

# Comparison study of different choke variants for PV boost converters

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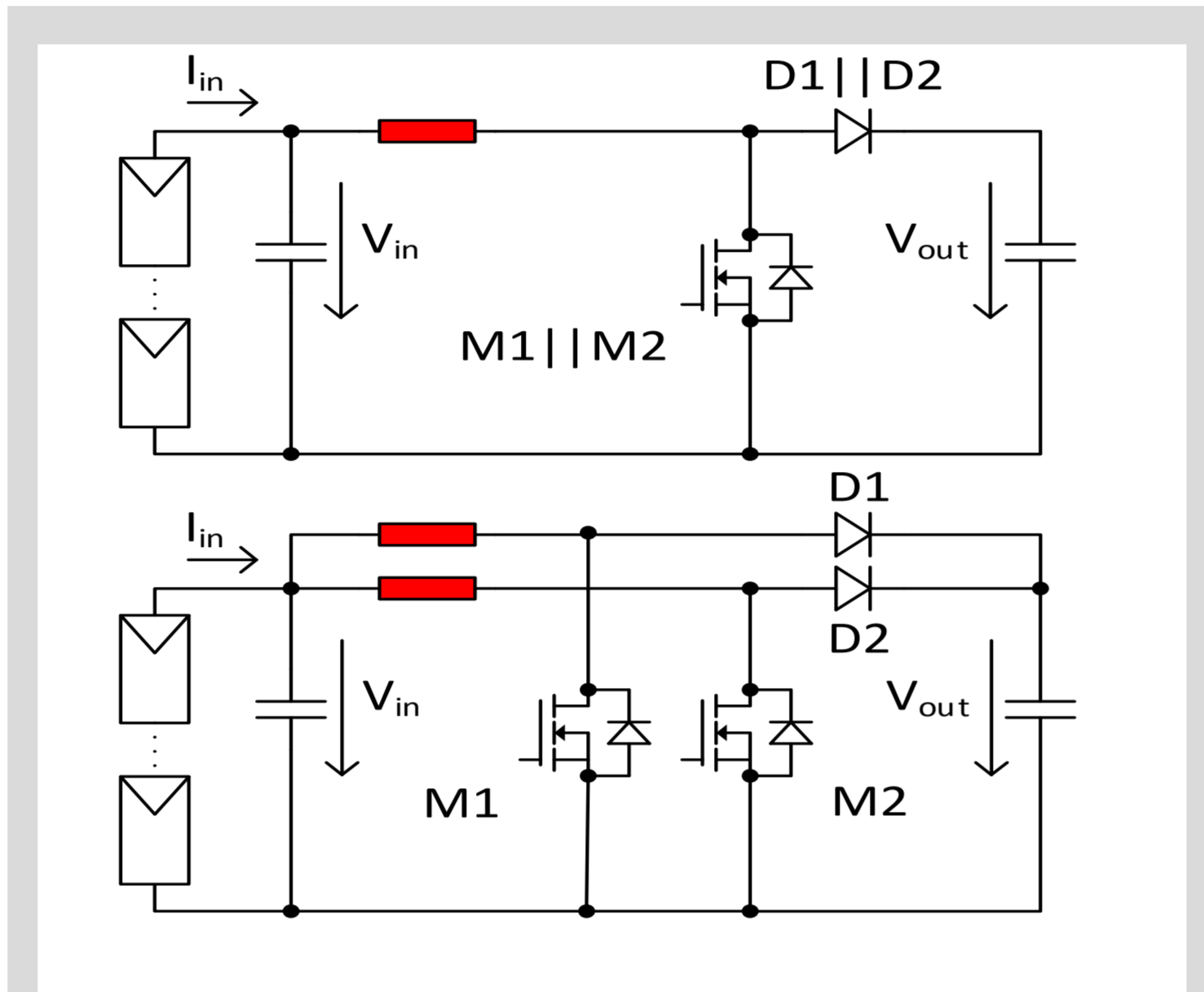
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## Introduction

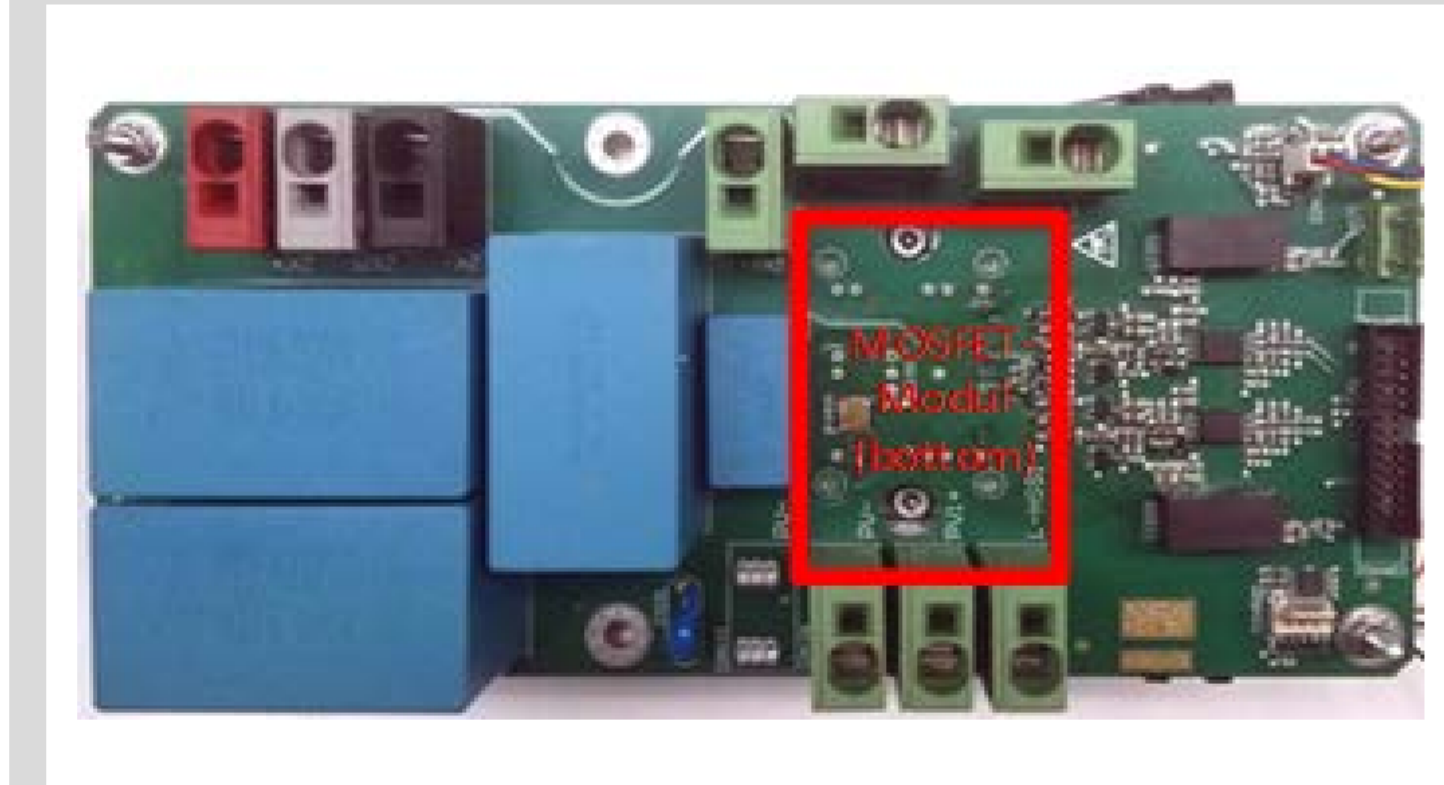
- Today's growth markets for PV are located in regions with high robustness climate demands (dust, radiation, heat)
- Ongoing demand for high efficiency
- Increased power density saves resources by moderate costs

## Boost converter topology concepts

- Single-phase
- Two-phase interleaved



Power electronic topology concepts: Single-phase boost converter (top) and two-phase interleaved boost converter (bottom)



Circuit board of the demonstrator

## Design of the chokes

- Development of
  - Single boost choke (double current)
  - 2 separate ("comparison") chokes
  - 1 coupled inductor

### Requirements for the chokes

Switching frequency $f_{sw}$	50 kHz
Input current $I_{in}$	30 A
Ripple current $\Delta I_{L,max}$	16 A
Maximum supply voltage $V_{in,max}$	1000 V
Output voltage $V_{out}$	700 V
Choke inductance L	220 $\mu$ H



Single-phase choke (left), two separated chokes (middle), coupled inductor (right)

### Technical characteristics of the boost converter chokes for 50 kHz

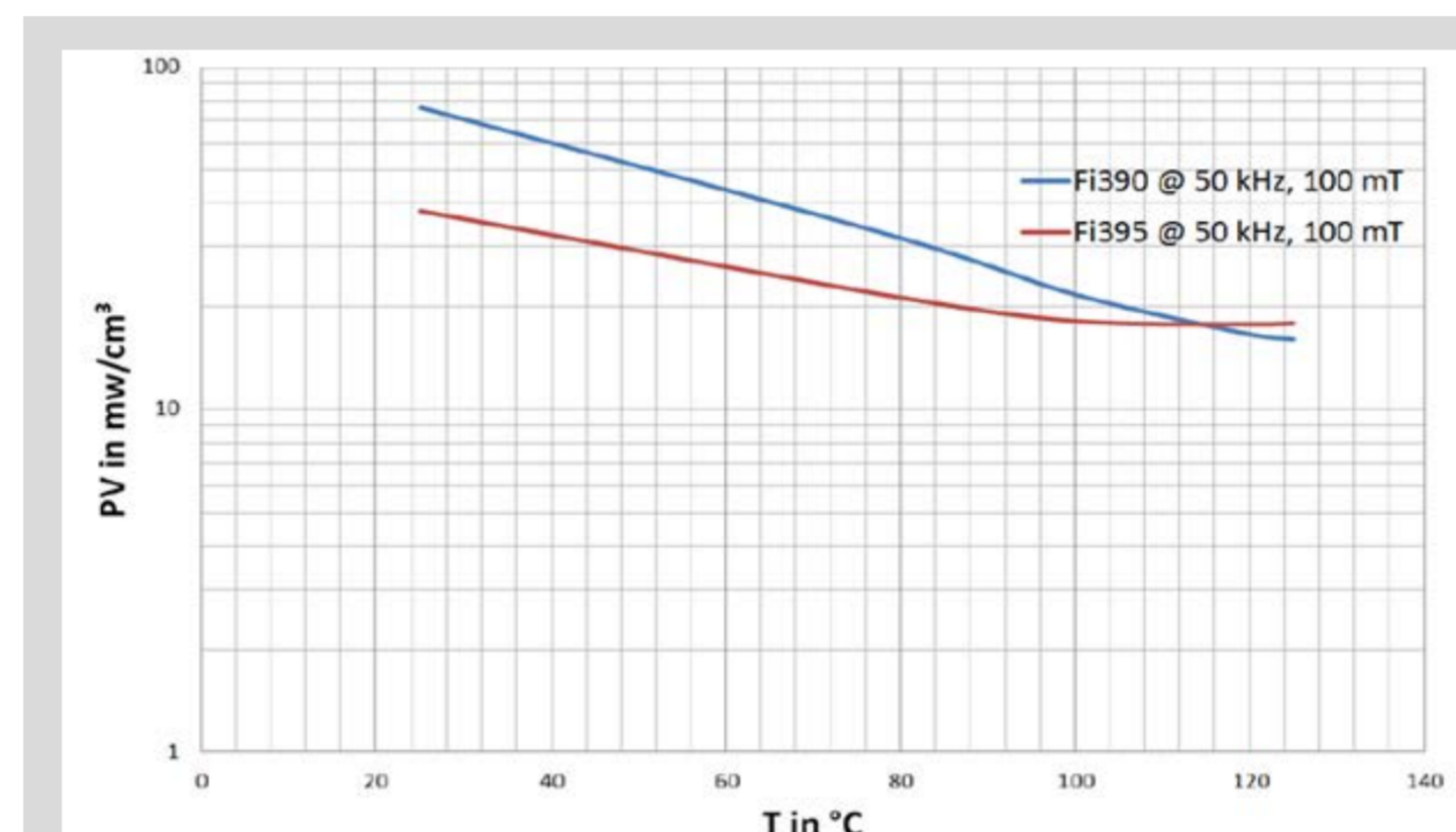
	Single Choke ES 141 001 11 94	Separated Chokes ES 141 001 11 96	Coupled Inductor ES 141 001 11 50
Inductance	220 $\mu$ H	2 x 220 $\mu$ H	2 x 220 $\mu$ H
Rated Current	30 A	2 x 15 A	2 x 15 A
Wire	1800 x 0.071 mm <sup>2</sup>	525 x 0.1 mm <sup>2</sup>	525 x 0.1 mm <sup>2</sup>
Ferrite material	SUMIDA Fi395	SUMIDA Fi395	SUMIDA Fi395
Ferrite volume	488 cm <sup>3</sup>	176 cm <sup>3</sup> (x2)	333 cm <sup>3</sup>
Ferrite weight	2362 g	851 g (x2)	1615 g
Overall volume	765 cm <sup>3</sup>	270 cm <sup>3</sup> (x2)	397 cm <sup>3</sup>
Overall weight	2688 g	1039 g (x2)	1983 g

## Core material

- New innovative magnetic material for best performance under increased thermal conditions and high saturation magnetization
- Material Efficiency Factor (MEF) as evaluation criterion:

$$MEF = \frac{B_{max}^2}{P_V}$$

- Development of a new ferrite material (SUMIDA Fi395) with lowest losses at high temperatures

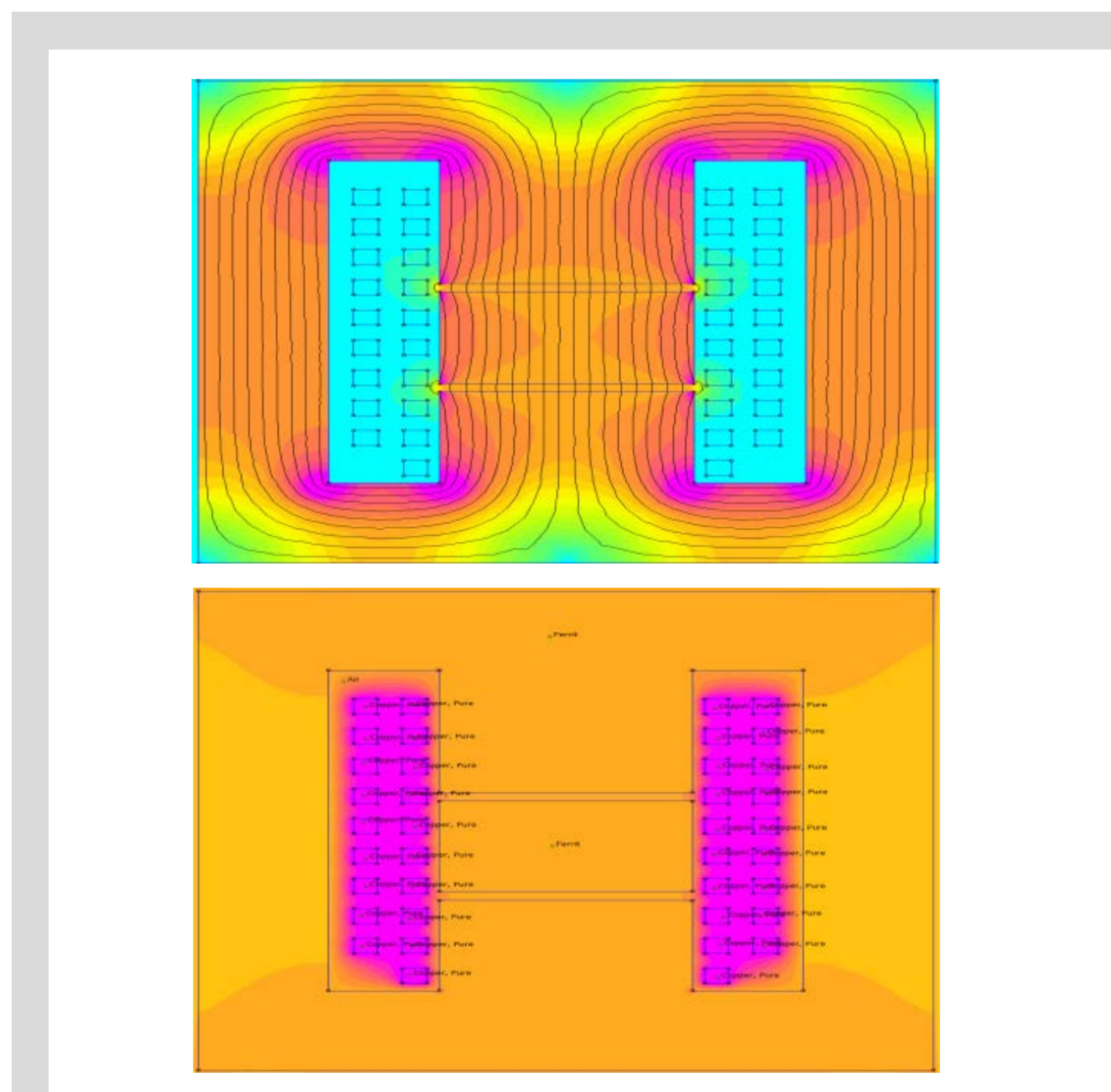


Comparison of lower loss curve of Fi390 and Fi395

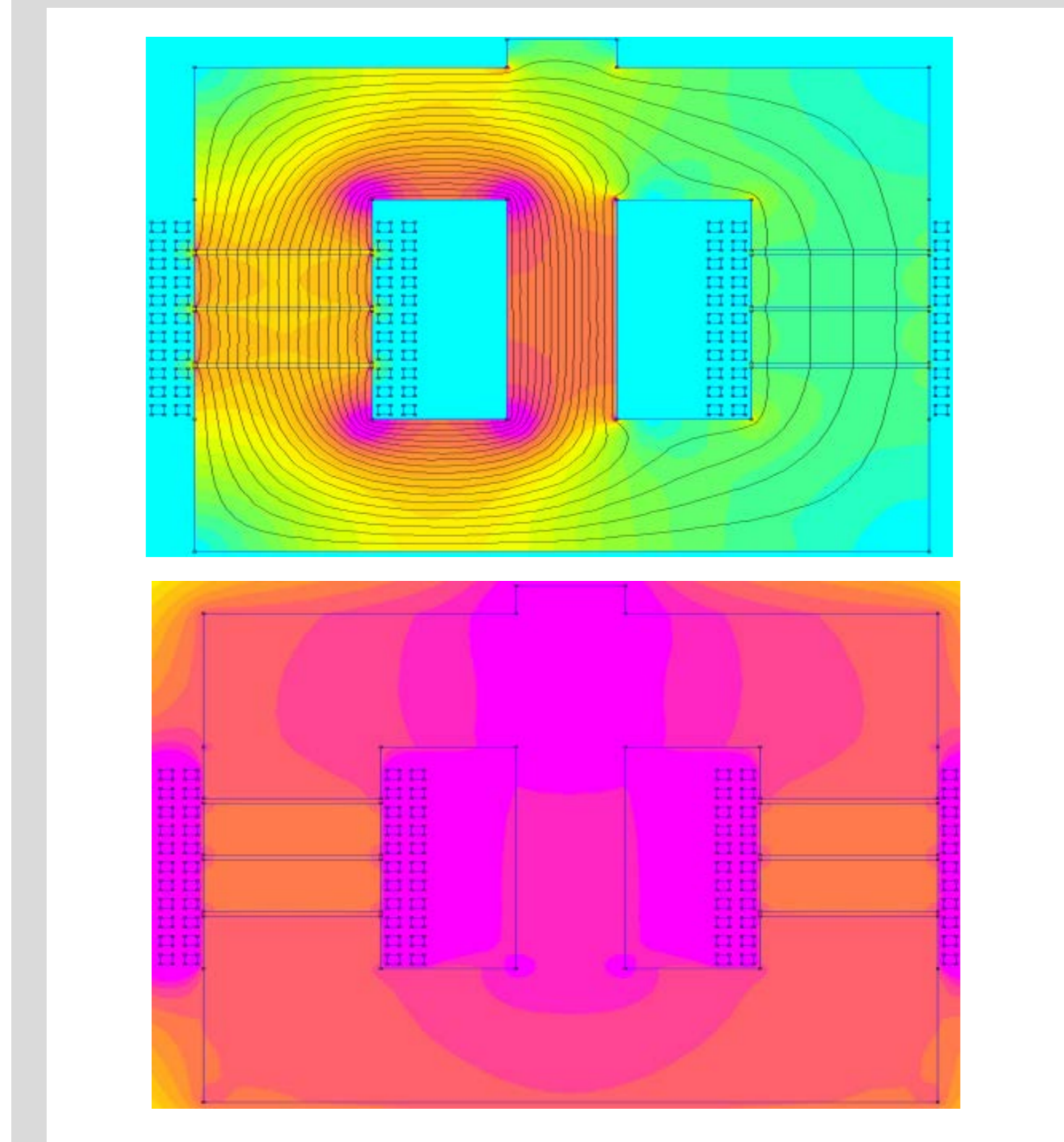
- 20 % lower resistive losses ( $P_{res}$ ) compared to power ferrites with equivalent saturation
- Size reduction of the boost chokes is achieved by approx. 20 %

## Magnetic and thermal simulation

- Both choke versions are comparable and match the same operating conditions



Magnetic (top) and thermal (bottom) simulation of one separated choke



Magnetic (top) and thermal (bottom) simulation of the coupled inductor design

- Simulation results match with the real measurements

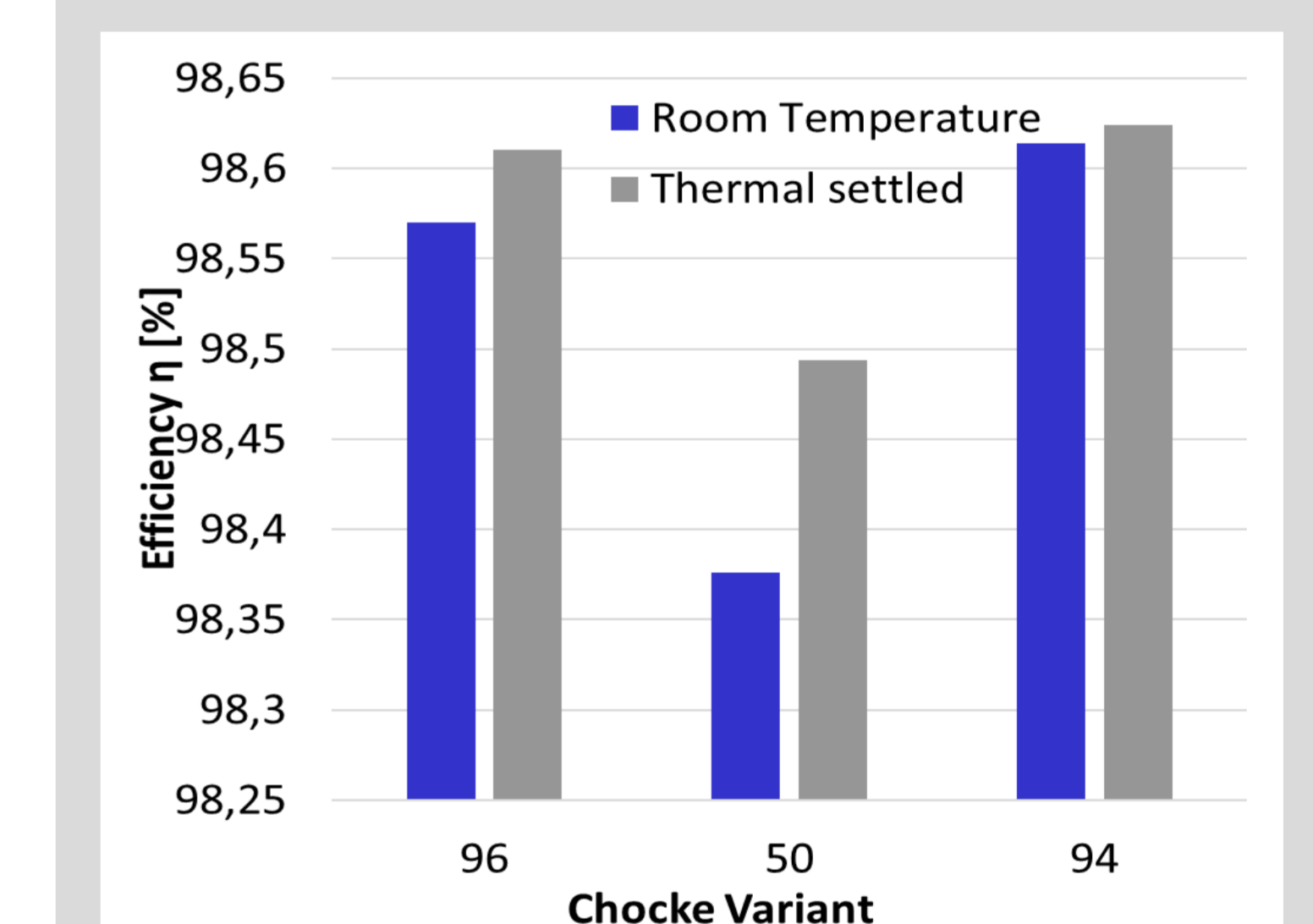
## Test setup and experimental results

- 30 A boost converter demonstrator with SiC-MOSFETs and different new chokes were investigated
- The boost converter with the separated chokes leads to the best compromise between weight, volume and efficiency

### Weight and volume comparison of the chokes

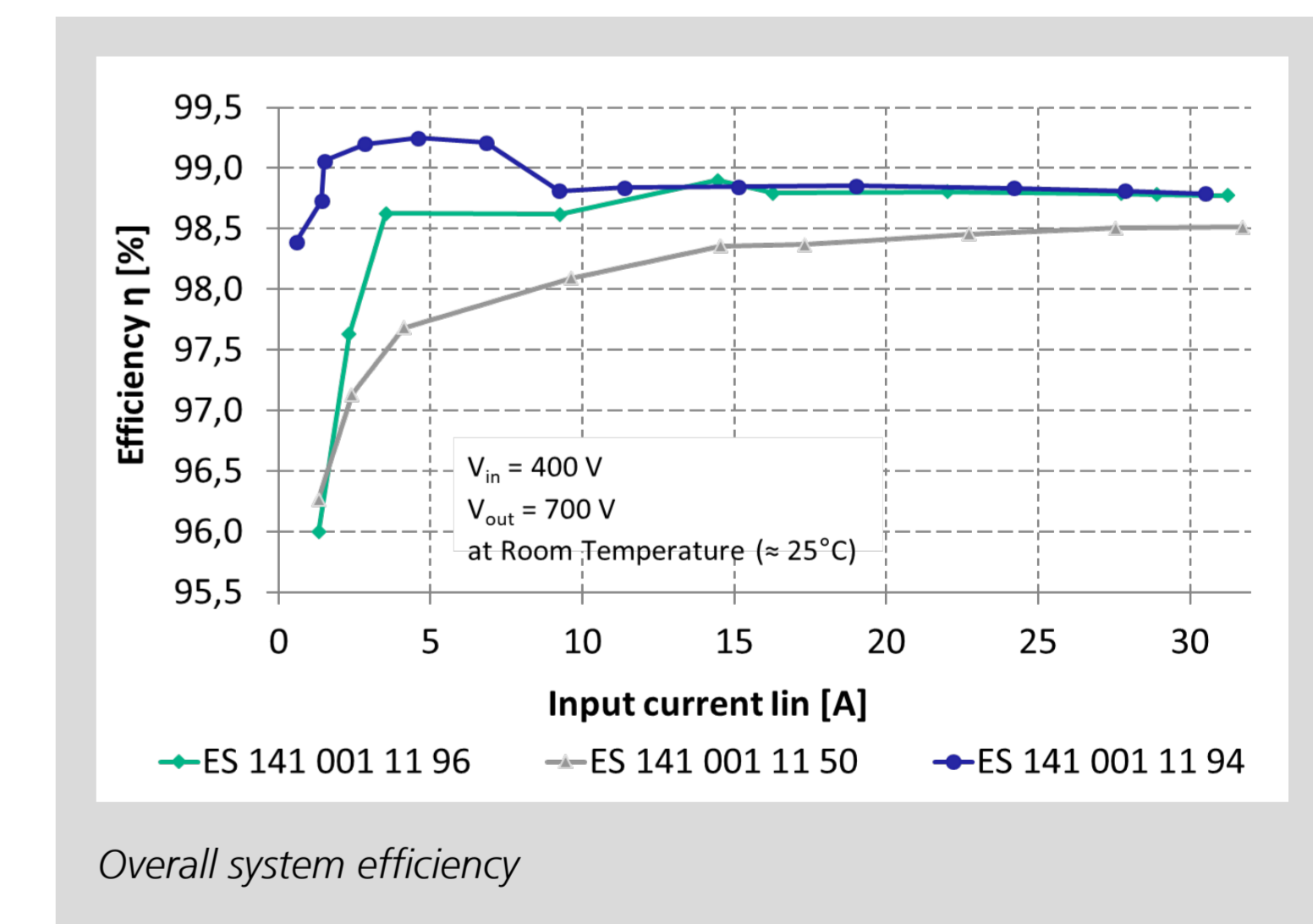
	Single Choke ES 141 001 11 94	Separated Chokes ES 141 001 11 96	Coupled Inductor ES 141 001 11 50
Volume of ferrite	488 cm <sup>3</sup>	176 cm <sup>3</sup> (x2)	333 cm <sup>3</sup>
Mass of ferrite	2361 g	1702 g	1615 g
Volume (Reference outer dimension)	765 cm <sup>3</sup>	540 cm <sup>3</sup>	397 cm <sup>3</sup>
Ferrite mass comparison	100 % (Reference)	72 %	68 %
Volume comparison	100 % (Reference)	71 %	52 %
Total weight of chokes	2688 g	2078 g	1983 g
Relative mass of chokes	100 % (Reference)	77 %	74 %

- Efficiency of the chokes increase with temperature till ~ 120°C



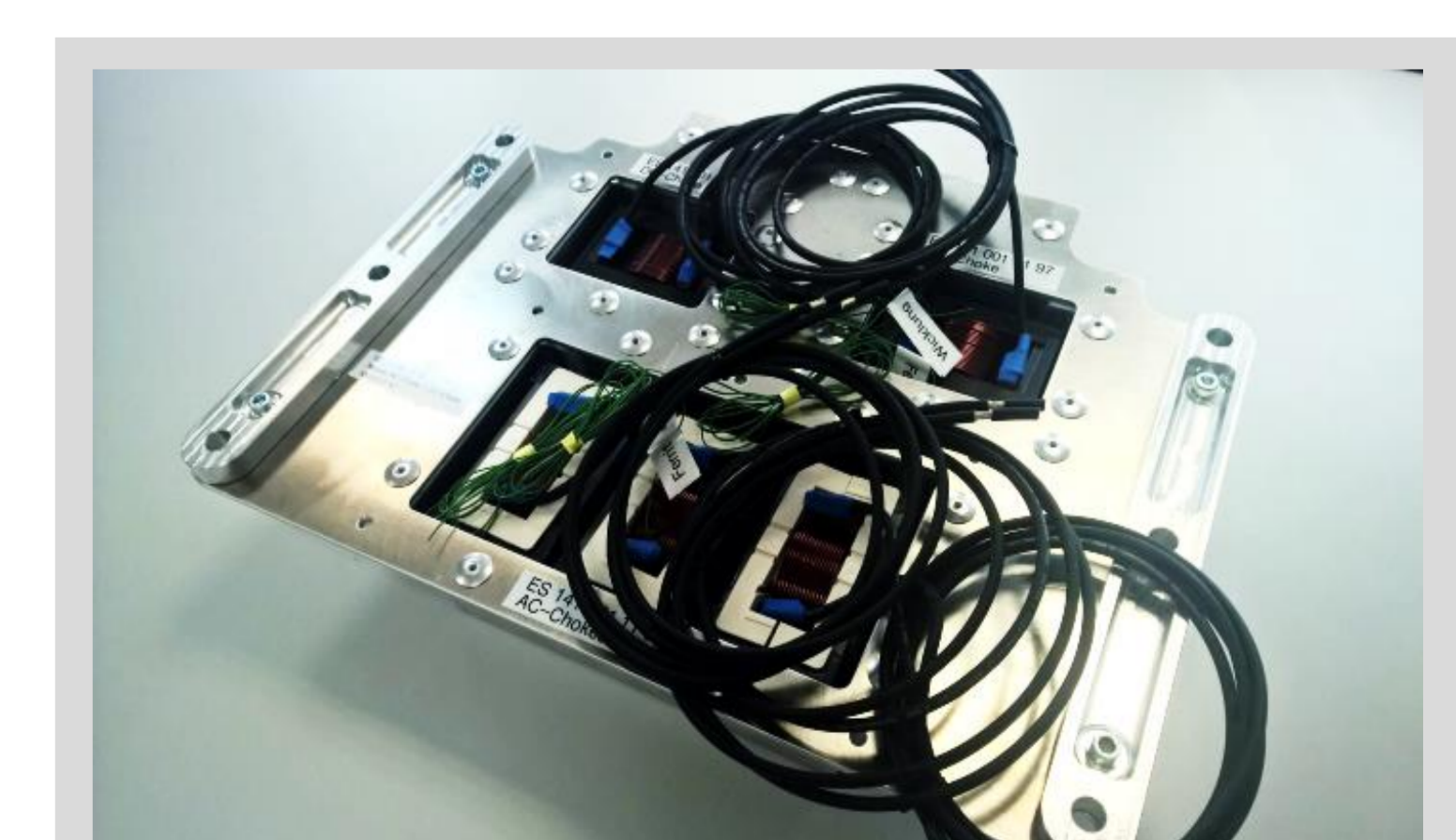
Thermal measurement results at rated current ( $V_{in} = 400$  V,  $V_{out} = 800$  V,  $I_{in} = 30$  A)

- A full load efficiency of 98.75 % at 50 kHz was measured



Overall system efficiency

- The demonstrator achieves a weight reduction of 23 % and a volume reduction of 29 %



Demonstrator for 30 kVA converter, size reduction through new ferrite material and thermal management by mechanic design (heat spreading body, special resin and passive ventilation effects)

Supported by:



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