Research Report

High Speed GaN-based Green LED for POF

Satoru Kato, Osamu Fujishima, Takahiro Kozawa, Tetsu Kachi

Abstract

The performance of gallium nitride (GaN) green LEDs that have been developed for use in plastic optical fiber (POF) data links is described. The LEDs consist of a conventional surface-emitting structure with a single quantum well (SQW) that emits at a wavelength of 495 nm. In order to verify the performance of an optical data link based on SQW-type green LEDs and a polymethyl methacrylate (PMMA) POF, we evaluated the temperature dependence and the time response of the injection current of the SQW-type LED samples compared with commercially available display-type GaN green LEDs with a multi-quantum well (MQW) structure. As a result, 250 Mbit/s transmission over 20 meters of a PMMA-POF was successfully demonstrated with a BER of less than 10^{-12}. This optical device can be applied for high-speed digital interfaces, such as IEEE1394.

Keywords GaN LED, PMMA-POF, Data link, SQW structure, IEEE1394

1. Introduction

Recently, plastic optical fiber (POF) data links have generated great interest for low-cost, short-distance transmission systems that are usable in local area networks (LAN), home networks and automotive networks. Data links incorporating a green light source at 520 nm are required for use with polymethyl methacrylate (PMMA) POF systems, because they have a lower attenuation coefficient compared with conventional red light sources at 650 nm. Green LEDs have been developed based on GaN materials, and high optical-output-power GaN green LED lamps are now commercially available for general use in display applications. In recent studies of data transmission employing green LEDs or resonant cavity LEDs (RCLEDs),[1-3] digital data transmission at 200 Mbit/s over a distance of 100 meters[2] and analog video signal transmission over 400 meters[3] have been demonstrated.

We have reported the fundamental characteristics of display-type GaN green LEDs[4,5] for the realization of a high-speed POF data link employing a green light source, and we found that GaN green LEDs have the ability of high speed response at up to several decades MHz for small signal response and have advantages for use in optical data links under high temperature conditions. Therefore, we demonstrated a POF data link that complies with IEEE 1394 S100 operation and which employs a green LED. In this demonstration, it became clear that high-speed operation employing display-type green LEDs was limited by their fall time, and it was hard to transmit an optical signal at above 100 Mbit/s.

In this paper, we will present a demonstration of 250 Mbit/s POF data transmission employing GaN green LEDs with a single quantum well (SQW) structure. These LEDs have been developed for optical communications applications, and the layer structure and chip size are optimized for lower capacitance. These devices have an emitting size that is about half that of conventional display-type LEDs, and do not have the resonant cavity design that is a feature of conventional surface-emitting type LEDs.

As a result of this improvement in terms of fall time, higher response was observed compared with display-type LEDs with multi-quantum well (MQW) structure, and 250 Mbit/s transmission can be made using SQW-type green LEDs and PMMA-POFs.

2. Performance of SQW-type LEDs

In order to achieve high brightness, commercially available display-type LEDs generally have an MQW-based structure as the active region, and the number of wells in these LEDs differs between different manufacturers. We found out that the responses of these LEDs are also different from each other. We fabricated LED samples with different numbers of wells in the active layer and estimated the time response of these structures. The specifications of these samples are summarized in **Table 1**. The operating conditions for these samples were set as a 1 MHz repetition rate pulse signal with 20 mA (peak-to-peak) current, without any pre-bias current. **Figure 1** shows the well-number dependence of the time domain response of these samples. The rise and fall time data are plotted as a

Table 1 Summary of the specifications for the LED samples.

Sample	Operating voltage	Central wavelength	Spectral width
SQW	3.08 V	505.4 nm	33.2 nm
3QW	3.16 V	505.9 nm	34.2 nm
5QW	3.34 V	506.3 nm	36.5 nm

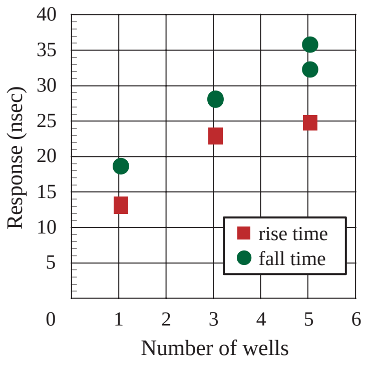

Fig. 1 Relationship between the number of wells and the time domain response of GaN green LEDs at an operating current of 20 mA (peak-to-peak) pulse signal without the use of a pre-bias current at 1 MHz repetition rate.

function of the number of wells in the structure. These results show that the SQW device has a faster response compared with the other MQW samples, both in terms of rise time and fall time characteristics, and we decided to develop an LED with a SQW structure for use in optical communication devices.

We first evaluated the performance of this SQW-type LED. **Figure 2** shows the temperature dependence of the optical output swing. The operating conditions of the LED are the same as those described above. The normalized output power was plotted as a function of temperature. A linear fit to this data gives a temperature coefficient of -0.078 %/K. The temperature coefficient for a display-type green LED at 20 mA DC operation was measured as -0.22 %/K,[4] as detailed in our previous report. The temperature coefficient of an SQW-type LED is about one-third of that of a display-type green LED under DC operation. Next, we evaluated the time response of the injection current of the SQW-type LED samples. In general, in order to obtain the best performance from LED and driver combination, two simple techniques known as pre-bias and drive-current peaking should be employed. However, we evaluated the time response of these LEDs without the use of pre-bias and drive-current peaking. **Figure 3** shows the relationship between the high-state operating current and the time response without pre-bias and drive-current peaking. It also shows the data transfer rate, as calculated from the response time. The current for the high-state was set at 40 mA, and we found that the SQW-type LED has the ability for high speed operation at more than 125 Mbit/s without pre-bias and drive-current peaking.

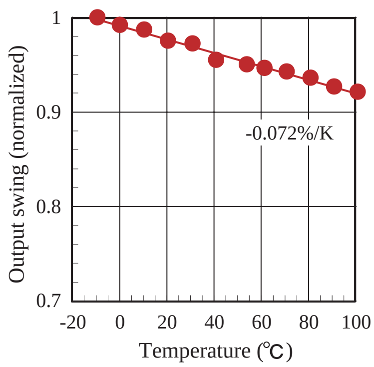

Fig. 2 Temperature dependence of the optical output swing of an SQW-type LED at an operating current of 20 mA (peak-to-peak) pulse signal without a pre-bias current at 1 MHz repetition rate.

3. 250 Mbit/s data transmission

In order to observe the eye-diagram at 250 Mbit/s operation with an SQW-type LED, we constructed a driver circuit, taking into consideration standard high-frequency design rules. In this exercise, pre-bias and drive-current peaking were employed in order to obtain the best performance. **Figure 4** shows the eye-diagram of the optical output, which was measured using a high-sensitivity, wide-band silicon photodiode (Si-PD) at up to 1 GHz. This shows the performance of the SQW-type LED at 35 mA (peak-to-peak) signal (250 Mbit/s, 2^7-1 pseudo random bit sequence (PRBS)) with 5 mA pre-bias current. In this condition, the extinction ratio was measured at 5.6 dB.

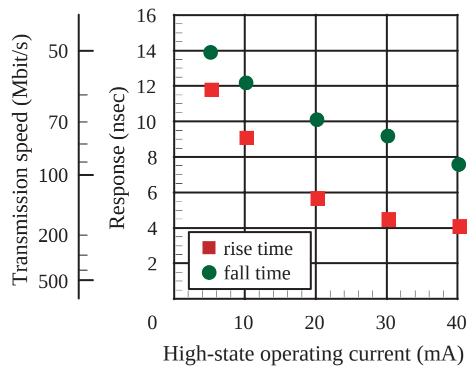

Fig. 3 Relationship between the high-state operating current and the time domain response of the SQW-type LED at 1 MHz repetition rate.

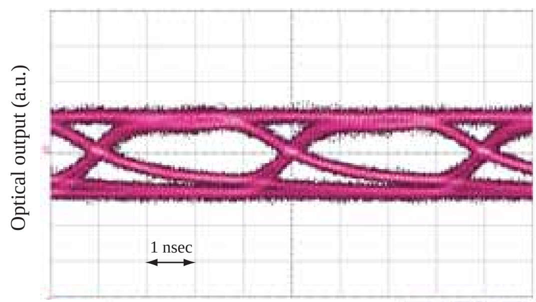

Fig. 4 Eye-diagram of optical output at 250 Mbit/s transmission.

As well as the eye-diagram measurement, data links were established to perform bit error rate (BER) measurements. For these demonstrations, an SQW-type LED was mounted on a driver circuit, and the POF was aligned under butt-jointing conditions. The output from the POF was detected using a receiver module (TODX-2404) made by Toshiba. The dependence of the BER properties on the received optical power is depicted in **Fig. 5**, and a minimum received power of -17.0 dBm was observed at a BER of 10^{-12}. The launch power into a 1 meter PMMA-POF for this SQW-type LED was measured at -6.0 dBm. As a result, the transmission length was estimated at over 80 meters by using a power margin of 3 dB and a PMMA-POF loss coefficient of 0.1 dB/m at 495 nm.

When using these SQW-type LEDs and the Eska-MEGA POF with a length of 20 meters, 250 Mbit/s transmission was successfully demonstrated with a BER of less than 10^{-12}.

4. Conclusion

We developed GaN green LEDs with SQW structure for use in PMMA-POF, and demonstrated 250 Mbit/s data transmission over 20 meters POF. We evaluated the fundamental characteristics of GaN green LEDs with a SQW structure, and we found that these LEDs have the capability for higher speed data transmission compared with other GaN green LEDs with MQW structure.

The temperature dependence of the optical output swing at an operating current of 20 mA (peak-to-peak) pulse signal was measured at -0.075 %/K, which was small enough to be embedded into an optical data link.

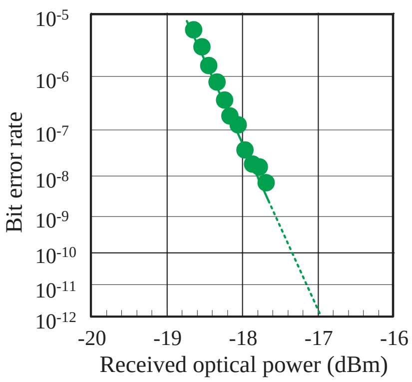

Fig. 5 Result of BER characteristics at 250 Mbit/s.

As a result of the BER measurements, the transmission length at 250 Mbit/s was estimated as being over 80 meters when combining this LED with PMMA-POF with a loss coefficient of 0.1 dB/m at 495 nm wavelength.

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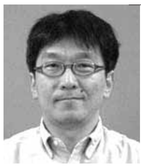

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