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New Generation High Power Rare-Earth-Doped Phosphate Glass Fiber and Fiber Laser

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Abstract

High power, high brightness fiber lasers have numerous potential commercial and military applications. These lasers offer unique flexibility as they may be coherently combined to provide a potential multi-kilowatt laser source and integrated delivery system. Fiber lasers with cladding pump designs represent a new generation of diode pumped configurations that are extremely efficient, have single mode output and may be operated with or without active cooling. They have a number of novel or unusual attributes, stemming from the fact that they represent the extreme case of a long gain length thin laser cavity. Reports indicate that over 100 watts of TEMoo CW output power are readily demonstrated from current cladding pumped fiber laser designs. [1,2]

Kigre has invented a new family of Er/Yb/Nd phosphate laser glass materials (designated QX) that promise to facilitate a rapid advancement in fiber laser technology. Phosphate glass Rare-Earth doped fibers exhibit many advantages over Silica or Fluoride base fiber with regard to fiber laser designs. [3,4] A comparison of phosphate glasses with other glasses is presented in Table 1.

Host Material	Rare-Earth Solubility	Up-Conversion	Dopant Level	Gain	Length
Silica	Low	High	<1000ppm	Lower	Long
Fluoride	Middle	High	Middle	Low	Long
Phosphate	High	Lowest	High	High	Short

Table 1. Performance comparison of phosphate laser glass with other glasses.

Phosphate glass offers a great advantage in gain. Table 2. Shows Erbium doped fiber gain measurements comparisons, with pumping at 980nm and 1480nm, made by [5]Harris, [6]Photon-X, [7]NTT Photonics Laboratories, [8]British Telecom and [9]Lucent. [5,6,7,8,9]

980nm pump			1480nm pump	
Silica[9]	**QX/Er[5]**	**Telurite[7]**	**Flouride[8]**	**QX/Er[6]**
1dB/meter	2dB/cm	3.5dB/meter	0.13dB/cm	3 dB/cm

Table 2.

Various parameters, such as core diameter, NA, cross sectional shape of the inner cladding, doping concentration, and energy transfer are considered for these double clad "DC" fiber designs.

Double Clad QX/Er Fiber

Kigre obtained approximately 2dB/cm gain from a 7cm long section of an experimental MIT commissioned double-clad 8-micron core test fiber with a 240 X 300 micron rectangular inner cladding and a 500um outer cladding. A cross section diagram of this fiber is shown in Figure 1.

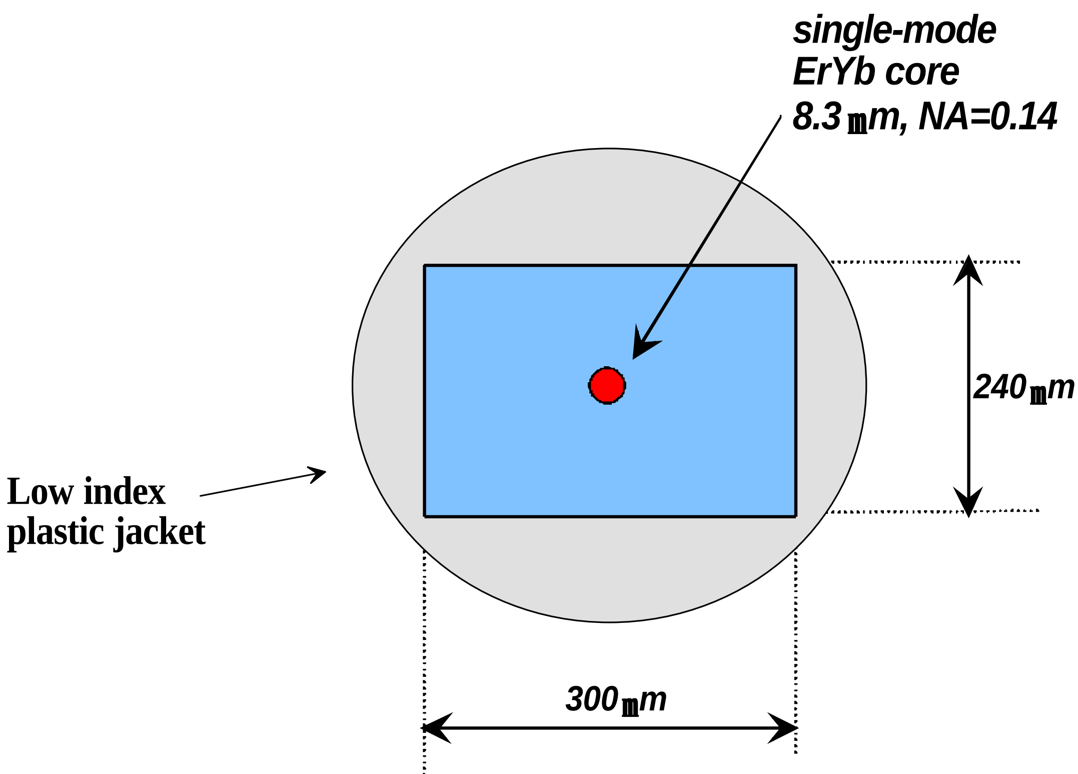

Figure 1. Double-clad QX/Er Glass ErYb Fiber

Researchers at MIT used the experimental set-up shown in Figure 2 to produce fiber performance data. A Polaroid PolyChrome 975nm laser diode pump was launched into the DC QX/Er fiber from a 200-micron core delivery fiber with a 0.22 NA. The launched pump power was measured by placing a core-less fiber into the set-up instead of the double-clad Er:Yb:Glass fiber. The absorbed pump power was calculated from the power leakage measured from the fiber laser and subtracting it from the total launch power value. The 30 cm long double-clad Er:Yb:Glass fiber laser was cleaved on both ends producing a Fresnel reflector laser resonator cavity. The output power at 1.55 micron was measured by inserting a pump-blocking filter before the power meter (92% transmission at 1.55 microns). The total output power was obtained by doubling the output power measured from one end.

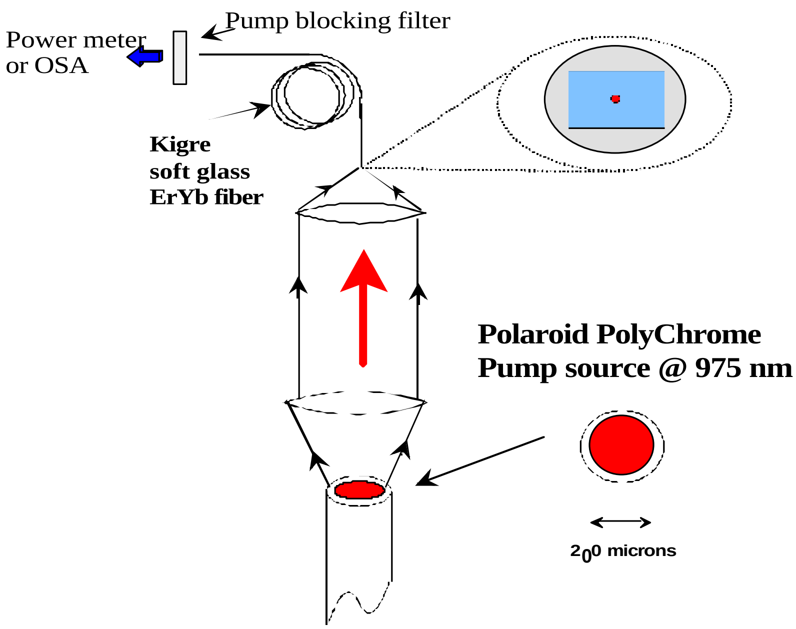

Figure 2. Experimental Set-Up

A fiber fluorescence output spectrum from 1500 to 1600nm was produced with various pump power inputs. (Figure 3) As the pump power is increased, laser threshold is reached, and the relatively flat spectrum changes to show two peaks (1536 and 1544nm). The laser action generated indicates an internal gain of ~ 30dB or ~ 1 dB/cm for the 30 cm long fiber sample employed

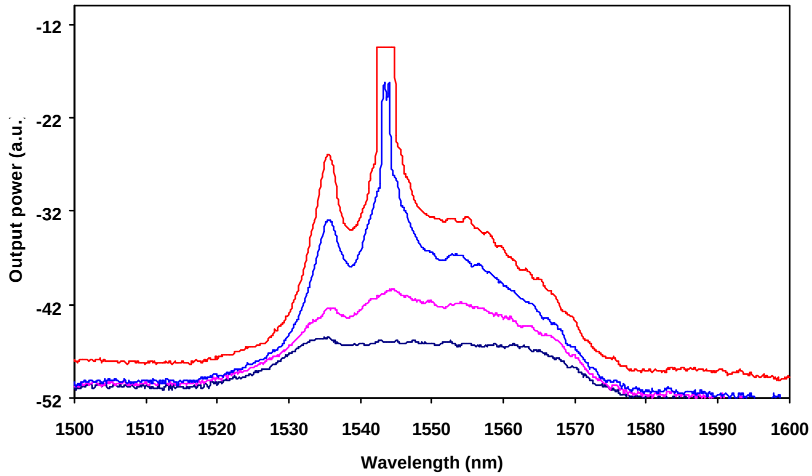

Figure 3. Fluorescence Output Spectrum

A fiber laser performance curve was produced (Figure 4) using a 30cm long sample of the QX/Er DC fiber with Fresnel reflection resonator mirrors. The overall efficiency was found to be ~ 31% and the slope efficiency 47%.

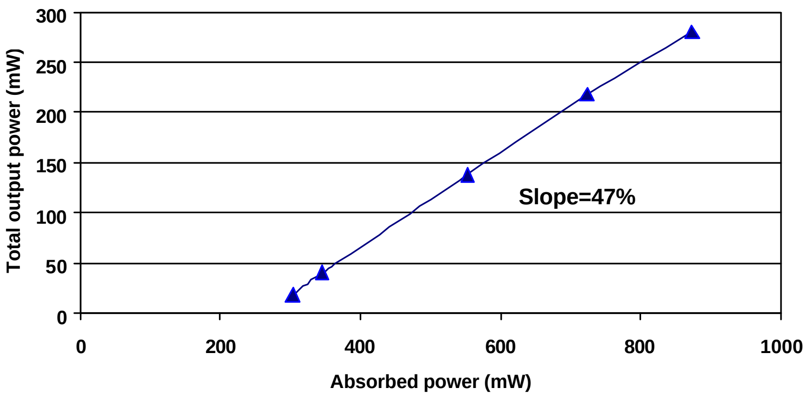

Figure 4. Efficiency Curve

Fiber Preform Laser Testing

Kigre has recently established a new test bed for the evaluation of laser performance for fiber performs. This test bed is intended to provide active laser gain and efficiency data for fiber laser designs in advance of the fiber pulling process. The new test bed uses (2) 20 Watt, 975nm diode arrays in "butterfly" arrangement. Each array is arranged horizontally (180^{o} from each other) on two opposing sides of a 1-3mm diameter x 12mm long clad rod. The rod is a section of a rod-in-tube fiber perform core. An added benefit of the use of this test bed is the acquisition of side pump laser perform performance data.

Initial side pump fiber perform laser data was produced by Jon Dahm of Peak Photonics [11]. A 2mm diameter (600um core) x 14mm long rod section of double clad QX/Er fiber preform was side pumped by a single 35 Watt CW 980nm diode array. The diode and rod were water cooled in a custom head with a 90%/HR 1.54um resonator and a coolant temperature of 22^{o}C. The diode array was optically contacted to the side of the rod. This configuration produced 5 Watts of CW 1.54um output in an asymmetric multimode beam.

Summary

The first double clad (cladding pump) QX/Er 1.54um fiber laser was produced and tested. Initial performance data indicates that high power fiber lasers may be designed and produced to take advantage of high concentration, high gain, phosphate laser glass materials. Samples of this first DC QX/Er fiber are presently being polished and applied with multi-dielectric resonator coatings. These samples are slated for use in future fiber laser optimization studies.

Note: The authors wish to express appreciation to Farhad Hakimi of MIT, Jon Dahm of Peak Photonics and Michael Lange & Ed Bryant of Harris, Corp. for their expertise and technical support of this work.

References

[1] M. Muendel**, "High-Power Fiber Laser Studies at Polaroid Corporation",** SPIE, Vol. 3264, Jan. 1998.

[2] J. Myers**, "Evolutionary Developments in Laser Glass",** American Ceramic Society, Ceramic Transactions Series, Vol. 67, Synthesis and Application of Lanthanide-Doped Materials, pp. 33-47, 1996.

[3] P. Laporta, S. Taccheo, S. Longhi, O. Svelto, C. Svelto**, "Erbium-Ytterbium Microlasers: Optical Properties and Lasing Characteristics",** Optical Matierals 11 pp. 269-288, 1999.

[4] V. Dominic, S. MacCormack, R. Waarts, S. Sanders, S. Bickness, R. Dohle, E. Wolak, P. Yeh, E. Zucker, **"110W Fiber laser",** OSA, (CLEO), Conference on Lasers and Electro-Optics, 1999.

[5] M. Lange, E. Bryant, M. Myers, J. Myers, R. Wu, D. Rhonehouse, "**High Gain Short Length Phosphate Glass Erbium-Doped Fiber Amplifier Material** Submitted to: OSA Optical Fiber Communications (OFC) 2001

[6] Private Communication, Ren Gao, Photon-X, Nalvern, PA 1999.

[7] M. Shimizu**, "Non-Silica_Based Fiber Amplifiers Open New Wavelength Regions for WDM"**, Lightwave, November, 1999.

[8] C. Millar, P. France**, "Diode-Laser Pumped Erbium-Doped Fluorozirconate Fiber Amplifier for the 1530nm Communications Window"**, Electronic Letters, Vol. 26 (10) pp. 634-635, 1990.

[9] P. Becker, N. Olsson, J. Simpson, **"Erbium-Doped Fiber Amplifiers",** Academic Press, Lucent Technologies, 1999.

[10] R. Wu, F. Hakimi, H. Hakimi, J. Myers, M. Myers**, "New Generation High Power Rare-Earth-Doped Glass Fober and Fiber Laser,"** OSA/SPIE, Opto Southeast 2000, Fiber Optics and Optical Communications Technology, Sept. 2000.

[11] Private Communication, Jon Dahm, Peak Photonics, Longmont, CO 2000.