



## 1. Motivation

Electrical power delivery is often impractical or unsafe in settings such as in substation (where voltage isolation is important), powering remote 6G terminals, or for in-body applications (powering cameras during endoscopy). Laser power transfer provides a wireless, EMI-immune alternative [1].

This project aimed to demonstrate the feasibility of using lasers and LEDs (as power converters) in the visible spectrum (405 nm and 450 nm) to power CMOS circuits. Blue is chosen as the bandgap is  $\sim 2.5$  eV delivering higher voltage output compared with silicon ( $< 0.6$  eV).

## 2. Approach and power converter characterisation

Laser power conversion avoids the losses under for example solar illumination due to a lack of below bandgap photons and limited thermalisation of the above bandgap photons. The source laser was a 405 nm Sharp GH0406AA2G, which was tested against a number of LEDs emitting around 460 nm acting as power converting cells. The laser emitted 622 mW at 500 mA and is limited by the heatsinking (Figure 1). One LED was an Osram OSTAR illuminator with two planar LEDs coupled in series (area 1.95 mm x 1.35 mm) and the second was a Lumileds single LED chip with lensed coupler. LEDs at this wavelength have strong absorption at 405 nm despite a low number of absorbing quantum wells. The LED absorption spectra were characterized using a calibrated monochromator (Figure 1). The current-voltage and power-voltage characteristics were recorded to demonstrate how effectively they convert laser power to electrical power (Figure 2).

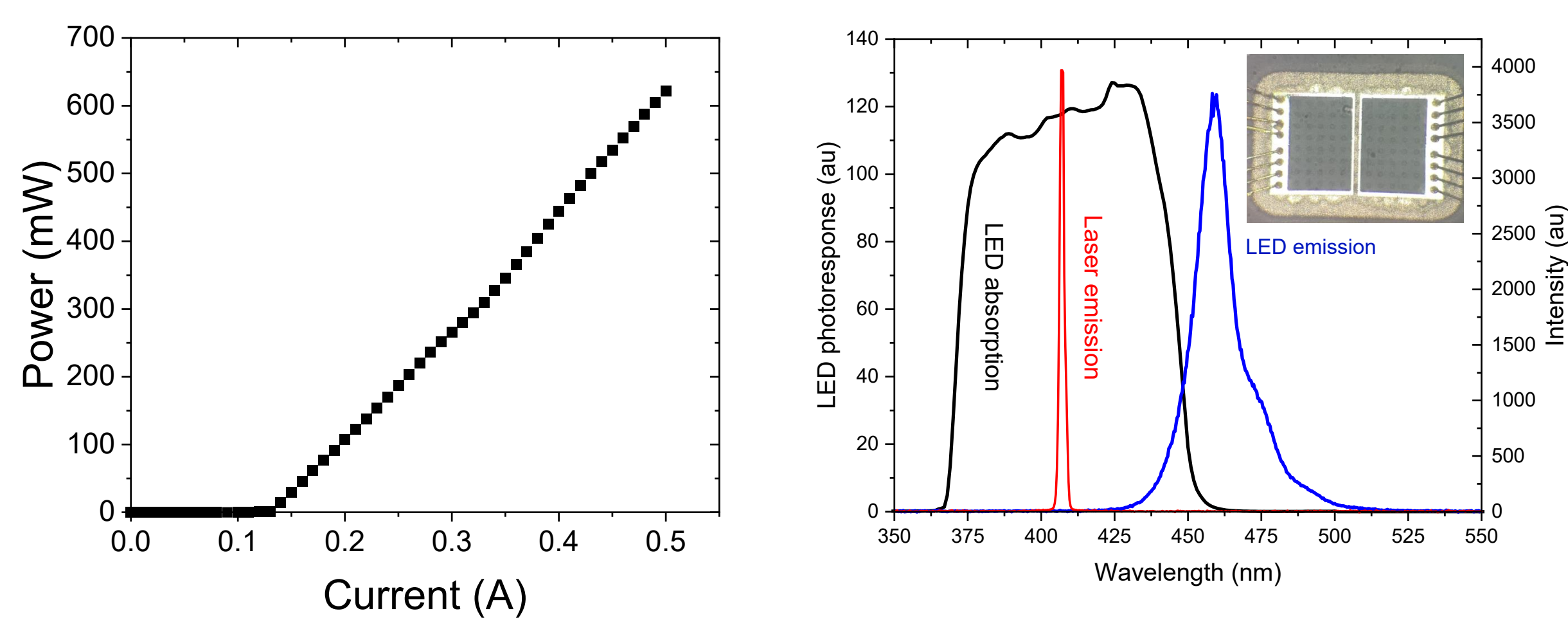


Figure 1: Power current characteristics of the laser (left) Spectral characteristics of laser and LED absorption and emission (right). The inset shows the Osram Ostar LED used as the photovoltaic cell.

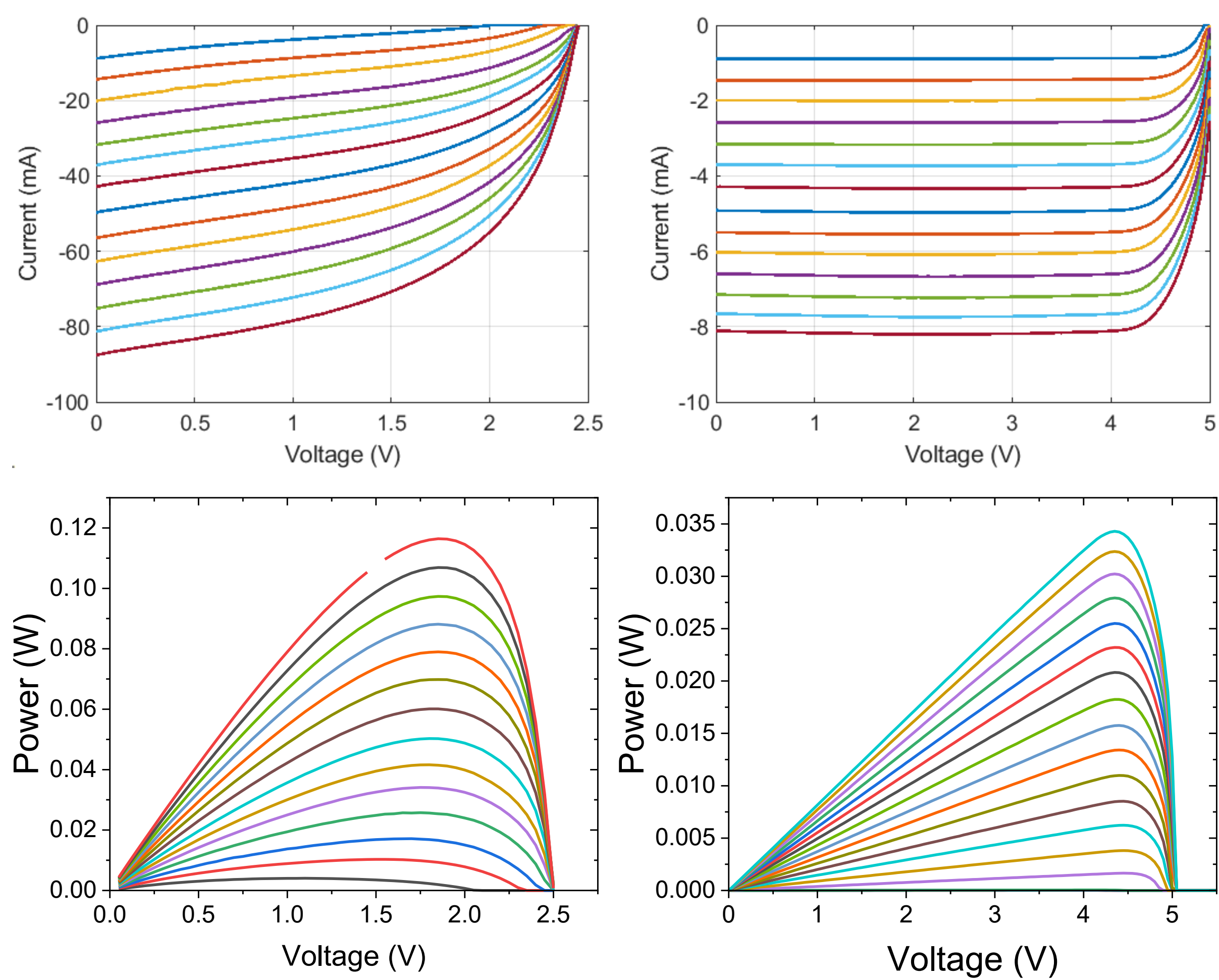


Figure 2: Illuminated IV curves for Lumileds LEDs (Upper Left) and for Osram double LED, (Upper Right) for the same optical powers. In this case, the current is lower, but the voltage is higher as the LEDs are connected in series. Power-voltage characteristic for Lumileds LED (Bottom Left) and for Osram double LED (Bottom Right). Incident optical power starts at 69 mW, and increases in 40 mW steps.

## 3. Circuit design and implementation

This data was then taken to create a polynomial SPICE model that describes the behaviour of these LEDs as PVCs (Figure 2). Details garnered from these experiments is shown in Table 1. With the model complete, SPICE simulations confirmed enough transmitted power and resultant voltage to drive a remotely powered CMOS based circuit. A circuit to emulate data transmission was designed based on a 555 timer and 630nm LED.

Table 1: Comparison of LED characteristics

LED	Peak Absorption Wavelength (nm)	$V_{OC}$ (V) @622 mW	$I_{SC}$ (mA) @622 mW	Max Power (mW) @622 mW
OSRAM LE B P1MS	424.5	5	8.12	34.30
Lumileds LUXEON C	400	2.45	87.53	113.29

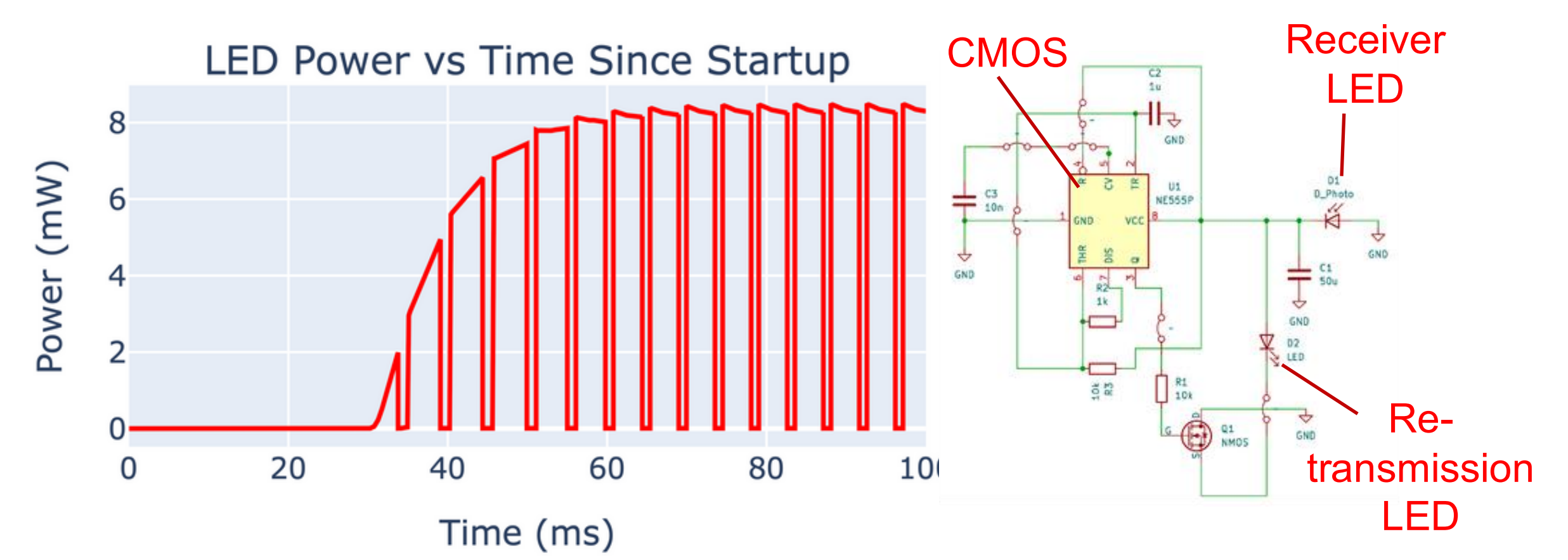


Figure 3: SPICE simulation results (left) and circuit (right)

The circuit, Figure 3 (right), was built, and values of resistance and capacitance changed to change the switching frequency. The construction showed that the optical power transfer was capable of driving both the CMOS circuit and the re-transmission LED, and the 555 timer successfully switched the LED (Figure 4, right), demonstrating data transmission capabilities with a peak rate of 5 kB/s (limited by the switching transistor, not the power supply).

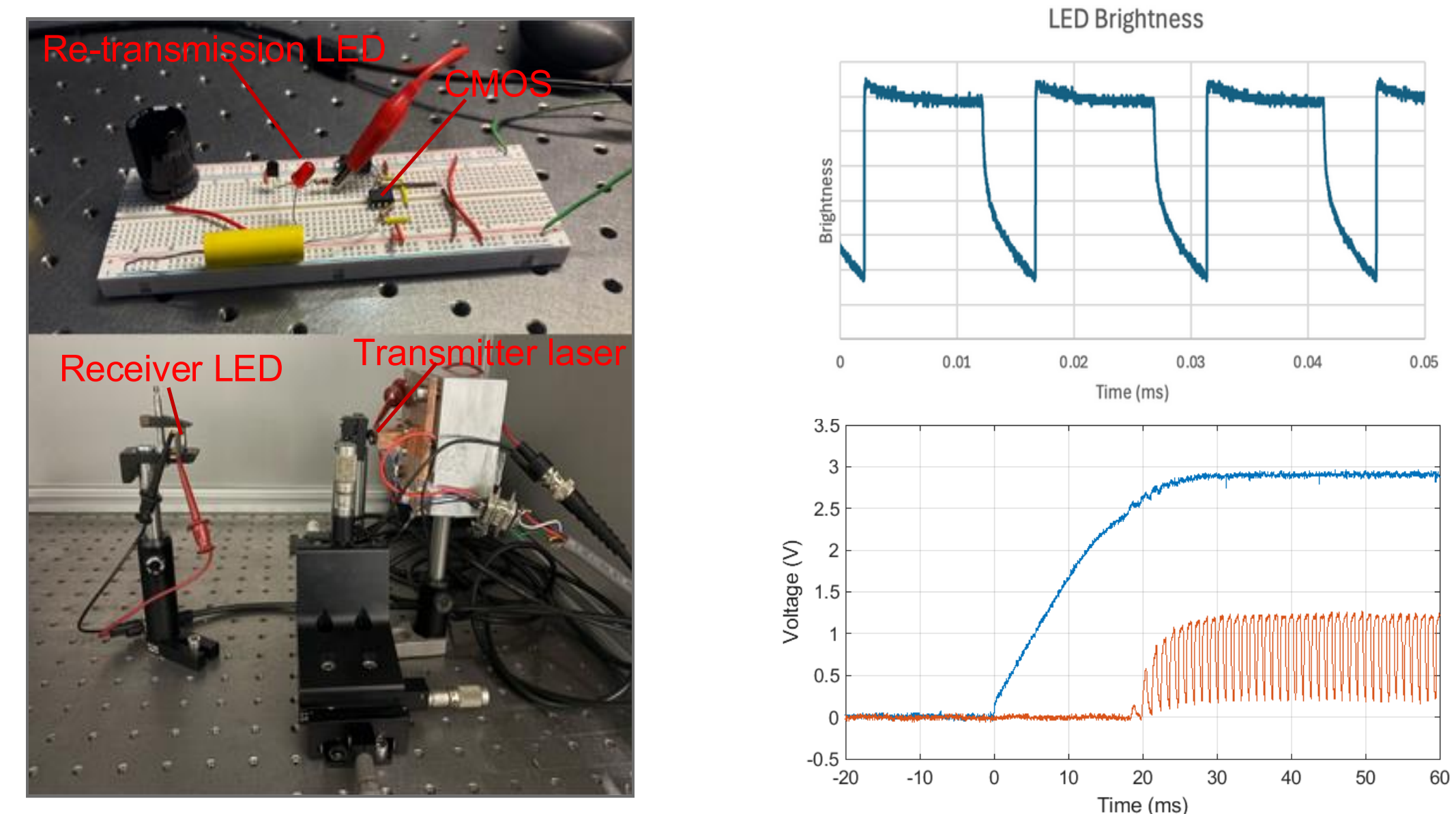


Figure 4: Physically constructed setup (left), LED brightness (upper right) and start up time (lower right, blue= rail voltage, red= optical signal). This shows that the re-transmission LED was successfully switched at different pulse rates, driven from the optically transmitted power.

## 4. Conclusions and future work

LEDs are effective power converters and can deliver high voltage when serially connected. Over 100mW can be delivered with 18% wall-plug efficiency.

The research shown here can primarily be furthered through three avenues:

1. **Real data transmission** – e.g. using low-power MCUs like the STM32-WLE5 with LoRa.
2. **Efficiency** – improved with better emission/absorption overlap, specialised photodiodes and direct fibre coupling.
3. **Range** – current tests were  $< 40$  cm, but longer distances are more relevant and challenging.

## 5. References

1. Zhao, J. et al. "Compact Optical Wireless Power Transmission Using LED Arrays and GaAs Photovoltaics." Photonics, 10(7), 824 (2023)

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