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Slotted Waveguide Antenna Design at W-Band Using Stacked Glide-Symmetric Metal Sheets

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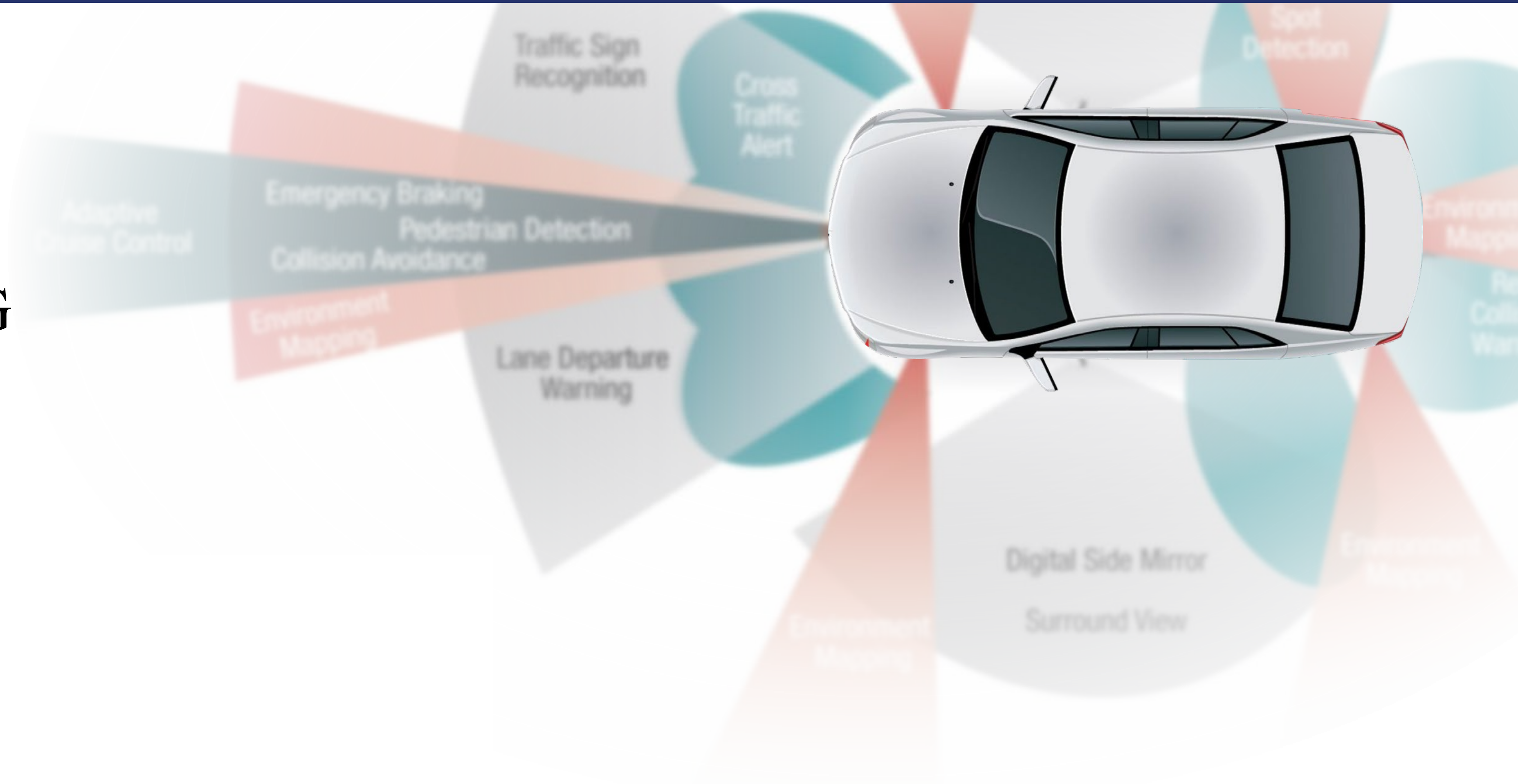
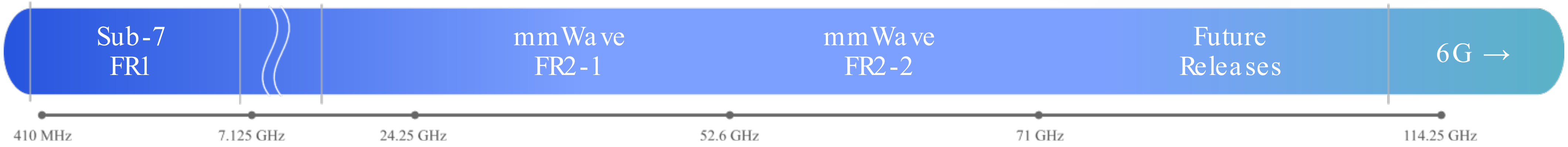
mmWAVE

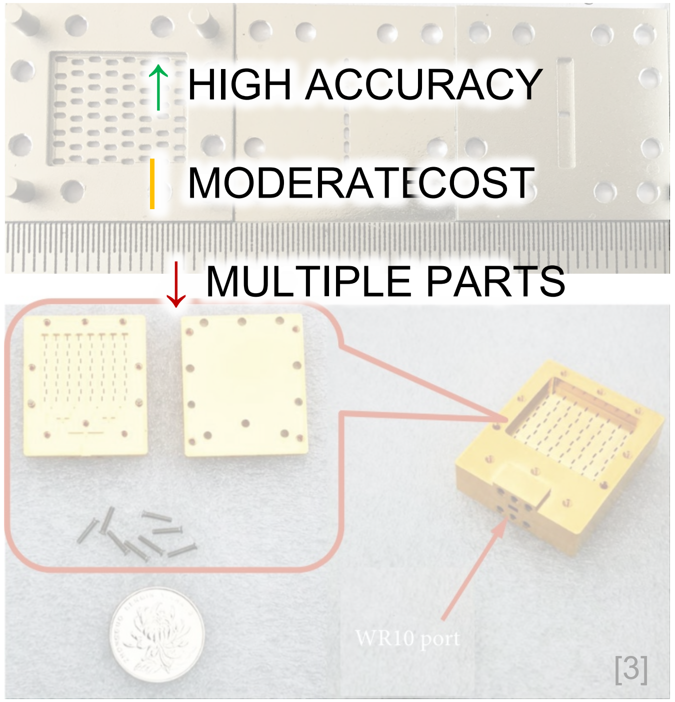


- Radiocommunications → 5G
- Autonomous vehicles
- Radioastronomy
- Medicine

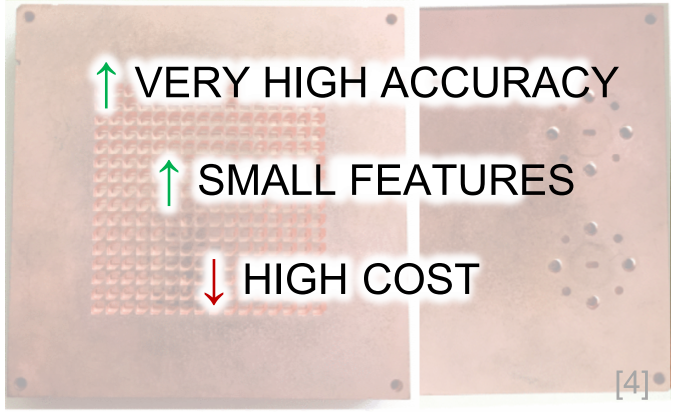


[1] [2]

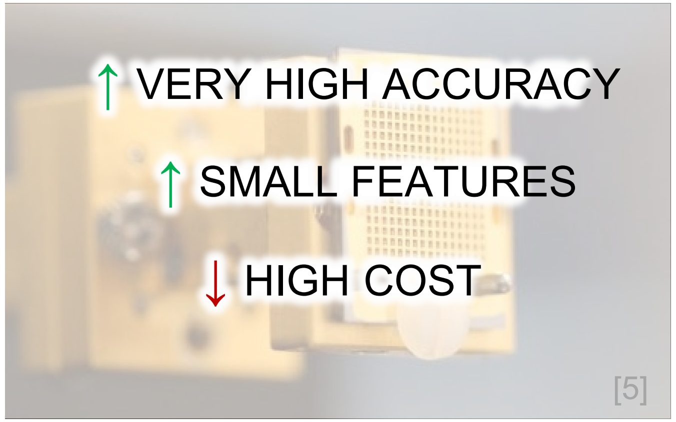
Conventional milling



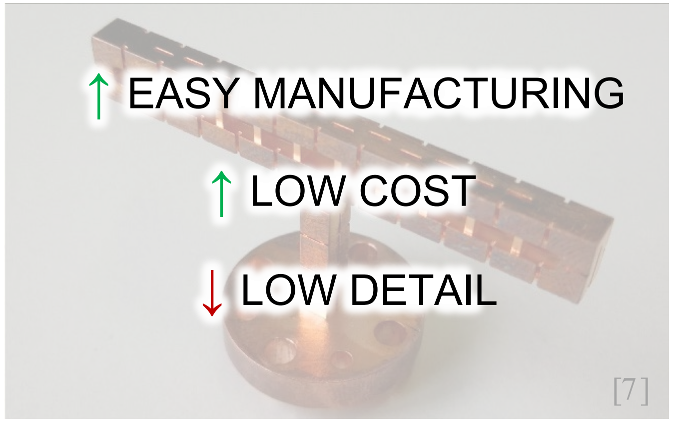
Diffusion Bonding



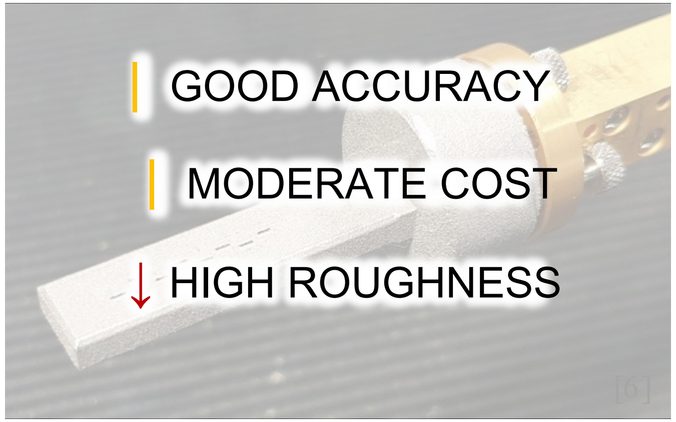
Micromachining (SOI)



Additive Manufacturing

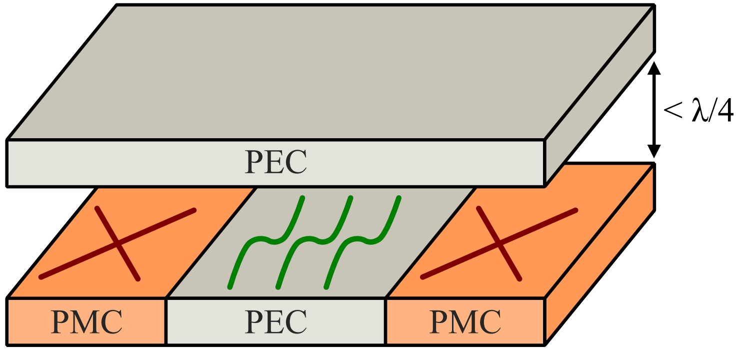


3D printed and copper plated



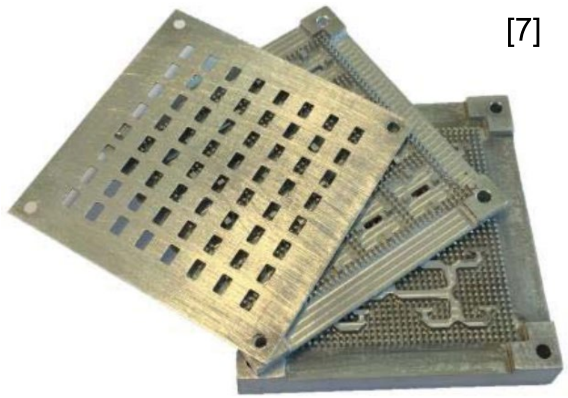
Direct metal laser sintering (DMLS)

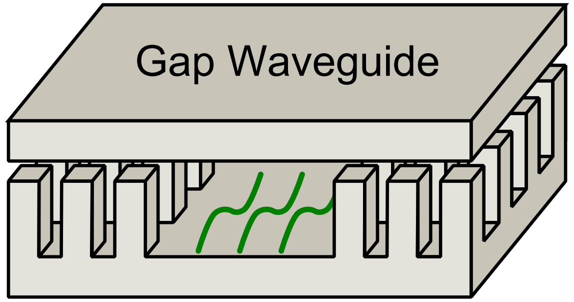
Electromagnetic Band Gap (EBG) Structures

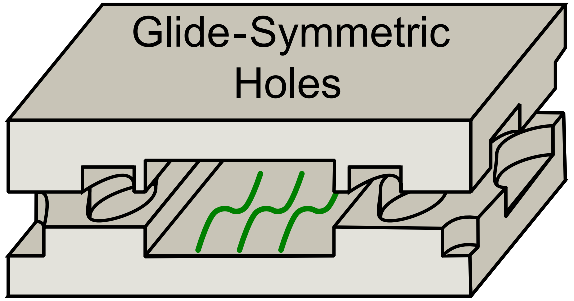


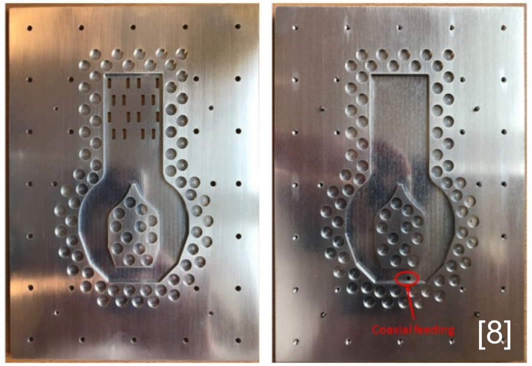
↑ NO NEED FOR CONTACT

↑ LOW MANUFACTURING COMPLEXITY









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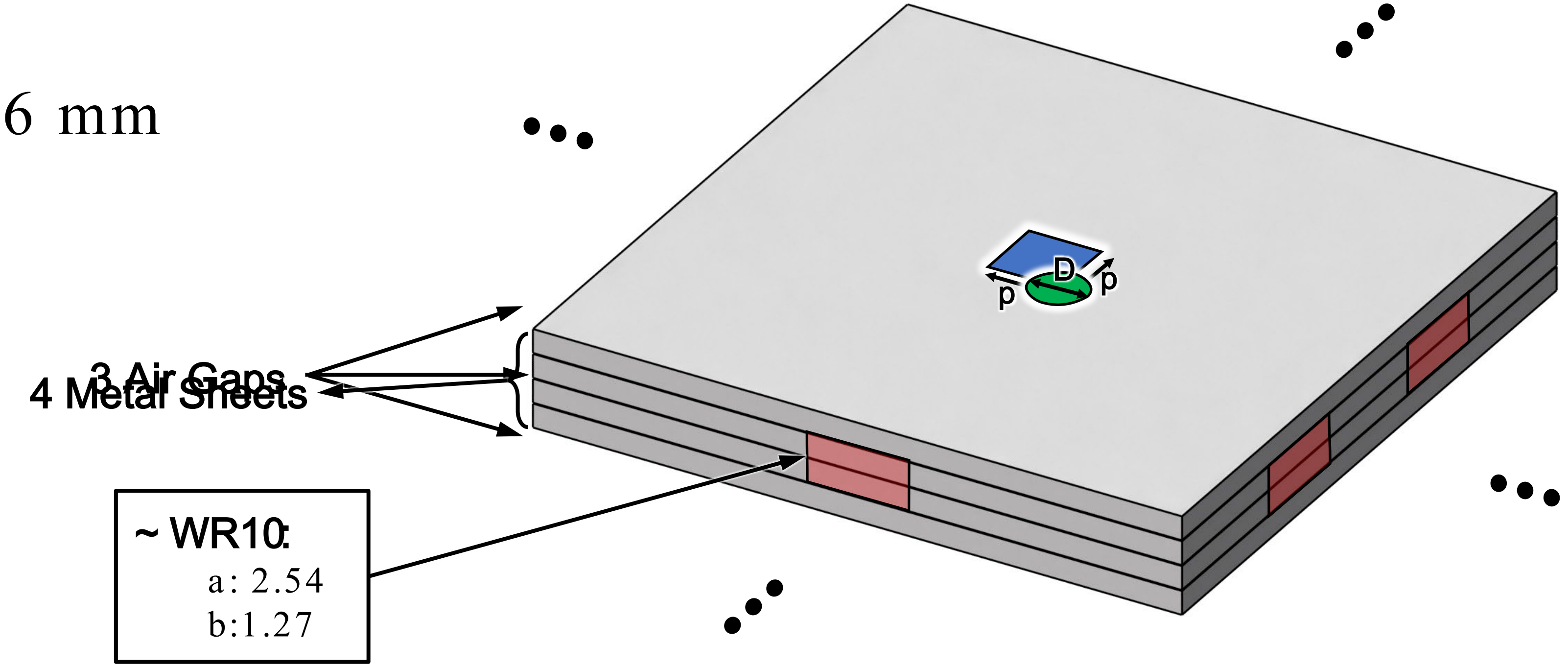
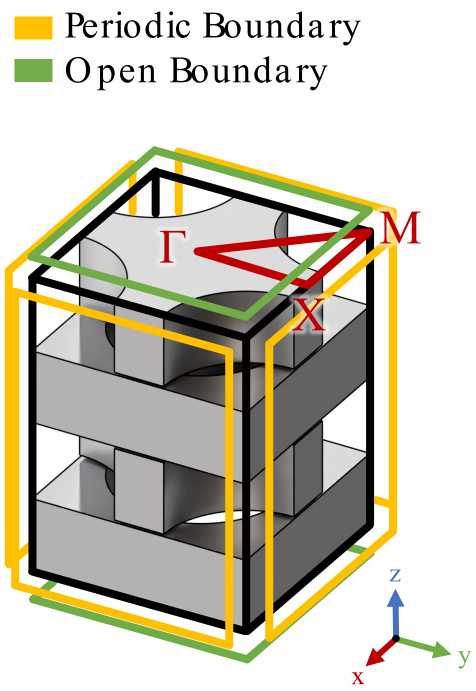
1. Introduction
2. Multilayer waveguide analysis
3. Slotted multilayer waveguide antenna
   - Design
   - Manufacturing
   - Results
4. Conclusions

2. Multilayer waveguide analysis

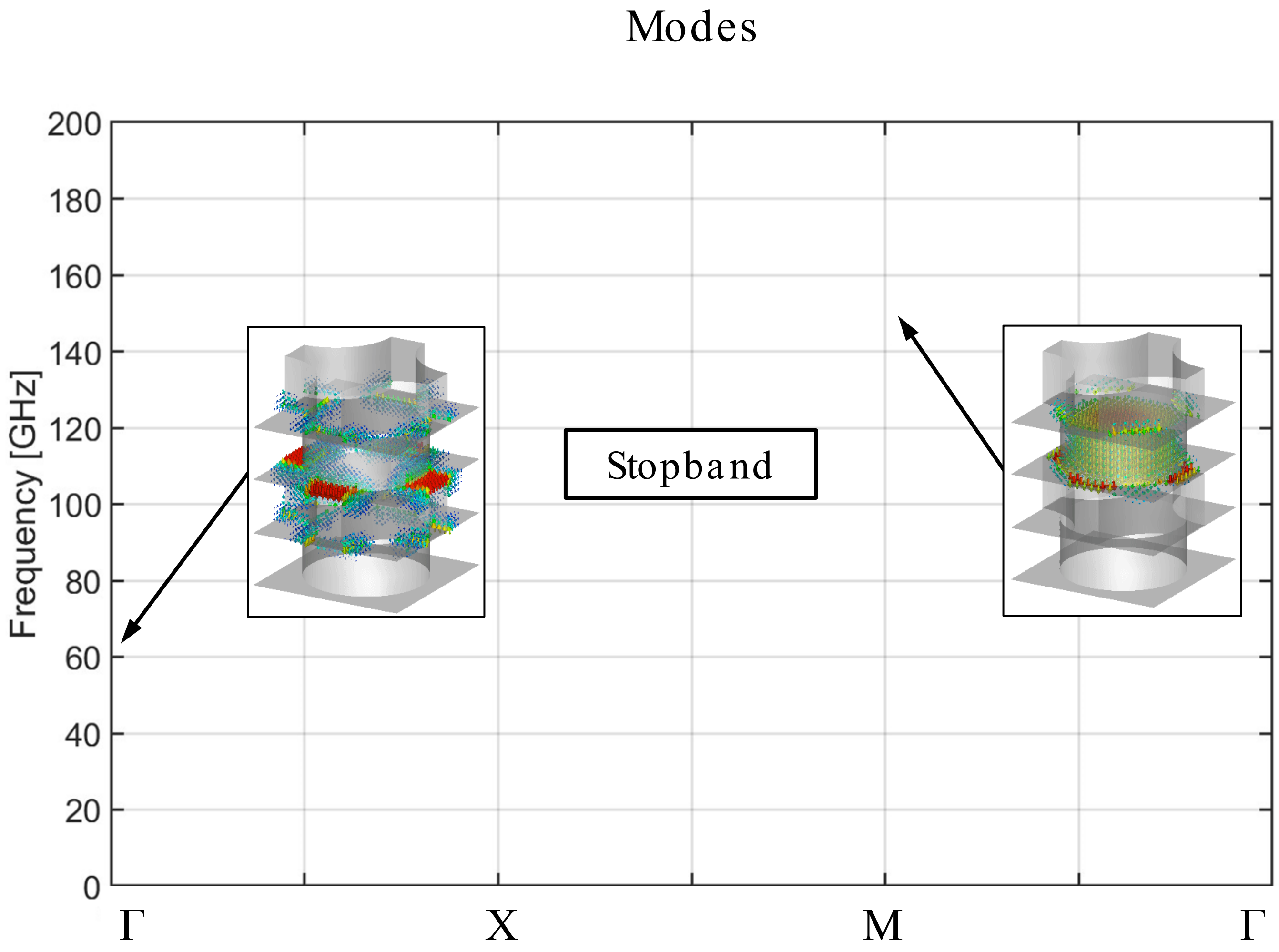
Unit Cell Parameters

- Layer height → h = 0.6 mm
- Gap → gap [µm]
- Period → p [mm]
- Diameter → D [%p]

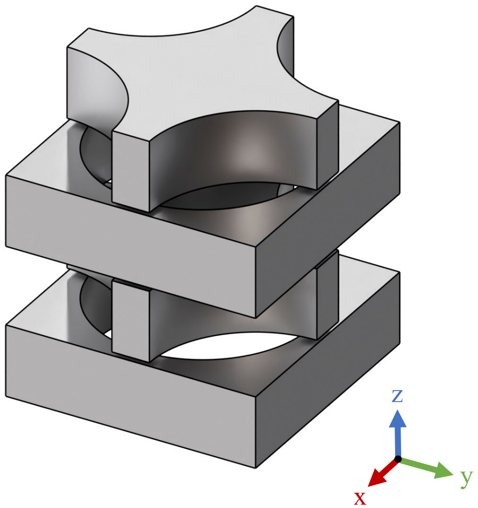




gap = 10 µm → 30 µm
p = 1.8 mm → 2.1 mm
D = 77 % → 85 %

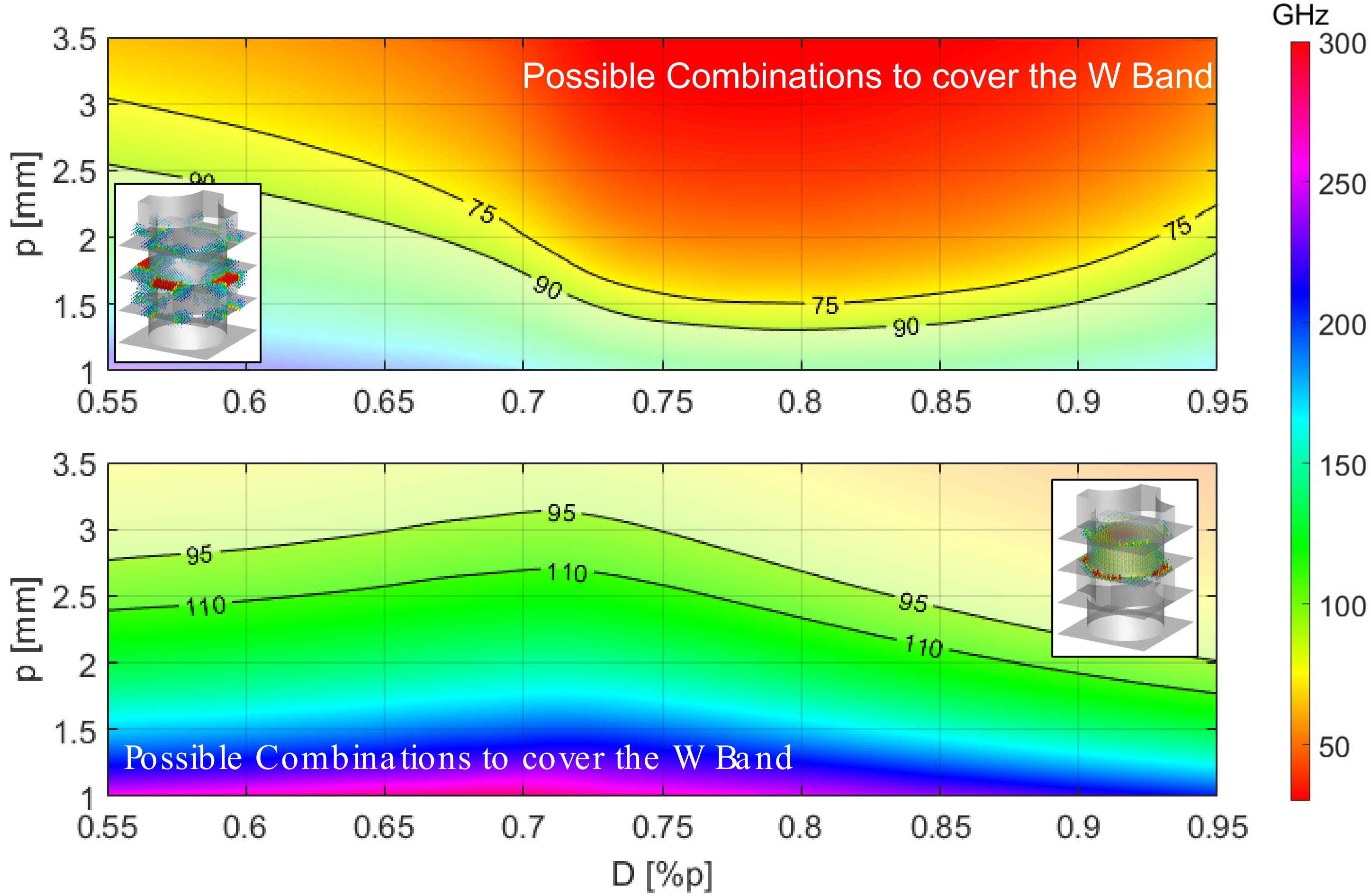


W BAND 75 – 110 GHz



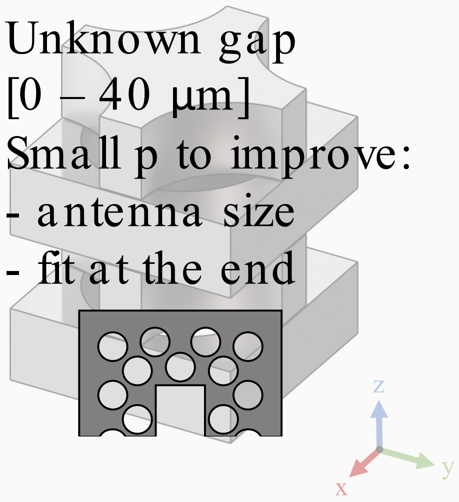
gap = 10 µm
p = 0.5 – 3.5 mm
D = 50 – 95 %

Max. Frequency of the Lower Mode /
Min. Frequency of the Upper Mode

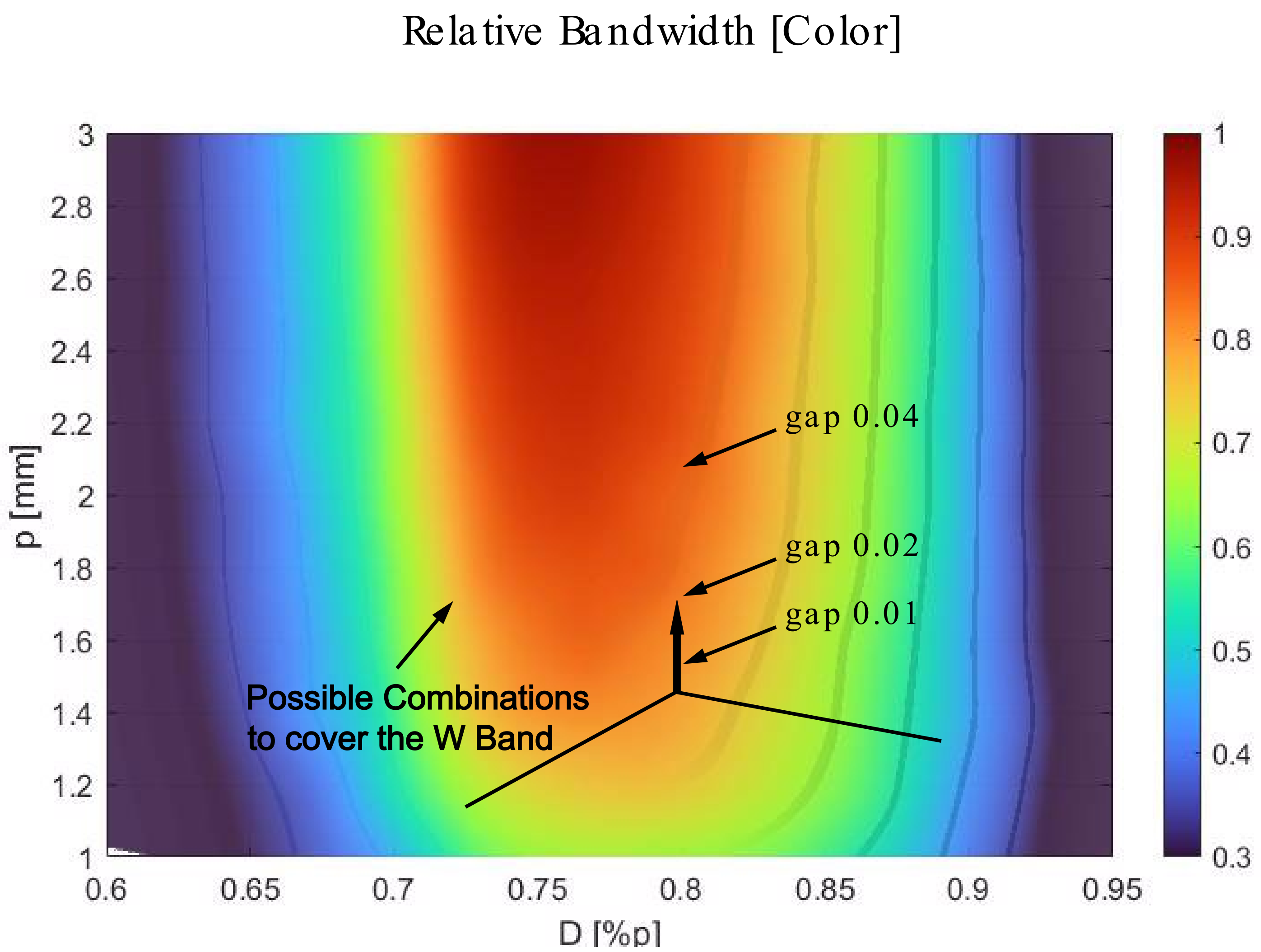


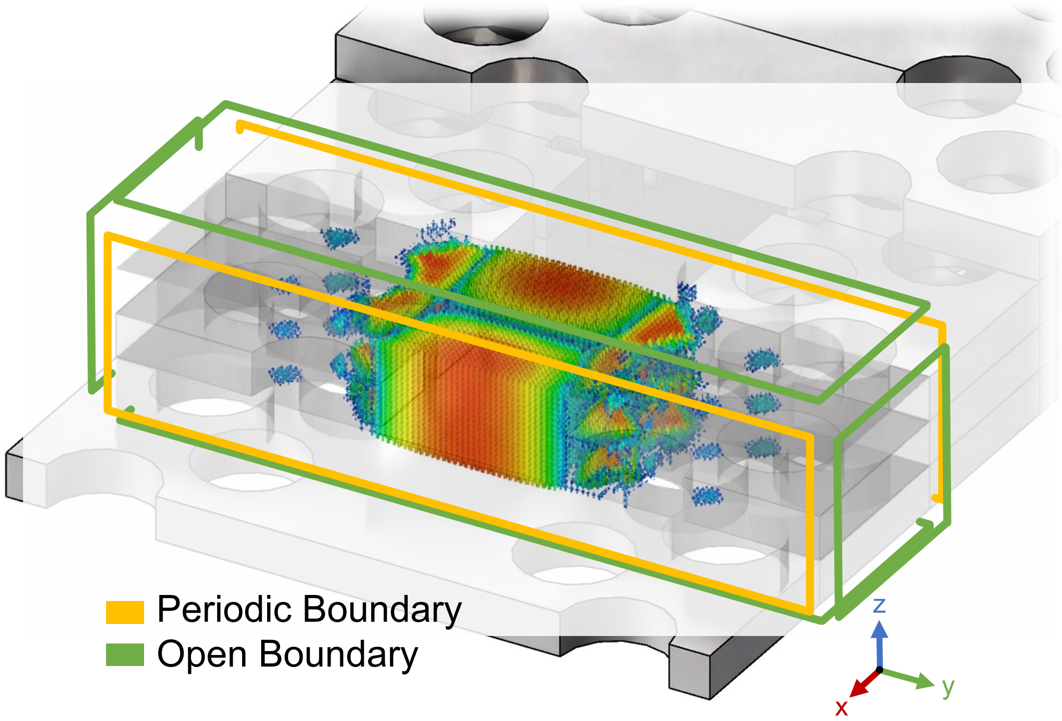
W BAND 75 – 110 GHz

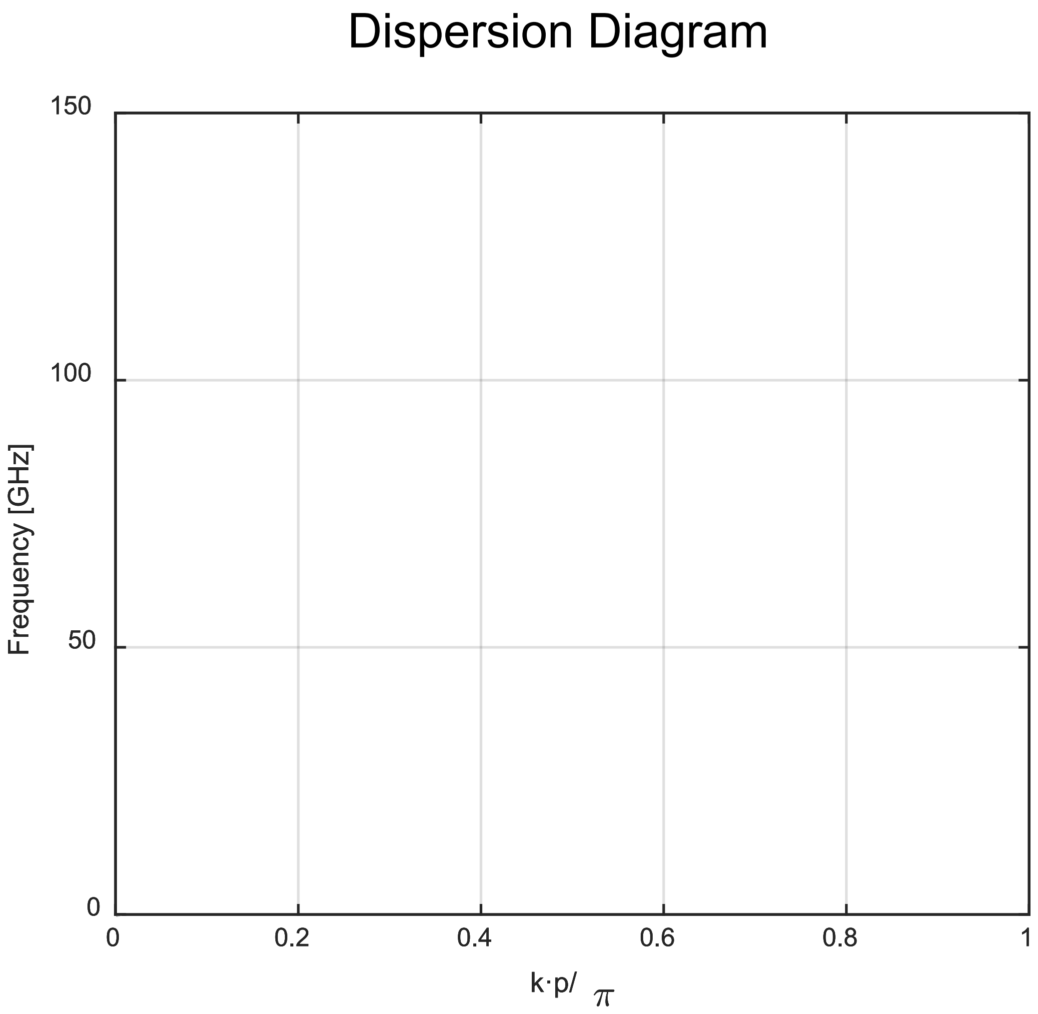
- Unknown gap [0 – 40 µm]
- Small p to improve:
  - antenna size
  - fit at the end



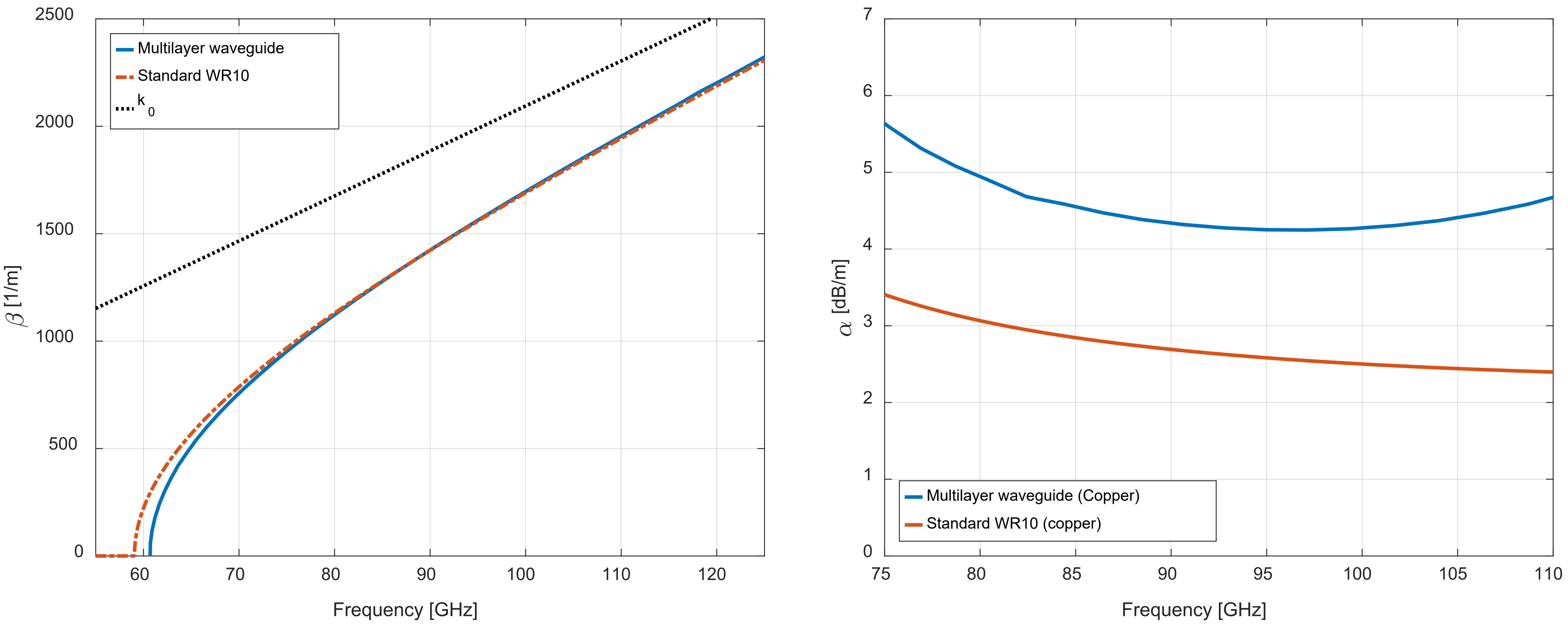
gap = 10 µm
p = 0.5 – 3.5 mm
D = 50 – 95 %



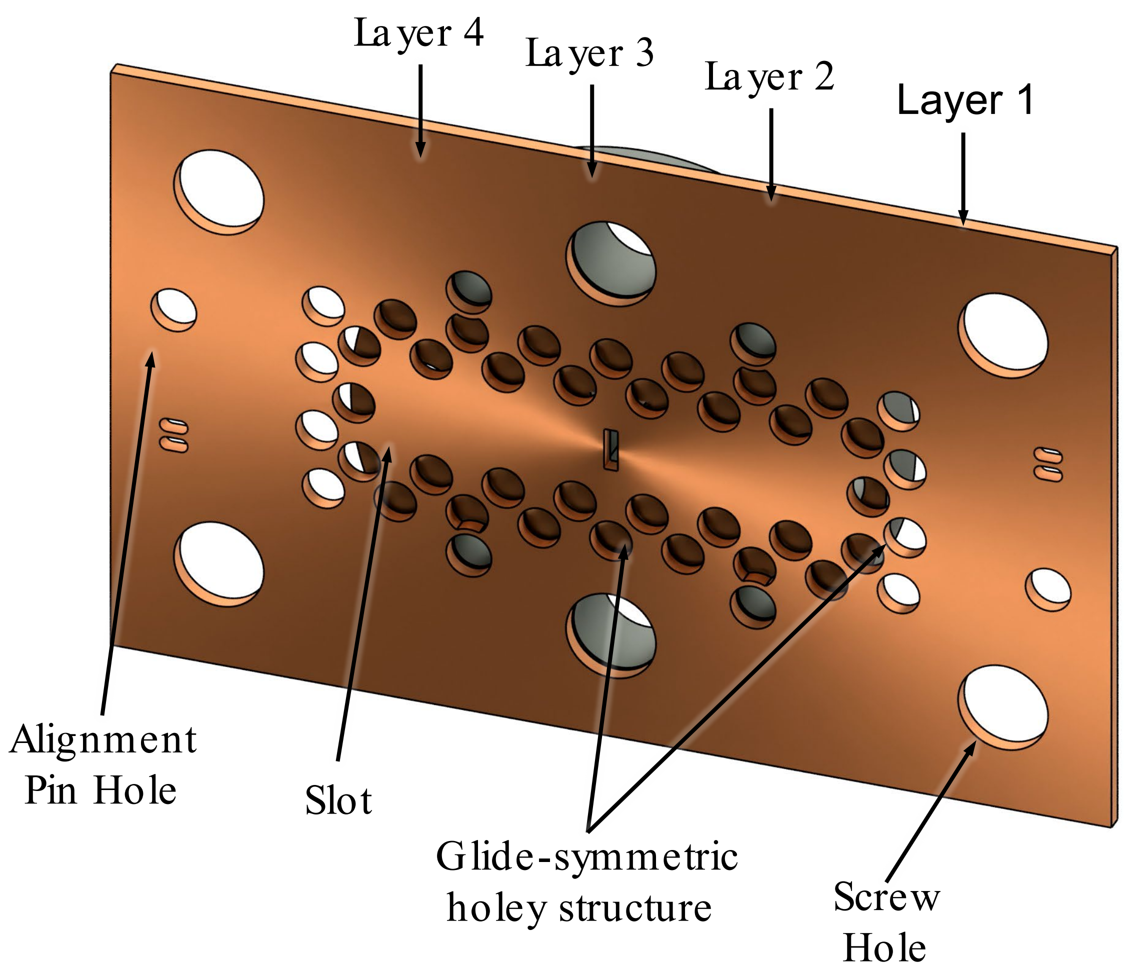

Periodic Boundary
Open Boundary
z
y
x

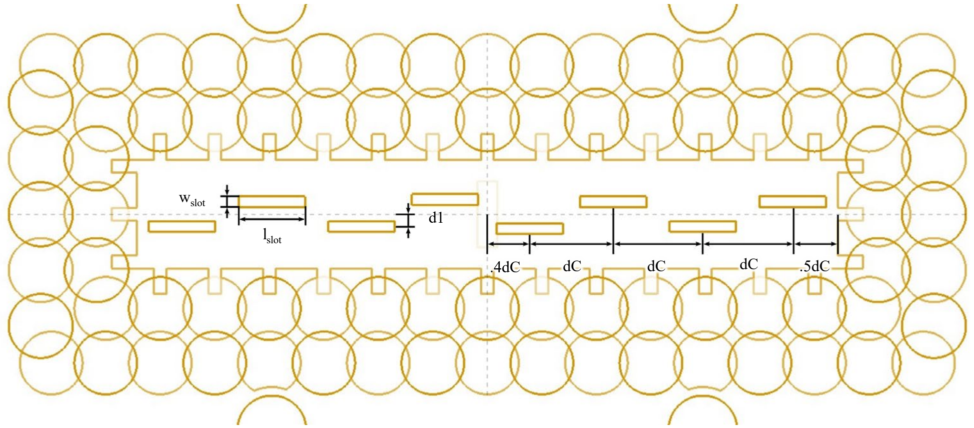

Dispersion Diagram
150
100
50
0
Frequency [GHz]
0
0.2
0.4
0.6
0.8
1
k·p/ π

Propagation Constant



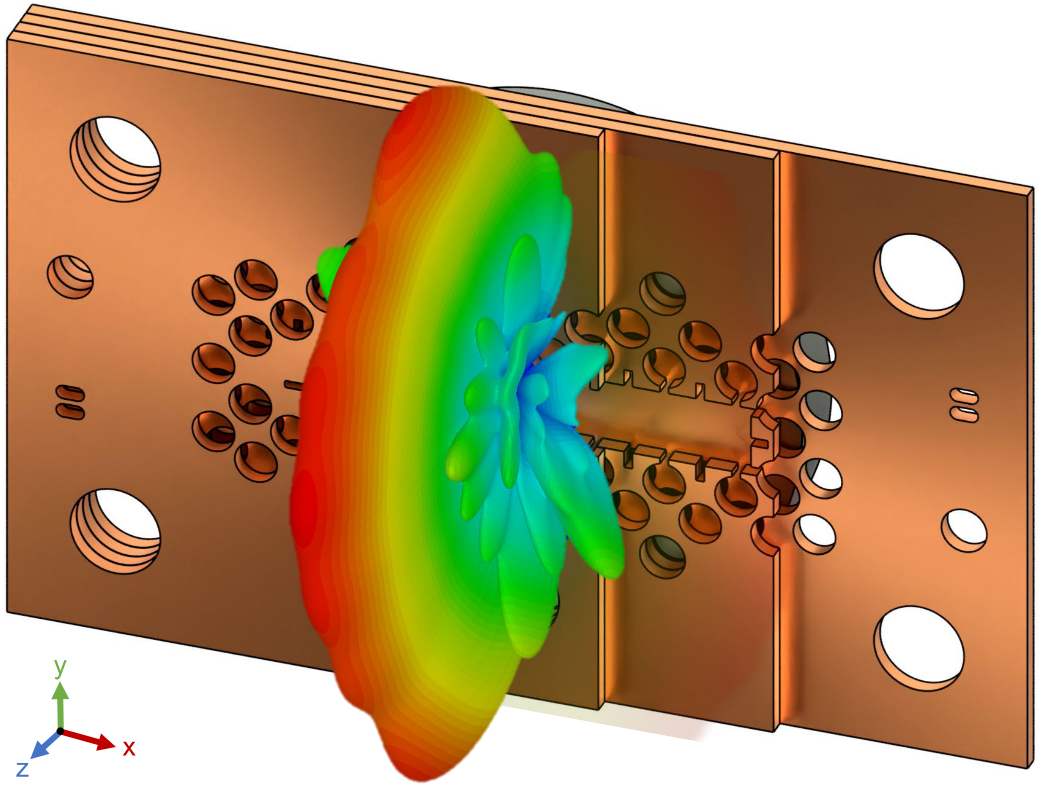
3. Slotted waveguide- Design

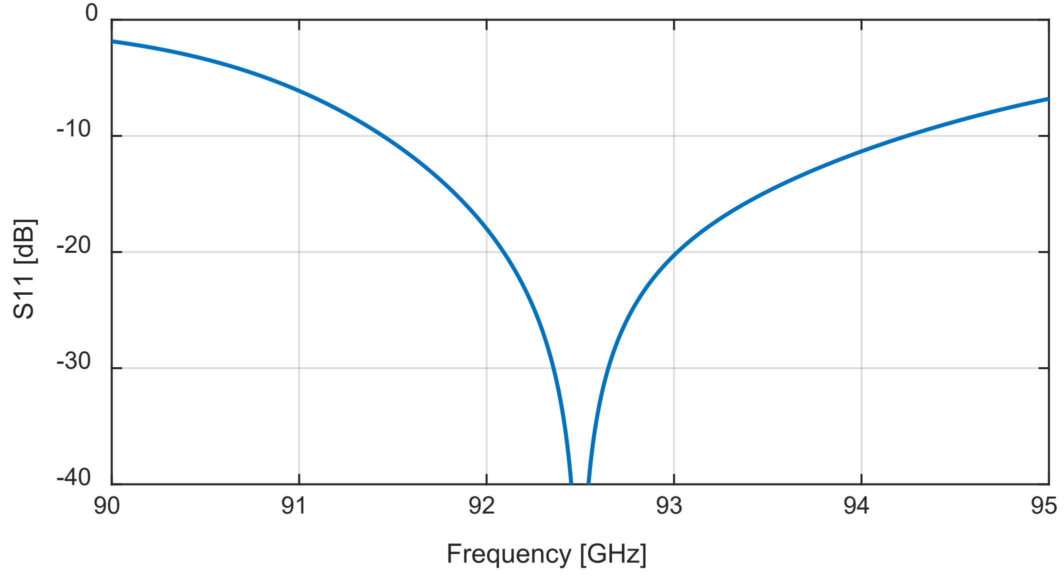


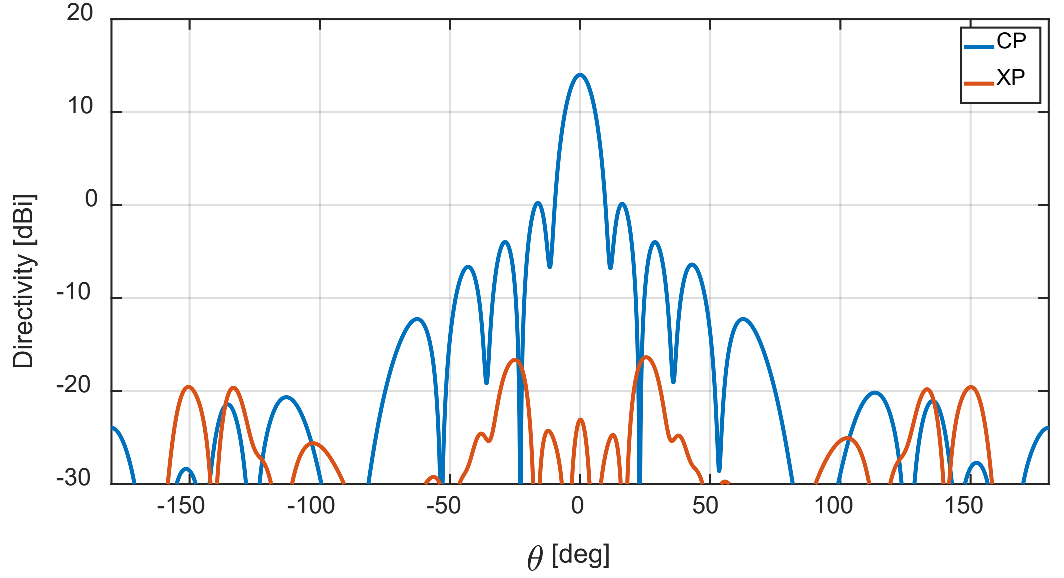


Parameter		Value (mm)
Unit cell period	p	1.85
Unit cell diameter	D_{hole}	1.47
Corrugation width	w_{corr}	0.3
Corrugation lenght	l_{corr}	0.6
Slot width	w_{slot}	0.25
Slot lenght	l_{slot}	1.55
Slot displacement	d1	0.29
Slot separation	dC	2.106

Antenna Dimensions:
35.6 x 22 mm







3. Slotted waveguide- Manufacturing

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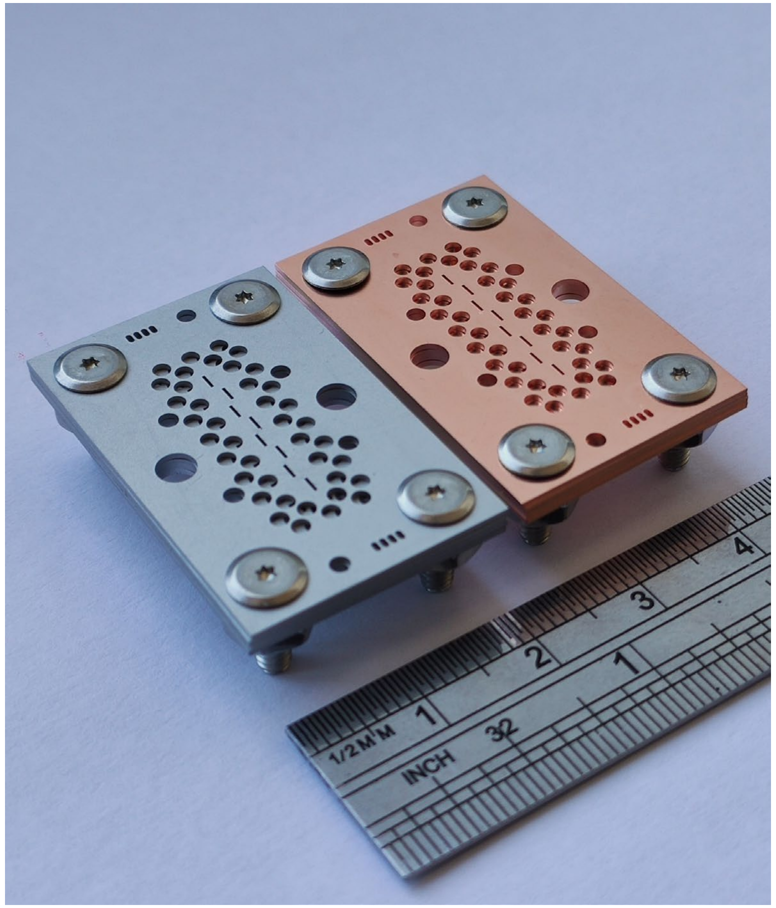

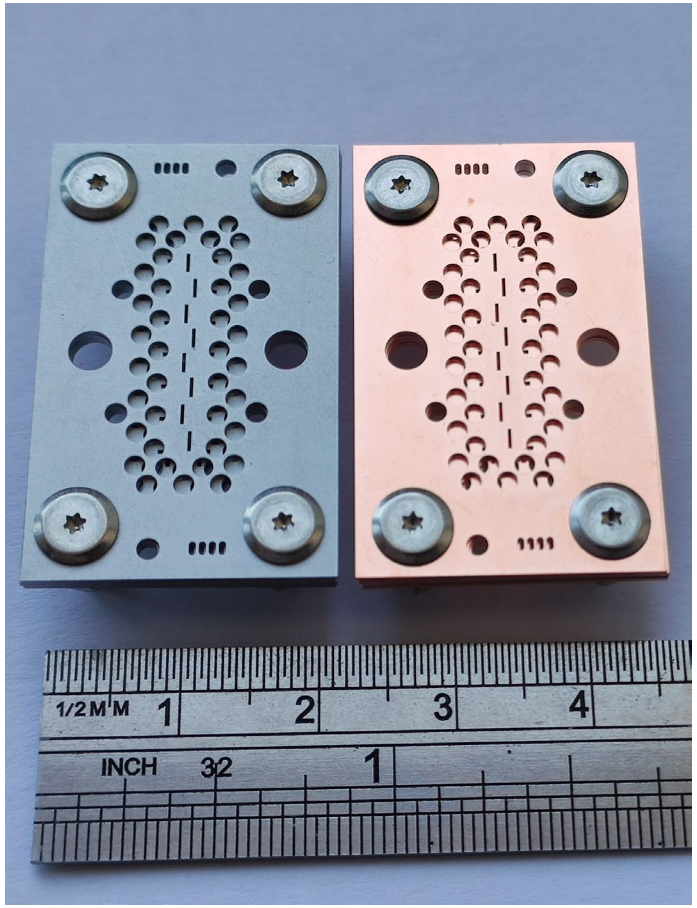

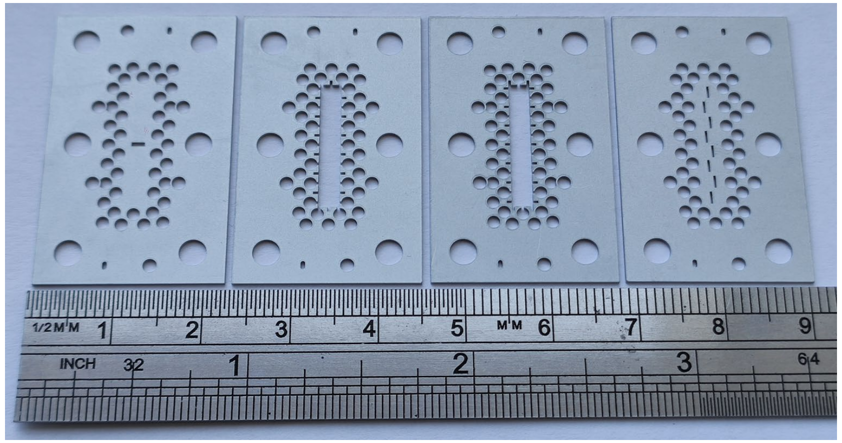

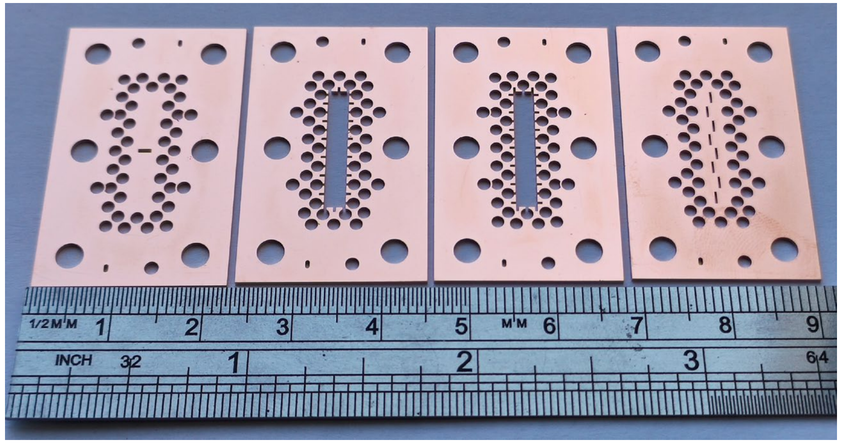

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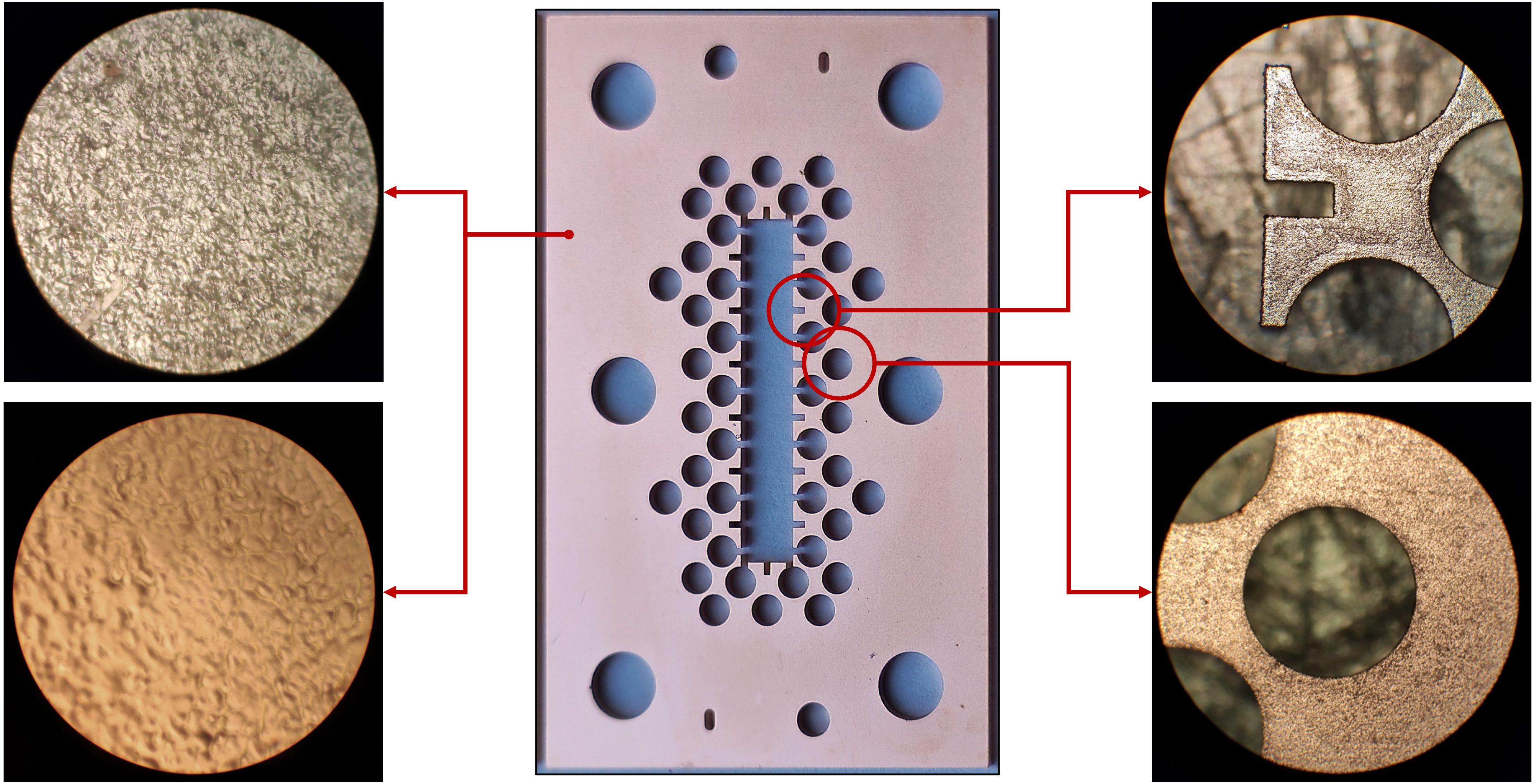
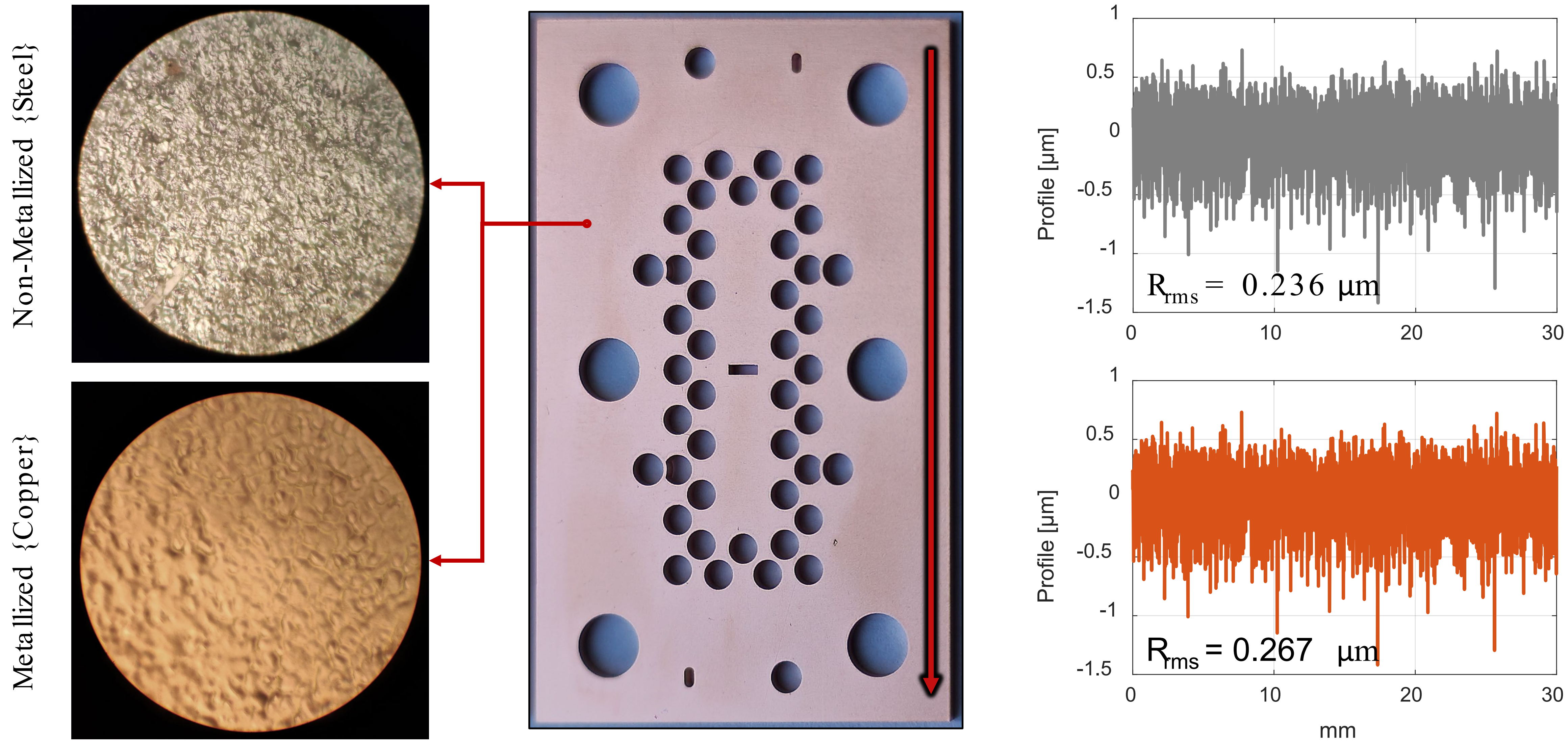
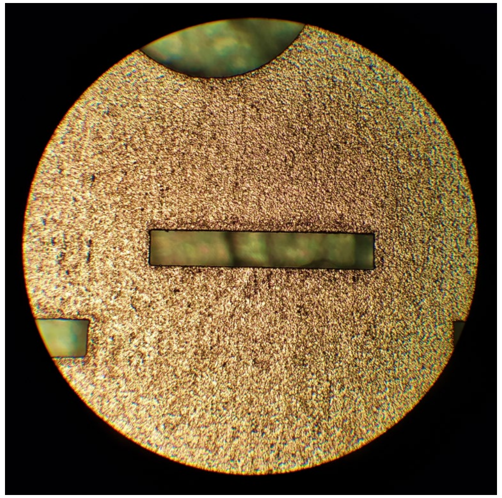
Non-Metallized {Steel}

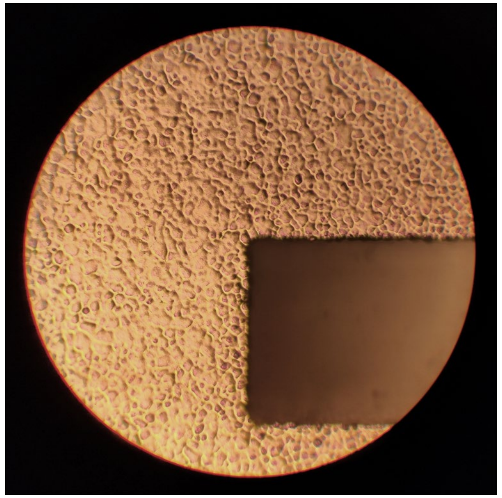
Metallized {Copper}

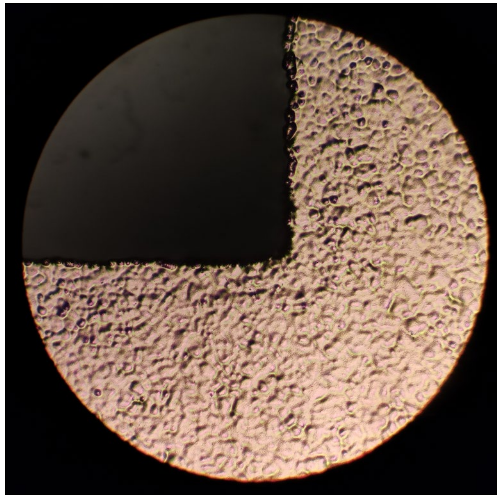


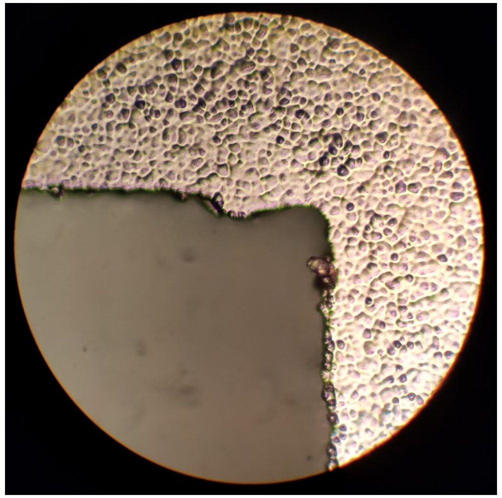


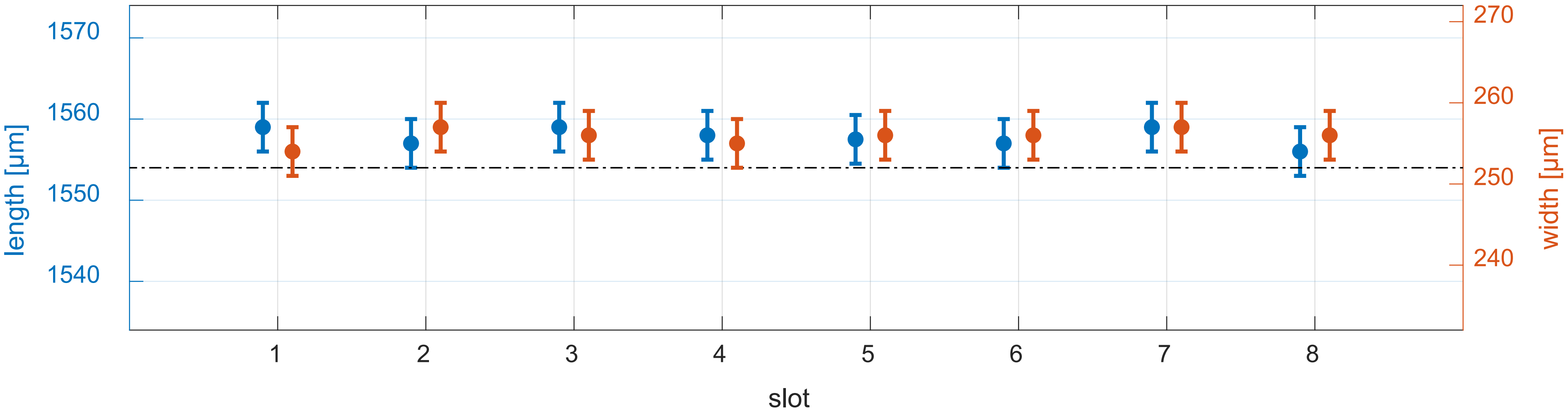
Non-Metallized {Steel}
Metallized {Copper}
Profile [µm]
R_{rms} = 0.236 µm
R_{rms} = 0.267 µm
mm
1
0.5
0
-0.5
-1
-1.5
0
10
20
30







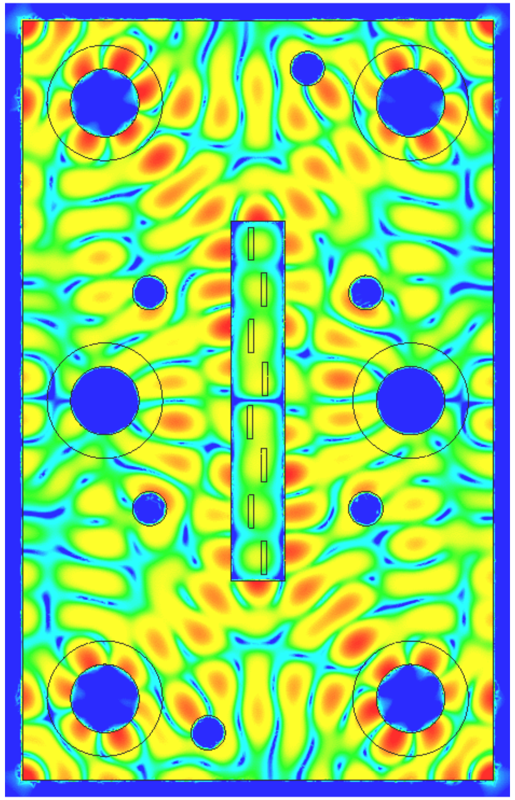



1570
1560
1550
1540
length [μm]
270
260
250
240
width [μm]
1
2
3
4
5
6
7
8
slot

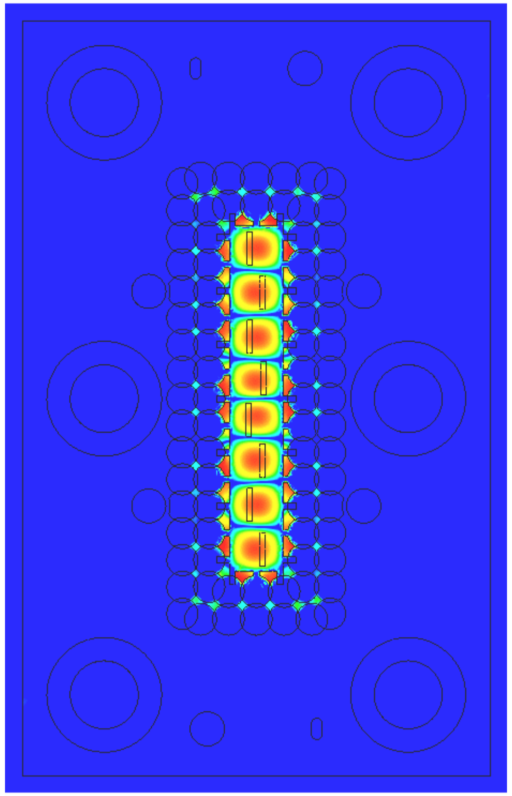
3. Slotted waveguide- Results

Without EBG

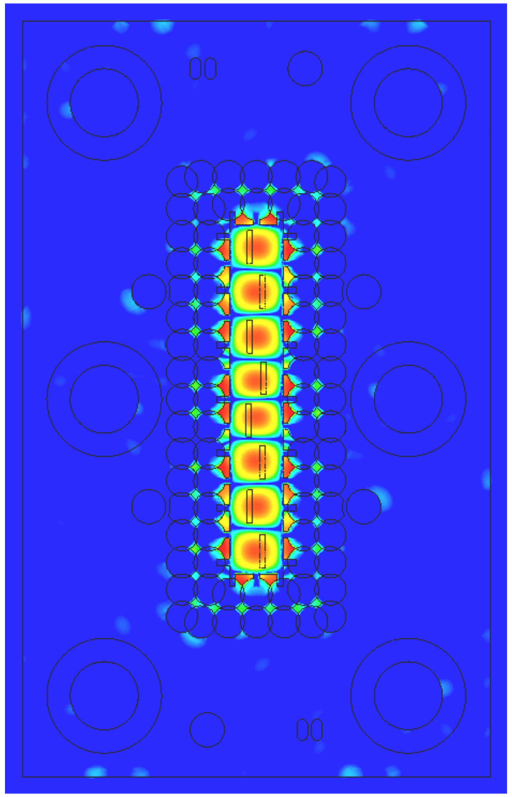
With EBG



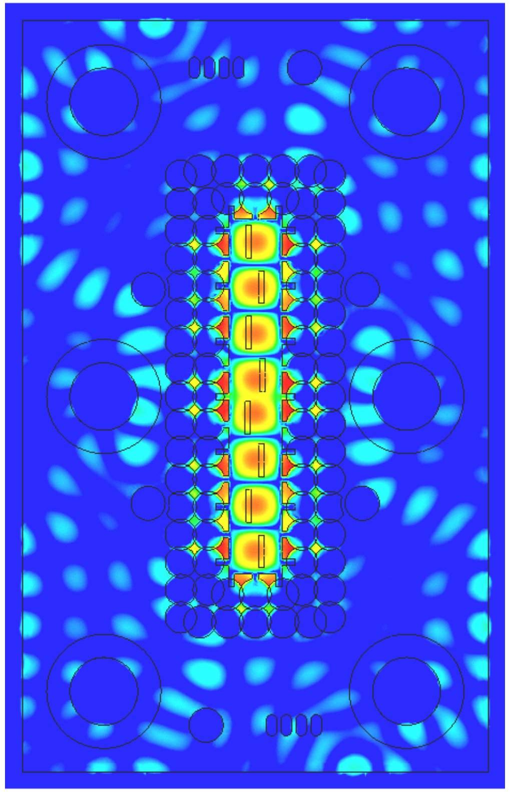
GAP = 20 µm



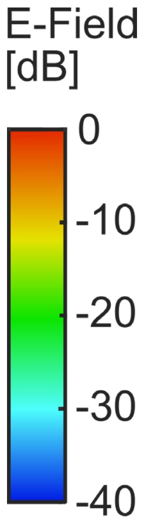
GAP = 10 µm

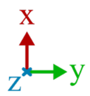


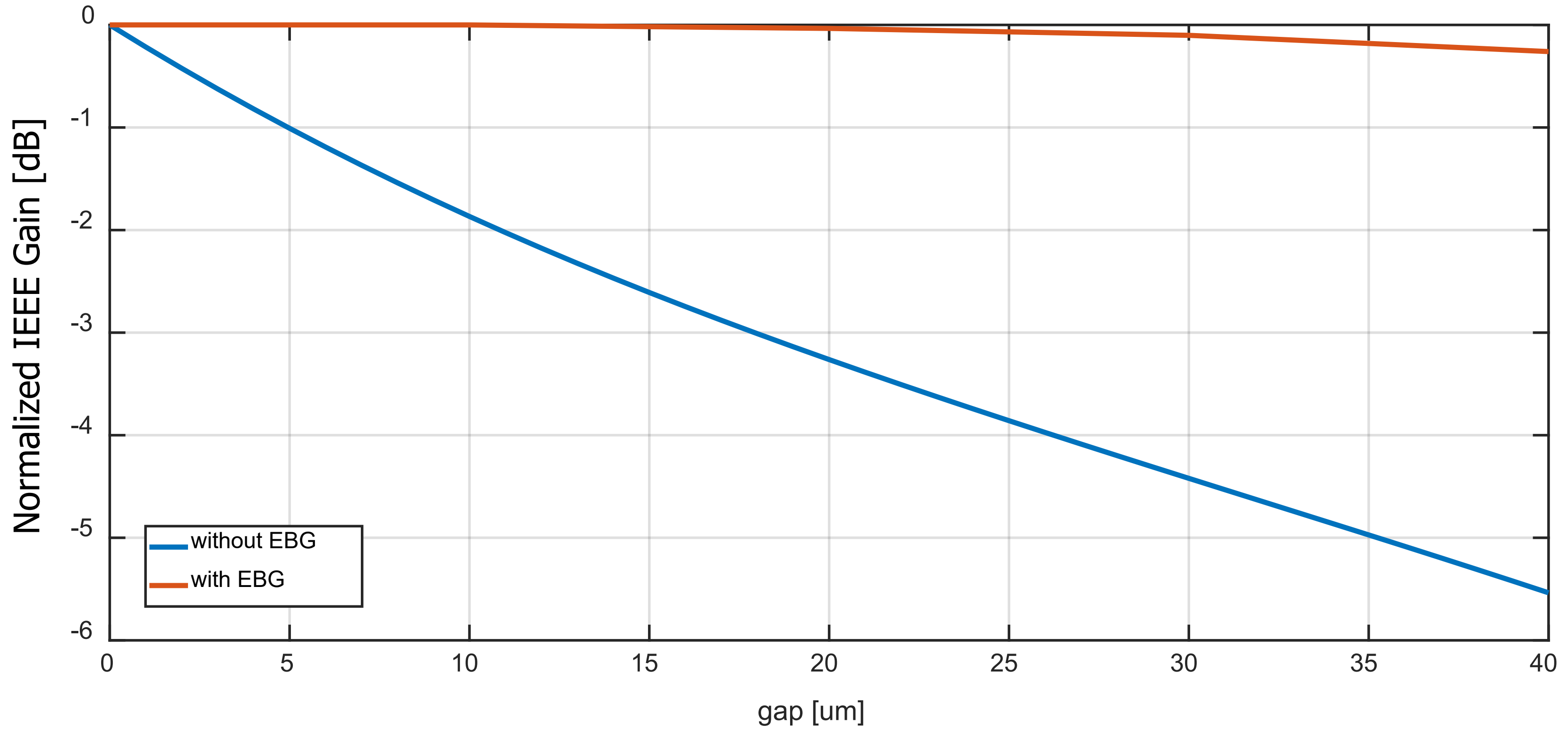
GAP = 20 µm

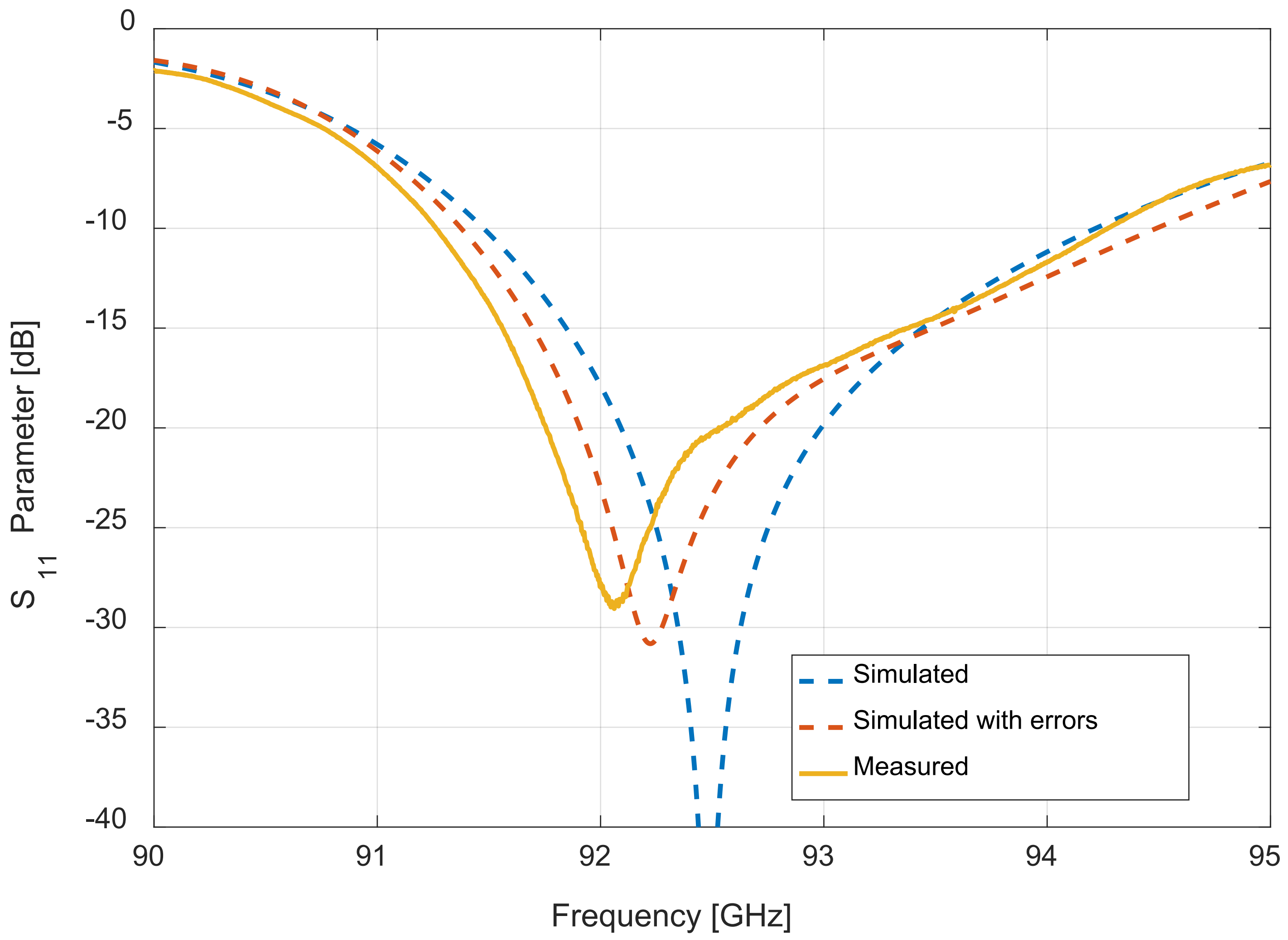


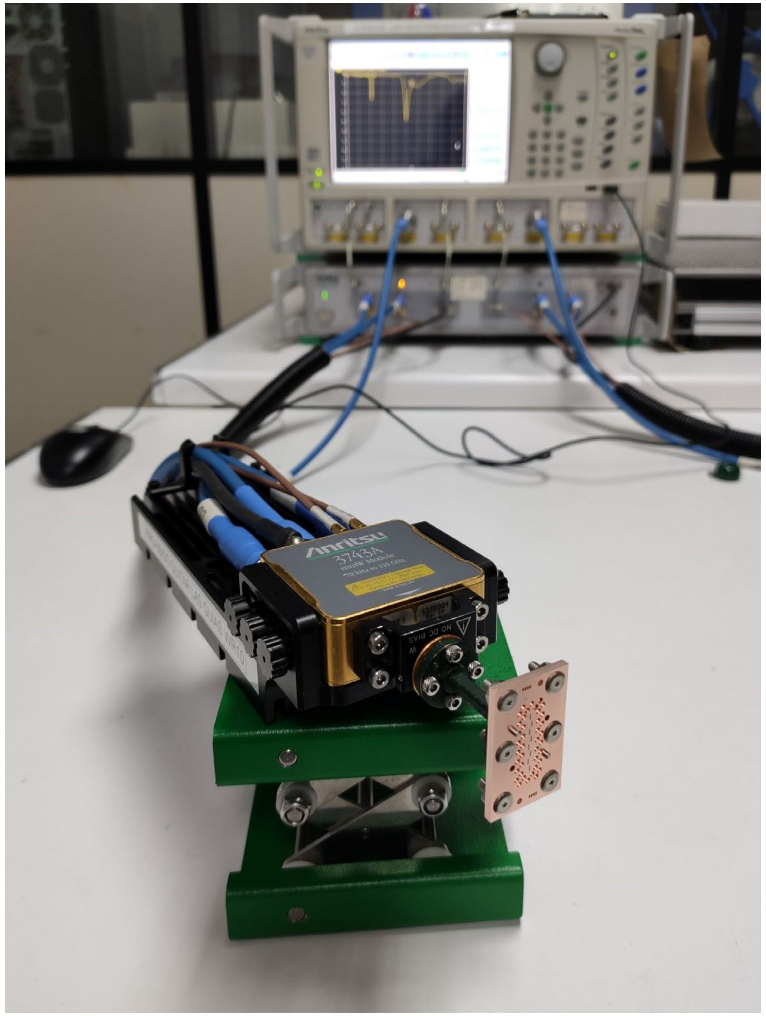
GAP = 40 µm



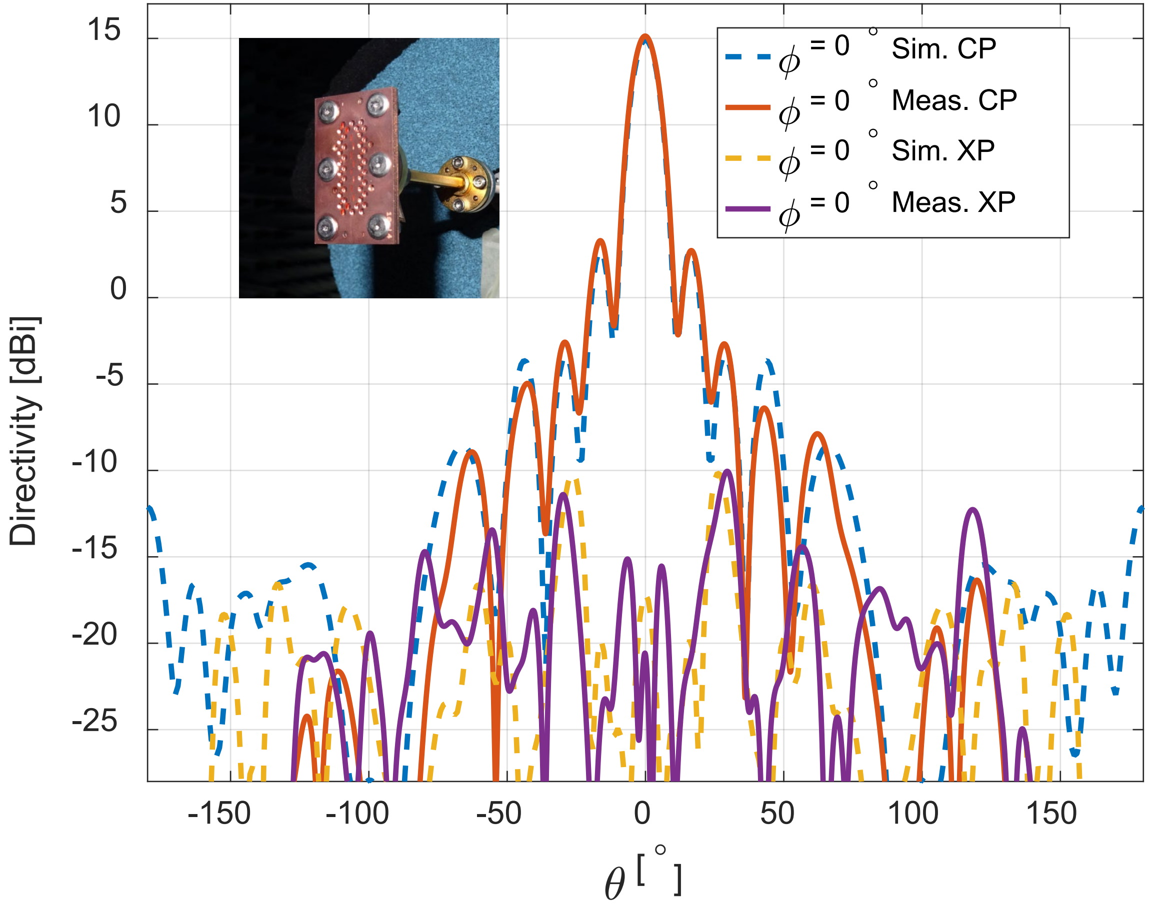


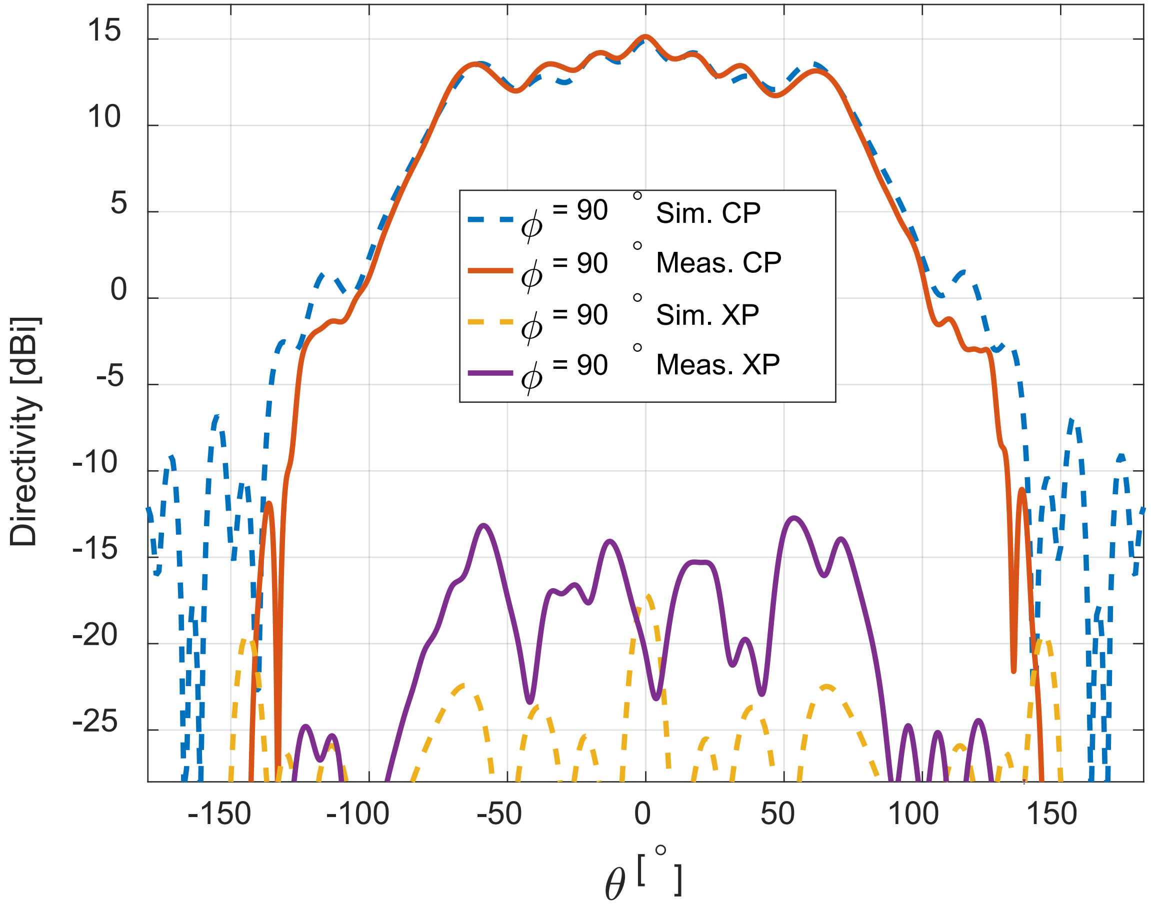

Normalized IEEE Gain [dB]
gap [um]
without EBG
with EBG
0
-1
-2
-3
-4
-5
-6
0
5
10
15
20
25
30
35
40


0
-5
-10
-15
-20
-25
-30
-35
-40
90
91
92
93
94
95
S_{11} Parameter [dB]
Frequency [GHz]
Simulated
Simulated with errors
Measured

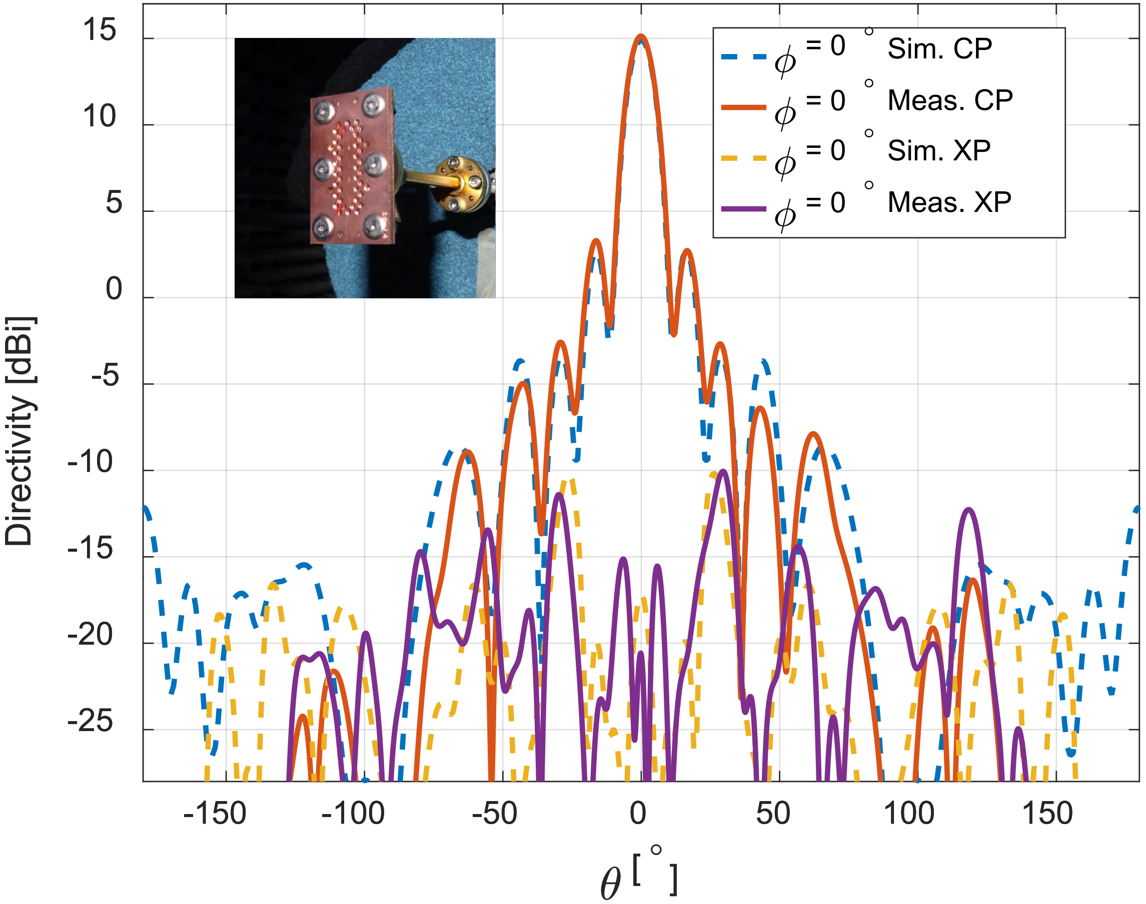


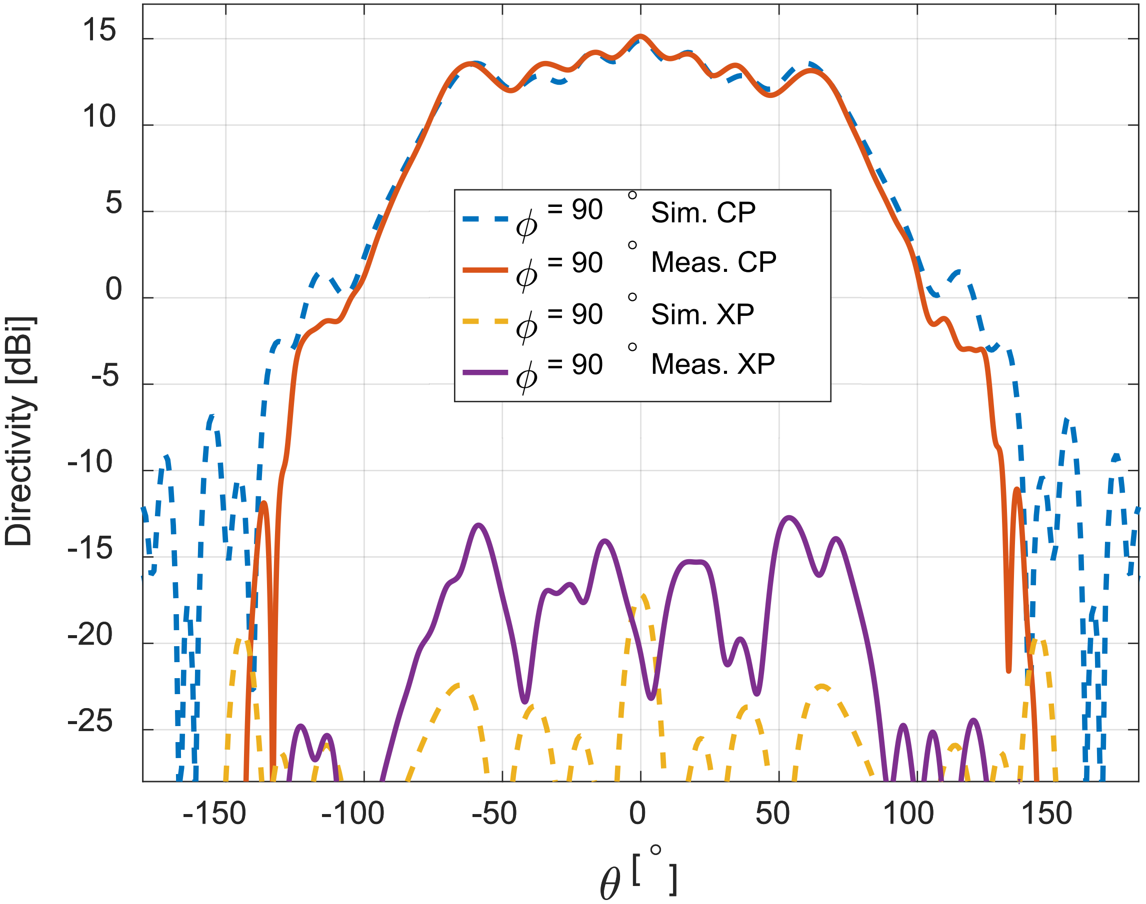
Measured Loss (with EBG structure) = 0.12 dB





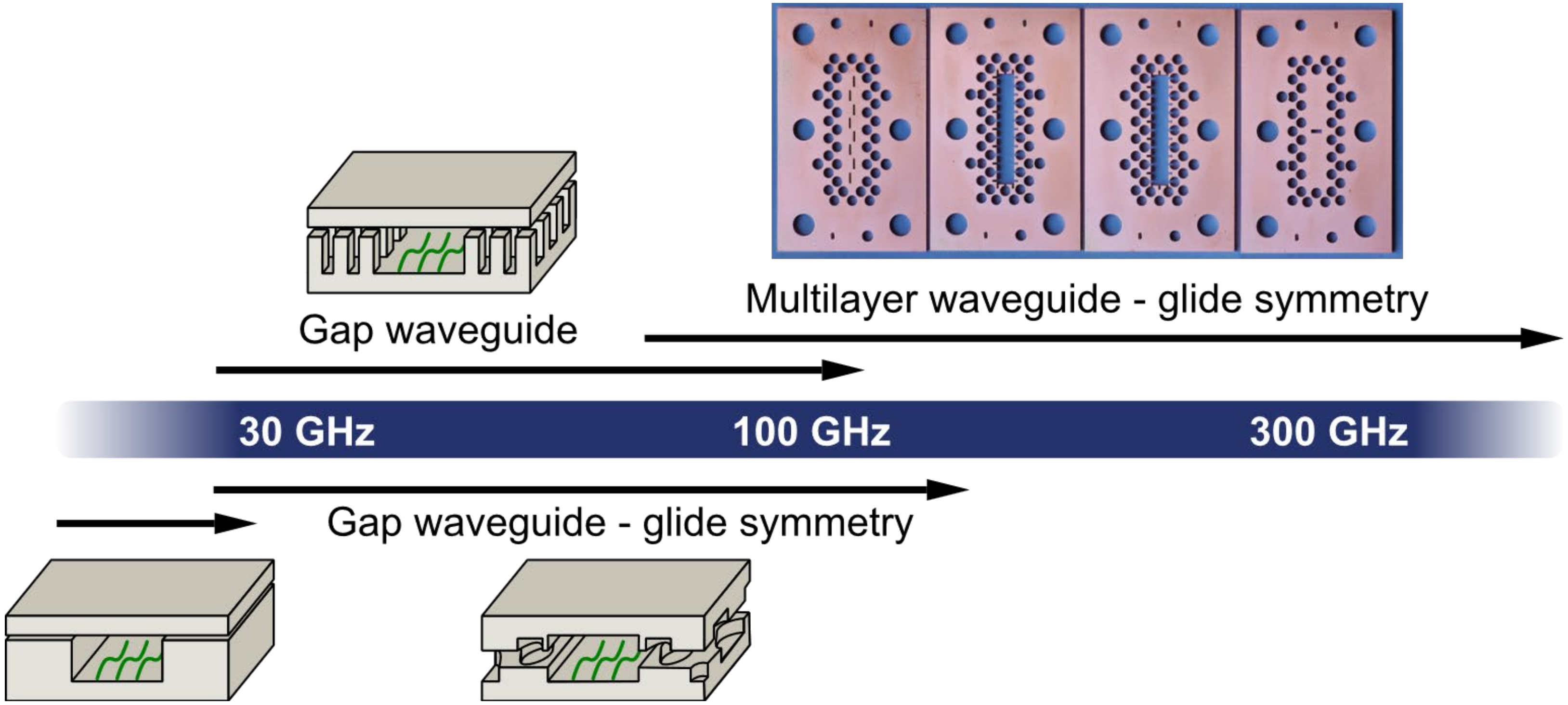
Measured Loss (with EBG structure) = 0.12 dB
Measured Loss (without the EBG structure) = 1.05 dB





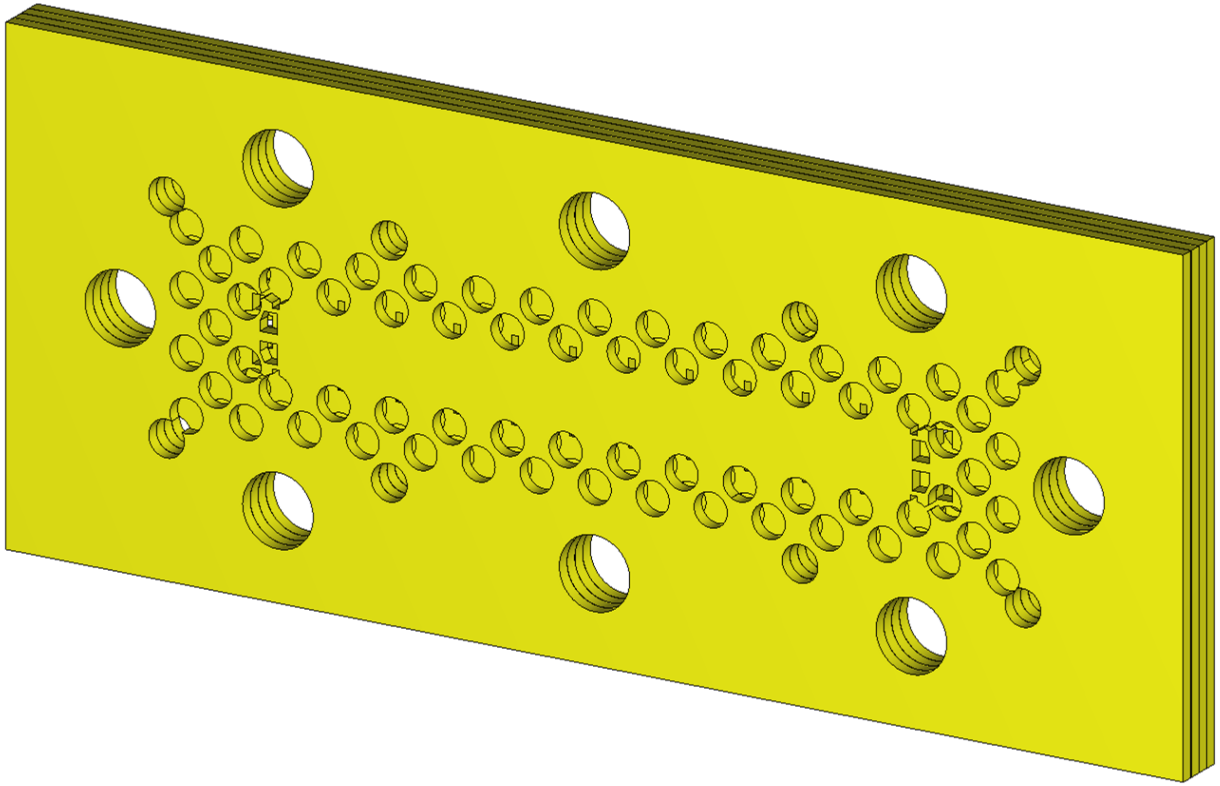
4. Conclusions

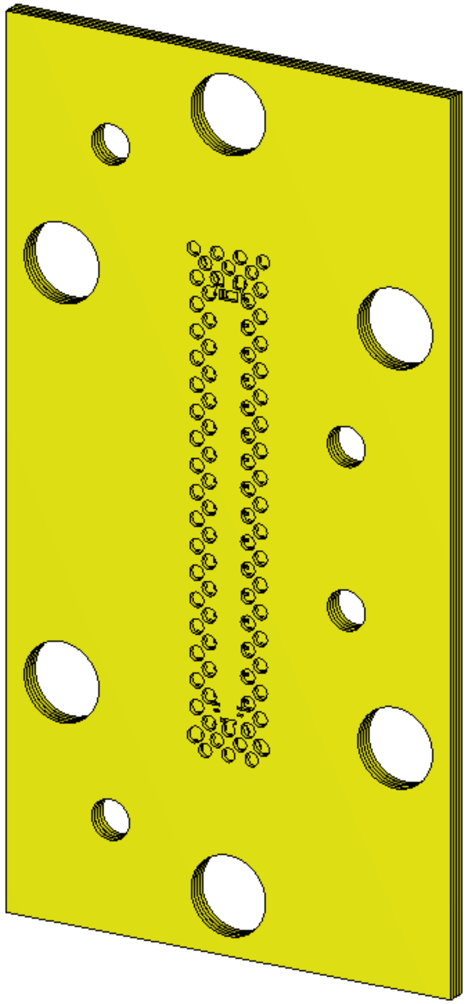
- Low-loss transmission line at W band
- Scalable to higher frequencies
- Easy-to-manufacture, high-precision and low-cost technology



Designs we are currently working on…

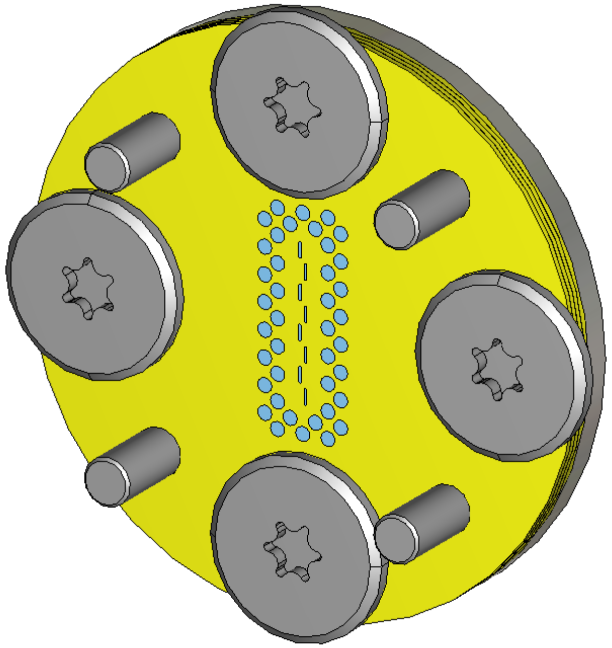
- Lines at W band and up to 300 GHz

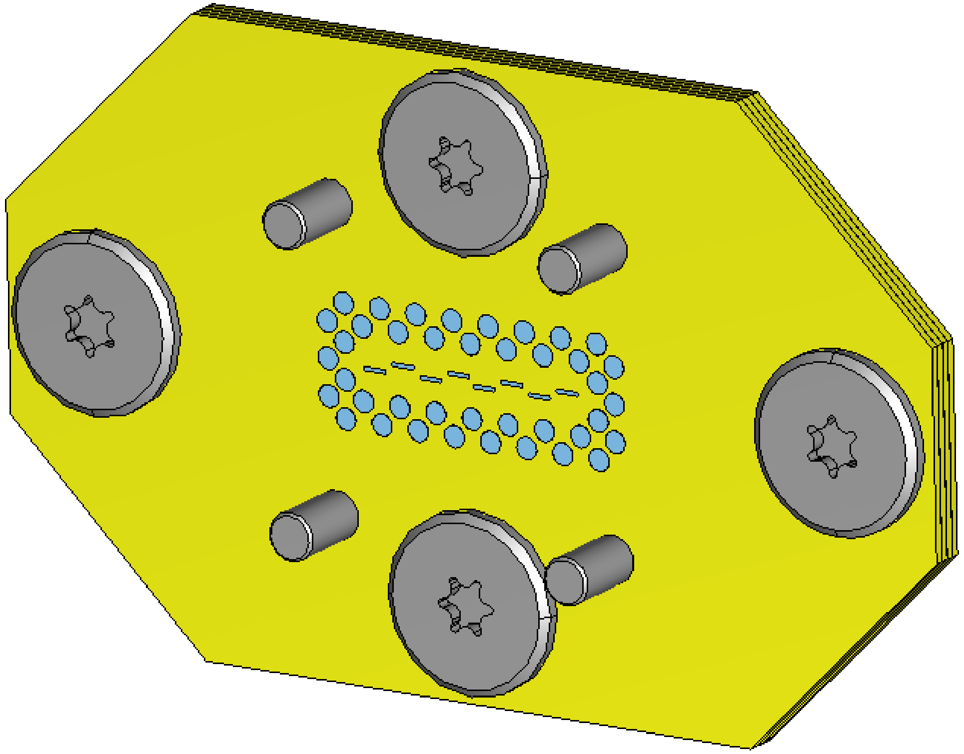




Designs we are currently working on…

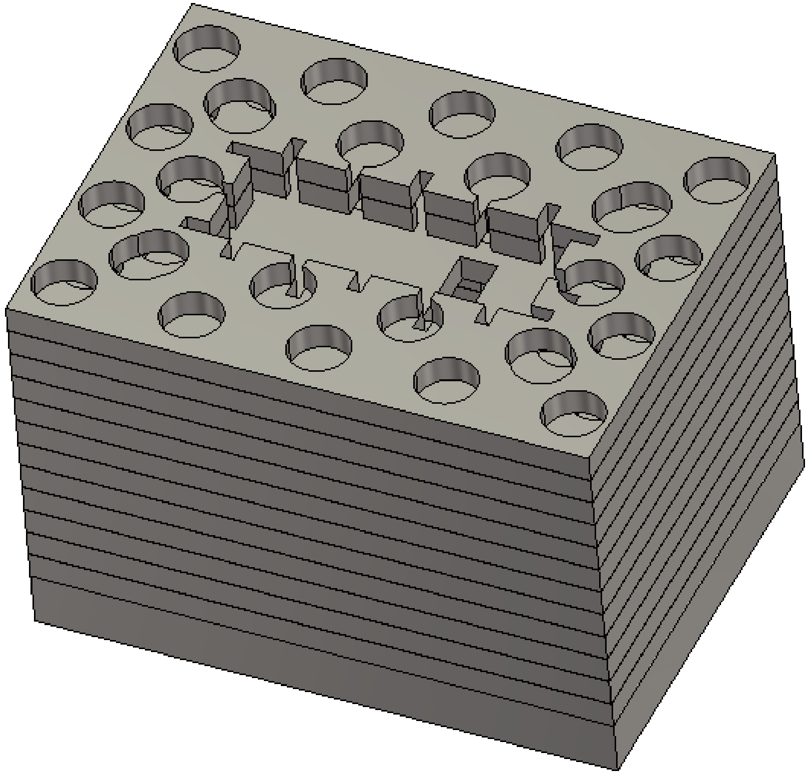
- SWAs at 200 and 300 GHz

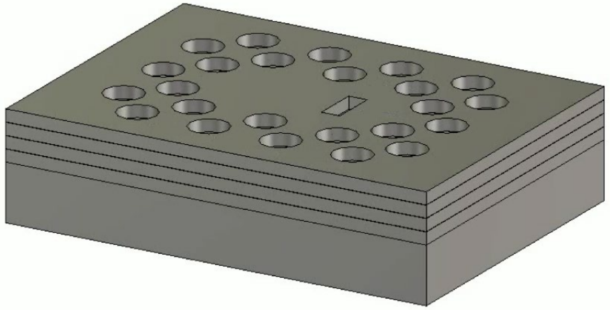


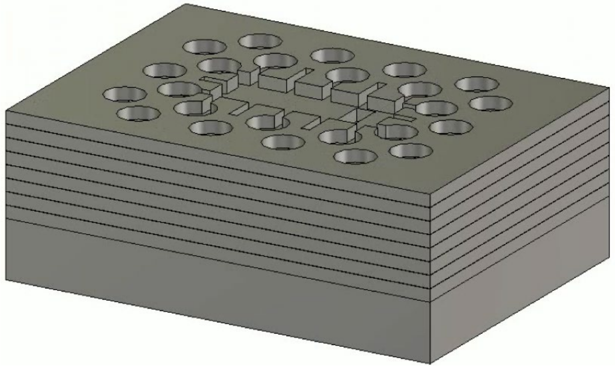


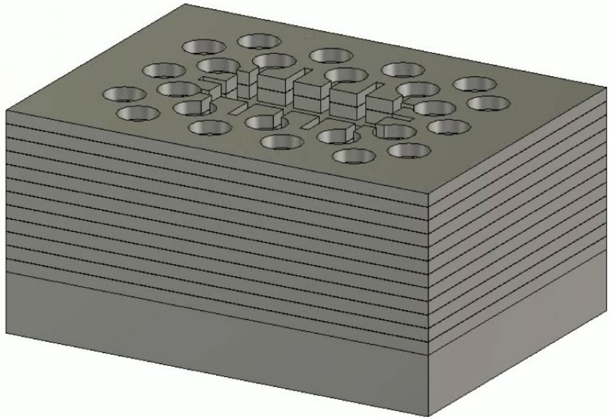
Designs we are currently working on…

- Filters at W band



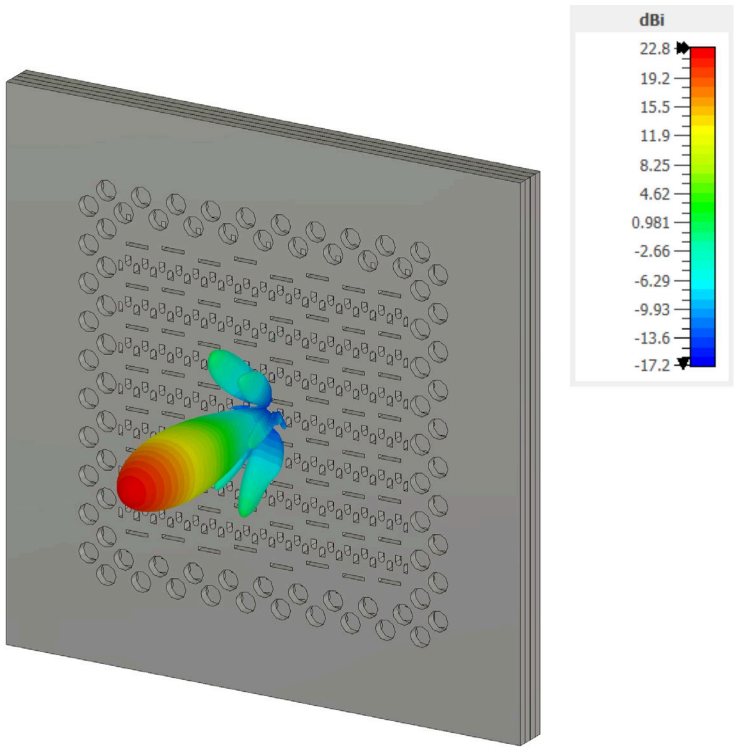


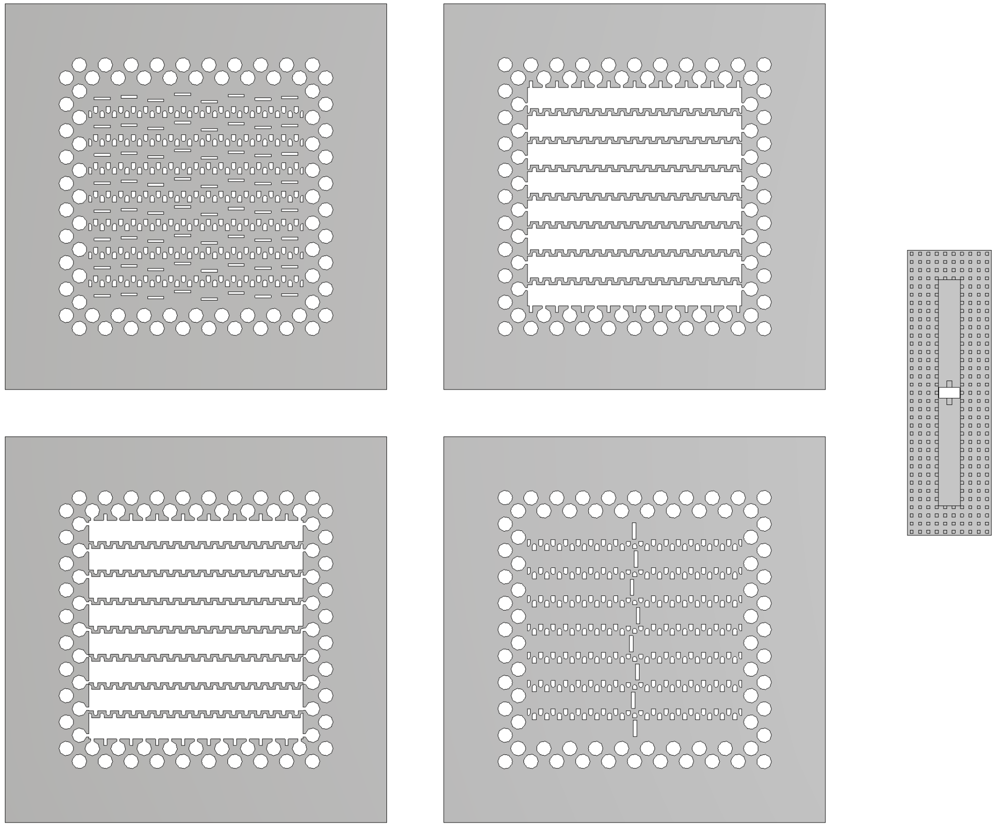




Designs we are currently working on…

- Planar arrays at W band





References

[1] Qualcomm, "5 key technology inventions in 5G NR Release 17," 13 April 2022. [Online]. Available: https://www.qualcomm.com/news/onq/2022/04/5-key-technology-inventions-5g-nr-release-17. [Accessed July 2023].

[2] Machine Design, "Saved by the Sensor: Vehicle Awareness in the Self-Driving Age," 18 January 2018. [Online]. Available: https://www.machinedesign.com/mechanical-motion-systems/article/21836344/saved-by-the-sensor-vehicle-awareness-in-the-selfdriving-age. [Accessed July 2023].

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Slotted Waveguide Antenna Design at W-Band Using Stacked Glide-Symmetric Metal Sheets

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