

SUBMIT TO: OPTICS IN THE SOUTHEAST 2001
CONFERENCE: Fiber Optics and Communication Technologies
SESSION CHAIR: John Ballato, Clemson University
Kigre Selected Publication Nd-Glass Paper #35

Nd-Doped Cladding Pumped Fiber Laser

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Key Words: Fiber Laser, Double Clad Fiber, Cladding pump
Presentation: Poster Presentation

Abstract:

A number of double clad (DC) or cladding pumped neodymium doped phosphate glass fibers were recently designed, fabricated and tested at Kigre, Inc. One fiber contains a 50-micron diameter core doped with 9 wt.% Nd₂O₃ and a 0.18 NA. The inner cladding is made from undoped glass with 1.5mm x 1.5mm cross-section and exhibits a 0.62 NA with a low index silicone polymer outer cladding.

Both annealed and un-annealed fibers were tested. The measured absorption for a 53 cm long un-annealed fiber was 73%, or 5.7 db. An 808nm fiber coupled diode array was used to end pump the neodymium fiber. Fiber laser action was observed in both pulsed and CW operation at 1.054um. Approximately 4.3 mj of pump energy was required to reach lasing threshold without resonator mirrors, (Fresnel reflection resonator only). A maximum of 2.1 Watts CW output power was obtained with 8.3 Watts absorbed pumping power using a 50% R output coupler. 34% slope efficiency was obtained with absorbed pump power.

This work was supported under contract by the US Army Night Vision Directorate and Quantum Group. "Opinions, interpretations, conclusions, and recommendations are those of the author and are not necessarily endorsed by the United States Army or Quantum Group."

ND-DOPED CLADDING PUMPED FIBER LASER

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Summary

A number of double clad (DC) or cladding pumped neodymium doped phosphate glass fibers were recently designed, fabricated and tested at Kigre, Inc. One fiber contains a 50 micron diameter core doped with 10 wt.% Nd₂O₃ and a 0.18 NA. The inner cladding is made from undoped glass with 1.5 x 1.5mm cross-section and exhibits a 0.62 NA with a low index silicone polymer outer cladding. Evaluation of the fiber laser performance in terms of pumping absorption, slope efficiency, gain and losses provides us with feedback that helps us to optimize our computer design predictions and fiber fabrication and testing methods.

Diode Pump

The fiber was pumped with an 808 nm 40W CW fiber coupled diode laser JOLD-40-CAXF from JENOPTIK. A collimated pump beam was focused into fiber's 1.5 x 1.5mm inner cladding. The NA of pump beam is 0.44. The pump laser was run in both pulsed and CW mode. Q-100 9% Nd-doped glass exhibits a very strong, broad absorption band that negates requirements for pump diode wavelength control. A 53cm long Q-100 fiber absorbs ~73% of the pump energy corresponding to -0.1db/cm internal absorption at pump wavelength.

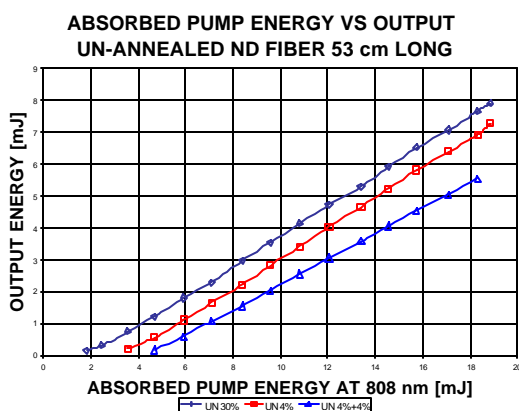


Fig. 1

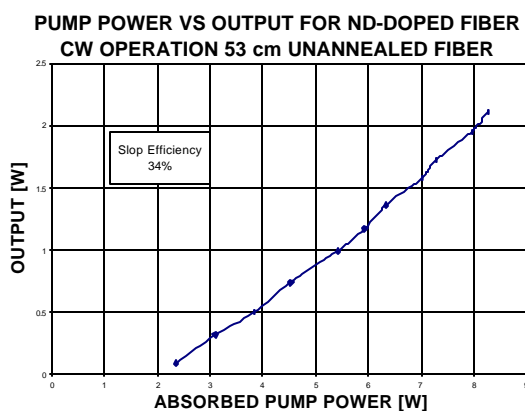


Fig. 2

Fig.1 and 2 show how the absorbed pump energy and power varies with output energy or power for pulse and CW operation. The maximum slope efficiency is about 46.9% with a 30% reflectivity output coupler in pulse pump mode. For CW operation the maximum slope efficiency is about 34% with a 50% reflectivity output coupler. A maximum of 2.1 Watts CW output power was obtained with 8.3 Watts absorbed pumping power using a 50% R output coupler.

Black-body Illuminator

Broadband lamp pumped multimode Nd:phosphate glass fiber bundle lasers have produced high gain and high-average-power performance in previous studies. [1, 2, 3] For this work, we determine the black body-pumping threshold for the 1.5 mm square neodymium double clad fiber. We then acquired/assembled a broadband flash lamp pumping apparatus that generates up to 20 watts per square centimeter of black body radiation. The air-cooled Mdl# 256 SM Spectral Energy Corp. driver and arc-lamp produces >1KW of broad band ultraviolet, visible and near-infrared output power. This output is sent through an aperture and focused down to a 1.5 x 1.5mm beam of ~ 1 watt at the end of the fiber. The apparatus is terminated in a fiber optic connector that is modified to receive a square double clad neodymium fiber.

During our first attempts at broad band pumping, the radiant intensity of the black body source overpowered our detector. We have added a chopper to this system and are currently running test to determine the presence of super fluorescence and/or laser action at 1.05 μ m. Experimental measurements of the output from this black body source indicate that we can generate in excess of 20 watts per square centimeter of pump power. A picture of the fiber laser black body pump experimental station is shown in figure 3 below.



Fig. 3 Dr. Wu and the Black Body Pump Experimental Station

Fiber Losses

Measurements were made to determine the total internal losses in the experimental double clad fiber. The total internal losses are equal to the cladding core interface scatter loss and the glass background loss. Loss measurements of both the fiber preform (before pulling) and the fiber were found to be 0.0058/cm. A curve for each loss measurement against threshold is show in figure 4 and 5 below.

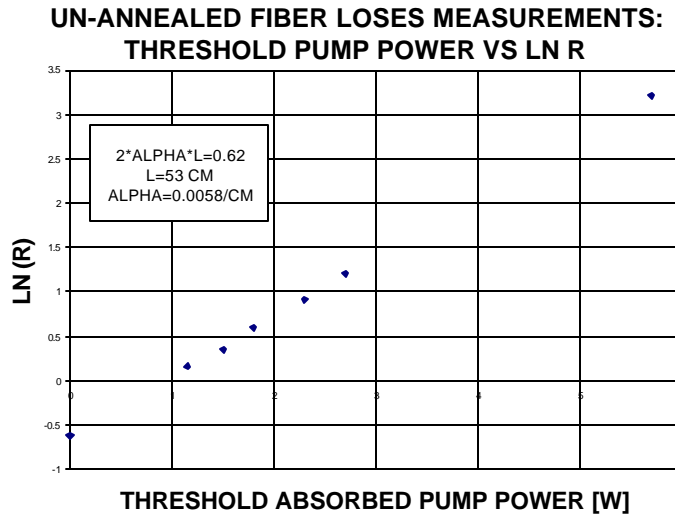


Fig. 4 Fiber Loss Measurements

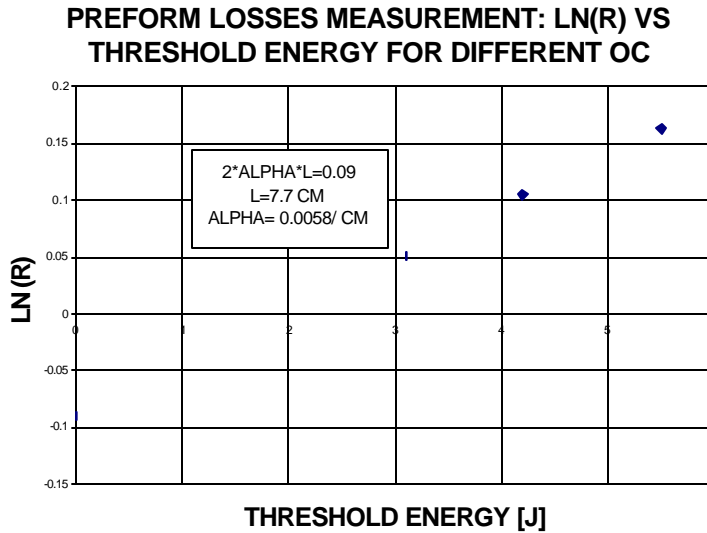


Fig. 5 Preform Loss Measurements

Conclusion

By their nature double clad fiber lasers offer advantages over conventional laser systems due to their ability to incorporate the laser medium and a laser power delivery system into a single element. The long & thin fiber laser shape with a small single mode/low order multimode aperture (~8-40um) provides for efficient heat removal, high laser power densities, and high laser brightness. Double clad fibers and fiber bundles allow for multimode laser or lamp pumping. As seen in this work, there is plenty of room for additional optimization of double clad fiber laser design parameters. Further optimization will include more effective cladding to core ratios, doping concentrations, and pump coupling techniques. In the future, new fiber laser designs and pumping configurations will provide users with low divergence, high brightness, high power laser devices that overcome the serious drawbacks, limitations and deficiencies of conventional laser systems.

References:

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