Transient State Analysis of MicroLEDs

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Introduction: MicroLEDs are commonly applied in display technologies, but there exists other applications such as in Visible Light Communication (VLC), imaging, and distance detection. For VLC, the microLED must quickly switch from on and off states to modulate at high frequencies. Similarly, imaging and distance detection need the microLED to operate at high frequency and luminance. Electrical and optical characteristics such as rise and fall times (transition between 10% and 90% max voltage), and the cutoff frequency (signal drops below 50% its original voltage while LED is driven at a constant voltage) are useful to evaluate an LEDs performance. This project explores developing a method to capture these characteristics using an Indium Gallium Nitride (InGaN) microLED. The intention is to identify LEDs with reduced rise and fall times to improve data transfer capabilities and maintain at optimal luminance.

Methods: The InGaN microLEDs under test and a photodiode, which converts light into electric current, are placed in a covered box to reduce noise from surrounding light sources. The LED is keyed on and off at frequencies set by an Agilent 3320A 20MHz Waveform Generator. The cutoff frequency of the other components in the system needs to be confirmed to be higher than that of the LED.

After experimenting with various photodiodes, the Silicon Avalanche Photodiode C30737MH-230-80, with a cutoff frequency of 1.3GHz, was chosen. This diode must be reverse-biased to operate in photoconductive mode and to perform avalanching, passing current only with incident light and increasing internal gain in the diode by multiplying incident photons. The signal received passes through a low-noise amplifier (LNA). While data was initially collected with the SR570 Current Amplifier, the 1MHz bandwidth limitation motivated the switch to the Nooelec LNA with an operating frequency between 50kHz – 150MHz.

The current generated by the photodiode is converted to a voltage through the amplifier and observed on a Keysight DSOX4043A 350MHz oscilloscope. The signal waveform, data presenting rise/fall times, max voltage, and fundamental frequency are saved and recorded.

When the received signal has a lot of noise or interference, the oscilloscope source is set to AC Coupling and put in averaging mode with every two samples.

Results: The Nooelec LNA amplified the signal by 20dB (equivalent to about 10V). Fig. 1(a) shows a signal at 10MHz received even when the LED is off or blocked from the photodiode receiver.

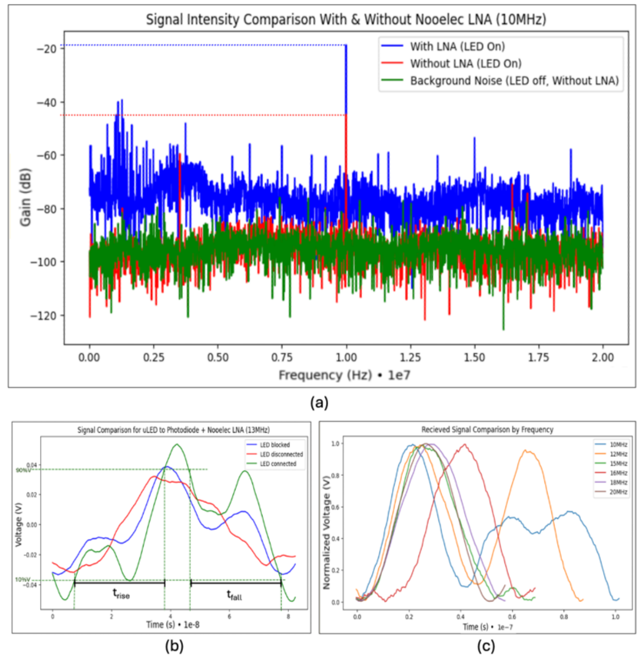

Figure 1. Amplification of the signal at high frequencies with LNA. (a) Gain vs. Frequency represents the intensity of frequencies present in the received signal while LED modulates at 10MHz. (b) One period of signal received in time-domain when LED is blocked and connected & disconnected to power. Rise/fall times are also labeled for when the LED is signal. (c) Normalized Voltage vs. Time at different high frequencies in the time-domain.

By focusing on a 13MHz signal, as seen in Fig.1(b), the resolved rise and fall time was approximately 32ns and 33ns, indicating a cutoff frequency at 15MHz. However, observing the signal at other high frequencies in Fig.1(c), there are varying rise and fall times. Some waveforms also have a mixture of different frequencies causing more cycles per period, such as the 12MHz signal in Fig.1(c).

Conclusions: The LNA and photodiode can receive the microLED output and amplify the signal. However, the resolved rise/fall times are affected by interference between wires and component delays in the system.

Our next steps will include gathering more data to validate the determined rise time or propose an alternative value. Additionally, we will factor in system component delays and adjust the setup to just show the signal received from the photodiode. We'll also investigate other modifications to enable the microLED to operate and receive signals at higher frequencies.

References: [1] Kumar V, Kymissis I. MicroLED/LED electro-optical integration techniques for non-display applications. Appl Phys Rev. 2023 Jun;10(2):021306. doi: 10.1063/5.0125103. PMID: 37265477; PMCID: PMC10155219.

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