Excited state absorption measurement in bismuth-doped silicate fibers for use in 1160 nm fiber laser

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Bi-doped fiber lasers (BiDFLs) demonstrated so far have been limited to 1080 nm pumping band at which high power laser diodes (LDs) are not readily available. [1,2] Direct LD pumping will make the BiDFLs more compact and cost-effective. Pumping wavelengths at 915 nm and 976 nm are interesting because they well overlap with the absorption band of the Bi-doped fibers (BiDFs). Here, we investigate feasibility of the 915 nm and 976 nm pumping band in addition to 1080 nm pumping by measuring excited state absorption (ESA) in BiDFs.

A BiDF showing 10 % laser slope efficiency when pumped at 1080 nm was used for the ESA measurement. [1] Transmission change in the BiDF from 900 – 1350 nm was determined with a 1047 nm pump on and off. A probe beam, white light source, was chopped at 37 Hz and counter launched to the BiDF. The transmitted probe beam from the fiber sent through a monochrometer. The output probe was collected by an InGaAs detector which was synchronized with 37 Hz lock-in amplifier. A small signal ground state absorption (GSA) was determined by cut-back method between fiber lengths of 2.7 and 1 m with pump off. The measured GSA well agreed with the same measurement done with an optical spectrum analyser and a white light source within 5 % difference in dB/m. The GSA and change in the transmission are shown in Fig. 1(a). A strong ESA can be seen in 900 – 1000 nm band. A ratio of ESA to GSA cross-section ($\sigma_{ESA}/\sigma_{GSA}$) was calculated at 915 and 976 nm from the figure despite uncertainty of σ_{GSA} due to unsaturable absorption. [1,2]. We assumed $\sigma_{ESA}/\sigma_{GSA} = (\alpha_{ESA}/\alpha_{GSA})(N2/N1) \cong \alpha_{ESA}/\alpha_{GSA}$ under strong pumping. N1 is ground state population and N2 is meta-stable state population, and α is absorption coefficient. The ratios of 2.5 at 915 nm and 1.3 at 976 nm indicate dominant ESA over GSA at these two wavelengths. It should be noted that the 1080 nm pumping band as well as emission band (1100 – 1300 nm) have negligible ESA effect. An influence of the pump ESA on laser performance at 1160 nm was calculated. We assumed that the population in the upper exited state accounting for ESA is negligible. Parameters such as emission and absorption cross-sections, and lifetime were taken from [2,3]. Other parameters regarding fiber dimensions were used from [1]. A linear 100-4 % laser cavity was assumed. No amplified spontaneous emission was considered. The ratio of unsaturable loss to small signal loss was fixed as 0.24 for all the pump wavelengths. [1] The fiber lengths were optimized for 915 and 976 nm pumping wavelengths. For 1080 nm pumping, we used 25 m which is close to optimized length (27 m). Figure 1(b) shows the calculated laser performances. The BiDFL performs best with the 1080 nm pumping. Laser performance at other pumping band is deteriorated by pump ESA. Note that we haven't observed any laser action with 977 nm pumping up to 400 mW of launched power in a ring cavity with 1 % output coupling although our calculation with the ring cavity expected laser oscillation at the given pump power level. This discrepancy indicates higher unsaturable loss at 976 nm than that has assumed in our calculation.

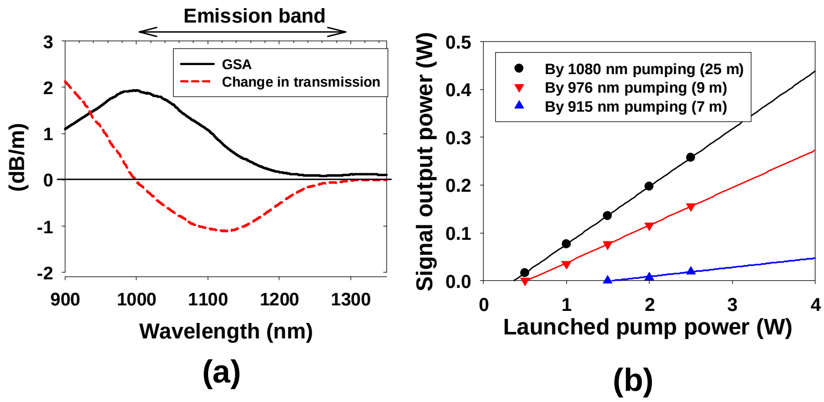

Fig. 1. (a) Measured ground state absorption and change in GSA in BiDF. (b) Calculated laser performances by 915, 976, and 1080 nm pumping wavelengths.

References

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