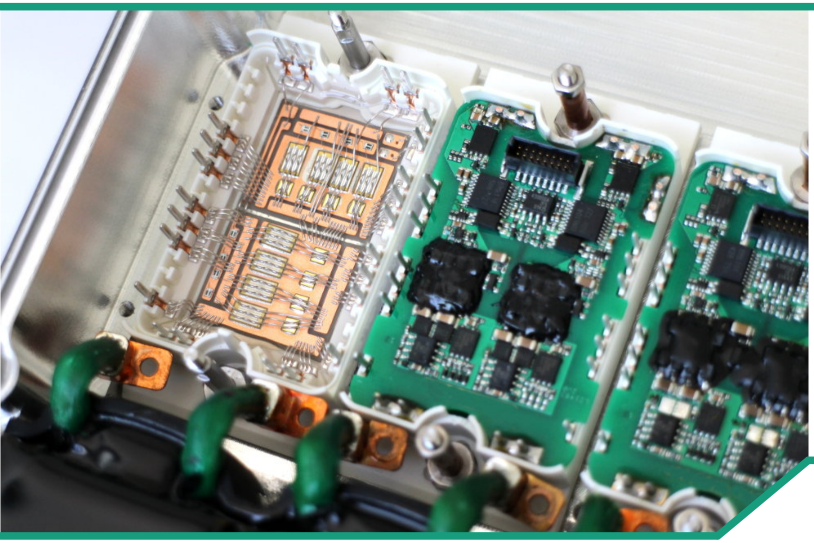
Potential of SiC for Automotive Power Electronics

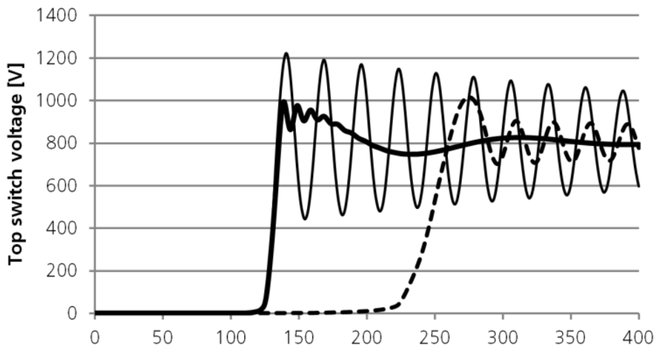
Overview

- Gain power density by SiC
  - Converter #1: Most compact full SiC power electronic
  - Converter #2: Industrial style SiC converter
  - Inverters: Standalone and modular Wheel Hub type



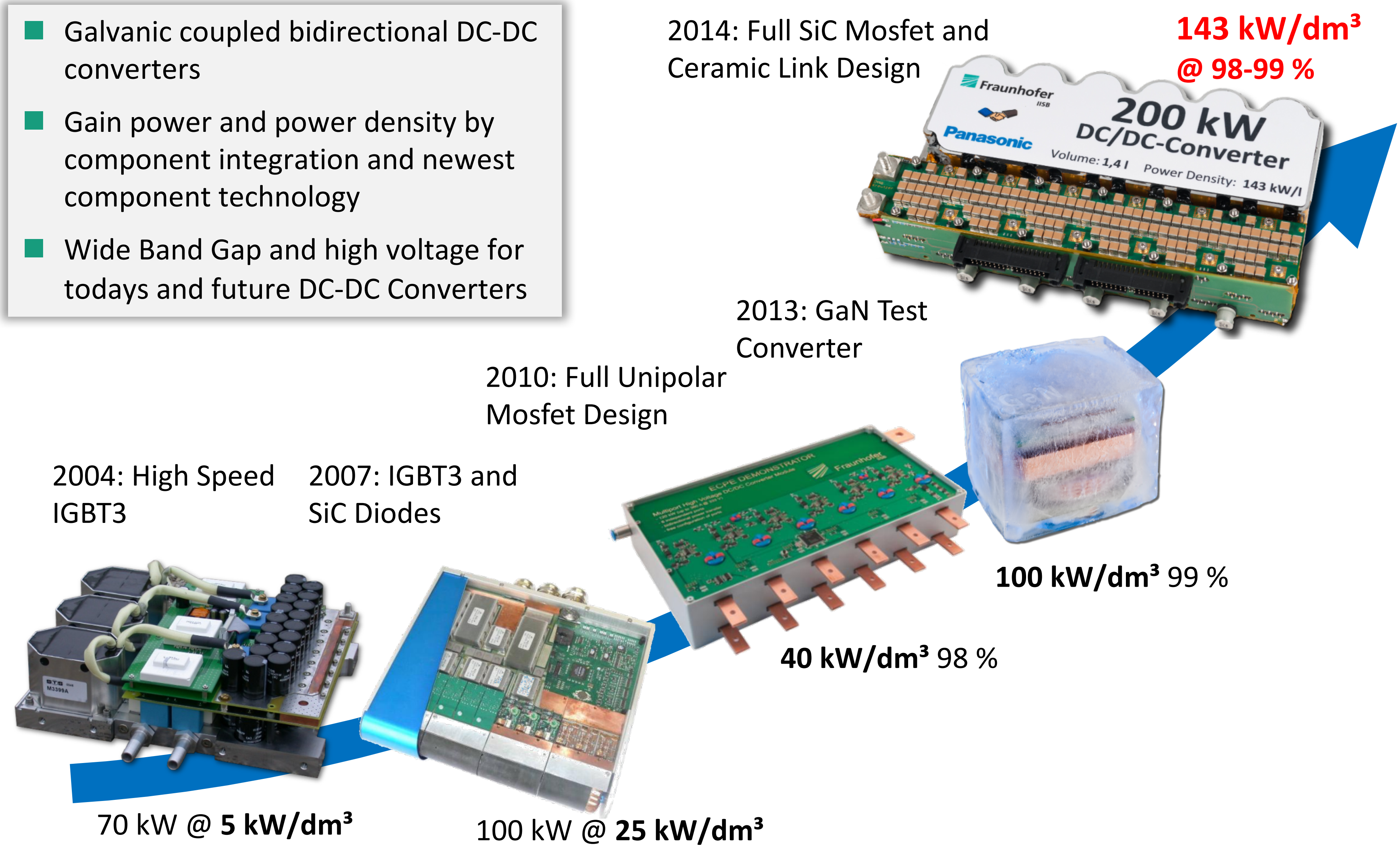
- Technical trends in SiC development
  - Optimizing towards more current
  - Impact on switching losses
  - Example and impact of parasitic capacitance

- Solution for newest and future SiC devices
  - Shift to resonant converters
  - Bus bar module
  - Using Si-RC Snubbers



Gain Power Density by WBG

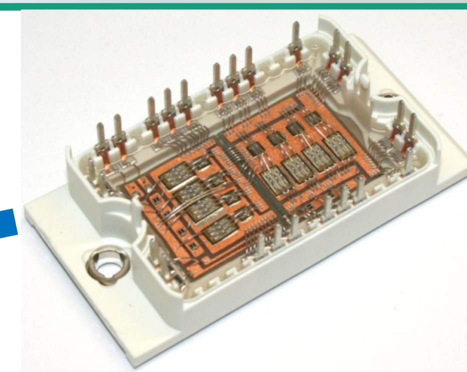
- Galvanic coupled bidirectional DC-DC converters
- Gain power and power density by component integration and newest component technology
- Wide Band Gap and high voltage for todays and future DC-DC Converters

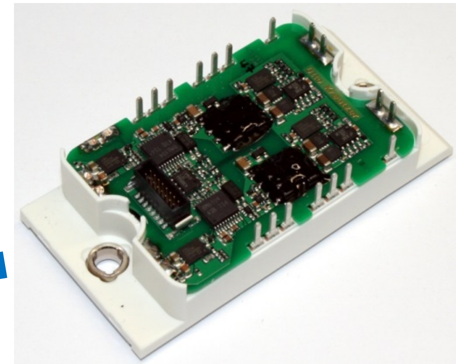


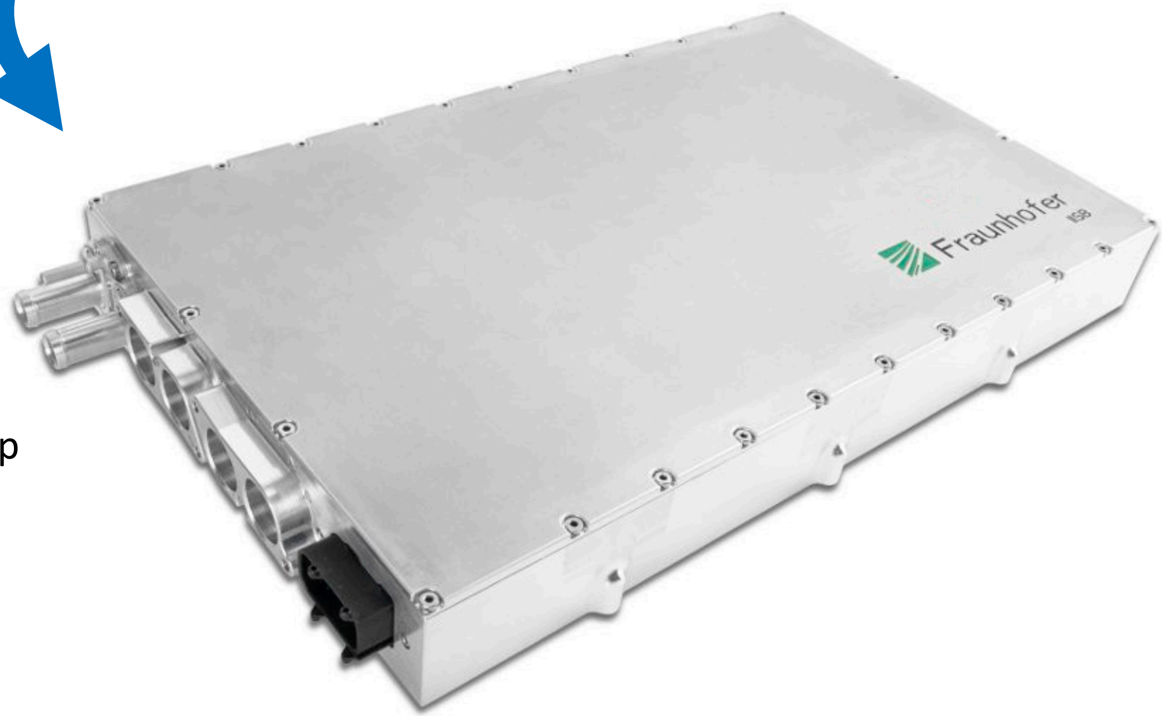
Gain Power Density by WBG

Fraunhofer IISB

- **Full SiC technology** in „industrial style“
- Converters up to **60 kW / dm³**
  - From 30 A to > 800 A
  - 900 V high side
  - 3 to 12 phases
- Serial production devices
  - Chips in module technology
  - Directly attached drivers
  - Ceramic snubbers,
  - Film capacitors
- Full IP6k9k housing
- EMV Filter (CAN, Aux)
- Full Voltage and Current Control Loop
  - CAN communication
  - Temperature depending derating
  - Overload limits
  - Adaptable control loop parameters



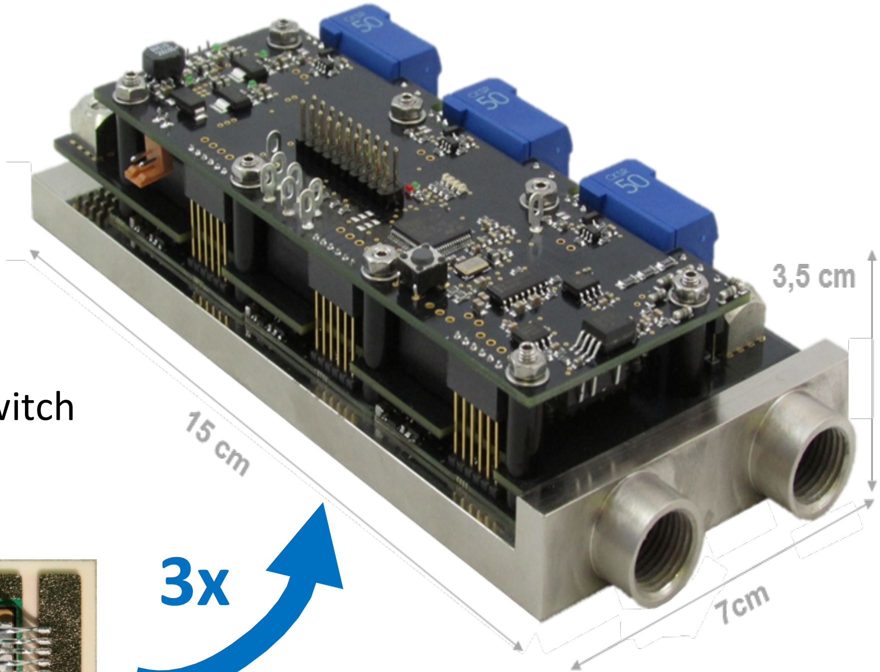


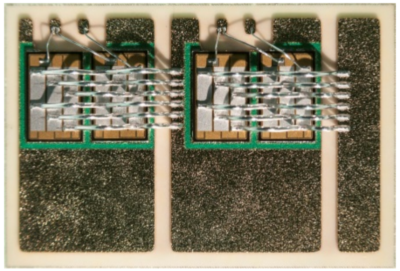


Full SiC Drive Inverter for High Speed Motor Drives

Max. Power	60 kW (at 900 V_{DC})
	30 kW (at 450 V_{DC})
Input Voltage Range	900 V_{DC} to 200 V_{DC}
Switching Frequency	up to 100 kHz
Dimension of Power Stage	~ 150x70x35 mm3
Volume	~ 0,37 l
Topology	3 Phase B6
Technology	2x 1200 V SiC Mosfets Cree Gen2 25mΩ per switch

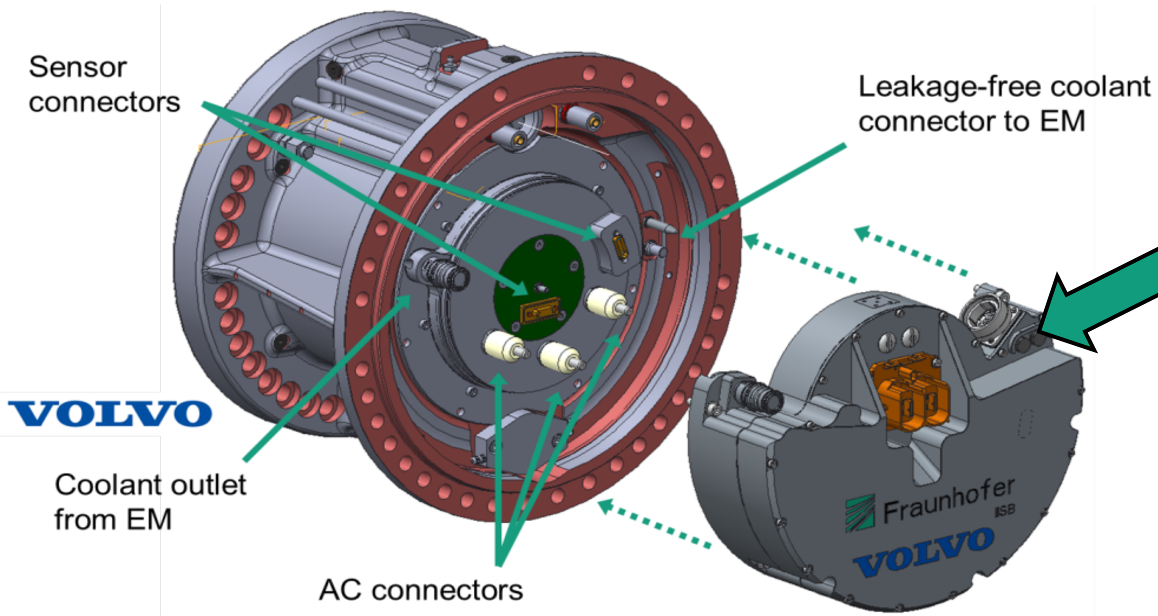
Power Density up to 160 kW/dm³



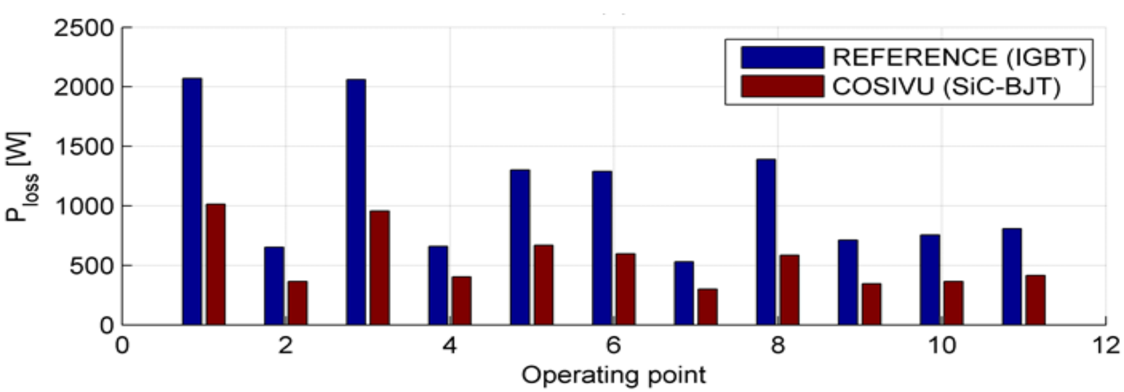


3x

Modular 1200V SiC inverter for commercial vehicles

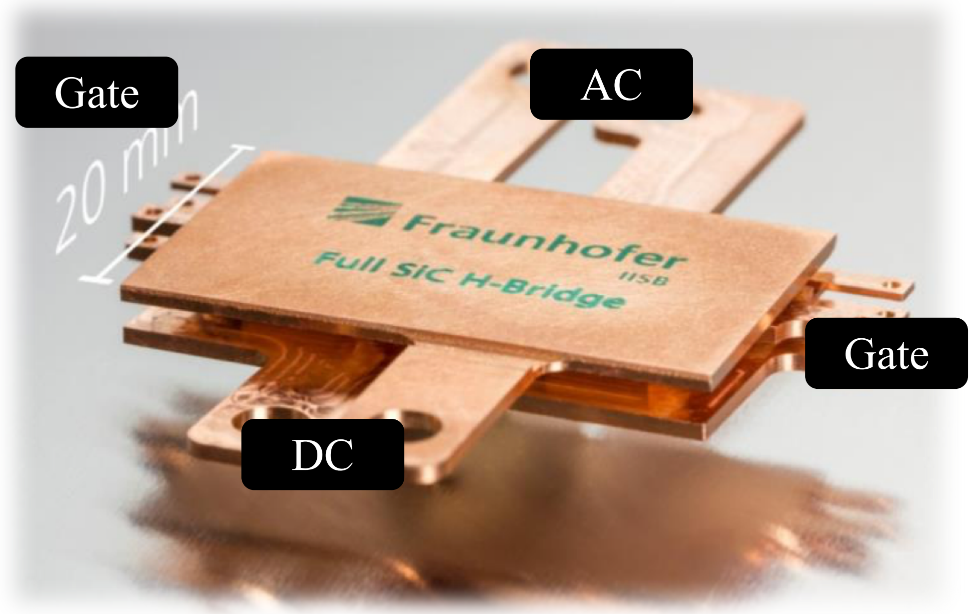


Maximum power rating	290 kVA
Maximum operating voltage	800 V
Continuous phase current	300 A_{RMS}
T_{max} **@ fluid inlet**	60 °C
$T_{j(max)}$	175 °C



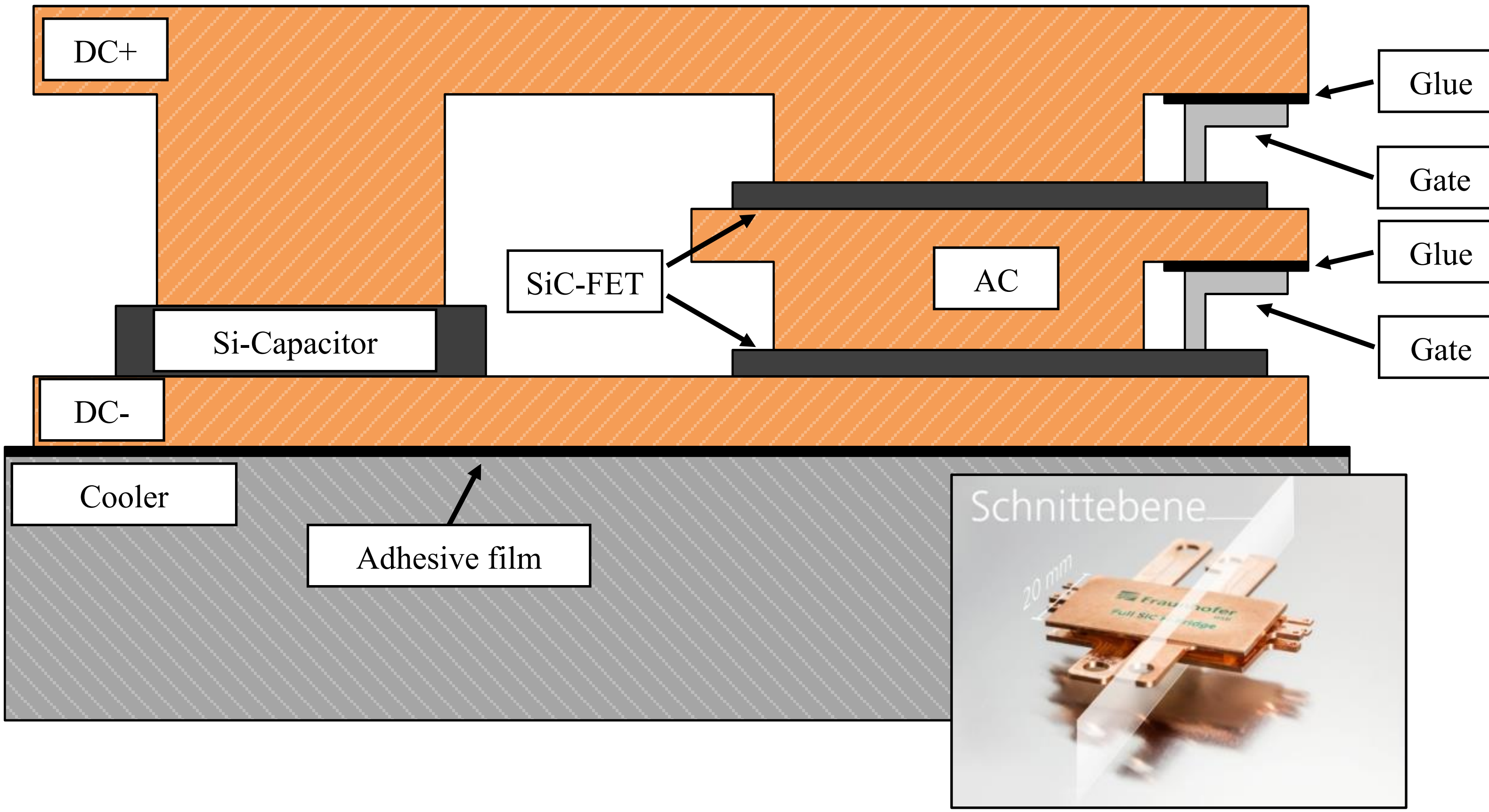
Innovative Modul Design

- Full Bridge - Busbar SiC-Modul
- Technologies
  - Chip on Busbar
  - Double Side Silver Sintering
- Module Data
  - max. 80A / 600V (1200V)
  - SiC-FETs
  - Silicium Puls Capacitors
  - Ultra Low Inductance
- Concept
  - Modular: H-/Half Bridge
  - Double Side Cooling
  - Small Dimensions



Innovative Module Design

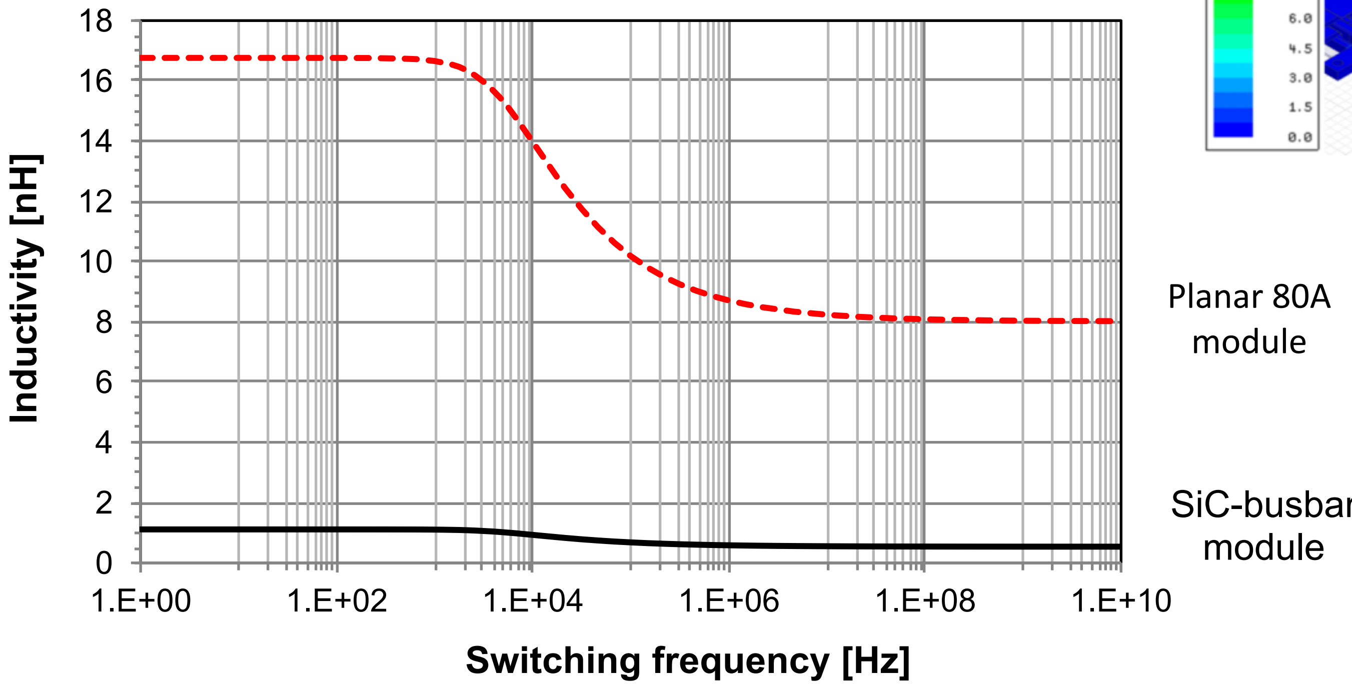
- Full bridge - bus bar SiC-Module

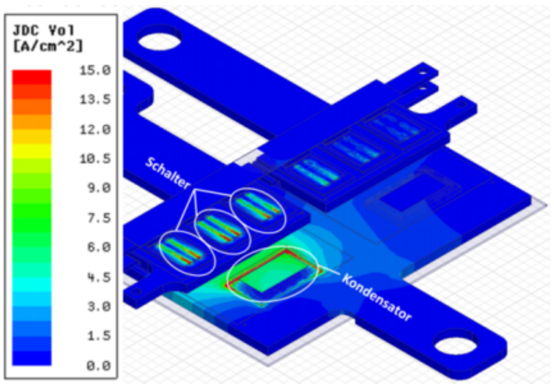


Innovative Modul Design

- Full Bridge - Busbar SiC-Module – Commutation Cell
  - Ultra Low Module Inductance
    - L < 1nH (@>1MHz)

  → Fast Switching and low Voltage Overshoot

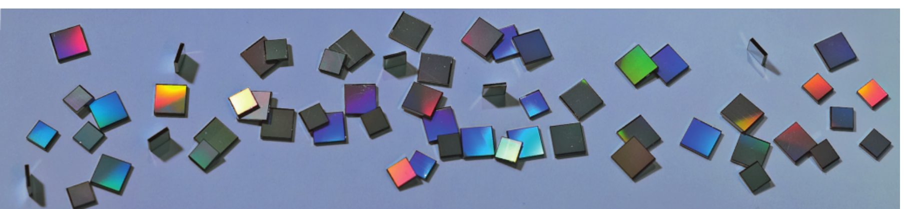


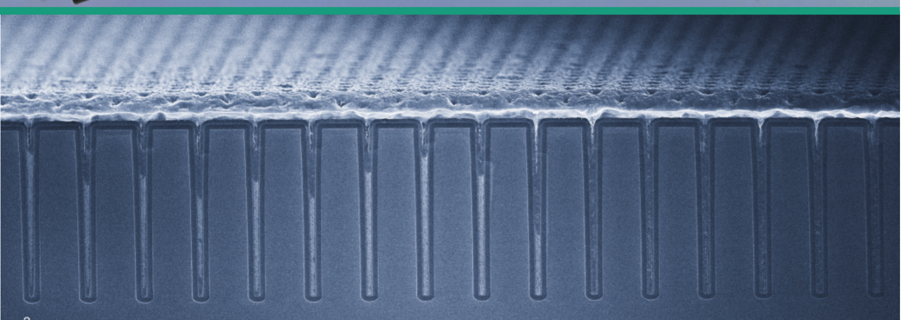


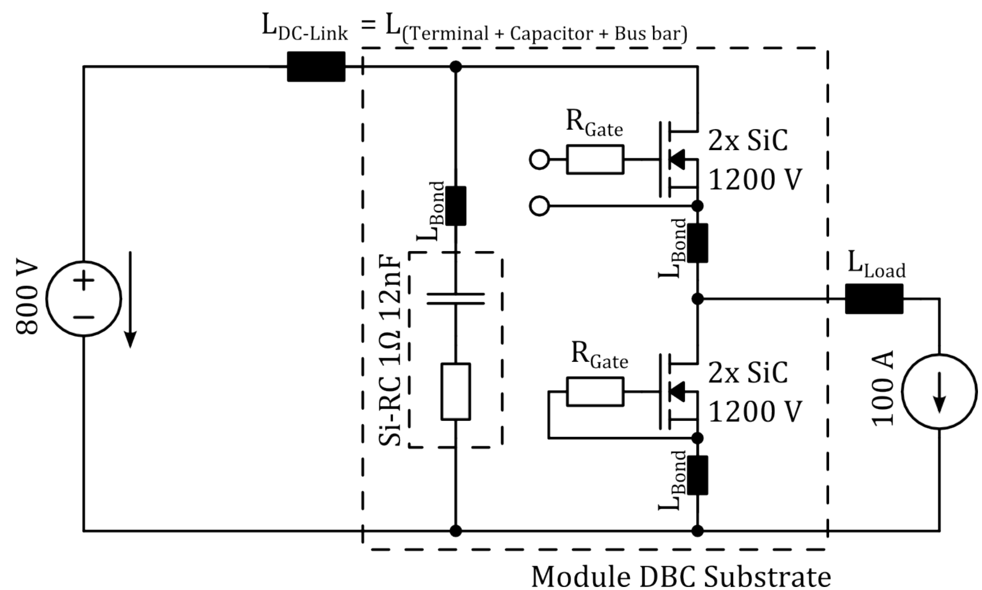
Outlook to faster SiC Modules

Fraunhofer IISB

- Parasitic terminal inductance leads to oscillation and overvoltage on SiC Chips
  - Voltage overshoot by large currents and fast turn-off
  - Voltage overshoot, huge turn on losses and oscillation on **fast turn-on**
- Both problems can be reduced, part wise eliminated, by using an Si-RC element.
  - Snubber element is located directly next to power chips
  - Damping is high enough to eliminate ringing inside and outside of the Module
  - **Key Feature: Si-RC can do very high power** compared to SMD parts or similar devices (about x100 !)



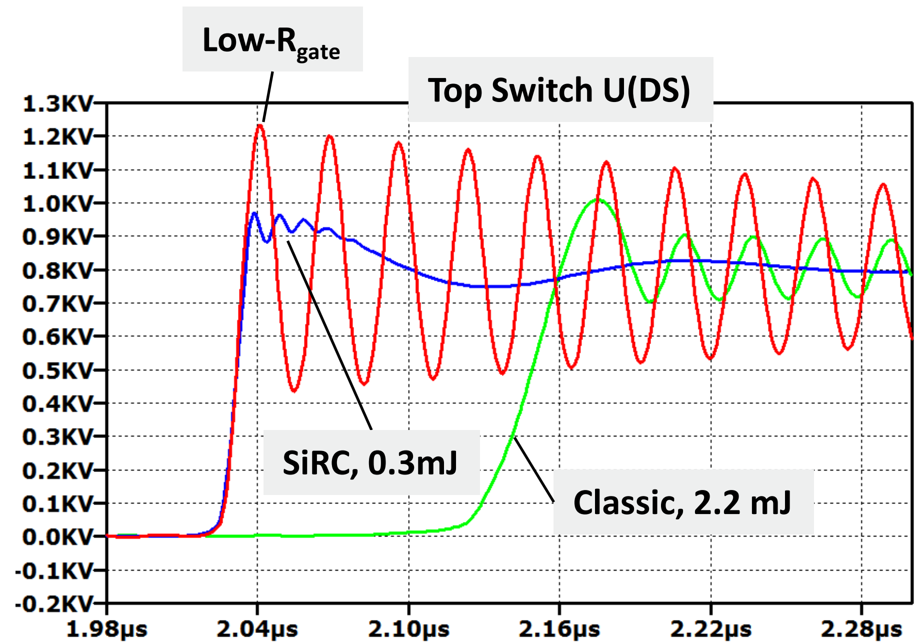




Outlook to faster SiC Modules

Fraunhofer IISB

- Buck Test - High speed turn off
  - High voltage overshoot
  - Massive ringing
- With Si-RC
  - Well limited overshoot
  - Very small Ringing
  - Only a fraction of classic turn-off losses



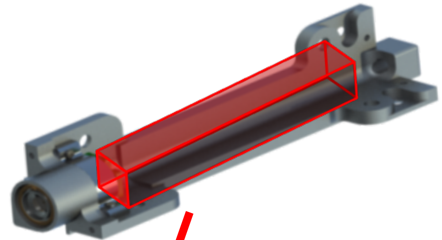
Further Information: Wolfspeed, design_considerations_for_designing_with_cree_sic_modules_part_1_understanding_the_effects_of_parasitic_inductance.pdf

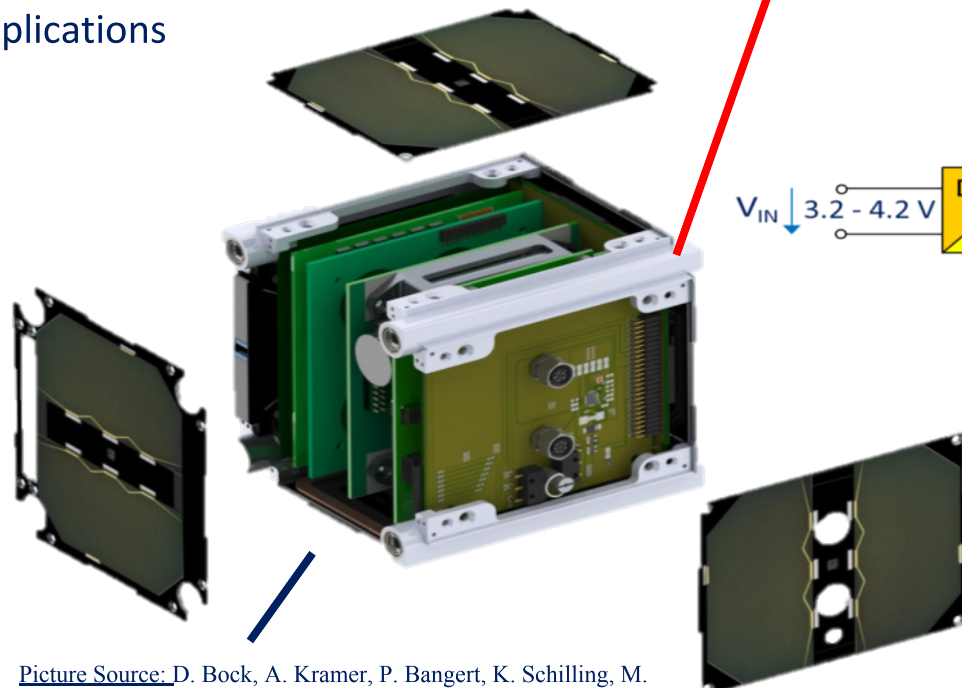
Power electronics for aerospace

Bild:esa

Project Example:

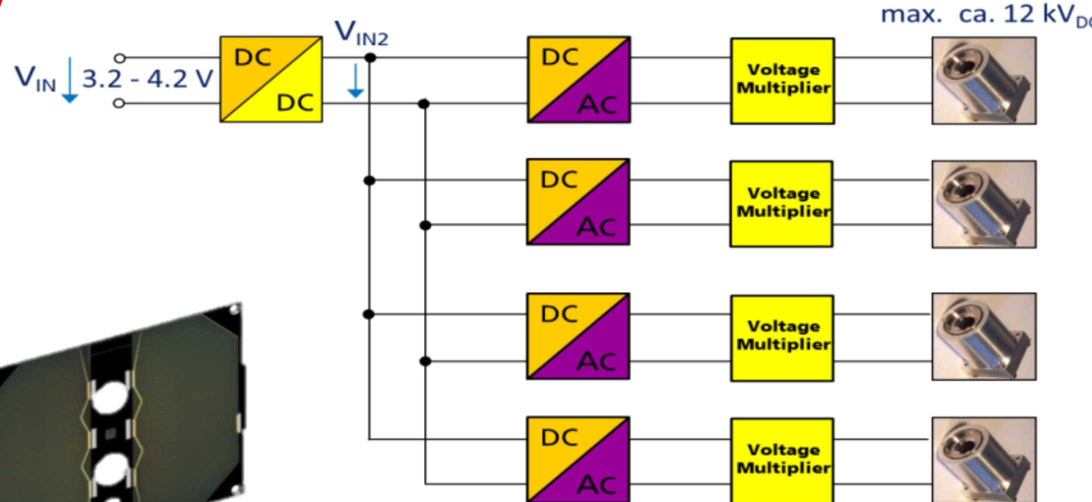
System integrated of 3,3 V to 12 kV DC/DC converters for **FEEP thrusters** in cupesat applications





4 independent system integrated, highly efficient 3,3 V to 12 kV (3W) DC/DC converters

Proposed DC/DC System Concept:



Picture Source: D. Bock, A. Kramer, P. Bangert, K. Schilling, M. Tajmar, *NanoFEEP on UWE platform - Formation Flying of CubeSats using Miniaturized Field Emission Electric Propulsion Thrusters*, Joint Conference 30th ISTS, 34th IEPC, and 6th NSAT, Kobe, Japan, 2015

Picture Source: D. Bock, M. Bethge and M. Tajmar, Institute of Aerospace Engineering, Technische Universität Dresden, *HIGHLY MINIATURIZED FEEP THRUSTERS FOR CUBESAT APPLICATIONS*

All / Full Electric Aircraft

Target:

- energy savings of 25 to 50%
- NOx reduction 80%, noise 50%
- 80 passenger
- driving power 1 to 20 MW

Google little box

Target:

- 2kW inverter for photovoltaics
- 900V SiC switches
- 100kHz clock frequency
- Efficiency < 96%
- Power density 200 W/in^3

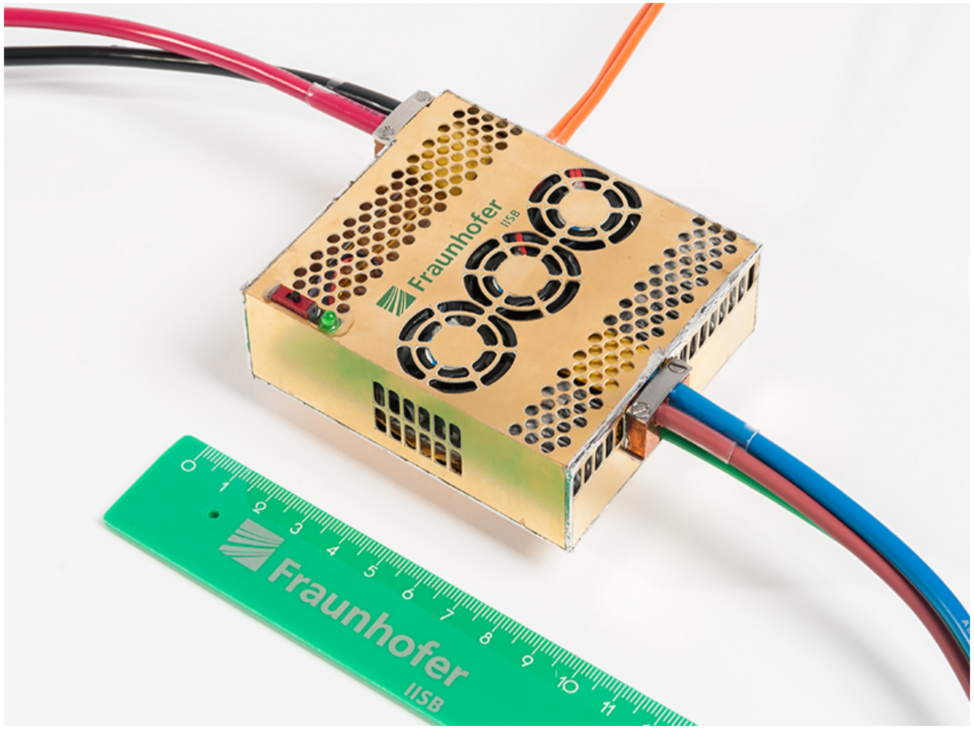


Bild:NASA

Outlook

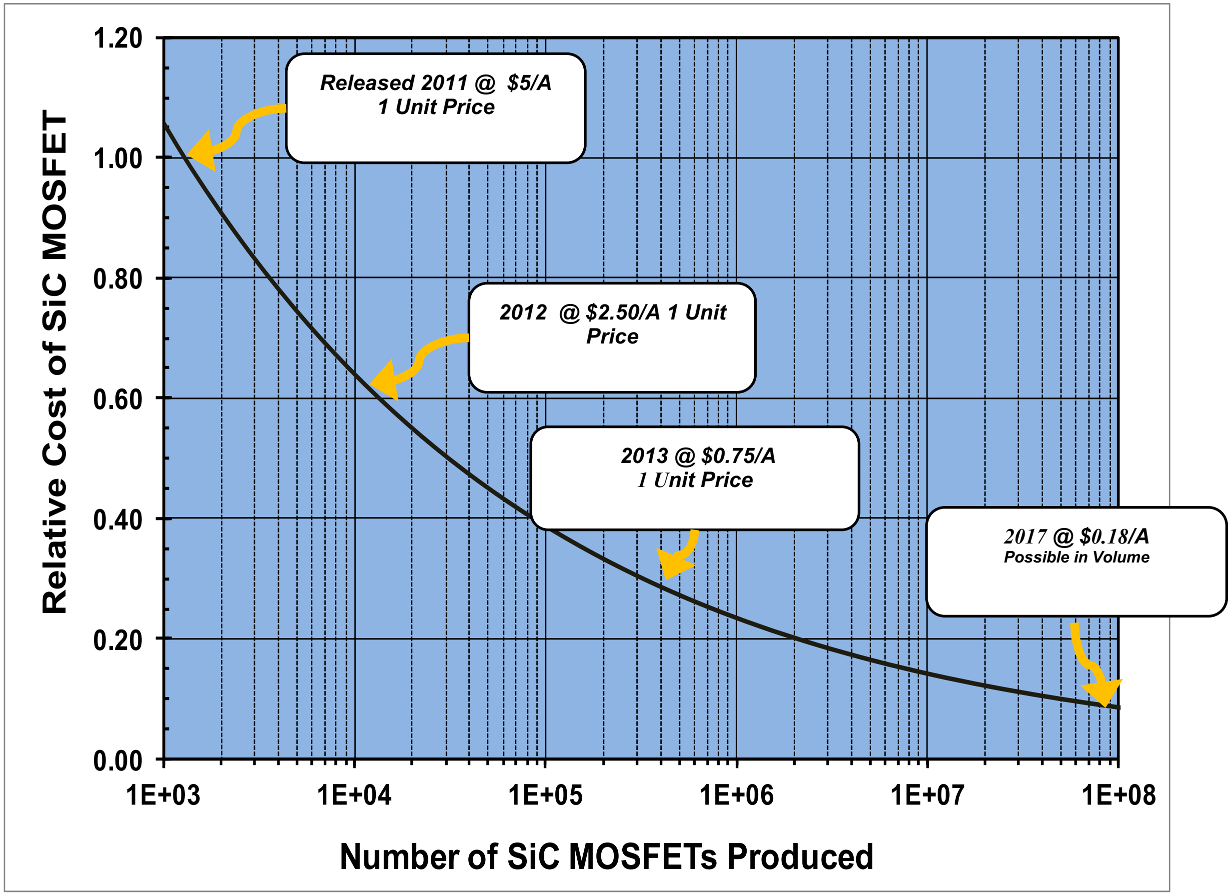
3.3kV	traction
4.5kV	traction, wind power
6.5kV	traction, grid, e-aircraft
6.5kV bipolar	grid
10…20kV BiFET/IGBT	grid
> 20kV	grid

- Compensation devices (6.5…20kV)

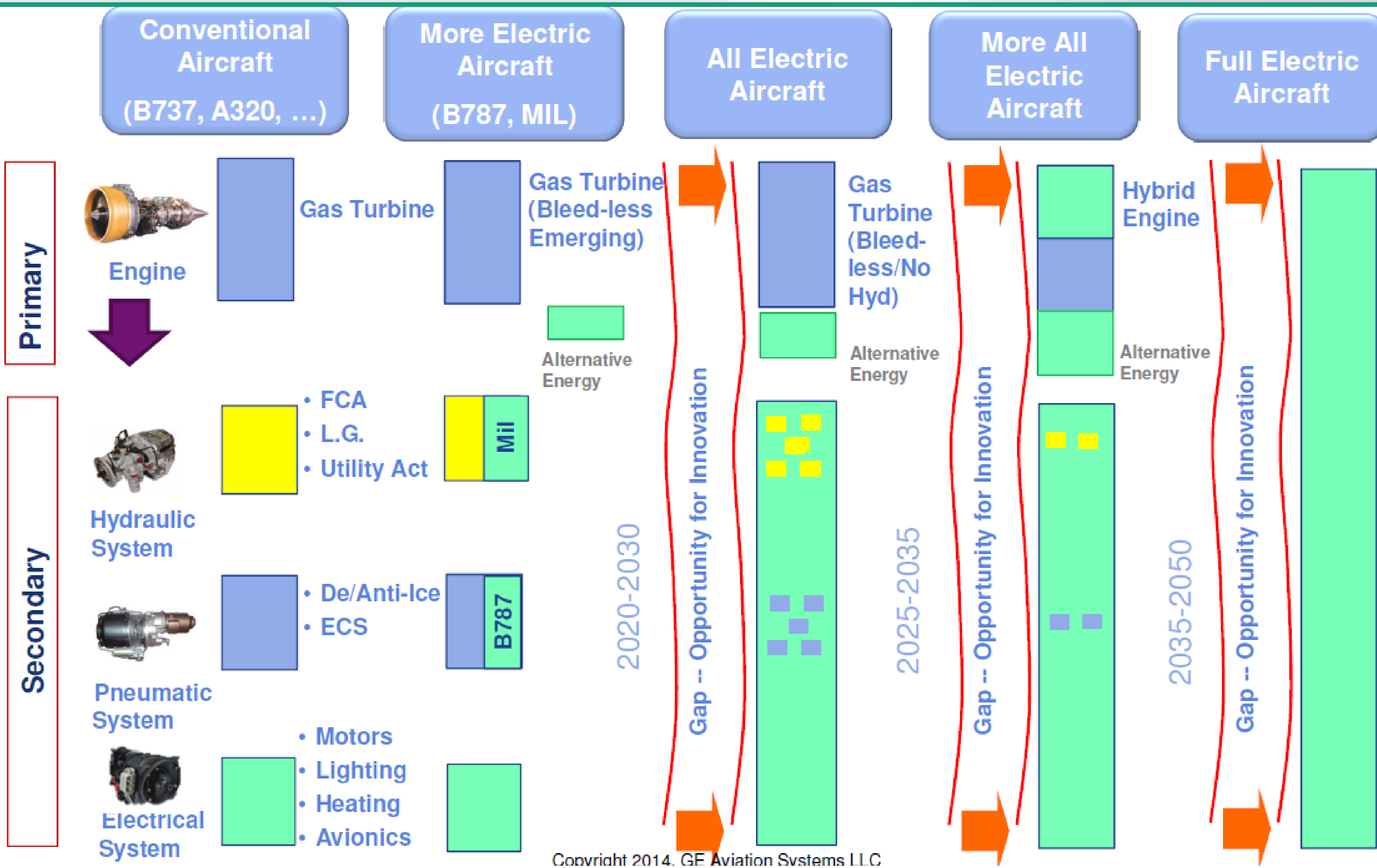
- Wafer thinning
- Backside processing
- 200mm

Questions and Discussion

Technical Trends in SiC



Source: © Cree / nist.gov


Conventional Aircraft
(B737, A320, …)
More Electric Aircraft
(B787, MIL)
All Electric Aircraft
More All Electric Aircraft
Full Electric Aircraft
Primary
Secondary
Engine
Gas Turbine
Gas Turbine (Bleed-less Emerging)
Alternative Energy
Gas Turbine (Bleed-less/No Hyd)
Alternative Energy
Hybrid Engine
Alternative Energy
Hydraulic System
• FCA
• L.G.
• Utility Act
Mil
Pneumatic System
• De/Anti-Ice
• ECS
B787
Electrical System
• Motors
• Lighting
• Heating
• Avionics
2020-2030
Gap -- Opportunity for Innovation
2025-2035
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