Zurich University
of Applied Sciences
zh
aw
School of
Engineering
ICP Institute of
Computational Physics

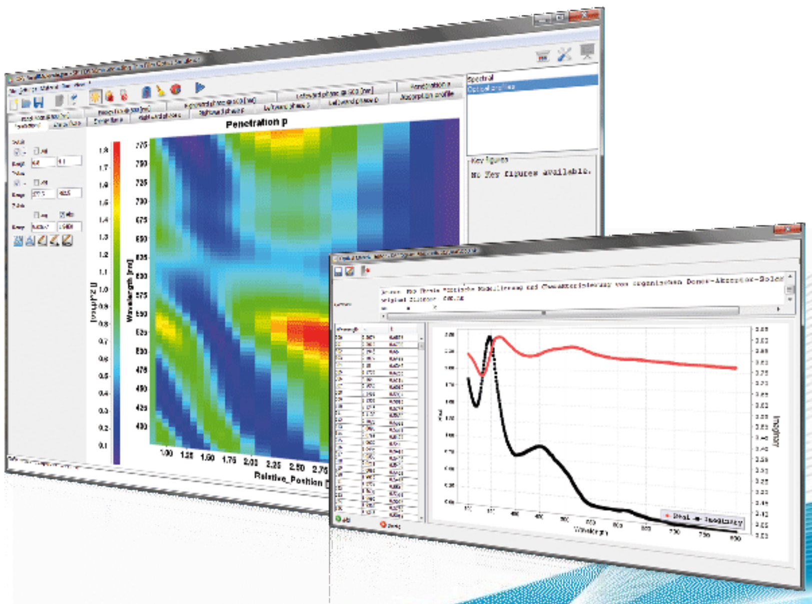
FLUXiM
www.fluxim.com

Design, Characterization and Optimization of OLEDs for Lighting

Beat Ruhstaller

Fluxim AG / ZHAW

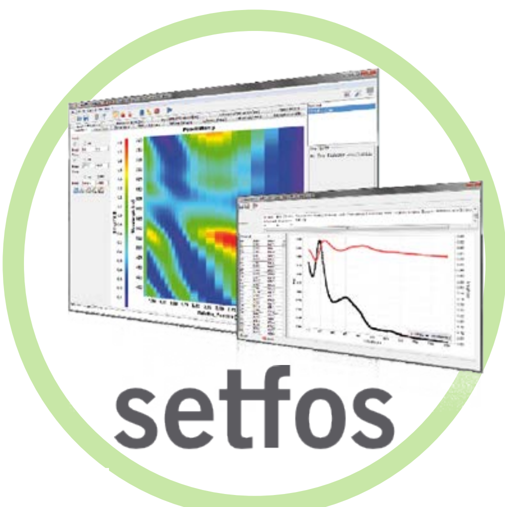
12.12.2016
SPN SSSL, Muttenz

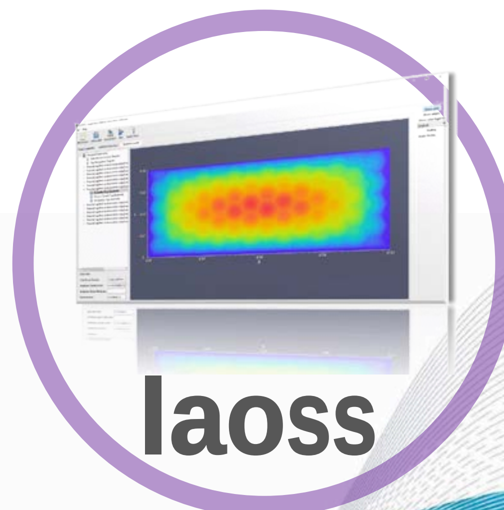


R&D Tools for OLEDs & Next Gen PV

FLUXiM
www.fluxim.com

- Easy-to-use simulation software **setfos** able to simulate OLEDs and thin film PVs on the small scale/cell level.
- Easy-to-use all-in-one characterization platform **paios** to extract device and material parameters by dynamic characterization.
- Easy-to-use large-area simulation software **laoss** able to simulate OLEDs and solar cells up to the module scale.





swiss made software

paios Measurement Techniques

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Impedance Spectroscopy

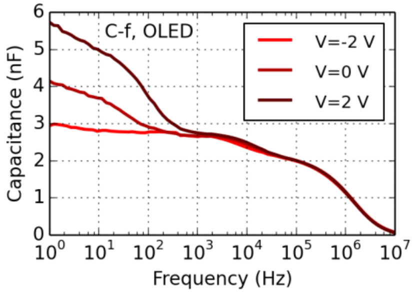
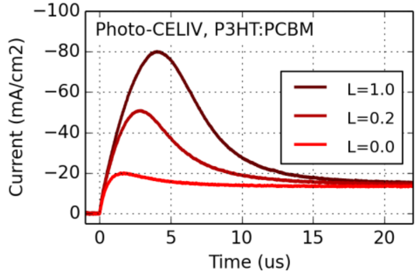
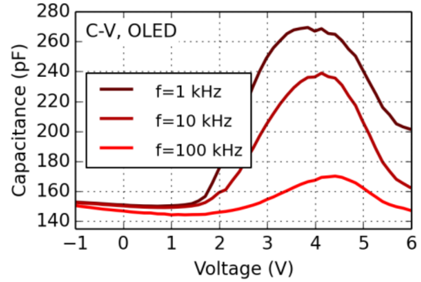


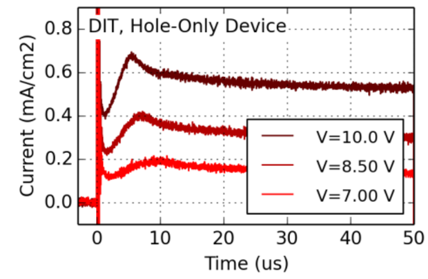
Photo-CELIV



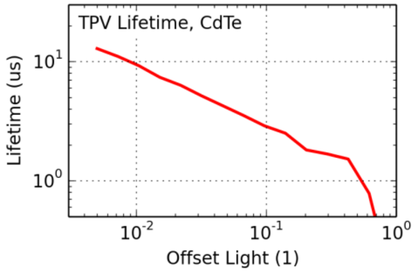
Capacitance-Voltage



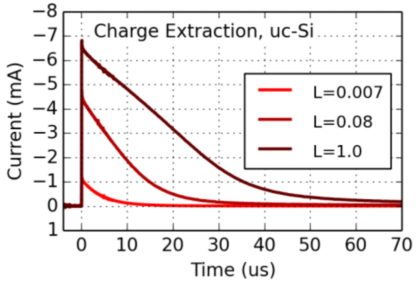
Dark Injection Transients



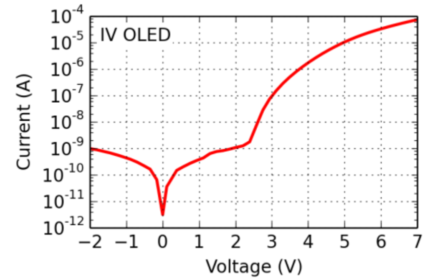
Transient Photovoltage



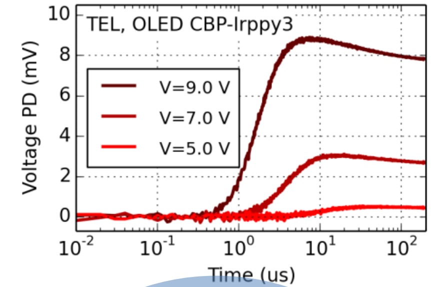
Charge Extraction



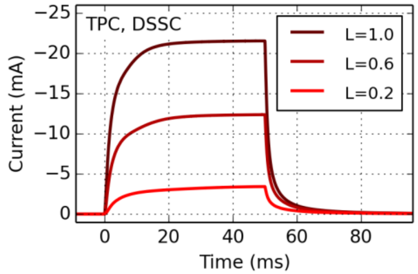
IV-Curves



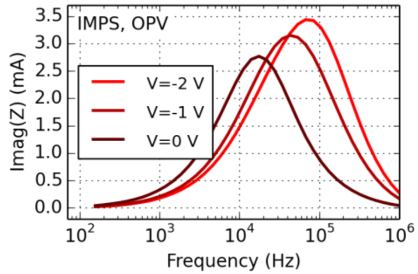
Transient EL



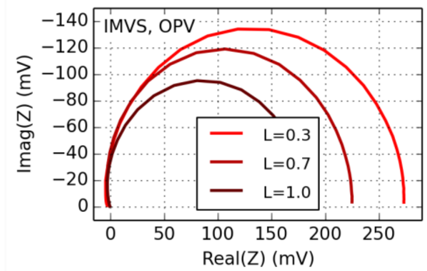
Transient Photocurrent



IMPS

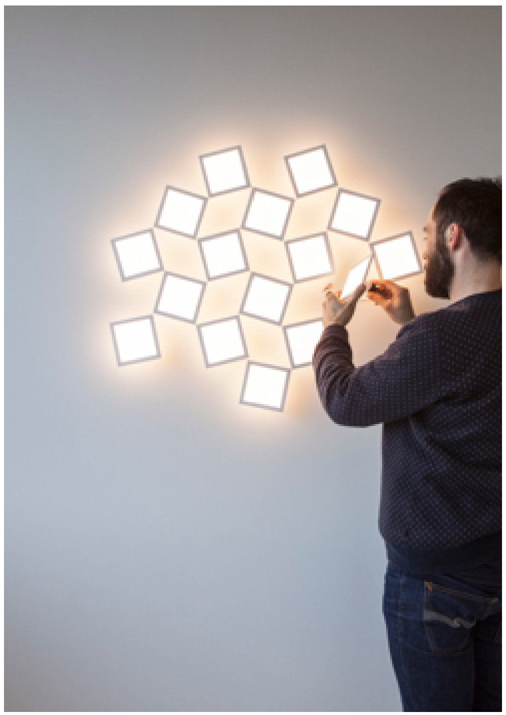


IMVS



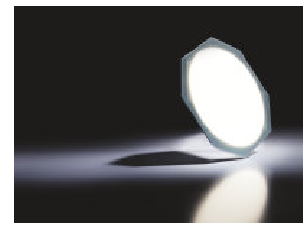
SoA OLEDs for Lighting

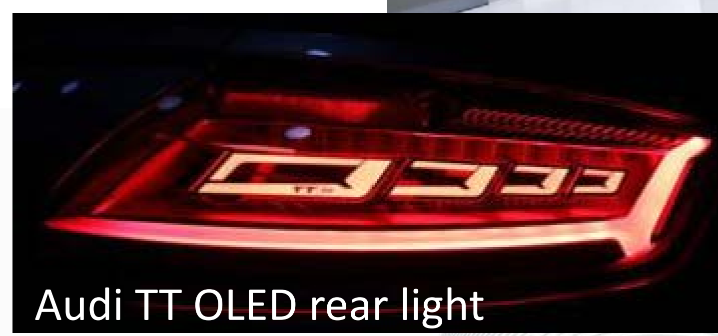
Lumiblades
(OLEDWorks)



LG Chem

OSRAM





Audi TT OLED rear light

OLED R&D Challenges

- Light-outcoupling (scattering…)
- Efficiency roll-off at high currents
- Exciton harvesting (TADF instead of phosphorescence)
- Driving voltage (power consumption)
- Device degradation
- Upscaling to large-area

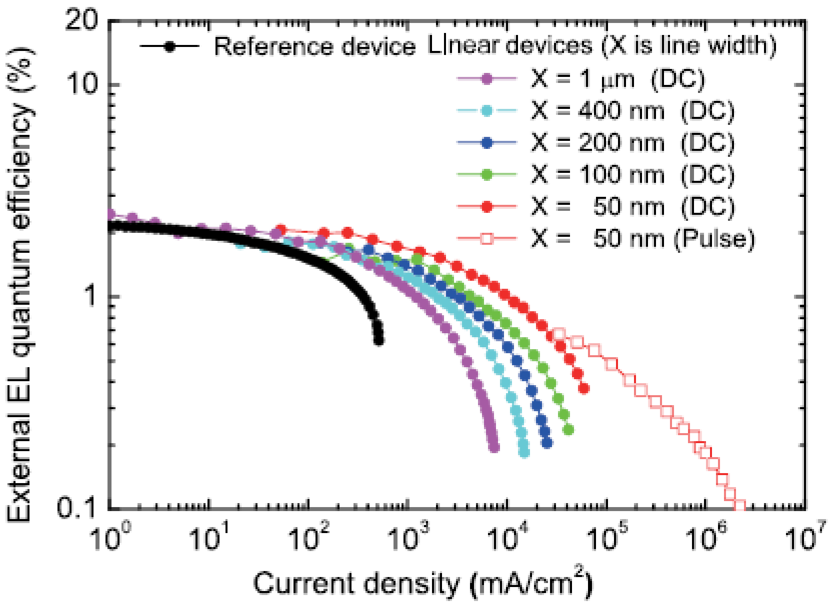
OLEDs & Self-heating & roll-off?

www.fluxim.com

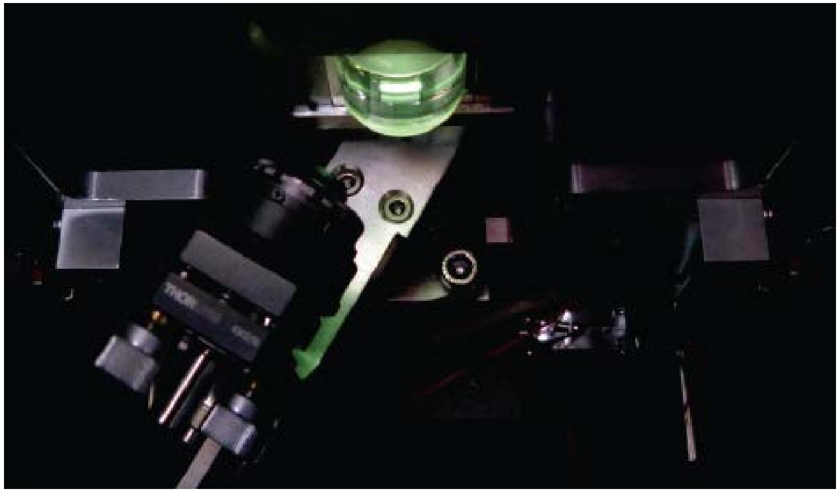
- OLED lighting: Though no heat sink is needed, some heat is produced!
- Heating is an issue in OLED displays, too:
  J. C. Sturm, IEEE JSTQE 4 1 (1998)

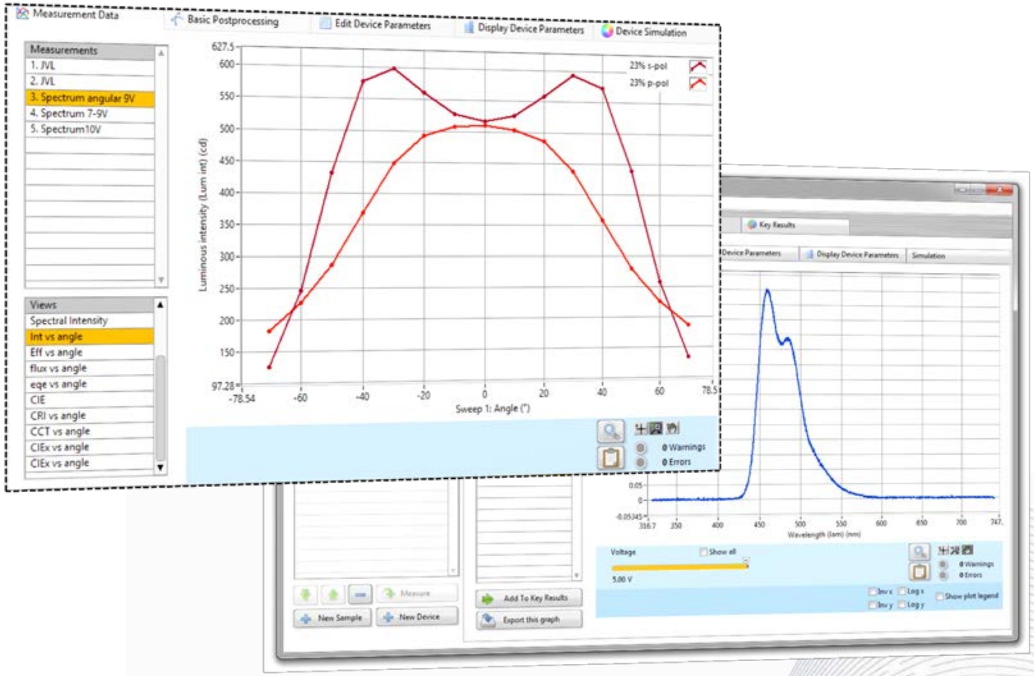
- Suppression of Joule heating in narrow OLEDs reduces **efficiency roll-off**!

  Hayashi, Adachi, Appl. Phys. Lett. ***106****, 093301 (2015)*



PAIOS with
Angular Spectrometer Module
for (O)LED Emission Analysis





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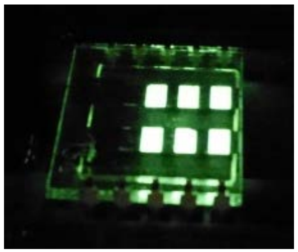
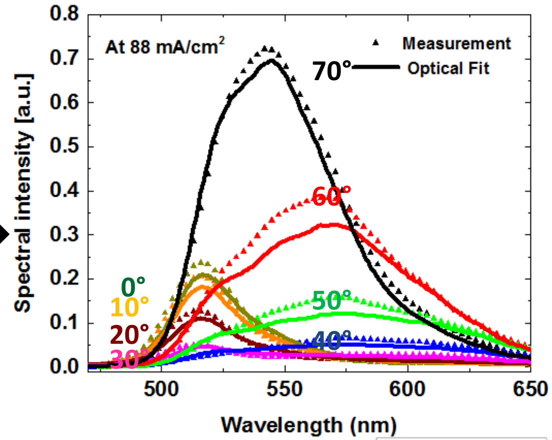
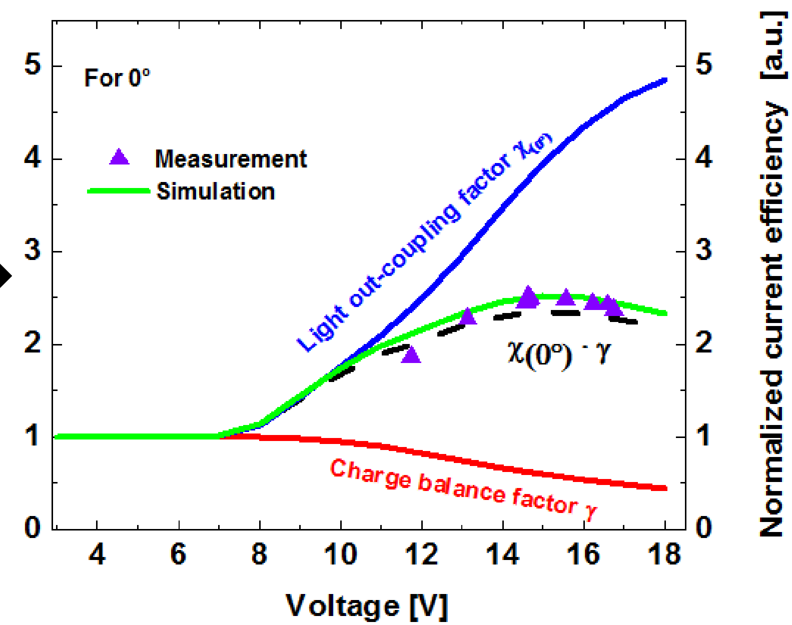
OLED Emission Zone Fitting Example

Phosphorescent OLED



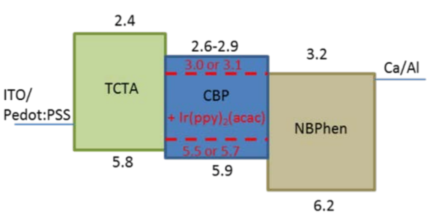
Angular Emission Spectra





30 nm

OLED stack



Measurements: paios

Simulations: setfos

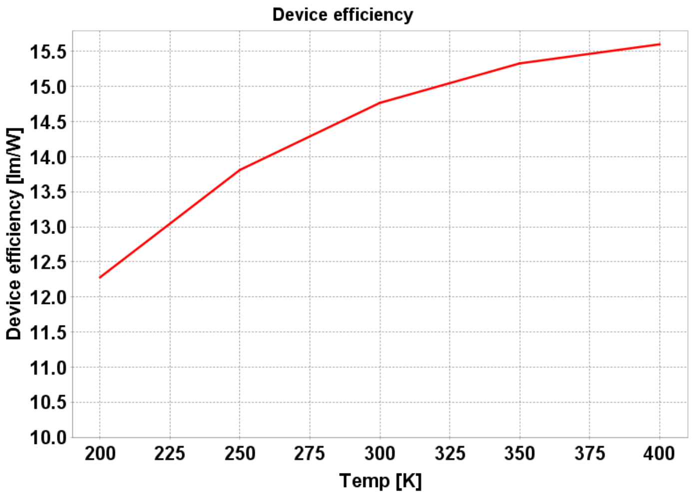
Monitor:

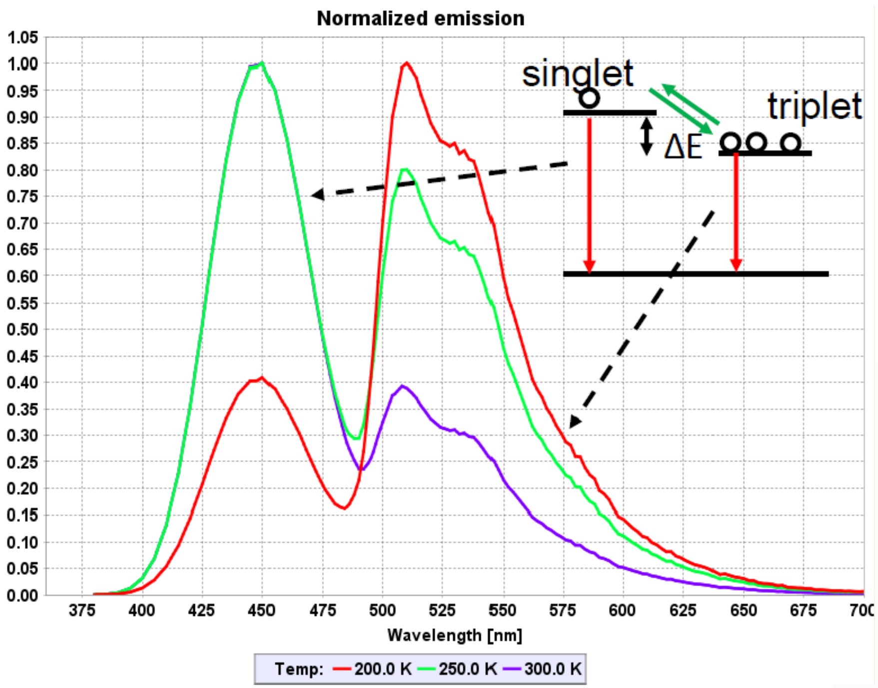
- **Dual-peak emission zone in EML**
- Emission **zone shift** to HTL/EML at **high current** density
- Correlation to efficiency roll-off, aging mechanisms, emitter orientation

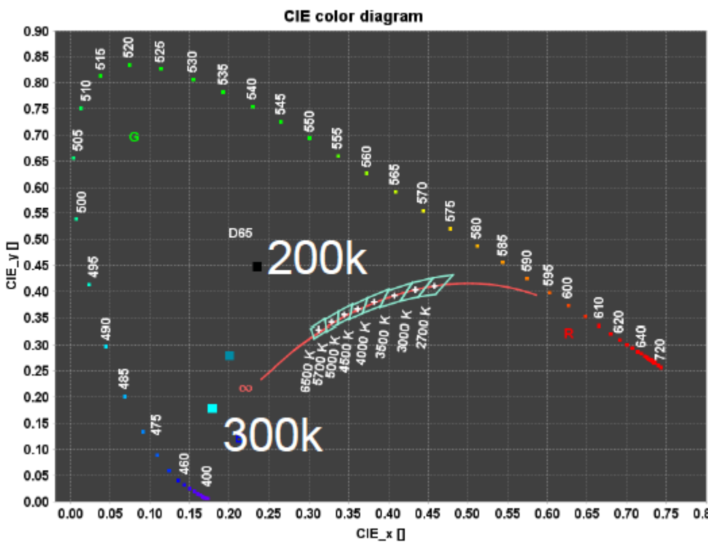
by Markus Regnat, ZHAW

Excitonics in (TADF) OLEDs

- Thermally activated delayed fluorescence (TADF) OLEDs as alternative to phophorescent OLEDs
- Example simulation with **Setfos**: Temperature variation





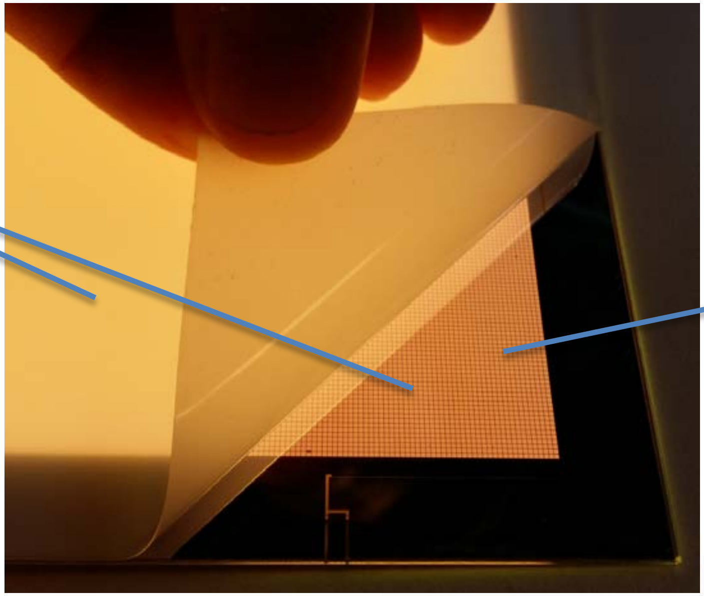


OLED R&D Challenges

Scatter foil improves brightness but changes color & angular dependence

Optical simulation (Setfos)

10 cm x 30 cm OLED by LG Chem



Metal grid enhances conductivity but shadows light

Electrical large-area simulation (Laoss)

OLED Panels w/ Light Extraction Foil – LG Chem Example

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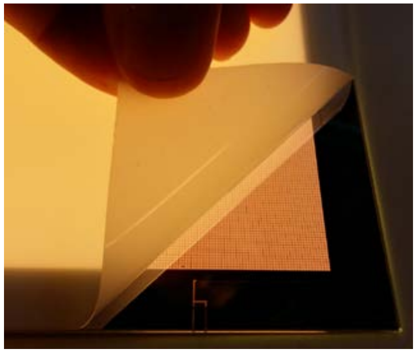
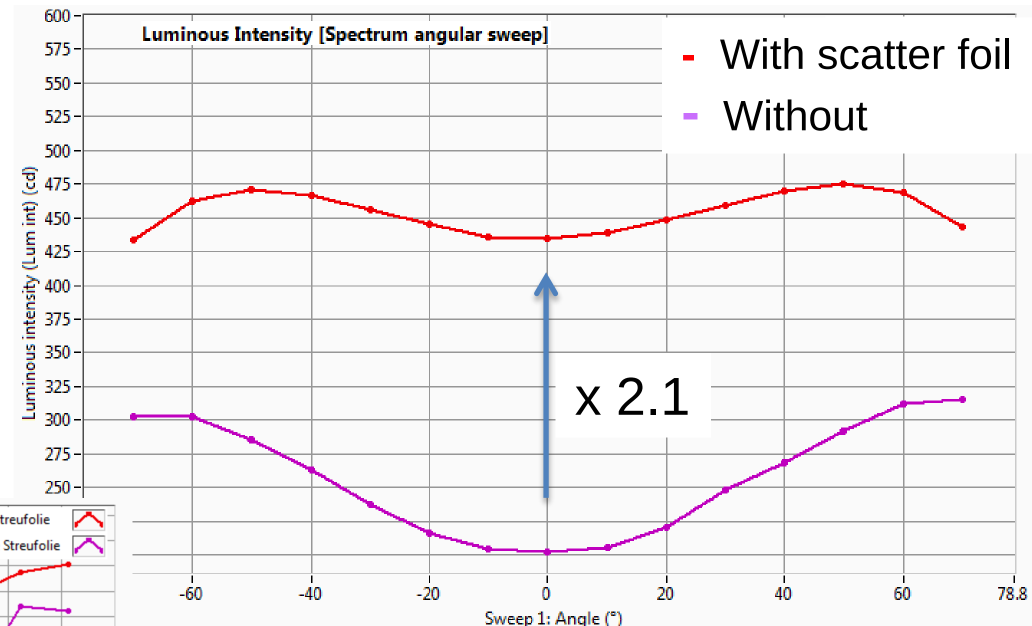


Angular Luminous Intensity
(measured by paios)



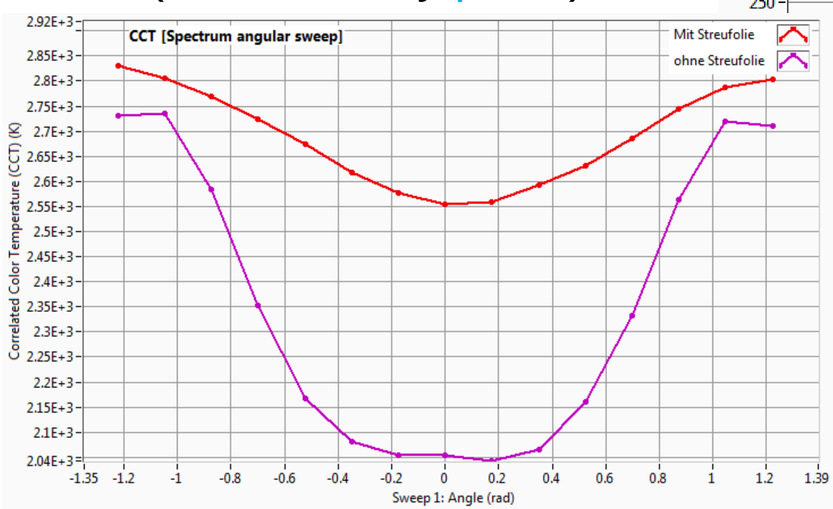
Viewing Angle

Angular Corr. Color Temp. CCT
(measured by paios)

2850 K

2450 K

2050 K



Viewing Angle

*Scatter foil and OLED stack need to be **jointly** optimized!*

Summary of Simulation Workflow

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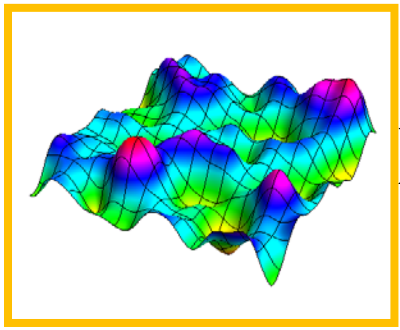
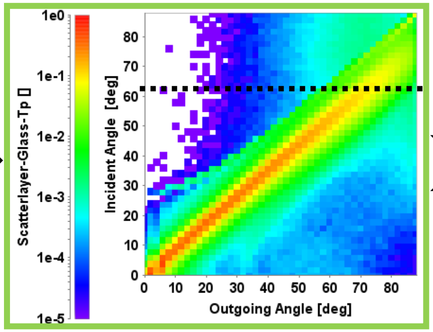
Scattering structure



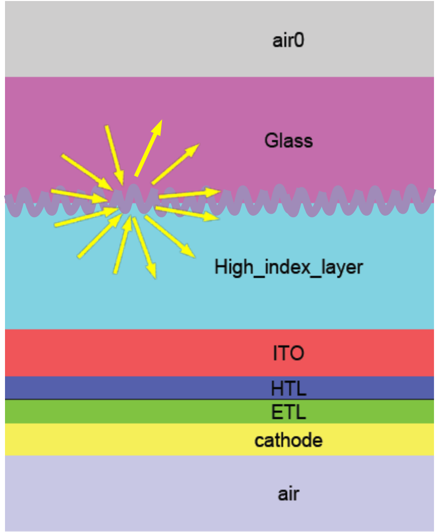
Examples:
textures,
particle scattering,
micro- and nano-structures

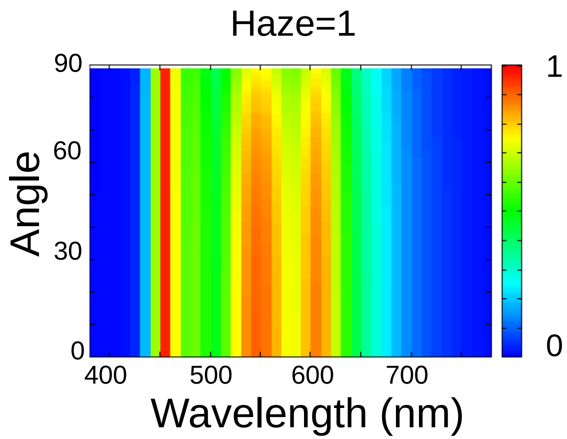
Bi-directional Scattering Function (BSDF)



Experiment or simulation

Design & optimize the OLED structure





setfos

Top-emitting flexible OLED with thin film encapsulation & scat. foil

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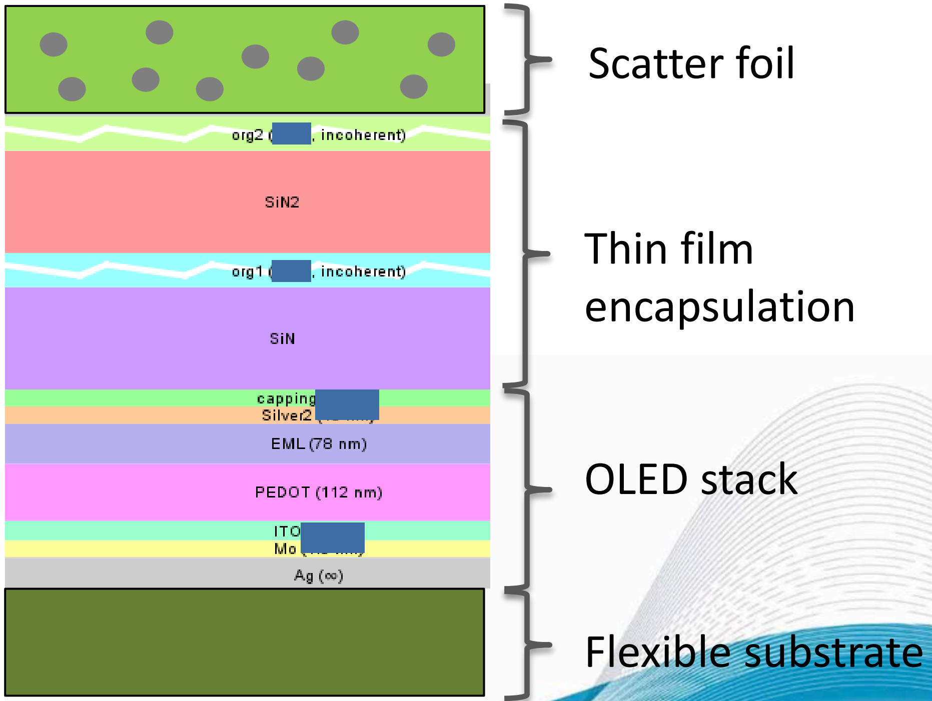
- Optional (commercial) outcoupling foils from Dupont Tejin Films with embedded particles were applied.
- Foils with different haze (9% vs. 59%) were used.

DuPont Teijin Films

Holst Centre
Open Innovation by IMEC and TNO

S. Harkema



Altazin et al. SID Symposium Digest of Technical Papers 46 (1), 564-567, (2015)

Excellent Agreement between Experiment (Holst) and Simulation (Setfos)

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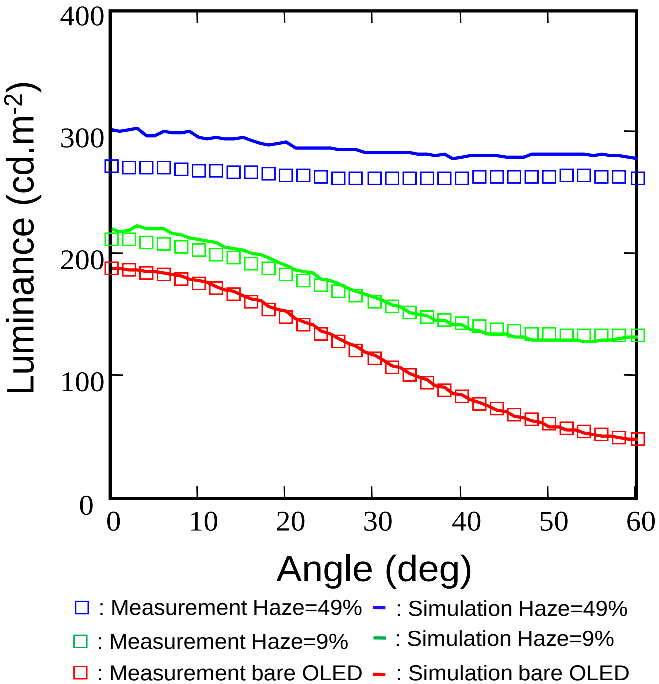

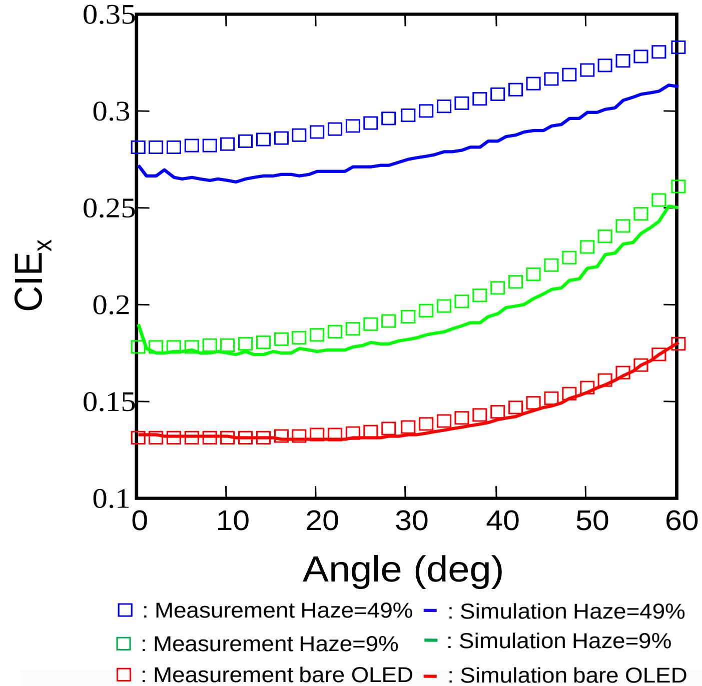

- Angular luminance increases with haze
- Blue color (no scatter foil) turns into white (with scatter foil)

S. Altazin (Fluxim), S. Harkema (Holst Centre)

Altazin et al. SID Symposium Digest of Technical Papers 46 (1), 564-567, (2015)

Optimization of the PET Scatter Foil

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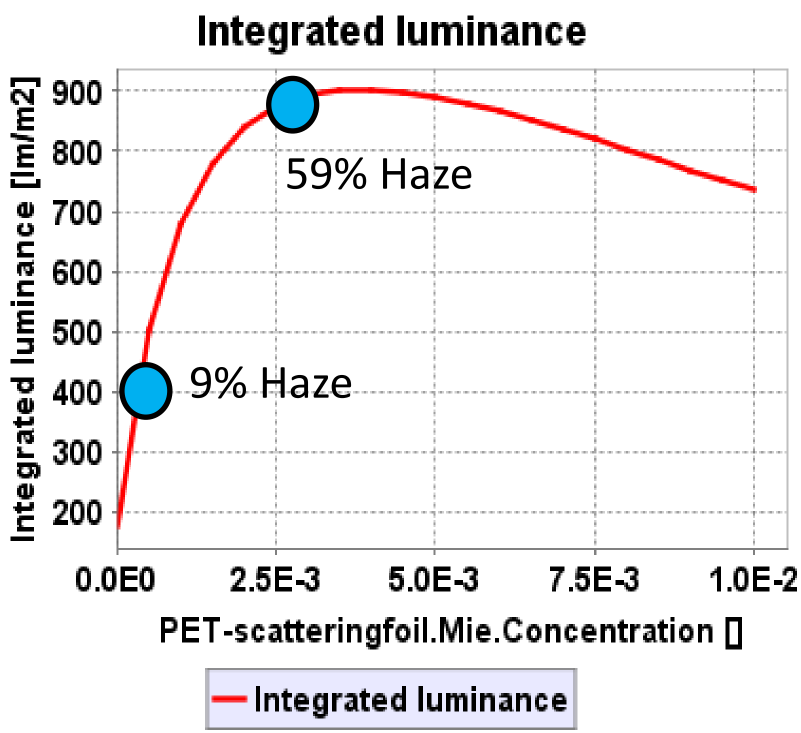
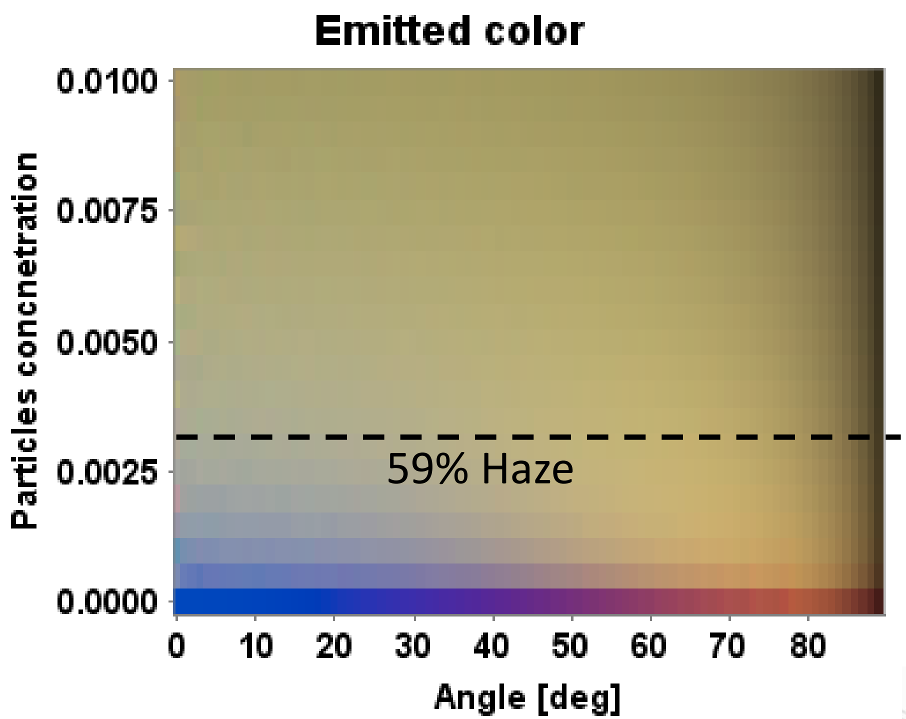
→ Easily sweep the particle parameters to optimize the device.





→ Maximum of luminance for a particle concentration = 2,75 E-3
→ The luminance and emitted color can be optimized at the same time
→ Maximum because of backscattering and absorption by the particles

Altazin et al. SID Symposium Digest of Technical Papers 46 (1), 564-567, (2015)

Rough surface scattering (BSDF)

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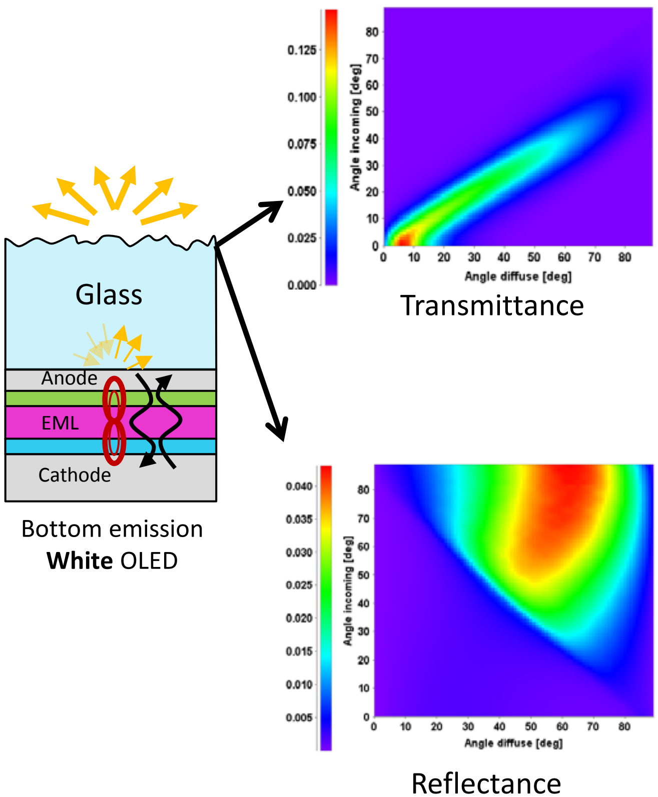
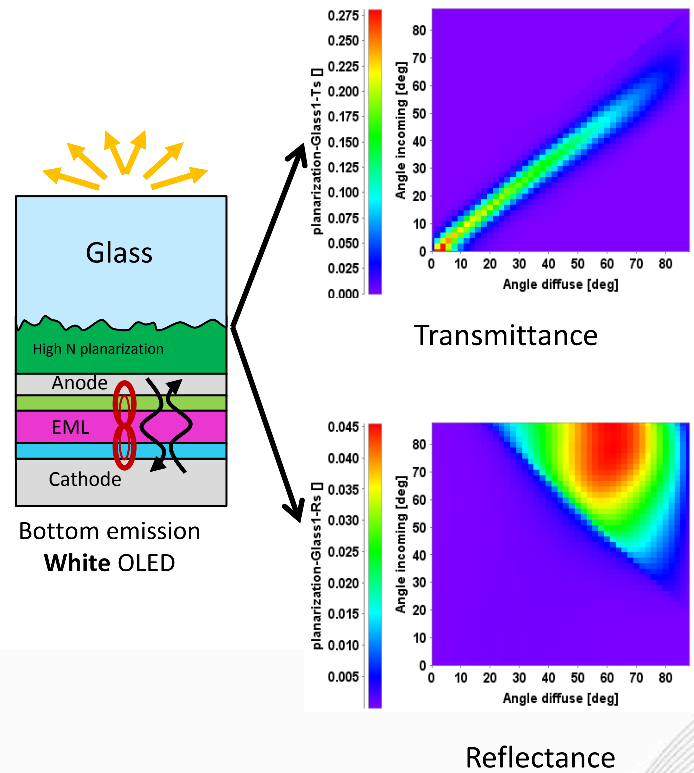
External extraction interface (E. E. I.)



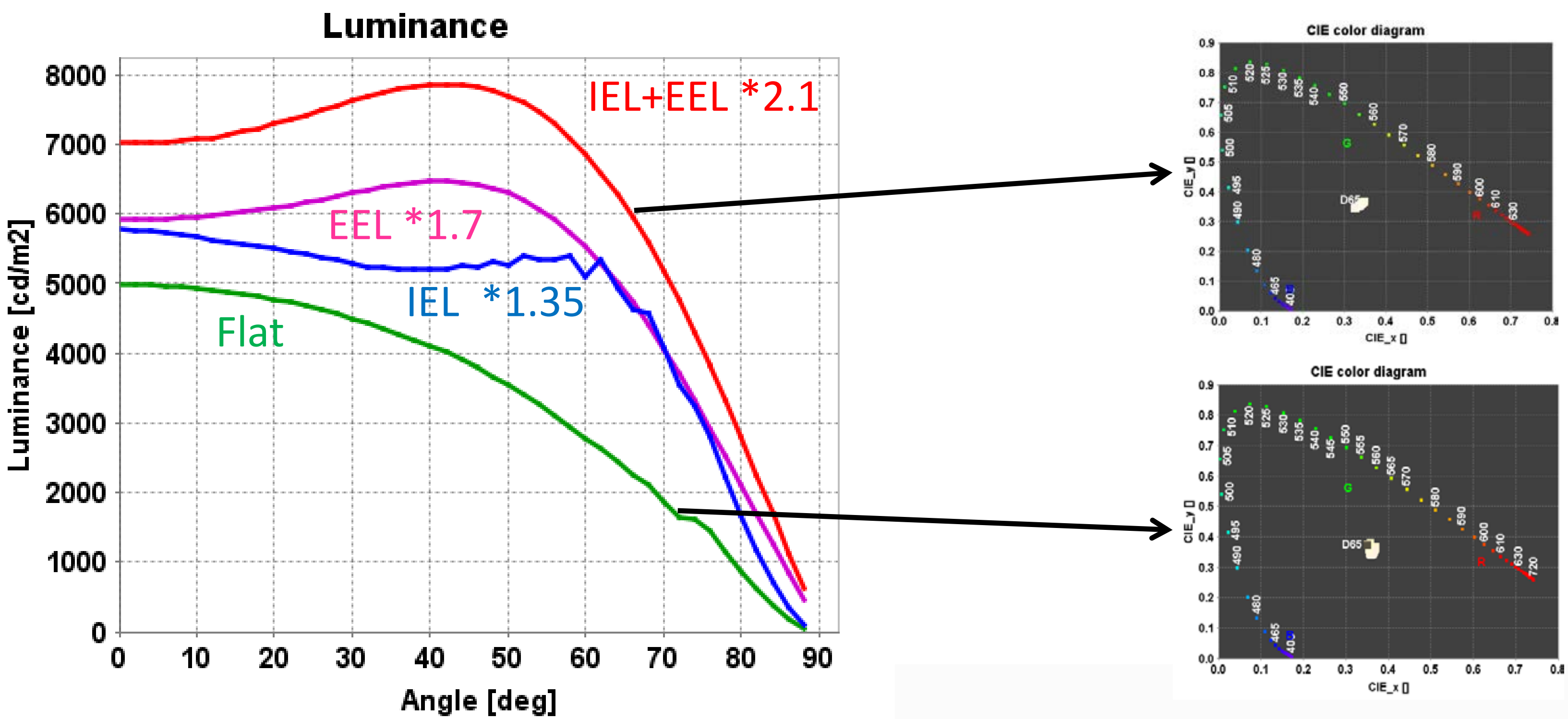
Internal extraction interface (I. E. I.)



→SETFOS can compute the BSDF of rough surfaces for both I. E. I, and E. E. I.

→Less scattering for I. E. I. because of smaller index difference.

Simulation of White OLED with Rough Interfaces



→Using two rough interfaces increases the emitted lumens by 2.1.

→The emitted color remains white with the scattering interfaces.

Getting the BSDF of a textured interface from simple optical measurement & Setfos

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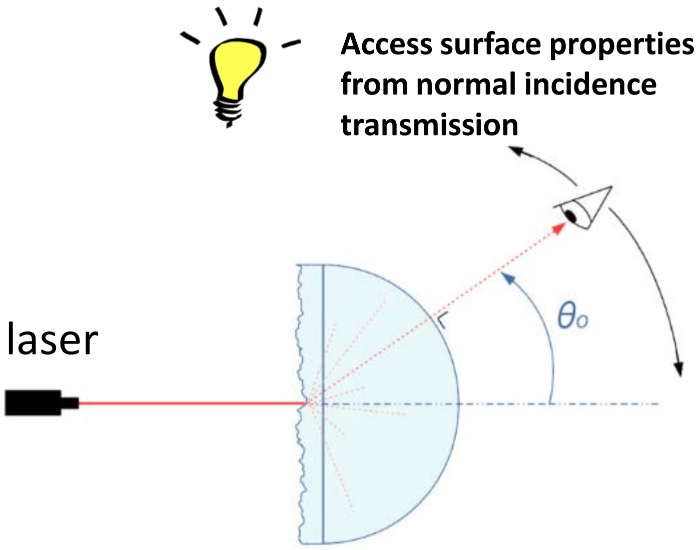
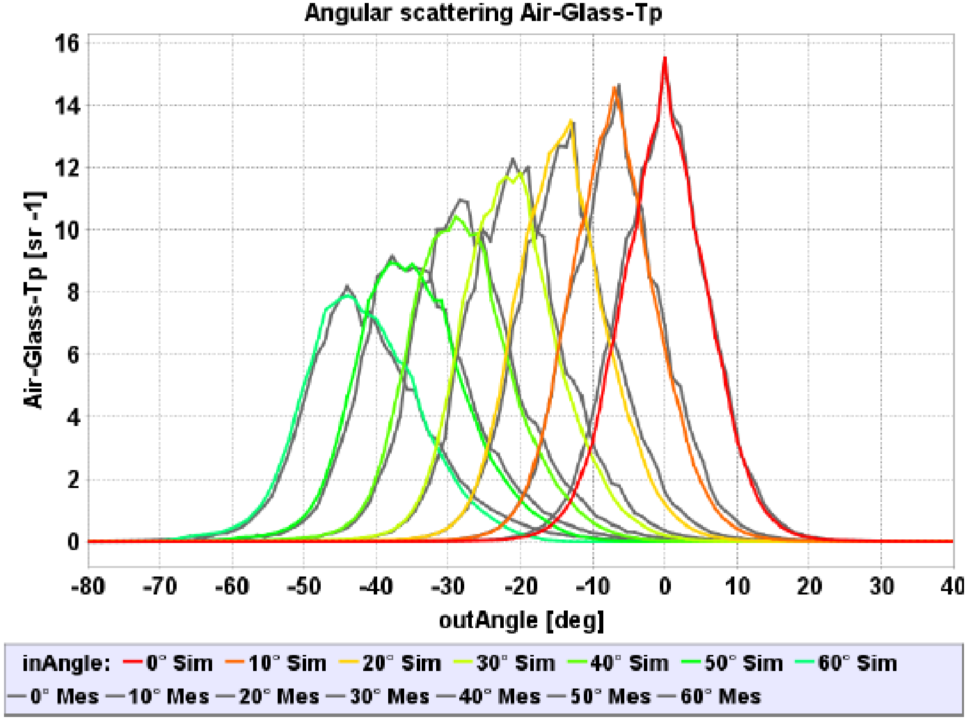
→Usually BSDFs are difficult to measure.

Access surface properties from normal incidence transmission



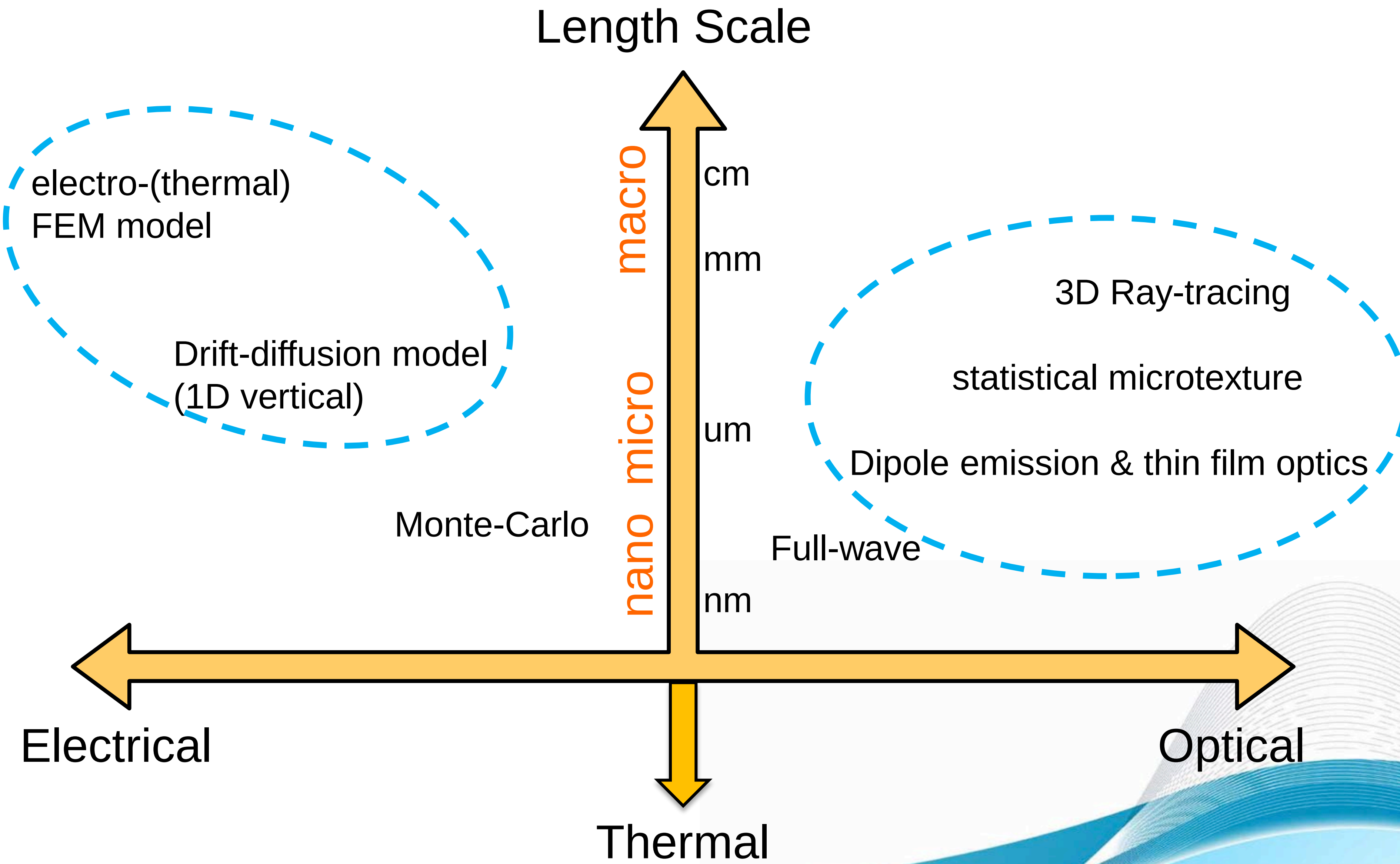
Experiment (ZHAW)

Setfos BSDF extraction



→ We just need angular transmission data at normal incidence to calculate the BSDF

Multi-scale, Multi-physics OLED Modeling



Laoss: Design of large-area panels

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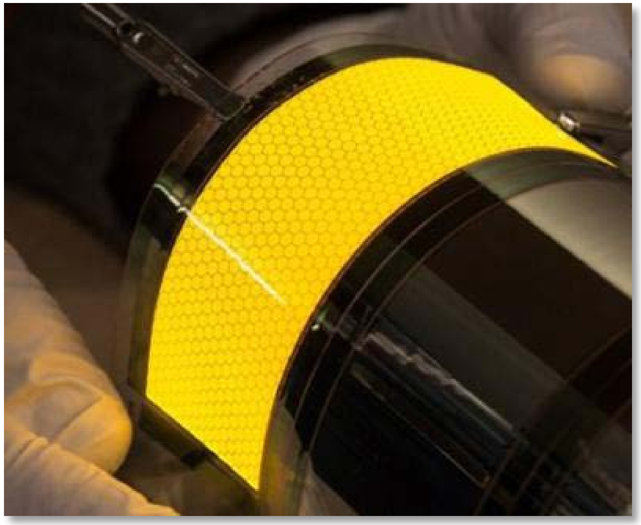
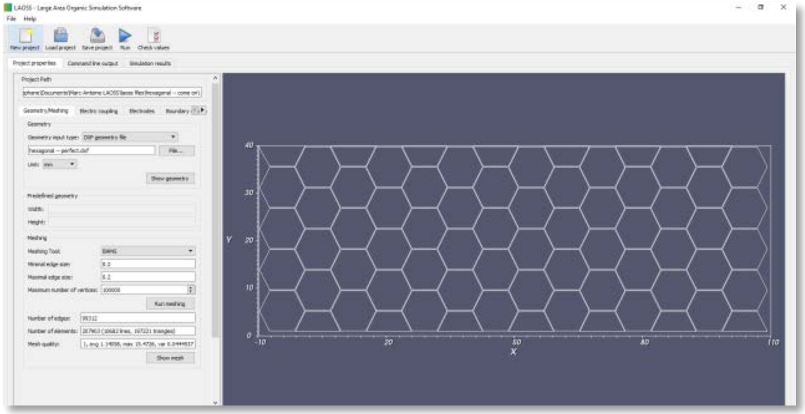
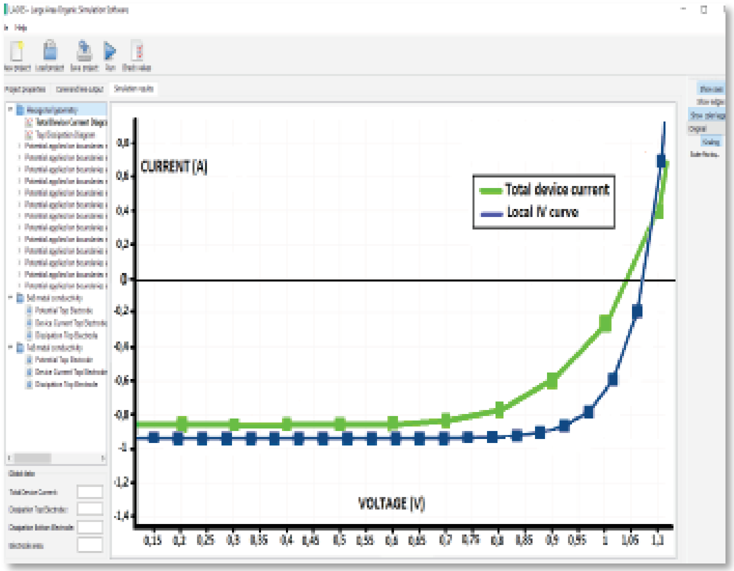
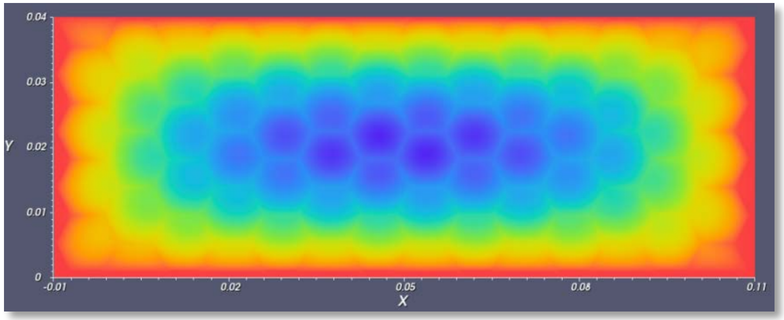


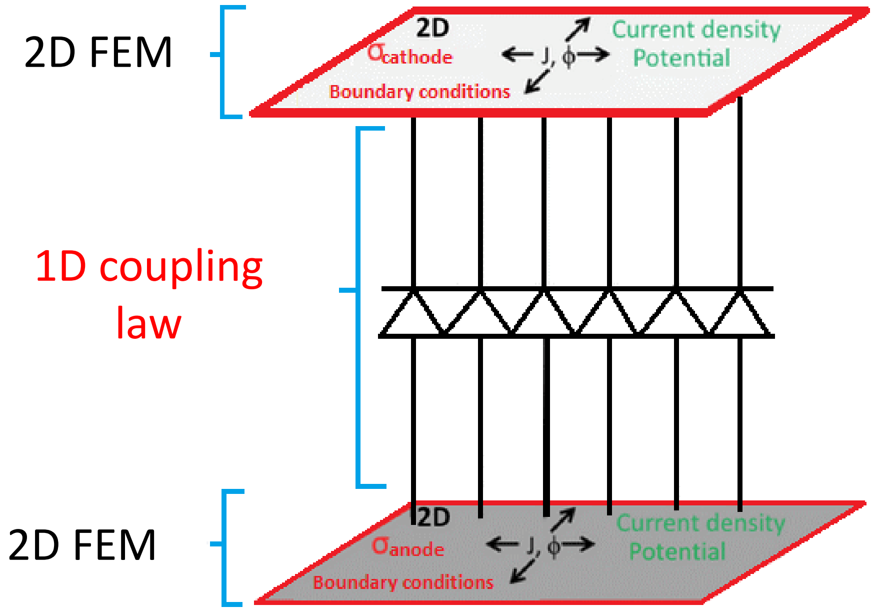






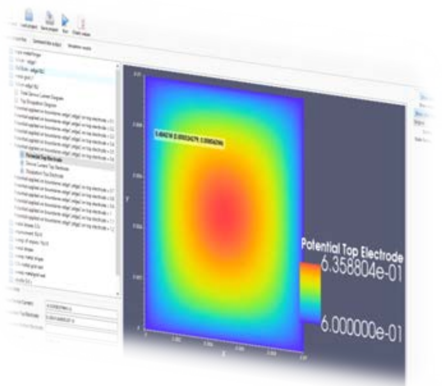
LAOSS: FEM Method

→ We do a 2D+1D coupling instead of 3D:
- import a 1D IV curve (from a small device)
- and solve Ohm's law in the large 2D anode by FEM.

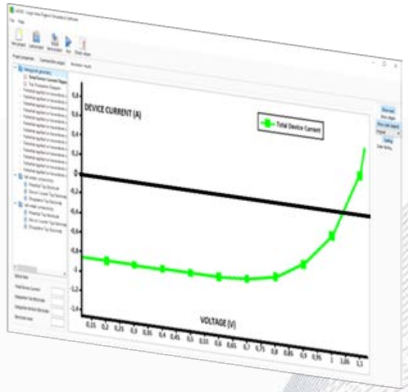


—: Input quantities
—: Output quantities

Calculates



Electric potential distribution



IV curve of the module

OLED Panel Example

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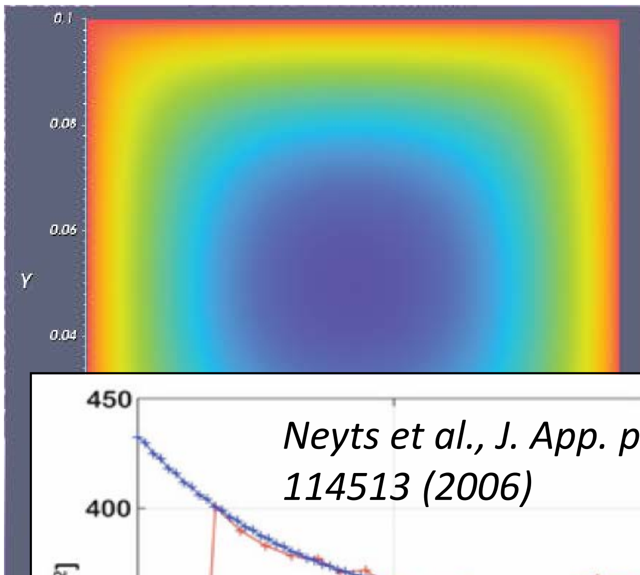
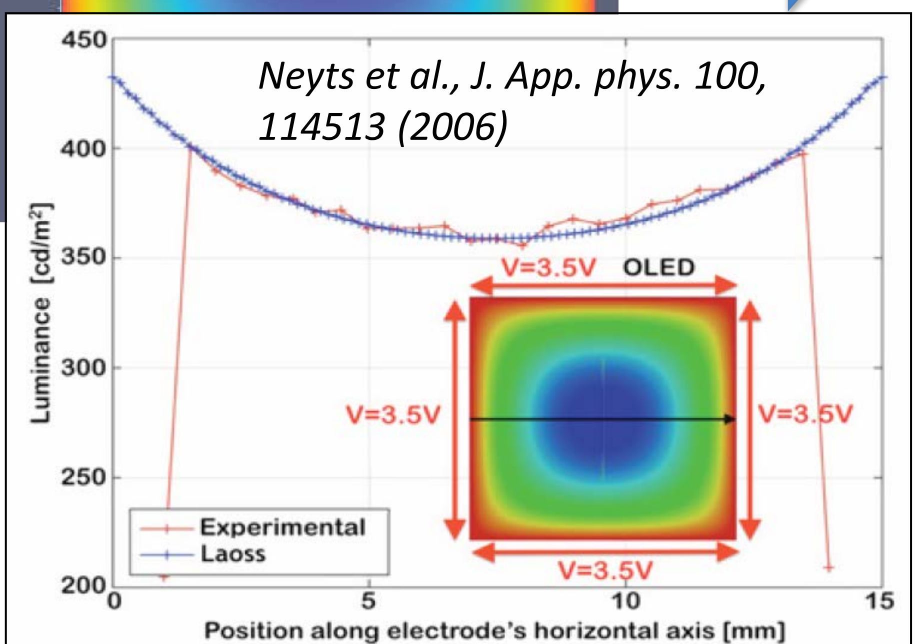
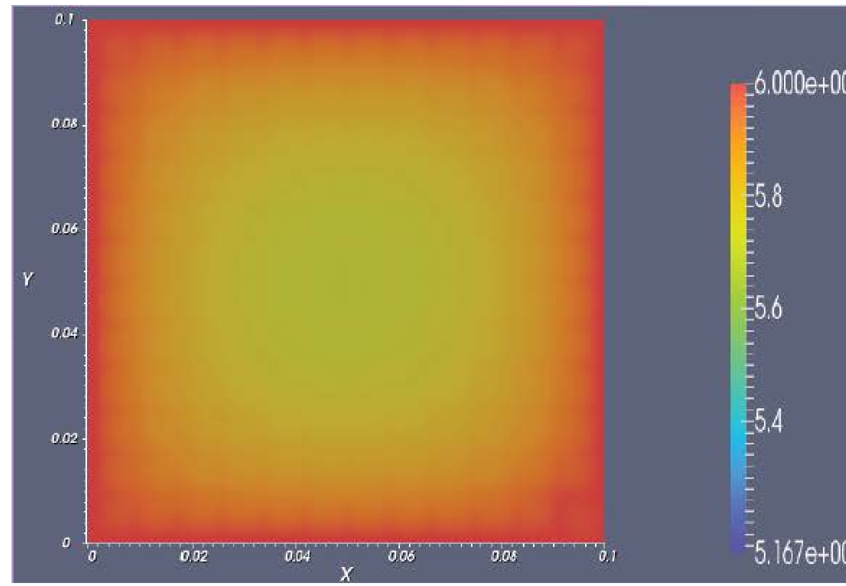
Without (left) and with (right) metal grid

10 cm x 10 cm OLED panel







Simulation Workflow with Laoss

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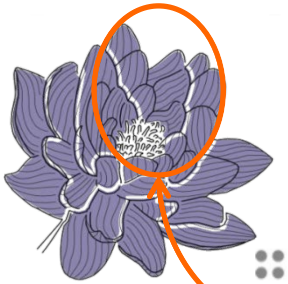
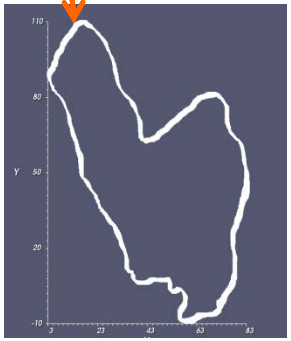
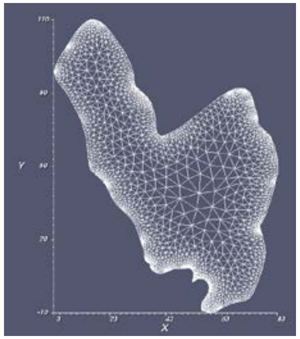


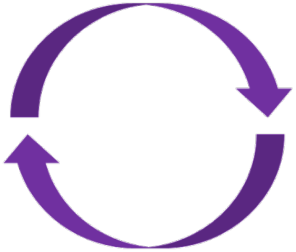
Draw and import the device geometry (.dxf file)



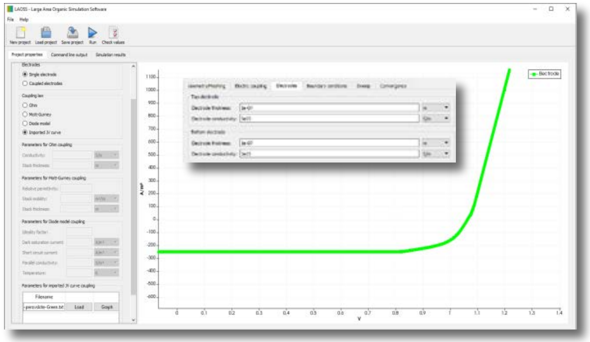
Alternative: Parametrized, pre-defined layouts

Run meshing

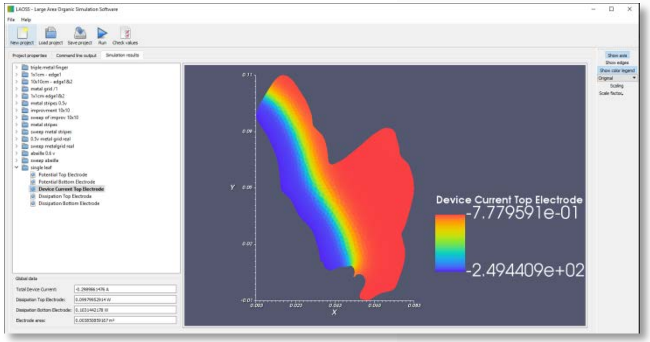




Import local IV curve & enter electrode conductivity



Run the simulation



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Swiss R&D Partners:
CSEM, EPFL, EMPA

Zurich University
of Applied Sciences

School of
Engineering

ICP Institute of
Computational Physics

Research group on Organic Electronics and Photovoltaics (OEPHO) www.zhaw.ch/icp/oehpo

Numerical algorithms / device fabrication & characterization
12 staff members in 2016
(3 PhD students, 4 lecturers, 5 research associates)
4 European research projects (FP7, 2007 - 2014)

FLUXiM

Commercial R&D tools for OLEDs and solar cells
11 staff members in 2016
(3 PhDs, 2 scientists, 6 engineers)
7 distribution partners worldwide
4 European research projects (FP7, H2020)