Passive alignment method of laser diode and waveguide device for fabricating SHG laser module

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Abstract

We demonstrate a new assembly method that realizes high coupling efficiency of a laser beam and a channel waveguide device. We adopted a passive alignment method[1] for fabricating an SHG laser module that consists of a laser diode and an SHG device with a channel waveguide. Here, we propose a new adjustment method that uses spacers to adjust the vertical position of the SHG device. We examined the potential for automatic assembly of the SHG laser module by detection of alignment markers formed on the laser diode and the SHG device. High coupling efficiency was realized by this proposed passive alignment method.

1. Introduction

There is growing demand for shorter-wavelength coherent light sources for high-density optical disk systems. Frequency doubling of a laser diode using a second harmonic generation (SHG) waveguide device is an important technique for realizing a compact blue-violet light source[2].

Figure 1 shows the construction of an SHG laser module, which consists of a laser diode and SHG device. The laser diode and SHG device are mounted on a Si sub-mount. The volume of the SHG laser is 0.1cc[3]. The laser beam（λ =820nm） is coupled to the waveguide of the SHG device. The coupled beam is translated into blue-violet light（λ =410nm） by the SHG device. Because the output light intensity is proportional to square of the coupled infrared light, it is important to achieve high coupling efficiency between the laser beam and the waveguide of the SHG device.

In the FTTH (Fiber to the Home) module, accurate alignment has been established by using a V groove formed on the surface of a Si or SiO_2 glass sub-mount. The optical fiber is held in the optimal horizontal and vertical position by the V groove. However, when assembling planer channel waveguide devices such as SHG devices, optical modulators and parametric oscillators, there is no set positioning method on the Si sub-mount. Therefore, it is necessary to establish a new assembly method for alignment of channel waveguide devices.

In this letter, we calculate the accuracy of the alignment and propose a new assembly method for the channel waveguide device. A high coupling efficiency is realized by adopting a passive alignment method that uses the image processing to determine the horizontal position of the SHG device and the spacers to adjust the vertical position of the SHG device.

2. Degree of tolerance of the optical coupling

The tolerance of the optical coupling was calculated to identify the degree of accuracy needed for the alignment. Figure 2(a) shows the tolerance of the optical coupling efficiency for each alignment direction. The line is calculated value by using the spot size of the waveguide and laser beam. The spot size of the laser beam is 1.5 $\times$3μm and that of the waveguide is 2.5$\times$3.5μm as shown in Fig. 2(b). The tolerance was examined for a maximum coupling efficiency of over 90% in each direction. The tolerance of the alignment was as described below.

X direction: $<\pm$0.5μm, Y direction: $<\pm$0.5μm, Z direction: $<\pm$0.3μm.

Very accurate alignment is required to achieve high coupling efficiency. We thought that using the image

processing technique[1] and the high-precision pulse stage would control the horizontal (XY plane) position of the SHG device. Alignment in the vertical direction is especially difficult because of the elliptical mode profile of the laser beam and the waveguide. The use of thin-film deposited on the SHG device was proposed for controlling the height of waveguide in the SHG device[4]. However, extreme control of the thickness of the thin-film was difficult. We had to consider the new assembly process that could control the vertical location of the SHG device extremely.

3. Experiments & results

In the manufacturing process of the SHG laser module, the laser diode is bonded onto a Si sub-mount. The SHG device is then assembled on this Si sub-mount. However, when assembling the SHG waveguide device, there is no established positioning method. We thus propose a new alignment method for locating the horizontal and the vertical position of the SHG device.

3-1. Alignment in the horizontal direction

The horizontal location of the SHG device is determined using an image processing technique. Markers are formed on the surface of the SHG device and the laser diode to identify the position of each device. The markers are monitored underneath the Si sub-mount by using an infrared vidicon camera as shown in Fig. 3(a). Figure 3 (b) shows the monitored image of the SHG device and the laser diode. The horizontal position of the SHG device is determined based on the position of the laser diode. This makes it less important to align the horizontal position of the laser diode.

The distance between the SHG device and the laser diode is determined by detecting the edge of each device (Fig. 4(a)). The SHG device is then moved by the required distance. The target interval in this test was under 1 micrometer. The location of the side direction (Y direction in Fig. 1) of the SHG device is determined by detecting the markers that are formed on the laser diode and the SHG device (Fig. 4 (b)). The SHG device is moved to align the centerline of the markers on the laser diode with the centerline of the markers of the SHG device. Using the same mask for the same process forms the markers on both the SHG device and the waveguide. So the location of the markers of the SHG device and the wavegide is tightly controlled. By using image processing, the horizontal location of the SHG device was limited to within $\pm 0.5\,\mu m$.

3-2. Alignment in the vertical direction

Alignment of the vertical direction is very accurate. The vertical position of the laser diode and the SHG device must be accurately controlled in order to realize a high coupling efficiency.

The distance between the emitting point of the laser beam and the surface is tightly controlled when the laser diode is fabricated. So the vertical position of the laser diode is determined by controlling the thickness of the solder that provides the connection material for the laser diode. The thickness of the solder is determined by controlling the temperature of the heater and the downward pressure on the laser diode while the laser diode is being bonded to the Si sub-mount. The thickness of the solder was accurate to within $\pm 0.2\,\mu m$.

As a method of controlling the vertical position of the SHG device, we propose a new assembly method using spacers as shown in Fig. 5. The spacers used in this experiment consisted of SiO_2. The size of the spacers was closely controlled, with the difference kept to within $\pm 0.1\,\mu m$. By mixing the spacers in an adhesive, it is possible to simultaneously achieve the secure attachment of the SHG device and to easily determine the space between the Si sub-mount. The ratio of the spacers to the adhesive was adjusted and the SHG device was assembled on the Si sub-mount.

Figure 6 shows the space between the SHG device and the Si sub-mount after assembling the SHG device. Using spacers allows very precise control of the space between the SHG device and the Si sub-mount. This data indicates that our proposed method is very effective for adjusting the vertical position of the SHG device since the space between the SHG device and the Si sub-mount was accurate to within $\pm 0.1\,\mu m$.

After the examination, as shown in Table 1, the target was realized in every direction. As a result, coupling efficiency for a maximum coupling efficiency of over 70% was achieved.

Table1.Accuracy of assembly

Direction	Target	Result
X	±0.5μm	±0.5μm
Y	±0.5μm	±0.5μm
Z	±0.4μm	±0.3μm

4. Summary

An alignment method employing the image processing to determine the horizontal position of the SHG device, combined with spacers to set the vertical position of the SHG device was proposed. A study of this system's applicability to automatic assembly was also carried out. The vertical position of the laser diode was adjusted by controlling the thickness of solder and that of the SHG device was extremely accurately set by the use of spacers. Horizontal position of the SHG device was determined accurately using the image processing. A high coupling efficiency for a maximum coupling efficiency of over 70% was realized. Our results indicate that this alignment method promises to be effective for the assembly of channel waveguide devices and is readily applicable for use in mass production.

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Reference

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2) Y.Kitaoka et al., The Review of Laser Engineering,26,256-260(1998)
3) Y.Kitaoka et al., ISOM/ODS'99 Technical Digest, 240(1999)
4) Y.Kitaoka et al., Jpn.J.Appl.phys.Vol.39(2000)pp.3416-3418

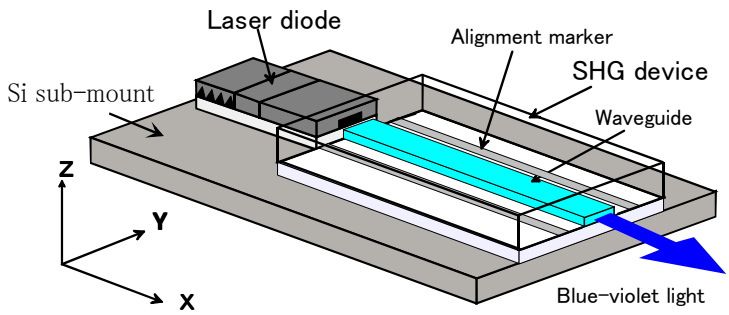
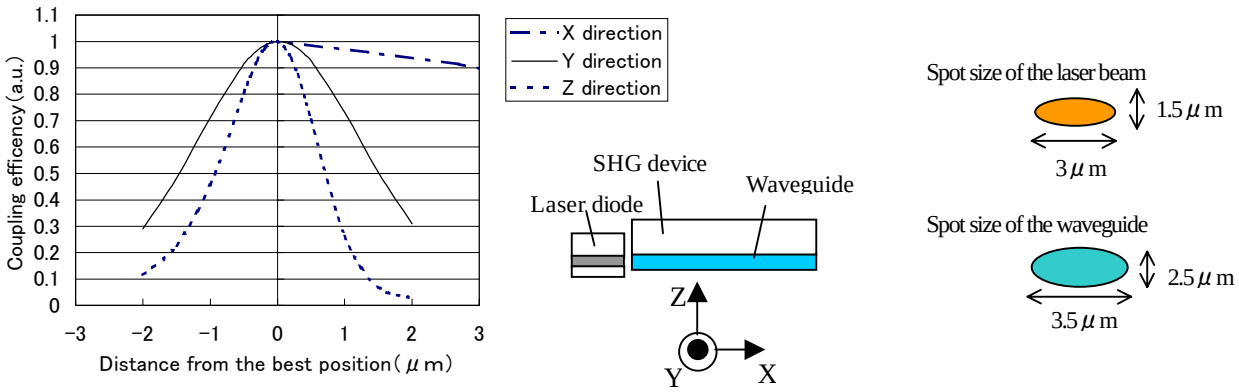
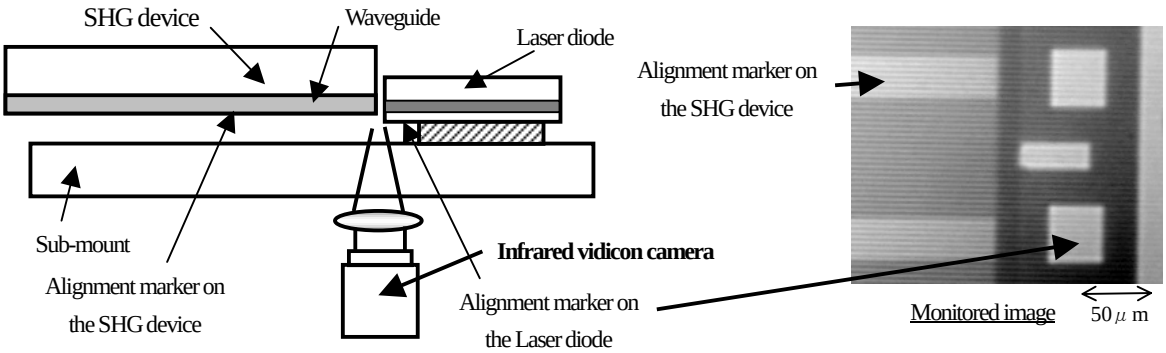


Fig.1 Construction of an SHG laser module



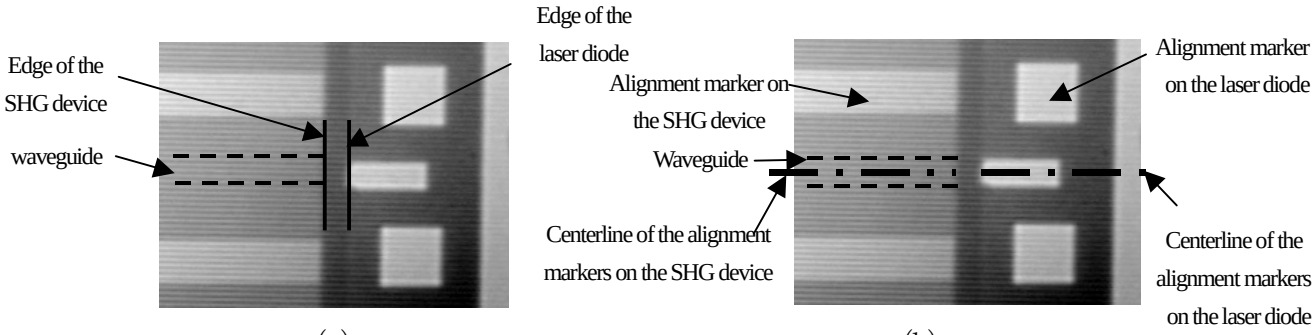
(a) (b)

Fig.2 Tolerance of the optical coupling efficiency for each alignment direction.
(a) Tolerance of the optical coupling efficiency, (b) Spot size of the laser beam and the waveguide.



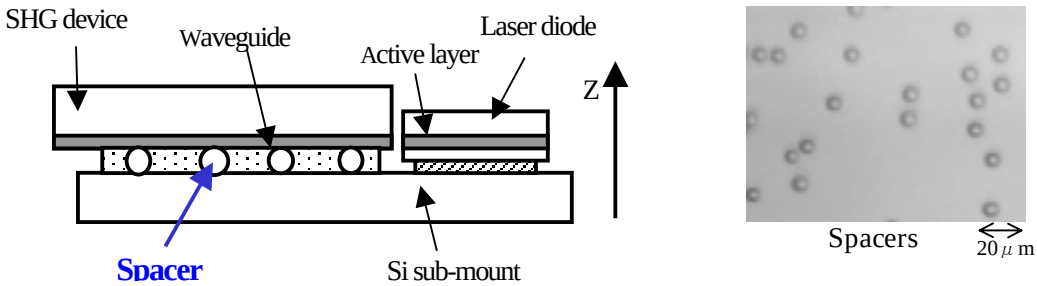
(a) (b)

Fig.3 Monitoring method of the alignment markers. (a) Monitoring method, (b) Monitored image.



(a) (b)

Fig.4 Alignment method in the horizontal direction of the SHG device.
(a) Alignment in the X direction, (b) Alignment in the Y direction.



(a) (b)

Fig.5 Adjustment method of the vertical position using the spacers.
(a) Cross-section, (b) spacers

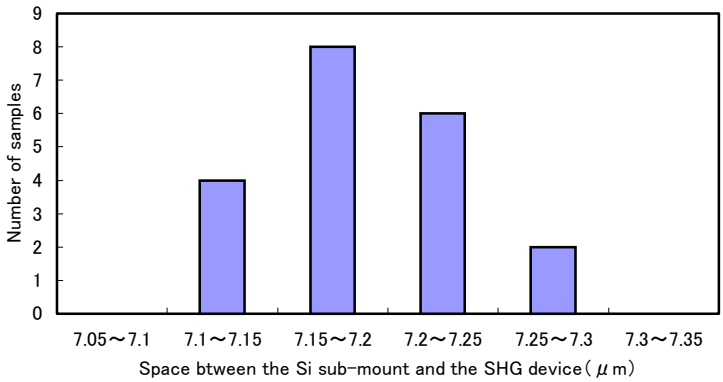


Fig.6 Measurement result of space between the SHG device and the Si sub-mount after assembling the SHG device.