}{\partial T}\cdot\Delta T\right) \tag{1}$$

Temperature inside the microchip cavity was determined by employing the intensity ratio of two green upconversion emission centered at 530 nm and 554 nm respectively. The levels $2(^4S_{3/2})$ and $3(^2H_{11/2})$ responsible for the green emission (see inset of Fig.2) can be considered to be in quasi-thermal equilibrium, and then the ratio of the emission intensities originating from the levels 3 and 2 can thus be expressed by the following equation

$$\frac{I_3}{I_2} = \frac{c(\upsilon_3)A_3g_3h\upsilon_3}{c(\upsilon_2)A_2g_2h\upsilon_2}\cdot\exp\left[-\frac{E_{32}}{kT}\right] \tag{2}$$

where $c(\nu_2)$, $c(\nu_3)$ are the responses of the detection system at frequencies ν_2 and ν_3, g_2 and g_3 the degeneracies $(2J+1)$ and A_2, A_3 the total spontaneous-emission rates of the level 2 and 3, respectively. E_{32} is the energy gap between the levels 2 and 3.

From Eq.(2) and the data in Fig.2, one obtains the cavity temperatures T= 464 K, 504 K, and 511 K corresponding to the incident pump powers P_{in}= 75 mW, 130 mW, and 145 mW, respectively. In combination with Eq.(1), the lasing wavelengths at these three pumping powers are 1535.38 nm, 1536.07 nm, and 1536.15 nm, which are in good agreement with the measured peak laser wavelengths shown in Fig.1.

Such a spectroscopic technique permits not only to calibrate accurately the cavity temperature but also to model the red-shift effect attributable to pump-induced thermal loading.

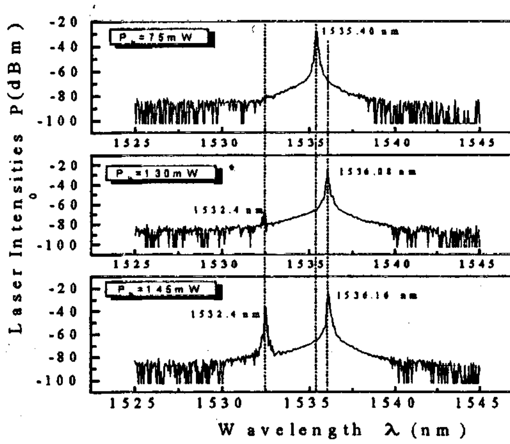

Fig.1 Evolution of laser spectra as pump increased.

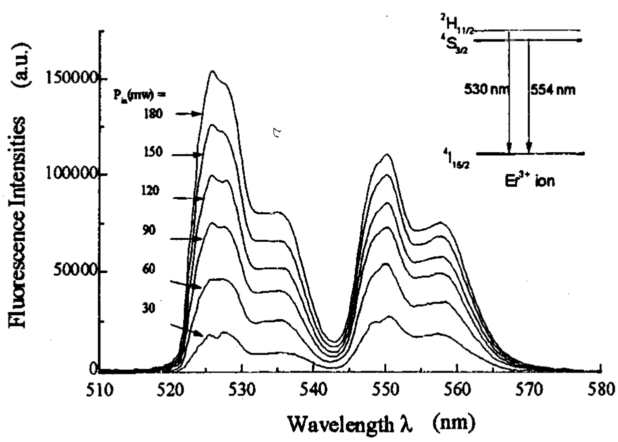

Fig.2 Green emission spectra as pump increased.

Reference

1. P.Laporta, S.Taccheo, S.Longhi, O.Svelto, and C.Svelto, "Erbium-ytterbium microlasers: optical properties and lasing characteristics", Optical Materials 11, 269-288 (1999)