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Optical Bistability Effects in a 2 μm Tm,Ho:YAG Microchip Laser

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Optical bistability has been observed in a 2 μm Tm,Ho:YAG microchip laser with plane parallel surfaces when pumped by a Ti:sapphier laser. The laser output was found to jump by nearly a factor of three at a certain incident power level. When the pump power was subsequently reduced, the laser exhibited a turn-off threshold which was significantly lower than the turn-on threshold. Similar jumps were also observed in the reflected and transmitted pump power. The bistability is believed to have a thermal origin.

In the course of the characterization of a Ti:sapphire laser pumped Tm,Ho:YAG (6% Tm, 0.5% Ho) microchip laser with plane parallel surfaces (1mm thickness) we observed that the 2 μm laser output exhibited a very pronounced bistable behavior. That is, when the pump power was increased beyond a certain level , a jump in the output power occurred. When the pump power was subsequently reduced, the output power showed a different dependence on the pump power (Fig. 1). When measurements were made of the transmitted and reflected pump power, corresponding hysteresis traces were obtained (Figs. 2&3). This led us to the conclusion that the double-valued laser output is caused by a bistability in the absorbed pump power as the incident pump power is first increased and then decreased.

Since the surfaces of the microchip laser had very low reflectivity at the pump wavelength, absorptive bistability as a result of pump saturation is ruled out as a possible explanation of the effect that we observed.[1] We sought for an answer in the thermal expansion of the crystal due to dissipation of the absorbed pump power, leading to changes in the resonance condition for the pump beam. Measurements on the reflected fringe pattern of a focused He-Ne beam showed that the microchip did indeed become thicker with increasing pump power. Using the approach outlined in Ref. 1, we found that when the

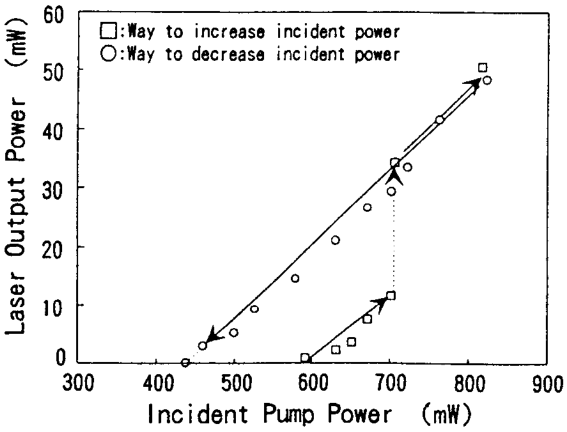

Fig. 1 Laser output power versus incident pump power.

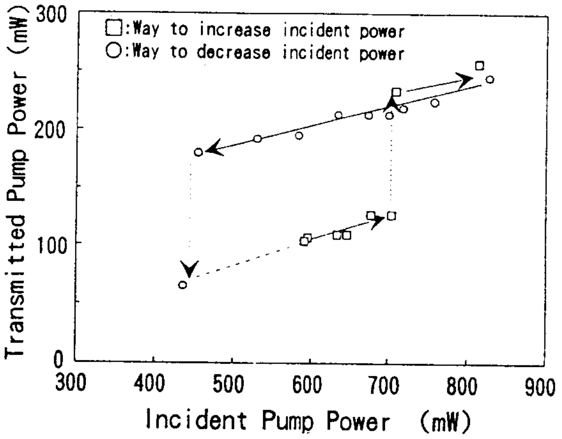

Fig. 2 Transmitted pump power versus incident pump power.

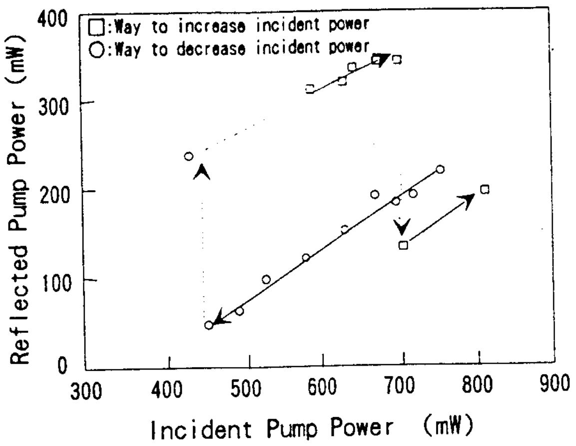

Fig. 3 Reflected pump power versus incident pump power.

thermal effect is included the incident intensity (I_1) is related to the transmitted intensity (I_3) by

$$I_1 = (T_1T_2)^{-1} e^{\alpha l}[1 + R_1R_2 - 2\sqrt{R_1R_2}\cos((2k\eta/T_2)e^{\alpha l/2}I_3 + \delta)]I_3 \qquad (1)$$

where $R_1(T_1)$ and $R_2(T_2)$ are the reflectances (transmittances) of the pump and output mirrors respectively, α is the saturated pump absorption coefficient, l is the thickness of the microchip laser when there is no pumping, k is the propagation constant, η is the thermal expansion per unit internal pump intensity, and δ is a phase factor which depends on the pump wavelength. This formula produced good agreement with the experimental data.

The thermal bistability effect is predicted for reflectivities for the pump as low as 10%. In practice the dichroic coatings on microchip lasers can only provide pump reflectivity down to about 20%. Therefore, it should be a common feature for all microchip lasers with strong pump induced thermal effects when they are pumped by sources with bandwidths small compared to the microchip's mode spacing. This effect should also be present for pumping with a multimode diode laser if the mode spacing of the diode is a multiple of that of the microchip. Advantage may be taken of this to maximize the absorbed pump power in such systems.

Reference:

1. R.W. Boyd, Nonlinear Optics, Academic Press, San Diego, 1992.