SUBMIT TO: OPTO SOUTHEAST 2000
CONFERENCE :[SE02] Fiber Optics and Optical Communications Technology
SESSION CHAIR: John M. Ballato

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

[a]Ruikun Wu, [b]Farahad Hakimi, [b]Hosain Hakimi, [a]John D. Myers, [a]Michael J. Myers

[a]Kigre, Inc.
100 Marshland Road
Hilton Head Island, SC 29926
Email: kigre@aol.com
Kigre@cs.com
Web Pag:http://www.kigre.com

[b]MIT Lincoln Laboratory
244 Wood Street, D-209
Lexington, MA 02173-9109
hakimi@ll.mit.edu

Key Words: Fiber Laser, Double Clad, Cladding pump, Rare-Earth Doped Fiber

Presentation : Poster Presentation

This work was sponsored under contract F19628-00-C-0002. "Opinions, interpretations, conclusions, and recommendations are those of the author and are not necessarily endorsed by the United States Air Force."

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

[a]Ruikun Wu, [b]Farahad Hakimi, [b]Hosain Hakimi, [a]John D. Myers, [a]Michael J. Myers

[a]**Kigre, Inc.,** 100 Marshland Road, Hilton Head Island, SC 29926
Email: kigre@aol.com, Kigre@cs.com
Web Pag:http://www.kigre.com

[b]**MIT Lincoln Laboratory**
244 Wood Street, D-209, Lexington, MA 02173-9109
hakimi@ll.mit.edu

Abstract

High power fiber lasers have numerous defense applications such as LIDAR, targeting, illumination, infrared countermeasures, directed energy, and isotope separation. High power fiber laser designs now provide potential high brightness, multi-kilowatt laser sources for tactical battlefield applications. Using various double-clad (cladding pumped) structures the next generation of diode pumped solid-state fiber lasers promise to produce efficient, single mode output powers with multimode input and air-cooling. Double-clad fiber lasers have a number of novel or unusual attributes, stemming from the fact that they represent the extreme case of a long, thin laser cavity. Fiber laser single mode output powers of greater than 110 watts have been reported. [1,2]

QX Laser Glass

Kigre has invented a new family of rare earth doped phosphate laser glass materials (designated QX) that promise to facilitate a quantum leap in fiber laser technology. Instead of 20 to 50 meters of fused silica fiber, Fiber lasers made from QX glass may be designed to be less than a few meters long. Table 1. Presents a comparison of phosphate glass with other glasses. Almost every aspect of the phosphate glass material offers an advantage for producing optimized high power fiber lasers. [3,4]

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

Table 1.

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	5 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 15cm 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.

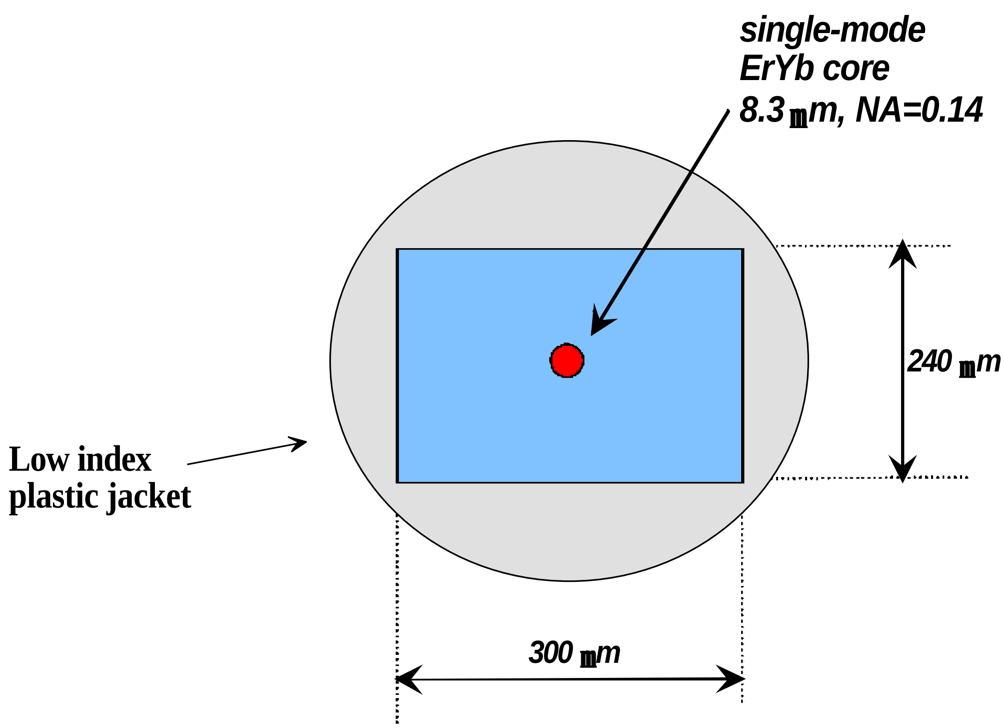

Figure 1 Double-clad QX/Er Glass ErYb Fiber

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. 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.

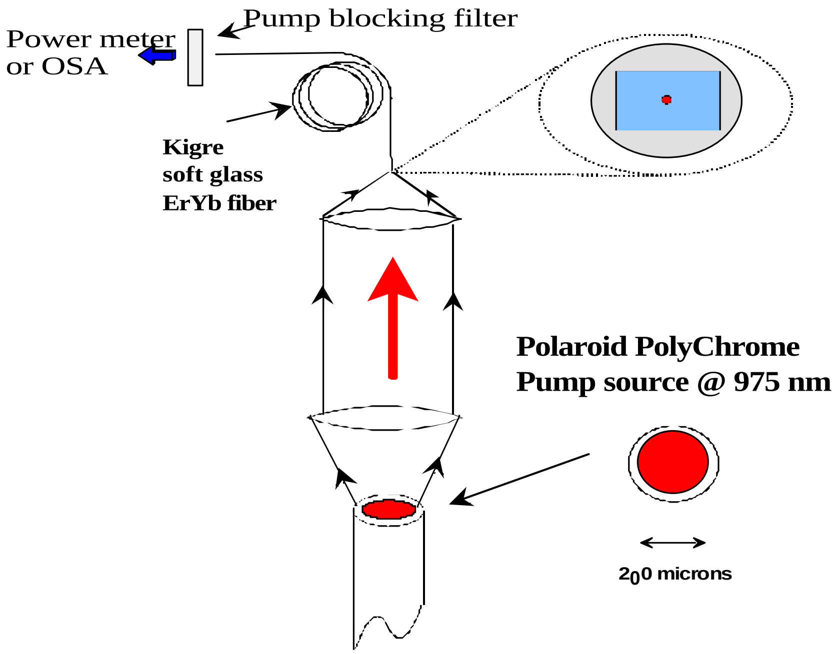

Figure 2. Experimental Set-Up

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

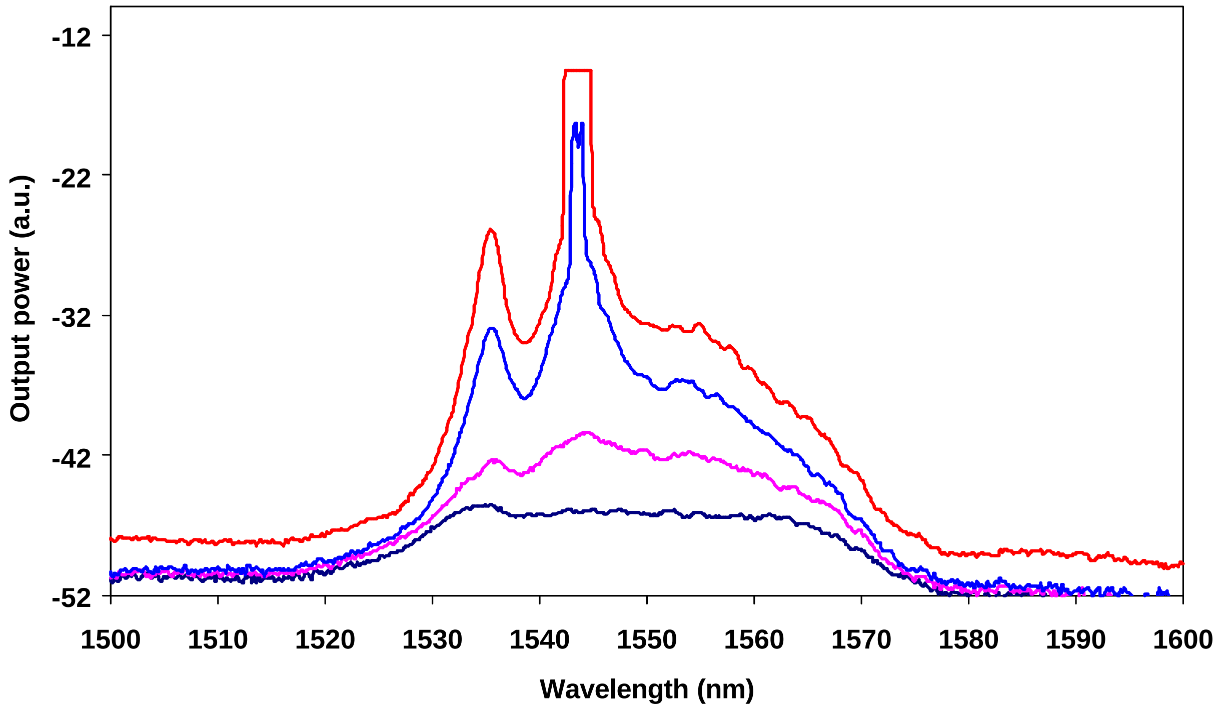

Figure 3. Fluorescence Output Spectrum

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%.

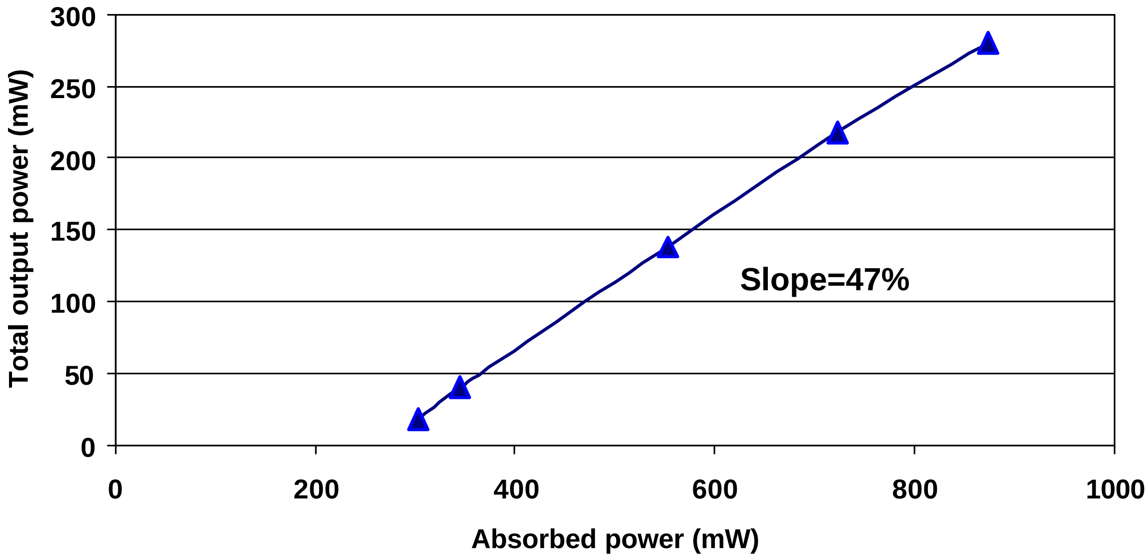

Figure 4. Efficiency Curve

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.

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] Private Communication, Ed Bryant, Harris Corp. Government Communications Systems Division, Melbourne, FL 1999.

[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.