Solutions of kW Continuous-wave All-fiber Laser

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Abstract. Solutions of kW continuous-wave (CW) all-fiber laser are proposed. In our solutions, master oscillator power amplifier (MOPA) configuration is applied. Output power of master oscillator is 10W, and then is amplified to 70W with 1st pre-amplifier and next scaled up to 400W. Finally, 400W fiber laser is used as a basic power unit, and 1000W all-fiber laser can be achieved by means of beam combining with large core double clad fiber (DCF) combiner. In this solution, fiber laser has good stability and reliability for dispersion coupling of pump source and inhibition of photon darkening effect in the fiber. In addition, this solution assures us realize a 1000W all-fiber laser product easily, and the cost is low.

1. Introduction

Fiber laser hold a number of advantages, such as small volume, high efficiency, energy saving and low using cost, etc. It is an ideal light source for industrial applications and be considered as the third generation of the most advanced industrial processing laser and arouses great interest all over the world. In the last decade, output power of fiber lasers increase dramatically. In the laboratory, several kilowatts can be achieved with a single fiber[1] and mature products of kW fiber laser can be offered in the field of industry[2].

In consideration of reliability and maintenance-free, all-fiber laser, which means all parts of the laser are optical fiber components literally is preferred in applications of industry. By now, only IPG company can provide mature product of all-fiber laser exceed 1kW. kW all-fiber laser can be used for laser cutting, laser welding, etc of metal and non-metallic materials as an alternative to conventional high power CO₂ laser and solid-state laser. And applications of it expand to the field of automobile making, shipbuilding and aircraft industry[3, 4], etc.

2. Solutions of kW CW all-fiber laser

Scheme of kW-class fiber laser of IPG company can be seen in the following Figure 1. Pump power of LDs is injected into the Yb-doped double clad fiber (YDCF) with fiber combiners and the laser oscillates within the cavity resonator consists of Fiber Bragg Gratings (FBGs). One of FBGs possesses high reflective (HR) for laser and the other one used as output coupler (OC), which has 4%~10% optical transmissivity for laser.
In this scheme, \((N+1)\times 1\) combiners are employed. Multi-mode fibers of combiners are spliced with LDs to get high pump power and input DCF fibers are spliced with FBGs. Served as cavity resonator, FBGs endure very high power. And above all, insertion loss of signal laser of combiners must be very low, always less than 0.1dB or they will burn out.

Different from this scheme, we present a kW fiber laser with MOPA configuration. In this solution, a 10W master oscillator is employed, and then is amplified to 70W with 1st pre-amplifier and next scaled up to 400W. Finally, 400W fiber laser is used as a basic power unit, and 1000W all-fiber laser can be achieved by means of beam combining with large core double clad fiber (DCF) combiner. Scheme of us can be seen in Figure2 and Figure3.

2.1. 10W Master Oscillator
6/125μm SM-YDCF is used as gain media and FBGs are also inscribed with 6/125μm photosensitive fiber used as the cavity resonator in the master oscillator. Figure4 shows reflection and transmission spectrums of HR FBG, whose reflectivity is higher than 99% for 1064nm. With this configuration, SM-DCF Bragg gratings can be inscribed in China and the cost is much lower than LMA-DCF Bragg gratings.
2.2. 70W Pre-amplifier

10W single mode laser with 1064nm from the master oscillator is then injected into the 12/125\(\mu\)m YDCF with a \((N+1)\times1\) side-coupler. And pump power of LDs can be coupled into the YDCF with multimode pigtails of the \((N+1)\times1\) side-coupler. On the basis of our invented patent, we develop and manufacture side-coupling fiber coupler collaborated with leading domestic fiber-optic enterprises. Coupling efficiency for pump power of the coupler is higher than 90% and signal insertion loss is less than 0.2dB. Moreover, it is worth noting that the cost of it is much lower compared with similar foreign products. Figure 5 shows side-coupler we used.

Figure 4. Spectrum of HR FBG.

![Figure 4](image)

Figure 5. Appearance of side-coupler.

![Figure 5](image)

2.3. 400W Power Amplifier

Similar with the pre-amplifier, another \((N+1)\times1\) side-coupler is used in the power amplifier. Signal of the amplifier is 70W laser from the pre-amplifier with 1064nm. In this stage, output of the laser is scaled to 400W then be used as a power unit in our solutions. Especially, 400W fiber laser can be applied in material processing, such as laser cutting and welding. Figure 6 shows 400W fiber laser of us.
To achieve 400W power unit, a three-stage MOPA configuration is employed. As we know, photo darkening effect of active fiber can not be ignored for high power fiber laser. In our solution, pump powers are dispersed injected into the active fiber and photo darkening effect can be inhibited efficiently, which can assure the unit operates reliably. Furthermore, mode field of the multi-stage can match well each other and this leads its beam quality is better than one-stage fiber laser.

2.4. DCF Combiner
By means of DCF combiner, three power units of 400W fiber laser are combined into 1000W all-fiber laser. Unlike usual combiner, all pigtails of the DCF combiner are double clad fibers, several input ports and one output port. Laser from power unit transmits in the core of input DCFs separately and then combined as one laser beam.

To make the DCF combiner, double clad fiber is corroded and only inner clad and core of the fiber is left. Three fibers have small size core and one has large. Then ends of four such fibers are polished and placed tightly, three fibers with small core in and one fiber with large core out. Joint of fibers is fused and tapered and then recoated. Coupling efficiency of this DCF combiner is always higher than 98% for laser and water cooling must be employed for the combiner during the operation.

3. Conclusion
High power all-fiber laser is a direction of fiber laser and it is the only one mature technology in commercial field. With these solutions, we can realize a 1000W all-fiber laser product easily, and the cost is low. Furthermore, fiber laser based on these solutions has good stability and can be used in industrial laser processing reliably.

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References
[1] Jeong Y, Sahu J K, Payne D N and Nilsson J. 2004 Opt. Express 12 6088-6092
[2] http://www.ipgphotonics.com/products_1micron_lasers_cw_ylr-hpseries.htm
[3] Ozden H. 2007 Welding Journal 5 26-29
[4] Quintino L, Costa A, Miranda R, Yapp D, Kumar V and Kong C J.2007 Materials & Design 28 1231-1237