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LETTER

Reduction of the Intensity Noise by Electric Positive and Negative Feedback in Blue-Violet InGaN Semiconductor Lasers

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SUMMARY Reduction of the intensity noise in semiconductor lasers is important subject to extend application range of the device. Blue-violet InGaN laser reveals high quantum noise when the laser is operated with low output power. The authors proposed a new scheme of noise reduction both for the optical feedback noise and the quantum noise by applying electric feedback which is positive type at a high frequency and negative type for lower frequency range. Noise reduction effect down to a level lower than the quantum noise was experimentally confirmed even under the optical feedback.

key words: *InGaN semiconductor laser, optical pick up, quantum noise, optical feedback noise, electric feedback*

1. Introduction

Blue-violet InGaN semiconductor lasers have been developed to be light sources in the high density optical disk systems [1]–[3]. The lasers used in the optical disk systems generate so-called optical feedback noise by re-injection of the output light which was reflected at surface of the optical disk [4], [5]. The optical feedback noise can be suppressed by introduction of the superposition of the high frequency current [6] or by utilization of the self-pulsing lasers [7]. However, the noise can not be reduced lower than the quantum noise level even by introduction of these reduction methods.

Word of the quantum noise in this letter is used for the noise which is generated by intrinsic fluctuations of the electron and photons in semiconductor laser. The quantum noise in blue-violet semiconductor lasers was found to be much higher than that in near-infrared semiconductor lasers when both types of laser operate with identical output power because of different photon numbers [5]. Reduction of the noise level to lower than the quantum noise level is required for the blue-violet lasers to operate with small output power.

On the other hand, operation of the laser with electric negative feedback is found as an effective method to reduce either the intensity noise [8] or the FM noise [9] by suitable setting up.

We propose here a novel scheme to reduce the intensity noise including the optical feedback noise and the quantum noise simultaneously, basing on the electric feedback.

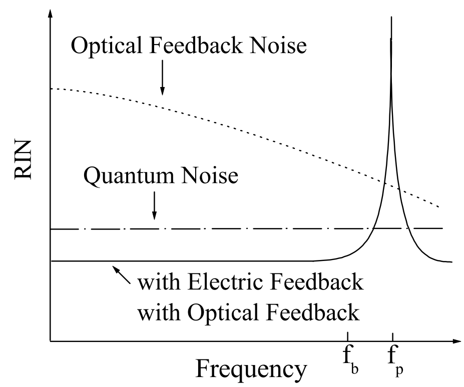

Fig. 1 Illustration of the electric positive and negative feedback.

2. Mechanism of Noise Reduction

The light output under optical feedback is detected with a photo detector and is put in an electrical feedback loop to the driving current source, where the electric feedback is negative type in lower frequency range and is positive type at a high frequency. Frequency spectra of the optical intensity are illustrated in Fig. 1. Levels of the optical feedback noise and quantum noise are indicated with dotted and chain lines, respectively. Solid line is an expected profile of the noise after application of the proposed noise reduction scheme.

The peak at frequency f_p indicates electric oscillation due to the positive feedback. This electric oscillation works to reduce the optical feedback noise to the level of the quantum noise by similar effect of the superposition of the high frequency current or the self-pulsing laser [10]–[12].

The negative feedback works in frequency range from 0 to f_b and reduces the noise to a level lower than the quantum noise.

3. Experimental Results

Experimental set up is shown in Fig. 2. The laser used for the measurement is a blue-violet InGaN semiconductor laser whose lasing wavelength is λ =410 nm. The optical spectrum of this solitary laser was multi-longitudinal mode. Temperature of the laser T was kept at 25°C. Distance from the laser to a mirror ℓ was 15 cm. Feedback ratio Γ was changed by an attenuator (ATT) and monitored

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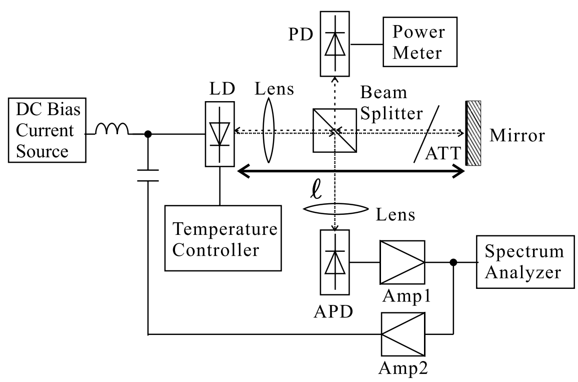

Fig. 2 Experimental set up.

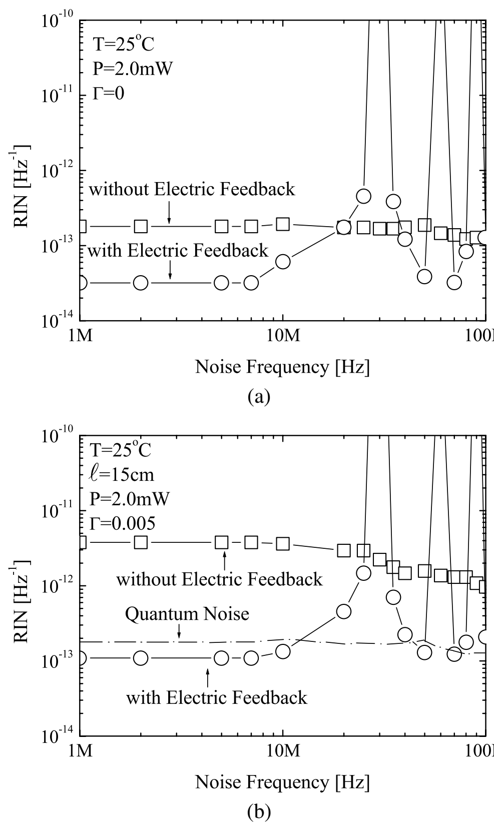

Fig. 3 RIN vs. noise frequency. (a) without optical feedback. (b)with optical feedback, when $\Gamma = 0.005$.

by a power meter. Current signal of the APD receiving the light from the laser was fed back through two amplifiers. Since conventional electric amplifier gives phase change for the higher frequency range than the band width, we utilize this property to apply the negative feedback in the lower frequency range and the positive feedback in a high frequency. The amplification ratio was 30 dB in the low frequency range.

Figure 3(a) shows noise spectra when there was no optical feedback. The noise level is represented in terms of RIN (Relative Intensity Noise). The output power of the laser P was 2 mW. The electric positive feedback worked

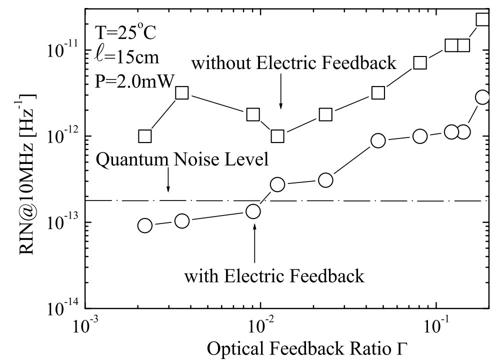

Fig. 4 RIN vs. optical feedback ratio Γ.

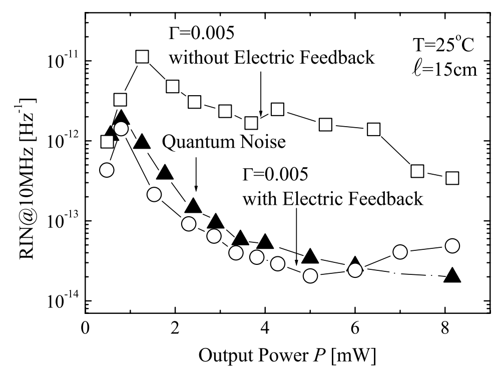

Fig. 5 RIN vs. output power P.

at 30 MHz. The electric negative feedback worked in frequency range from 1 MHz to 10 MHz. The intensity noise was reduced 7 dB by the electric feedback.

Figure 3(b) shows noise spectra when optical feedback ratio Γ was 5×10^{-3}. We regard here that the quantum noise is the noise of the solitary laser, that is, the line of "Quantum Noise" is the line of "Without Electric Feedback" in Fig. 3(a).

The noise was increased 12 dB by the optical feedback, but was reduced more than 15 dB down to a lower level than the quantum noise.

The optical spectra under optical feedback and/or electric feedback were still multi-longitudinal modes and were not so differ from that of the solitary laser.

Figure 4 shows variations of the noise with the optical feedback ratio Γ. The chain line is the quantum noise level of the solitary laser. The optical feedback noise was reduced lower than the quantum noise level when Γ was smaller than 1×10^{-2}.

Figure 5 shows variations of the noise with output power P. The optical feedback noise was reduced lower than the quantum noise level when the output power P was smaller than 5 mW.

4. Conclusion

We experimentally proposed a novel scheme to reduce both the optical feedback noise and the quantum noise. Electrical positive and negative feedback loop was inserted between the optical detector and the laser current driver by utilizing frequency characteristic of the conventional electric amplifier. The noise InGaN blue-violet laser under optical feedback was reduced down to a level lower than the quantum noise when the optical feedback is not so strong. Expansion of the reduced frequency range and more reduction of the noise level are next our subjects.

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