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A wide field-of-view receiver that incorporates fluorescent fibers and a SiPM

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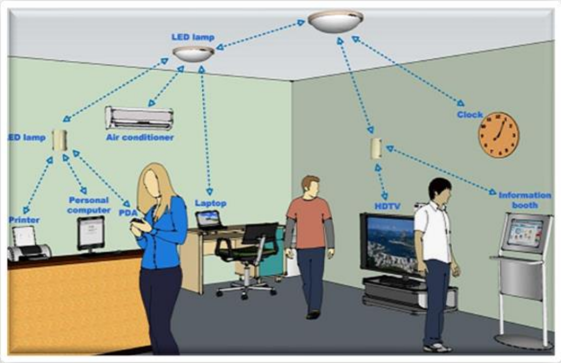
Motivation

- RF technology is facing congestion issue due to continuous increase in indoor data traffic.
- VL can complement RF but face challenges including the need for sensitive receivers with wide fields of view.
- SiPMs could be used to increase the sensitivity of VLC receivers.
- Fluorescent concentrators can provide signal gain with a wide FOV whilst rejecting some ambient light.



Outline

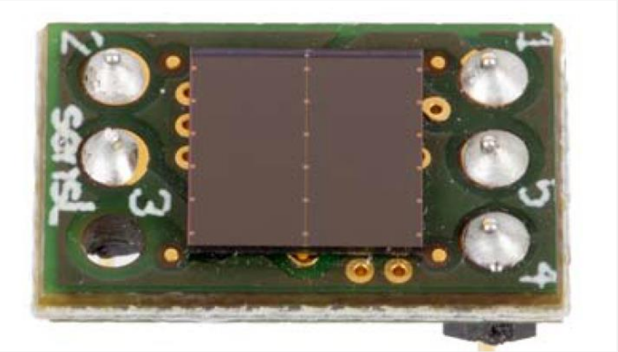
- Introduction to SiPM
- SiPM and wavelength selection
- Fluorescent fibers
- Data transmission and FOV results
- Predicted coverage
- Conclusion

Introduction to SiPM

- Single photon avalanche photodiodes (SPADs) are APDs operated above their break down voltage. However, SPADs have an associated quenching device.

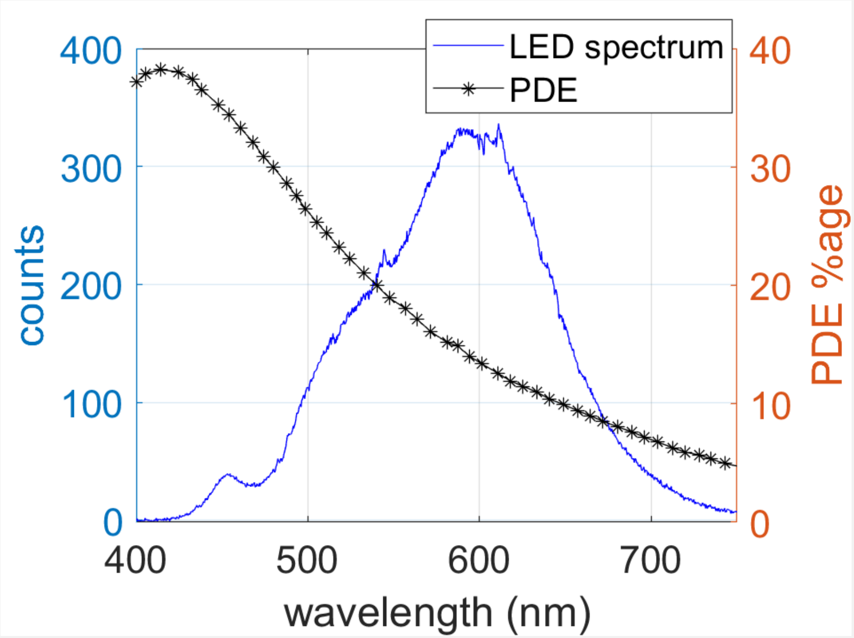
- Silicon Photomultipliers (SiPMs) are arrays of SPADs each of which is capable of detecting single photons.

- In the last few years SiPMs have been incorporated into some experimental OWC receivers because they provide much better sensitivity than APDs



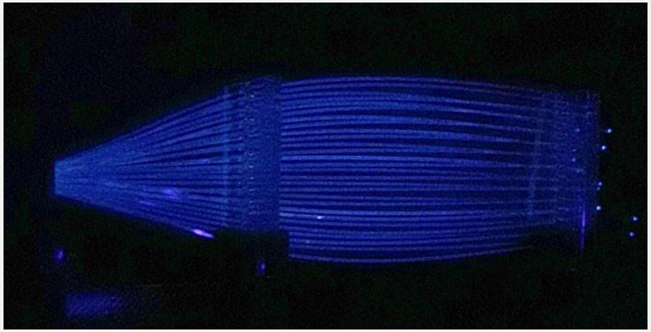
SiPM and wavelength selection

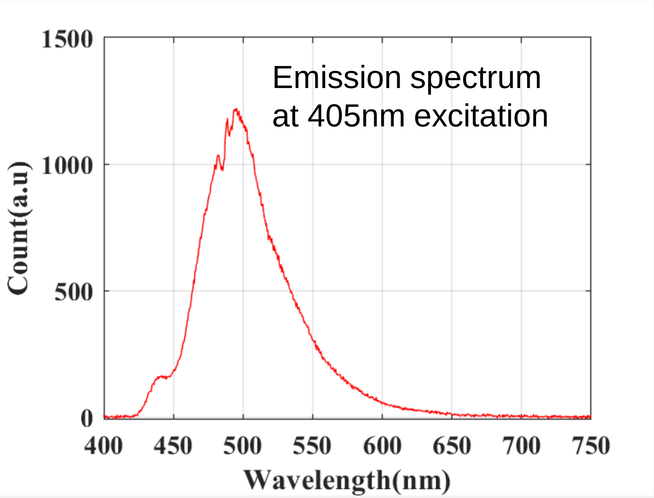
- SiPM selection is based on the area, output pulse width and maximum count rate.
- SiPMs are extremely sensitive to light and their output can become saturated. The amount of ambient light reaching them needs to be as low as possible
- We selected a transmitter wavelength of 405nm because of the higher SiPM PDE and possibility of lower background counts from ambient light.



Fluorescent fiber

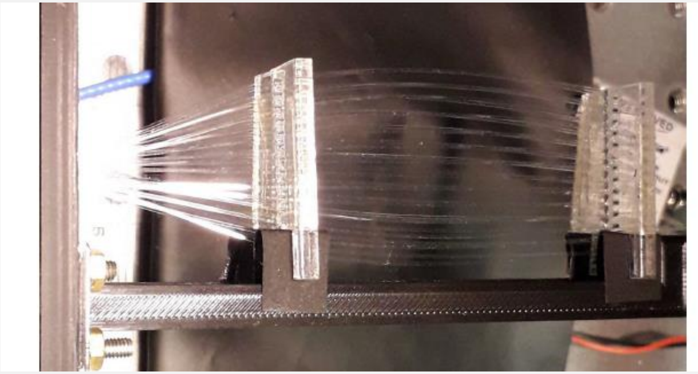
- Optical fibers containing a fluorophore.
- Absorbs light at some wavelengths and emits light at longer wavelengths.
- This light is contained in the fibre by TIR and reaches the receiver (PIN/APD/SiPM) placed at the fiber end.
- Unlike CPCs they do not conserve etendue and so can provide a high gain and wide FOV
- The selected absorption also reduces the impact of ambient light effect when used with SiPM
- Kuraray Fiber:
    - Bandwidth: ~117 MHz
    - Absorptions in ultraviolet and emits blue wavelengths.

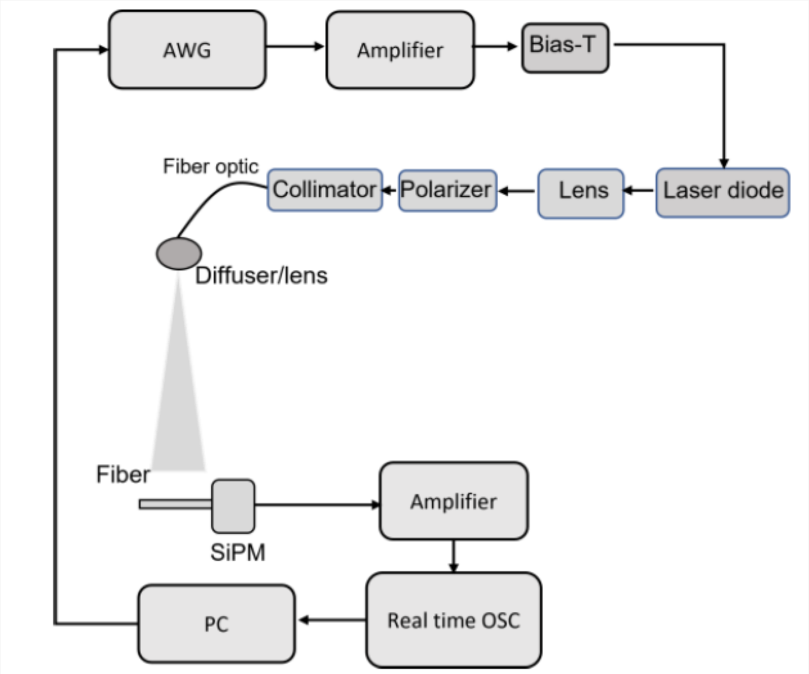




Experimental setup

- 30020 SiPM (3x3mm)
  - BW: 250 MHz
- 405nm transmitter
- Modulation : OOK +DFE
- BER: 10^{-3}
- 28, 12 cm long, fibers were coupled to the SiPM





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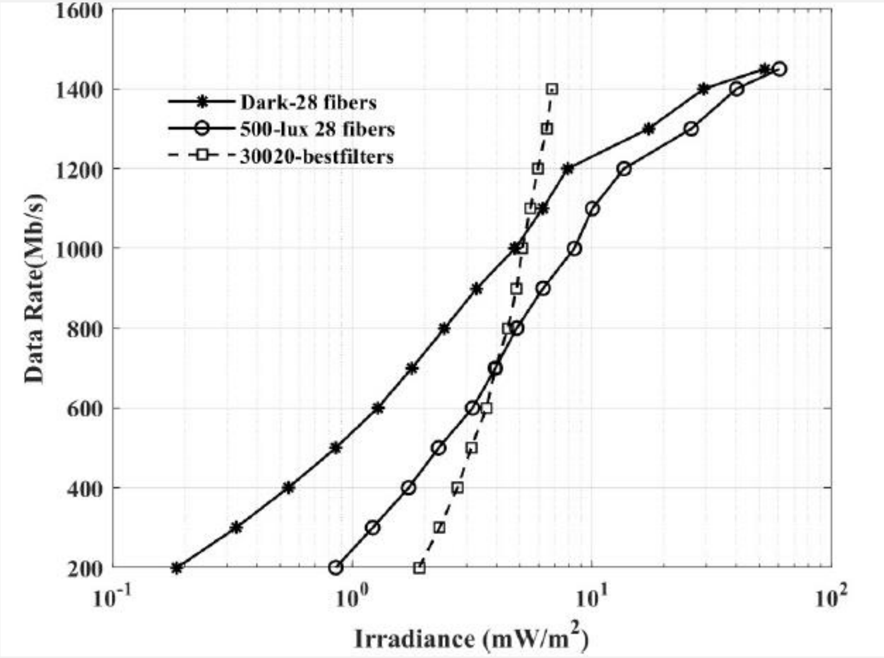
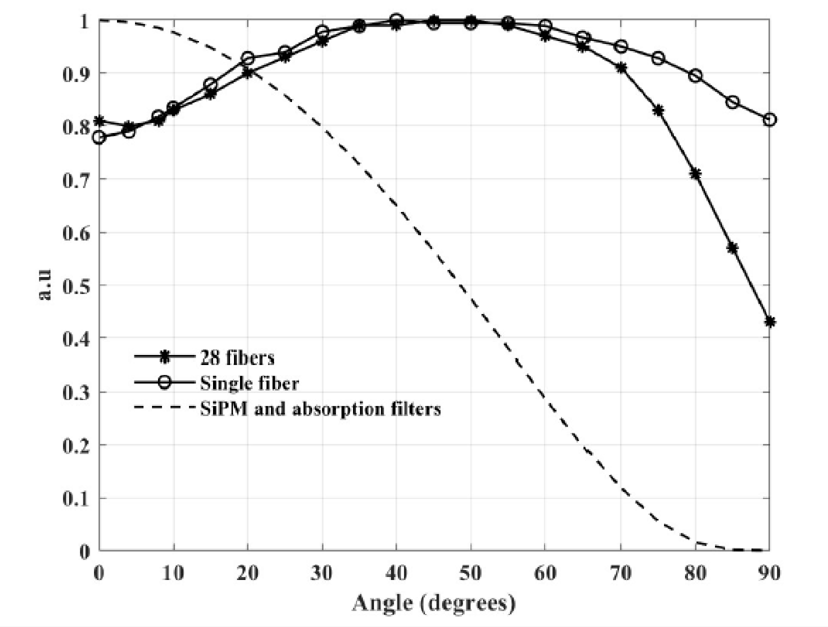
Data Transmission results

- Under 500 lux, the fiber based receiver needs 4.5 dB more irradiance than it did in the dark because some ambient light is scattered into the SiPM by the fibers.
- The bandwidth of the fibre means that the SiPM combined with color glass filters produces better results at higher data rates.
- Fiber based receiver needed lower irradiance at data rates less than 700 Mbps.
- 1 Gbps still achievable with irradiance of ~8.5 mW/m^2.



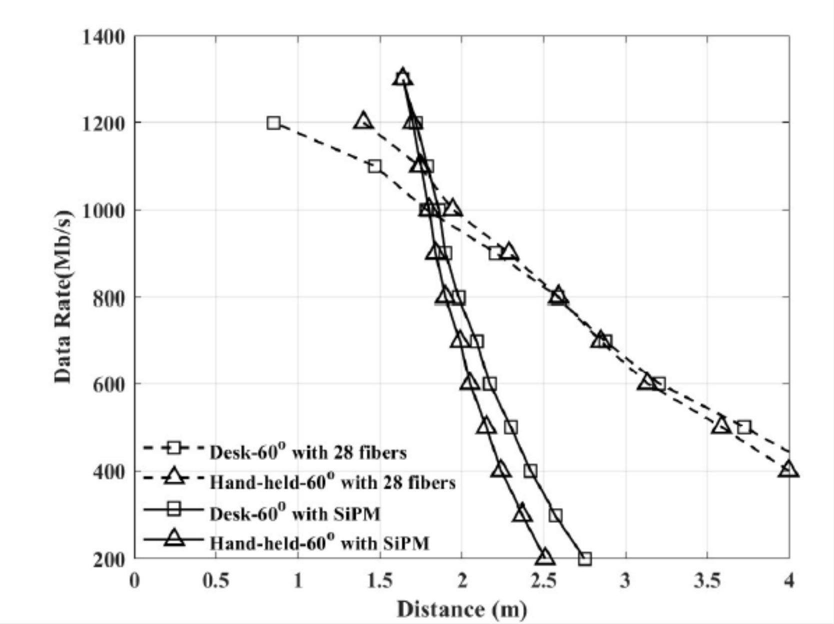
FOV results

- For single fiber: the received power increases as the fibre is rotated because the exposed area increases as the square fiber is rotated.
- For 28 fibers which are widely spaced, the fibers at higher rotation angle shadow each other. This causes the sharp reduction in the received signal from 70º to 90º.
- Fiber based receiver (FOV): ~ ±80º.
- In contrast the receiver containing absorptive filters (FOV): ~±50º.



Predicted coverage

- Assumption: Lambertian transmitter with 60º beam divergence (270mW Power). Ground-ceiling height of 3m.
- Desk height: 0.89m from ground
- Hand-held height: 1.3m from ground
- Data rates are significantly less sensitive to the horizontal distance for fiber receiver.
- Higher data rates can be supported with larger separations between transmitters



Conclusion

- SiPM and fluorescent fibers can be used to design sensitive VLC receivers. .
- A Gbps transmission at 8.5 mW/m^2 irradiance is achieved using 28 fibers and SiPM.
- The designed system provides a FOV of ±80^o.
- The angle dependence of the FOV means that the fiber based receiver provides much better coverage than receiver with absorptive filters.
- Further work is required to determine the best way to use multiple fluorescent fibres to create the optimum angle dependence of the receivers sensitivity.

Thank you