# Gigabit Per Second UV-C LEDs for Communications

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***Abstract*— We explore the modulation bandwidth, data communication capabilities and nanosecond pulsed performance of Ultraviolet-C (UV-C) AlGaN LEDs with peak emission wavelengths ranging from 235-275 nm. Data rates from 0.5 to 2 Gbps were achieved with -3dB modulation bandwidths up to ~100MHz.**

***Keywords—DUV, OWC, LEDs***

## I. INTRODUCTION

AlGaN-based light emitting diodes (LEDs) operating in the 200-280nm ultraviolet-C (UV-C) waveband have recently increased in quality and performance, driven principally by applications in disinfection and sterilization. These improvements to output power, efficiency and wavelength coverage are also enabling the use of these devices as sources for other applications such as optical wireless communications (OWC) [1]. UV communications is a form of OWC that has seen increased interest for, e.g. non-line-of-sight (NLOS) and inter-satellite communications [2]. This is motivated by facts that UV-C is in the 'solar blind' region of the electromagnetic spectrum where there is very little background light at ground level compared to the visible region and that Rayleigh scattering is a considerable mechanism in longer-range UV-C communications which can facilitate the development of NLOS communication systems [4]. Furthermore, pulsed UV-C sources are potentially applicable to stand-off detection of gases such as hydrogen and a range of pollutants and can facilitate photon-sparse communications links in conjunction with single photon avalanche photodiode or Si-PMT detectors. In this work, we present the characteristics of a range of UV-C LEDs with peak emission ranging from 235 to 275 nm, including light output versus current and voltage (LIV), modulation bandwidth, data transmission rates, and pulsed characteristics. Data rates of 0.68 and 1.53 Gbps are reported for 235 and 255 nm, respectively, these being to our knowledge, the highest reported thus far for LEDs emitting at wavelengths shorter than 260 nm.

## II. SET UP

We have characterized 4 commercial UV-C LED sources with nominal peak wavelengths of approximately 235, 255, 265 and 275 nm respectively (SF1-3T9B5L1, SN3-5T9B5L1, SUC ZHEF1VC-U1U2-LO-V2-250-R18, SU CULDN1.VC-MAMP-67-4E4F-350-R18). The 235 and 255nm devices are encapsulated in TO packages, and the 265 and 275nm devices are packaged in a surface-mounted package (SMD). For the LIV measurements the optical power was measured using a calibrated optical power meter (Thorlabs PM100A power meter and power meter head S120VC), and the electrical characteristics (voltage and current) were measured using a Source-Measurement Unit (Yokogawa GS610). The spectra were measured using a spectrometer (Avantes Avaspec-2048L). For the bandwidth measurements, we used two 2-inch diameter lenses (Edmund optics 84340 f/#=0.8) separated by a distance of 30cm to collect the light output and image it onto a 0.4 GHz bandwidth APD (Thorlabs APD430A2(/M)), and a network analyser (PicoVNA 106 Quad RX) was used to measure the corresponding frequency responses. The optical wireless communication setup comprised a similar configuration to the bandwidth measurements, however, the distance between the two lenses was increased to 0.5m. The encoded data was supplied by an arbitrary waveform generator (AWG) and this was then applied to the LED together with a DC-bias using a bias Tee. We used orthogonal frequency division multiplexing (OFDM) encoding with adaptive bit loading to keep the bit-error-rate (BER) low and using optimal peak-peak voltages in order to achieve the highest possible data rates [5]. Data rates of 0.68, 1.53, 1.3 and 2.49 Gbps were achieved for the 235, 255, 265 and 275 nm LEDs, respectively. For the pulse characterization, we used a transistor-based driver to generate nanosecond regime pulses, and optical pulses of approximately 40 ns duration (FWHM) with estimated pulse energies of approximately 20, 61, 271 and 435 pJ for the 235,255,265 and 275nm wavelengths were respectively achieved.

## III. RESULTS

The LI and IV plots are shown in Fig.1.a and b. Maximum optical output powers of approximately 0.17, 1.2, 29 and 21 mW were measured from the 235, 255, 265 and 275 nm devices, respectively, where we deliberately measured forward directed power output rather than total output from an integrating sphere. The corresponding electroluminescence spectra are shown in Fig. 1.c. As seen in Fig.1.d. the modulation bandwidths of the LEDs vary with current, reaching maximum values of approximately 65, 52, 58 and 117 MHz for wavelengths 235, 255, 265 and 275 nm, respectively. It is worth noting that the bandwidths are lower than those demonstrated by microLED and miniLED devices [6] but those have yet to be optimized across the UV-C and 'broad area' devices benefit from higher output powers. As the maximum data transmission rate depends on the available Signal-to-Noise Ratio (SNR), the achieved data rates from the devices follow a similar trend to the LIV results with the 235nm LED achieving the lowest data rate

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of 0.68 Gbps and the 275nm LED demonstrating the highest data rate of 2.49 Gbps (see Fig.1. e.). It can be observed that the 265 nm LED has a lower data rate than the 255nm devices despite having similar bandwidth and higher optical output power, which can be attributed to unoptimized biasing, this being under further investigation. To the best of our knowledge, our results are the first report of ~Gbps data rates from LEDs with peak emission wavelengths shorter than 260 nm. Regarding the pulsed characteristics, we can see the pulses are limited to around 40ns, which could be the result of set up limitations. However, looking at the pulse energies, we can see a more telling trend. It is noticeable that the 275nm and the 265nm LEDs can produce short pulses with higher pulse energies with this trend matching the CW performance. Overall, when comparing device packaging the SMD LEDs perform better compared to the TO can devices.

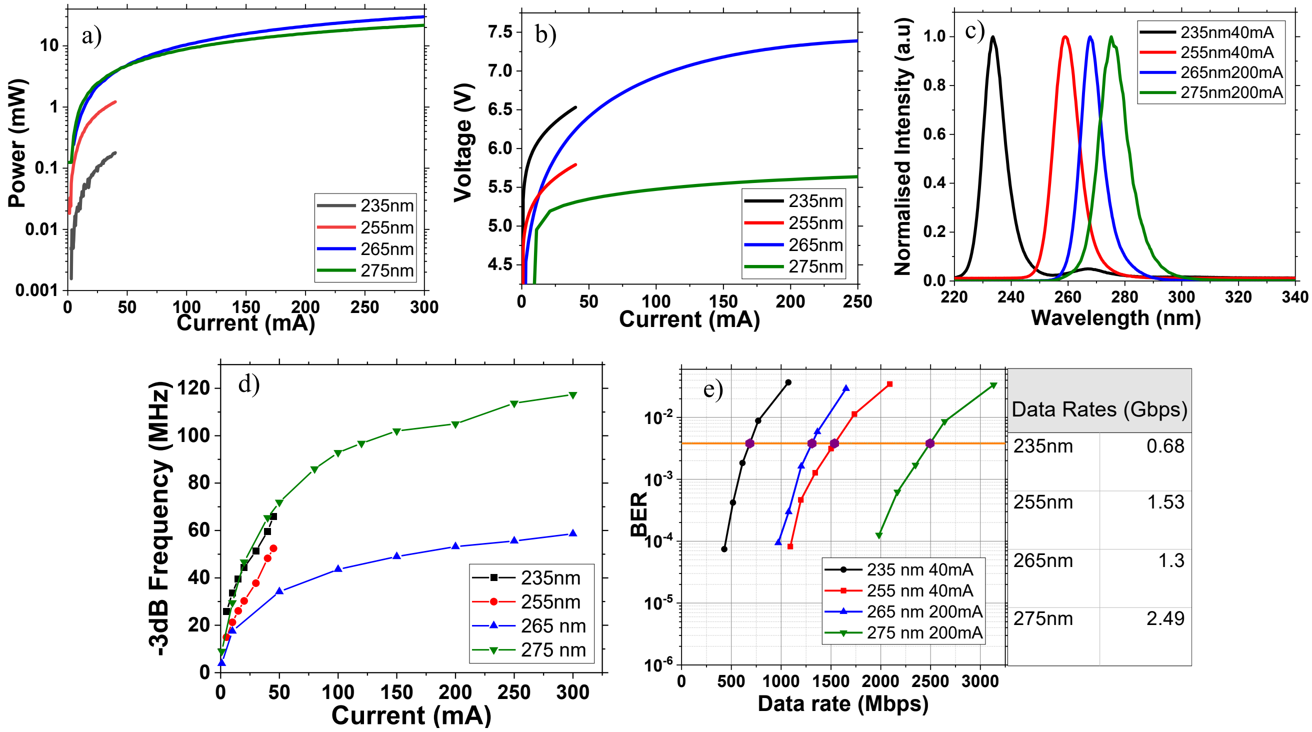


Figure 1 a) The LI b) IV c) spectra d) modulation bandwidth e) BER vs data rate for the 235nm, 255nm, 265nm and 275nm LEDs.

## IV. CONCLUSION

We have compared pertinent performance characteristics of commercial UV-C LEDs, which include modulation bandwidth, data communications capability, and nanosecond pulsed performance not highlighted in the manufacturers' data sheets. In particular, the 235nm and 255nm LEDs are pushing towards the short-wavelength limits of AlGaN LEDs and to our knowledge, our results are the first to extend such measurements to very short wavelengths. The encouraging data rates of ~1Gb/s using OFDM encoding offer exciting prospects for use in solar blind, non-line-of-sight and photon-sparse optical communications.

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