Gb/s Optical Wireless Communications up to 17 meters using a UV-C Micro-Light-Emitting Diode

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***Abstract*—We demonstrate Gb/s data rates up to distances of 17m using a single UV-C micro-light-emitting diode and Orthogonal Frequency Division Multiplexing modulation . To our knowledge, this is the longest reported range for Gb/s UV-C LED-based optical wireless communications.**

Keywords- Deep UV, Ultraviolet Communications, Micro-LEDs, Optical wireless communications, OFDM

I. INTRODUCTION

In recent years optical wireless communications (OWC) has shown promise as an alternative or complement to conventional radio frequency (RF) communications. OWC benefits from license-free spectrum and can be integrated with existing solid-state lighting technology, lowering barriers to widespread deployment of the technology [1]. Meanwhile, micro-Light-Emitting Diodes (µLEDs), being LEDs with dimensions <100 µm, have seen increased interest for several applications including communications and displays. Gallium-Nitride-based µLEDs can emit light from the solar-blind ultraviolet (UV) to the visible, and have several benefits for OWC in including high bandwidths which can support Gb/s data rates per µLED pixel [2]. Furthermore, there is increasing interest in UV OWC as the properties of UV light, such as strong atmospheric scattering, support applications such as non-line of sight (NLOS) communication [3]. UV OWC in the solar-blind region of the electromagnetic spectrum (UV-C band) can also take advantage of a naturally background-free environment. Previously we demonstrated 4 Gb/s at line-of-sight range up to 5 m using a single UV-C (280 nm)-emitting µLED [4]. Here we report further progress where systematic optimization of the optics, µLED biasing conditions, and data encoding scheme parameters has allowed us to reach distances up to 17 m using a UV-C µLED while maintaining error-free data rates greater than 4 Gb/s. To our knowledge this is the longest reported range for Gb/s UV-C LED-based OWC.

II. EXPERIMENTAL METHOD

In this work, we used a UV-C µLED array comprizing 8 trapezoidal pixels, each pixel being equivalent in area to a circular device of around 40 µm diameter. This pixel size was chosen as it balances transmitted power with high modulation bandwidth [2]. The system consisted of two UV-enhanced mirrors, to increase the optical path length, and two 2-inch lenses (Edmund optics 84340) to collimate the transmitted light and focus the light on the receiver (see Fig. 1). The modulation for the µLED was applied using an arbitrary waveform generator (AWG) and the signal amplitude from the AWG was increased using an amplifier. This signal was combined with the DC bias from the source unit using a bias tee and is used to drive the LED. On the receiver side, a 1 GHz bandwidth UV-enhanced avalanche photodiode (APD) was used as the detector, and the received signal was recorded by an oscilloscope. After alignment was optimized the received signal was sent to a laptop for offline decoding and processing. The modulation technique used in this work was orthogonal frequency division modulation (OFDM) which is commonly used in OWC to pursue a high transmission data rate. This technique also used adaptive bit loading which adapts the number of loaded bits on each subcarrier based on the channel quality thus allowing maximization of the achievable data rates. Here we targeted a bit error ratio (BER) below 3.8×10^{-3} as this can be considered quasi error-free because forward error correction (FEC) coding is able to correct bit errors by addiding redundancy resulting in bit error ratios close to zero $<10^{-9}$. The net data rate will be slightly lower due to the added redundancy bits.

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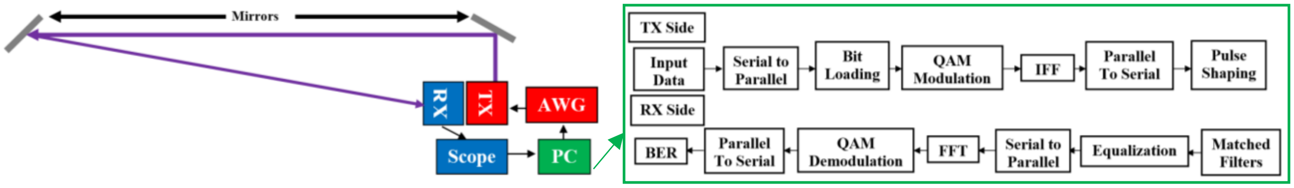

Fig. 1 a) Schematic diagram of the experimental setup showing the optical path, transmitter (Tx), and receiver (Rx) configuration (insert OFDM system blocks)

III. EXPERIMENTAL RESULTS

The µLED light output versus current, and voltage versus current (L-I-V) was characterized using a source measurement unit and an optical power meter. As seen in Fig. 2 a) the µLEDs each emit up to 0.5 mW of power, and the L-I-V was used to select the optimum bias point of the µLED based on the linearity of the IV. The modulation bandwidth was measured using a network analyzer and the results are shown in Fig. 2 b) with the bandwidth reaching a maximum of ~915 MHz. The rollover in bandwidth with increased current is tentatively attributed to thermal effects such as carrier overflow resulting in an increased effective carrier lifetime and hence reduced modulation bandwidth.

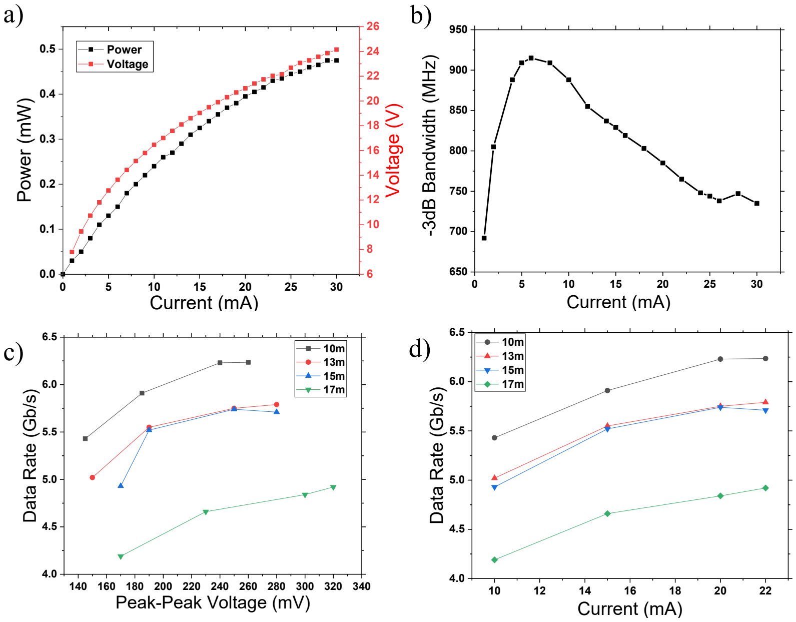

Fig. 2 a) The LIV performance b) the -3dB response of the current c) peakk-peak voltage vs Data rate d) current vs data rate at various distances

The peak-to-peak voltage (VPP) applied to the µLED was optimized to provide the maximum data rate at each distance. By examining Fig. 2 c) it is clear that the VPP increases with distance due to the decrease in the signal strength over these longer distances. The maximum data rate as a function of bias current and distance is shown in Fig. 2 d). The data rates of > 6 Gb/s recorded at 10 m and the > 4 Gb/s at 17 m are the highest data rate at these distances thus far recorded in the DUV, to the best of our knowledge. We also noticed that as the current increases the data rate also increases until it seems to plateau after 20 mA. From this observation, we have determined the optimum bias point to operate these devices to be 20 mA as this allows for high data rates but does not degrade the device with extended use.

IV. CONCLUSION

In this work, we have shown a UV-C communications system capable of transmitting Gb/s data rates over distances up to 17 m, demonstrating the ability of high bandwidth µLEDs to transmit high data rate communications over greater distances than those previously explored. This work to our knowledge demonstrates is the highest data rate recorded using a single µLED pixel at a distance greater than 10 m. These results indicate that even longer transmission distances should be feasible, which is currently being investigated.

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