

4 kW Continuous Wave Fiber Laser

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In recent years, the demand for the continuous wave (CW) fiber lasers of several kilowatts output power is increasing in use for metal materials processing. Fujikura group have all principal technologies required for constituting fiber lasers. We succeeded in commercializing the CW fiber laser of 4 kW output power by using those technologies. Our 4 kW CW fiber laser product has a high tolerance to the backward light reflected from the workpiece due to our own structures, and can provide stable materials processing.

1. Introduction

A fiber laser which employs an ytterbium-doped fiber (YbDF) to oscillate in an infrared region around a wavelength of 1 μm is superior in many aspects such as beam quality, power efficiency and reliability in comparison with conventional solid state lasers. Therefore fiber lasers are spreading rapidly in the field of materials processing such as marking, scribing, welding and cutting. The demand for the continuous wave (CW) fiber lasers of several kilowatts output power is increasing in use for metal materials processing year by year. The market size of the fiber laser grows up more than \$700 million and is expected to grow steadily in the future¹⁾.

Figure 1 shows the basic configuration of a fiber laser. A fiber laser consists of an optical fiber with a core doped with a rare-earth element as the lasing medium, high power laser diodes (LDs) for pumping the rare-earth element in the optical fiber, pump combiners which combine the pump light emitted from the LDs and launching the pump light into the rare-earth element doped optical fiber, and a pair of Fiber Bragg Gratings (FBGs) which have a function of mirrors and compose a resonator. Fujikura group have all principal technologies for constituting fiber lasers such as optical fiber technology, optical fiber components technology, optical fiber splicing technology, and high power LD technology, all of which have been cultivated in the field of optical communication. We have already commercialized high-power pulsed fiber lasers and CW fiber lasers up to 300 W output power by utilizing these technologies²⁾. Subsequently, we succeeded in commercializing a CW fiber laser of 4 kW output power.

In this report, we introduce the characteristics and outstanding features of our 4 kW CW fiber laser.

2. Basic specifications

The configuration of our 4 kW fiber laser is shown in Fig. 2. We realize the high output power of 4 kW by combining laser output from plural fiber laser units using an optical combining device (called the output combiner). Each fiber laser unit oscillates in single-mode and outputs the power of several hundred watts. Since the output combiner is exposed to high optical power, it is important to minimize its insertion loss and improve the heat radiation efficiency. We have developed the output combiner which has our own structure and achieved the low insertion loss of less than 5%. High reliability enough to handle the high output power of 4 kW has also been achieved.

The appearance and specifications of our 4 kW fiber laser product are shown in Fig. 3 and Table 1, respectively. Our fiber laser product provides the nominal output power of 4 kW at the wavelength of 1080 nm. Beam Parameter Product (BPP) is less than 2.5 mm mrad, which is enough to obtain the good processing quality. The cabinet has a dust-proof and waterproof structure which satisfies IEC IP54, and can support installation in various environment.

Figure 4 shows the output characteristics of our 4 kW CW fiber laser. The conversion efficiency (Wall Plug Efficiency) of more than 26% is achieved as the whole fiber laser equipment, which suggests that the fiber laser is superior to the conventional solid-state laser in power-saving performance.

Redundancy is given to pump LDs currently used, and it is designed so that a fiber laser's nominal output power can be obtained by driving pump LDs of a redundant part when the pump LD output has declined. This has secured the longer operating life of the fiber laser as a system.

3. High power technology of fiber laser

When using the kilowatt output fiber laser for materials processing, there are some issues which should

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Panel 1. Abbreviations, Acronyms, and Terms.

BPP—Beam Parameter Products

It is defined as a product of the radius of beam waist and the half width at half maximum of the divergence angle of a beam. A unit is denoted by mm·mrad. It is used when evaluating a beam quality of the laser output.

FBG—Fiber Bragg Grating

An optical fiber component having a periodically modulated refractive-index region longitudinally in the core of an optical fiber. The structure gives FBG the function of reflecting the light of a specific wavelength.

be solved for realizing good processing. We achieved solutions to these issues by utilizing our abundant platform technologies.

In this chapter, typical issues which a fiber laser encounters, and our approach to solve them are introduced.

3.1 Photodarkening

A photodarkening (PD) is the phenomenon which is produced under an extremely high level of pumping in the core of YbDF. Defects are generated in the transparent glass core by strong light and make it opaque. As a result, the optical loss is increased. Therefore the PD is a serious issue for a high power fiber laser.

It was known that suppression of clustering of Yb ions in the core of the YbDF is effective to reduce PD³⁾. We have reported that aluminum co-doping in the core of the Yb-doped fiber is very effective to suppress clustering of Yb ions⁴⁾. Subsequently, we have continued to study the mechanism of PD phenomenon and succeeded in complete suppression of PD.

Figure 5 shows the result of PD in two types of Yb-doped fiber lasers (YbDFL). In this experiment, the power density of incidence pump light is raised from the actual operating condition in order to observe the influence of PD in a short time. The power degradation caused by the PD appeared and output power declined to 10% or less in the conventional YbDFL. On the other hand, there is no power degradation in the YbDFL which employs the PD suppression technique.

All kinds of our fiber laser products adopt this PD suppression technique.

3.2 Tolerance to the back reflection from the work-piece

It has been pointed out that fiber laser has the poor tolerance to the light reflected from the workpiece due to its own structure. A part of the reflected light is inputted into the core of the output fiber and goes back to the YbDF. Then the backward light is amplified again in the YbDF and its power level becomes high. The amplified backward light which leaks into the cladding layer at the splice point reaches to pump LDs and gives the serious damage to them.

We have developed a new pump combiner which can prevent the backward light inputting into the pump port of the combiner by our own structure and protection of the LDs has been achieved.

Table 1. Specifications of 4 kW CW fiber laser product.

Item	Specifications
Center Wavelength	1080 nm (Typ.)
Output Power	4 kW
BPP	≤ 2.5 mm mrad
Feed Fiber Core Diameter	50 μm
Stability	< ±2 %
Modulation frequency	10 kHz max.
Power source	200 V, 3P + PE, 50/60 Hz
Cooling	Water-cooled
Dimensions	W 690 x D 1200 x H 1570 mm

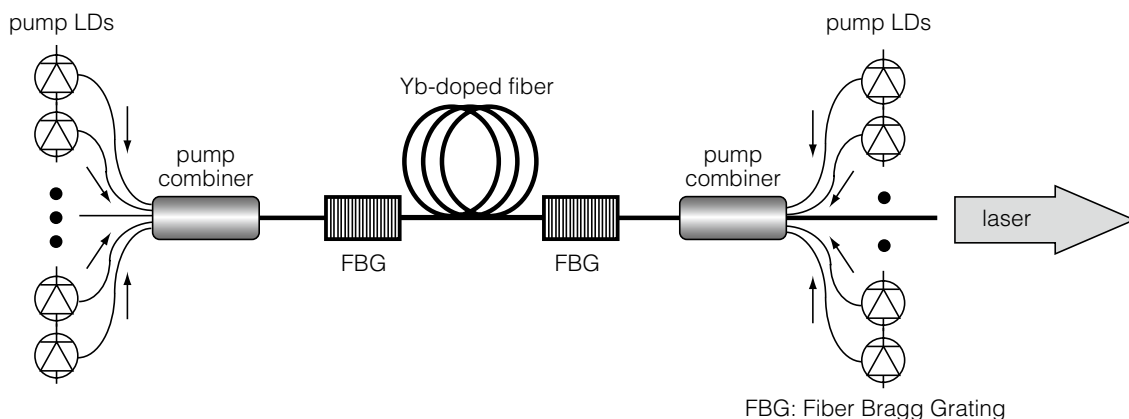


Fig. 1. Basic configuration of fiber laser.

3.3 Output power instability in processing

Another problem which the reflected light from the workpiece causes is the output power instability. The backward light has a bad influence on the oscillation state of the laser and makes it unstable. As a result, stable processing cannot be realized.

We have succeeded in inhibiting the influence of the backward light and obtained a good output power stability by optimizing structural parameters of the optical fiber.

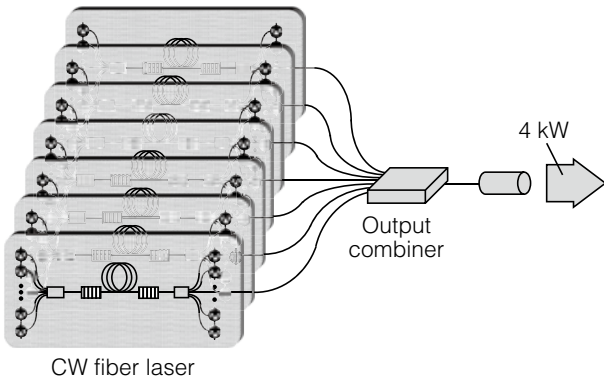


Fig. 2. Configuration of 4 kW CW fiber laser.



Fig. 3. Appearance of 4 kW CW fiber laser product.

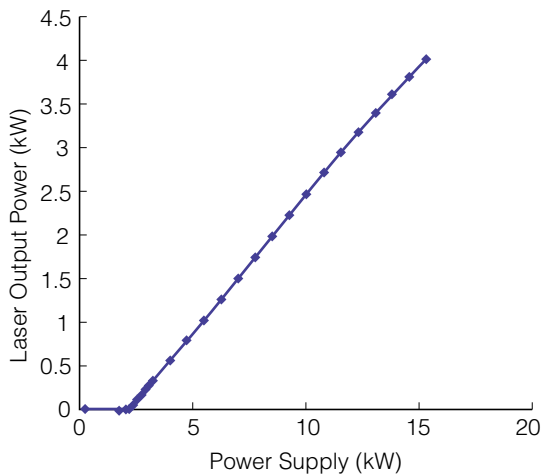


Fig. 4. Output characteristics of 4 kW CW fiber laser.

Figure 6 shows the time variations of output power level and backward light level. It is observed that the output power level is also changed at the same time the backward light arises in the conventional fiber la-

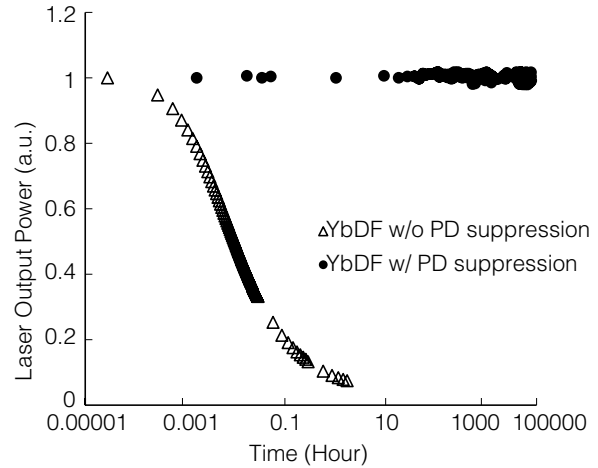
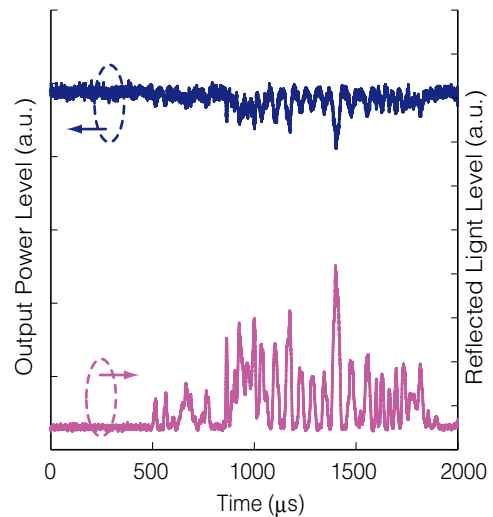
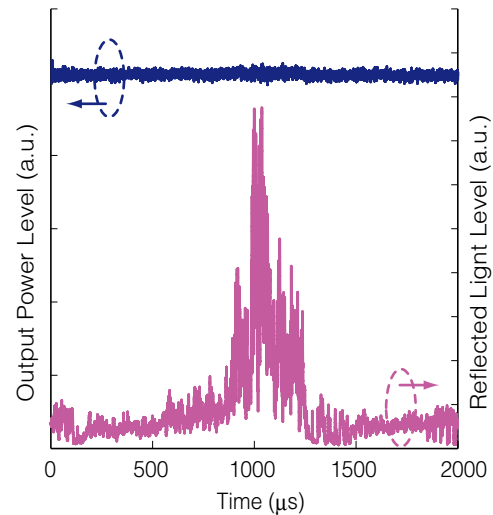


Fig. 5. Suppression of PD



(a) Conventional Fiber Laser



(b) Fujikura's Fiber Laser

Fig. 6. Output power stability

Table 2. Examples of processing

Processing	material	thickness (mm)	Laser Output Power (kW)	processing speed (mm/s)
Cutting	ceramic	1.5	2.5	80
	CFPR	0.6	1	100
	SS400	16	2	12
	copper	3	2	33
	copper	3	4	100
	copper	4	3	30
	copper	5	3.5	20
	brass	5	3	20
Butt Welding	SPCC	3	3	33
	copper	3	3	5

ser. In our fiber laser which inhibited the influence of backward light, however, the output power level is stable even in the existence of the backward light.

4. Examples of processing

Examples of metals processing performed using our 4 kW output CW fiber laser are shown in Table 2. We have carried out the processing experiments using many kinds of materials and confirmed that our fiber laser has sufficient performance for the metals processing. Moreover, cutting processing of the copper plate which is high reflective material can be realized without leaning a laser processing head due to its high reflected light tolerance. Improvement of the processing speed, the increase of plate thickness which can be cut, and the increase of material kinds which can be processed will be expected by performing more experiments using our fiber laser.

5. Conclusion

We have introduced the basic performance of our 4 kW CW fiber laser which succeeded in commercial

production. Our specific technology employed in the laser is also described. Our 4 kW CW fiber laser can be realized by utilizing optical fiber technology which is a strong point of Fujikura. We will contribute to industries mainly for creative and sophisticated manufacturing by introducing our technologies into fiber laser products.

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