A green absorbing fluorescent fibre concentrator for VLC

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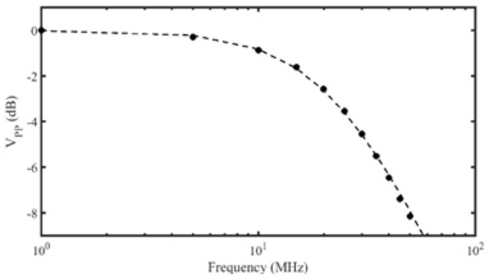
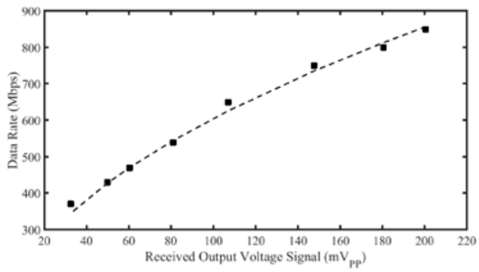
When designing a VLC receiver an important aim is to achieve a particular data rate and bit error rate (BER) with the lowest irradiance at the receiver. One approach to reducing the required irradiance is to use an optical concentrator. However, conventional optical concentrators conserve etendue and so increasing the gain of the concentrator is associated with a reduction in its field of view.

The limitations caused by conservation of etendue can be avoided if concentrators doped with a fluorophore are used to collect light from the transmitter[1]. In addition to avoiding the limitations caused by etendue fluorescent concentrators can be made in a variety of forms, including optical fibres, which can easily be incorporated into host systems. An important example of the possible advantages of these fibres is within smart phones. Any receiver in a smartphone must create a robust link despite random orientation of the smartphone [2]. One solution to this challenge that has been suggested is to employ a transceiver on each of the 6 faces or sides of the phone [2]. Recently it has been suggested that the most two useful receivers, could be replaced by a single receiver and a fluorescent fibre [3]. A feature of the fluorescent fibres in previous papers is that they absorb violet light [4]. To create the opportunity to employ wavelength division multiplexing the performance of a commercial fluorescent fibre that absorbs green light has been tested and the results reported for the first time.

The finite lifetime of the excited state of the fluorophore means that a fluorescent fibre will have a finite bandwidth. The bandwidth of the red emitting fibre has therefore been determined using a L520P50 520 nm laser diode and a 0.5 mm, 1 GHz C5658 APD. The data in Fig. 1 (a) shows that the fibre has a single pole response with a bandwidth of 22 MHz. The potential performance of this fibre in a smart phone has been determined by threading it through two 1.11 mm holes at one end of a 3D printed replicate of an iPhone XR smart phone. Since light is retained in the fibre by total internal reflection the holes held the fibre 5 mm from the body. In addition, the holes were positioned so that the centre of the fibre was located over the middle of the top edge of the 'smart phone'. Results obtained previously using a 1 mm diameter BCF-20 SC1.00 fibre in this position results in a receiver with a wide field of view of 240° when rotated about the long axis of the fibre[3].



(a)



(b)

Fig. 1. (a) The measured frequency response of the fibre (dots) and a single pole response with a 3 dB frequency of 22 MHz (b) The data rate as a function of the amplitude of the receiver output voltage for eye safe irradiance levels at the receiver.

OOK data has been transmitted from the L520P50 to the receiver formed by the fibre coupled to the C5658. The signal received by the C5658 was captured by an Agilent 33 GHz oscilloscope with a sampling rate of 100 GSample/s. This signal was then synchronised to the transmitted signal, demodulated and equalised using decision feedback equalisation in a MATLAB script before the BER was calculated. The data rates at which a BER of 10^{-3} were achieved as the irradiance falling on the fluorescent fibre was varied are shown in Fig. 1(b). In these experiments the peak-to-peak amplitude of the output voltage of the C5658 at 1 MHz for each irradiance was measured before data was transmitted. As with other fluorescent fibres in links with a single pole response the data rate was found to be approximately proportional to the square root of this measure of the signal at the receiver [4]. This observation highlights the contribution that the wavelength shift can make to the performance of the receiver. In this case the data was transmitted at wavelengths around 520nm but the fluorophore emits wavelengths around 650nm. The responsivity of the C5658 is approximately 10 A/W at 520 nm and approximately 35 A/W at 650 nm. Taking into account the lower energy of each red photon the wavelength dependence of the responsivity of the C5658 represents a change in the receiver's output voltage per photon of a factor of 2.8. The observed square root relationship between receiver output voltage and data rate in Fig. 1(b) means that the wavelength shift alone increases the data rate by a factor of 1.67.

Fluorescent concentrators avoid the trade-off between optical gain and field of view of conventional optical concentrators. Furthermore, they can be created from inexpensive fluorescent fibres which are easily integrated into host systems to create a receiver that is more resistant to line-of-sight blockage than a conventional receiver. In addition, the availability of fluorescent fibres that absorb green light means that they can be used to either support wavelength-division multiplexing or to create transceivers that avoid self-interference by transmitting and receiving data with different wavelengths.

References

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