DEVELOPMENT OF A MODIFIED SIX-PORT DISCRIMINATOR FOR PRECISE BEAM POSITION MEASUREMENTS

A. Penirschke, T. Mahn, A. Angelovski, M. Hansli, R. Jakoby

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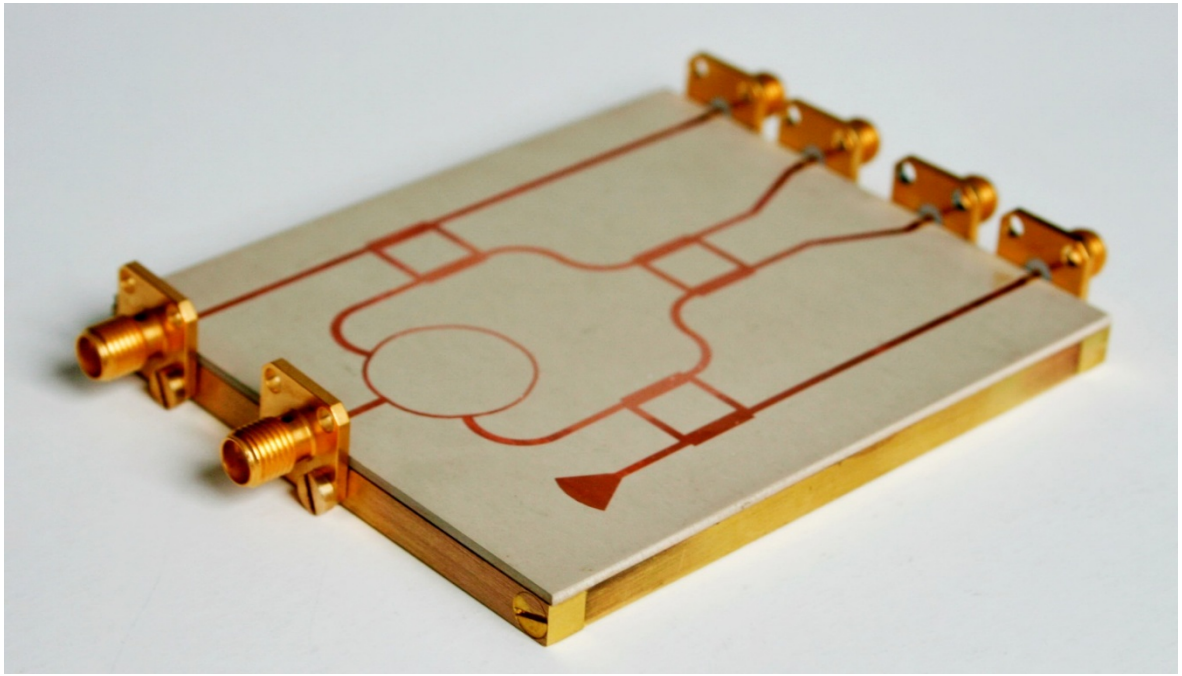

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Outline

TECHNISCHE UNIVERSITÄT DARMSTADT

- Motivation - Energy BPM for FLASH and XFEL
- Six-Port Reflectometer
- System Measurements
- Conclusion & Outlook

New Energy Beam Position Monitors for FLASH and European XFEL

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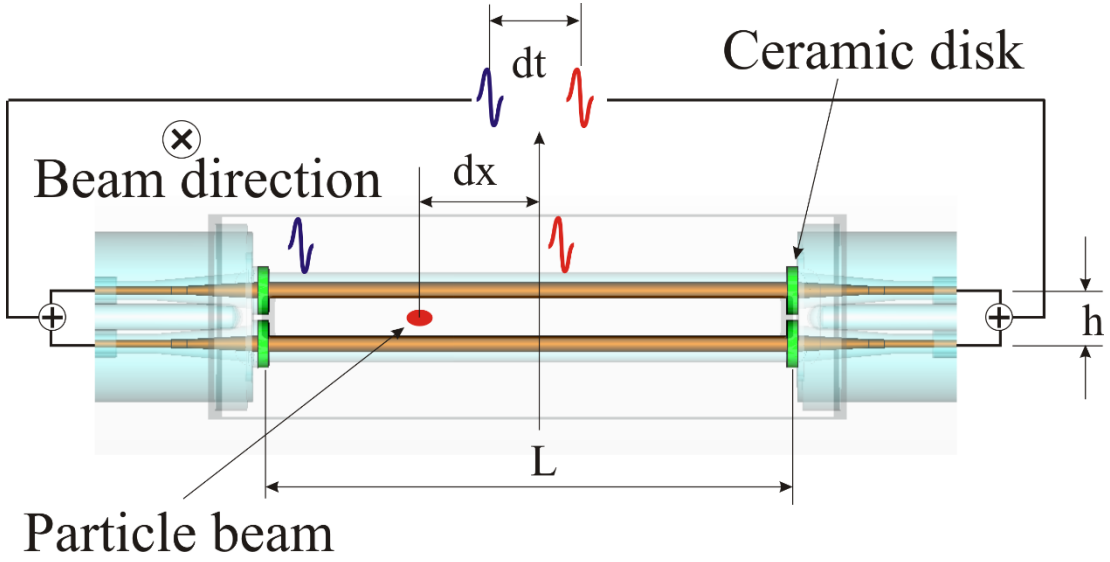
- EBPM: Energy Beam Position Monitor in the dispersive section of a bunch compressor chicane for energy measurements
- Position measurement proportional to bunch energy $dx \sim \frac{dE}{E}$
- Current implementation at FLASH



New Energy Beam Position Monitors for FLASH and European XFEL

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- Upgrade of EBPMs at FLASH and European XFEL necessary

- Design parameters for FLASH and the European XFEL

	FLASH	XFEL
L [mm]	183	400
H [mm]	8	40.5
Frequency [GHz]	1.3	3
Bunch charge [pC]	<200	20

- Improved, mechanical stable design of the pickup structures necessary

New Energy Beam Position Monitors for FLASH and European XFEL

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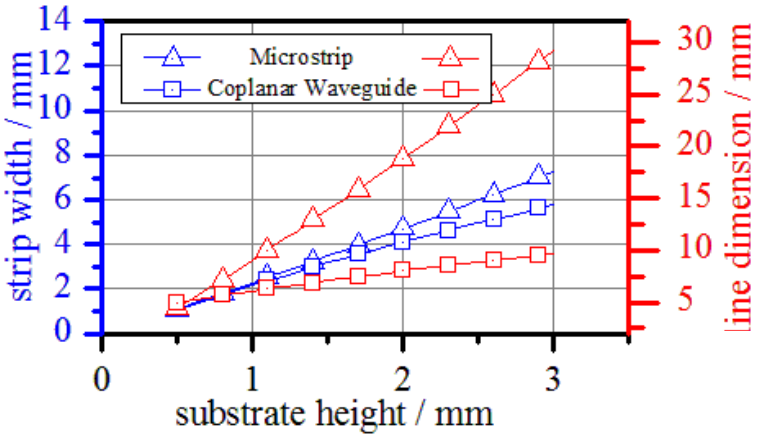
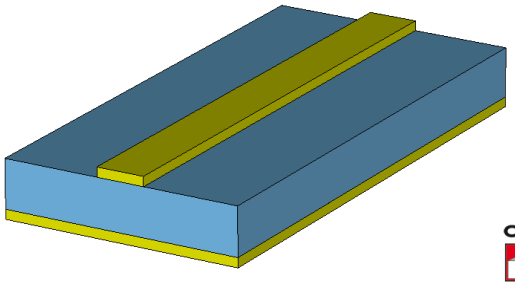
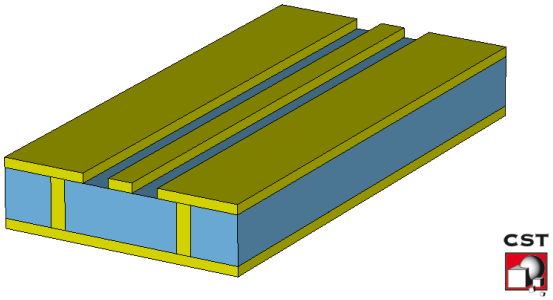
Planar transmission line pickups







- Microstrip transmission line as a **Baseline** design[1] for FLASH and XFEL
- Grounded coplanar waveguide transmission line as an **Improved** option[2] for FLASH and XFEL

[1]Angelovski et al. MOPA47, IBIC 2012, Tsukuba, Japan
[2] Penirschke et al. TUPC29, IBIC 2013, Oxford, UK

New Energy Beam Position Monitors for FLASH and European XFEL

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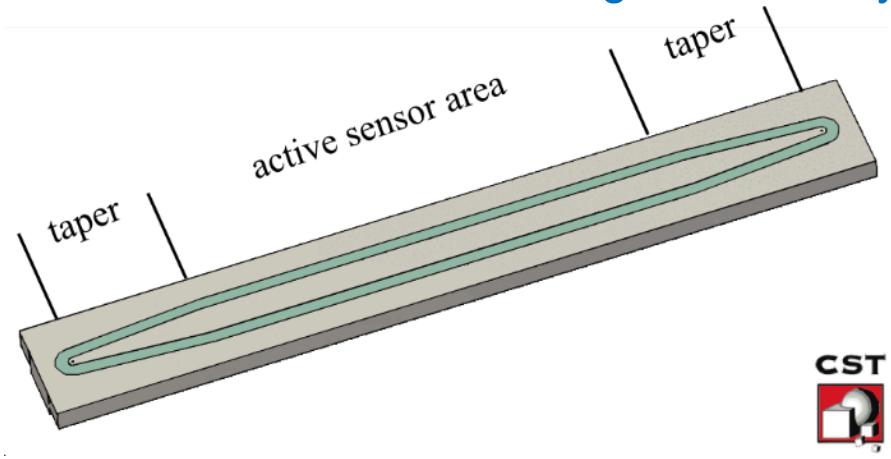
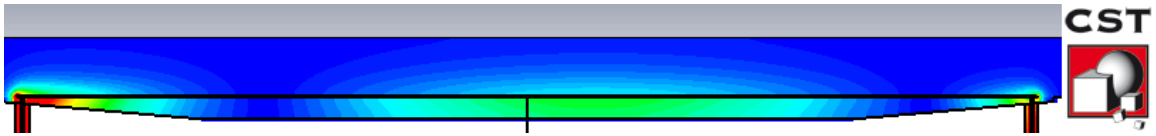
- Taper of substrate height improves the input reflection
- Complicated structure; fabrication with standard substrate hardy possible
  - ✓ Substrate made of melted glass in cavity





E-field distribution @ 1.3 GHz and 3 GHz

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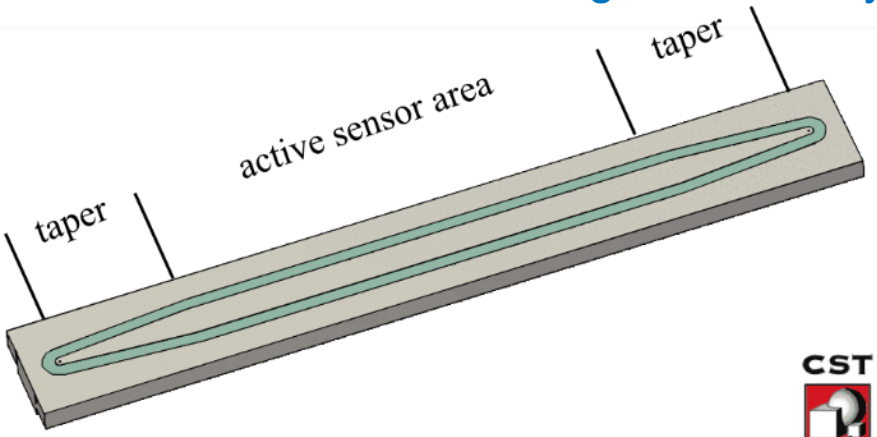
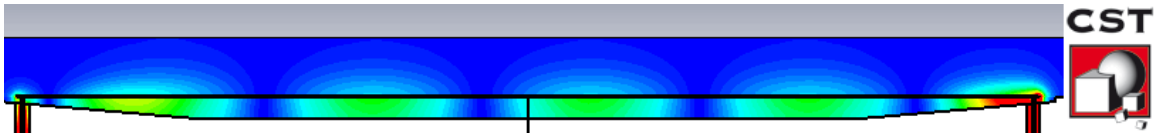
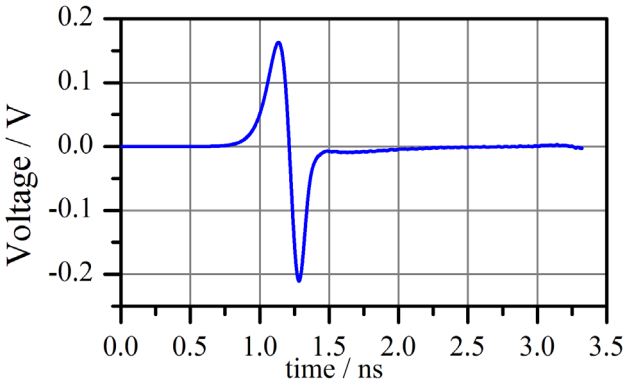




E-field distribution @ 1.3 GHz and 3 GHz

Pickup voltage signal @ 20pC



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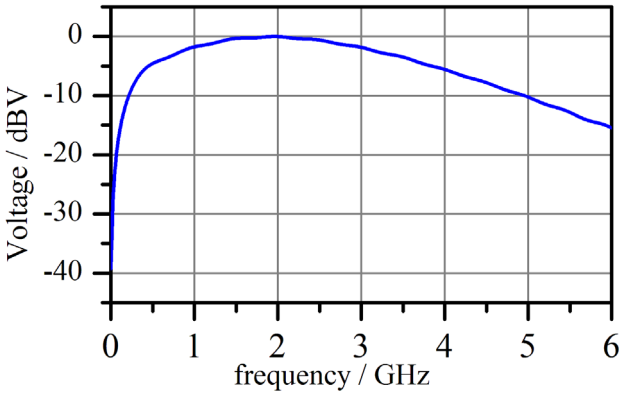

Frequency domain

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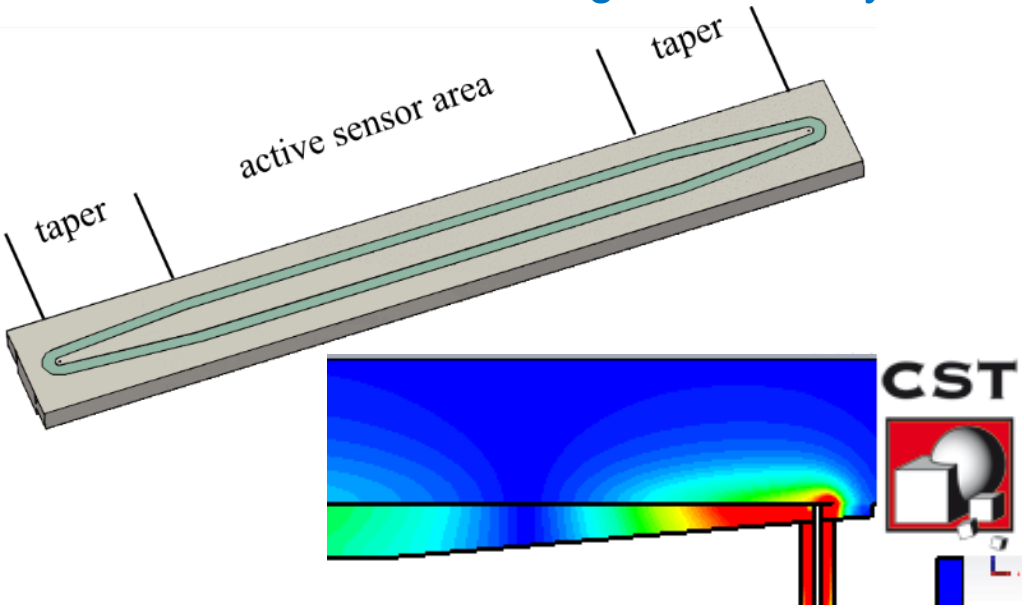

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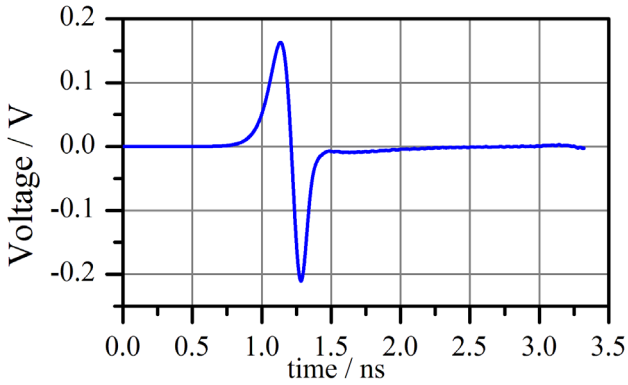

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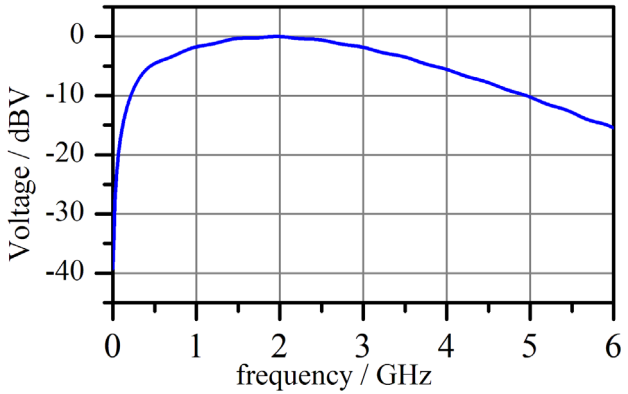

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Six-Port Reflectometer for Phase Difference Measurements

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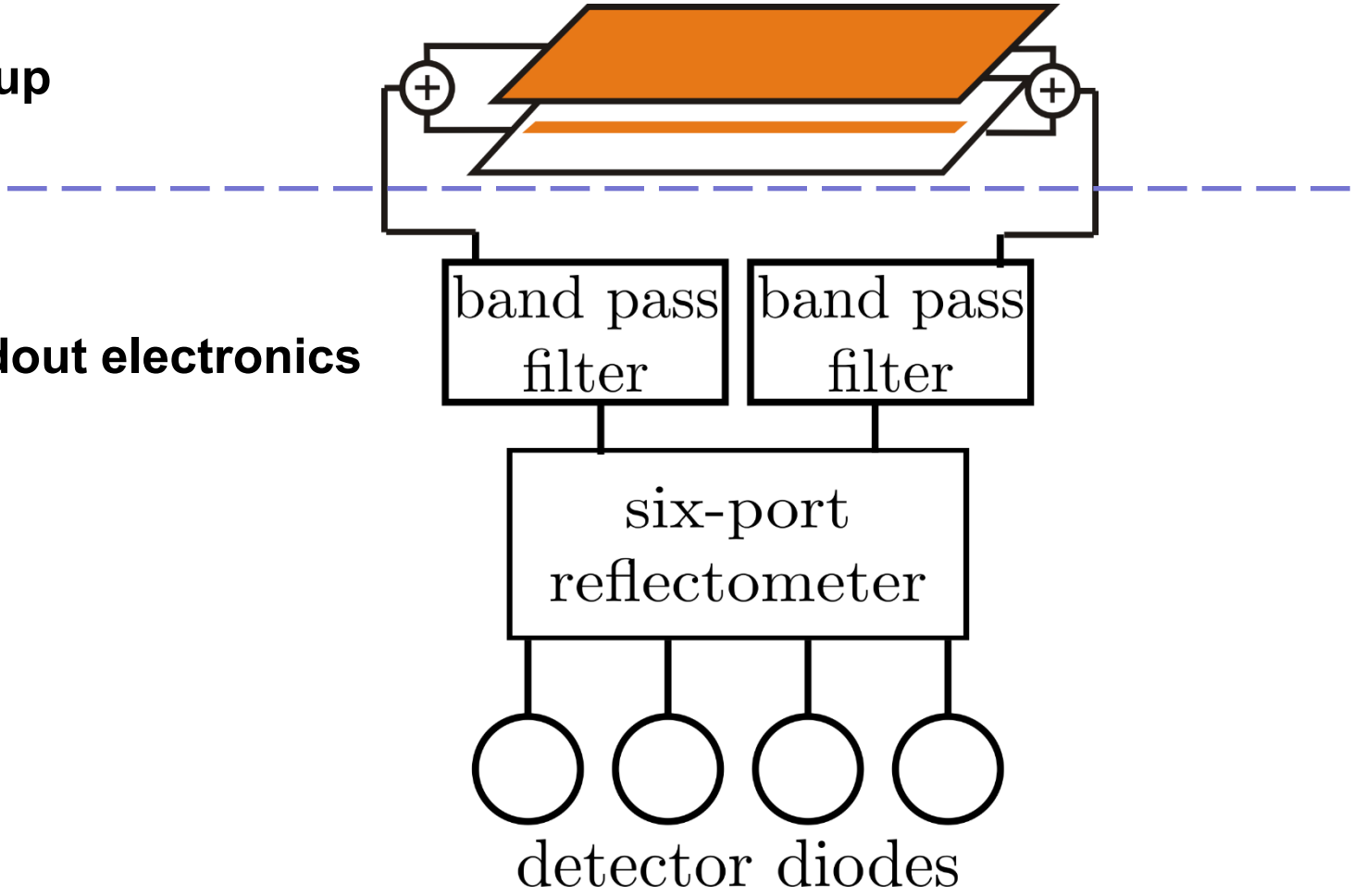
Pickup

Readout electronics



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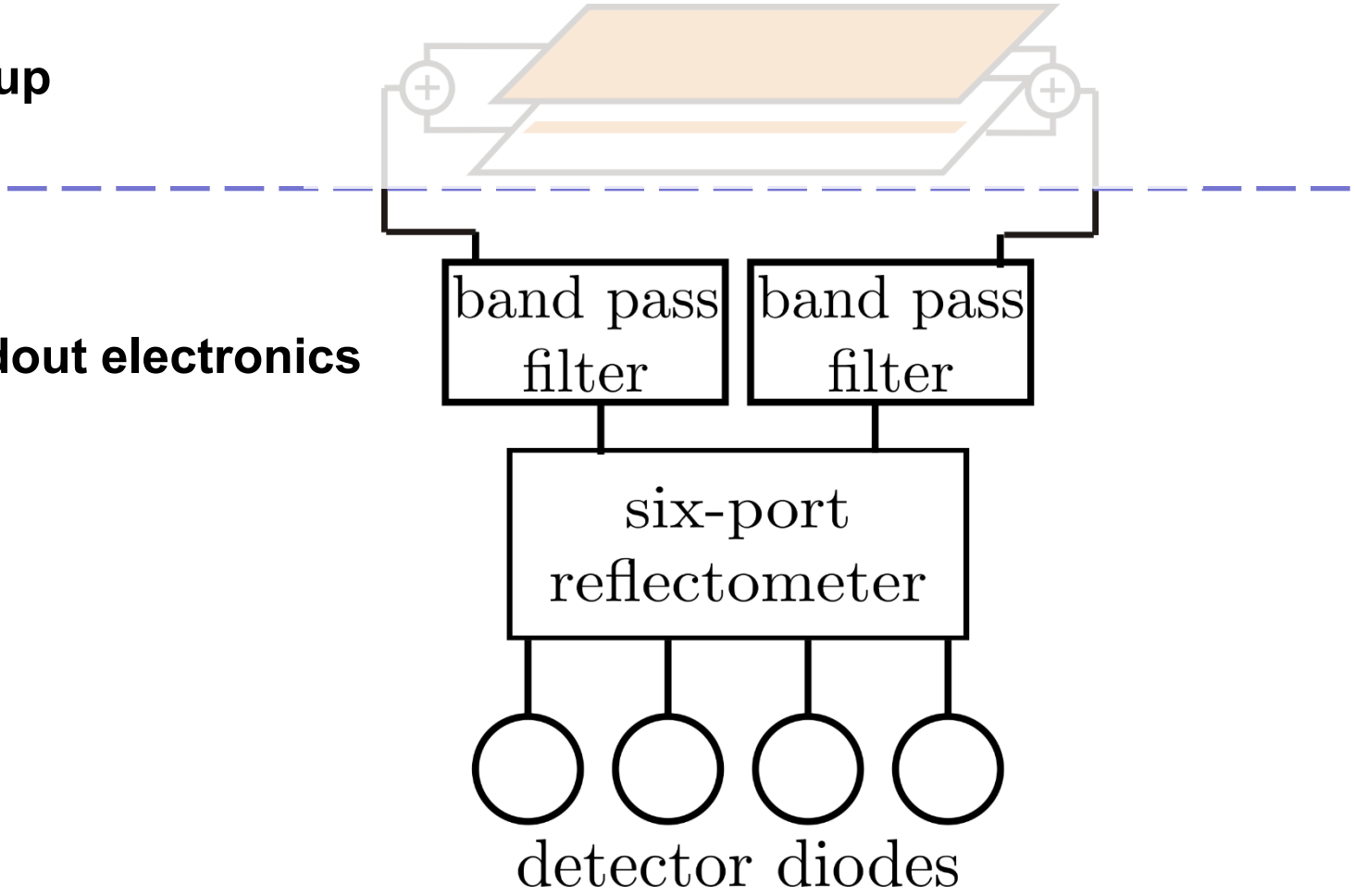

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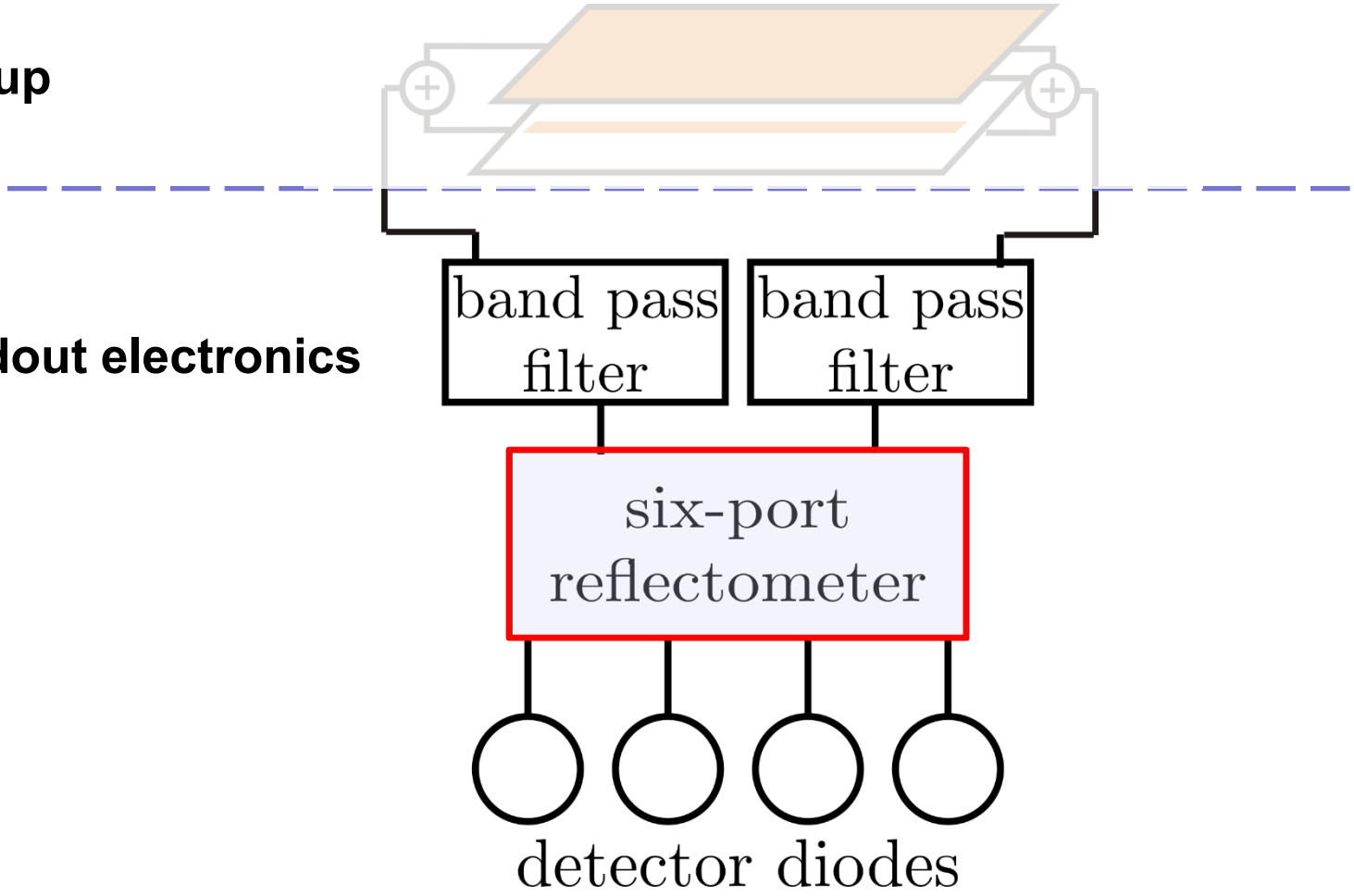
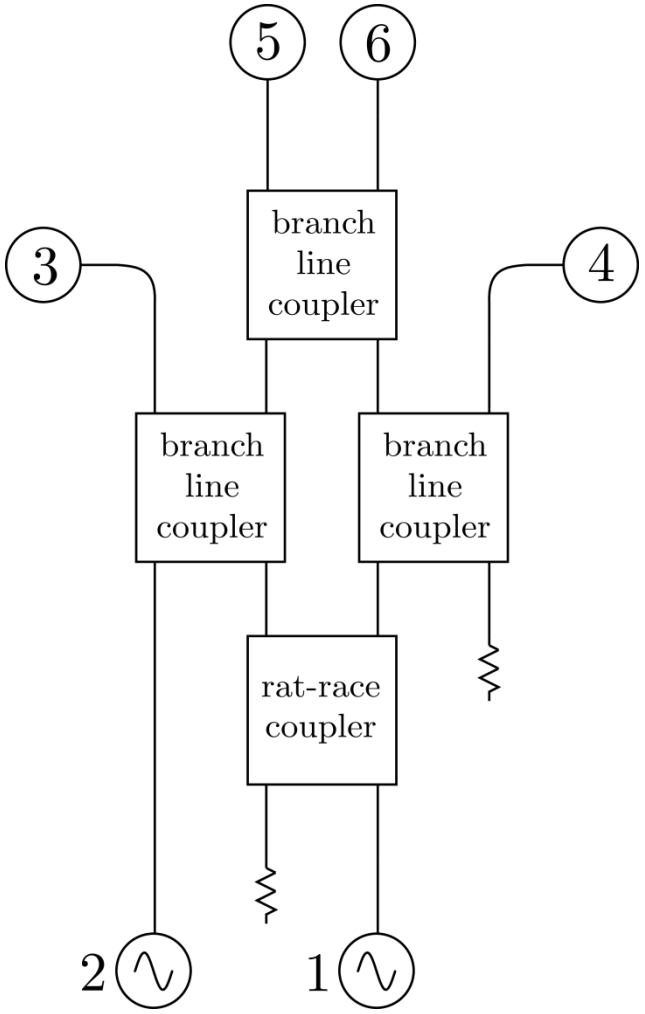
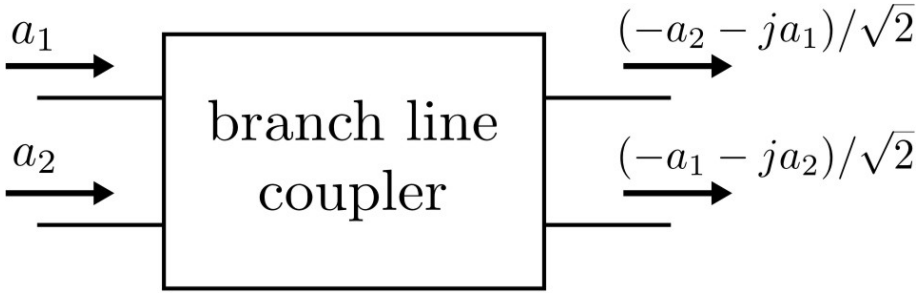


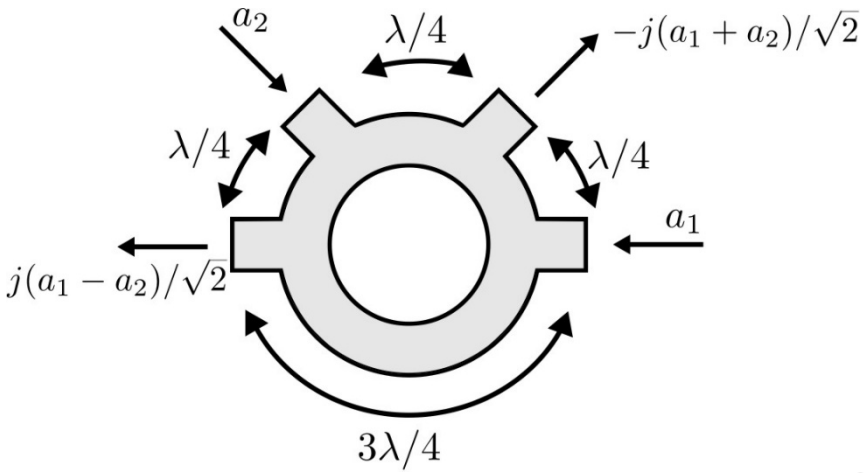
Six-Port Reflectometer
Operation principle



Branch line coupler



Rat race coupler



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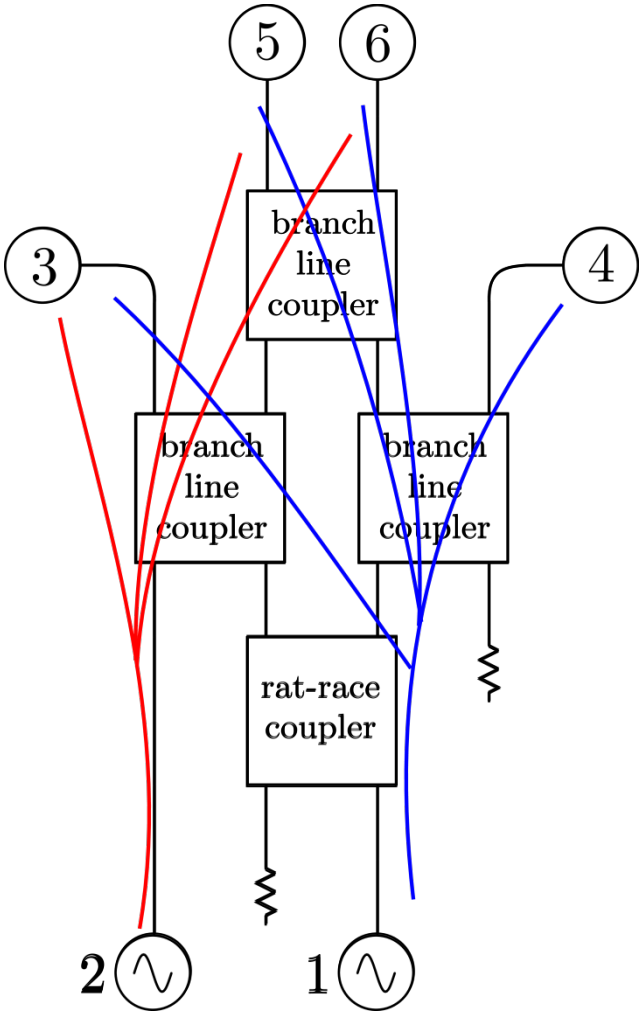

Port 1: $2a$

Port 2: $2b$

Port 3: $\frac{\sqrt{3}}{2}a - \frac{\sqrt{3}}{\sqrt{2}}b$

Port 4: $\frac{\sqrt{3}}{2}a$

Port 5: $\frac{\sqrt{3}}{2\sqrt{2}}a + j\frac{\sqrt{3}}{2}b - j\frac{\sqrt{3}}{2\sqrt{2}}a$

Port 6: $\frac{\sqrt{3}}{2\sqrt{2}}a - j\frac{\sqrt{3}}{2}a - j\frac{\sqrt{3}}{2}b$

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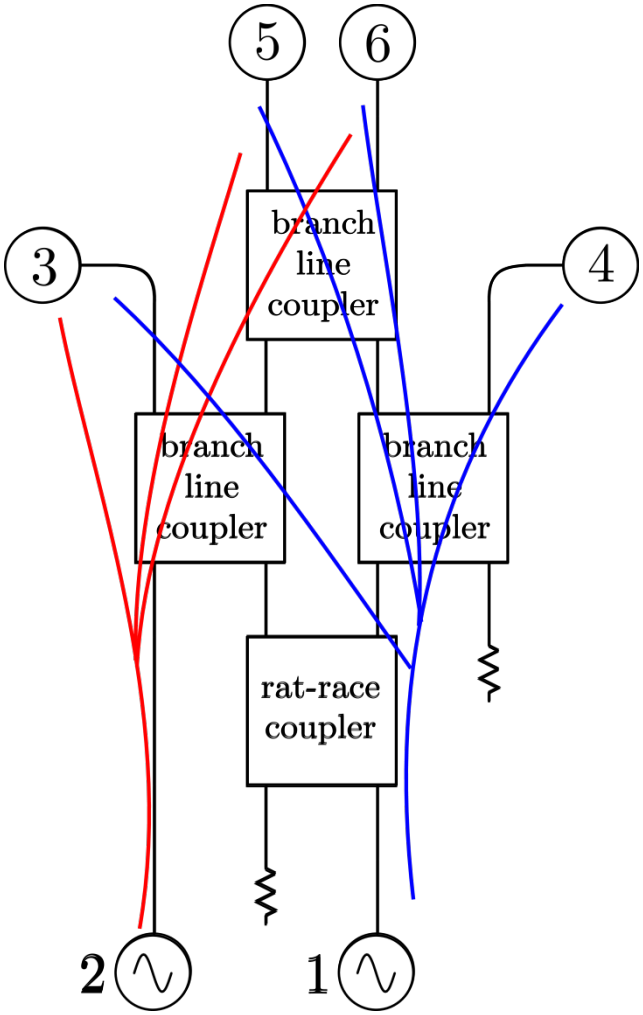
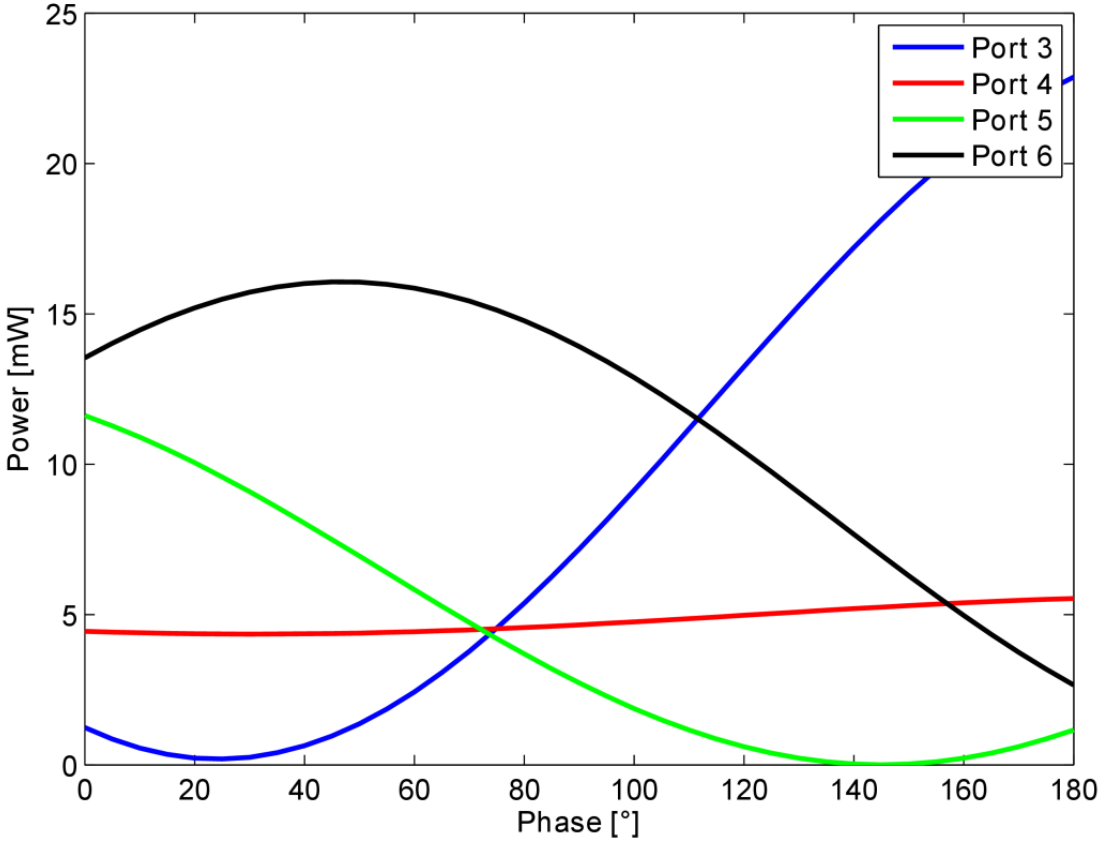
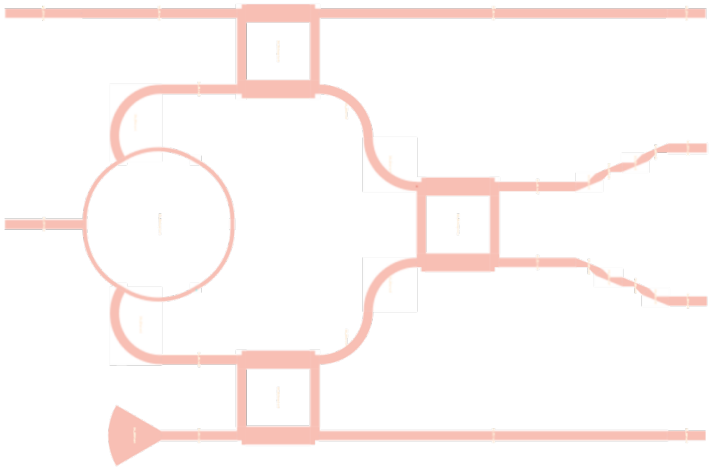
Operation principle

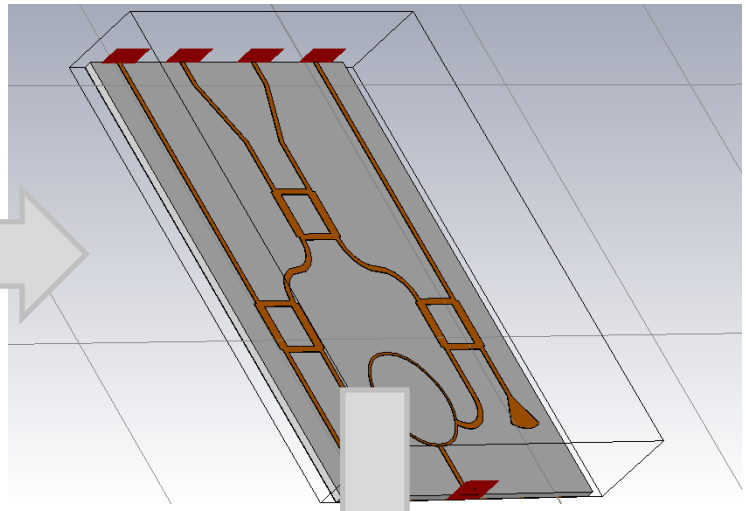




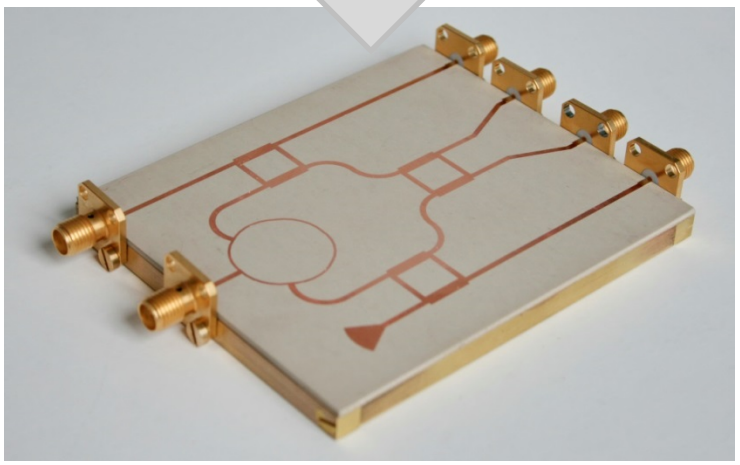
Six-Port Reflectometer Design



Agilent ADS layout



CST simulation model

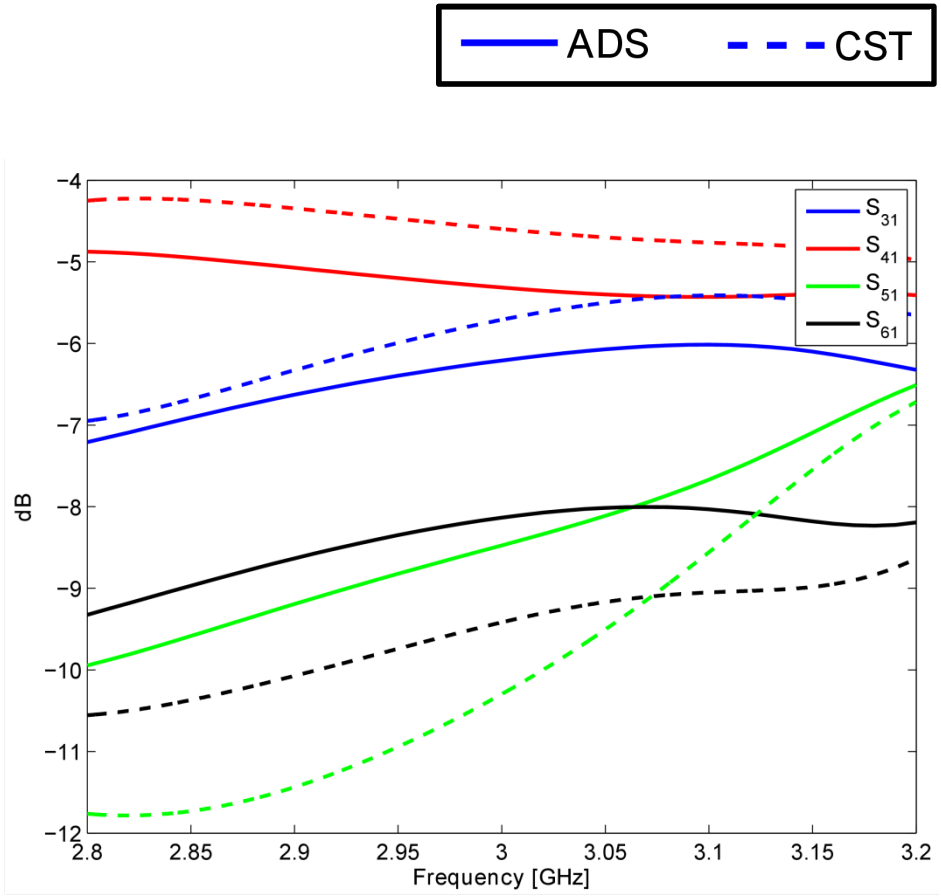


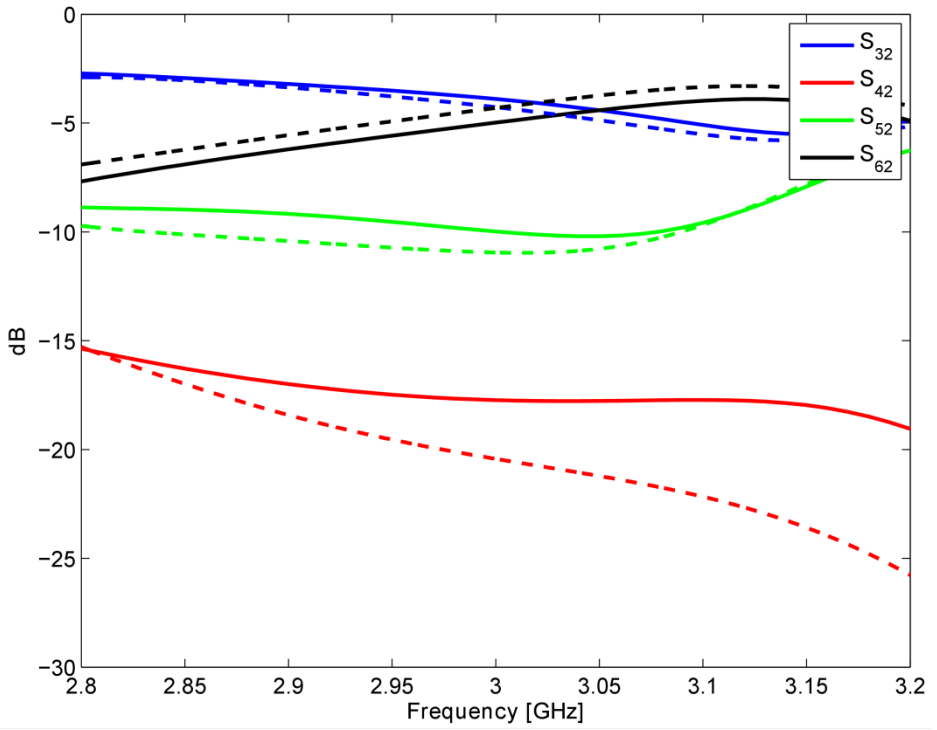
Realized circuit

Rogers RT/Duroid® 6010LM	
Dielectric constant	10.2
Substrate thickness	1.27 mm
Conductor thickness	18 µm

Six-Port Reflectometer Design

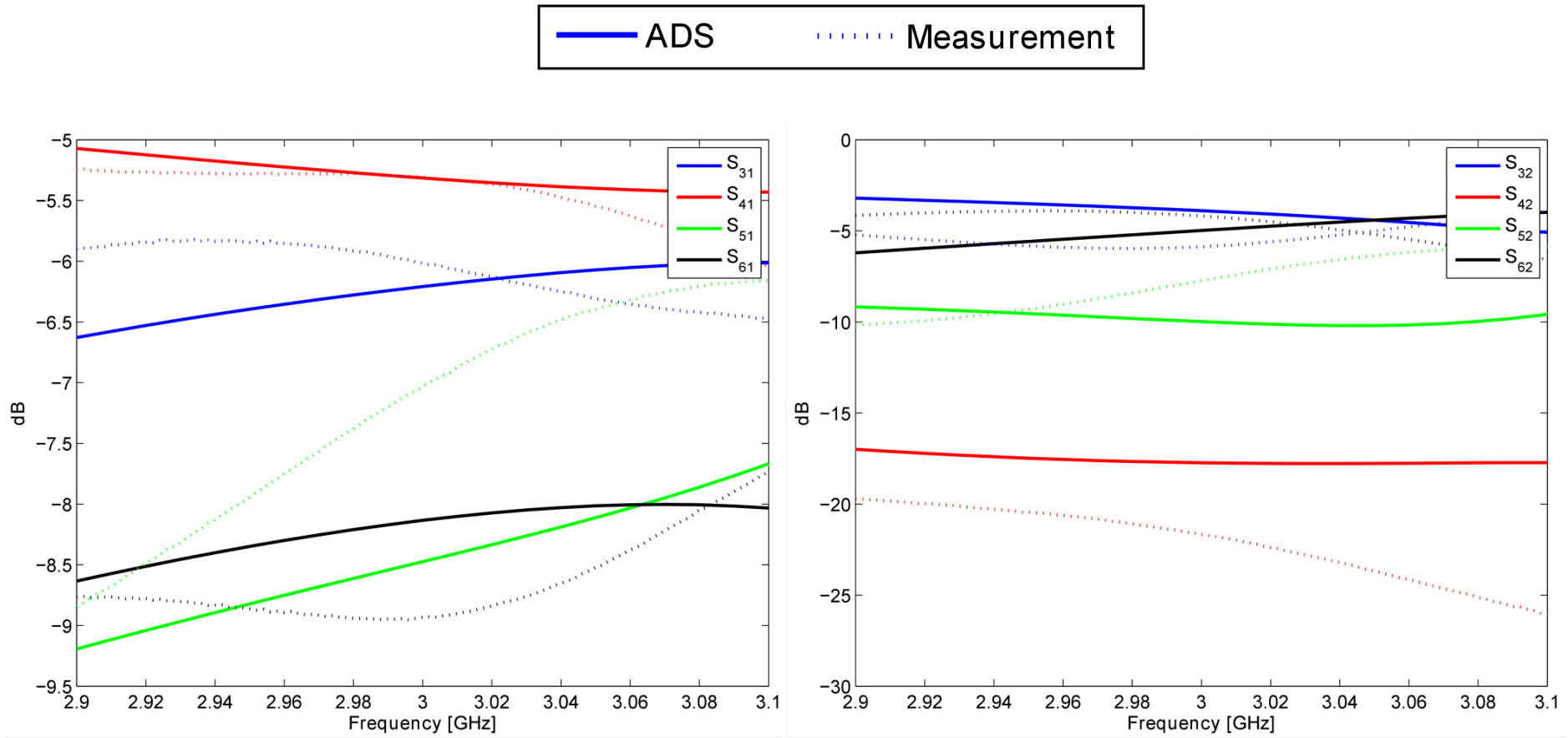
comparison between *ADS* and *CST* simulations





Six-Port Reflectometer Design

Comparison between *ADS* simulations and Measurements



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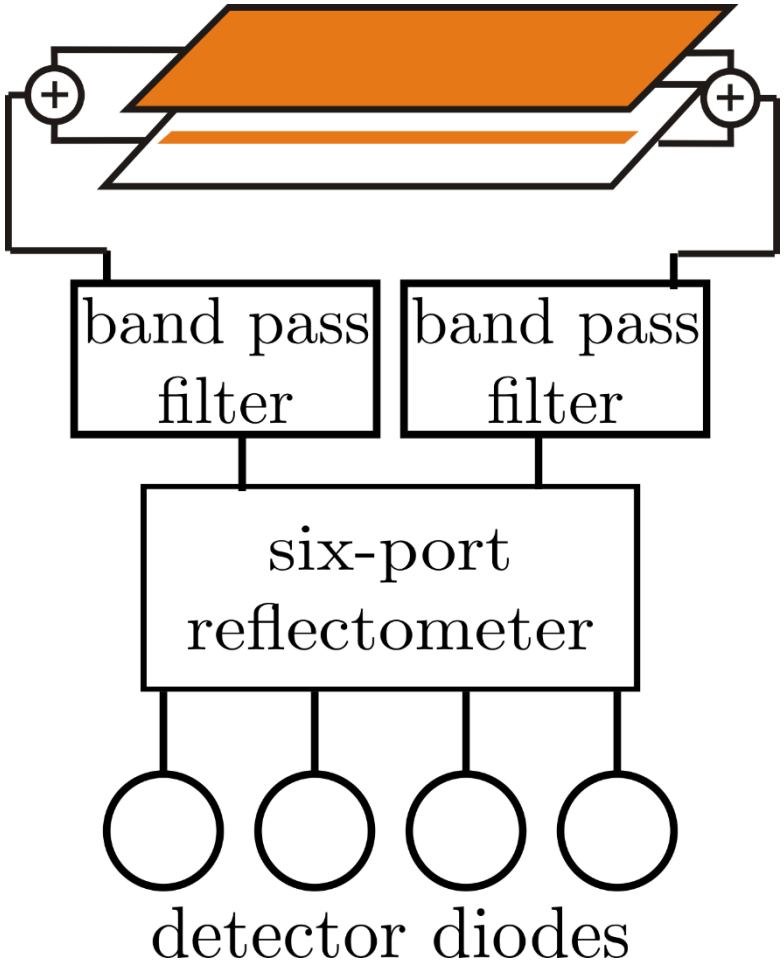

Measurement Setup

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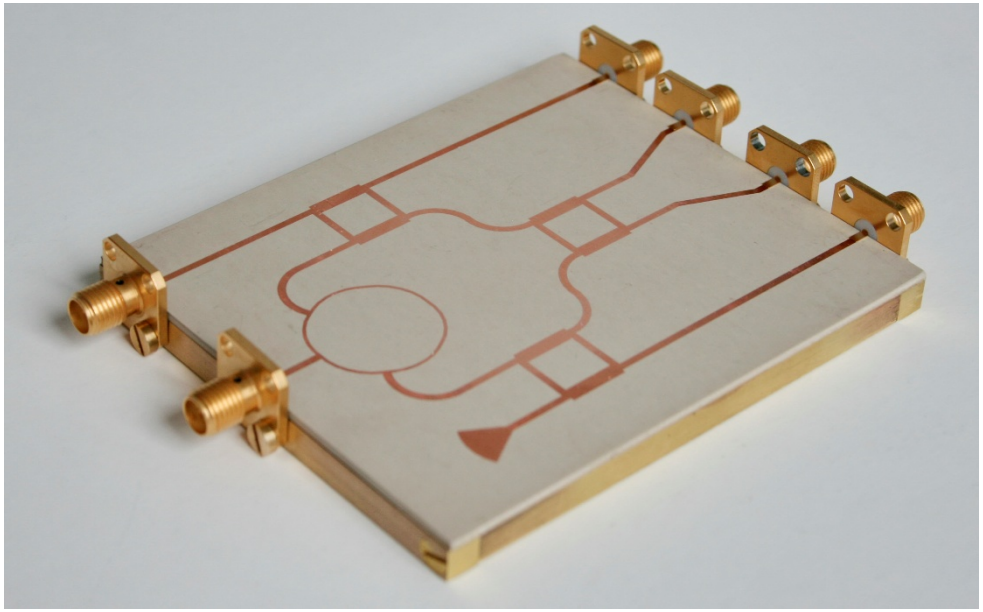
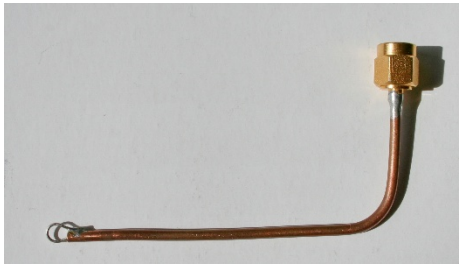
Six Port Reflectometer



Microstrip EBPM Pickup

Coupling loop (not to scale)



Measurement Setup

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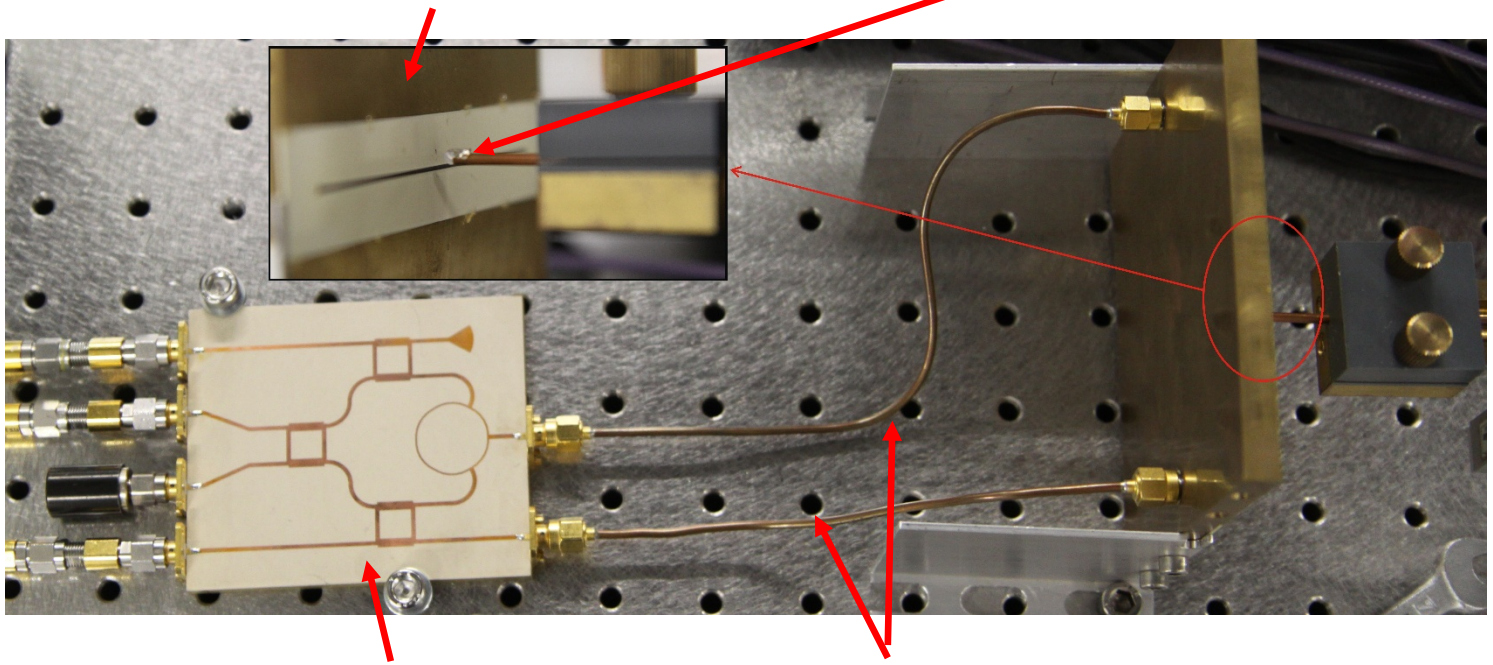
Beam induced excitation modeled with a small coupling loop in the vicinity of the transmission line

Non-hermetic TL Pickup

Coupling loop



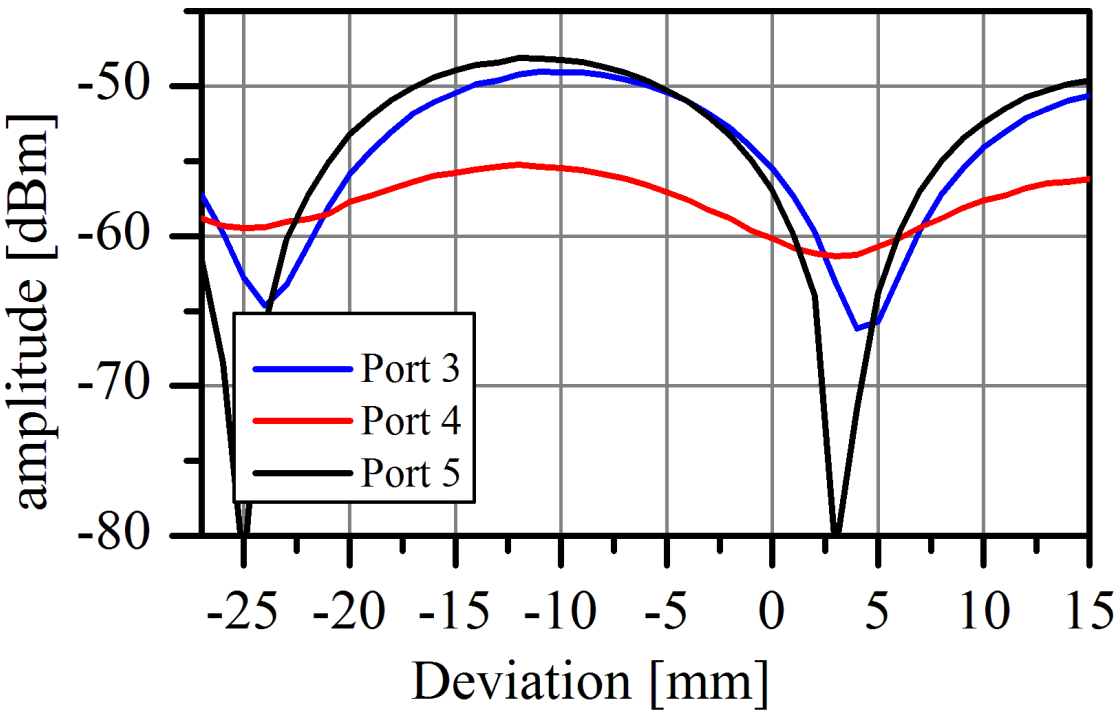
3D Micro-Positioner (not shown)

Six Port Reflectometer

Phase stable Semi-Rigid cables

Measurement Results

Detection range: 43 mm (1mm step size)



Power measurements

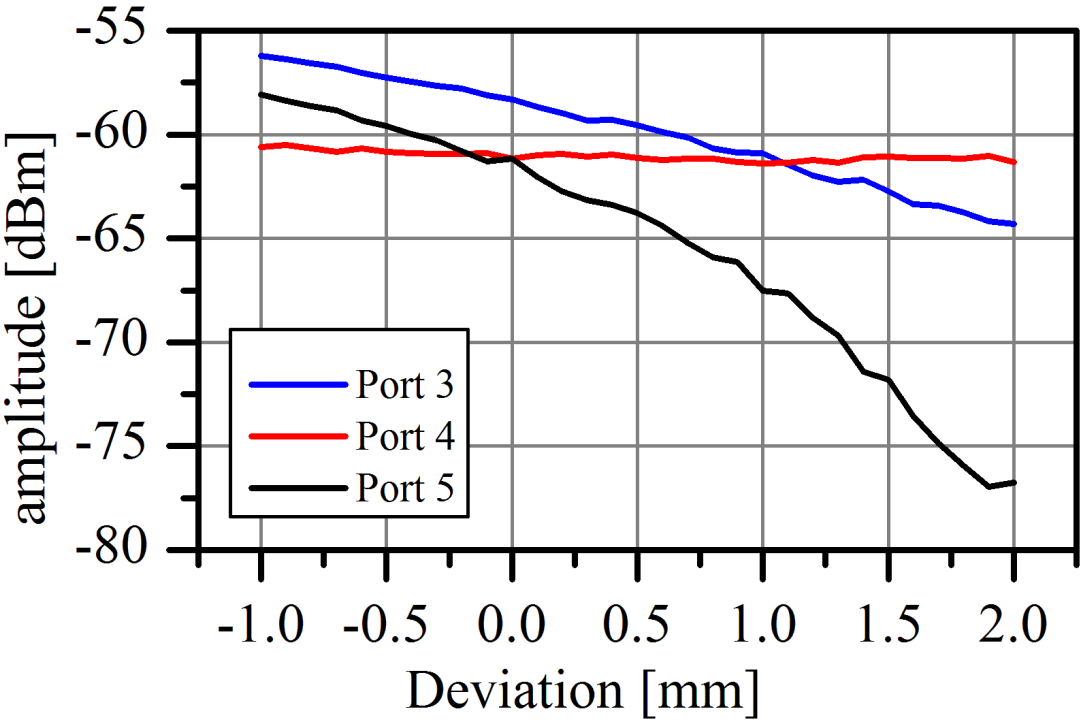
Port 4: 3 dBm variation due to
- mismatch &
- TL-losses

Port 3: 15 dBm periodic variation
Port 5: 35 dBm periodic variation

phase ambiguity, leads to multiple solutions, when position is calculated
- Lower operation frequency needed for coarse detection

Measurement Results

Detection range: 3 mm (100μm stepsize)



Port #	Variation [dBm]	Sensitivity [dBm/μm]
4	1	0.0025
3	8	0.02
5	20	0.05

A standard power meter fulfills the requirements of 0.1dBm typically down to -70dBm.

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Conclusion and Outlook

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Conclusion

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- The EBPM requires a high dynamic range over the sensor length of 183 mm and high resolution of less than 20 μm
- The proposed design provides a sensitivity of more than 5dBm/mm beam offset for a mean value of -60dBm for the non hermetic test setup
- For the high resolution of less than 20 μm a sensitivity of 0.1dB at the given power level is sufficient

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Outlook

- Realization of a Six-Port Spectrometer @ 1.3GHz to prevent phase ambiguity
- Further investigations about the detector circuit is needed

Outlook
Diode Detector Circuit

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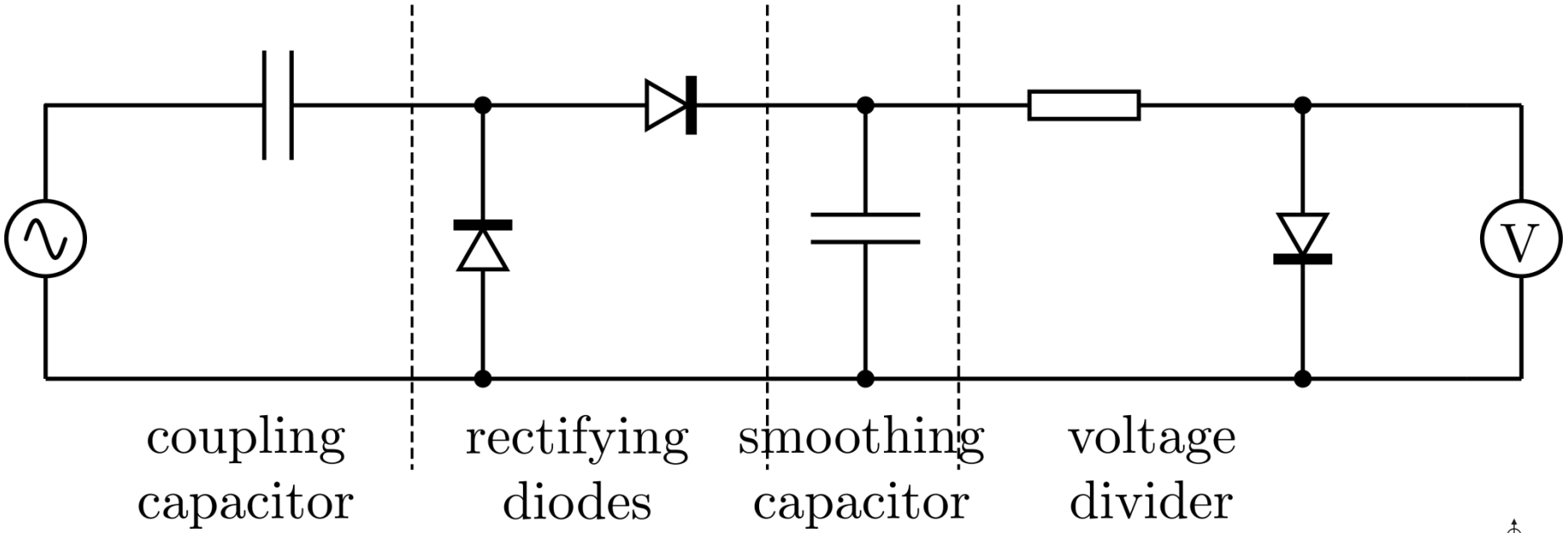
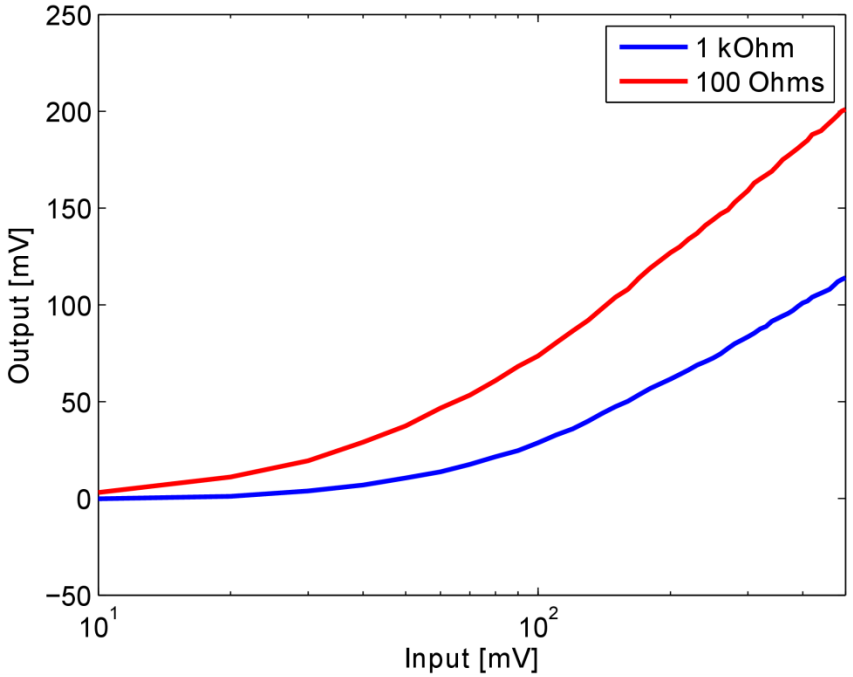
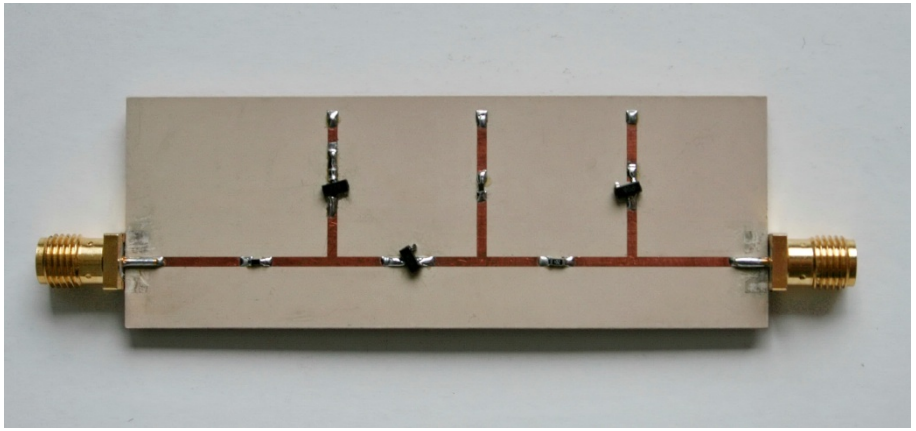
- Power detection using Zero-Bias Schottky diodes

- dBm linear rectifier circuit based on a combination of a Villard circuit and a voltage divider



Outlook
Diode Detector Circuit





Detector circuit

- Sensitivity needs to be improved
- Adaption to input and output impedance necessary
- Integration to six-port discriminator

Thank you for your attention