Visible Light Communications (VLC) – An investigation into LED sources

1. Introduction

Visible Light Communications (VLC) systems have increased in popularity with the advent of solid state lighting. With the proliferation of wireless devices which make considerable use of the limited RF spectrum, tapping into the optical portion of the spectrum (between 380 nm – 780 nm) alleviates the issue of ‘spectral deficiency’ [1,2,3]. In addition to this, growing concern on the harmful health effects associated with extended exposure to RF radiation [3,4]. VLC provides a harmless alternative to both private and public communication needs. Some examples of VLC applications include indoor home communications, underwater communications, Optical Wi-Fi (Li-Fi) for Wireless LAN applications, and vehicular communications and several others. This work deals with the characterisation of different LEDs to determine their suitability for use in VLC systems.

2. Methodology

The bandwidth measurements for the through hole LEDs were setup using a DC power source, and small signal input via a network analyser, and a bias tee. For spectral measurements, the ‘Ocean Optics HR-4000’ was used, and this was replaced by a power meter for optical power measurements.

The micro LEDs used in these experiments are made up of 16x16 arrays, with 8 different sizes (5μm to 60μm). These are driven using a special high speed pico-probe, which have a bandwidth of around 40GHz – several times higher than the capabilities of µLEDs, allowing them to measure the frequency response with ease [5]. Spectral measurements were obtained with a similar setup but with the Ocean Optics replacing the network analyser.

3. Through-hole LEDs

The operational wavelength for the LEDs were around 470nm (Blue), 570nm (Green), 580nm (Yellow). This wavelength varied with drive current. The peak wavelength of light emitted generally increased with a rise in drive current. A rise in temperature reduces the band gap energy, therefore increasing the wavelength of light emitted [6]. The optical bandwidth (FWHM) variation can also be explained by the same phenomenon. This process can be characterised by the Varshni parameters [7] which accurately fit the results obtained, and can be characterised as below –

\[ E_g = E_g(T=0) - \alpha T^2 + \beta T \]

The modulation bandwidth of the LEDs is restricted by the RC time constant of the LED, and hence the capacitance and series resistance of the device, and carrier lifetime as well. ‘Droop’ in LEDs, and the ‘green-yellow’ gap could explain the difference between the high modulation bandwidth obtained for the blue LED (~40MHz), and the low bandwidth for the green and yellow LEDs (~1MHz). The differences in device structure and materials used also affect the LED bandwidth.

4. Micro-LEDs

The Blue micro-LED operated at around 443nm, and the Green operates at 502nm. However, as seen in Figure 8, the peak wavelength did not vary much with drive current. The optical bandwidth (FWHM) of the LEDs does vary with current however. A roughly 10nm shift is seen with both LEDs, and can be explained by the temperature dependence of the bandgap. The high modulation bandwidth is achieved by both LEDs and in this case too. However, device capacitance and series resistance play less of a role here. The differential carrier lifetimes have a significant impact, and restrict the modulation capabilities of these devices. Lower carrier lifetimes, and hence higher bandwidths may be achieved through modulation doping, or the addition of ‘luminescence killers’ [7,8,9].

5. Conclusion

This work analysed optical, and electrical properties of commercial available LEDs. It was found that through-hole LEDs achieved a maximum modulation bandwidth of around 40GHz (Blue). Other colours only reached a maximum of only 1MHz. It seems the maximum modulation of the LEDs is not entirely dependent on the device capacitance or resistance, but rather the carrier lifetime in these devices. This is especially true in the case of Micro-LEDs. This suggests that the through-hole LEDs may be better suited for higher optical power applications requiring lower data-rates; while micro LEDs may be used in high speed applications requiring less optical power. Research into application based testing is recommended for future works.