Numerical Optimization of a Microtransformer

more than you expect

WOST
June 22, 2018

Presenter:
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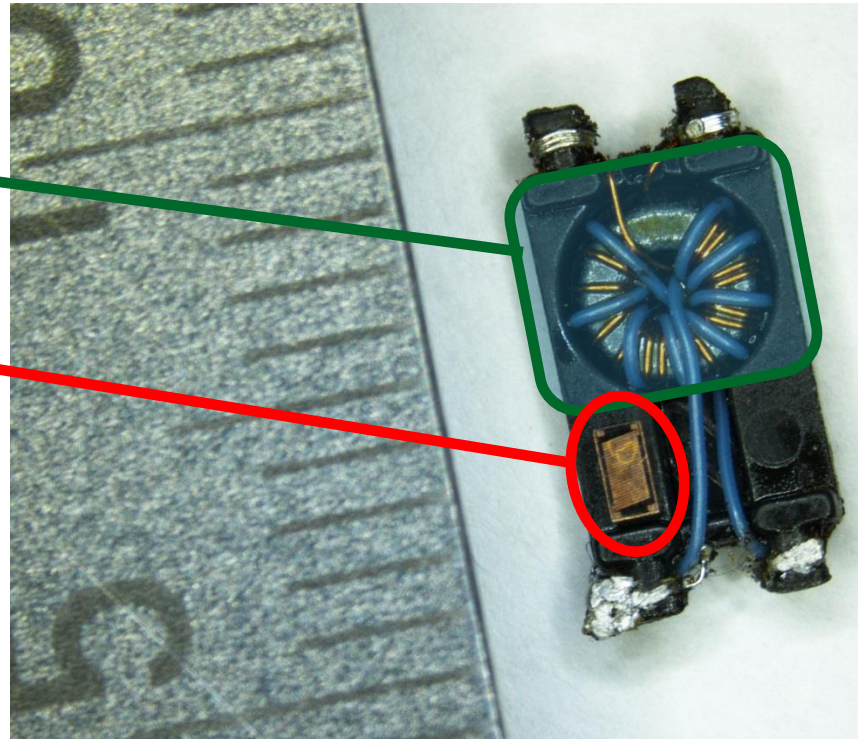
Agenda

- *Motivation*
- Target
- Electromagnetic Simulation
- Workflow
- Sensitivity Analysis
- Optimization
- Results and Outlook

Motivation

- **Target:**
  - Reduction of device size with simultaneous extension of the range of functions
- **Realization:**
  - High switch frequency (over 20 MHz) ➔ Decrease of inductance value ➔ Reduction of device size
- **Problem:**
  - Difficult fabrication
  - Expensive prototype manufacturing
- **So far:**
  - Parameter sweep based on experience
- **Approach:**
  - Model optimization using ANSYS optiSlang



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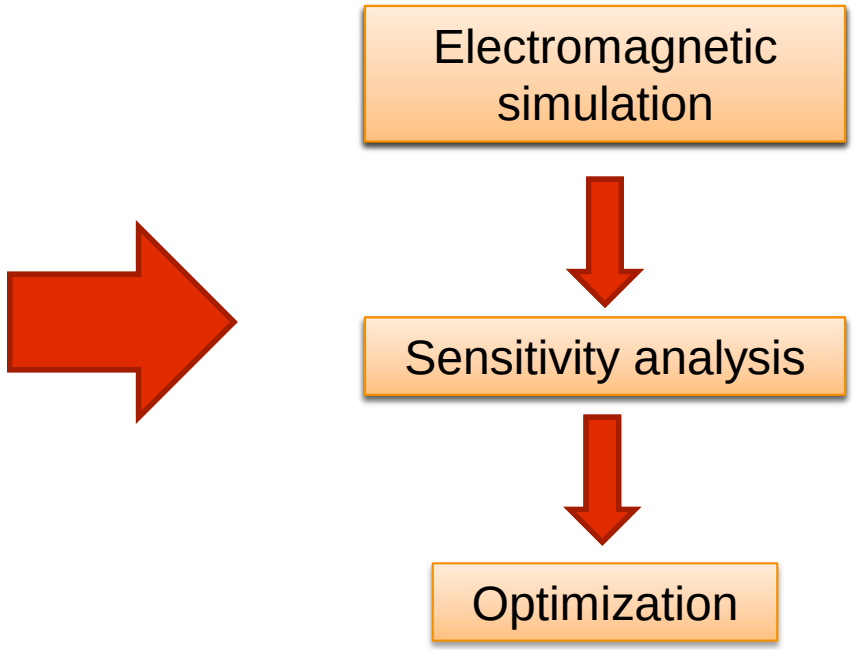
Target

- Optimiziation of a microtransformer by using ANSYS Maxwell and ANSYS optiSlang:

Market requirements:

- Minimization of the ohmic restistance
- Inductance between 20 - 50nH
- Coupling factor ≥ 0.8
- Capacitance ≤ 5pF



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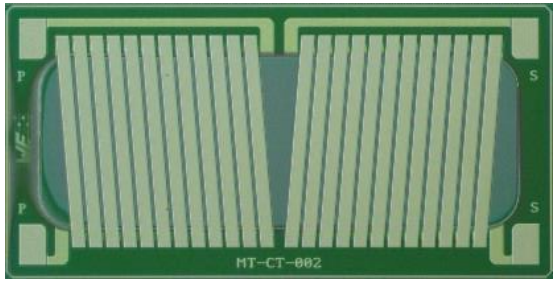
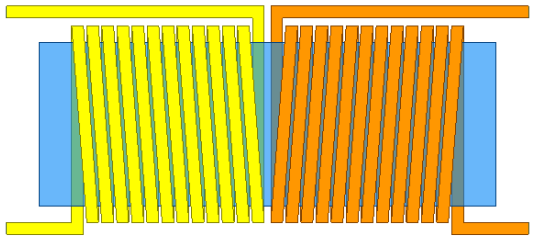
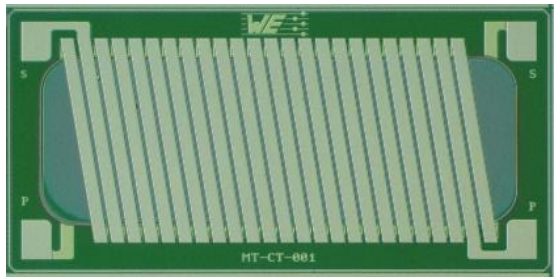
Electromagnetic Simulation

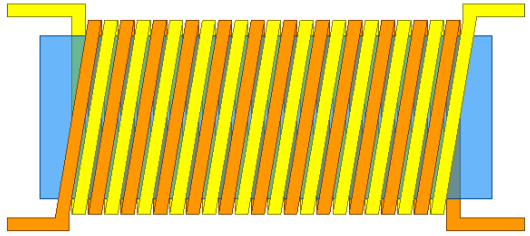
- Comparison of the primary-secondary model and the interleave model





Primary-secondary model



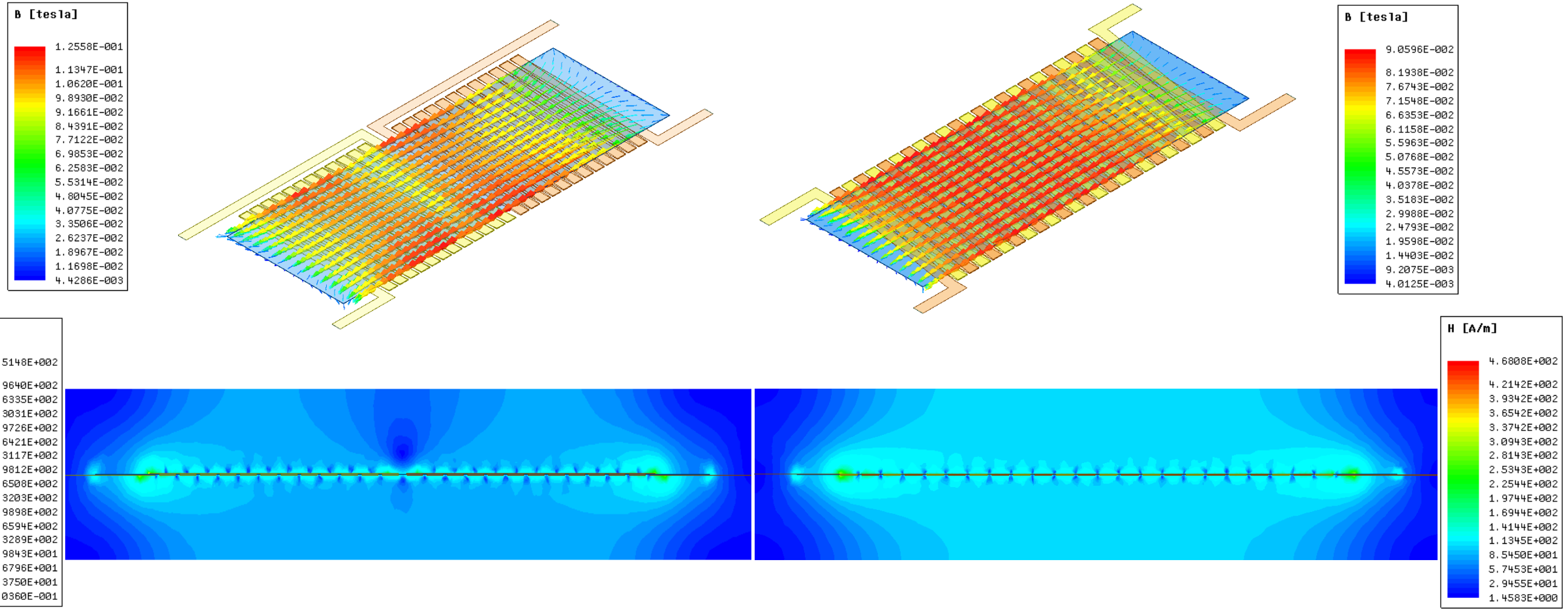


Interleave model

Dimension: 1400 µm × 600 µm × 3.3 µm

Electromagnetic Simulation

- Comparison of the field results from primary-secondary model and the interleave model



Electromagnetic Simulation

- Comparison of the simulation results from primary-secondary model and the interleave model

Parameter	Primary-secondary model	Interleave model
Resistance	19.23 Ω	16.08 Ω
Inductance	41.54 nH	23.11 nH
Coupling factor	0.07	0.74
Capacitance	20.35 pF	21.93 pF

Target:

- Minimization of the ohmic resistance
- Inductance 20 – 50 nH
- Coupling factor ≥ 0.8
- Capacitance ≤ 5 pF

Comparison of the coupling factor: *Interleave model* will be used for further analysis

Electromagnetic Simulation

	Number	Parameter	Description
Input parameter	1	coreLength	Length of the core
	2	coreWidth	Width of the core
	3	coreHeight	Height of the core
	4	coilHeight	Height of the coil
	5	distanceEnd	Length of the core, which sticks out of the coil
	6	gapCoilX	Gap between two turns in x-direction
	7	gapCoilZ	Gap between two cores
	8	gapBetweenCC	Gap betwenn coil and core in z-direction
	9	via	Gap between coil and core in y-direction
	10	turns	Number of turns
Response	1	RDC	Ohmic resistance – objective
	2	L	Inductance – constraint
	3	CplCoef	Coupling factor – constraint
	4	C	Capacitance – constraint

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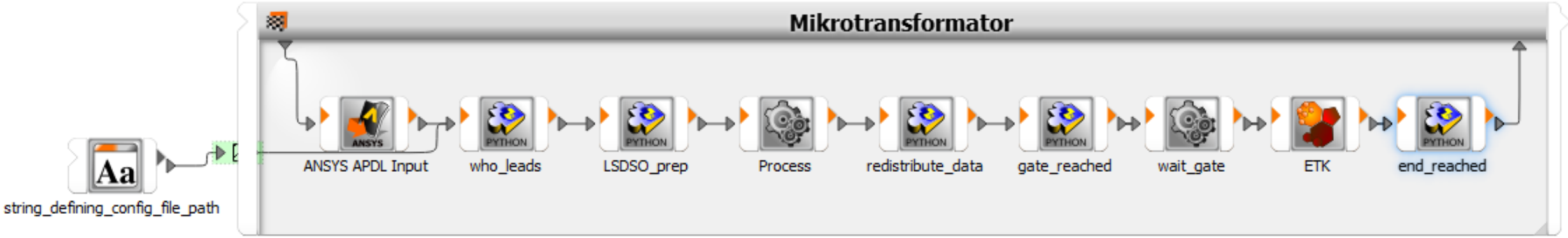
Workflow

- Implementation of the coupling between ANSYS Maxwell und ANSYS optiSlang with the LS-DSO (Large Scale – Distributed Solve Option) workflow



- Advantages:
  - Parallelization of the computation
  - All designs of one iteration bounded in one LS-DSO job
  - Simulation works in the background

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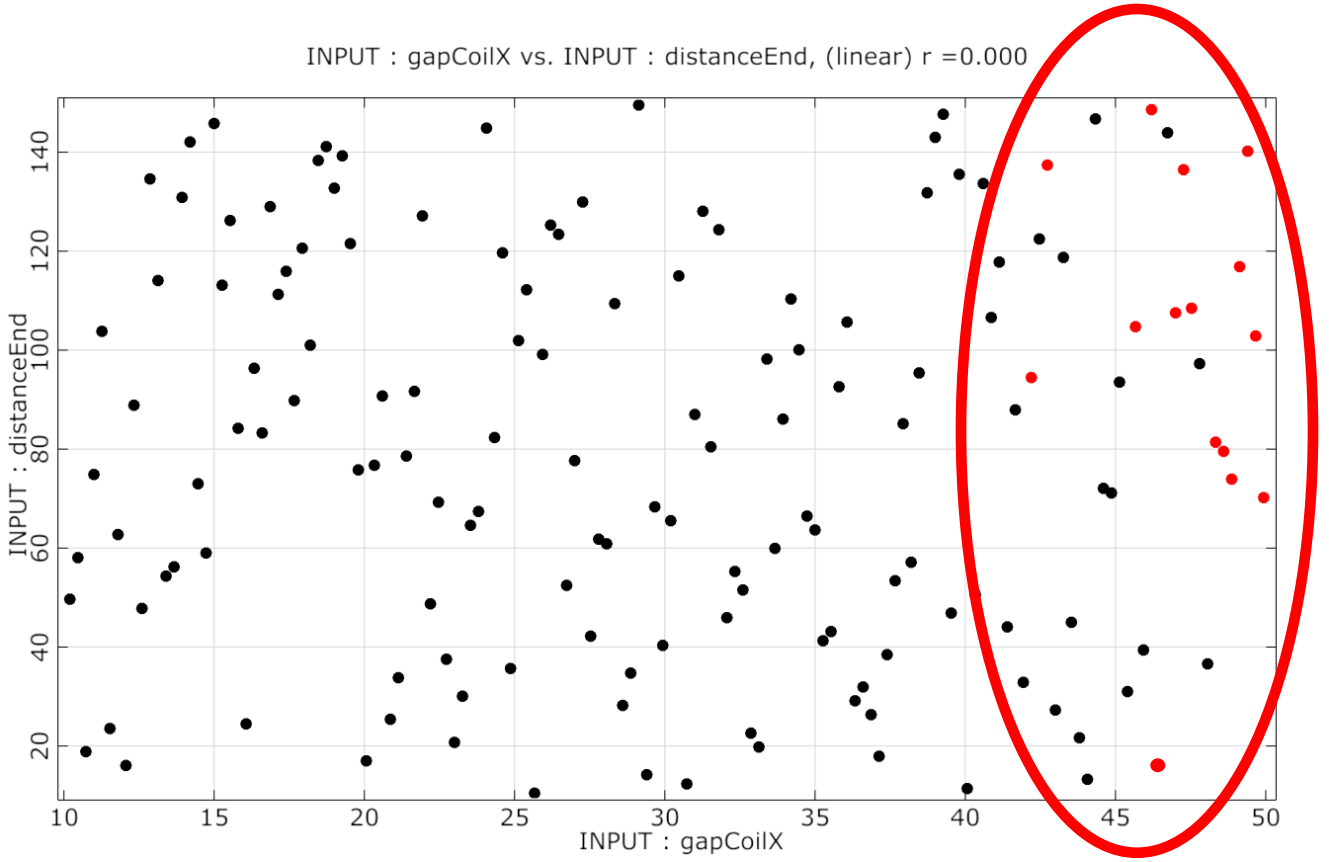
Sensitivity Analysis

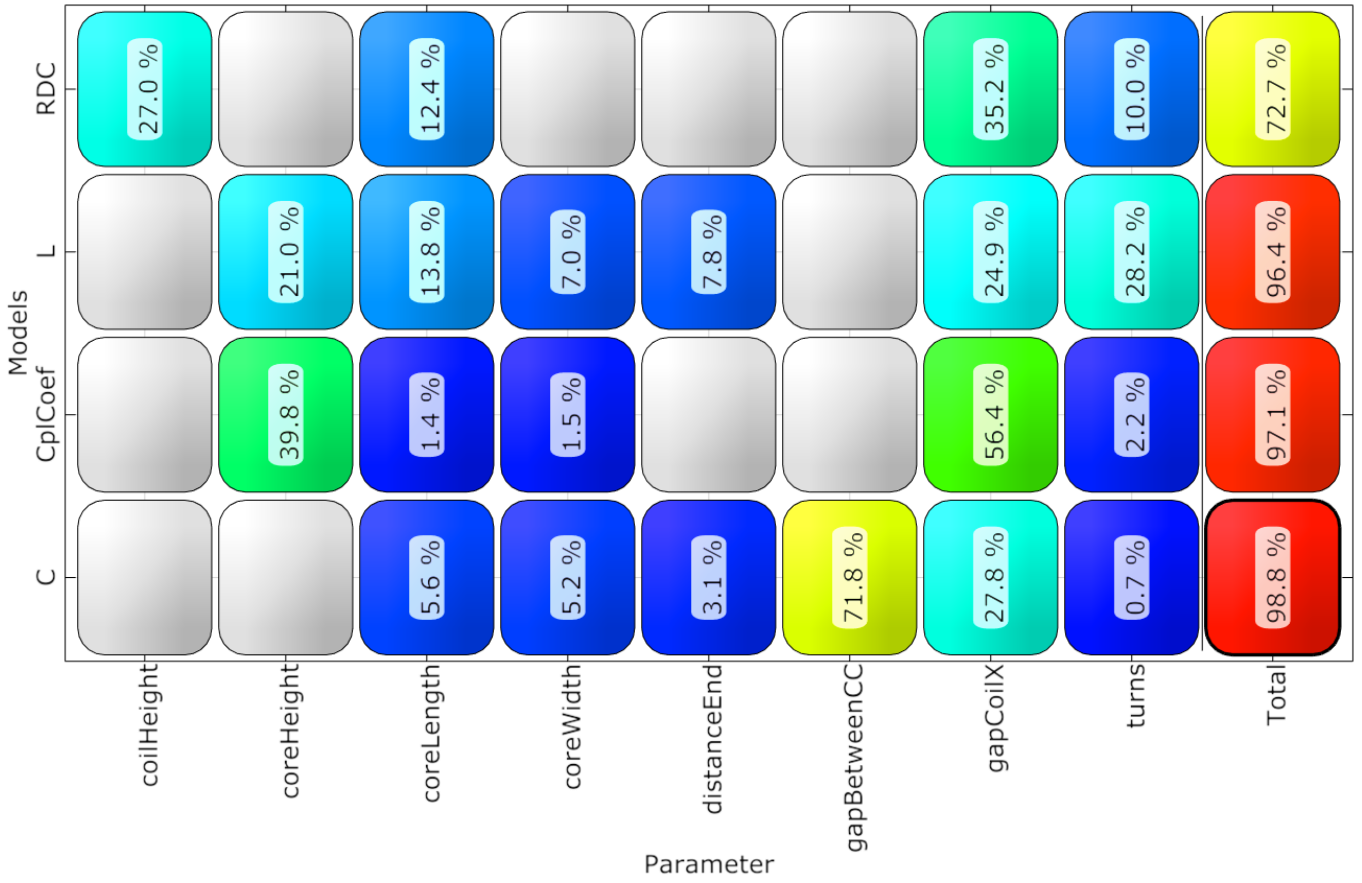
Target of the sensitivity analysis:

- Understand system behavior
  - ➢ 15 failed designs in the range of small coil cross sections
  - ➢ No automatic identification of the boundary condition
- Determine dependence and ranking between input parameters and responses
- Receive a “Metamodel of Optimal Prognosis” (MOP) with a reduced number of the input parameters



Sensitivity Analysis

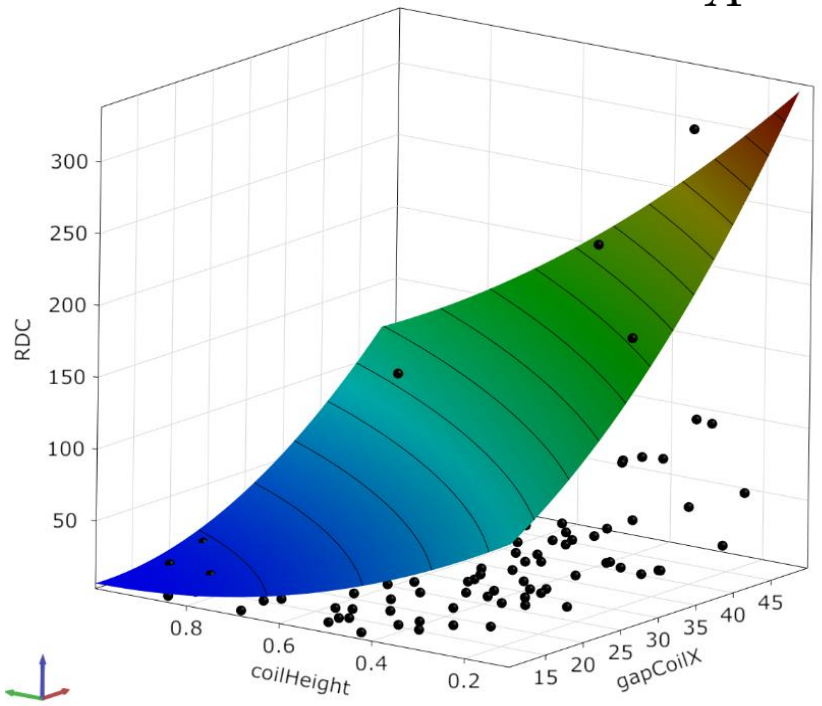
- "Coefficient of Prognosis" (CoP) matrix
  - CoP as a measure of quality for the MOP
  - Illustrates the dependence of the input parameters and the responses with ranking
  - *2 input parameters are irrelevant for all responses*
  - *Objective depends on 4 input parameters instead of 10*
  - Influence valid only within the chosen input parameter range



Sensitivity Analysis

- Response Surface Plot: relation between one response and the two input parameters

ohmic resistance: $R = \rho \frac{l}{A}$



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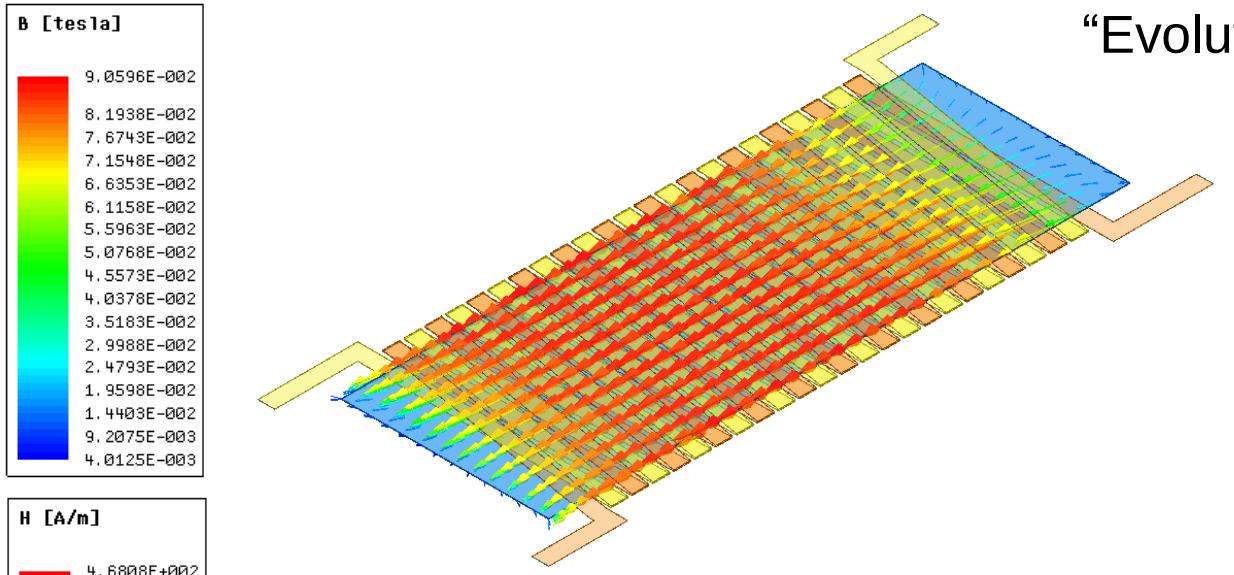
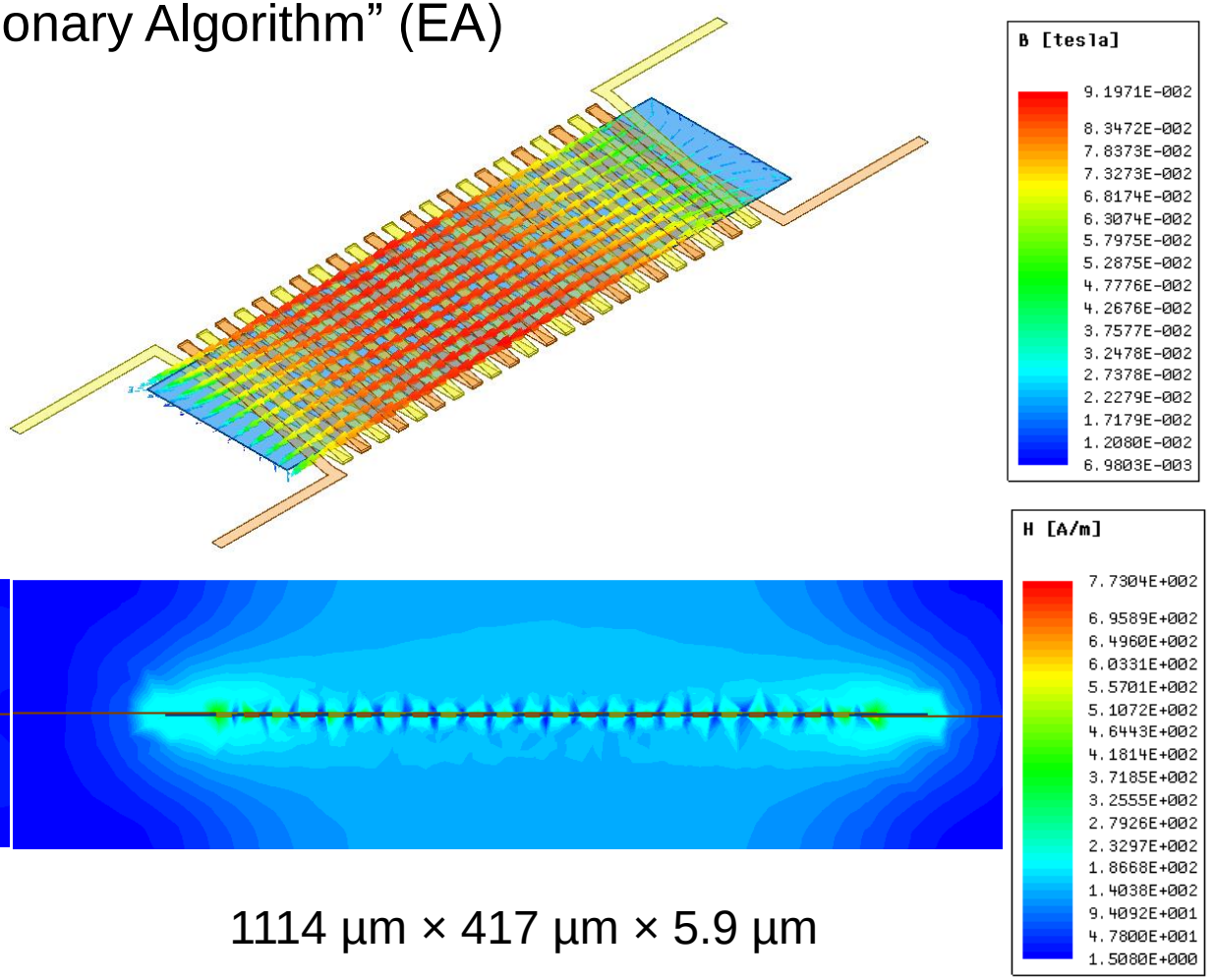
Optimization

- Insufficient CoP of 73% for the objective RDC resulted in the use of “Evolutionary Algorithm” (EA)



1400 µm × 600 µm × 3.3 µm



1114 µm × 417 µm × 5.9 µm

Optimization

- Comparison of the results of the initial model and the opimized model

	Initial model	Optimized model
Dimension	1400 µm × 600 µm × 3.3 µm	1114 µm × 417 µm × 5.9 µm
Ohmic resistance	16 Ω	9 Ω
Inductance	23.11 nH	28.46 nH
Coupling factor	0.74	0.8
Capacitance	21.93 pF	4 pF

- Reduction of the ohmic resistance ✓
- Inductance of 20 – 50 nH ✓
- Coupling factor ≥ 0.8 ✓
- Capacitance ≤ 5pF ✓

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Results and Outlook

Results:

- Sensitivity analysis: Reduction of the number of the input parameters from 10 to 8 for the optimization, in particular, from 10 to 4 input parameters for the objective
- Achieve the opimization target by downsizing the area of the model and increasing the thickness of the model
  - Ohmic resistance ✓
  - Inductance ✓
  - Coupling factor ✓
  - Capacitance ✓

Outlook:

- Improvement of the simulation model
- Verification of the simulation results with the measurment results

Thank you for your attention!

Questions?