SWTEST

PROBE TODAY, FOR TOMORROW

2022 CONFERENCE

# Challenges of Magnetic Field Probe Cards

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June 5 - 8, 2022

# Presentation Overview

- **Background for magnetic field probe card presentations at SW Test**
- **Probe card requirements**
- **Wafer prober chuck simulation**
- **Simulation of magnetic fields**
- **Challenges to overcome**
- **Summary of production results**
- **Questions?**
- **Answers!!!**

# Magnetic Field Probe Cards

- **Multi-site probing of magnetic sensors at 175 deg C – Melexis/JEM**
  - Presented SW Test 2016
  - http://www.swtest.org/swtw_library/2016proc/PDF/S07_01_Gouwy_SWTW2016.pdf

- **Sensors at Test – "Magnetic" Probe Cards – T.I.P.S. Messtechnik GmbH/TI**
  - Presented SW Test 2017
    https://www.swtest.org/swtw_library/2017proc/PDF/T01_01_Gaggl_SWTW2017.pdf

- **3D Magnetic sensor simulation - T.I.P.S. Messtechnik GmbH**
  - Presented at SW Test 2021
  - https://www.swtest.org/swtw_library/2021proc/pdf/od_02_franz_swtest_2021.pdf

- **Simple explanation of magnetic field**
  - **https://www.youtube.com/watch?v=bq6IhapfucE**

# Probe Card Requirements

- Design probe card for single Z-axis hall effect magnetic field sensor
- Product will be a small die with PDPW greater than 25K
- Parallelism 64 DUT's
- Advantest 93K test system which is standard production tester/prober setup
- Magnetic field target: 200 Gauss ±7 Gauss
- Out-of-Plane, Hz
- Maximum distance of all hardware from bottom of PCB <=20mm
- Single Coil ("LARGE")
- Test Temperature: Room Temperature

# Chuck Simulation Plan

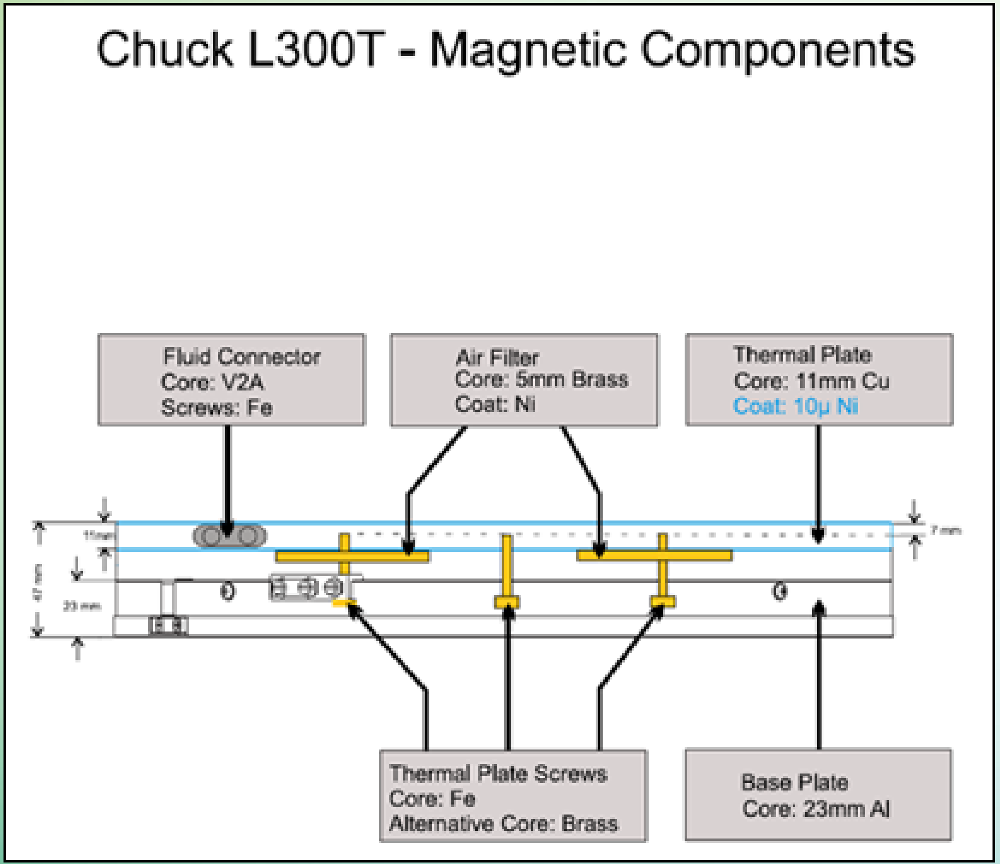
1. Hz on chuck surface ≥ requirement spec?
   - Use simulation to determine coil size and appropriate chuck to coil distance

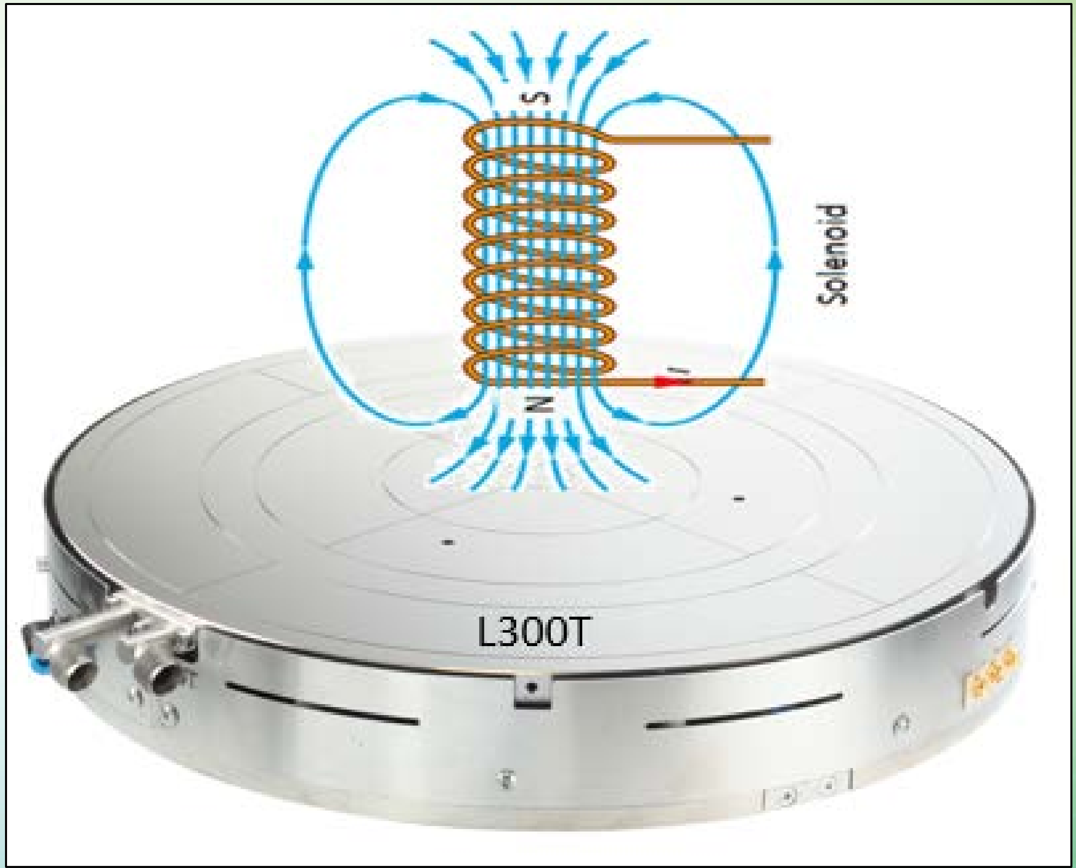
2. Hz already inaccurate due to background fields?
   - Chucks alone were measured at vendor
   - Chucks in prober were measured in NXP: For both “standard chuck” and “non-magnetic” chuck at 30°C

3. Magnetization of chuck components by strong Hz field?
   - Vendor provided a drawing/sketch about the “standard-chuck” top layers
   - Simulate (top layers, w.r.t. DUT area, with magnetic properties), monitoring various components
   - All chuck components were found to be exposed to Hz fields << their corrective field strength

4. Hz sufficiently homogeneous over DUT area?
   - Initial thought: Field lines distorted into x- and y-direction when penetrating the chuck (might be even worse with TiN coating of non-magnetic chuck, which is intended for parallel field lines)
   - Use simulation for standard chuck and components: Hz variation within DUT area of ±2.3%
   - Experiment: Over chuck and driven with current; measure Hz vs. DUT area.

# Chuck Illustration

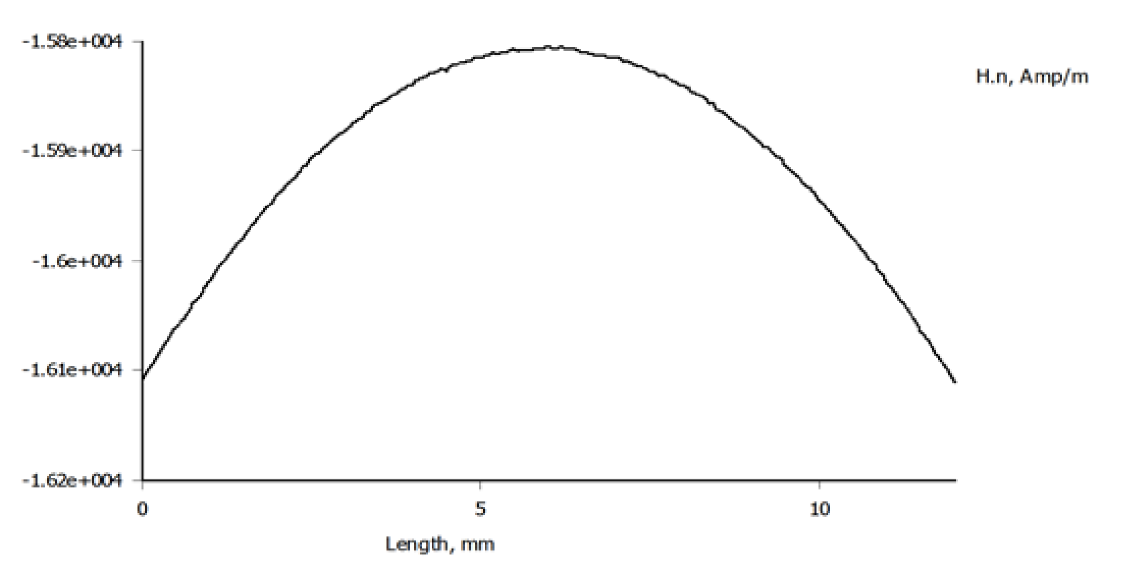


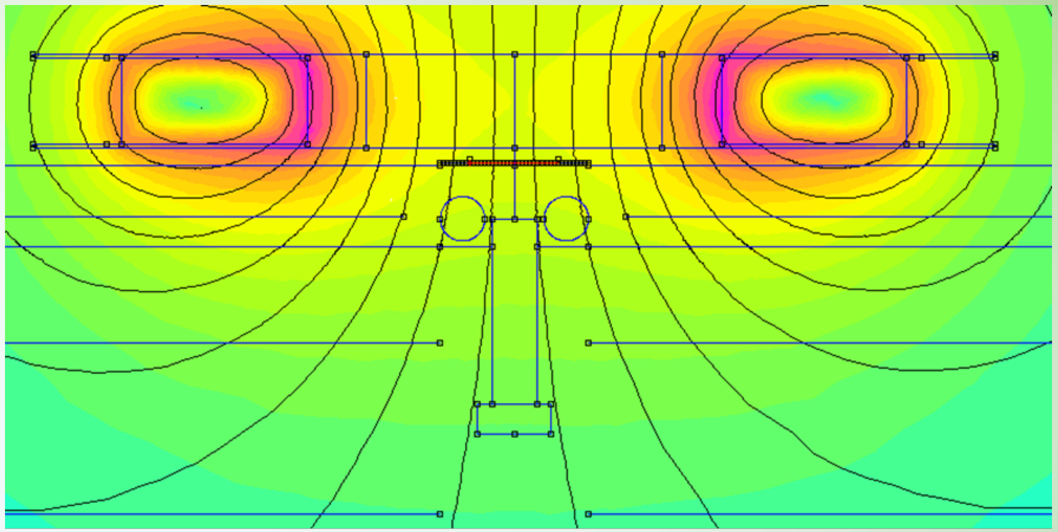



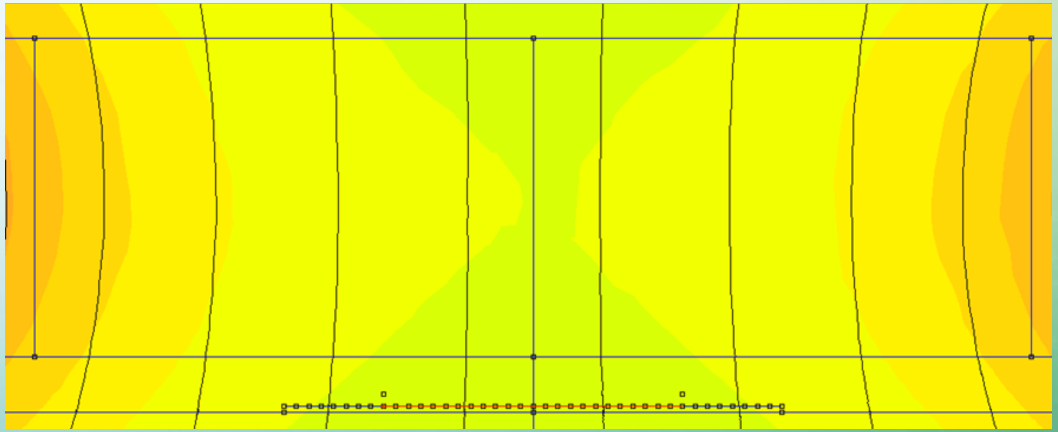
# L300T Chuck Simulation 1

**No Ferromagnetic Parts or Coatings**

- 2D simulation in cross-cut view
- Readings for showing basic effects only!
- Red dotted line indicates DUT area
- Hdut = 15948.2 A/m (200.4 G) ± 0.9%



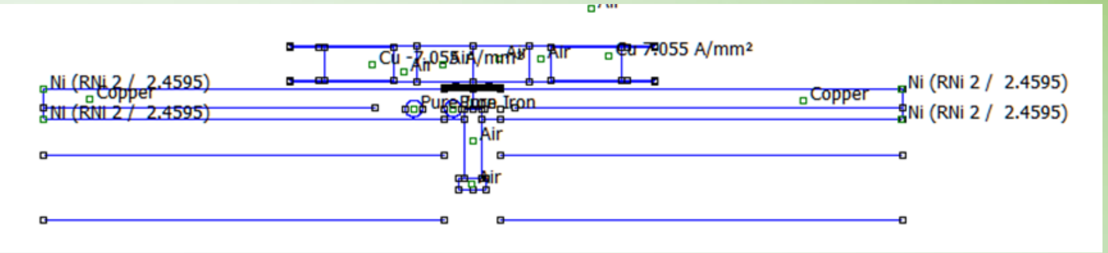



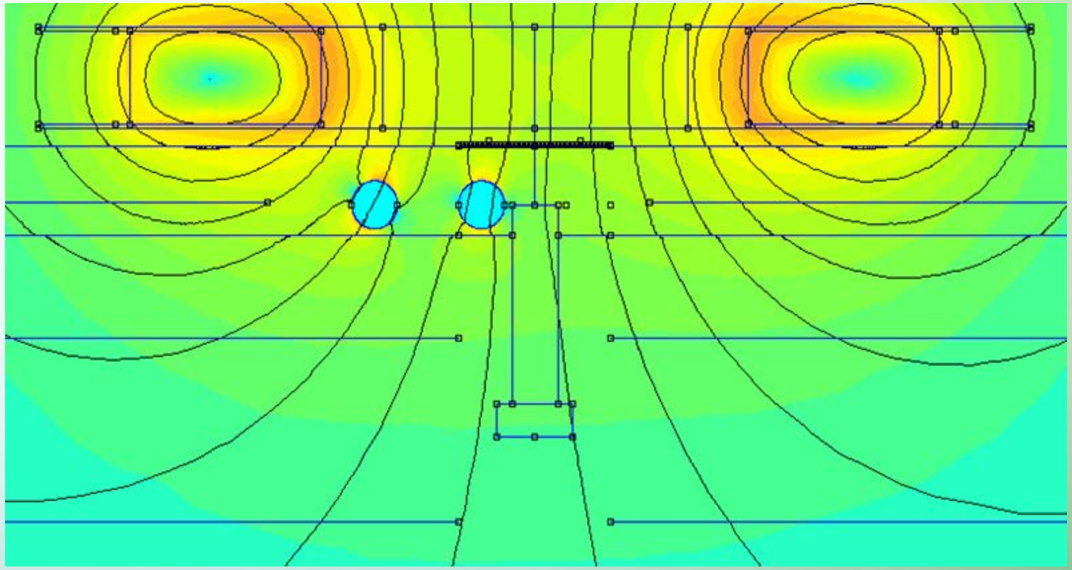


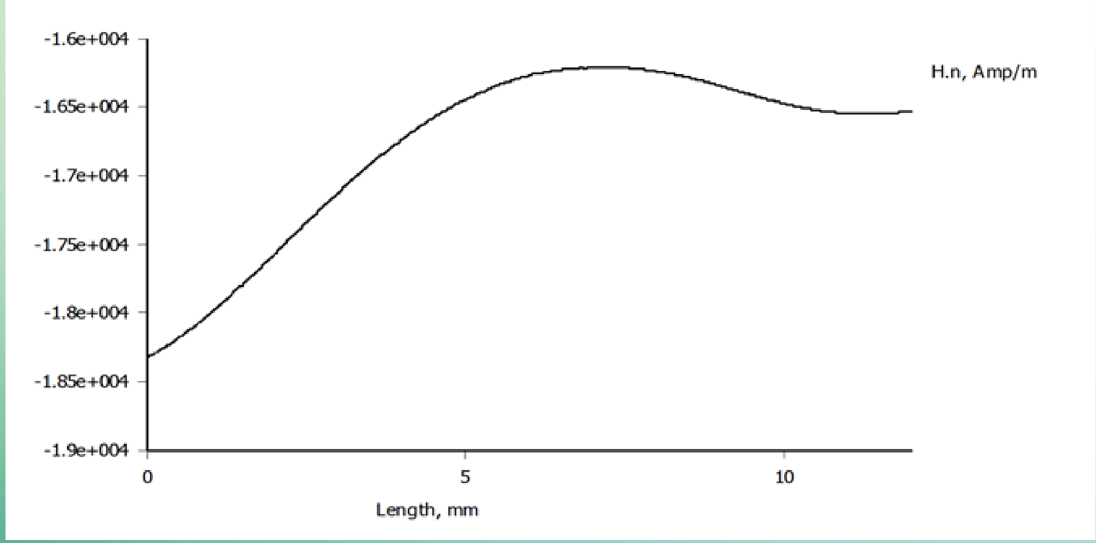
# L300T Chuck Simulation 6

**Shifted Ferromagnetic Screws at Fluid Connector**
**With Top & Bottom Ni Coating**

- 2D simulation in cross-cut view
- Readings for showing basic effects only!
- Hdut = 18337-16264 A/m
  „linear“ (217.4 G) ± 6.0%



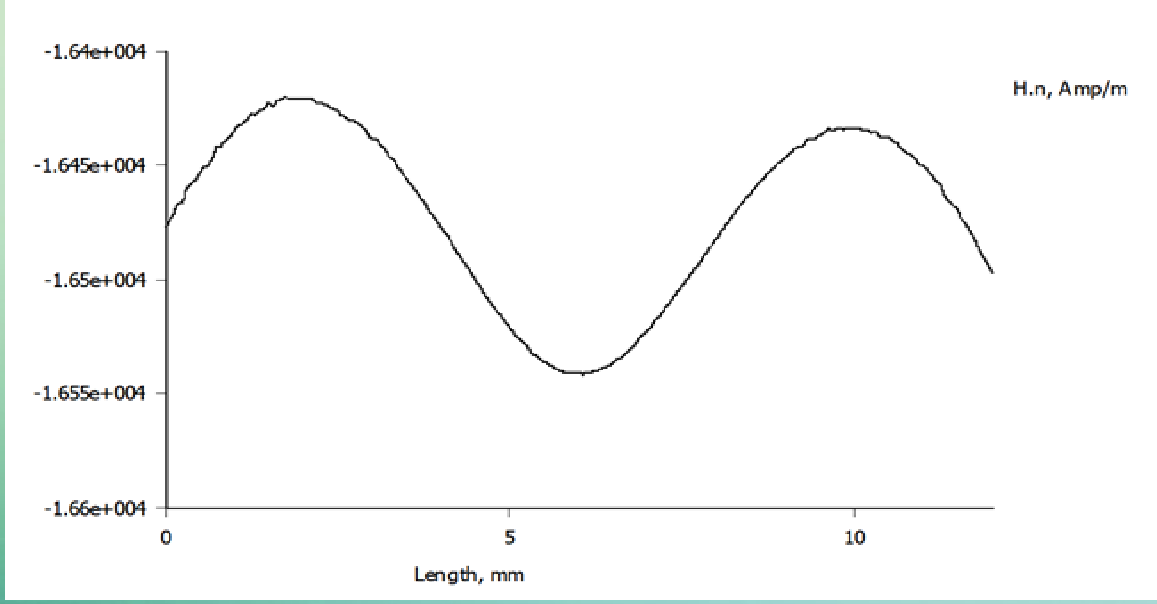



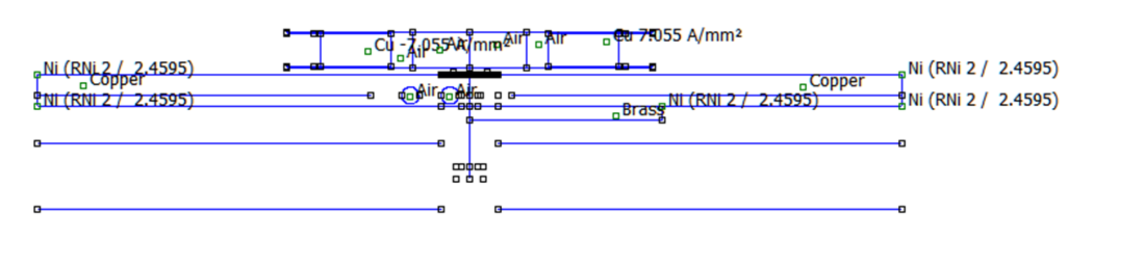


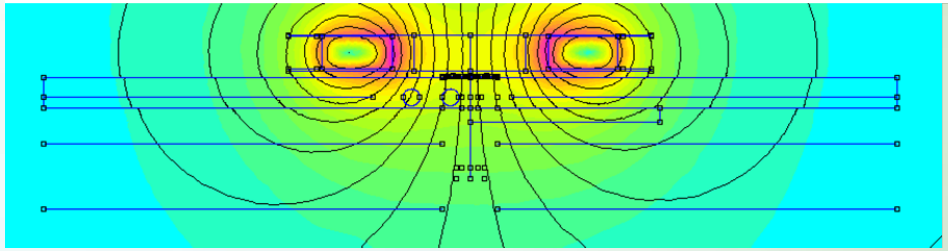
# L300T Chuck Simulation 7

**5µ Ni Coated Brass and Top & Bottom Coating**

- 2D simulation in cross-cut view
- Readings for showing basic effects only!
- Hdut = 16480 A/m (207.1 G) ± 0.37%



# L300T Chuck Simulation Summary

- Nickel coat on thermal plate does not hamper
- Nickel coated brass has minor impact
- Thermal plate screws have high impact on homogeneity
  - Recommendation: to be replaced by non ferro magnetic parts to reduce variation from ±2.3% down to < 0.5%
- No magnetizing with remanence observed in simulations, all magnetization of the standard chuck screws is below coercivity force
- Air, Brass, Aluminum, V2A Steel, copper taken as magnetic inert, $\mu r=1$
- Calc: Hdut= (Hmax+Hmin)/2; Range: (Hmax-Hmin)/2/Hdut

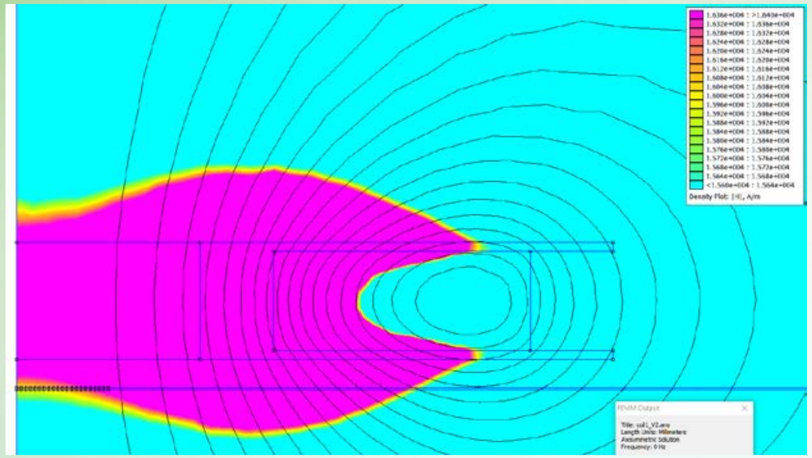
# Coil Design – 1st attempt

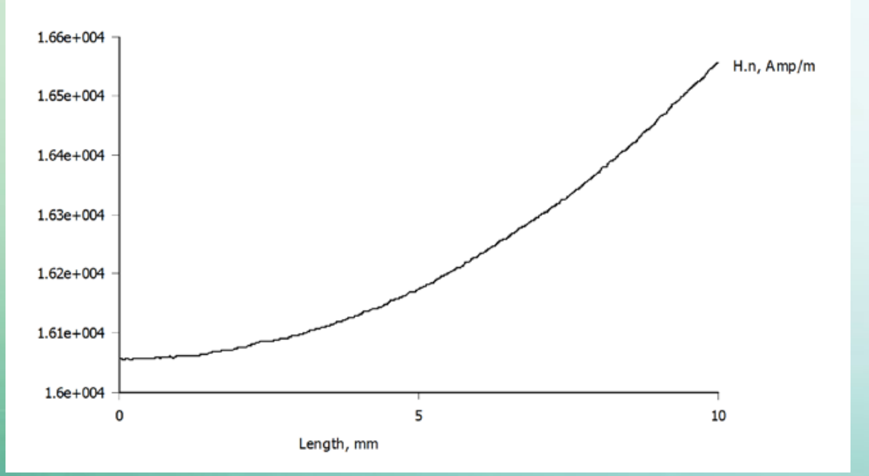
1. Z= 12.75mm
2. Inside Diameter = 40mm
3. Outside Diameter = 130mm
4. 200 Gauss
5. Resistance 900mΩ
6. Temp @ 20% Duty Cycle -> 53C coil center in air

- Pro's of this Coil design
  - Meets requirements by production of overall height to be <= to 20 mm
  - Resistance is low
- Con's of this Coil design
  - Need to maintain room temperature at DUT with no external input
    - This could be difficult to achieve with coil temperature at simulated 53°C

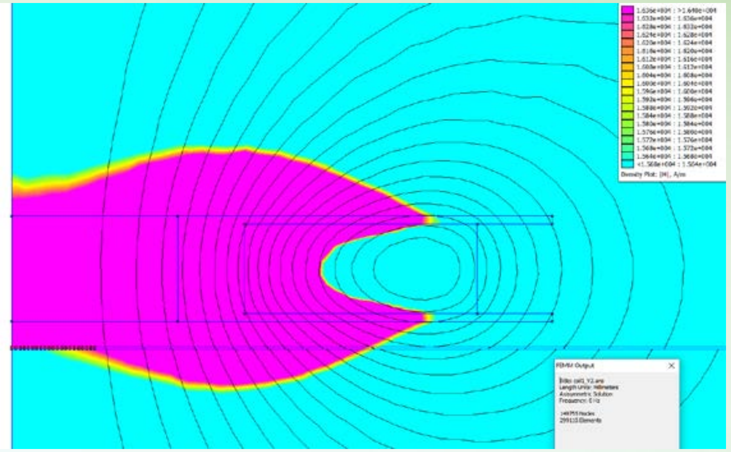
- **Need simulation to verify coil design meets requirements**

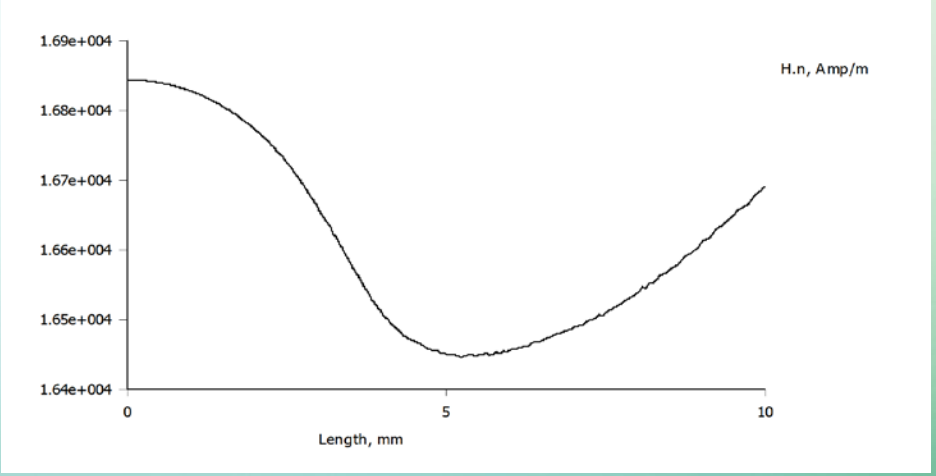
# Coil Design 1 Simulation






Without Mu-Metal






With Mu-Metal

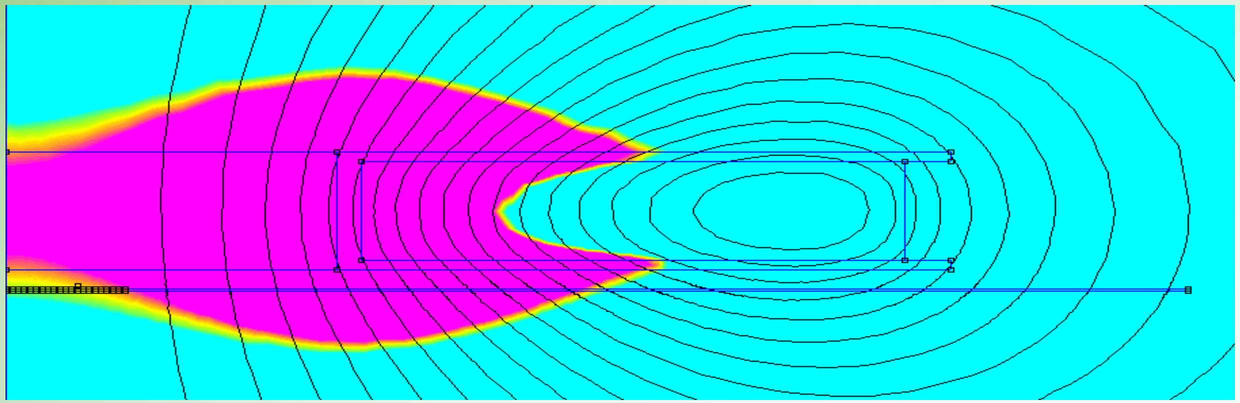
# Coil Design Final Attempt

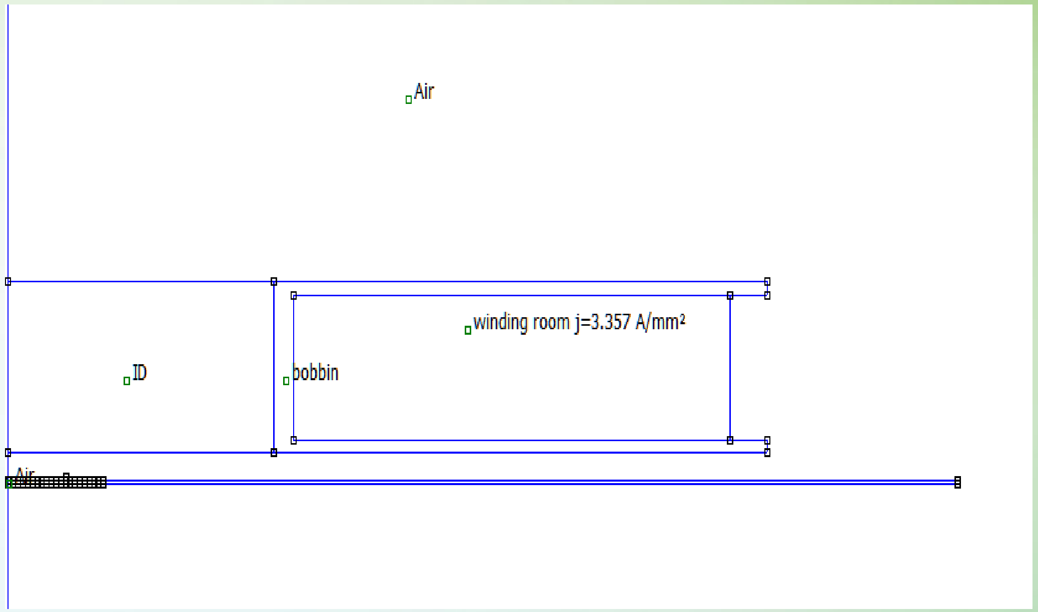
- **The coil design and simulation process continued for 6 additional designs before concluding design 7 met all specifications**

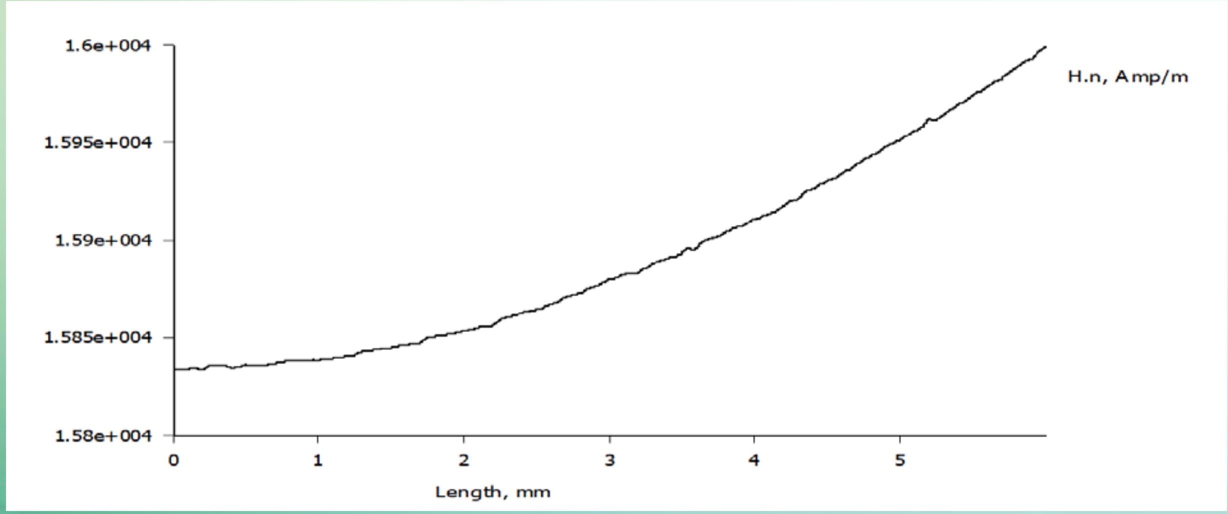
1. **Z = 12.5mm +/-0.25mm**
2. **Inside Diameter = 56mm**
3. **Outside Diameter = 160 mm**
4. **200 Gauss**
5. **Resistance 470mΩ**
6. **Temp @ 20% Duty Cycle -> 52°C Coil center**

- Changes from 1st design
  - Decrease Z
  - Increase inside and outside diameter
  - Lower resistance

# Coil Design Final Simulation






The radius of interest covered approximately 5mm. The accuracy in the area of interest was 200Gs +/- 0.53%.

# Challenges - Temperature

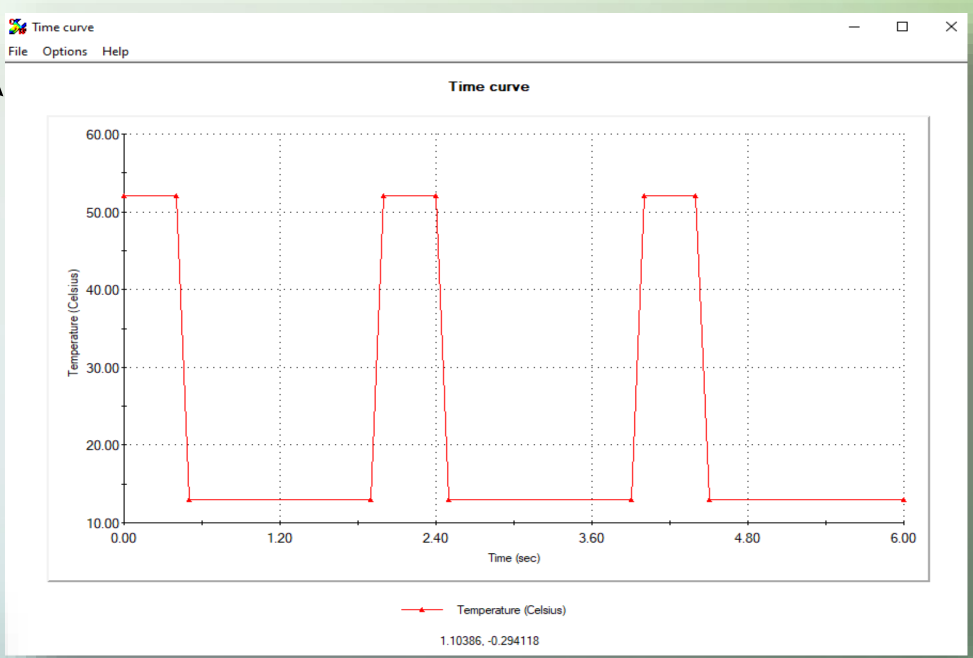
- **The coil specifications complete - time to tackle the remaining challenges:**
- **Temperature of DUT required to stay at room temperature**
- **Coil temperature surrounding the DUT 52°C**
- **Need ways to reduce the temperature of the DUT to room temperature????**
  - Thermal chuck
  - CDA (Clean Dry Air)
  - CDA through coil
- **Would it work to use the PCB stiffener as a heat sink?**

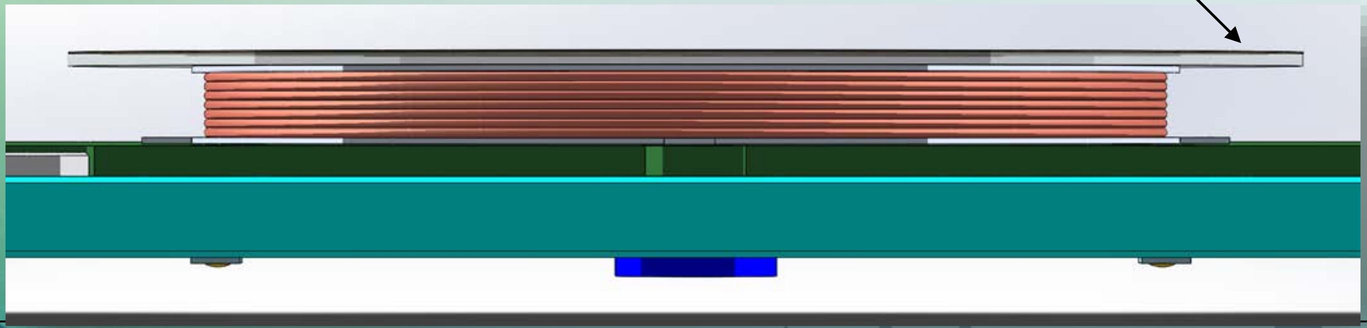
# Challenges – Temperature- Model

- **Create the model specifications to perform simulation**

Studying the thermal response of a wafer under a 52°C coil. 20% PWM under 2 seconds oscillation at the coil.

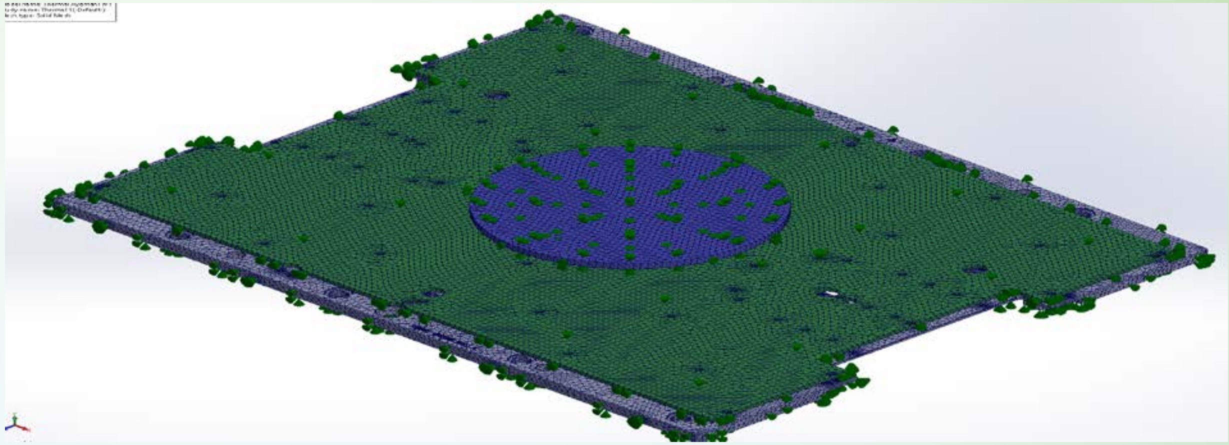
Air disk modeled, 2mm separation between wafer and coil.



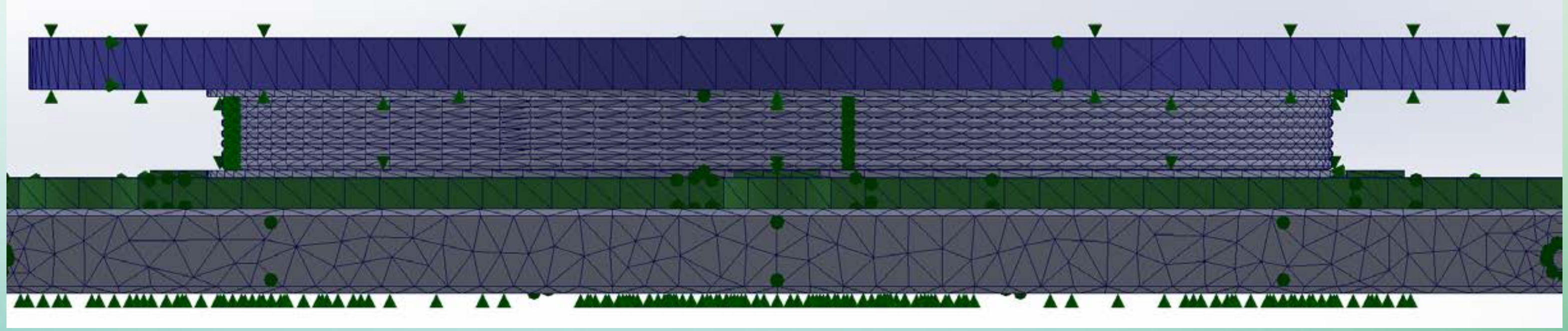



# PCB and Coil Model

- **Standard 5mm mid quality element refined mesh, with 0.25mm tolerance**
- **Mesh refinement at wafer and board**
- **1,043,533 nodes**
- **624,703 elements**

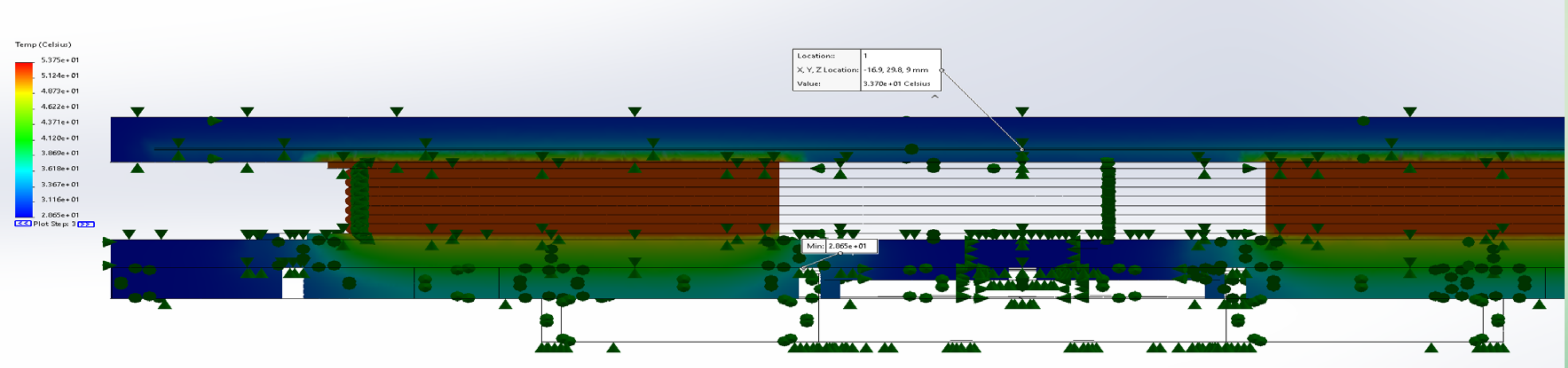


The final mesh stack included the board, stiffener, and inlay plate.



# Challenges – Temperature Simulation

- 29°C ambient temp. Board, Stiffener, & inlay plate included. Increased copper pads for thermal dissipation added. Air volume unchanged from previous simulations.
- 33°C result in wafer, slight improvement from previous simulations
- Coil is heating evenly, small help from copper features




Conclusion: Despite the small improvement by adding the copper it is highly recommended to add copper or thermal relieves where possible

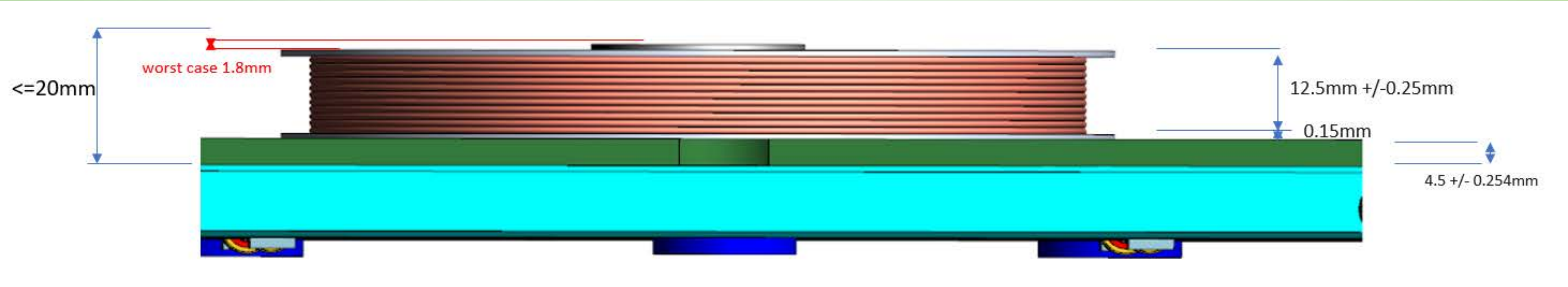
# Probe Card Design Challenges:

## During the Probe Card Design. There were a couple challenges that had to be overcome.

1. **Maximum distance of all hardware from bottom of PCB(PCB tester side) <=20mm**

2. **Design of the thin copper layer 150um that goes between coil and PCB for heat dissipation continuity.**

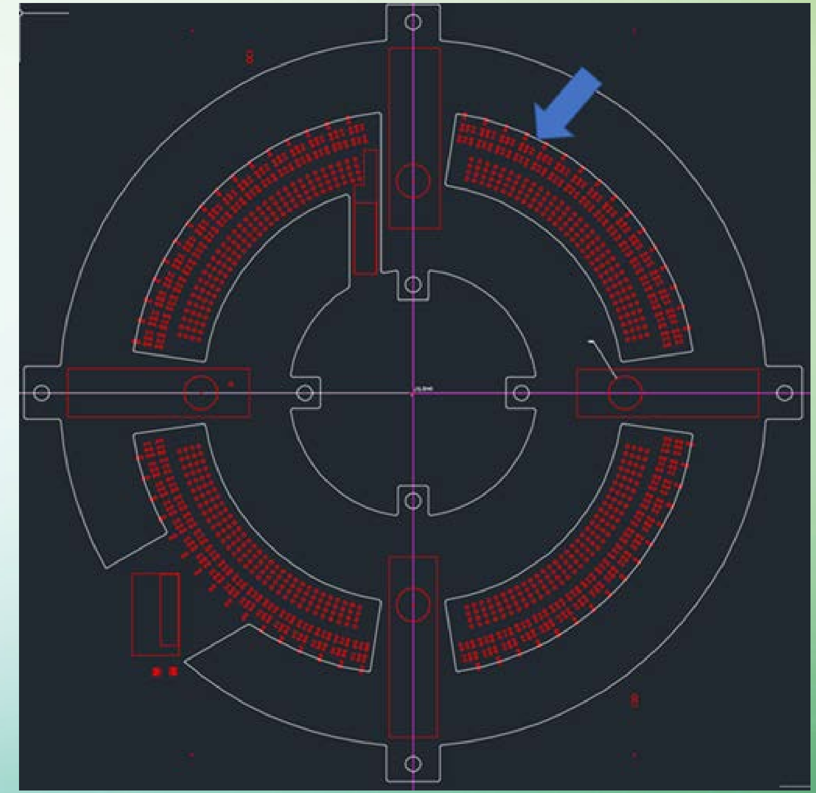
# Design Challenges: Max Clearance </=20mm



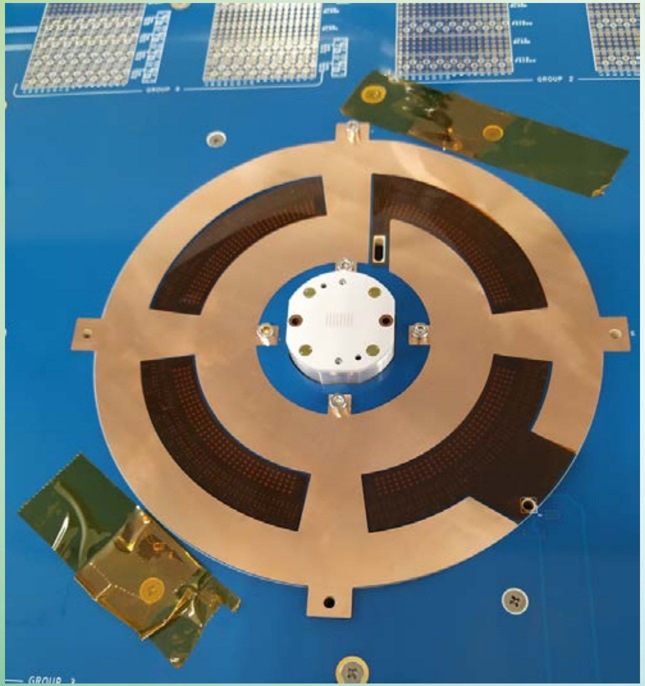

- **Fix the Coil on PCB wafer side with small room between coil surface and needle tip (ideal target of 1.8mm but not below 1.5mm safety margin).**
- **Other suggestions:**
  - Don’t reduce furtherly the room between needle tip and coil surface
  - If coil thickness needs to increase, you can act by the below in order to keep safety margin unchanged:
    - Reducing PCB thickness
    - Increasing maximum distance acceptable  from bottom PCB

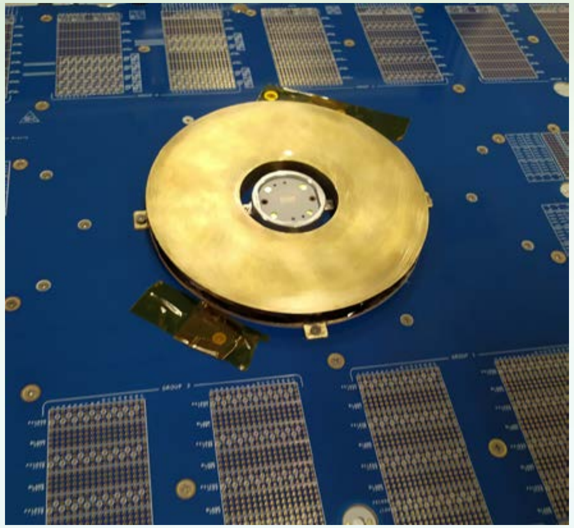
# Design Challenge: Heat Dissipation

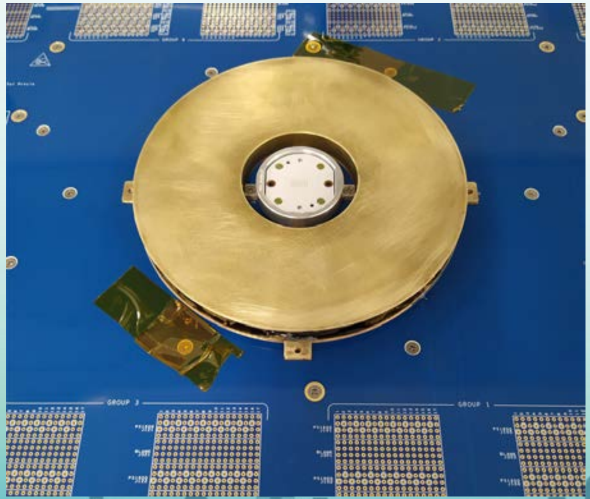
- **Design of the thin copper layer 150um that goes between coil and PCB for heat dissipation continuity.**
- **Characteristic of the thin copper layer:**
  - Compensate the different height between PCB surface and coil
  - Guarantee thermal continuity between heat dissipation pads on the PCB and coil cover
  - Avoid short between solder pads, components and the coil terminal pad

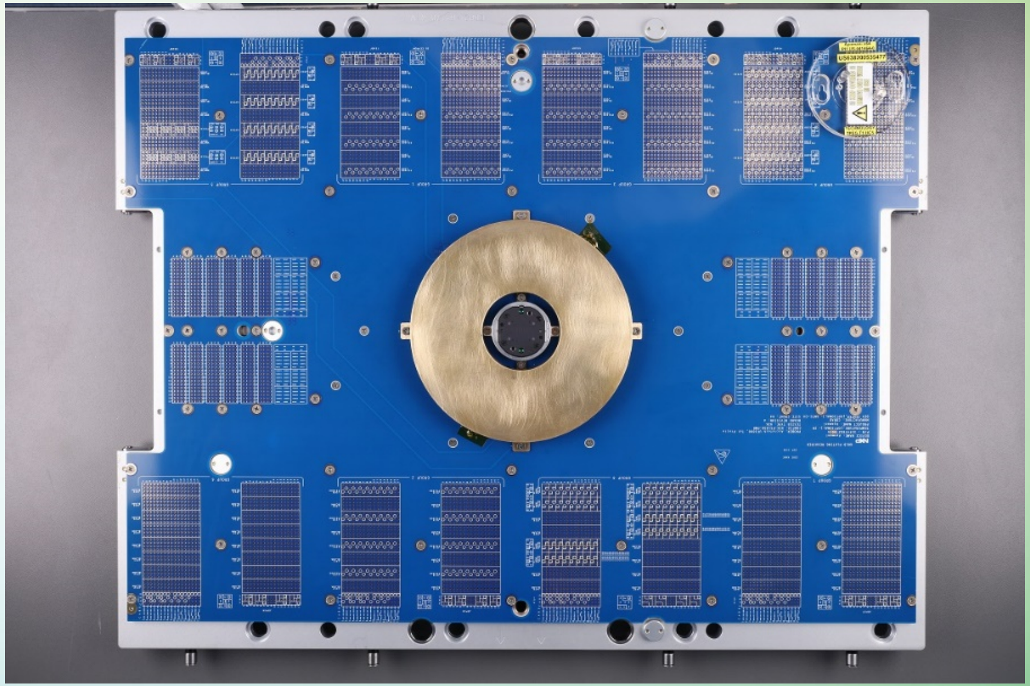


# Probe Card Photos









# Summary/Follow Up Work

- Summary from business line:
  - Yields are as expected on initial wafers processed
  - Final simulation data matches the actual wafer data for uniformity of magnetic field across the DUT array
  - Temperature measured on the die is consistent at 30°C

- Follow up work to be completed:
  - Production Probe Design of Experiment (PDOE) passes
  - Wafer Test to Final Test comparison - Was there any unexpected fallout
  - Monitor lifetime of probe card, coil

# Thank you

- **NXP and TechnoProbe would like to thank the following people for their work in helping make this project a success**

Thank you

NXP

- Weng Yap
- Joe Millazo
- Trent Cohrt
- Bary Turley
- Brian Nakai
- Engelbert Steffens
- Peter Löptien
- ATT Systems

Technoprobe

- Andrea Motta
- Stefano Beretta
- Antonino Riolo
- Alessandro Albanetti

- **We would also like to thank SW Test committee for allowing us to present on this topic**

# Questions????