

# Improving The Design Process Of A MEMS-IR-Emitter

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# SHORT FACTS - „CiS Forschungsinstitut“

- Research institution in Erfurt, Thuringia, Germany
- Independent - non-profit - close to business

## 16,5 MIO. € TOTAL OUTPUT IN 2022

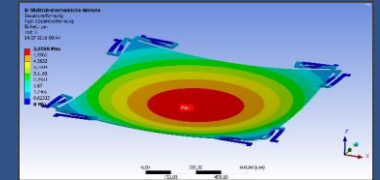
- ~120 Employees
- 52 % Public research projects
- 48 % Industrial contract research and manufacturing
- No basic funding, only project funding

→ **MOEMS Development and Prototyping**

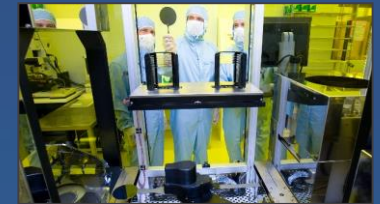


## TECHNOLOGICAL EXPERTISE In MEMS and MOEMS sensors

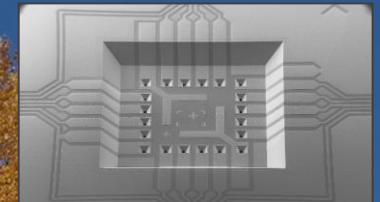
Simulation  
& Design



Wafer Technology  
& Manufacturing



Packaging &  
Assembly



Test &  
Analytics

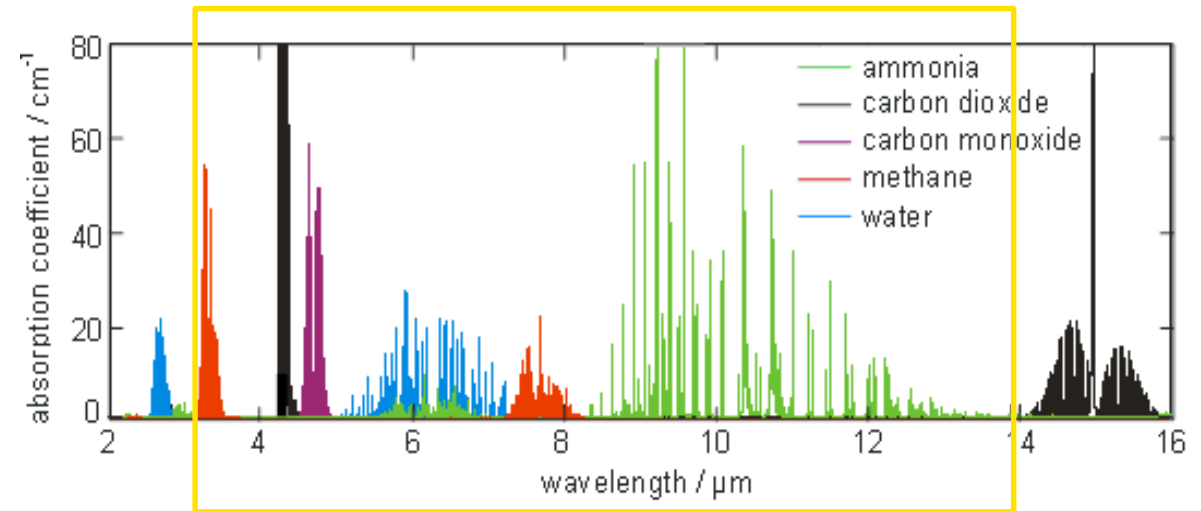
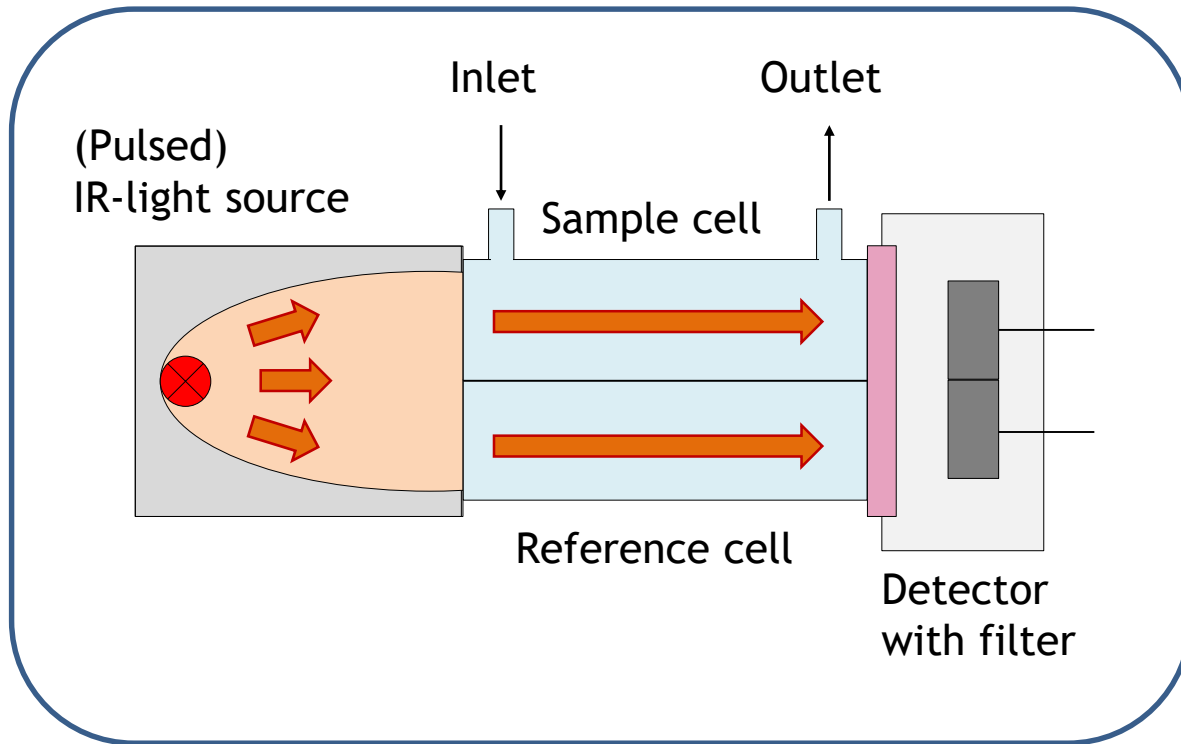


# Background: IR-MEMS-Technology And Fabrication



# Background: IR-Emitter-Technology

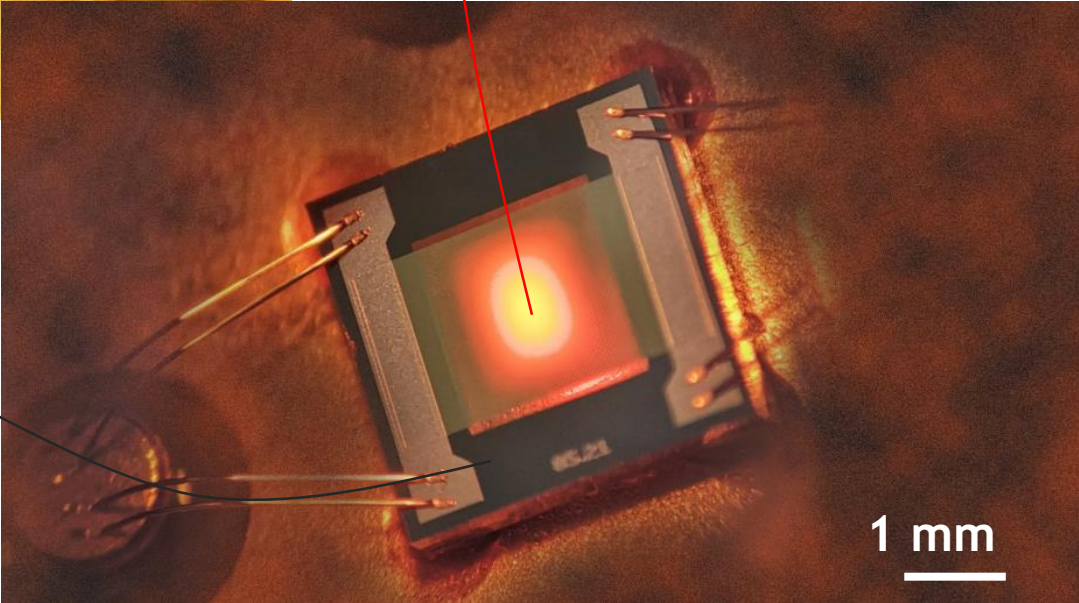
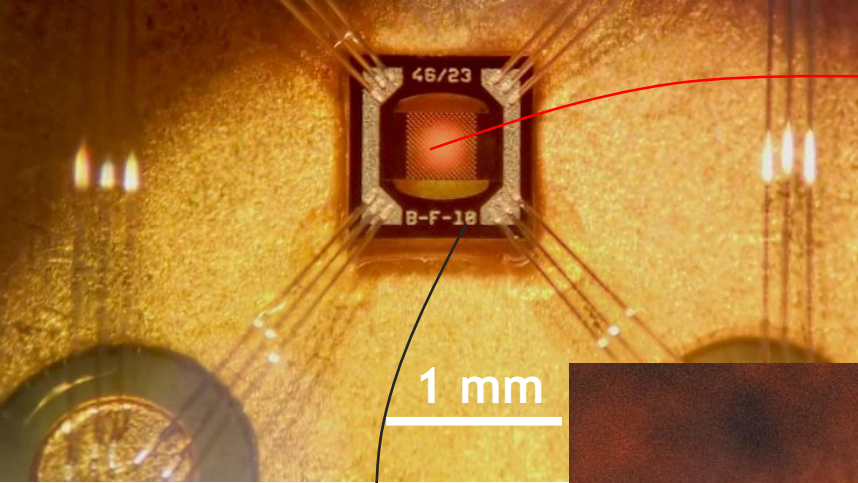
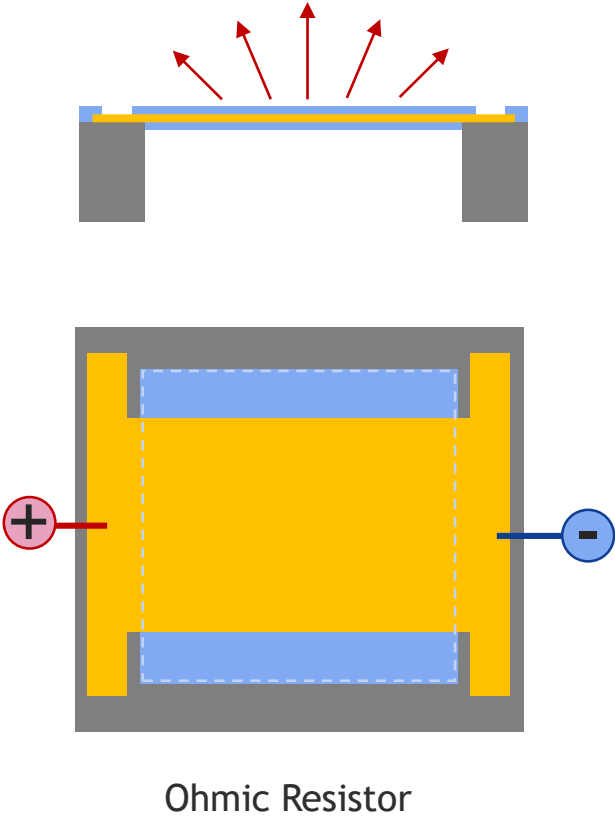
## Nondispersive Infrared Gassensor



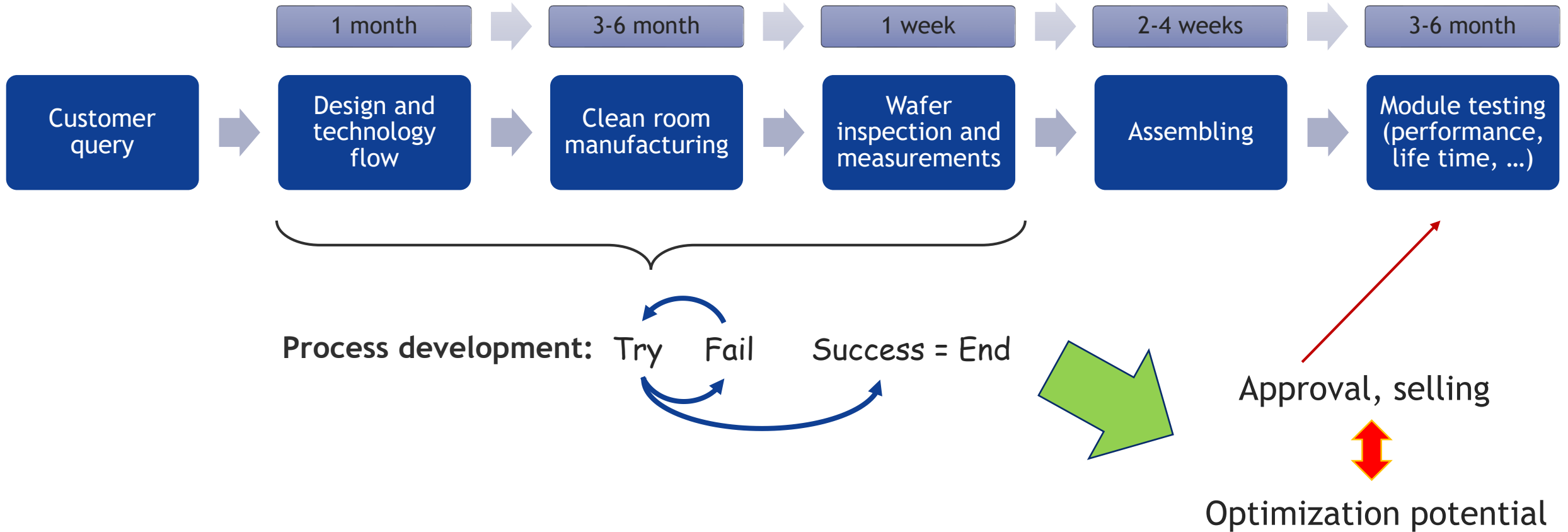
Rogalski, Antoni & Chrzanowski, K. (2014). Infrared Devices And Techniques (Revision). Metrology and Measurement Systems. 21. 10.2478/mms-2014-0057



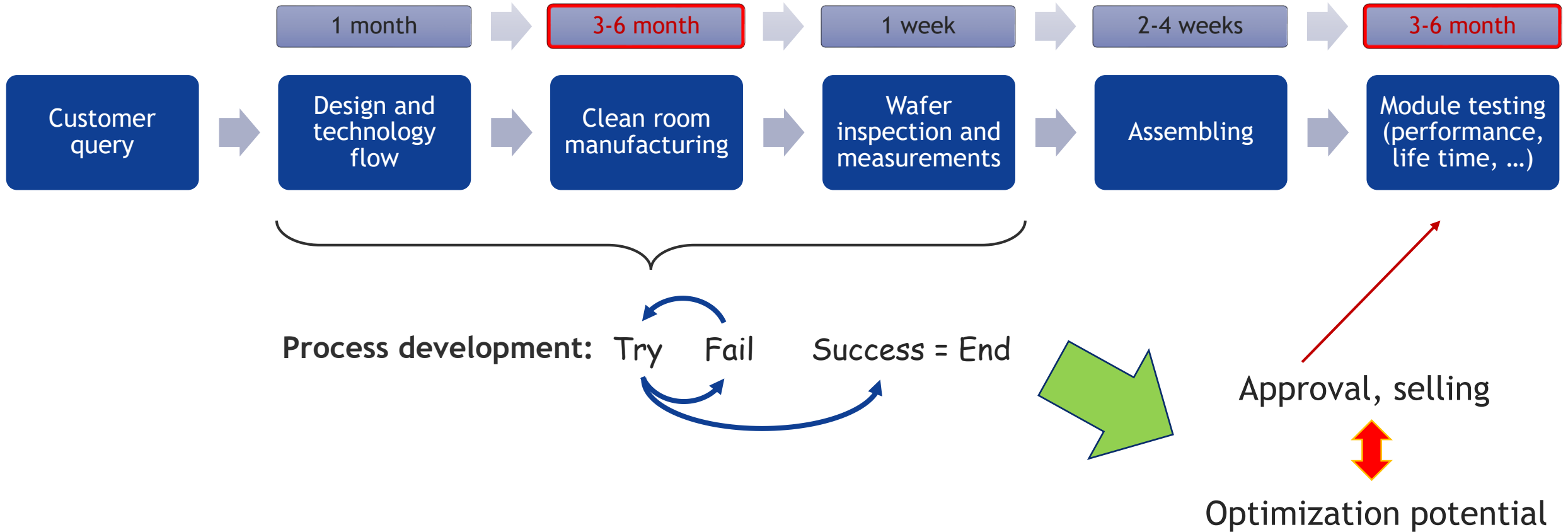
# Background: IR-Emitter-Technology



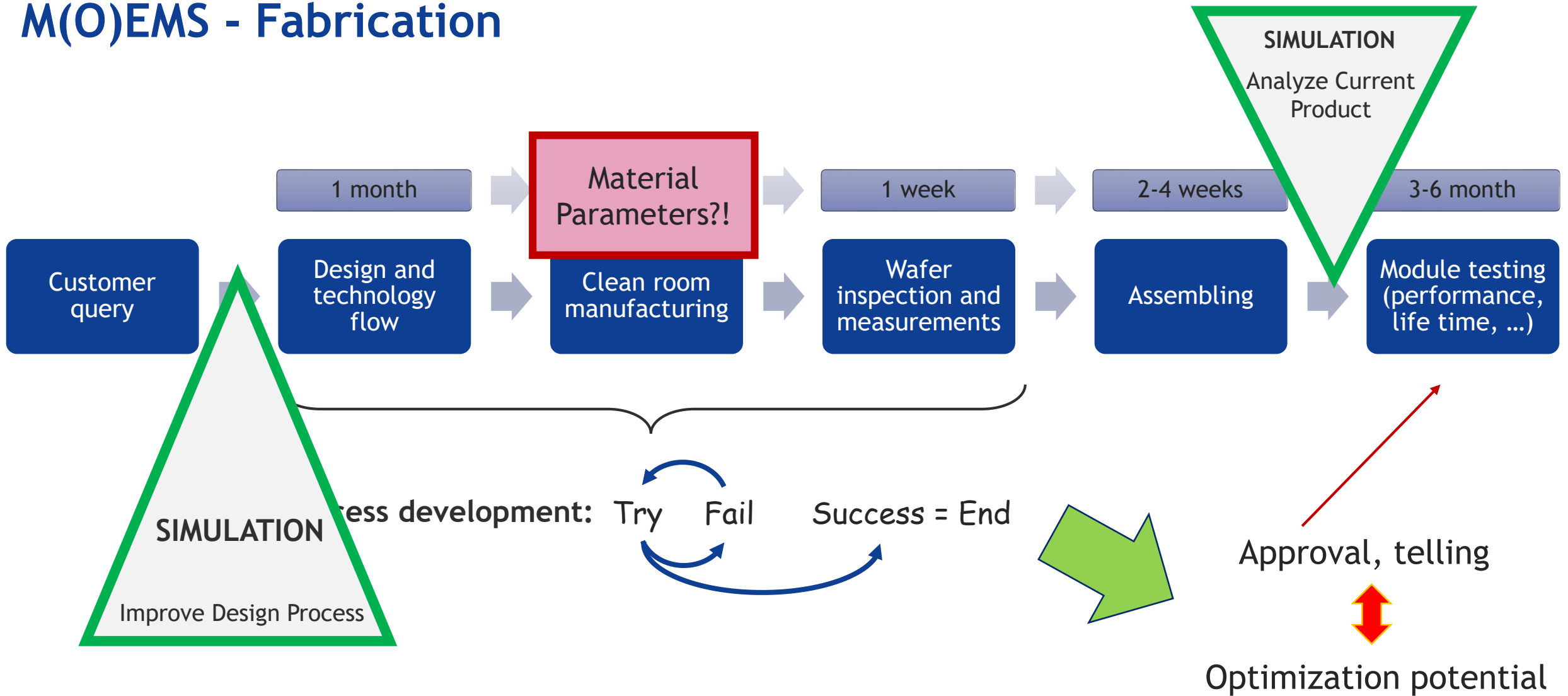
# M(O)EMS - Fabrication



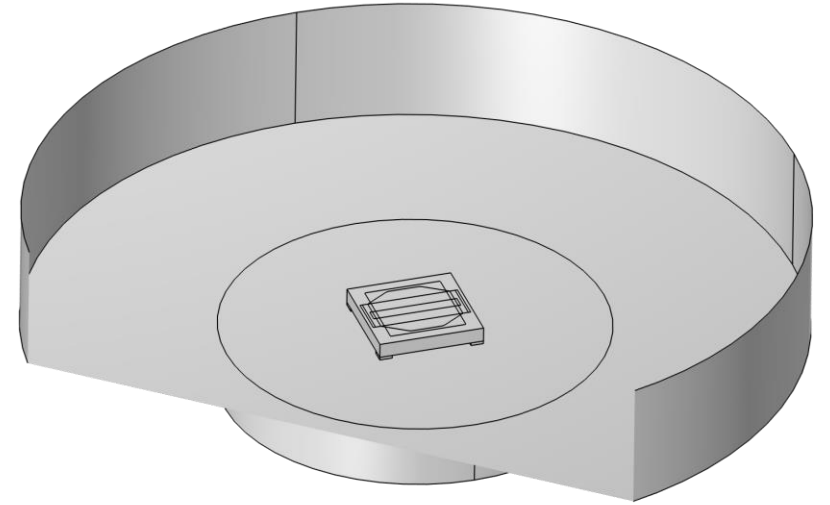
# M(O)EMS - Fabrication



# M(O)EMS - Fabrication





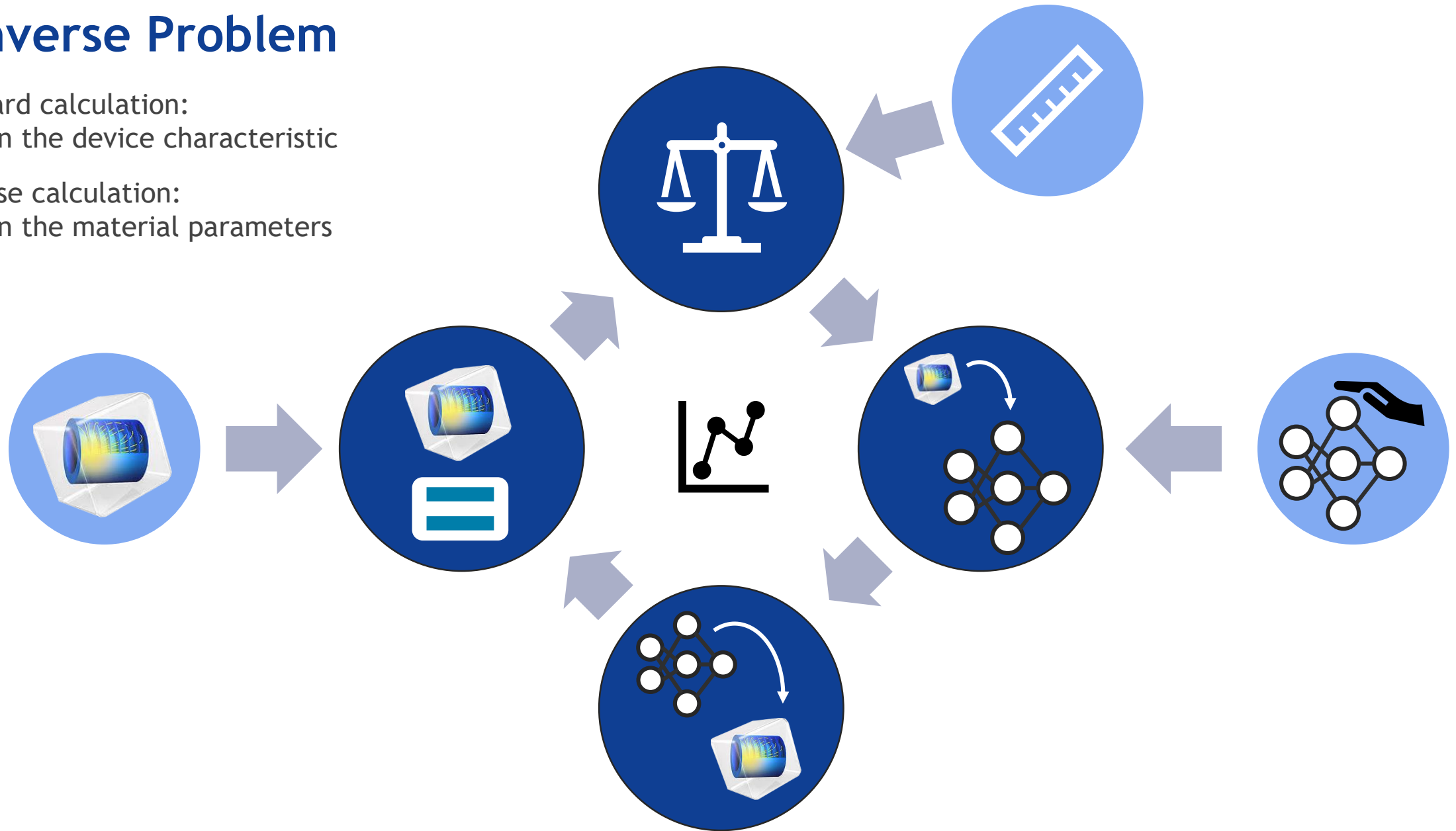


## Building The Model

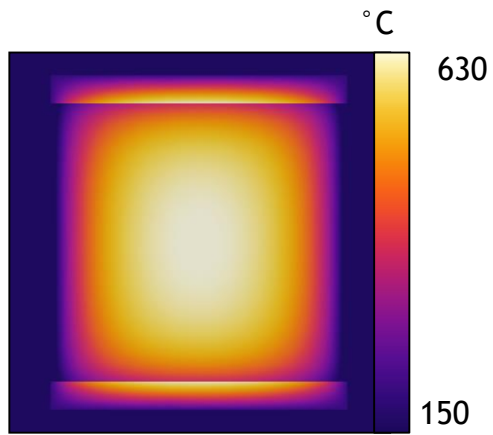
Challenge: Material Parameters Of Our Thin Layers

# The Inverse Problem

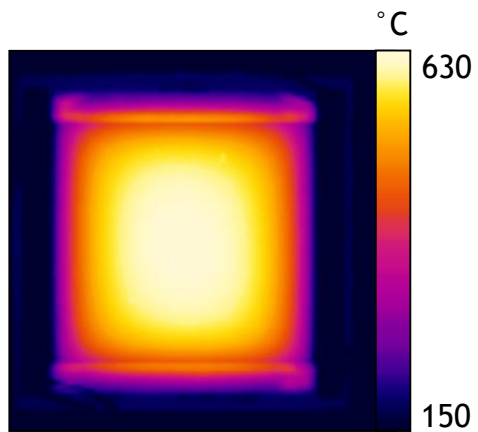
- forward calculation:  
obtain the device characteristic
- inverse calculation:  
obtain the material parameters



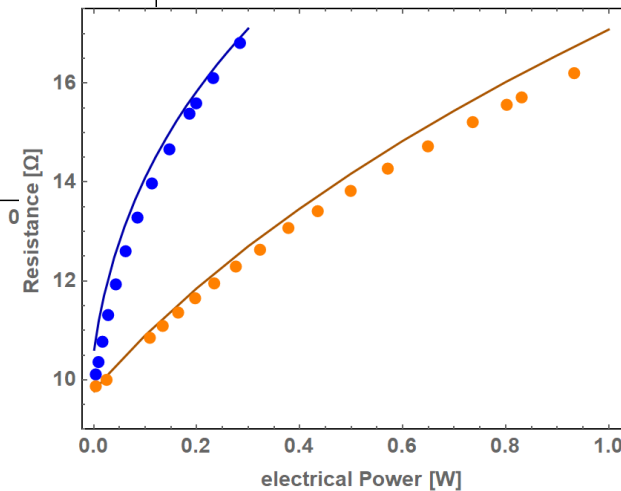
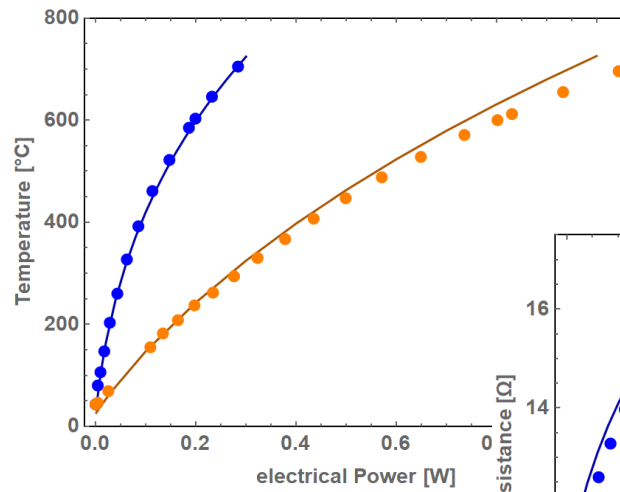
# The Inverse Problem - Result



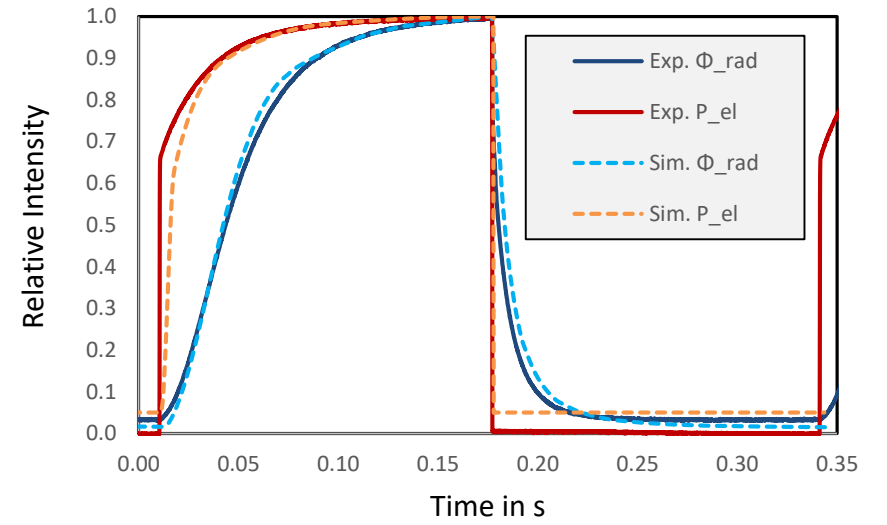
Simulation



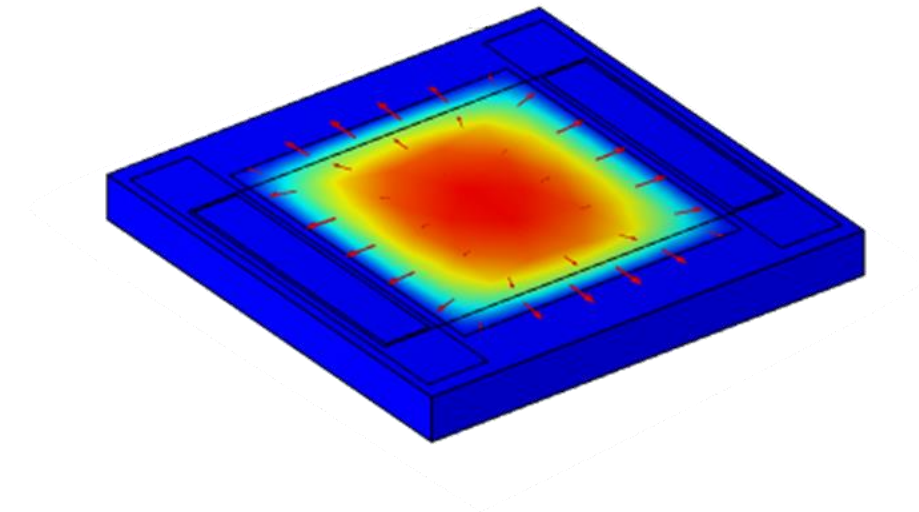
Heat camera image



Time Scale Comparison

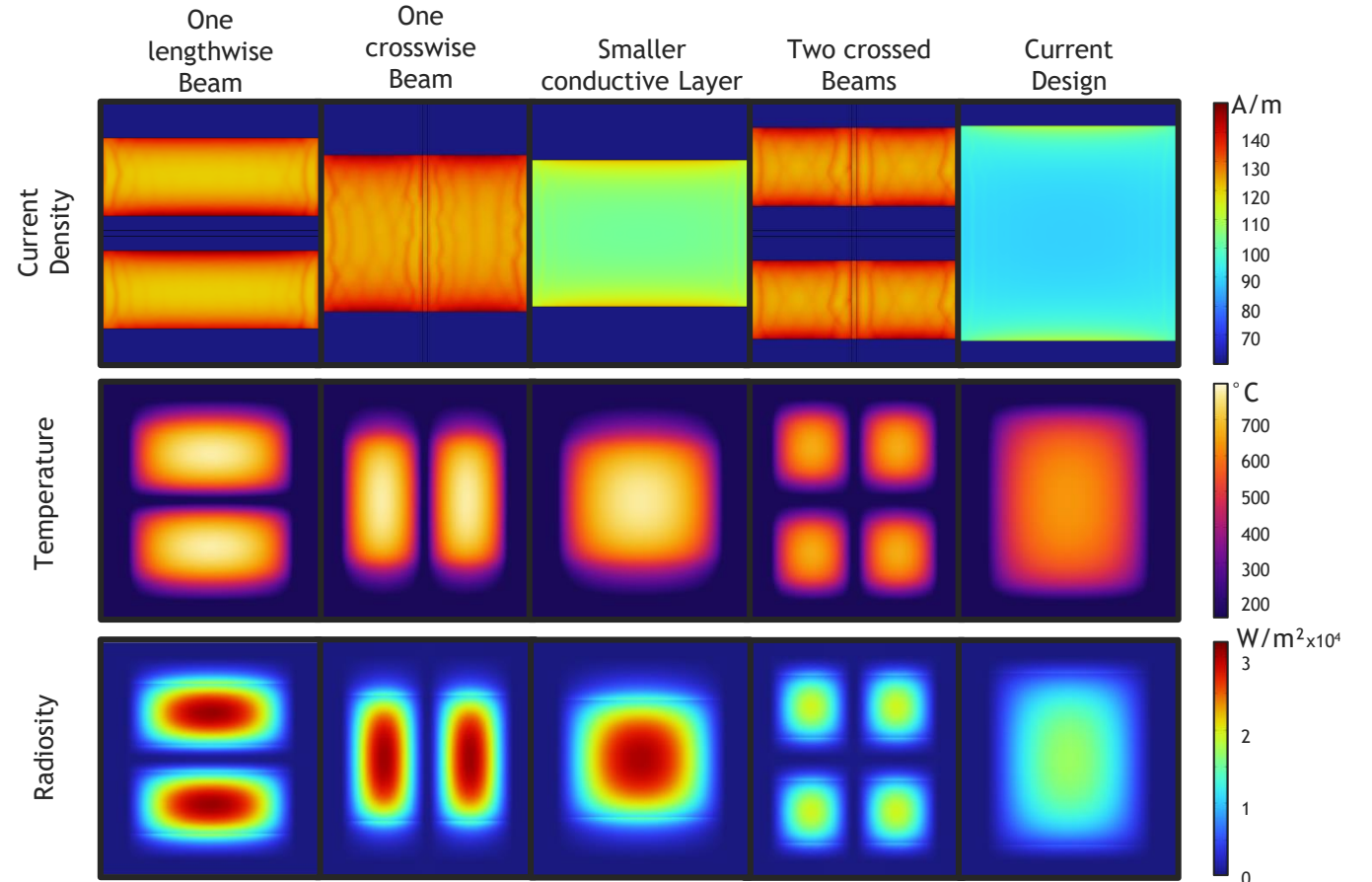
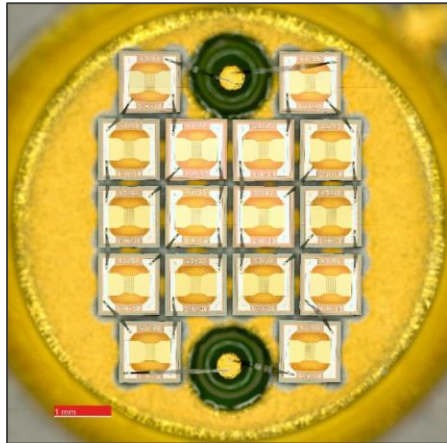


# Using The Model In Design Processes



# First Design Task

- Either bright or fast
  - Fast
- Big discrete parameter studies
  - Good prediction, what is worth to manufacture

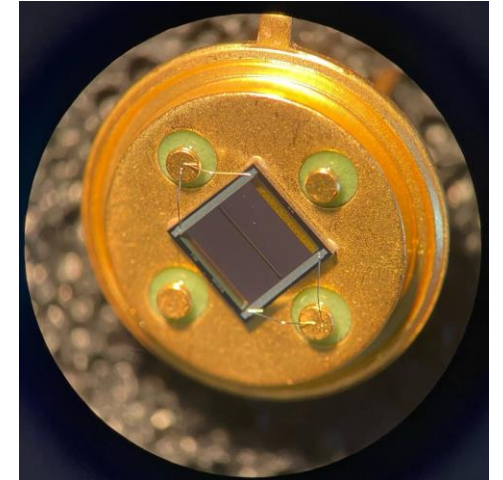
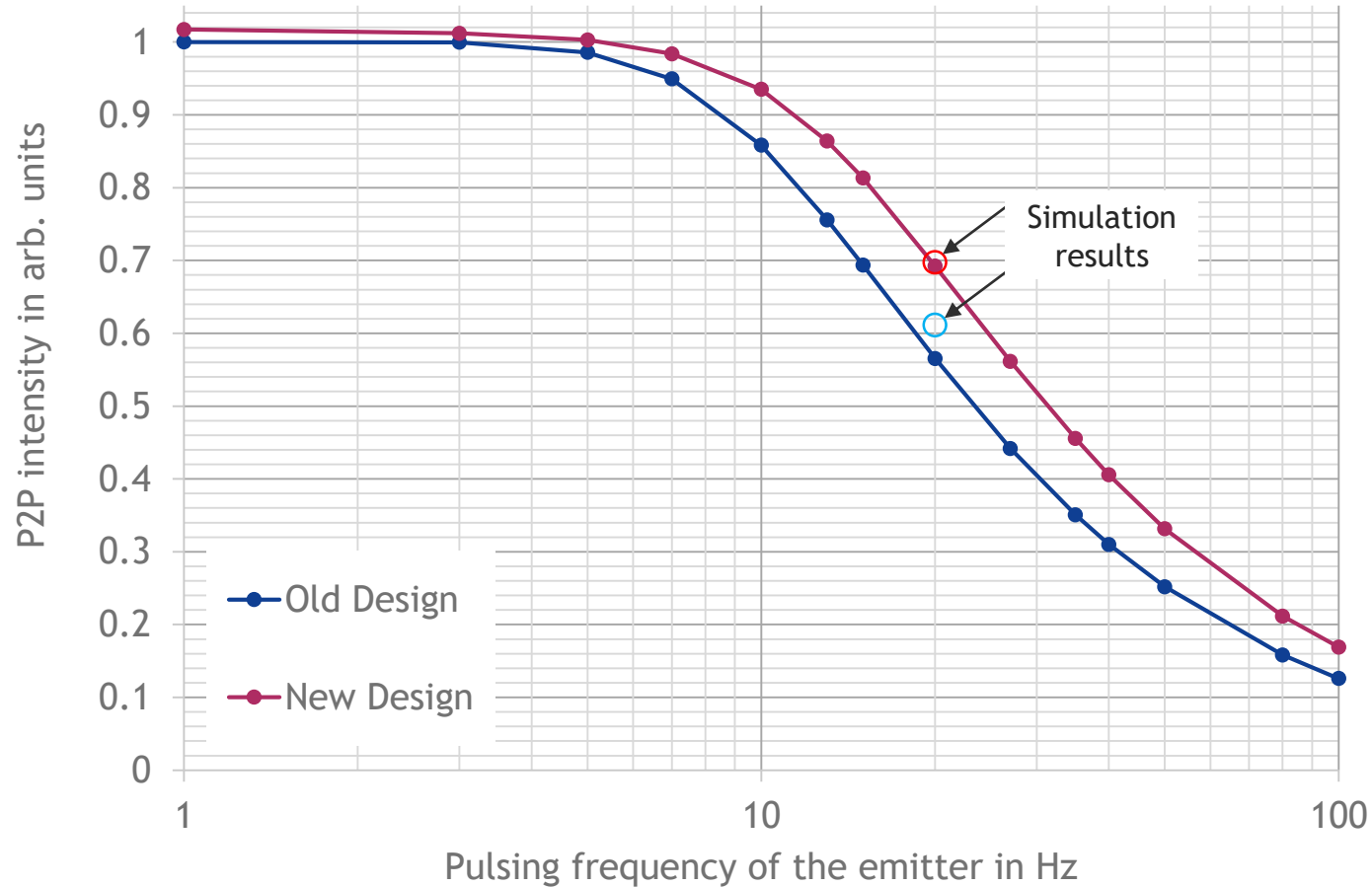




# Helping In Design

- Same life time in simulation

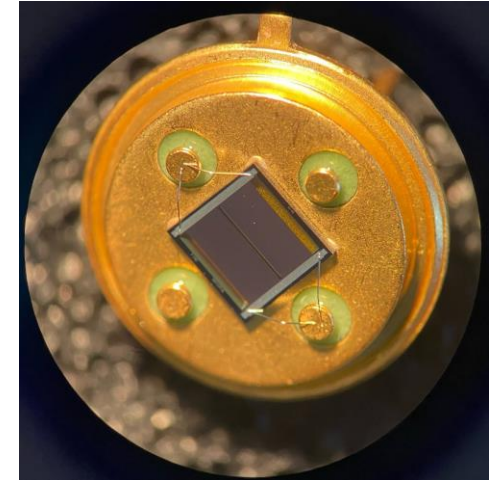
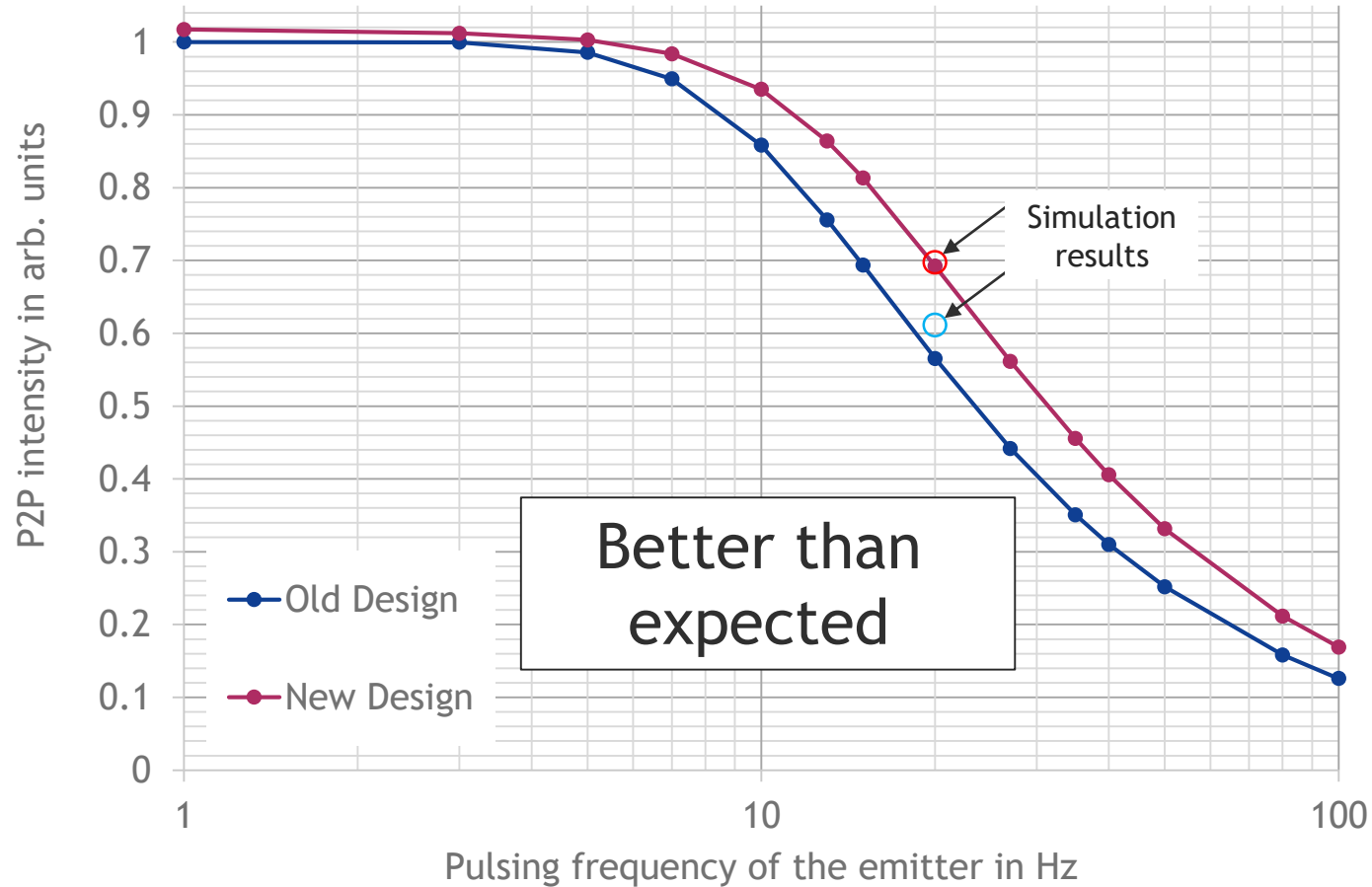
Measurements with fabricated chip



# Helping In Design

- Same life time in simulation

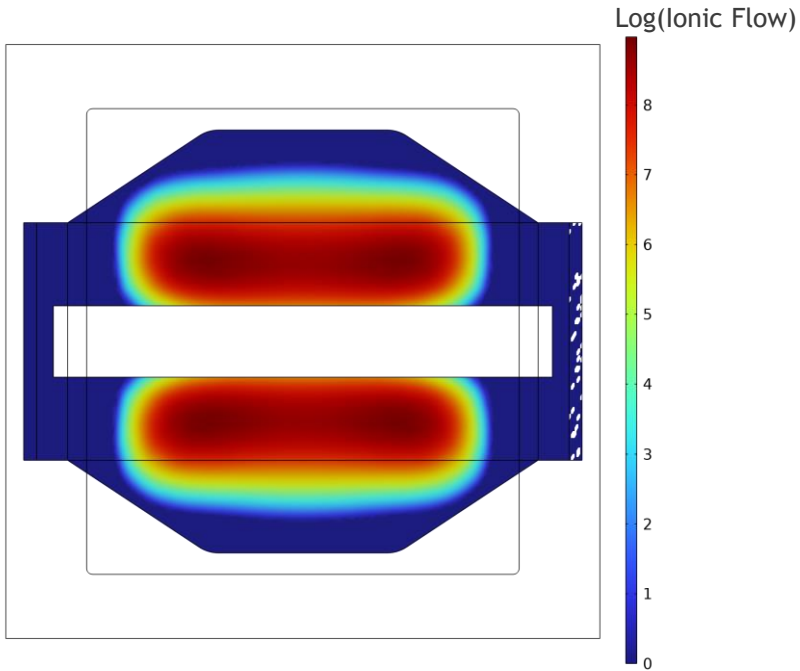
Measurements with fabricated chip



# Improve Design Process With Surrogate Modelling

- 3 geometrical parameters + applied electrical power
- In parameter study only discrete combinations

→ Surrogate Modelling



Settings

Surrogate Model Training

Compute

Label: Surrogatmodell-Training

Study Settings

Compute action: Compute and build surrogate model

Solution to use: Automatic

Surrogate model: Design of experiments (No surrogate model)

Output table group: Statistische Versuchsplanung 1 {de2}

Quantities of interest (Outputs)

Expression	Description	Individual solution to use
comp1.bnd2	Tmax	From "Solution to use"
comp1.bnd1	EMigr	From "Solution to use"
comp1.var1	Radiation	From "Solution to use"

Input Parameters

Parameter	Source type	Parameter description
A_dy (Abstand zur Gru)	Analytic	Uniform from [30, 150]
A_Px (Ecken)	Analytic	Uniform from [-400, -40]
A_Al (Aussparung: Lär)	Analytic	Uniform from [100, 400]
P_el (eingespeiste Leis)	Analytic	Uniform from [420, 770]

Correlation groups

Correlation matrix

Active

Input parameters sampling settings

Number of input points type: Manual

Number of input points: 1000

Random seed type: Automatic

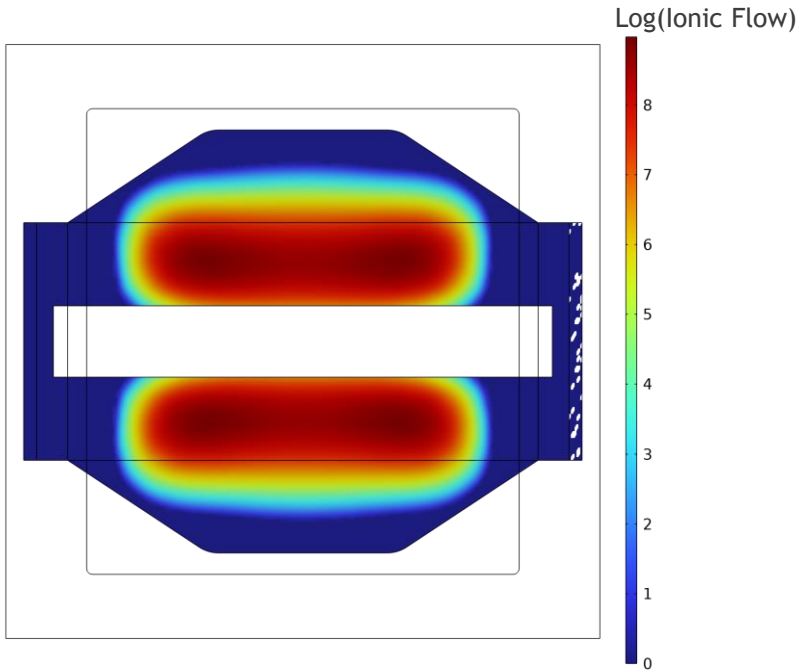
Initial random seed: 1014

Advanced Settings

# Improve Design Process With Surrogate Modelling

- 3 geometrical parameters + applied electrical power
- In parameter study only discrete combinations

→ Surrogate Modelling



Settings

Deep Neural Network

Plot Create Plot Train Model Continue Training

Label: Tiefes neuronales Netzwerk 2

Layers

Type	Settings
Dense	Input, Input features=4, Output features=32, Activation=tanh
Dense	Hidden, Output features=18, Activation=tanh
Dense	Hidden, Output features=10, Activation=tanh
Dense	Hidden, Output features=6, Activation=tanh
Dense	Output, Output features=3, Activation=tanh

Data

Data source: Result table

Result table: Designdaten 1 {tbl8}

Ignore NaN/Inf data points

Data Column Settings

Columns	Type	Settings
A_dy	Argument	Name=x1, Scaling=to01
A_Px	Argument	Name=x2, Scaling=to01
A_Al	Argument	Name=x3, Scaling=to01
P_el	Argument	Name=x4, Scaling=to01
comp1.bnd2	Function values	Name=dnn_T, Scaling=to01
comp1.bnd1	Function values	Name=dnn_EM, Scaling=to01
comp1.var1	Function values	Name=dnn_Rad, Scaling=to01

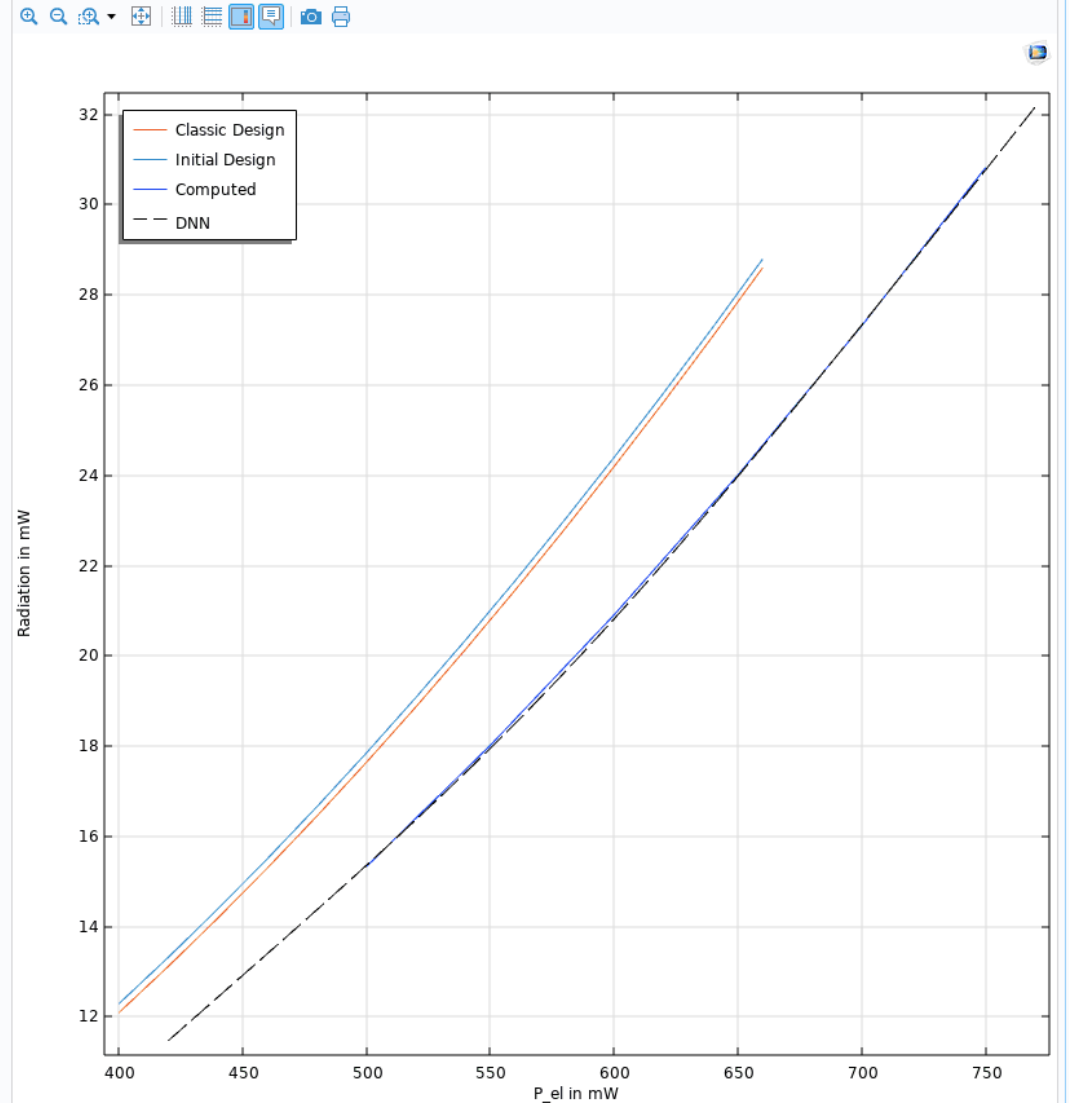
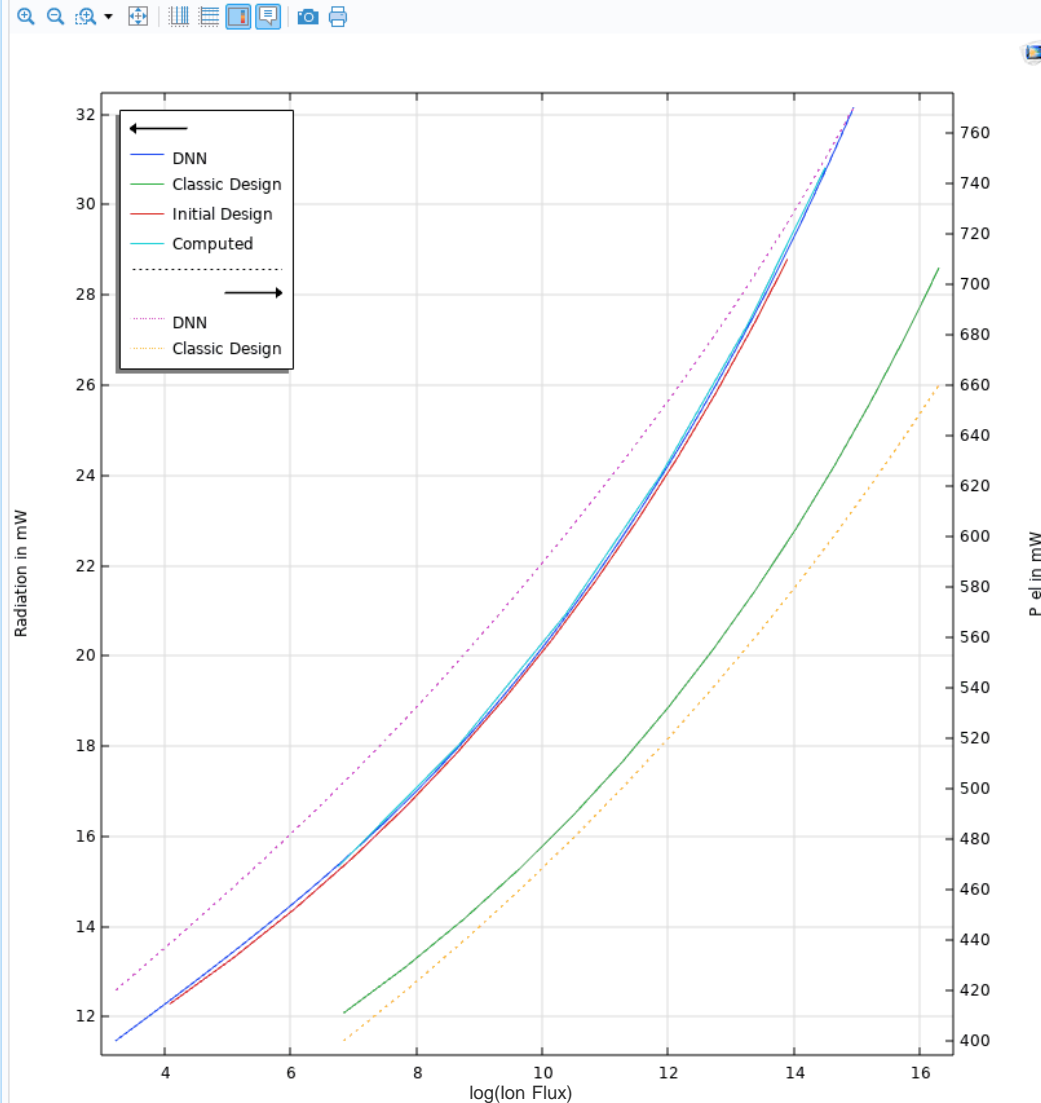
# Application For Better Visualisation

Datei Home

Compute

Haupt

Eingaben

Slit Width: 150  $\mu\text{m}$ Corner: -200  $\mu\text{m}$ Distance To Wall: 50  $\mu\text{m}$ 



# Conclusion

- Model building of existing technology without knowing exact material parameters
- New evaluation of current designs
  - Life time prediction
- Developing new designs
  - Better preselection of design worth manufacturing
  - Surrogate Modelling allows steplessly adjustable parameters



# Thank you for your attention!

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QSolid  
Funding code: 13N16172

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# Verification experiment

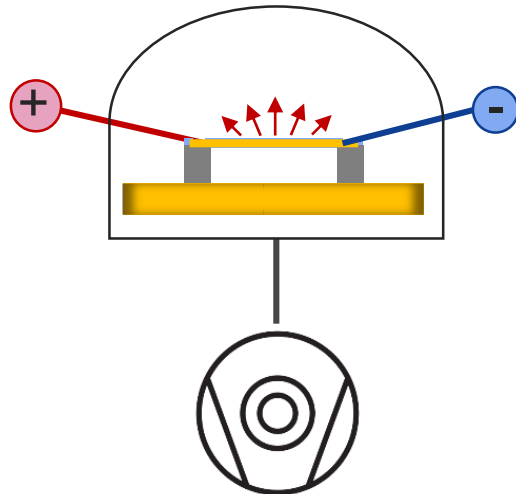
Unknown parameters:

- Temperature dependent resistance
- Temperature dependent thermal conductivity

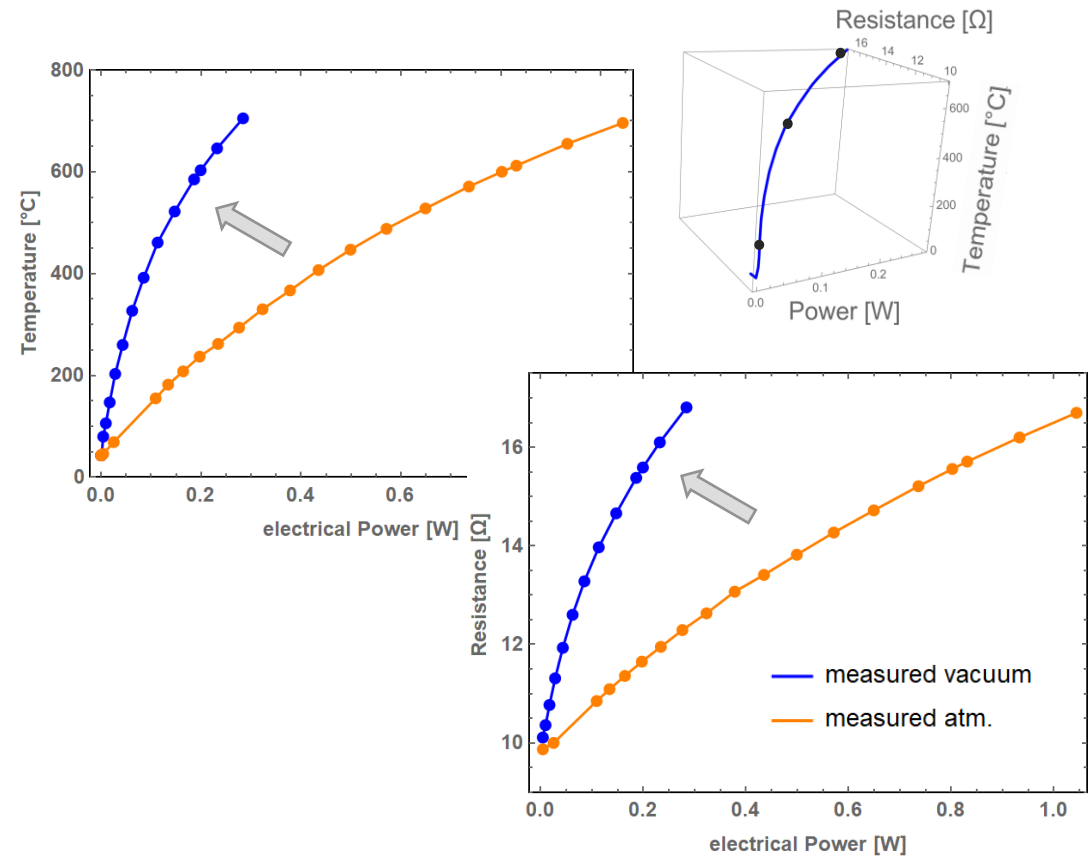
Vacuum container

Source measure unit

Turbo pump



Remove influence of thermal conduction and convection by air

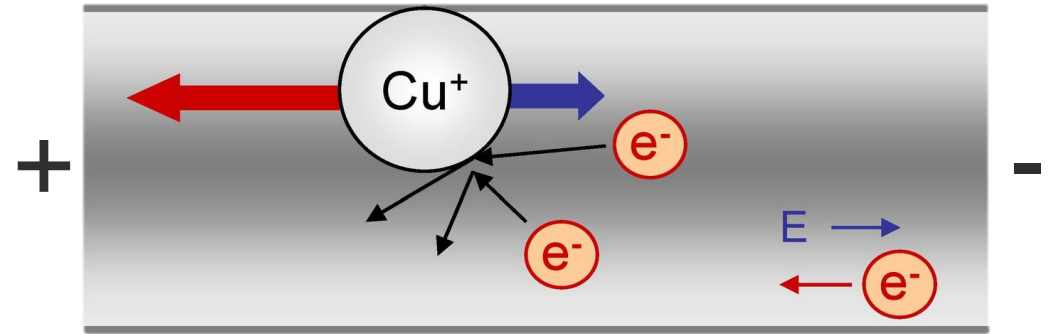


# Life Time Modeling

- Dominant failure mechanism is Electromigration

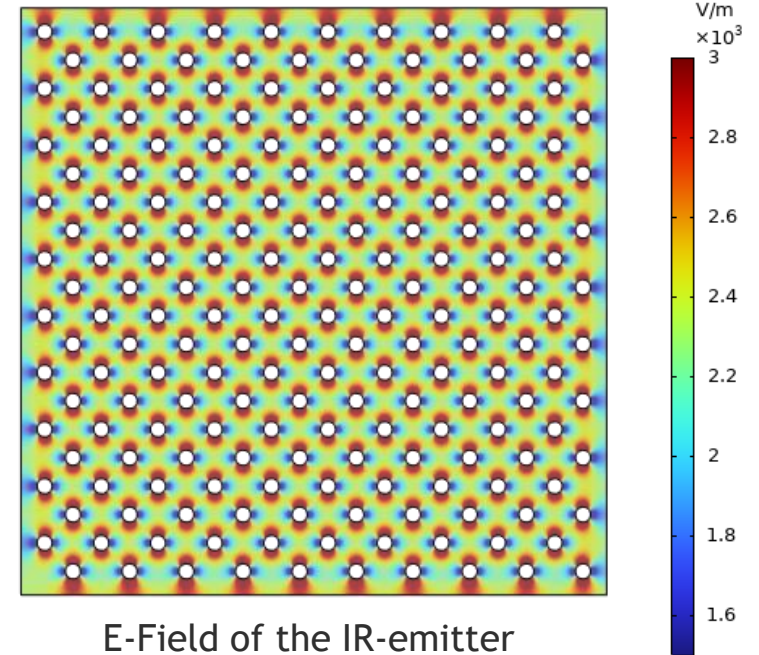
$$J_{max} = K \cdot \frac{kT}{E} \cdot \exp\left(\frac{E_A}{kT}\right)$$

- $K$  - summarized material properties,  $k$  - Boltzmann constant,  $T$  - Temperature,  $E_A$  - Activation energy,  $E$  - Electric Field



<https://commons.wikimedia.org/wiki/File:Electromigration.png>  
 Authour: Linear 77, Source: Own work

Analyzing current design  
 with perforated conductive layer



E-Field of the IR-emitter