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

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Abstract
Charaterization of a new family of double clad (cladding pumped) phosphate glass fibers is presented. Phosphate glasses are readily pulled into fibers, exhibit high cross section, gain, and rare earth solubility. Phosphate glass fibers are useful in the design of high performance Erbium Doped Fiber Amplifiers, (EDFAs) and high average power fiber lasers.

Introduction
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 pumping. 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]

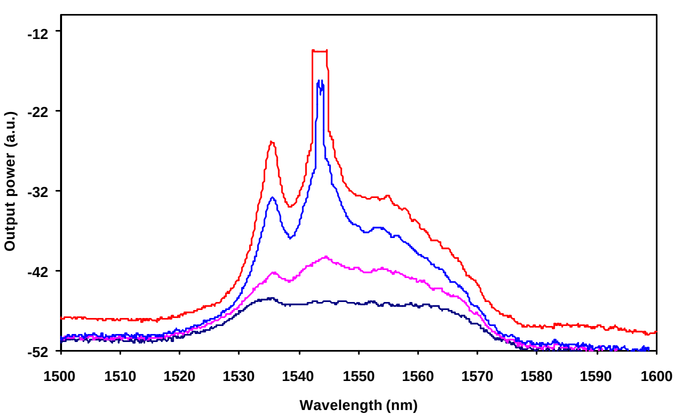
980nm pump			1480nm pump	
Silica[9]	**QX/Er**[5]	**Telurite**[7]	**Flouride**[8]	**QX/Er**[6]
1dB/meter	2dB/cm	3.5dB/meter	0.13dB/cm	5 dB/cm

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. This same fiber was evaluated by researchers at MIT. They used a Polaroid PolyChrome 975nm laser diode pump to pump a the double clad 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.



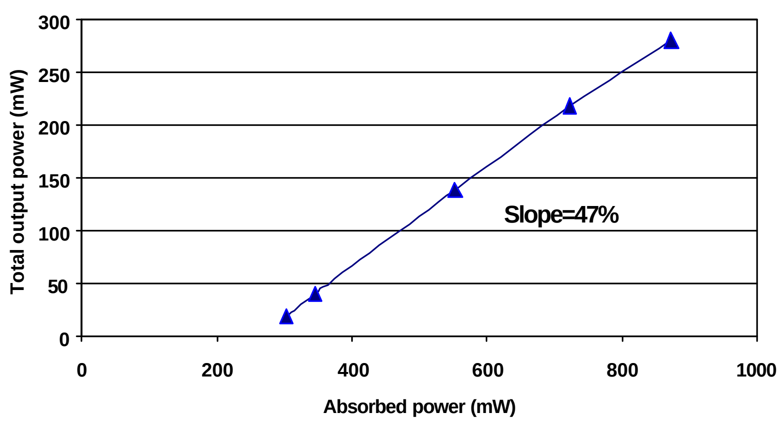


Figure 1. Fluorescence

Figure 2. Efficiency Curve

A fiber fluorescence output spectrum from 1500 to 1600nm was produced with various pump power inputs. (Figure 1) 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

A fiber laser performance curve was produced (Figure 2) using a 30cm long sample of the fiber with Fresnel reflection resonator mirrors. The overall efficiency was found to be ~ 31% and the slope efficiency 47%.

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 double clad 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.

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