808-nm fiber coupled module with a CW output power up to 130 W

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A fiber coupled module is fabricated with integrating the emitting light from four laser diode bars into multimode fiber bundle. The continuous wave (CW) output power of the module is about 130 W with a coupling efficiency of around 80%. The output power is very stable after the temperature cycling and vibration test. No apparent power decrease has been observed as the device working continuously for 500 h.

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High power laser diode bars become more and more important in industrial and medical applications. Because of the characteristic merits of fiber, it is often necessary to couple the output light of laser diode bars into multimode optical fibers[1]. From the application's point of view, high laser power and low price are in demand. Nowadays, the output power can nearly satisfy the needs. However, the cost is the biggest obstacle for fiber coupled laser diode bars in industry[2].

Because the output radiation produced by a laser diode bar is highly divergent and astigmatic, it has been problematic to couple the radiation into optical fiber efficiently. In general, there are two methods to couple the output radiation of a laser diode bar into multimode optical fibers. One employs microoptics to couple the emitting light of a laser diode bar into single fiber. Using this method the resulted fiber output is brighter since the total emission area is smaller, but the microoptics used in the coupling systems is complicated and expensive[3−5]. The other uses a multimode optical fiber as a collimator to couple the light of a laser diode bar into fiber array bundle. The output spot size is larger than that of the former one, but the coupling system is easier and cheaper. Therefore it is more often used in practical applications. Using this method we have obtained a laser module with the power of 30 W from a 1-cm laser diode bar with 19 stripes with 150-μm-aperture spaced on 500 μm centers[6]. An output power of 60 W has also been achieved with integrating two laser diode bars lately[7].

In this paper, we report that four laser diodes bars have been combined together with a continuous wave (CW) output power up to 130 W. A high power laser diode bar is a monolithic linear array of semiconductor laser. It usually consists of 19 broad area emitting apertures electrically connected in parallel; the area of each aperture is about 1×150 (μm). Since the width of the active layer of a stripe (150 μm) is much larger than the depth of the active layer (1 μm), the far-field pattern of the single stripe of a laser diode bar exhibits a relatively close resemblance to Gaussians. The cross section of the beam is elliptical. The numerical apertures (NAs) of the light cone are different in different directions. The beam divergence angles (full-width at half maximum (FWHM)) are about $30° - 40°$ (NA: $0.26 - 0.34$) in fast axis perpendicular to the junction and $3° - 8°$ (NA: $0.03 - 0.07$) in slow axis parallel to the junction, respectively. Since the beam divergence angle in slow axis is very small and much less than that in fast axis, it is not necessary to collimate the beam in the slow axis. For the fast axis, a multimode optical fiber (NA = 0.11) of 140-μm diameter has been used as a cylindrical microlens to collimate the emissions of the laser diode bar in fast axis. The distance between the laser diode bar and the microlens is about 35 μm. The beam divergence angle after collimation is 2.6° in fast axis for a single bar[8].

In this work, each laser diode bar (operating wavelength is 808 nm) has 19 stripes with 150-μm aperture spaced on 500 μm centers. Figure 1 shows a schematic diagram of the coupling system with four bars. The CW operating output power of a single bar is 40 W before coupling.

The number of the fibers aligned to make up of the fiber array equals the number of the emitter regions of the laser diode bars. So the radiation from individual emitters is optically coupled into individual ones of fiber array. The diameters of the core and the cladding of each fiber in the fiber array are 200 and 220 μm respectively. The NA of the multimode fiber is 0.11.

To obtain high power output, the question is how to combine more submodules together, since the output of

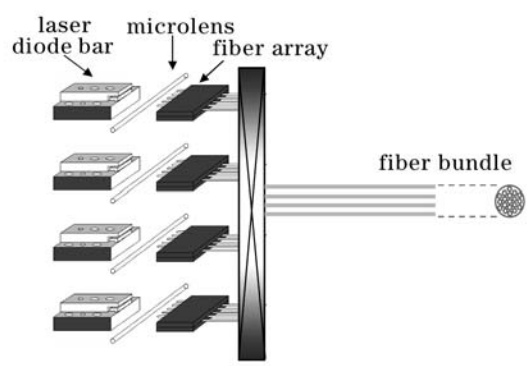

Fig. 1. Schematic diagram of the coupling system with four bars.

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a single module is only 30 W. In this experiment, output fibers from each submodule were glued together with optical glue, which has high thermal conductivity. Figure 2 shows an optical image of a typical system combining 4 coupling submodules. The total diameter of the fiber bundle is 2.4 mm. The output power at the end of fiber of the module is 130 W. No apparent power decrease has been observed as a device working for 500 h continuously. The overall coupling efficiency for four bars is more than 80%. To improve the coupling efficiency, antireflection coatings on the microlens and the butt coupled end of the fiber array are under investigating.

To verify the stability of the four-bar module, the whole devices have been tested under temperature cycling and vibration at different frequencies. With temperature cycling from −10 to 70 °C, the change of output power is less than 3% after the temperature cycling test. The vibration test has been performed 4 times along each direction of x, y, and z, each time for 4 minutes. The frequency varies from 10 to 2000 Hz with an acceleration of 196 m/s^2. To protect the optical fibers, the fibers and the package were mounted strictly together. The output

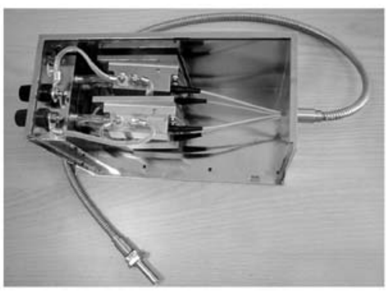

Fig. 2. Photograph of combining 4 coupling submodules.

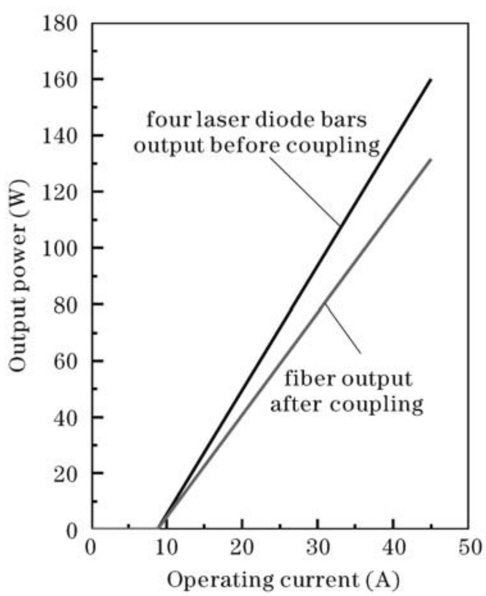

Fig. 3. Comparison of P-I properties between before and after fiber coupling.

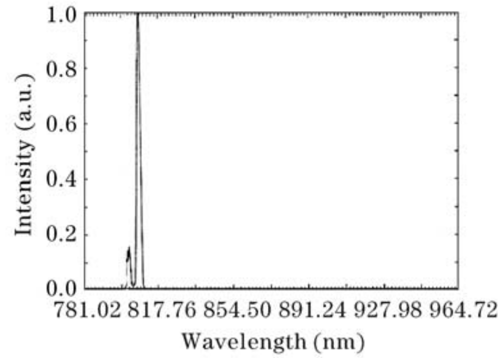

Fig. 4. Spectrum of 808-nm fiber coupled module with a CW output power up to 130 W.

power variation is less than 5% and no fiber damage has been observed after the vibration test.

Figures 3 and 4 show comparison of P-I properties and the spectrum of the coupling laser diode module, respectively. The maximum output power is 131.6 W with an injection current of 45 A, and the central wavelength is 807.58 nm.

In conclusion, a piece of multimode optical fiber is used as an inexpensive microlens to collimate the output radiation of a single laser diode bar in the high NA direction. For each submodule, the emissions from a 1-cm laser diode bar with 19 stripes with 150-μm aperture spaced on 500 μm centers are coupled into a multimode fiber array. Combining 4 coupling submodules, we obtain 130-W CW output power, which shows a very good stability after temperature cycling and vibration tests.

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