Optical Properties of Polycrystalline Neodymium (Nd)-Doped Yttrium Aluminum Garnet for Different Levels of Nd Doping

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The synthetic mineral yttrium aluminum garnet (YAG) is a well-established host material for laser gain media. Near-infrared high-power lasers use a polycrystalline version because of the larger sizes available. Also, lidar transmitters commonly use lasers based on the single-crystal version this material.

Single-crystal neodymium-doped YAG (Nd:YAG) is widely available in doping percentages of ~1% Nd. However, higher doping levels and the ability to vary doping level as a function of position have not yet been demonstrated in the single-crystal material. However, polycrystalline YAG can be doped to much higher levels, and the doping can be varied with position. This offers important design options to the laser engineer. Polycrystalline Nd-doped YAG is now commercially available in percentages of up to 10% Nd from Konoshima, a Japanese company. Applications such as high-energy lasers and laser transmitters for lidars require complete characterization of the optical properties of this new material. Past work at APL examined similar material produced by Raytheon.[1]

The purpose of this work is to model the scatter and absorption properties of polycrystalline YAG from Konoshima as a function of the Nd doping level. We summarize current characterization progress on samples of undoped and Nd-doped material up to 10% doping.

The characterization is in terms of the extinction coefficient (Fig. 1). The following formula is used to derive the extinction coefficient from transmittance measurements (d is material thickness, and R is the Fresnel power-reflection coefficient)[2]:

$$\beta_{ext} = \frac{1}{d} \ln\left[\frac{2R^2\tau}{\sqrt{(1-R)^4 + 4R^2\tau^2} - (1-R)^2} \right].$$

Figures 2 and 3 illustrate the pump band absorption and background scatter level for various doping levels of Nd in YAG. Also shown is a classical oscillator fit to the absorption spectra for a 4% sample. The bidirectional

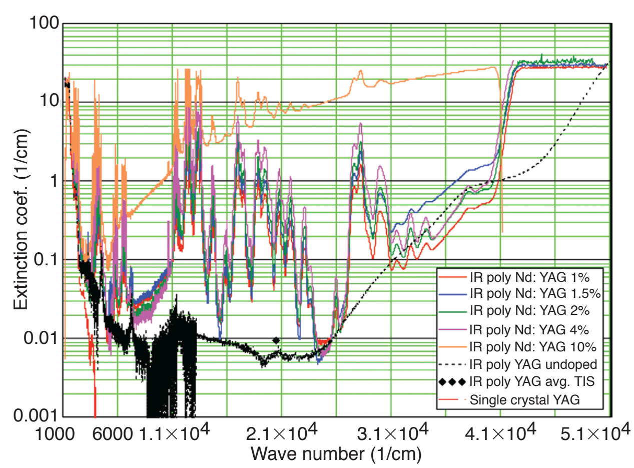

Figure 1. Extinction coefficient. IR, infrared; TIS, total integrated scatter.

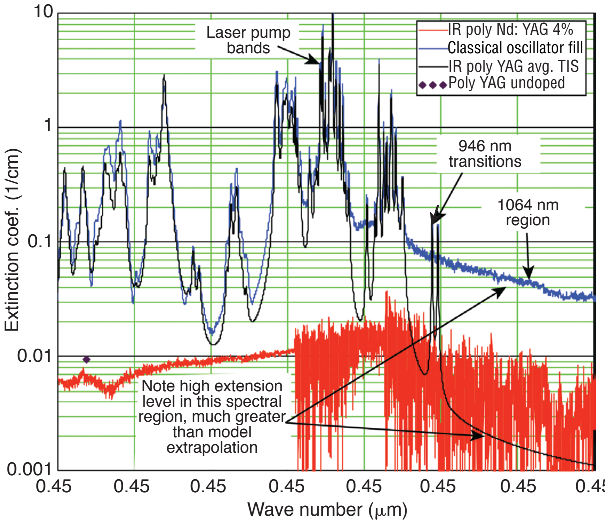

Figure 2. Classical oscillator model.

scatterance distribution function (BSDF) models are described in Ref. 3.

The Konoshima polycrystalline YAG has excellent optical properties for laser applications. However, low-level scatter is observed with a total integrated scatter of <0.01 at 488 nm for materials with ≤4% doping. The 10% material has unacceptable scatter levels. Also, low-level extinction (<0.1 cm^{-1}, most likely absorption) is observed in the near-infrared where the laser transitions exist (see Fig. 2). Quantification of this extrinsic loss effect will be determined by future measurements. Spectrally resolved pump band absorption is modeled in terms of a classical oscillator model for any Nd concentration level. The information provided by this study on pump band absorption and bulk extinction should be of great use to laser designers.

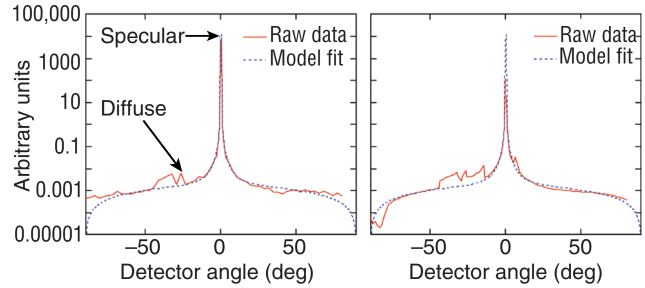

Figure 3. Scatterance BSDF at 488 nm. Excellent model fit is observed, and 1–4% of the Nd-doped material is of high optical quality.

For further information on the work reported here, see the references below or contact mike.thomas@jhuapl.edu.

[1] Thomas, M. E., Carr, A. K., Limsui, D., and Huie, J. C., "Optical Properties of Nd Doped and Undoped Polycrystalline YAG," in *Window and Dome Technologies and Materials X*, R. W. Tustison (ed.), Proc. of SPIE, Vol. 6545, SPIE, Bellingham, WA, 65450F (2007).

[2] Thomas, M. E., *Optical Propagation in Linear Media*, Oxford University Press, New York (2006).

[3] Thomas, M. E., and Duncan, D. D., "BRDF and BSDF Models for Diffuse Surface and Bulk Scatter from Transparent Windows," in *Window and Dome Technologies and Materials X*, R. W. Tustison (ed.), Proc. of SPIE, Vol. 6545, SPIE, Bellingham, WA, 65450I (2007).