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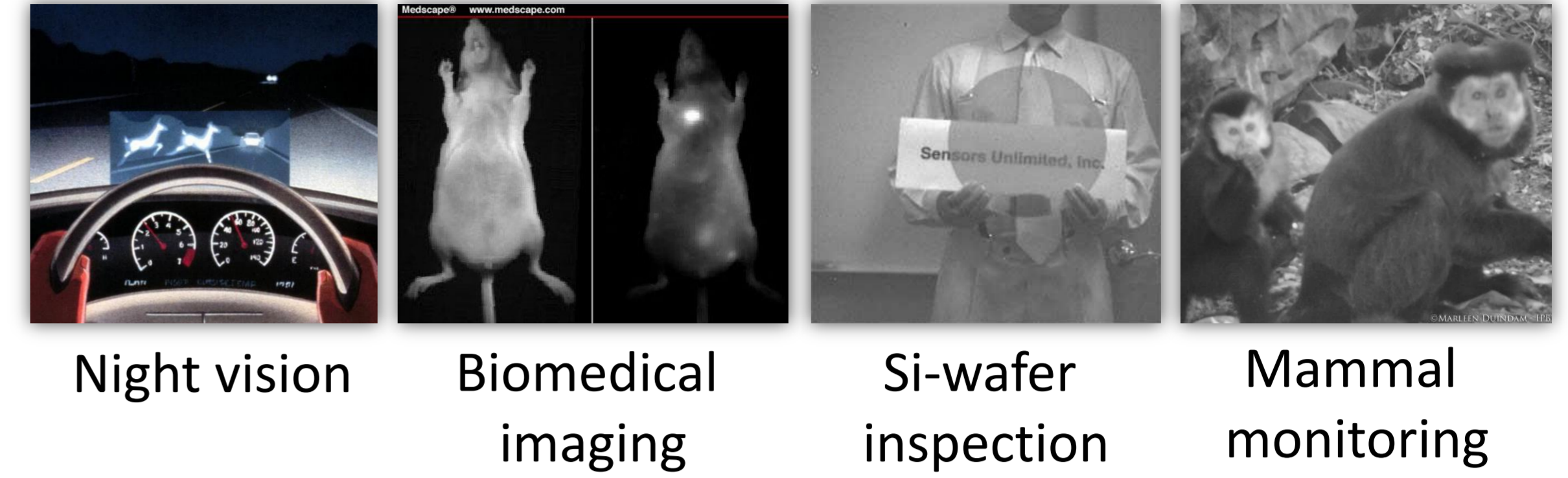
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## Introduction

- Organic NIR upconverter (OUC) combines an organic photodetector (OPD) with an organic light emitting device (OLED)
- The OUC converts NIR light into visible light
- So far only few OUCs reported
- No device sensitivity beyond 900 nm reported
- Here we present a squaraine based OUC with sensitivity beyond 1000 nm
- With a transparent top electrode the OUC shows an average transmittance over 65%

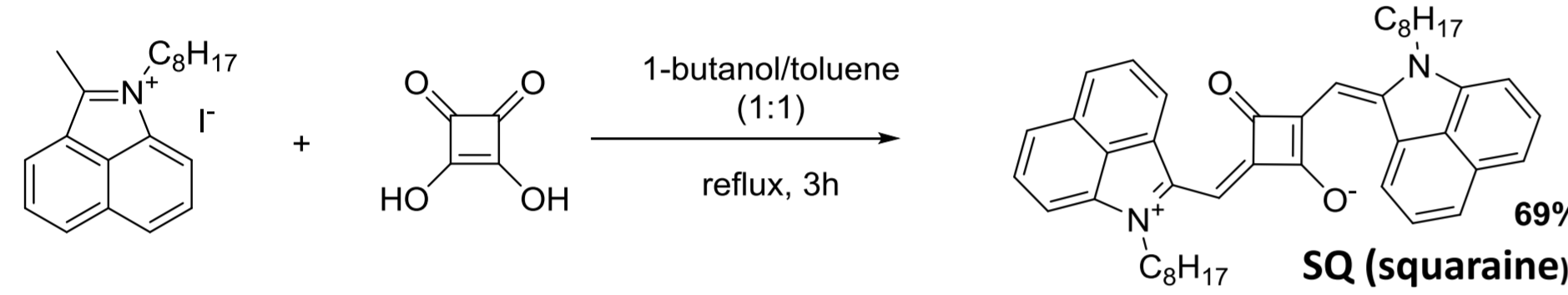
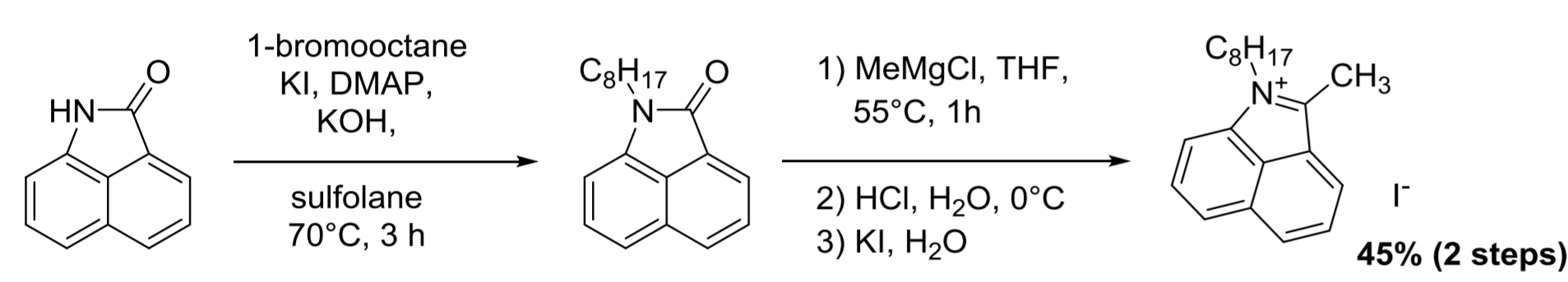
## Applications



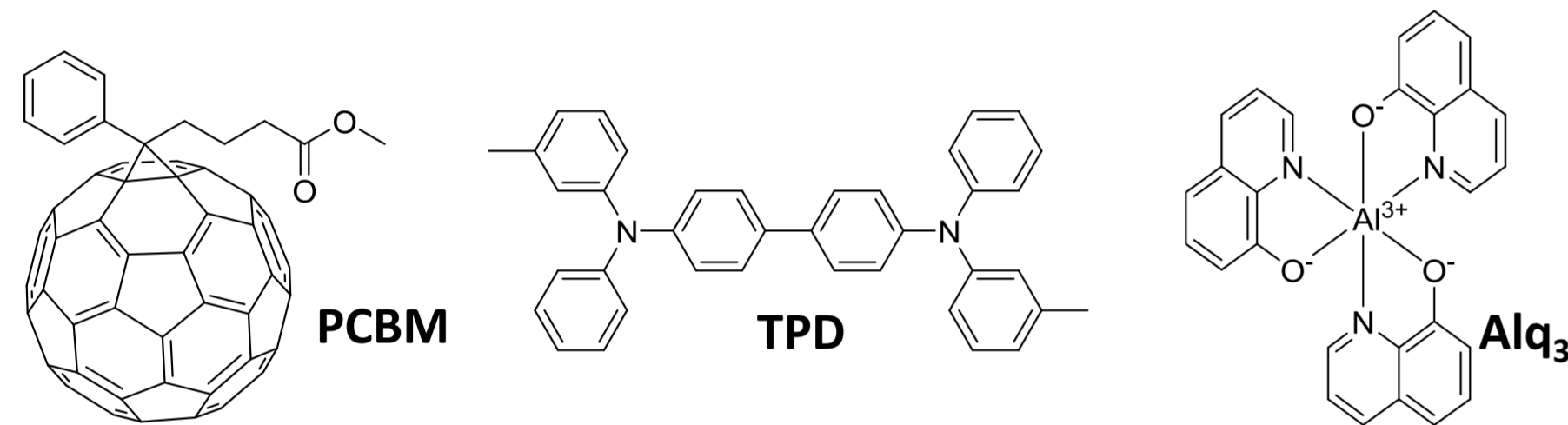
## Results

### Materials

- The squaraine dye ( $\lambda_{\max} = 965 \text{ nm}$ ) was synthesized in three steps

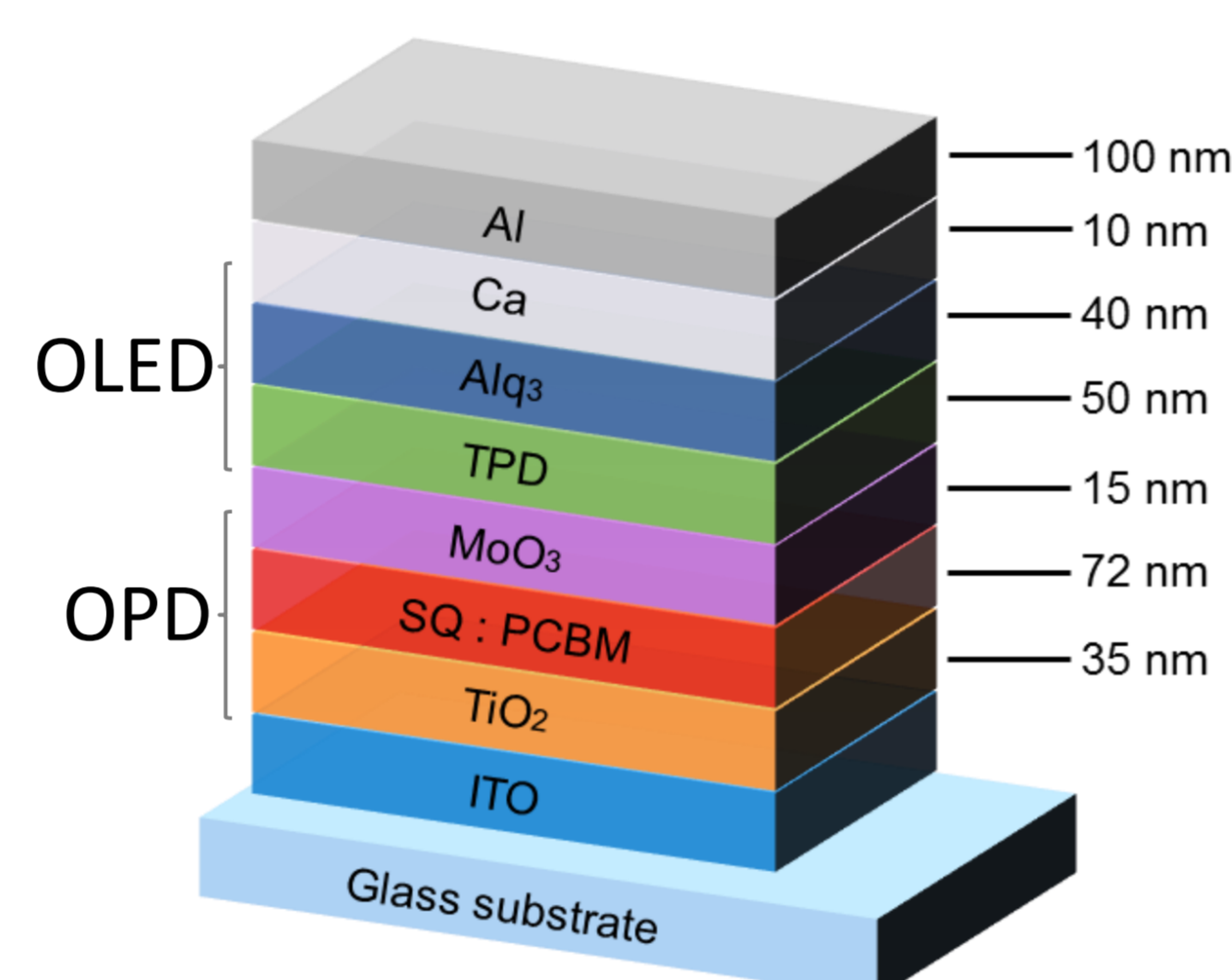


- PCBM was used as acceptor, TPD as hole transport layer and Alq<sub>3</sub> ( $\lambda_{\max} = 530 \text{ nm}$ ) as emitter in the OLED

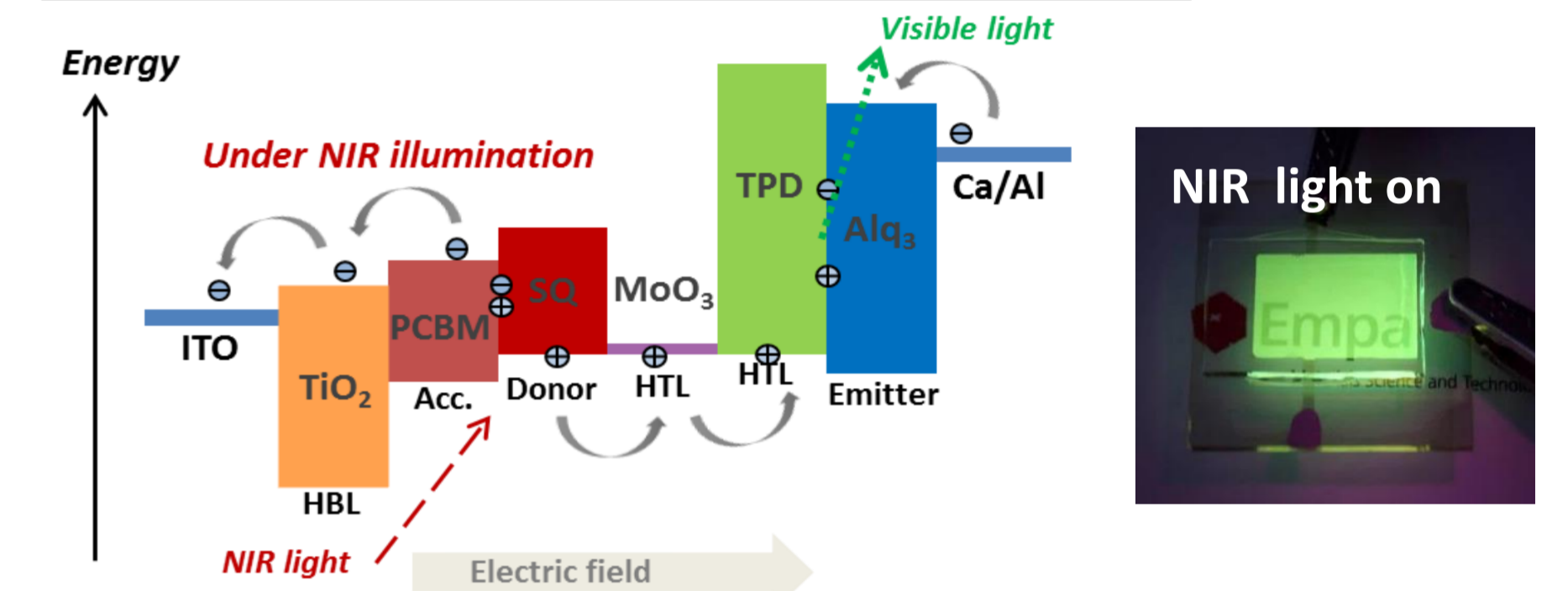
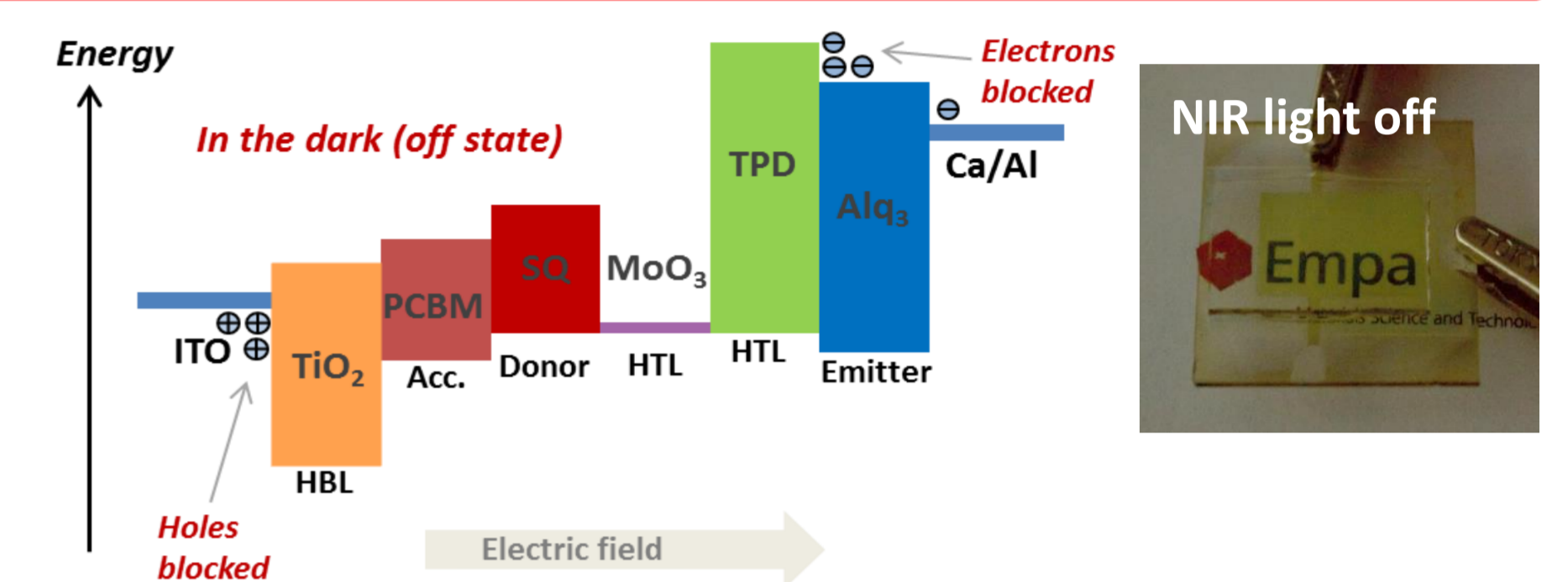


### Device structure

- The different layers were deposited on an ITO coated glass substrate
- Spin coating was used for TiO<sub>2</sub> and the SQ:PCBM blend
- Thermal evaporation was used for MoO<sub>3</sub>, TPD, Alq<sub>3</sub>, Calcium and Aluminum



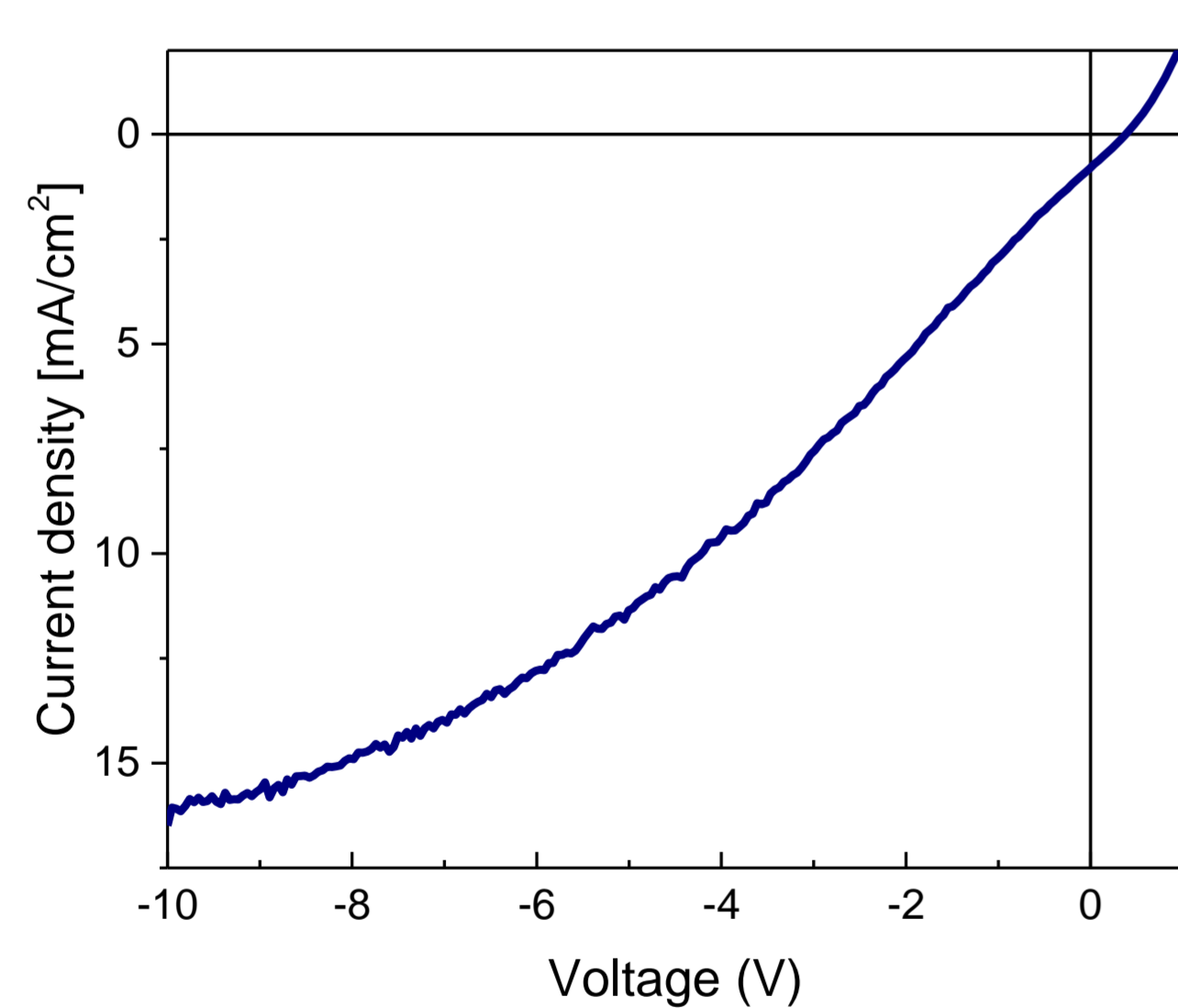
### Operation mechanism



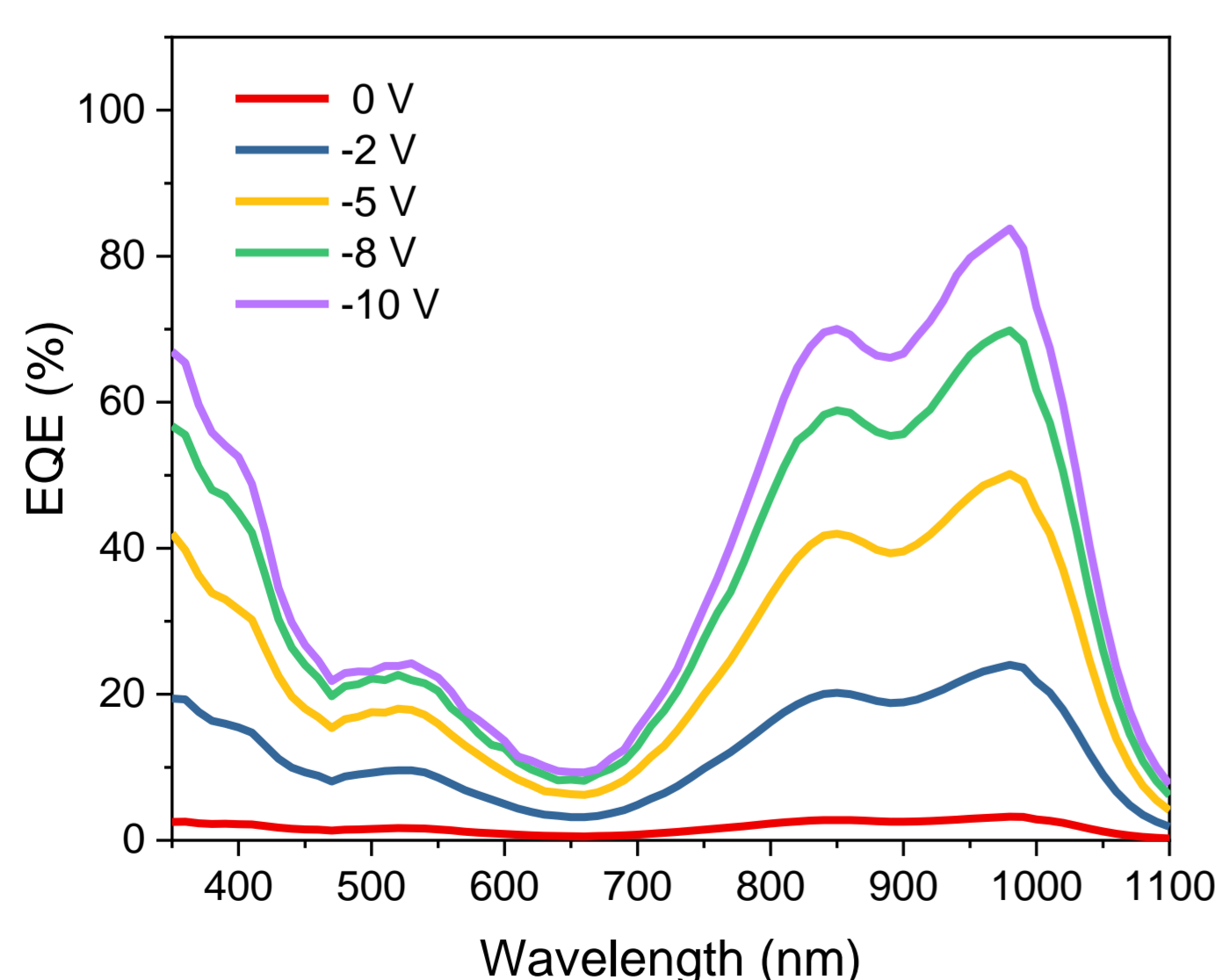
- In the dark, electrons and holes are blocked
- NIR leads to exciton formation which separates at the PCBM:SQ-interface
- Holes recombine with electrons from the Ca/Al electrode at the TPD:Alq<sub>3</sub> interface under emission of visible light

### Photodetector performance

- Before integration in an OUC, the OPD was investigated separately
- Optimized OPD device shows an unusual linear dependency in the I-V curve

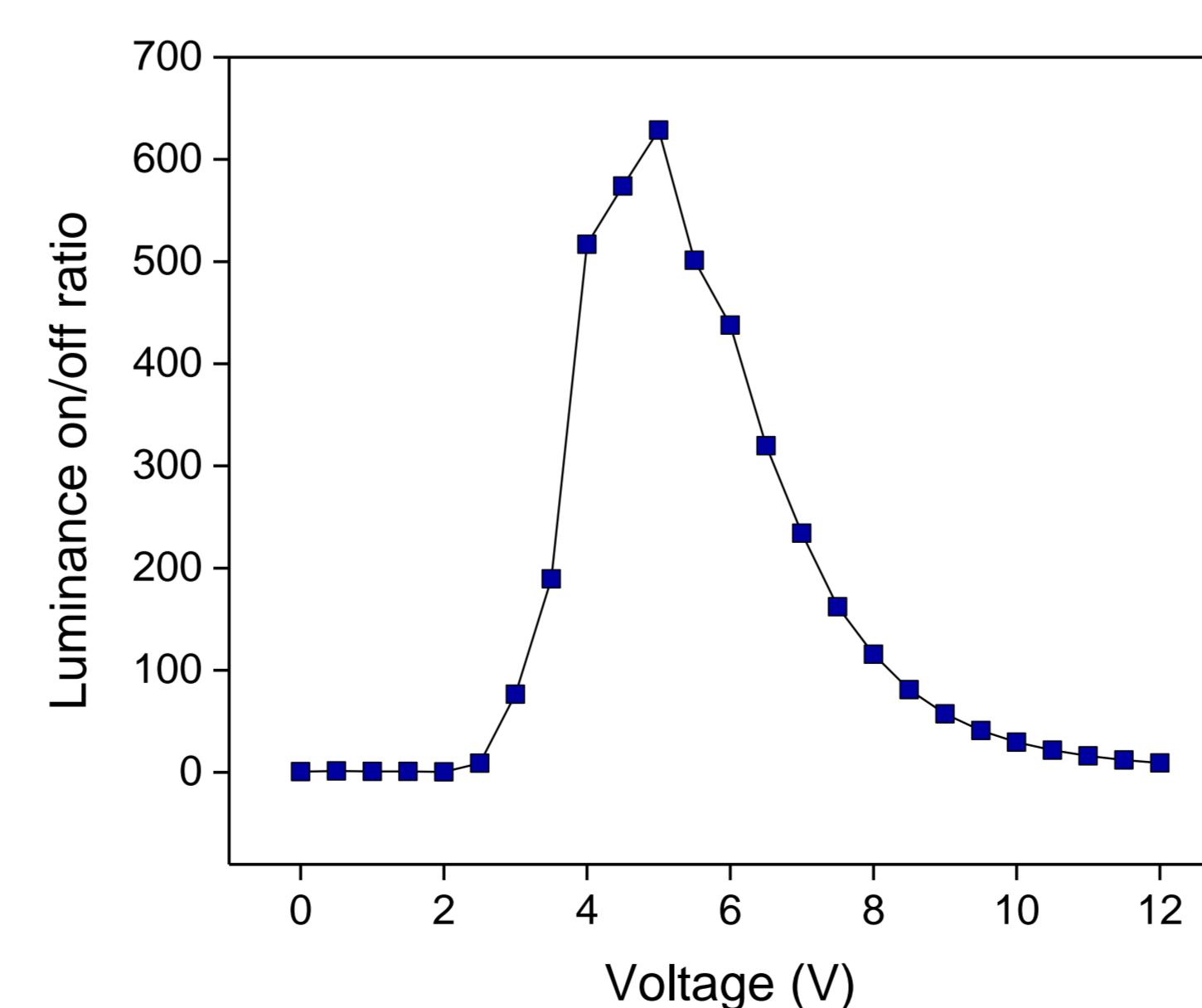
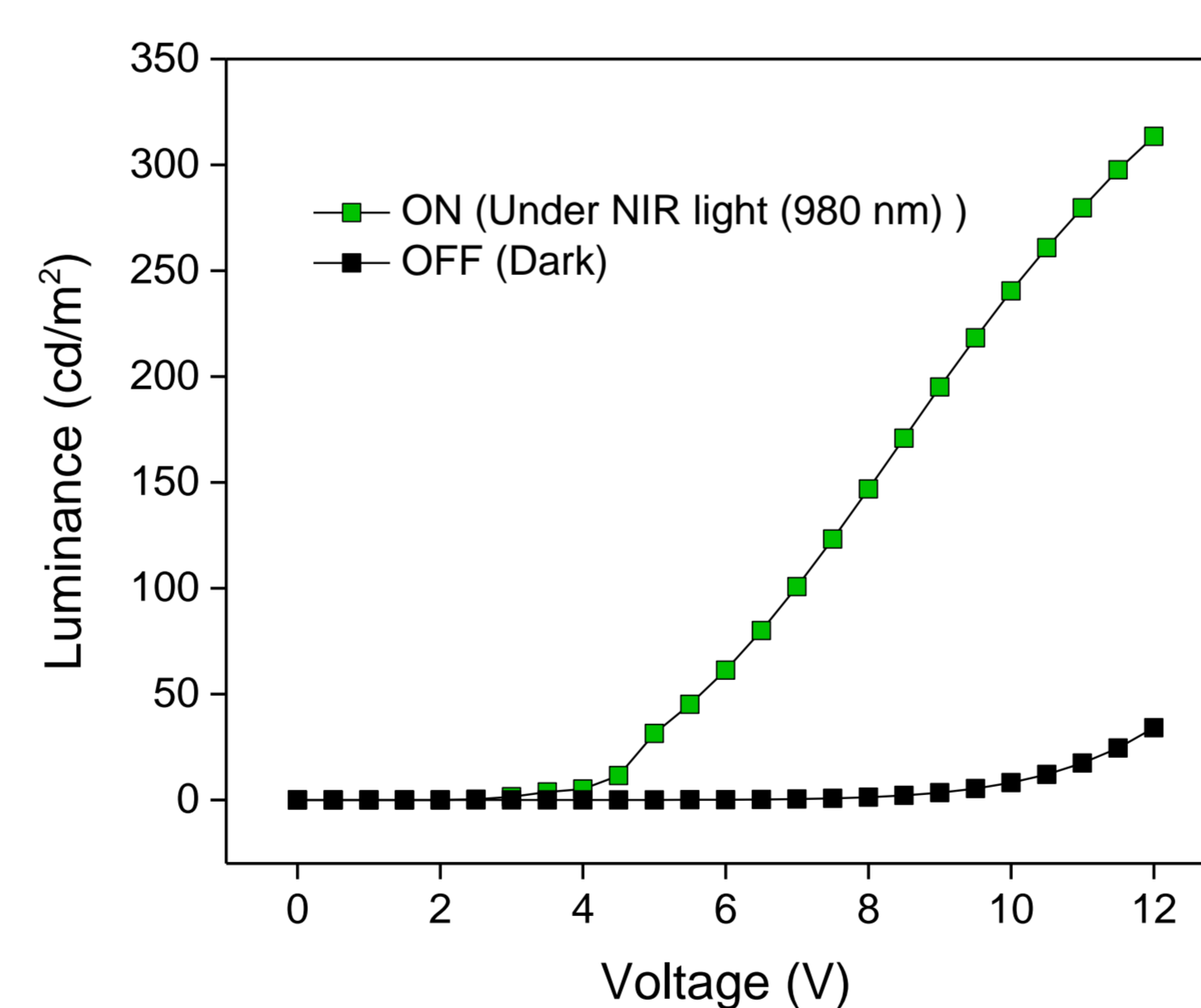


- External quantum efficiency (EQE) of more than 80%



### Upconverter performance

- OPD was integrated in the OUC
- Key parameters of an OUC can be obtained by measuring the I-V-L (current-voltage-luminance) characteristics



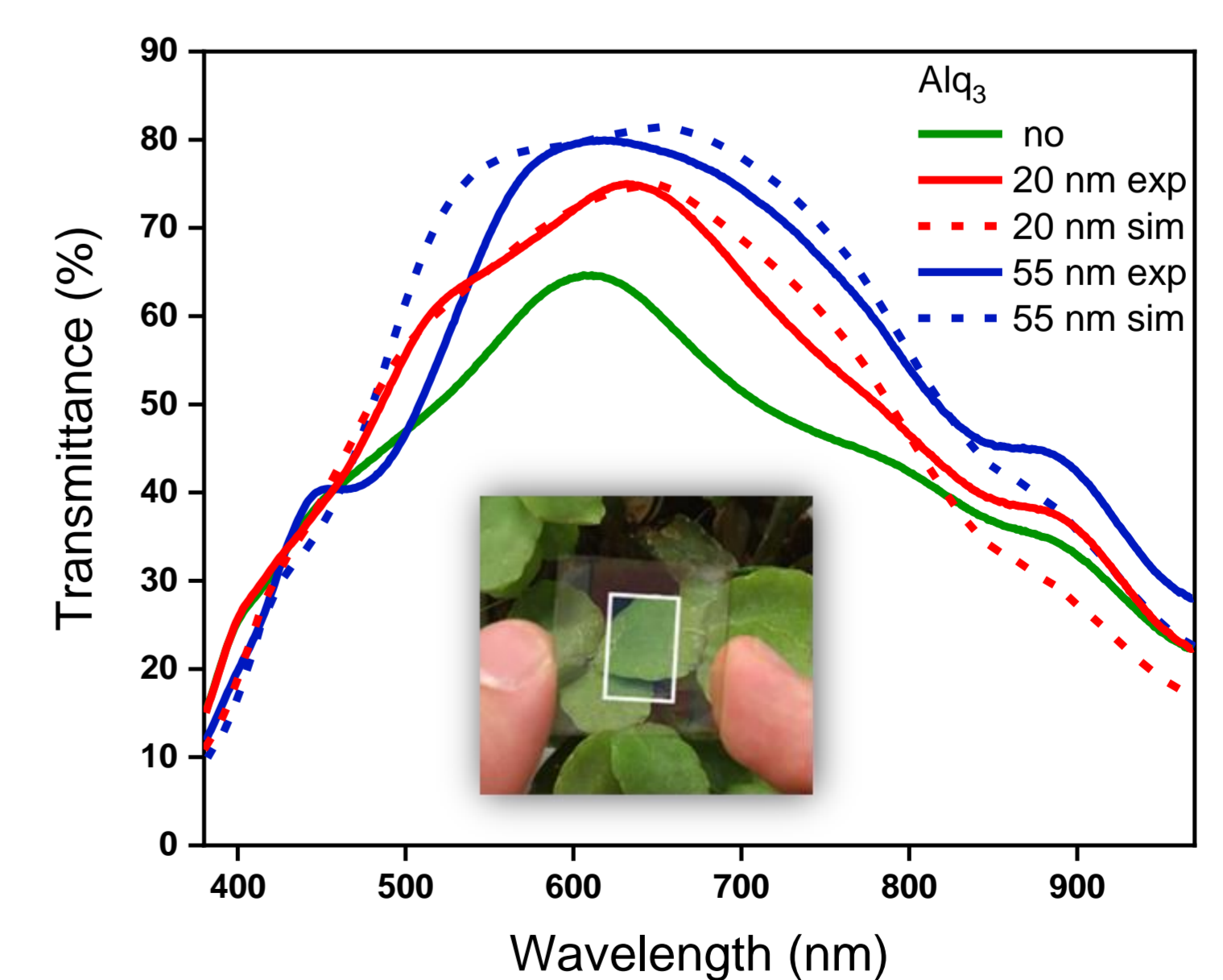
- Key characteristics of the optimized OUC

| Electrode              | V (turn on) | Current density at 12 V |
|------------------------|-------------|-------------------------|
| Ca/Al                  | 2.5 V       | 16.1 mA/cm <sup>2</sup> |
| Ca/Au/Alq <sub>3</sub> | 3.0 V       | 18.0 mA/cm <sup>2</sup> |

| Luminance at 12 V     | Luminance on/off ratio at 4 V | P2PCE* |
|-----------------------|-------------------------------|--------|
| 328 cd/m <sup>2</sup> | 633                           | 0.27%  |
| 140 cd/m <sup>2</sup> | 454                           | 0.14%  |

\*photon-to-photon-conversion efficiency

- Optical simulations and the experiment showed that replacing the cathode stack (Ca 10nm/ Al 100 nm) with Ca (2 nm)/Au (8nm)/Alq<sub>3</sub> (55 nm) leads to an average visible transmittance (AVT) of over 60%



## Conclusion

- A squaraine dye was used in an OUC for the first time
- Optimized OPD shows EQE of more than 80%
- The corresponding OUC shows a P2PCE of 0.27% (theoretical maximum 0.3 - 0.6%) and a low turn-on voltage of 2.5 V
- So far, no other OUC with an absorption over 1000 nm has been reported
- The transmittances of the optical simulation and the experiment are consistent and show an AVT of over 65%

## Acknowledgement

- This work was supported by the Brazilian-Swiss Joint Research Programme (BSJRP)
- We thank Peter Ganovsky and Sasa Vranjkovic for help with the demo device
- Pictures: [www.quora.com/What-are-the-organic-molecules-in-the-OLED](http://www.quora.com/What-are-the-organic-molecules-in-the-OLED); [www.ipbio.org.br/](http://www.ipbio.org.br/); [www.astrainc.co.jp/sui\\_wafer\\_inspection.jpg](http://www.astrainc.co.jp/sui_wafer_inspection.jpg); [www.techcraves.com/car-night-vision-whats-the-deal/66/581/](http://www.techcraves.com/car-night-vision-whats-the-deal/66/581/); [www.medscape.com](http://www.medscape.com)