Brief

Measurements on Low-Frequency Fluctuation in the Laser Diodes

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***Abstract*—A system for analyzing low frequency light fluctuation is set up with a multi-channel detector and a few results are shown. The multi-channel detector includes a PCD image sensor which has 256 sensing elements. The light output of a laser diode is divided into various wavelengths and the light spectral intensities are obtained at various wavelengths. The current noise is also measured. The noises show $1/f$ spectra. The correlation coefficient between the light and the driving current is calculated from the measured values.**

I. Introduction

Low-frequency excess noise is widely found in electron devices. The presence of the excess noise is particularly troublesome, because its amplitude is usually much higher than that of thermal noise or shot noise.

Laser diodes are widely used as light sources for transmitting information and in instrumentation. However, the low frequency fluctuations of the radiating light cause many problems in the applications. In order to investigate the noise source, we developed a multi-channel light analyzing system which consists of a monochromator (Nikon G-250) and a multi-channel detector (Hamamatsu C2326). The light can be divided into various wavelengths, and the light fluctuations can be analyzed at each wavelength. The current noise is also measured. The correlation coefficient between them is calculated from the measured values in single- and multi-mode operations.

II. Measuring System

Using a multi-channel detector, we set up a light analyzing system as shown in Fig. 1. The multi-channel detector includes a PCD Image Sensor which has 256 sensing elements. The scanning rate of the multi-channel detector is 20 μs/ch. Thus it takes 5.12 ms to scan all the sensing elements. The wave length resolution of the system is about 0.08 nm. The wavelength is calibrated with a 632.8 nm He-Ne laser. For details of the device, see Hamamatsu Data Sheet.[1]

The light spectral intensity can be measured in this system. The light is divided into various wavelengths by the monochromator and introduced to the sensing elements in such a way that one channel of the multi-channel detector corresponds to each light wavelength. The wavelength interval over all the channels is 20.4 nm. By setting the storage time of the multi-channel detector, the sampling time interval of the system is determined. The sampling frequency of the system equals the inverse of the storage time. Its maximum is 10 kHz. The number of channel scanned is inevitably determined when the sampling frequency of the system is selected. The relationships between the storage time, sampling frequency and the number of channels are shown in Table I. The system has a data accessing time and the number of channels scanned is limited to be 256. Therefore the number of channels scanned is not exactly equal to the ratio of [storage time] per [scanning rate].

Scanning the detector with a sampling frequency repetitively, the fluctuations of light spectral intensity can be also measured at various light wavelengths. Thus the light noise can be measured at various light wavelengths. In order to measure a higher frequency noise, it is necessary to select a higher sampling frequency of the

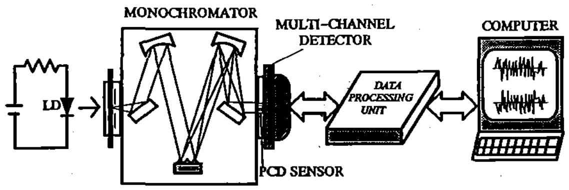

Fig. 1. Configuration of light analyzing system.

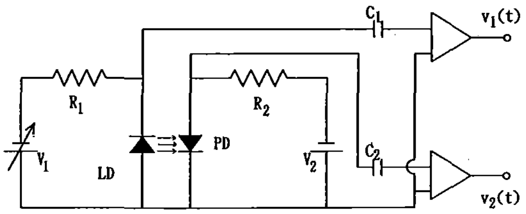

Fig. 2. Electrical connecting configuration of the samples. $R_1 = 100(\Omega)$, $R_2 = 1(k\Omega)$, $V_2 = 6(V)$, and $C_1 = C_2 = 10 + (100)(\mu F)$.

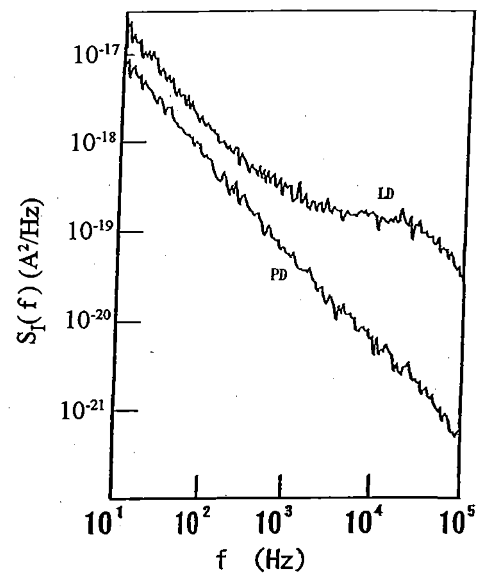

Fig. 3. Current noise spectra of InGaAlP laser diode (LD) and photo diode (PD).

Manuscript received September 9, 1993; revised June 21, 1994. The review of this brief was arranged by Editor-in-Chief R. P. Jindal. This work was supported in part by a Grant-in-Aid for Science Research from the Ministry of Education, Science, and Culture, Japan.

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IEEE Log Number 9405159.

[1] Hamamatsu Technical Data Sheet: C2327 Series; C2890 Data Processing Unit Manual. (Hamamatsu Photonics Co. Ltd.).

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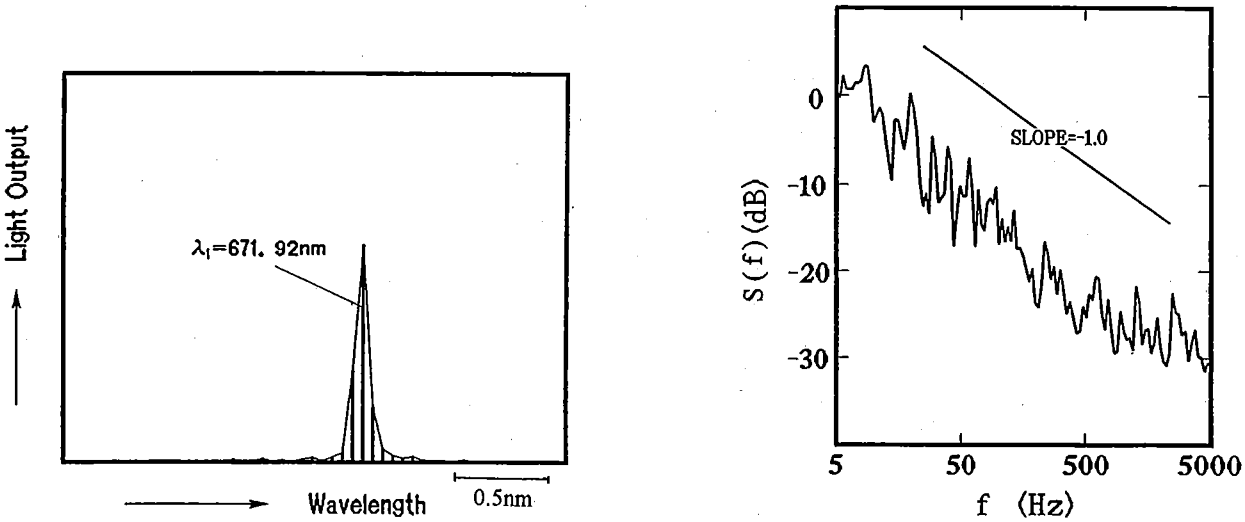
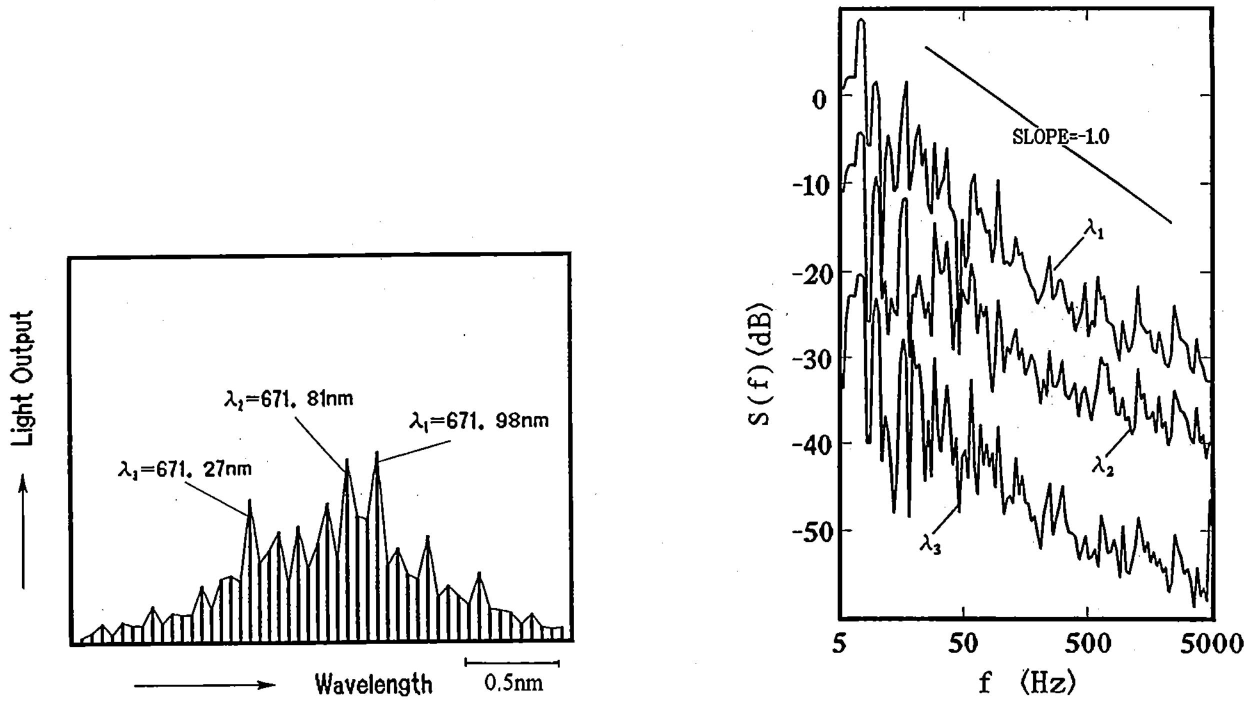


(a) (b)

Fig. 4. InGaAlP laser diode in the single mode operation (I = 42.9 mA). (a) Relative light spectral intensity. (b) Relative noise power spectrum of light fluctuation.



(a) (b)

Fig. 5. InGaAlP laser diode in the multi-mode operation (I = 48.4 mA). (a) Relative light spectral intensity. (b) Relative noise power spectra of light fluctuation.

system. Then the number of channels scanned becomes smaller as shown in Table I. The light signal data at various wavelengths measured by the multi-channel detector are introduced to the host computer.

The electrical connecting configuration of the samples is shown in Fig. 2. The current fluctuations of the laser diode (LD) and photo diode (PD, receiving the total light from LD) were both measured by the FFT analyzer and the noise intensity analyzer. The correlation between the noises from LD and its light is calculated by obtaining the cross correlation function [1] between the current fluctuations of LD and PD. The temperature of the sample is controlled by a Peltier controller.

III. Experimental Results

The sample is an index guided InGaAsP laser diode of a wavelength 670 nm. The threshold current is 38 mA. The current noises of the laser diode and of photo diode are shown respectively in Fig. 3. Note that they are of $1/f$ type. The current noise of the laser diode was proportional to the driving current in the low frequency range. Therefore its fundamental origin is believed to be the fluctuations in the diffusion coefficient as in junction diodes [2]. The laser is in single mode operation below 46.8 mA, but in multi-mode operation above this current. Measurements were carried out on the light output of the laser diode both in single mode operation ($I = 42.9$ mA) and in multi-mode operation ($I = 48.4$ mA).

Fig. 4 shows the relative light output spectral intensity and noise power spectrum in single mode operation. The correlation coefficient was calculated to be $-0.1 \sim -0.2$ between the light output and laser current noise at 200 Hz and 1 kHz.

Fig. 5(a) shows the relative light output spectral intensity in the case of multi-mode operation. We picked up three different wavelengths λ_1, λ_2, λ_3. Each relative noise spectrum is shown in Fig. 5(b). The correlation coefficients were calculated to be below 0.1 between light fluctuation of each mode and the current noise and to be almost zero between the total light output and the current noise in this measurement. The fluctuation spectra were calculated with the FFT method. The spectra were all of $1/f$ type. The mode hopping noise should be measured in next measurement.

TABLE I
RELATIONSHIPS BETWEEN THE STORAGE TIME, SAMPLING FREQENCY, AND THE NUMBER OF CHANNELS SCANNED

Storage Time	Sampling Frequency	Scanned Channel Number
100 μs	10 kHz	4 ch
200 μs	5 kHz	9 ch
500 μs	2 kHz	24 ch
1 ms	1 kHz	49 ch
2 ms	500 Hz	99 ch
10 ms	100 Hz	256 ch

IV. CONCLUSION

The low frequency noise in the light output of laser diodes can be analyzed at different stimulated emission modes with the analyzing system developed in this study. It is found that the light output fluctuation spectra were all of $1/f$ type and that the correlation coefficients were small between the light and driving current noise. The latter means that the light fluctuates independently on the driving current. The mode-hopping noise and mode partition noise would often occur in multi-mode operation on the light output of laser diodes. Employing this analyzing system, more detailed study including the current dependence of the noise will be carried out and the $1/f$ fluctuation problem should be studied more intensively in the low frequency range.

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