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A new beam parameter product for the collimating and focusing lenses' impact on semiconductor laser

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ABSTRACT

The M^2 factor and other parameters often used in evaluating the beam quality of lasers are not sufficient. Based on the beam characteristics of semiconductor laser, the paper presents a new expression for the beam quality on semiconductor laser. The new beam quality factor can not only evaluate the beam quality of the semiconductor laser but also evaluate the beam quality of the semiconductor laser chips via collimating and focusing lenses. The results give us grounds to make the following conclusions: the new beam parameter product succeeds in its universality and adaptability in collimating and focusing lenses of a multi-emitter semiconductor laser made by stacking several signal emitter chips.

1. Introduction

It is very important and useful to study the beam quality factor of semiconductor lasers. Many methods are taken, for example, the focus spot size, the far-field divergence angle, the times diffraction limited factor β, the beam parameter products (BPP) and the factor M^2. None of them can evaluate the beam quality of the semiconductor lasers adequately because the different definitions and methods give different results [1]. Therefore, it is very important and useful to study the beam quality factor of lasers [2,3].

Multi-emitter semiconductor laser chips [4,5] have been extensively applicated because of the most reliable and the lowest cost technology. Beam quality has an important influence and much of the literature has discussed it [6–8]. We have studied that the beam quality factor M_q^2 succeeds in its universality and adaptability for the semiconductor laser in the literature [9]. In this paper, the beam quality factor M_q^2 take into account the effect of collimating and focusing lenses of a multi-emitter semiconductor laser made by stacking several signal emitter chips.

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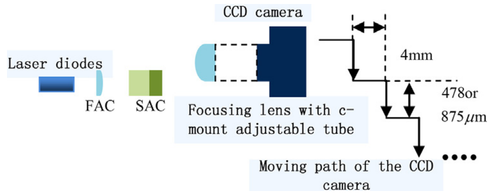

Fig. 1. Approach to emulate stacking a plurality of diode laser chips.

Table 1
Measurements and calculations for 6 combined beams using an 1100 μm FAC ($N_\perp = 6$, $N_{//} = 1$, $A_s = 0$).

Item		Measurement	Calculation	Difference (%)
Focusing lens of EFL = 100.1 mm	$L_\perp$ (μm)	154.0	145.4	5.9
	$L_{//}$ (μm)	726.0	777.5	6.6
	$N_\perp \cdot \theta_\perp$(mrad)	5.5	5.5	0.3
	$N_{//} \cdot \theta_{//}$(mrad)	0.5	0.5	2.1
	$M_q^2(mm \cdot mrad)$	6.9	6.9	0.6
Focusing lens of EFL = 49.8 mm	$L_\perp$ (μm)	79.2	72.7	8.9
	$L_{//}$ (μm)	376.2	388.7	3.2
	$N_\perp \cdot \theta_\perp$(mrad)	11.1	11	0.3
	$N_{//} \cdot \theta_{//}$(mrad)	0.9	1.0	2.1
	$M_q^2(mm \cdot mrad)$	14.4	13.9	3.8
Focusing lens of EFL = 8 mm	$L_\perp$ (μm)	13.2	11.6	13.8
	$L_{//}$ (μm)	61.6	62.2	1.0
	$N_\perp \cdot \theta_\perp$(mrad)	69.0	68.8	0.3
	$N_{//} \cdot \theta_{//}$(mrad)	5.9	6.0	2.1
	$M_q^2(mm \cdot mrad)$	92.1	85.8	7.4

2. The new beam parameter product

We should use the beam quality factor M_q^2 to evaluate the beam quality and take into account the effect of collimating and focusing lenses of a multi-emitter semiconductor laser made by stacking several signal emitter chips. The beam quality factor M_q^2 can be expressed as

$$M_q^2 = \sqrt{\left(L_{//} \cdot L_\perp\right) \cdot \left\{(N_\perp \cdot \theta_\perp)^{k_\perp} \cdot (N_{//} \cdot \theta_{//})^{k_{//}}\right\}^2} \cdot F(A_s) \quad (1)$$

where $N_{//}$and $N_\perp$ are the number of laser diodes along slow- and fast-axis directions, respectively. $L_{//}$ and $L_\perp$are the near-field beam widths in slow- and fast-axis directions via collimating and focusing lenses, respectively, $\theta_{//}$ and $\theta_\perp$ are the far-field angles in slow- and fast-axis directions via collimating and focusing lenses, respectively. $k_\perp = \frac{N_\perp \cdot \theta_\perp}{(N_\perp \cdot \theta_\perp + N_{//} \cdot \theta_{//})/2}$ and $k_{//} = \frac{N_{//} \cdot \theta_{//}}{(N_\perp \cdot \theta_\perp + N_{//} \cdot \theta_{//})/2}$ are the weight factors via collimating and focusing lenses in slow- and fast-axis directions, respectively, which are used to strengthen the influence of the main factors on the round right spot collimating and shaping. The influence of astigmatism is shown exponential change as shown in the formula $F(A_s) = e^{\frac{A_s}{\lambda}}$, λ is the wavelength of the laser beam, $A_s$is the astigmatism distance.

Let us consider a semiconductor laser chip via collimating and focusing kenses, $k_{//} = \frac{N_{//} \cdot \theta_{//}}{(N_\perp \cdot \theta_\perp + N_{//} \cdot \theta_{//})/2}$<1, $k_\perp = \frac{N_\perp \cdot \theta_\perp}{(N_\perp \cdot \theta_\perp + N_{//} \cdot \theta_{//})/2}$>1, we can find $L_{//}$ and $\theta_\perp$ are the key effects. In addition, the effect of the astigmatic factor A_s and the wavelength λ have been clearly reflected in the formula $F(A_s)$. As a result, the factor M_q^2 can reflect the effects of collimating and focusing lenses.

3. Experimental setup and analysis

In order to verify the influence of the collimating and focusing lenses on the semiconductor laser chips, an experiment setup is illustrated in Fig. 1 [10]. We choose a commercial laser ship with the output power of 9 W and the center wavelength of 915 ± 10 nm. We have a single focusing lens, thus the effective focal length (EFL) of the focusing lens in fast-axis direction is equal to the EFL of the focusing lens in slow-axis direction. We set the EFL of the slow axis collimator (SAC) until the beam is well collimated. We start test, we record the experimental data and process experimental data, then fill in the following tables. There we just consider the situation of $A_s = 0$.

First, we consider the influence of the fast axis collimator (FAC) focal length. The results of combining six chips with two different FAC lenses (EFL = 600 μm and EFL = 1100 μm). We compared Table 1 with Table 2, we can find that the EFL of FAC reduced, the values of M_q^2 reduced, the beam quality is better. Secondly, we consider the effect the number of laser diodes.