High Power (110W), High Efficiency (55%) monolithic FBG based Fiber Laser Operating at 2µm

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Abstract: We report a fiber Bragg grating (FBG) based laser, delivering 110W CW at 2µm with 55% slope efficiency from a conductively cooled Tm-doped silica fiber pumped with 200W of 793nm radiation. The laser operates in a single transverse mode at 2050nm (FWHM ~2nm) independent of the operating power; as determined by the peak reflectivity of the FBG. This demonstration has been made possible by the recent development of true large mode area (LMA) Tm-doped fibers which employ the use of an up-doped pedestal surrounding the rare earth doped core. High reflectivity fiber gratings were written in a matching photosensitive fiber, spliced to the Tm-doped LMA fiber and an end pumped monolithic laser cavity demonstrated.

Recent optimization of high concentration Tm-doped silica fibers has enabled the demonstration of ~65% slope efficiency from a fiber laser operating at around 2µm when pumped at ~790nm, results achieved through the optimization of the cross-relaxation process between adjacent Tm-ions in highly doped fiber[1,2,3]. More recently, this cross-relaxation has also been demonstrated very effectively in soft glasses fibers made from germanate glass[4]. It is encouraging that with appropriate thermal management of the active fiber many of these results have recently begun to approach the 100W CW benchmark. However, to the best of our knowledge these high efficiency Tm-doped fiber lasers have only been demonstrated with the use of free space optical components to form the cavity, with either dielectric mirrors butted to the fiber end[1] or directly deposited onto the fiber end[4]. The use of free space components is not ideal for high power operation due to the increased likelihood of failure. Furthermore the lack of predictable wavelength control associated with the use of broadband mirrors in the fiber laser inevitably leads to changes in the laser operating wavelength with pump/laser power[1]. This is a significant problem in most practical applications where the control of laser wavelength and line-width are critical.

In this paper we demonstrate a high power FBG based laser cavity that utilizes the recent development of a truly large mode area Tm-doped fiber with**out** sacrificing the high slope efficiency[5]. This was achieved by surrounding the relatively high NA Tm-doped core (typically ~0.2NA for a doped core with ~4wt% active oxide) with a pedestal of intermediate refractive index reducing the effective NA of the core to ~0.1. This low NA core can now be engineered to support a few modes rather than the highly multimode core of the traditional step index design, even at core diameters in the order of 20µm. A matching photosensitive fiber with 20µm core diameter (0.06NA) and 400µm clad diameter (0.46NA) was made and fiber Bragg gratings written through side exposure of the fiber with UV light. The fiber was recoated after the gratings were written to allow the high power pump to propagate with low loss through the grating. We used an active fiber length of ~5m and spliced it directly to the high reflectivity grating, with the cavity being defined by the cleaved fiber end (R~4%) and the grating. The schematic of the FBG based laser cavity is shown in figure 2, the pump was a fiber coupled (400um 0.22NA) 200W module,centered at 793nm with ~4nm FWHM.

Figure 1: Schematic of FBG based laser

The slope efficiency of the laser cavity as shown in figure 2 was around 55% and we achieved ~110W output power (after correcting for the Si filter loss at 2µm) from the laser without any sign of roll-off in the slope efficiency, indicating that the laser can readily operate at high output powers. The fiber was wound onto a mandrel of around 12cm diameter so as to facilitate conductive cooling of the fiber. At full power the electrical to optical efficiency of the system was estimated to be ~17%. The output spectrum for the laser is essentially independent of the operating conditions and was centered at 2050nm with a FWHM of 2.1nm and ~2.5nm at 25W and 100W respectively.

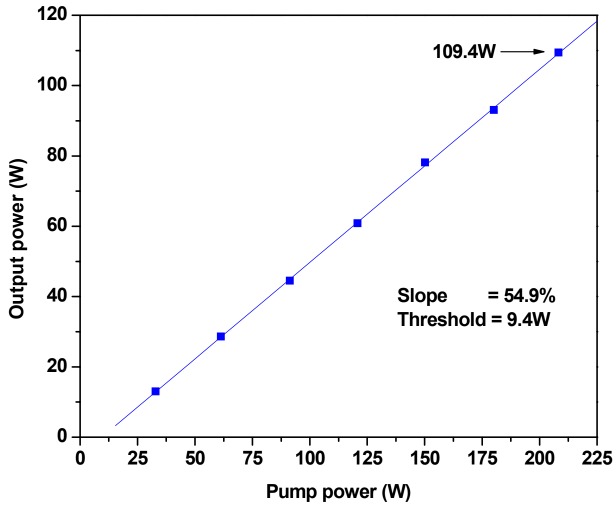

Figure 2: Slope efficiency for the grating based Tm-doped laser

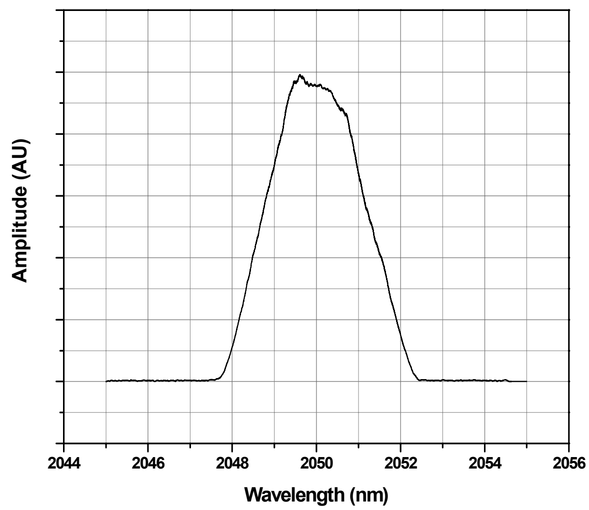

Figure3: Lasing spectrum at 100W

The beam quality from the laser was robustly single transverse mode as shown in figure 4.

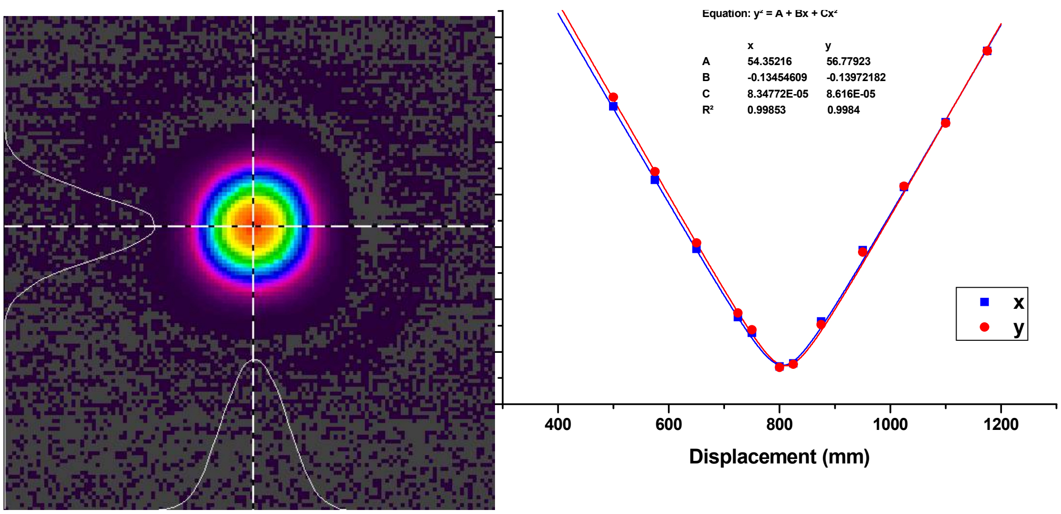

Figure 4: Beam quality data

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