Electrical and Thermal Analysis of an OLED Module

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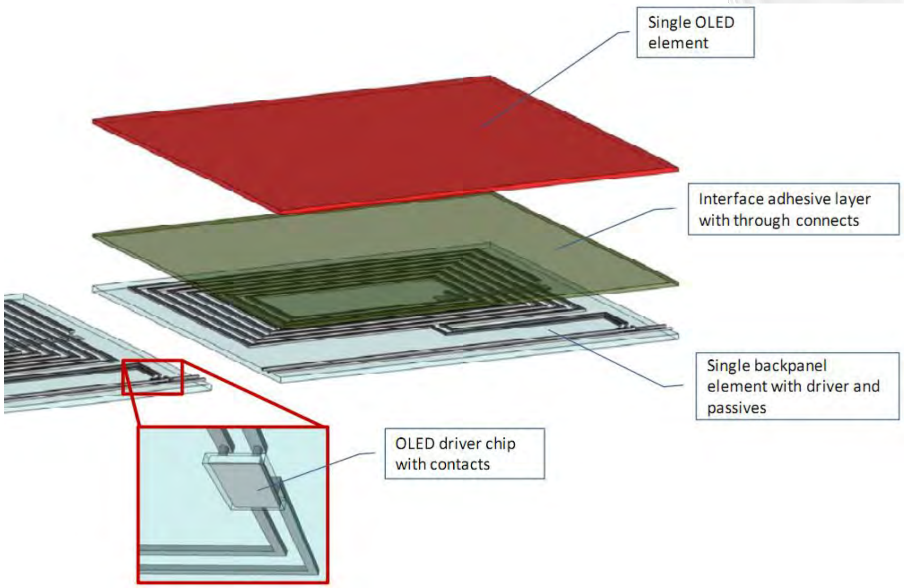
Outline

- Introduction:
  - The FP7 project IMOLA
  - The OLED module
- Methods:
  - Use of COMSOL Multiphysics:
    - Geometry and Meshing
    - Electromagnetic Waves Module
    - Heat Transfer in Solids Module
  - Electrical model
- Results:
  - Electrical characteristics
  - Far-field radiation
  - Thermal performance
- Conclusions

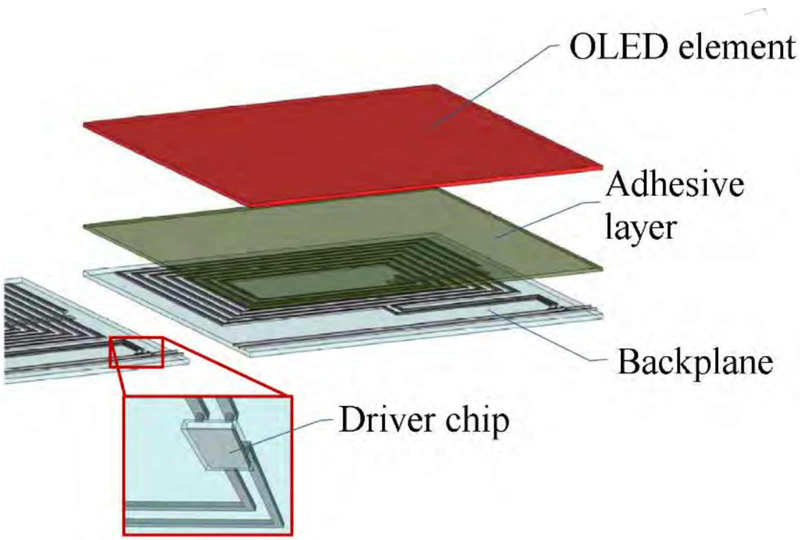
Motivation - FP7 project IMOLA

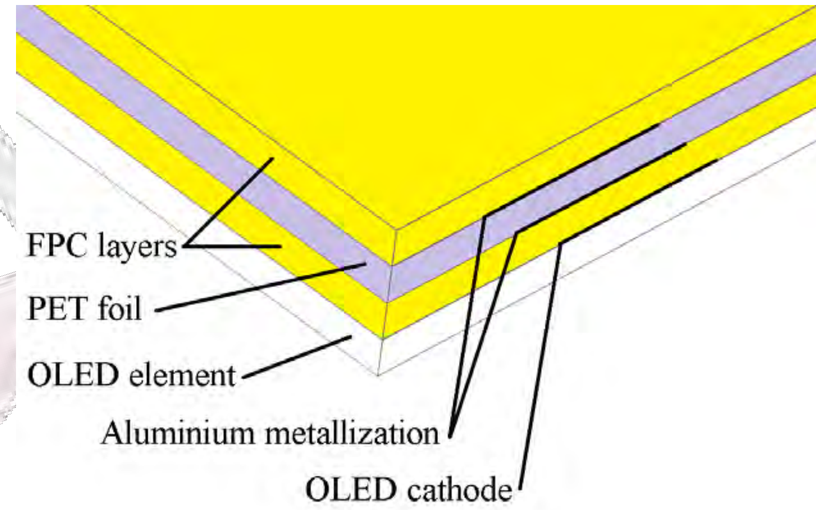
- "Intelligent light management for OLED on foil applications"
- Project objective:
  - Large-area OLED-based lighting modules with built-in intelligent light management
    - Applications: automotive (dome and tail lightning), wall light



- Funding:
  - Seventh Framework Programme (FP7)
- Project duration:
  - 2011-10-01 to 2014-09-30

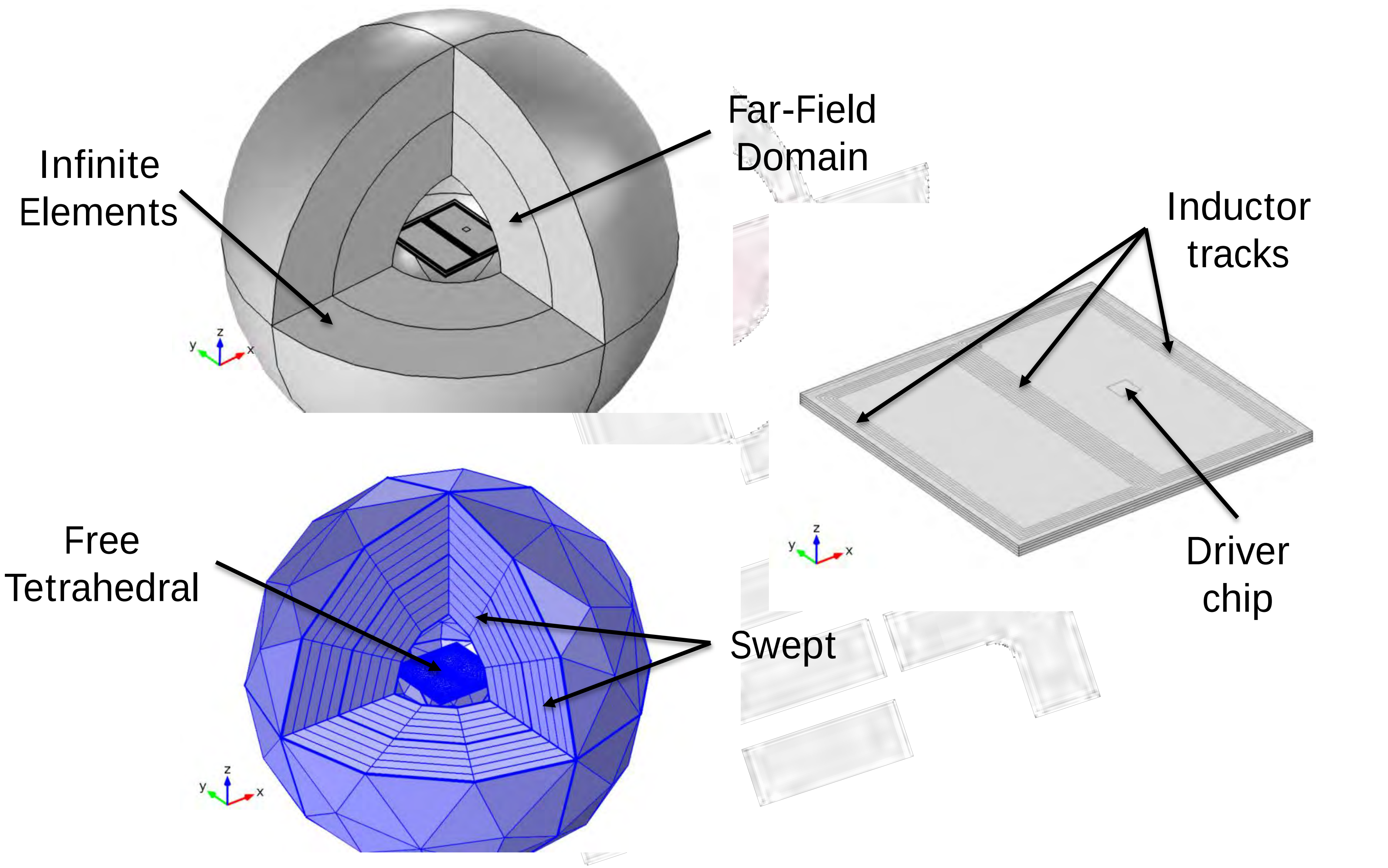
The OLED module structure





- The OLED element and the backplane → connected via an adhesive layer
- The driver chip and the inductor → embedded in the backplane (PET foil)
- The inductor → sandwiched between two Ferrite Polymer Composite (FPC) layers

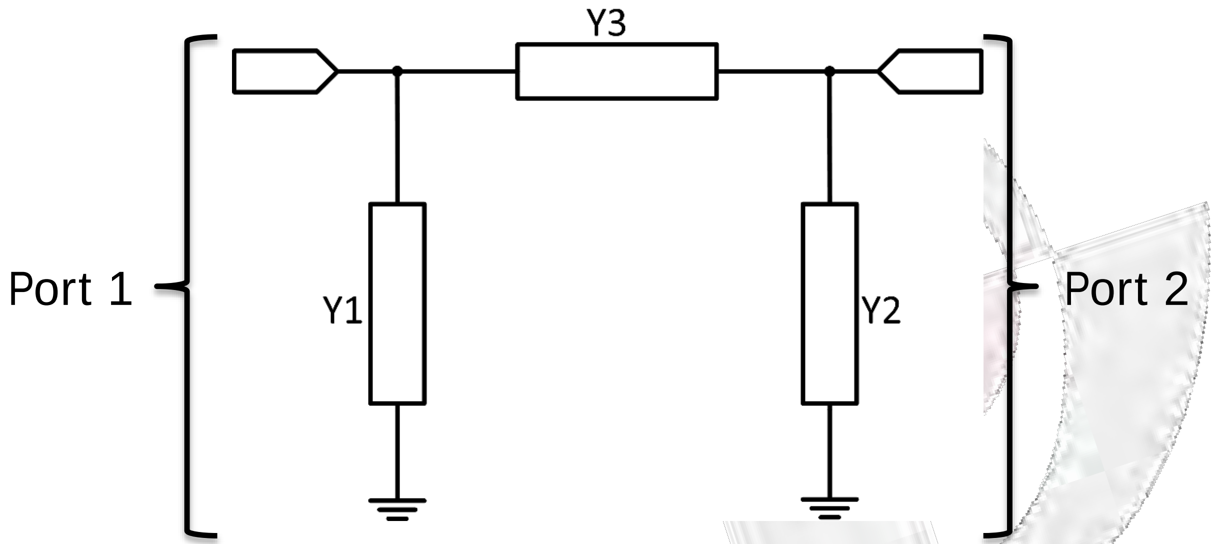
Use of COMSOL Multiphysics (I)



Use of COMSOL Multiphysics (II)

- Electromagnetic Waves Module:
  - The inductor tracks → Transition Boundary Condition
  - Two-port inductor structure (two Lumped Ports)
    - Uniform/Current → the Heat Transfer simulations
    - Uniform/Cable → generating the Touchstone file (*.s2p)
  - Perfect Electric Conductors added for the ports
  - Far-Field Domain → the middle geometry layer
- Heat Transfer in Solids Module:
  - Inductor resistive heating → Boundary Heat Source as a General source (coupled via *emw.Qsrh)*
  - DC-DC converter IC heating → Boundary Heat Source with Total boundary power (IC dissipation power estimate)
  - Aluminum heat spreader → Highly Conductive Layer

Electrical model



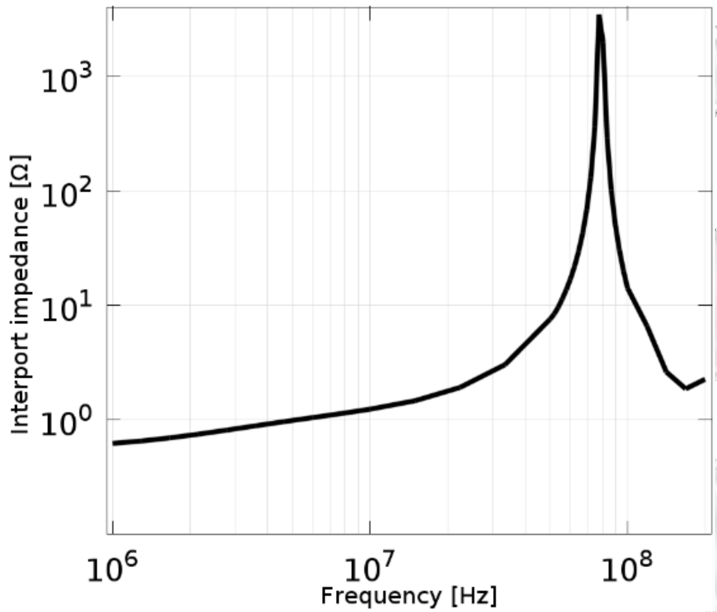
$$L_s = \frac{Im\{{Y_3}^{-1}\}}{\omega}$$

$$R_s = Re\{{Y_3}^{-1}\}$$

$$C_{1,2} = \frac{Im\{Y_{1,2}\}}{\omega}$$

- A simple π-model
- Interport admittance, *Y3* → series inductance & resistance
- Port admittances, *Y1* & *Y2* → port capacitances

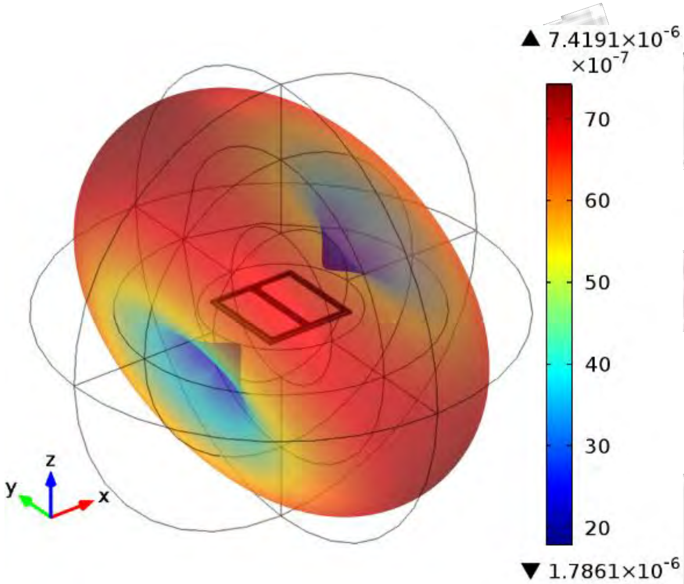
Electrical characteristics



Electrical parameter	Simulated value	Required value	
Series inductance L_S	1.42 µH	1 – 3 µH	✓
Series resistance R_S	2.36 Ω	< 2 Ω	~
Port 1 capacitance C_1	0.327 pF	< 50 pF	✓
Port 2 capacitance C_2	0.350 pF	< 50 pF	✓
Resonant frequency f_r	~ 75 MHz	> 50 MHz	✓

- The electrical parameters → extracted @ 10 MHz
- The parameters conform to the DC-DC converter requirements
  - The series resistance slightly exceeds the requirement → lower DC-DC converter efficiency

Far-field radiation

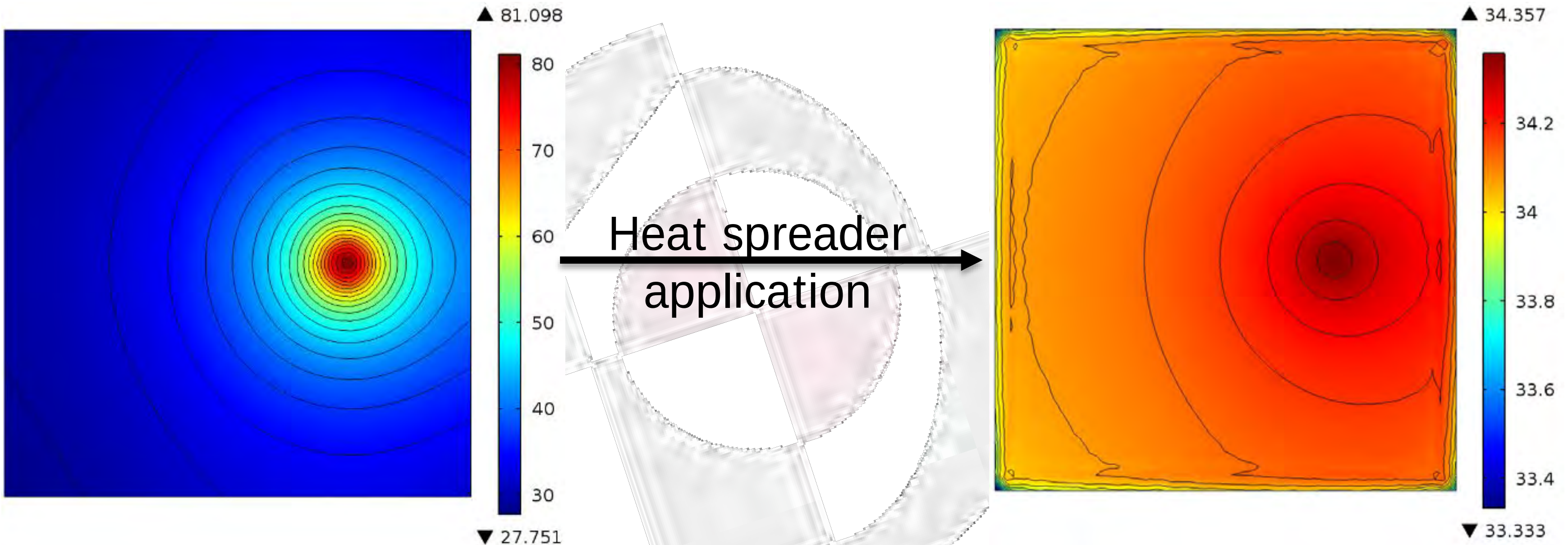


Method / requirement	Max. electrical field* [dBµV/m]
Simulation	-2.59
CISPR 15 limit	< 30

* Electrical field calculated @ 10 m

- The two-inductor design (two inductors wound in opposite directions) → minimizes the radiated disturbance
- The maximum electrical field @ 10 m → conforms to the CISPR 15 limits

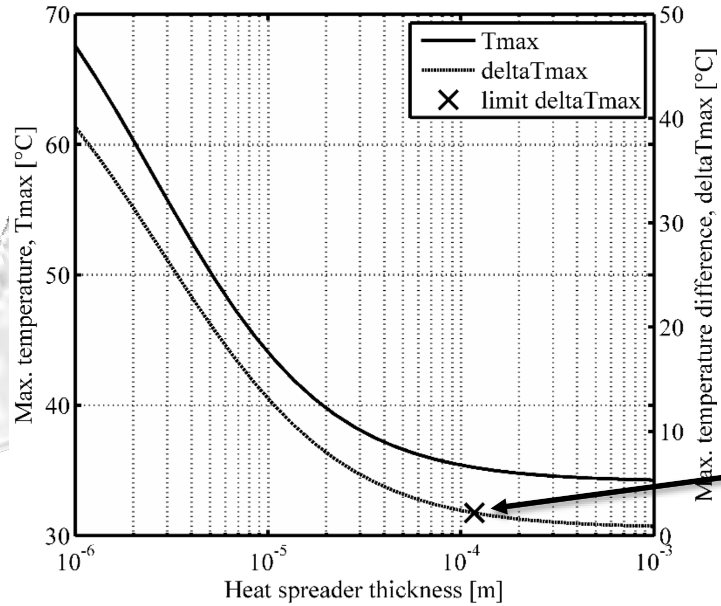
Thermal performance (I)



Thermal parameter	Simulated value	Required value	
Minimum – maximum OLED temperature [°C]	27.8 – 81.1	< 70	✗
Maximum OLED temperature difference [°C]	53.3	< 2	✗

- The starting OLED module substrate configuration doesn’t conform to the OLED material requirements
- Applying the heat spreader is necessary!

Thermal performance (II)



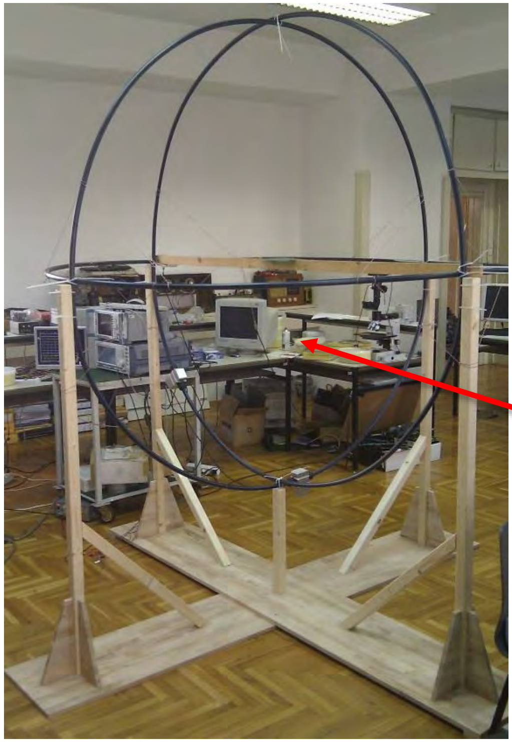
Minimum required heat spreader thickness

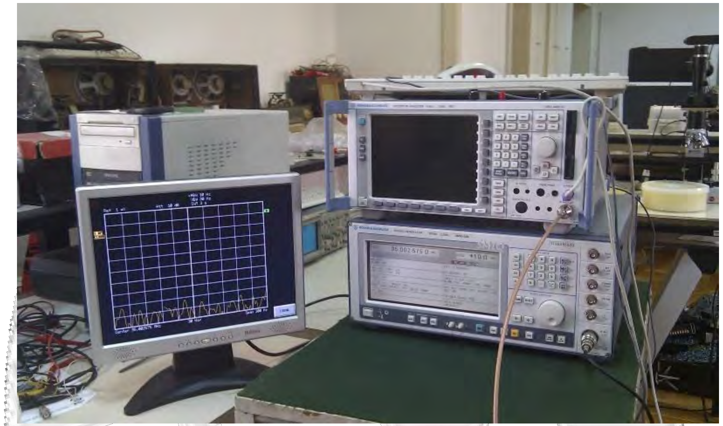
- The heat spreader layer → aluminum foil
- A sweep of heat spreader thickness → 30 steps in logarithmic scale
- A heat spreader of minimum 100 µm thickness → max. temperature difference requirement

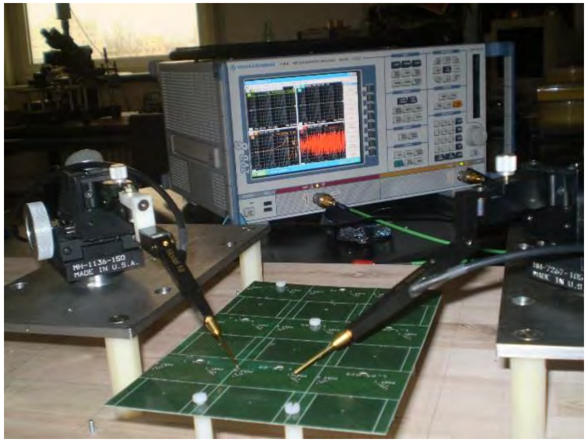
Conclusion

- The structure of the OLED module is described
- The module geometry and meshing procedure are shown
- The specifics of the COMSOL Multiphysics use are presented
- The results are analyzed from several viewpoints:
  - Electrical → the inductor conforms to the OLED driver requirements
  - EM → the radiated disturbance is within limits of CISPR 15 standard
  - Thermal → the performance was unsatisfactory and the application of a heat spreader is identified as the solution
- The future developments:
  - Expanding the model with the high voltage supply lines
  - Applying the Electrical Circuits (switch and OLED models) to the Lumped Ports

Some photos

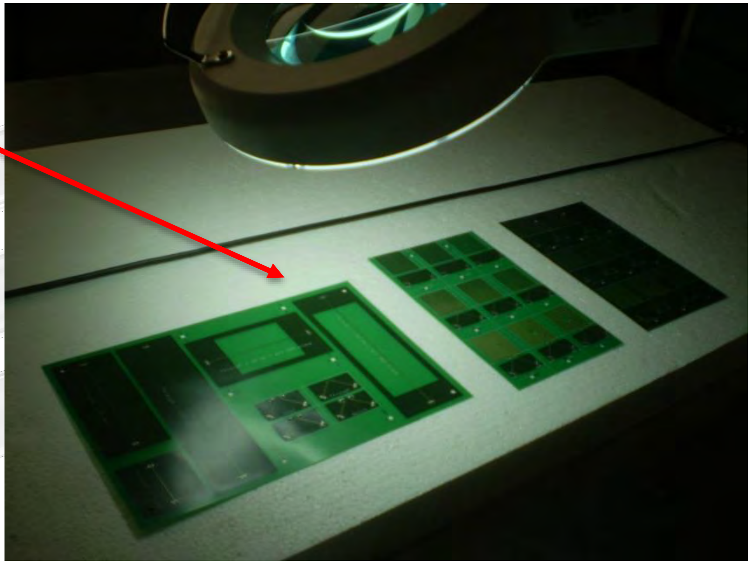




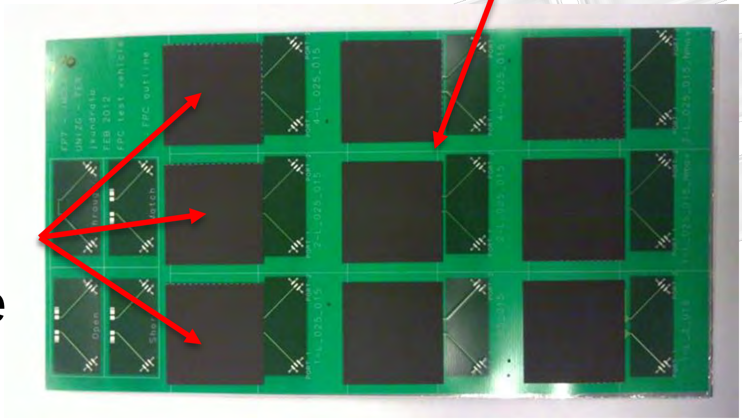


CISPR 15 – Large Loop Antenna

Inductor design experiments



Ferrite Polymer Composite



Thank You!