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Design Parameters for The Additive Production Of Electronics

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Outline

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Goals

- Identify limiting factors for 3D-Electronics using Benchmark Tests
- Combine various Benchmarks to create a complete Test for different systems
- Tests are focused on manufacturability and **not** on performance
- Create a basic summary of results for future reference
- Identify issues and their causes
- Offer solutions for certain issues

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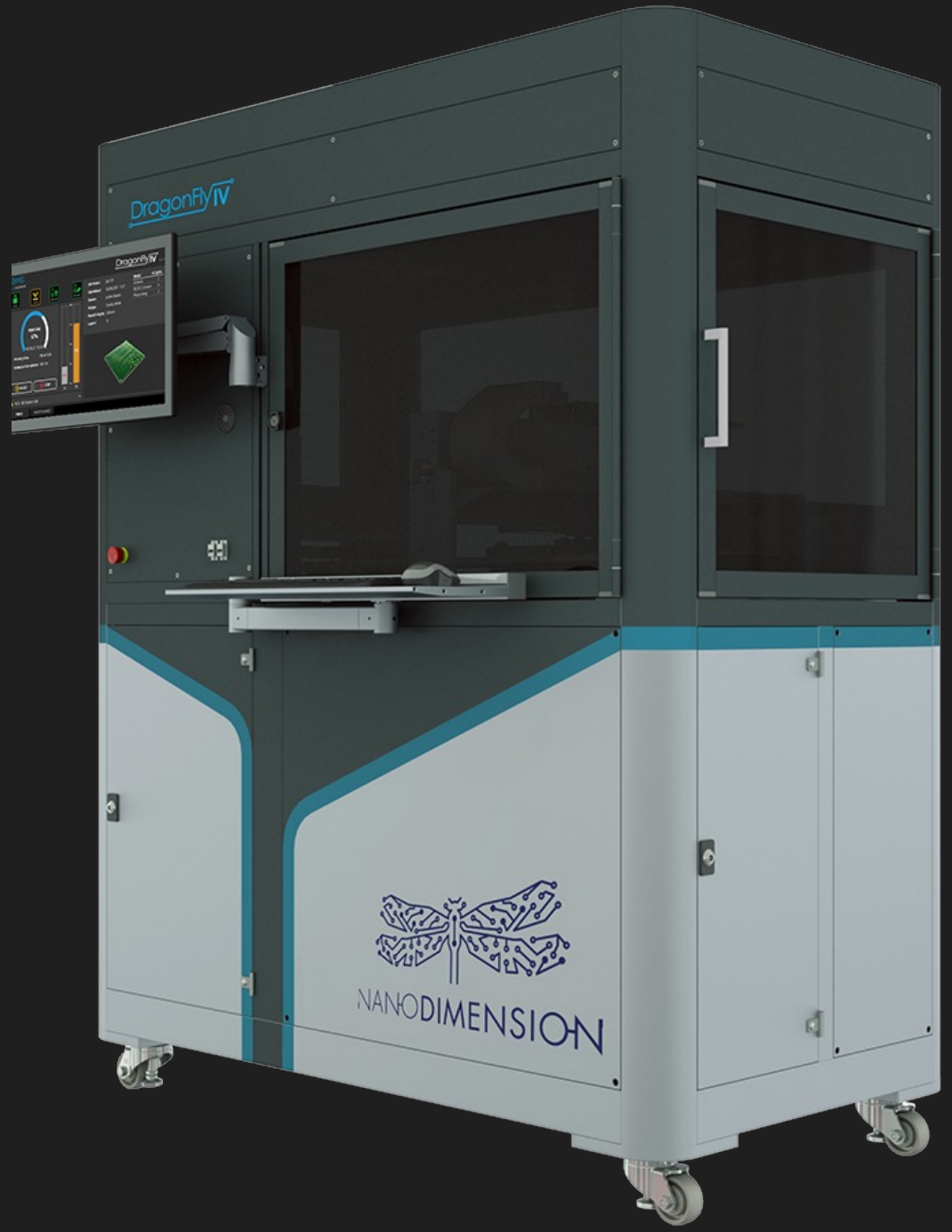
Setup

- All tests are done on the DragonFly IV platform
  - Retrofitted LDM
  - Production DFIV
- Ohmic measurements on HM8118 LCR-meter
- Visual inspection using the Keyence VHX-3000
- Software development is done in MATLAB (R2021b)



Order of Work

- Determine minimum dimensions in X and Y
- Development of reconstruction software
- Effects of different file formats
- Behaviour in the third dimension
- Development of the final Benchmark-test

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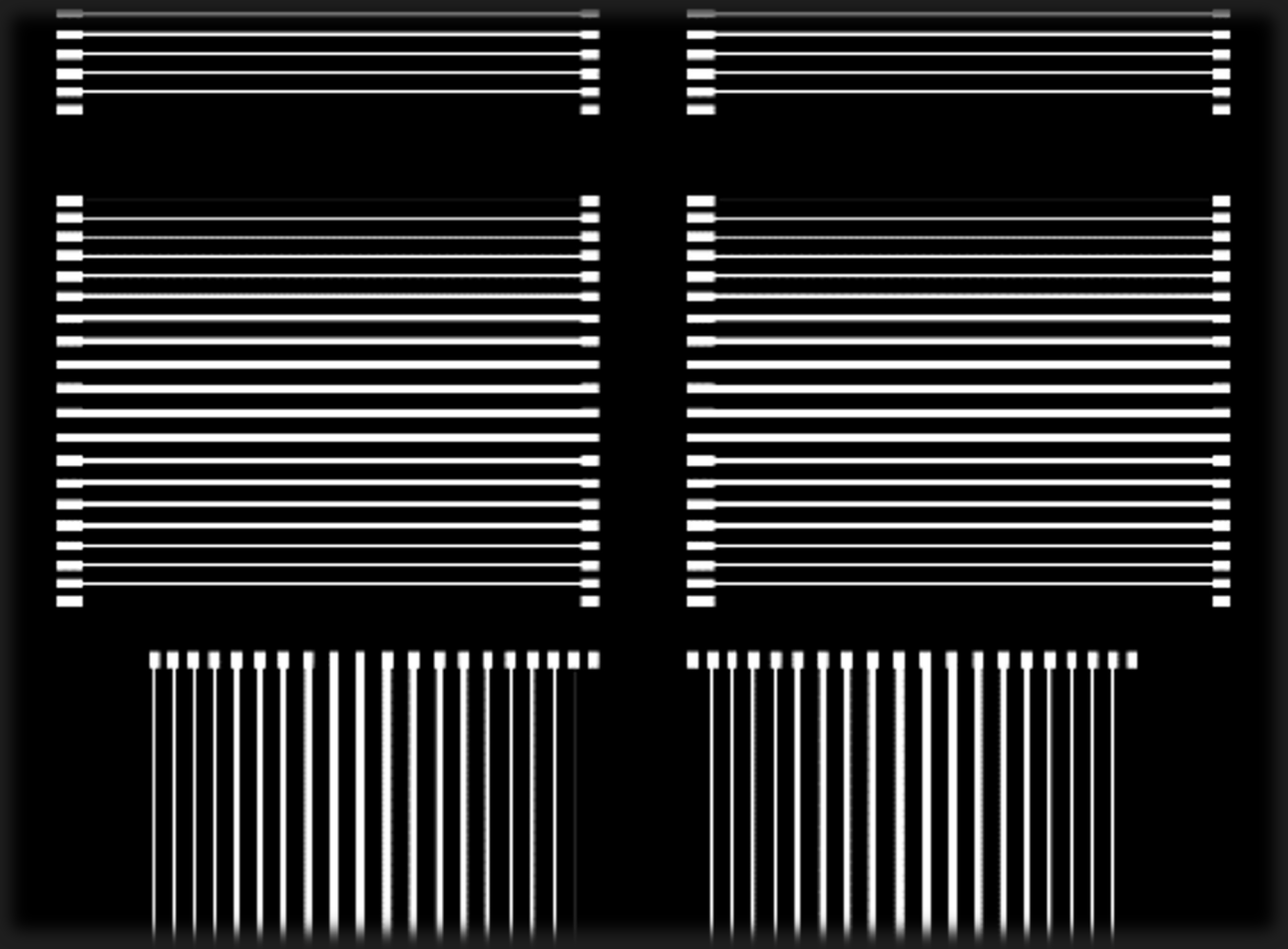
Minimum Dimensions in X and Y Description

- Lines with a width between 1 to 10 Pixels were designed in Fusion360
- Lines were printed in both X and Y direction
- Lines were tested at different heights



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Minimum Dimensions in X and Y Results

- All lines were intact and usable
- Width appears to be larger than the designed model
- Offset of approximately 40µm to 50µm or about 2/3 pixels
- Effect can be seen on all tested Samples
- Number of Pixels appears to be correct

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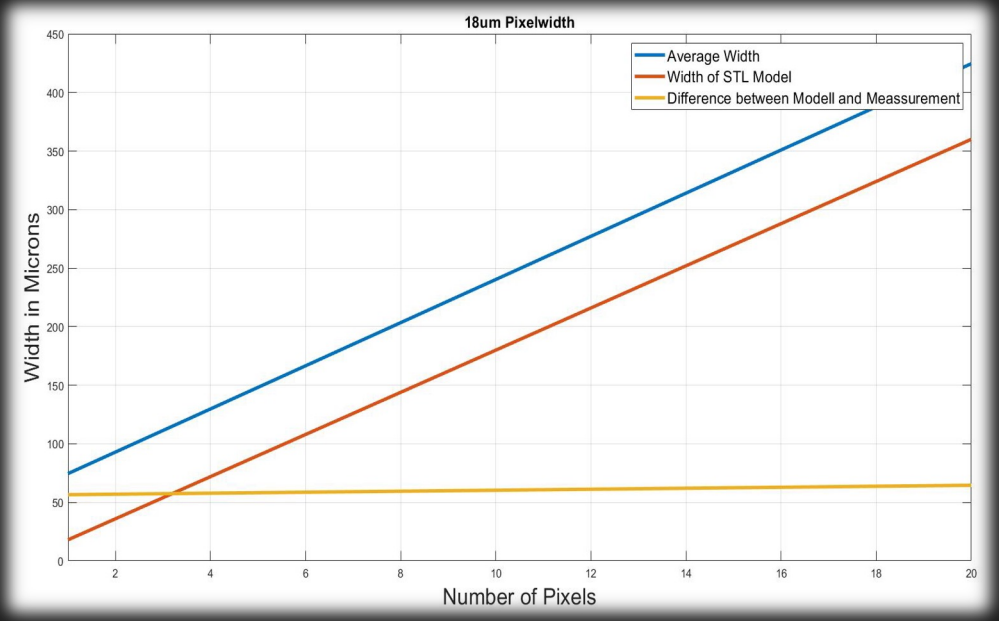
Minimum Dimensions in X and Y Explanation

- Slicing software creates files with pixels equivalent to 18µm
- Actual size of the pixels is **not** 18µm
- Size of pixels is **not** constant
- Samples between 1 to 10 pixels were tested
- Offset appears to be constant
- Difference between X and Y is negligible
- Difference between design and result can be estimated



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Reconstruction program

Overview

- Identification of errors through reconstruction of the files
  - Read individual images
  - Reduce size
  - Create stack
  - Generate a mesh
- Better visualization
- Find Errors before printing
  - Lower risk of failed prints
- Used for analysis of 3D Tests

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Effects of different file formats
overview

STL-format

- The correct number of pixels is shown in the images
- Pixels are equal to 18µm in the respective models
- Spacing between structures is identical to the design
- Sliced models are as expected from the design

Gerber-format

- The number of pixels is on average two pixels lower than expected
- The represented width of the Pixels larger than 18µm
- The spacing between the lines is not uniform and varies by up to two pixel
- The print jobs are warped compared to the original Gerber

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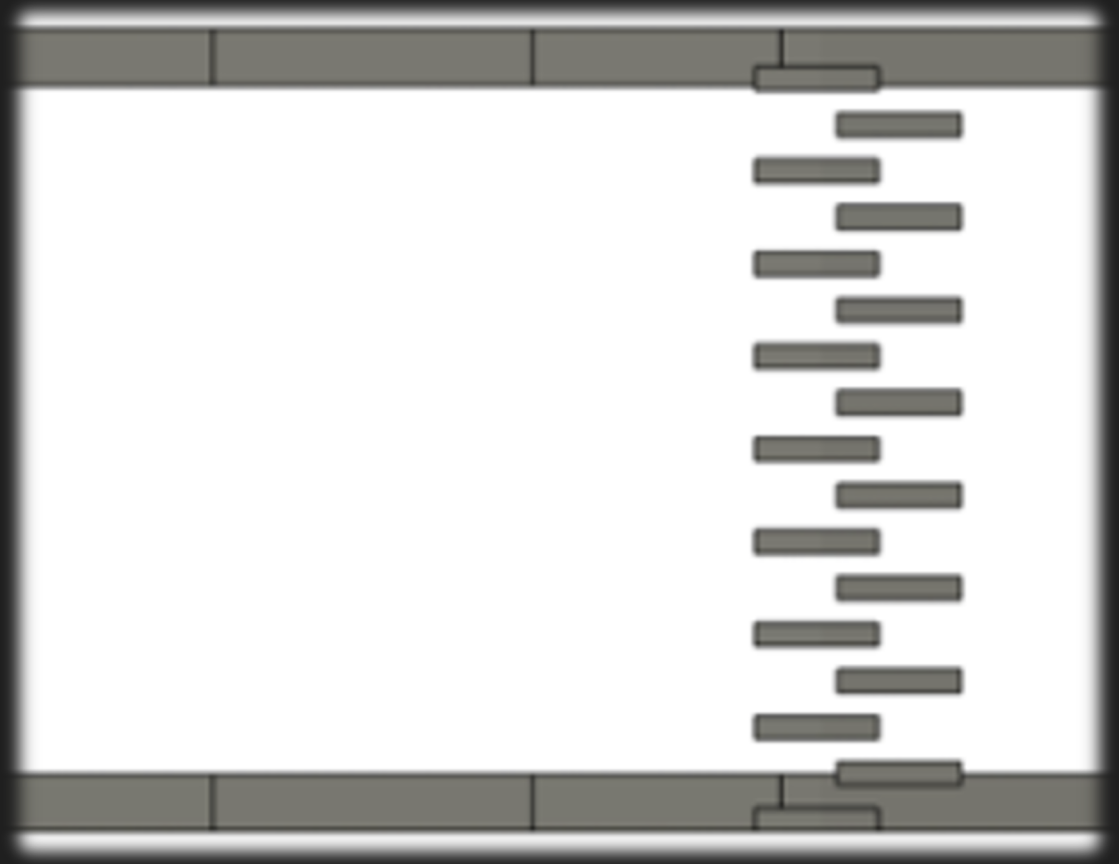
Effects of different file formats
Summary

- Ecad files are processed differently than the STL-files
- **The manufacturer is aware of the issue**
- Fixes are done in the image files used during printing
- Actual limit of printed circuits is approx. **75µm**



Behavior in the third dimension
Spacing in Z-Direction

Setup:

- Several staggered stacks of plates with a thickness of 20µm
- Spacing between 10µm and 30µm

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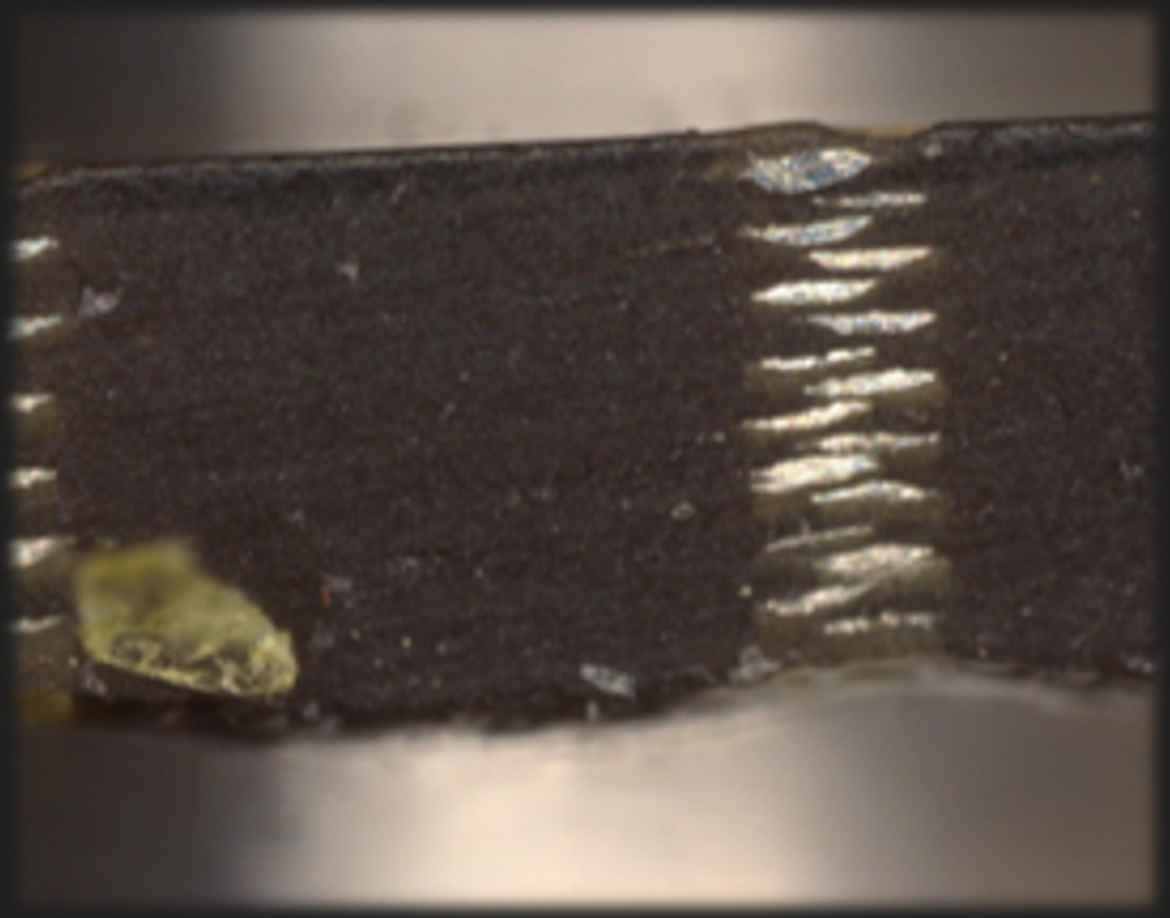

Behavior in the third dimension
Spacing in Z-Direction

Result:

- Plate thickness is not constant in the final print
- Spacing between plates is not uniform
- Shorts occur between adjacent plates
- Results dependant on layer thickness of the machine

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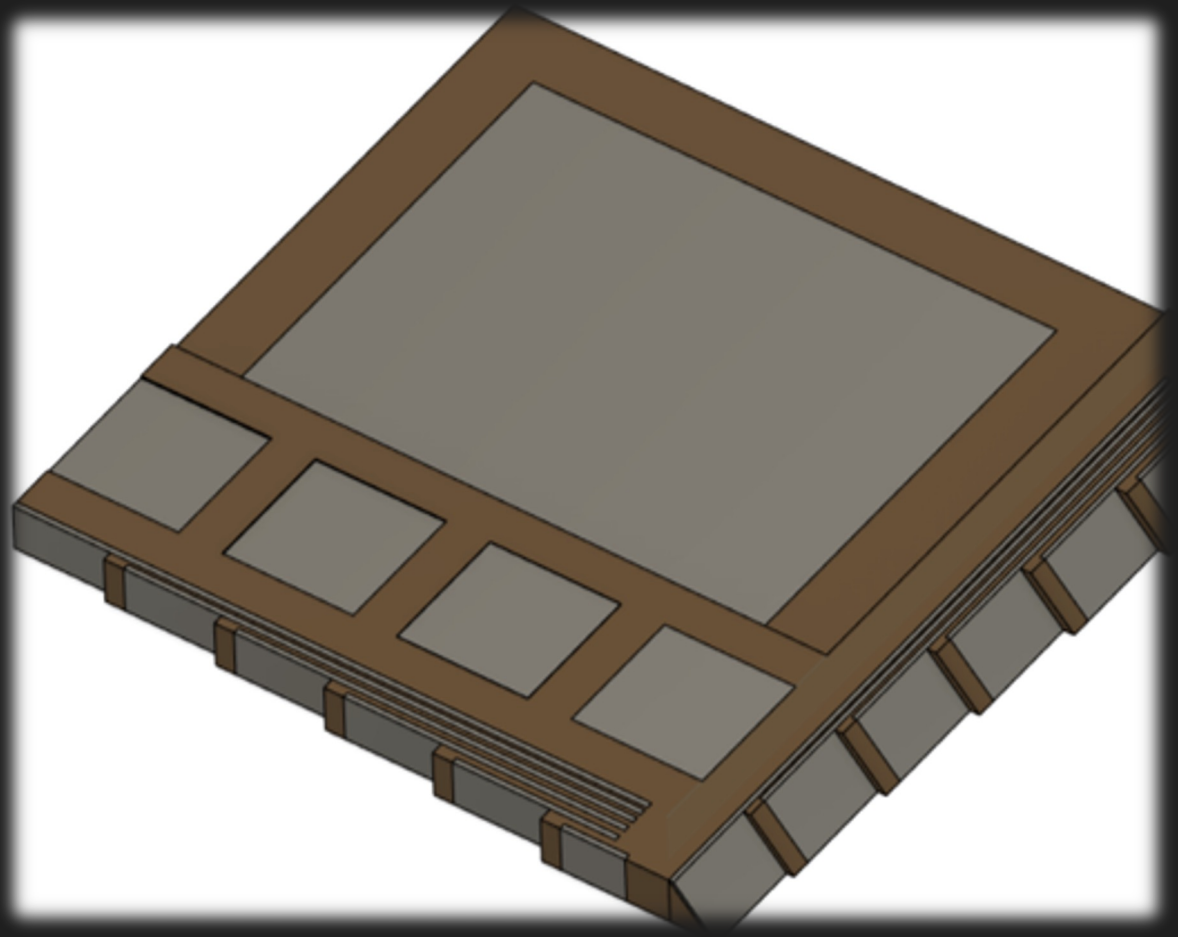
Behavior in the third dimension
Spacing in Z-Direction

- **Setup:**
- Vertically stacked plates with 10-40µm spacing
- Vertical walls stacked with 36-126µm spacing
- Angled walls at 45° with 36-126µm spacing
- **Results:**
- Vertically spaced plates are isolated at 40µm
- All vertical walls are shorted



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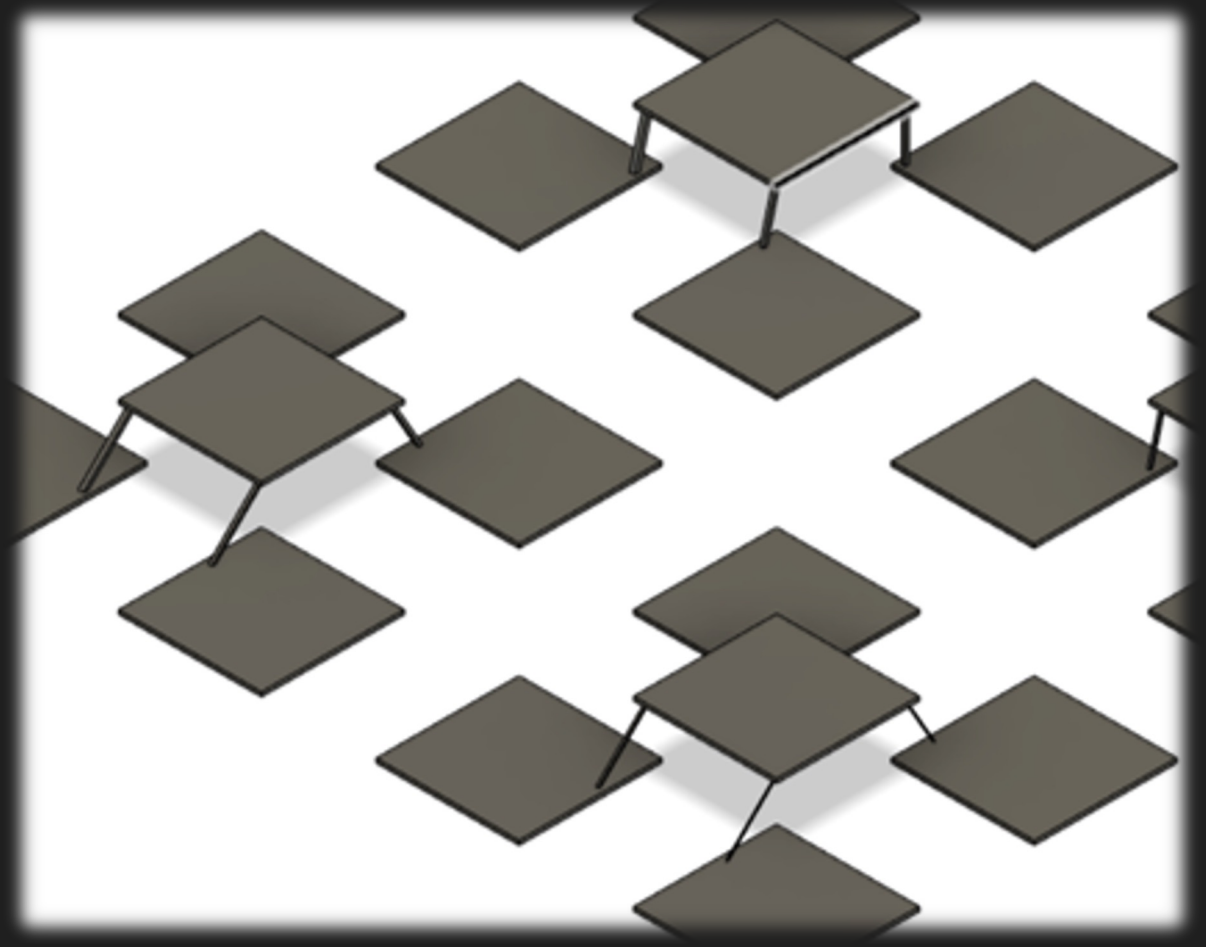
Behavior in the third dimension
Vertical connections and bending Radius

Setup:

- Design of vertical connections with 45°, 60°, 75° and 90° angle

Result:

- All connections with 4 or above Pixels were functional
- 4 Pixels will be used as reference



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Behaviour in the third dimension
Vertical connections and bending Radius

Setup:

- Connections with a curve at the end to contact pads

Result:

- All connections were functional
- Resistance between different radii in XY was almost identical
- Resistance in Z-Direction increased with the Bend diameter
- Probable cause is the slicing behaviour

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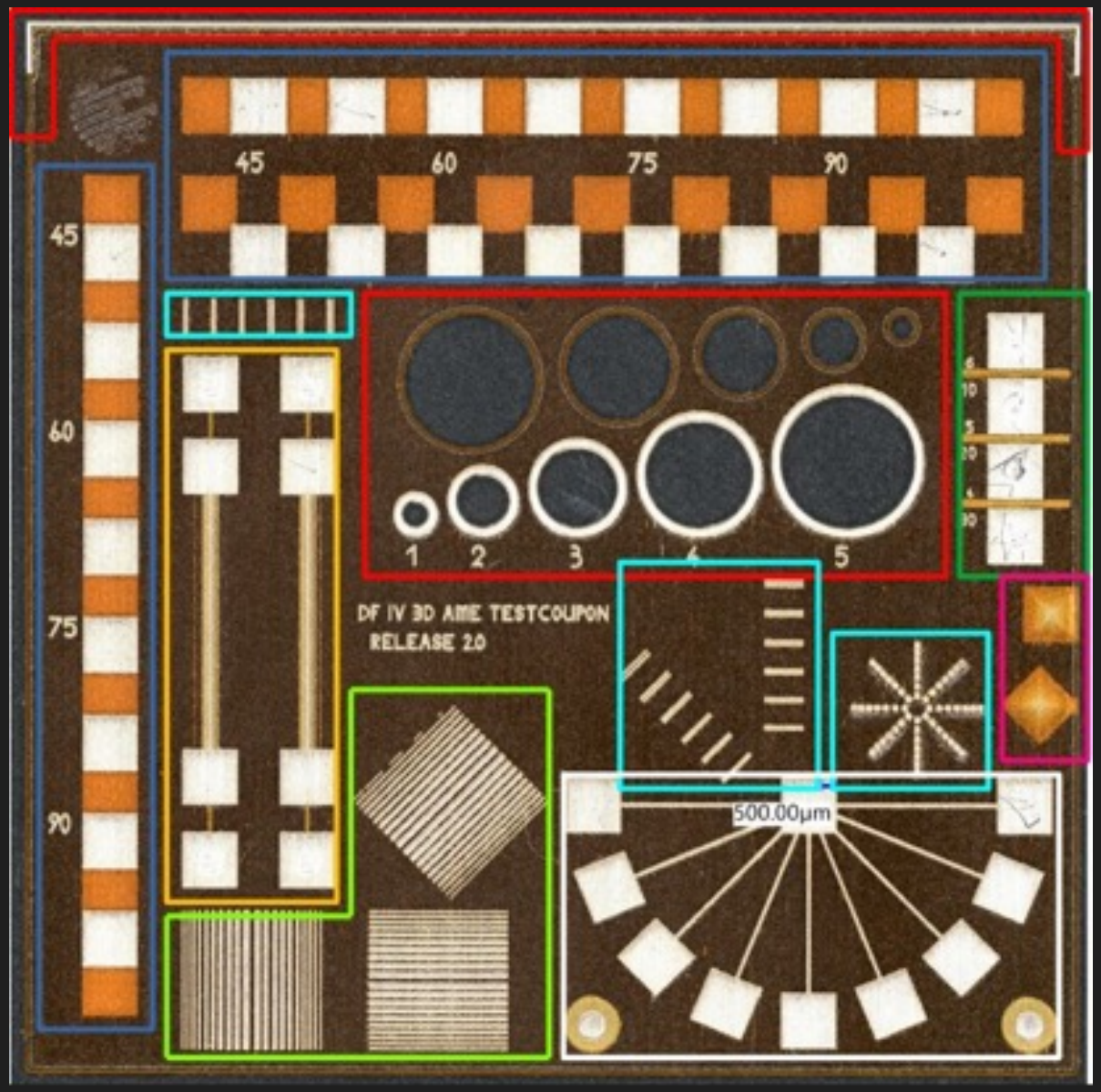
Final Benchmark-test
Design

Design of eight segments:

- **RED:** determining of border sagging effects
- **CYAN:** spacing between lines and vertical structures
- **BLUE:** minimum Via and Bend sizes
- **WHITE:** Behavior for different angles
- **DARK GREEN:** spacing between plates in Z-direction
- **LIGHT GREEN:** pixel size in different directions
- **YELLOW:** Coax lines for spacing in 3D
- **Magenta:** Behavior of slicing



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Final Benchmark-test
Results

Important notes:

- Spacing in X/Y was determined using the Coax
- Spacing in Z is depending on the state of the machine
- 18µm lines in 45° were broken
- Sagging is a rough estimation

	Design	Reality
Line width	36µm	93µm
Spacing X/Y	180µm	126µm
Spacing Z	30µm	-/-
Via width	72µm	130µm
Pixel size	18µm	74µm-21µm
Sagging	-/-	0.1785µm

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Summary and possible Solutions
Design rules

Aspect	Model	Reality	Notes
Minimum line width	36µm	93µm	1px lines are broken
Minimum Spacing X/Y	180µm	126µm	
Minimum Spacing Z	40µm	-/-	Depending on Printer
Minimum 3D-Via width	72µm	130µm	Depending on Printer
Pixel size X/Y	18µm	74µm-21µm	Only tested until 10px
Sagging per µm in Z	-/-	0.1785µm	Verified for Z<=560µm
Minimum Radius X/Y/Z	-/-	D/2	D= Via width

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Summary and possible Solutions

Issues

- Most issues are related to the software and missing documentation from the manufacturer
- Pixels are not identical to the given specifications
- Gerber are adjusted to solve the issues, but STL is not adjusted
- **Specifications for Gerber-Files are not applicable for STL**

Summary and possible Solutions

Adjust the design accordingly:

- A lot of effort
- Needs to be done on every model

Implement function in the slicer:

- No additional work required
- Needs to be done by the manufacturer

Development of a standalone Program:

- Automation of the process
- Use of additional programs increases work steps

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