Transient State Analysis of MicroLEDs

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Background & Motivation

Transient State of an LED → transition period of LED switching from off to on (rise) and on to off (fall)

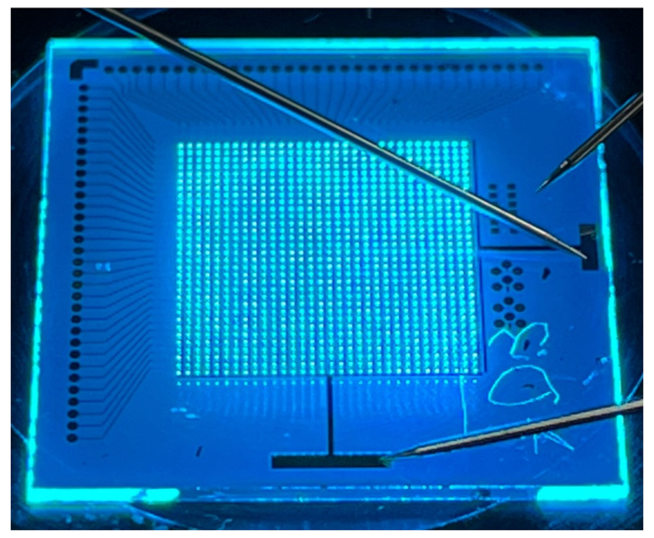


Figure 1. Illuminated microLED matrix. This project uses one MicroLED [1]

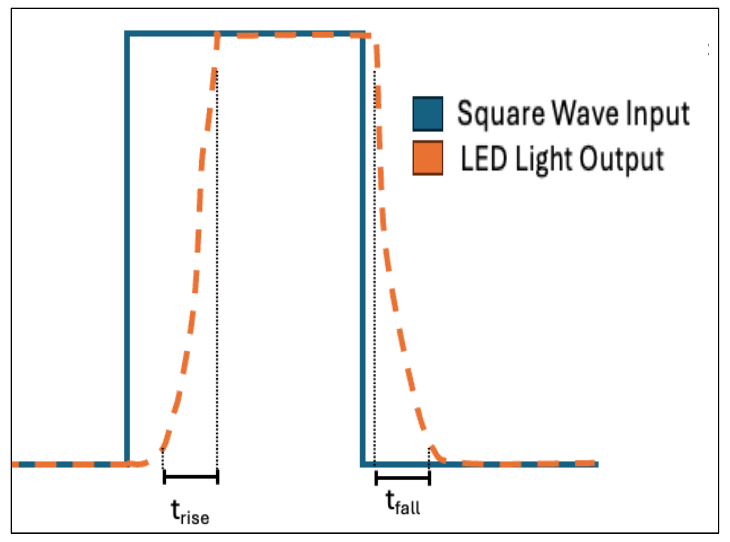


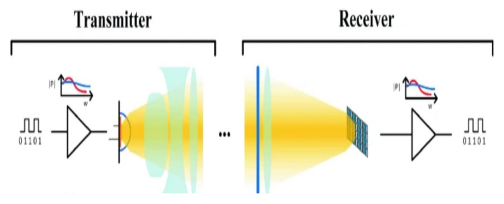
Figure 2. LED rise and fall response when keyed on-off by a square wave

- Intend to reduce rise and fall times of microLEDs to improve data transfer capability and maintain at optimal luminance
- To do so, we must collect LED characteristics: rise/fall times and cutoff frequency

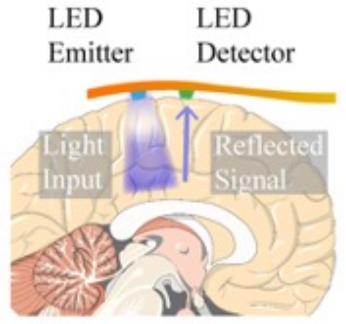
Rise/Fall time → Transition between 10% and 90% of max voltage

Cutoff Frequency → Frequency where max voltage drops 50% of the original, driven at constant voltage LED brightness reduces beyond it

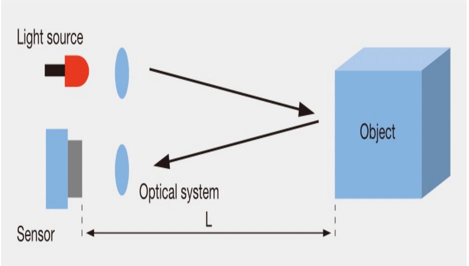
Applications of microLEDs



Visible Light Communication (VLC)

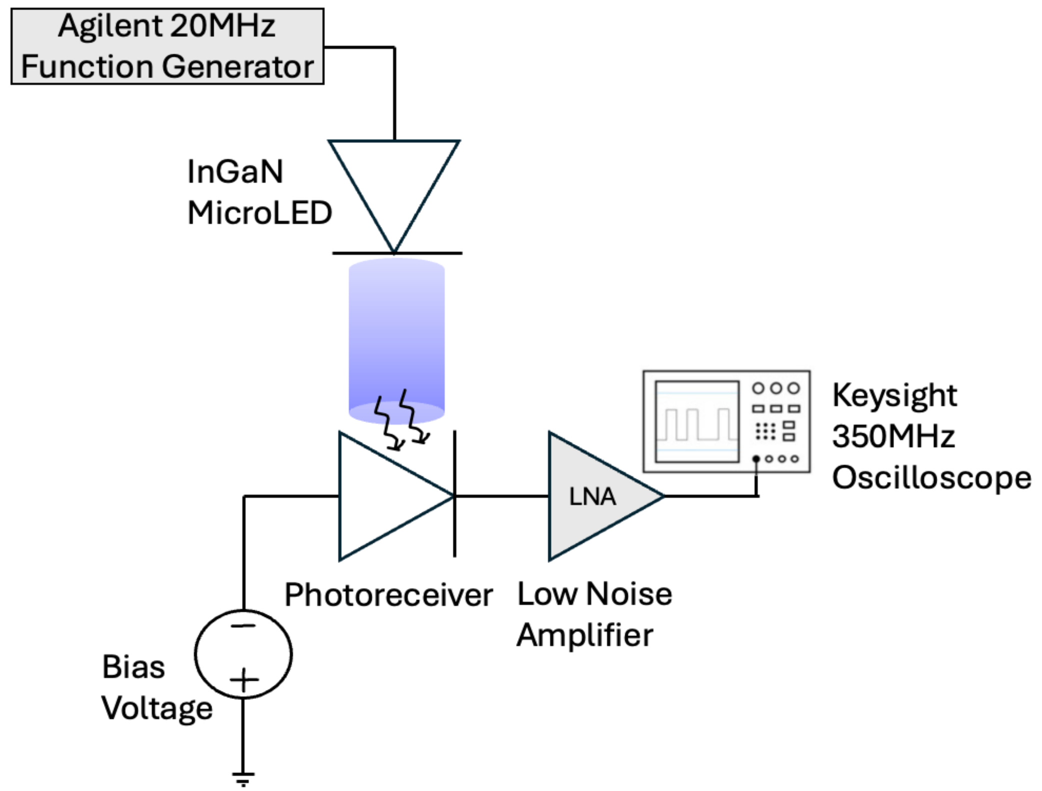


Imaging Technologies



Distance Detection

Experimental Setup



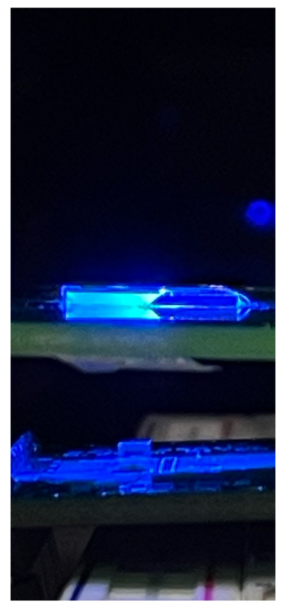


Figure 3. setup of microLED & photodiode

Results

Adjusting to System Limitations:

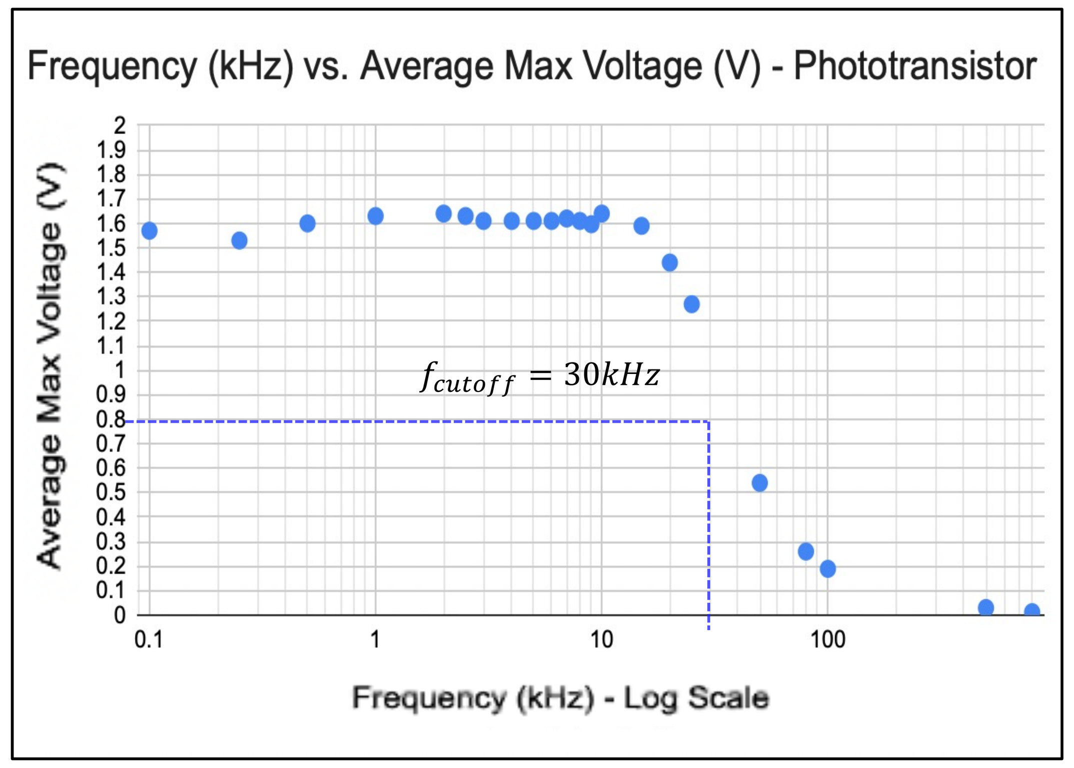


Figure 4. Using a phototransistor as a receiver the cutoff frequency is 30kHz

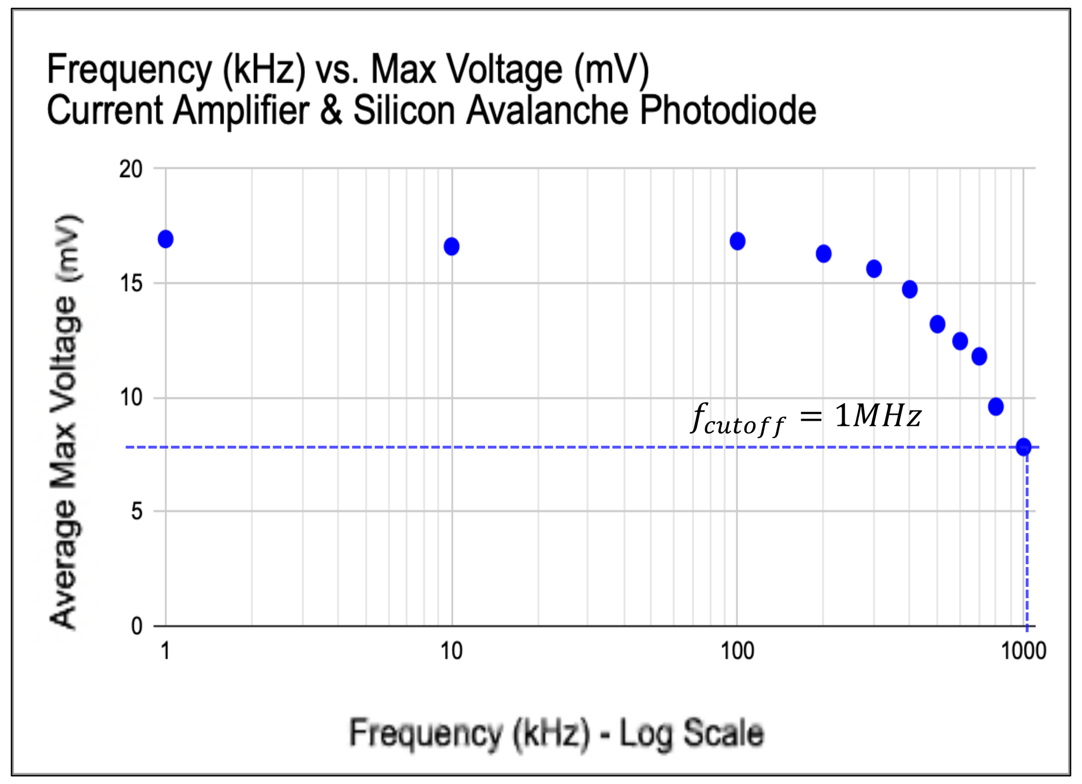


Figure 5. Using Silicon Avalanche Photodiode ($f_{cutoff} = 1.3GHz$ and $0.3ns$ response time) and current amplifier SR570 shows a cutoff frequency at 1MHz

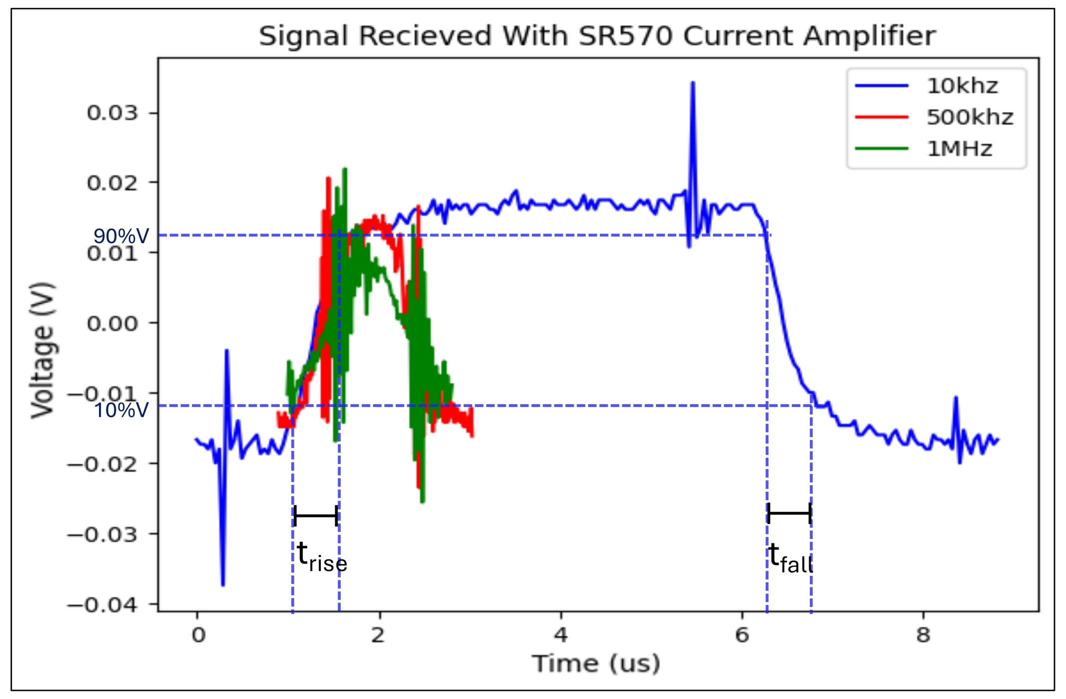


Figure 6. Comparing rise/fall of LED at 10kHz, 500kHz, & 1MHz with current amplifier SR570

$$t_{rise} = 0.4\mu s, t_{fall} = 0.5\mu s$$
$$f_{cutoff} = \frac{1}{(0.4+0.5)*10^{-6}s} = 1.1MHz$$

Signal Amplification & Analysis:

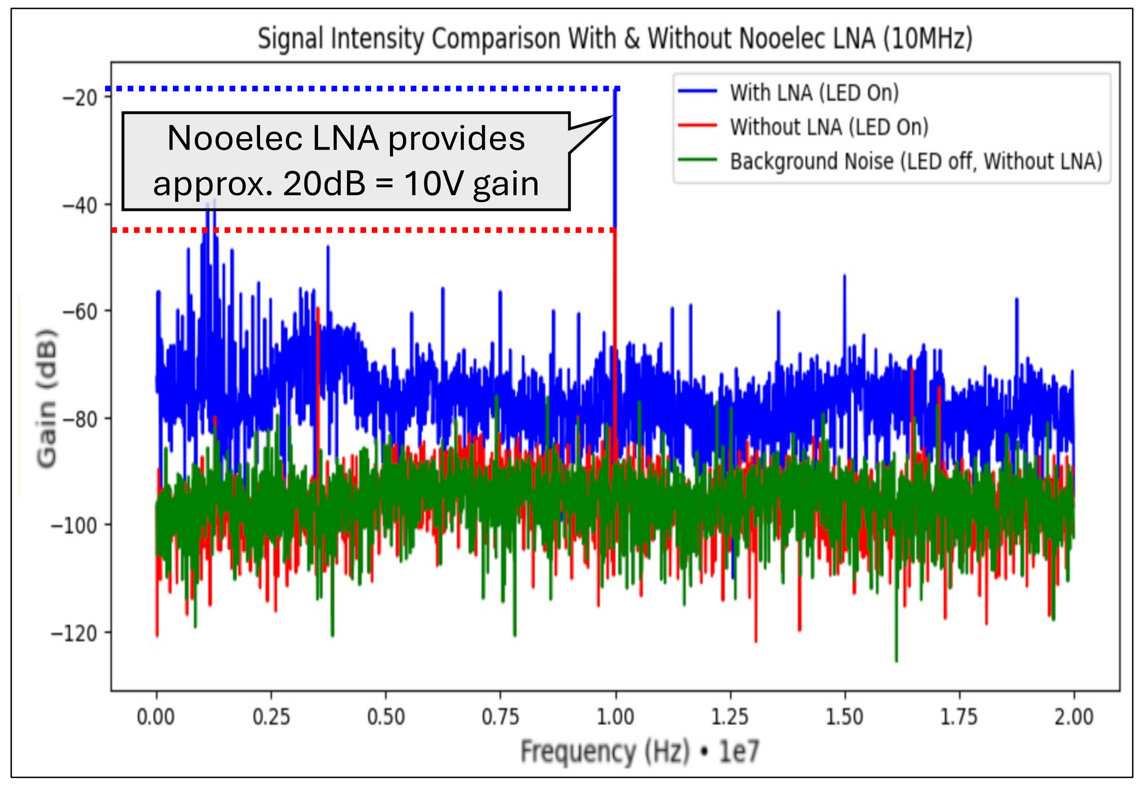


Figure 7. Frequency response of background noise and the signal at 10MHz with and without LNA

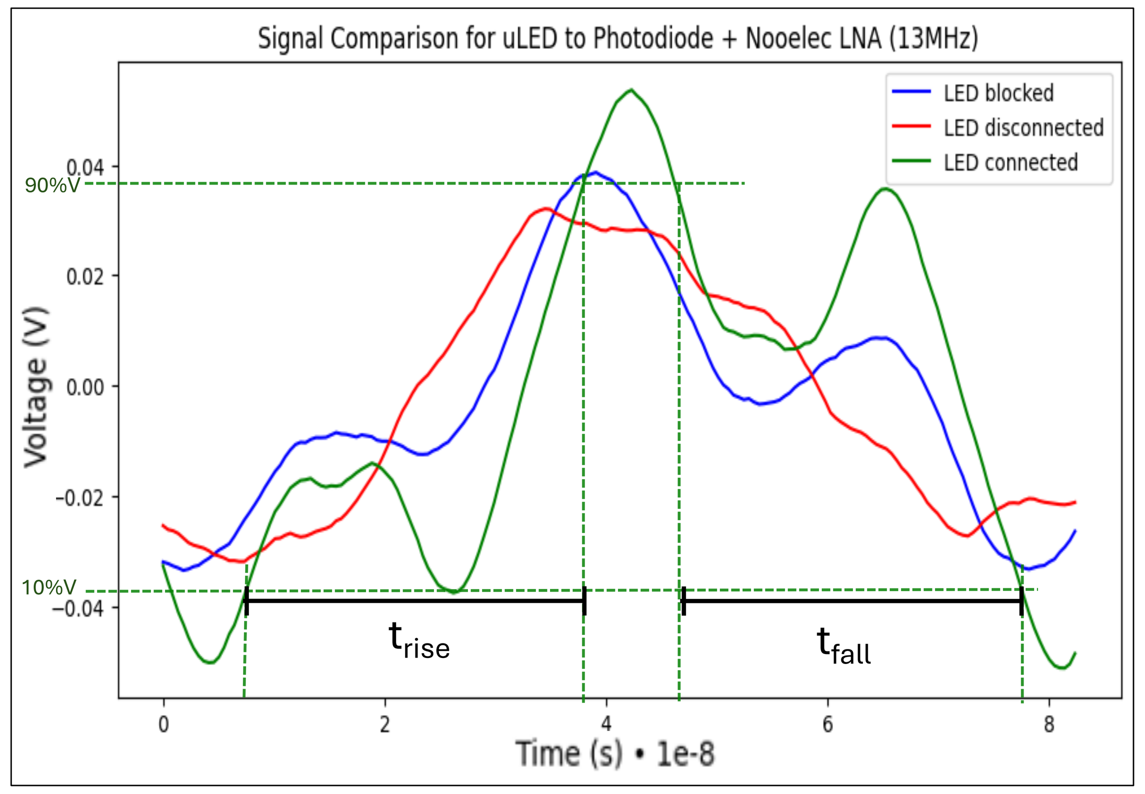


Figure 8. Comparing signal received when the LED is connected, disconnected, and blocked. Signal is still received while LED is not emitting. Estimated rise/fall of LED are detailed.

$$t_{rise} = 32ns, t_{fall} = 33ns$$
$$f_{cutoff} = \frac{1}{(32+33)*10^{-9}s} = 15.4MHz$$

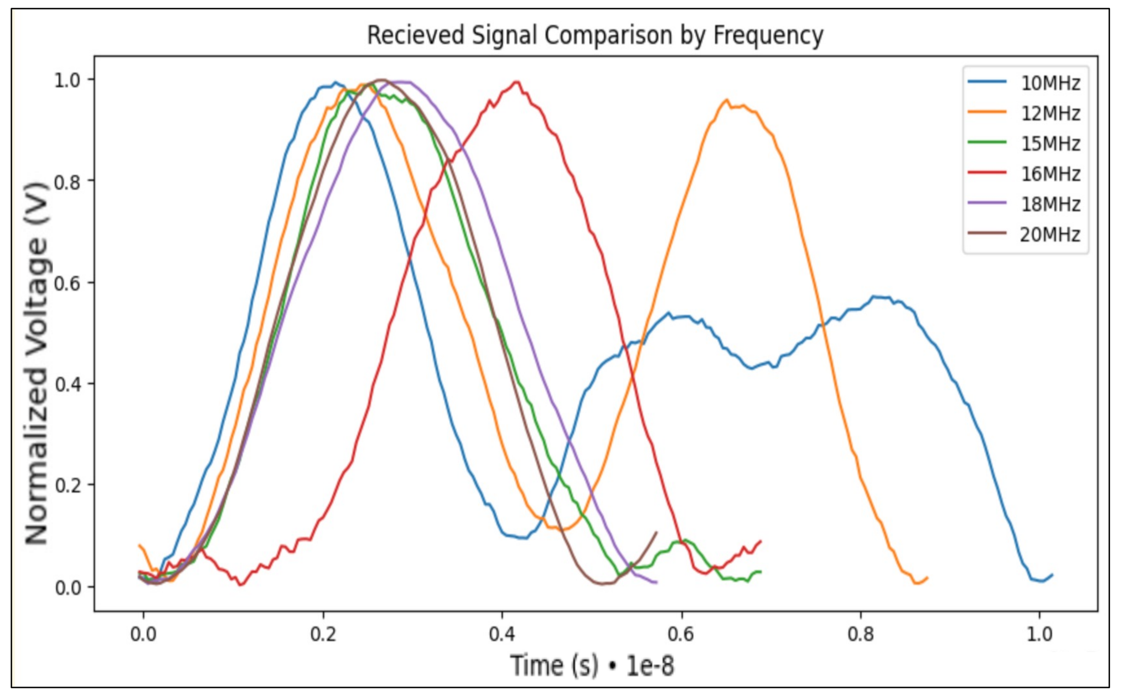


Figure 9. Comparing one period of signal at different frequencies

- Varying rise/fall times by frequency
- Some waveforms have a mixture of frequencies, causing more cycles per period than expected

Discussion

- Lower frequency bandwidth of photoreceiver and amplification devices causes earlier cutoff frequencies and longer rise/fall times than expected
- Nooelec Low Noise Amplifier (LNA) distinguishes the received signal from the noise floor but interference between wires causes signal presence without LED
- Data collected with Nooelec LNA at 13MHz suggests a cutoff frequency at 15MHz, but this is inconsistent when measured at varying frequencies

Future Work

- More data collection with microLED and experiments to reduce interference in the time-domain signal and retrieving consistent rise/fall time.
- Collect delays caused by other components and calibrate the system to receive signal from just the photodiode
- On-Off Keying LED at higher frequencies (20MHz-1GHz+)

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CLUE Columbia Laboratory for Unconventional Electronics

amazon

References:

[1] O. Durnan, V. Kumar, R. Alshanbari, M. Noga, and I. Kymissis, "An active-matrix microLED display based on monolithic integration with IGZO backplane," Journal of the Society for Information Display, vol. 32, no. 5. Wiley, pp. 350–359, May 2024. doi: 10.1002/jsid.1299.

[2] 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.