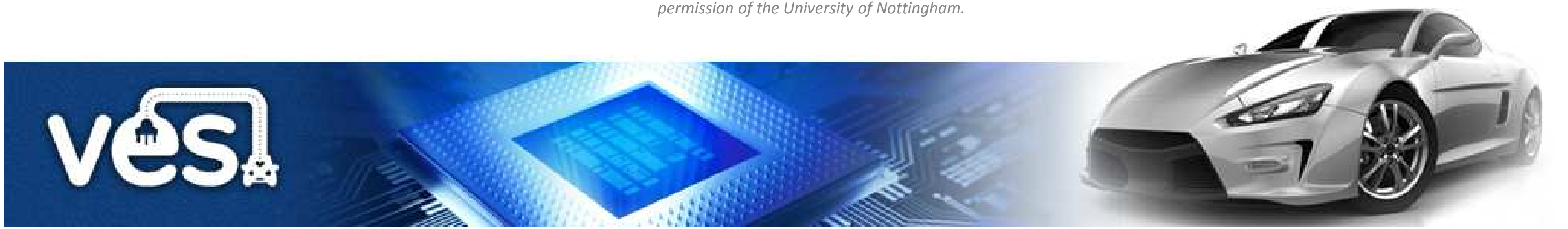
Theme 3: Packaging and Integration 7-4-2014

Lee Empringham, Mark Johnson,
Rasha Saeed, Jordi Espina



Scope of Theme

- Power Module integration / packaging
- The use of basic (low-level) components, such as dies, substrates etc.
- Co-design of electromagnetic, mechanical and thermal properties
- Modular design for scalable power
- Implementation of promising technologies such as: SiC, Ag nano flakes sintering, Jet impingement / turbulator cooling
- Embedded filters and integrated gate drive

Main Team Members

- Prof Mark Johnson
- Dr Lee Empringham
- Ms Rasha Saeed
- Dr Jordi Espina (Demonstrators)

Power Module Aims

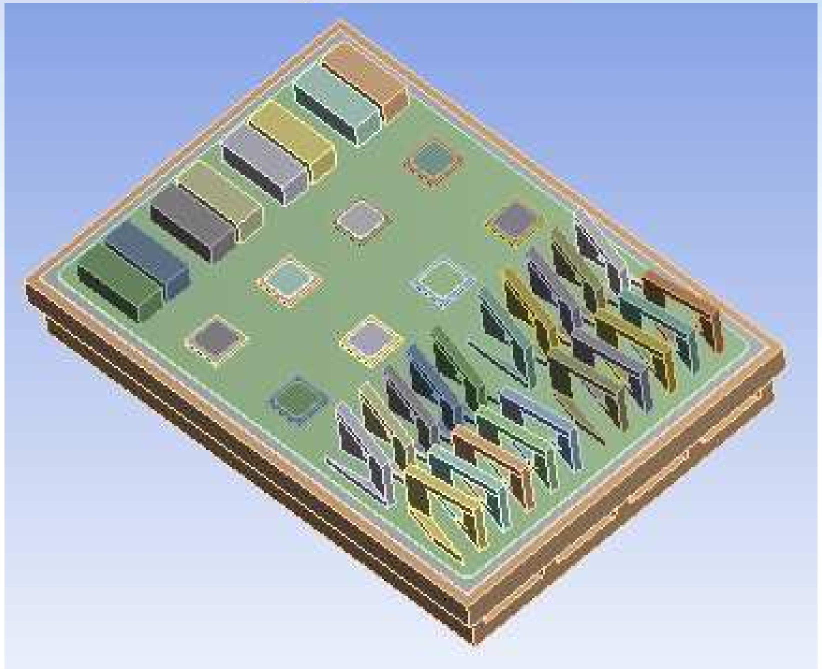
- Increased Power density
- Without compromising on efficiency
- Use of SiC devices – pros and cons
- Reduce EMI
- Integrated filtering
- Integrated control

- Power Electronic Building Block?? (PEBB)

VESI Power Module Vision

- Multi cellular approach to high power
  - Multiple smaller switching cells
  - Reduced commutation loops
  - System performance (overshoot / EMI) ensured by physical design
- Integrated output Inductances
  - Reduced EMI
  - High Frequency interleaved operation
- Integrated Cooling

Power module concept



- Multiple commutation cells per module
  - Input Capacitance, active devices, output inductance
  - Parallel output connection
    - Modular choice of power ratings using standard building block
    - Interleaved operation

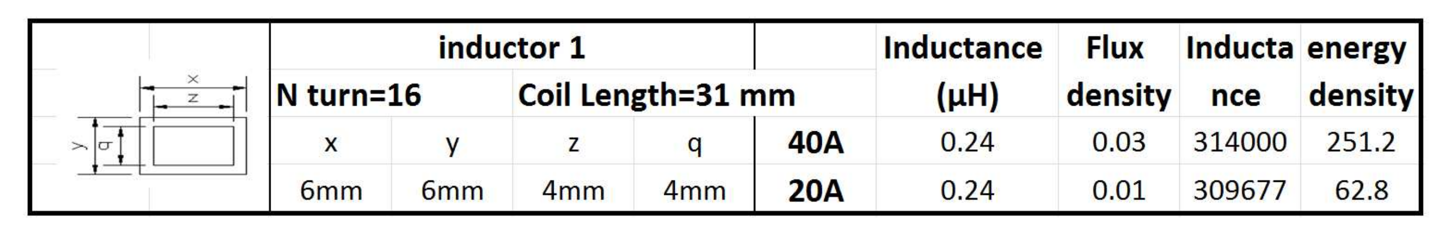
Recent Activities

- Circuit simulations – EMI / switching behaviour comparison of VESI modular topology with traditional power module
- Integrated inductance optimisation matrix
- Validation of inductance calculations using Ansys
- Inductor Manufacturing tests
- Tri-metal device coating tests

Inductance Optimisation Spreadsheet

- Excel spreadsheet used to determine the different parameters of the integrated inductances
- Aim is to be able to perform a trade-off and quickly determine the limiting factors when trying to maximise
  - – Inductance
  - – Energy density
  - – Efficiency

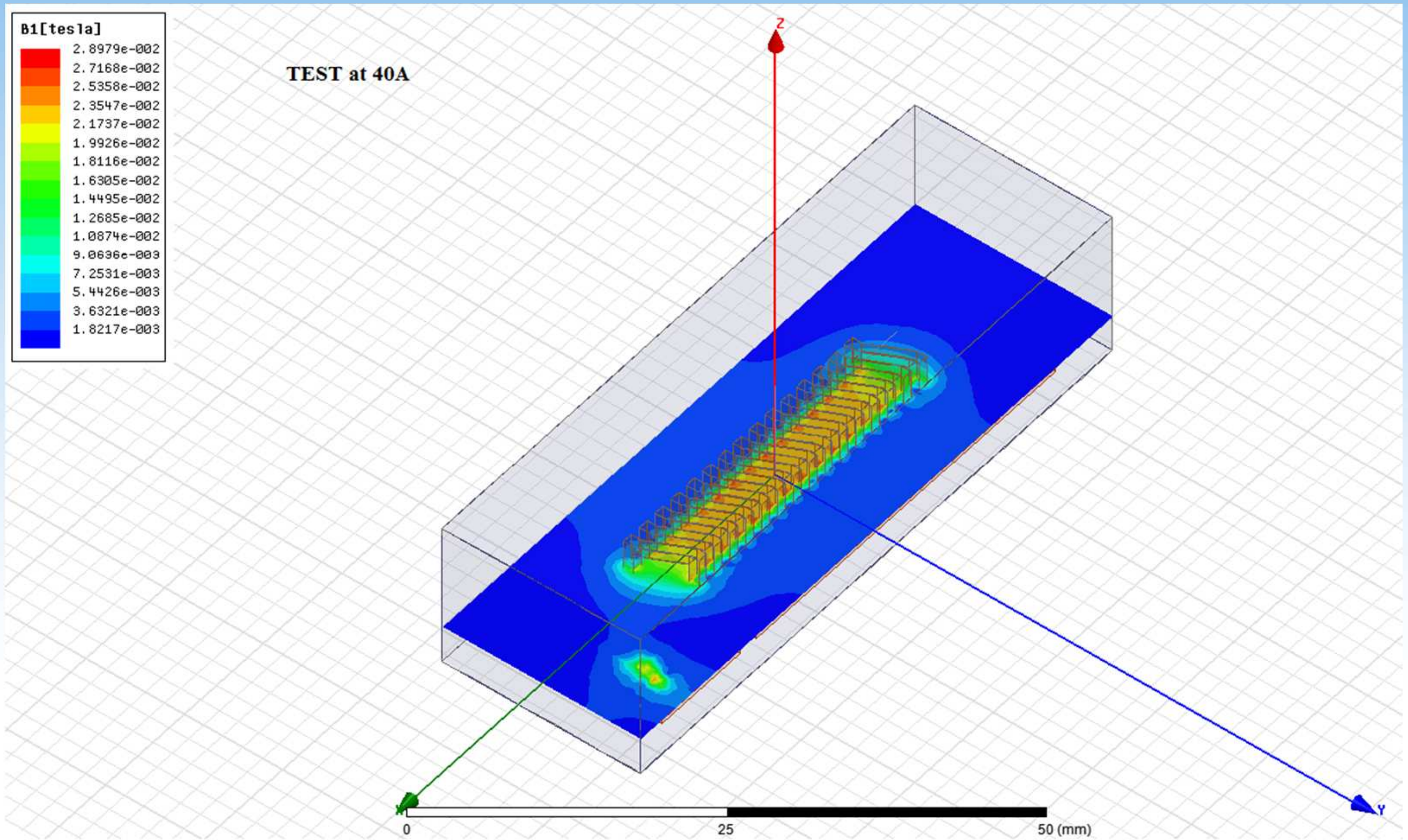
Inductance Optimisation Spreadsheet



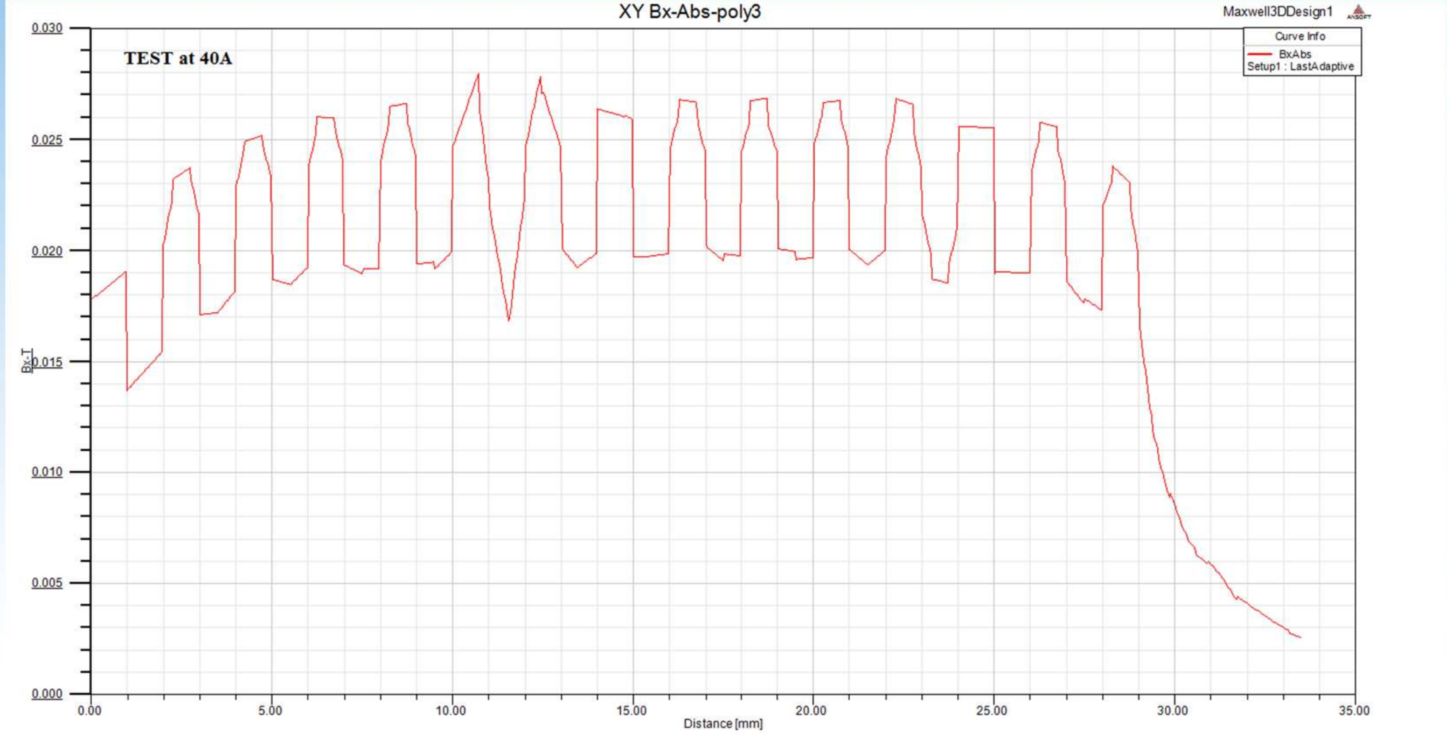
	inductor 1					Inductance (µH)	Flux density	Inductance	energy density
	N turn=16		Coil Length=31 mm						
	x	y	z	q	40A	0.24	0.03	314000	251.2
	6mm	6mm	4mm	4mm	20A	0.24	0.01	309677	62.8

- Different inductor geometries addressed
- Linear approximations used
- Both air cored and cored inductances (metglas, ferrite)

Ansys B – Field results (Air cored @ 40A)

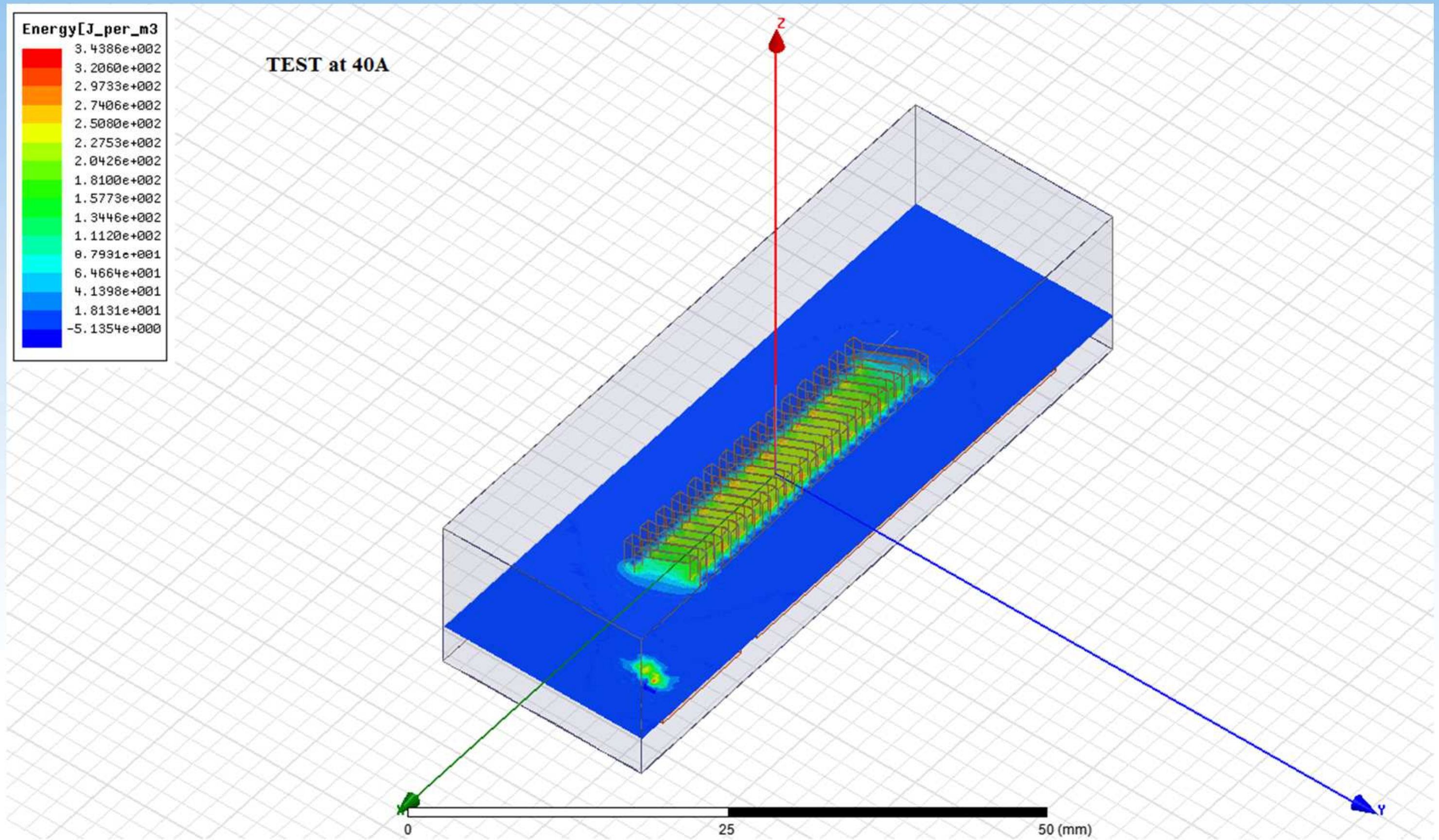


B – Field (x slice) results (Air cored @ 40A)

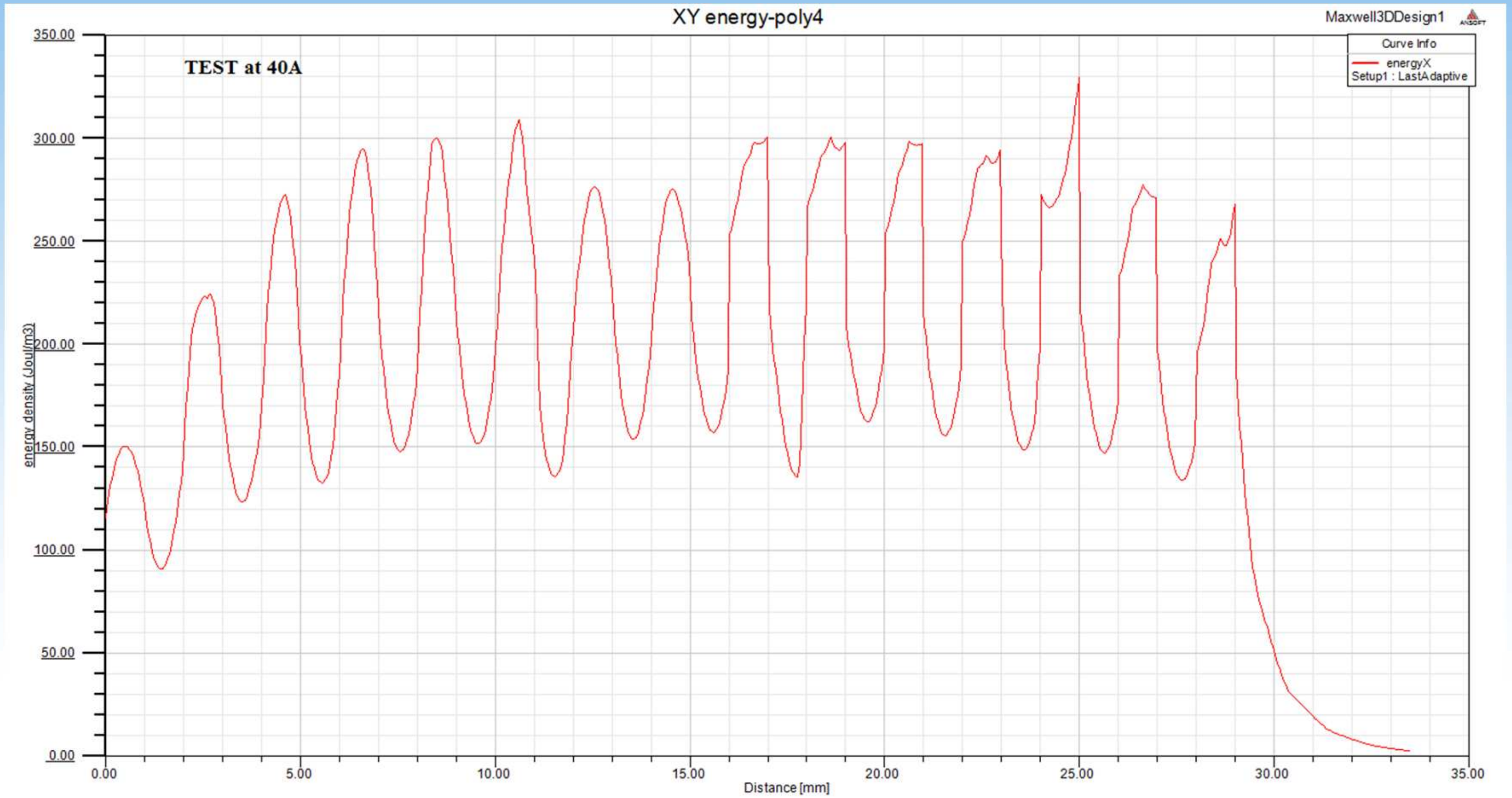


- Spreadsheet average value prediction – 0.03

Energy Density results (Air cored @ 40A)



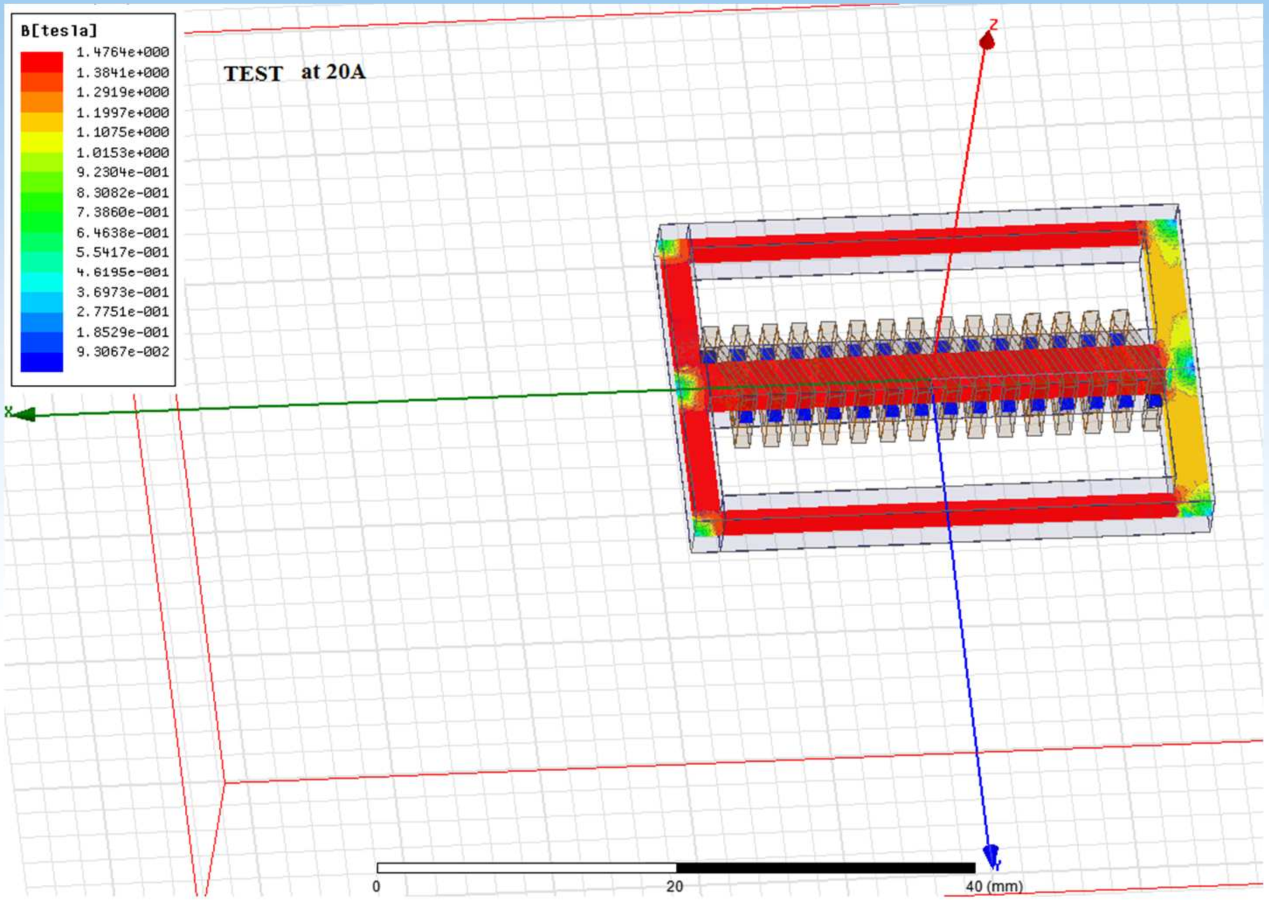
B – Field (x slice) results (Air cored @ 40A)



- Spreadsheet average value prediction – 251 J/m^3

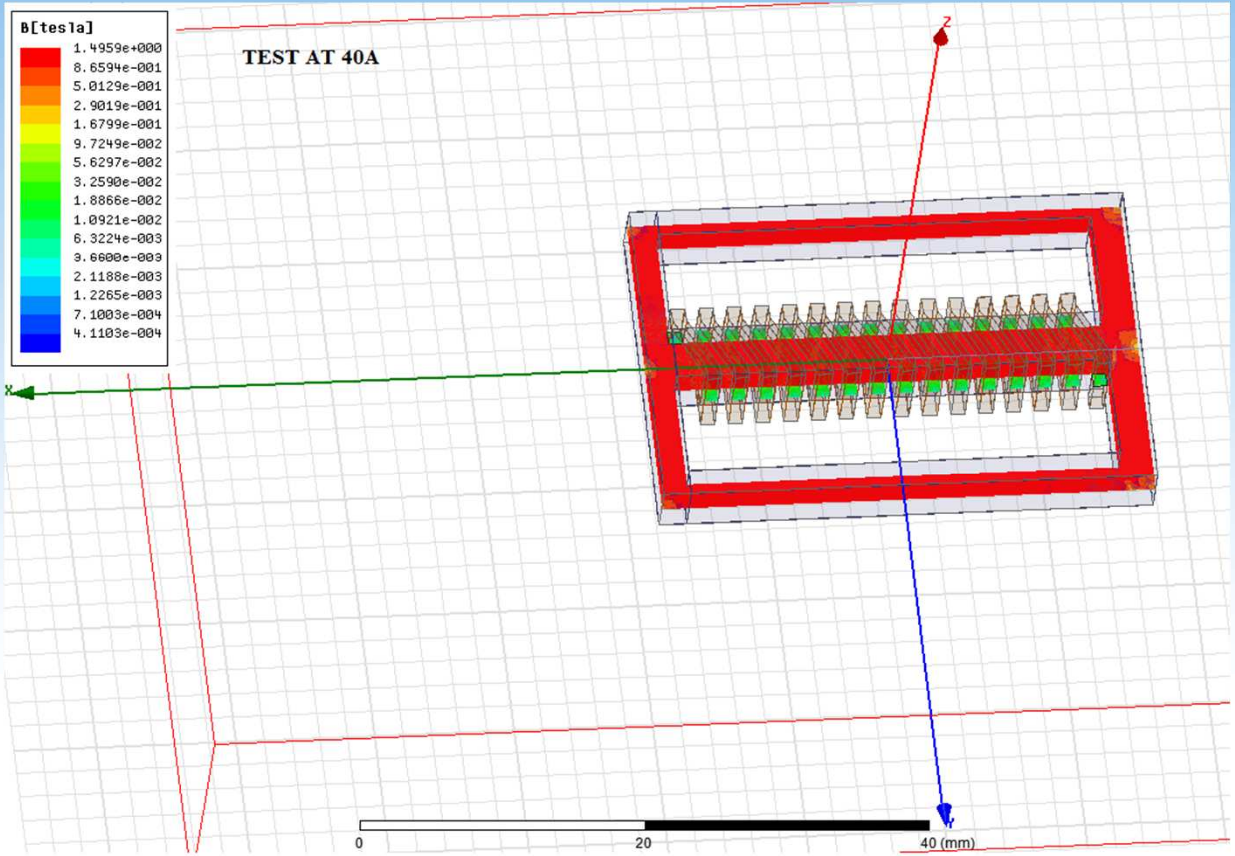
Initial results using Metglas 2605S3A HFA core (20A)

- Test at 20A significant saturation (B-Max = 1.41T)



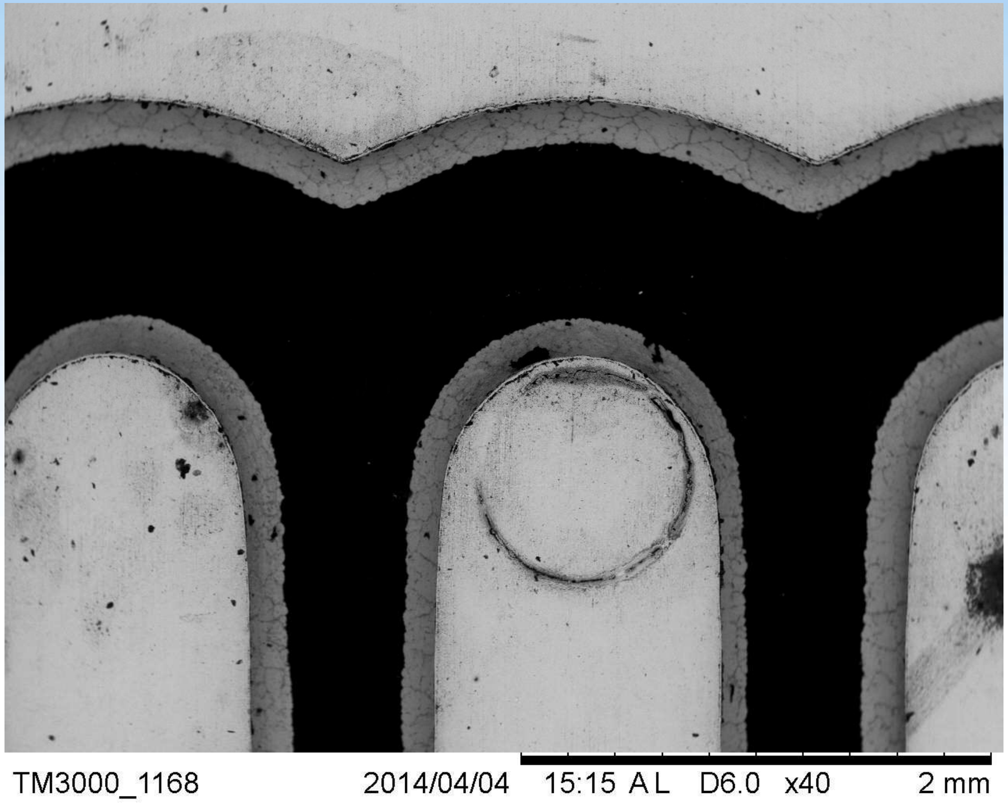
Initial results - Metglas 2605S3A HFA core

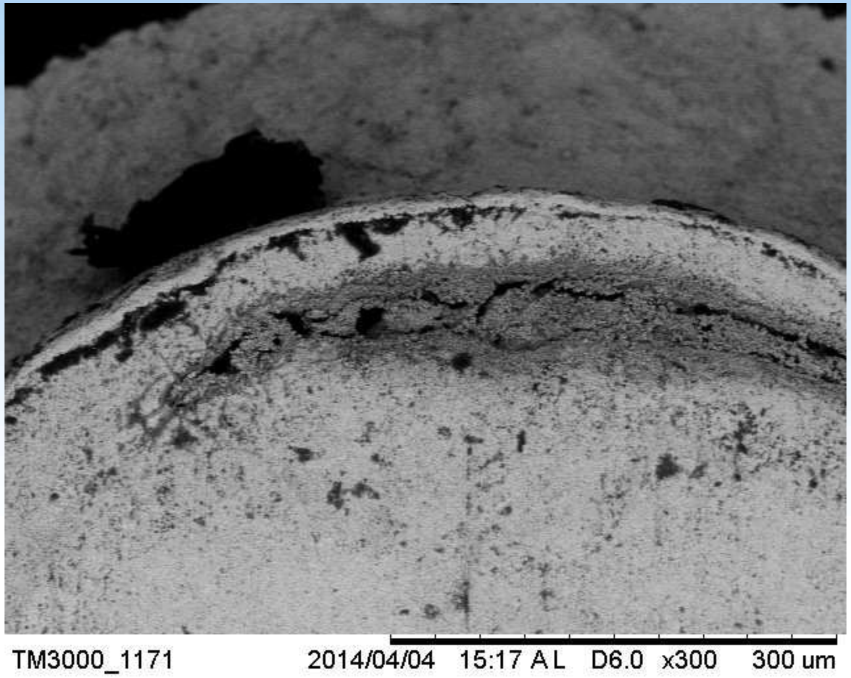
- Test at 40A shows complete saturation



Inductor Manufacturability tests

- PCB type approach tested – 1mm solid pins, 0.3mm surface thickness.





Significant voids observed

Next steps

- Continue to investigate SiC devices using solderable drain connections
- Continue to explore inductor trade off when core is used
  - Efficiency – Inductance – Volume
- Continue manufacturing investigations
  - Inductors
  - Tri-metal coating of SiC devices