Impact of piezoelectric nano-positioner displacement accuracy on On-wafer S parameters repeatabilities

EMPIR Project 14IND02 PlanarCal

Khadim Daffé[1], Gilles Dambrine[1], Fabian von Kleist-Retzow[2], Kamel Haddadi[1]

[1]Institute of Electronics, Microelectronics and Nanotechnology (IEMN-CNRS), University of Lille, Villeneuve d'Ascq, France
[2]Division Microrobotics and Control Engineering, University of Oldenburg, Oldenburg, Germany

khadim.daffe@etudiant.univ-lille1.fr

HF On-Wafer (or On-Device) Characterizations in Nano-electronics

The next-generation nanodevices will all depend on our ability to **accurately** and **reproducibly** *measure properties and performance characteristics at the nanoscale over a wide frequency range.*

- Providing robust modeling for circuit/system designs.
- Providing feedbacks for technological developments.
- Increasing knowledge of new material/device properties into complex technologies.

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Outline

Context of the Study

Measurement set-up

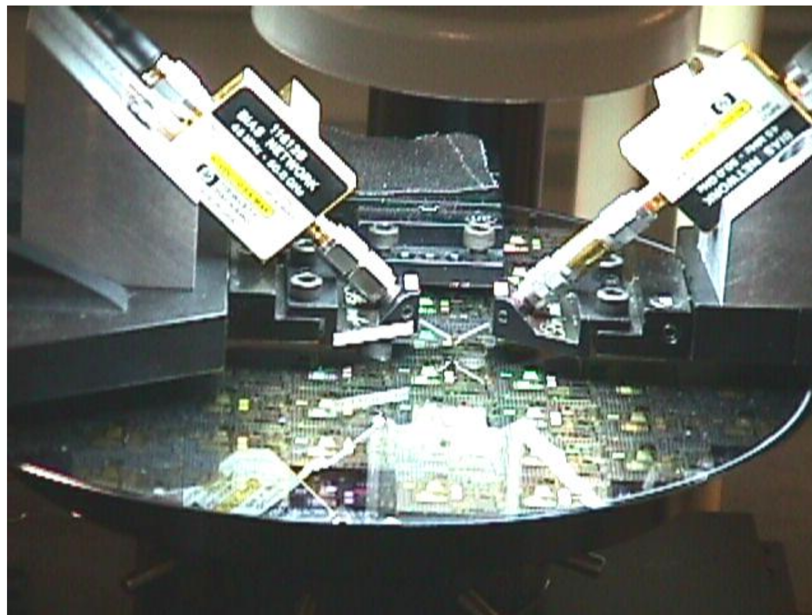
Methodology

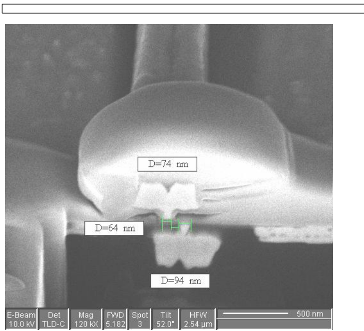
Results

Conclusion

Microwave & mm-Waves Measurements: Why?

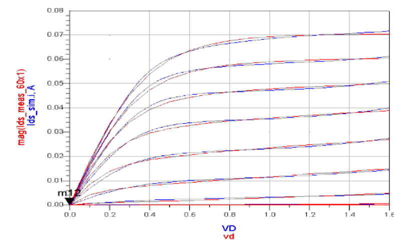
Microwave to sub-mm wave length characterizations provide an important quantity of information on the electrical, physics and technological behaviors of devices.

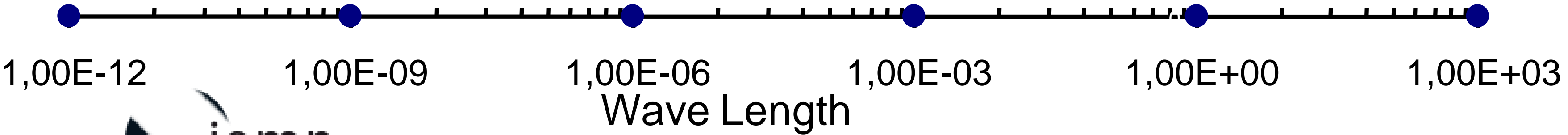




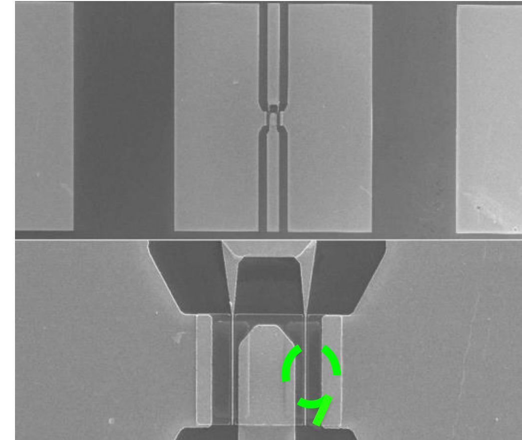
THz

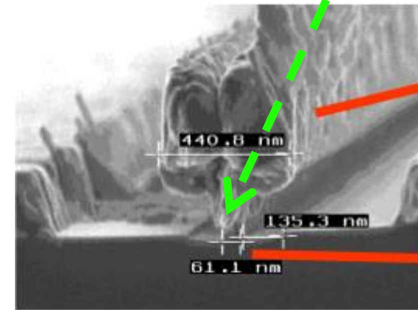
MHz

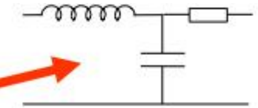


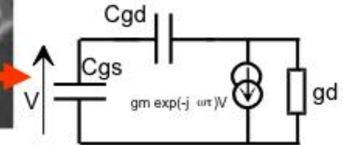


HF On-Wafer Measurements: Why?









Calibrated/De-embedded S, Y, Z-Significant Parameters for physics / technology/modeling

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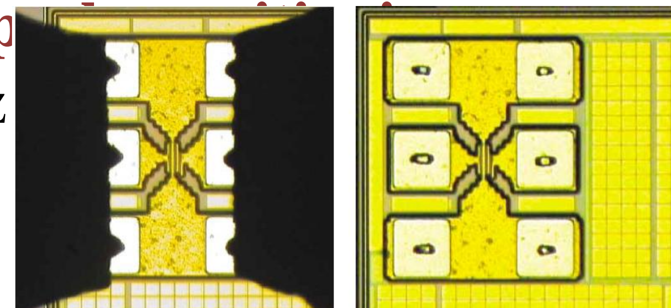
Context of this study

On-Wafer Measurements Repeatability: Many causals

- ❑ Drift over measurement time
- ❑ Random effects
  - Instrument/external noise sources (HF, LF …)
  - Probe/Pad contacts degradation
  - Probe positioning
  - Others

This study aims to study the influence of **p**
accuracy on S_{ii} repeatability up to 50 GHz
(***action only on Z-axis***)



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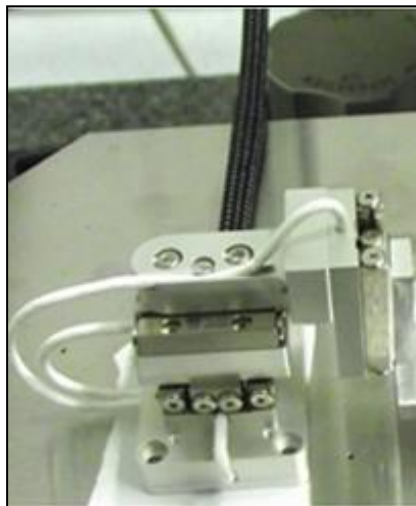
XYZ Positioners: several types

Mechanical:
X, Y, Z reticule ~2.5 µm



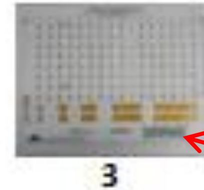
Piezoelectric:
X, Y, Z accuracy ~ 25 nm
Displacement range ~ 1 cm
© SmarAct Company

Industrial on-wafer station
X, Y Accuracy ~ 1µm
Z Accuracy ~ 0.5 µm

Description of the Measurement Set-up

➢ EXPERIMENTAL SET-UP

3. Impedance Standard substrate (ISS #101-190)
   - (Cascade ®)
4. PNA N5225A
   - (Keysight ®)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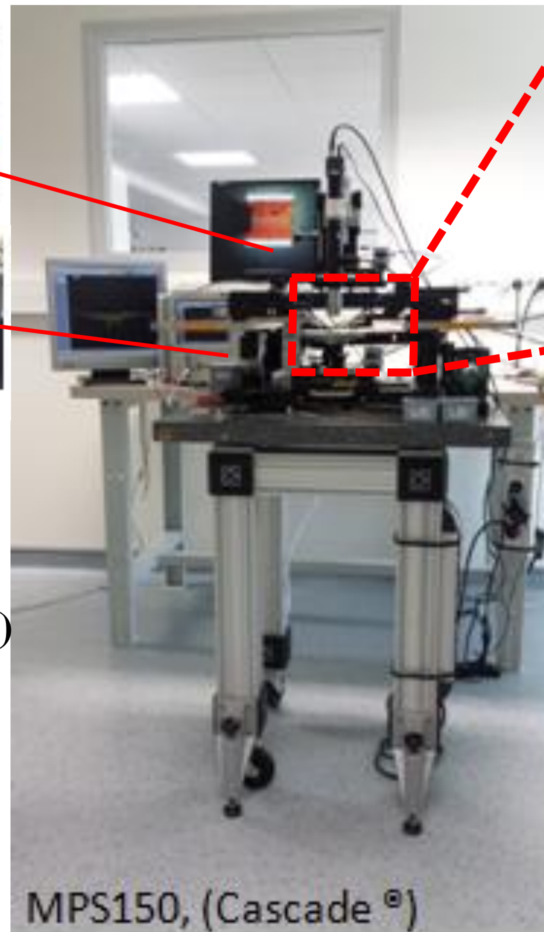
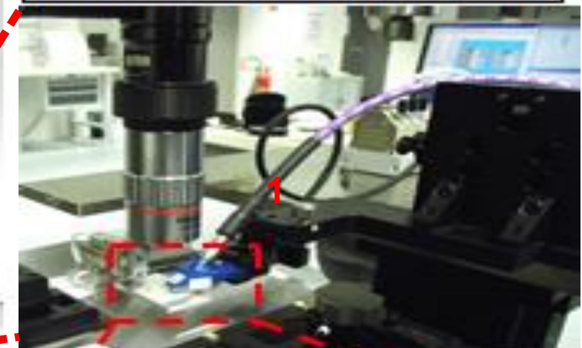

MPS150, (Cascade ®)

Modified Probe Station



1. Microwave cable (2,4mm)
   - (Gore ®)
2. RF GSG Probe 100µm pitch
   - (Infinity ®)

➢ EXPERIMENTAL CONDITIONS

- ❖ 0.05-50 GHz
- ❖ 100 MHz (Frequency step)
- ❖ 491 (# frequency points)
- ❖ 100 Hz (IF bandwidth)
- ❖ 0dBm (RF signal power)

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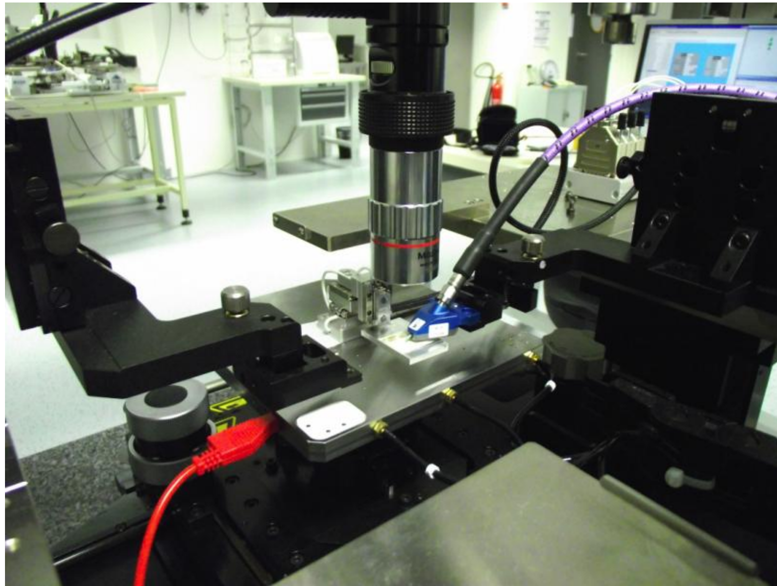
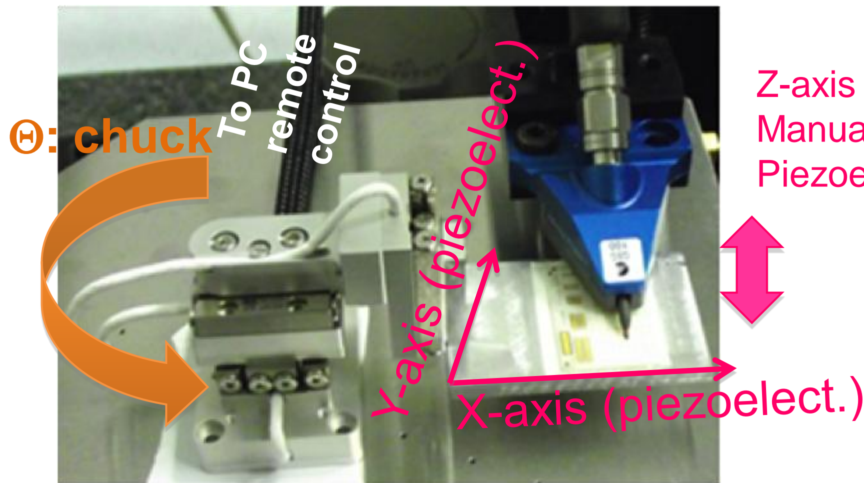
Methodology 1/2

- 1-Port uncalibrated measurements of Short, Open-air and Load
    - dependent contact measurement
        - Short, Load
    - Independent contact measurement
        - Open-air
- Number of measurements (for each device): 15
- Measurement duration: almost One day (half day: mechanical; half day: piezoelectric)

Methodology 2/2





Initial positioning:

•ISS Theta alignment;
•Initial manual Z-axis positioning to ensure S_{11} stable frequency response;
•X_i and Y_i positions recorded for i= short, open and load (Piezoelect. in remote control).

Z-axis up and down displacements:

•Mechanical displacements (to the same cursor position for all measurements): estimated set-point accuracy +/-2.5µm

•Piezoelectric displacements (the Z-axis displacement was controlled in close loop operation): set-point accuracy +/-25nm

Measurement environmental conditions

All measurements are carried out in a controlled environment (IEMN Nano-characterization Center) with:

•Temperature variations less than +/- 1° ,
•Anti-vibration building and experimental tables
•Stable ambient hygrometry close to 50 %.

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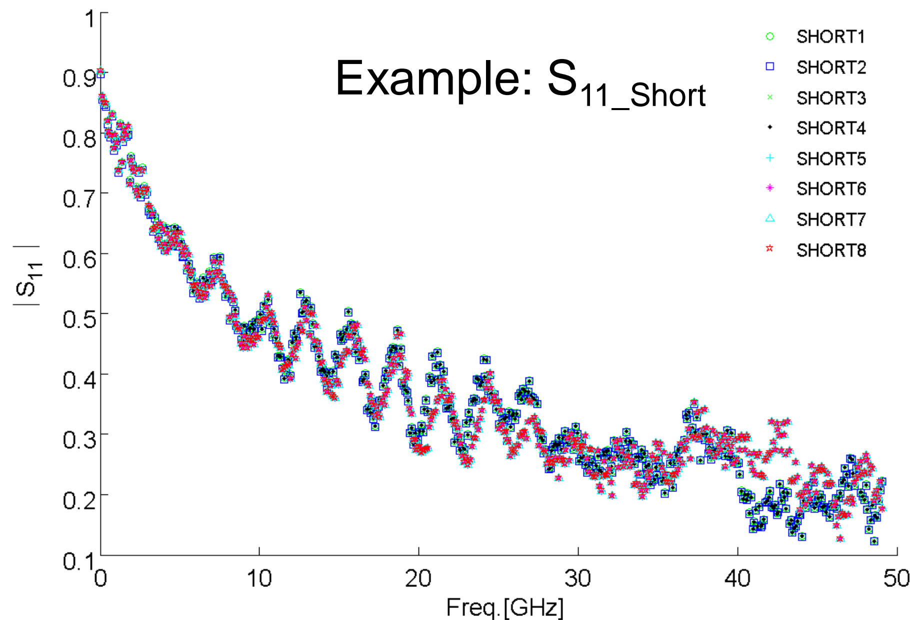
Measurements Analysis

From uncalibrated reflection coefficient S_{11}....



We calculate the standard deviation of the complex reflection coefficient defined by:

$$\sigma = \left(\frac{1}{n-1} \sum_{i=1}^{n} |S_{11_i} - \overline{S_{11}}|^2 \right)^{\frac{1}{2}}$$

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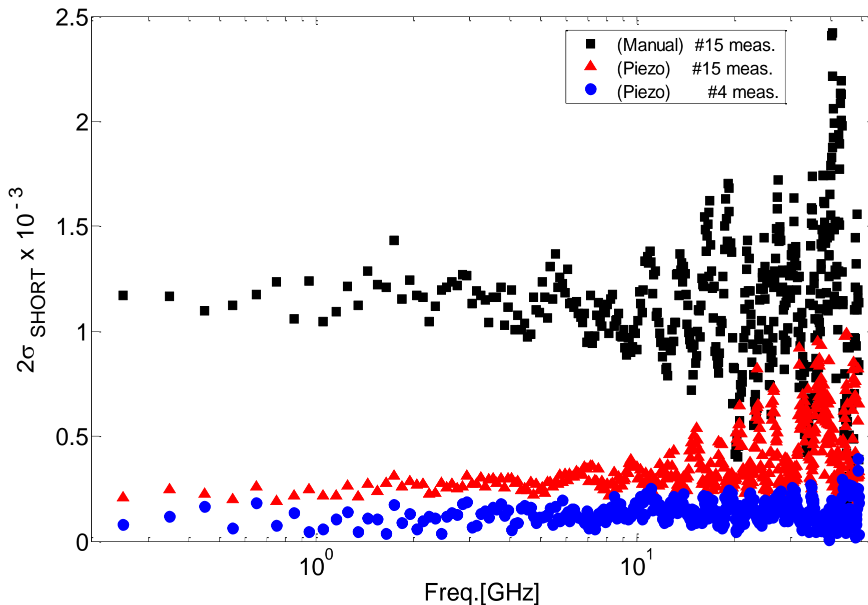
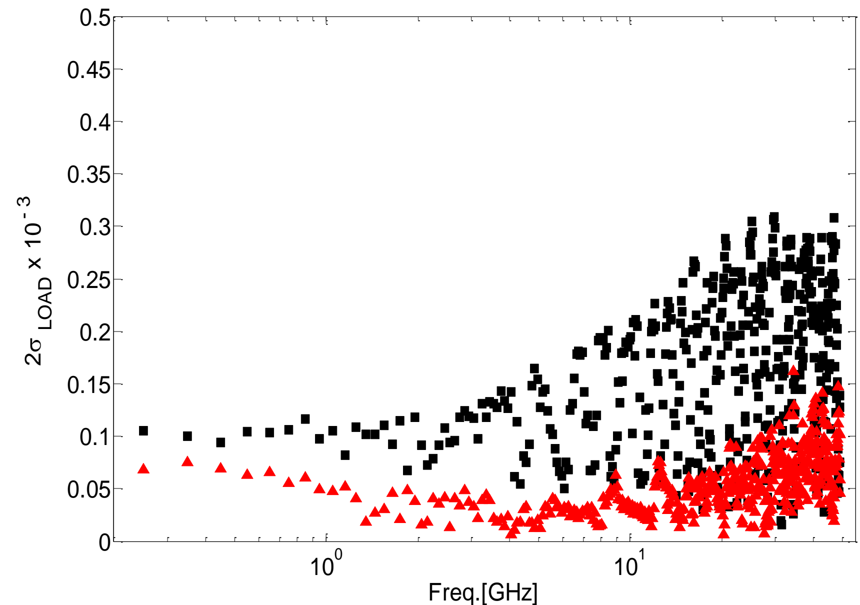
Results and Discussion 1/3

- The Standard Deviation of « Short » is reduced by a factor of 4 in case of the Nano-positioner
- For frequencies above 15-20 GHz, other sources of random deviations are predominant.
- The Standard Deviation is also reduced by 2 for "Load"

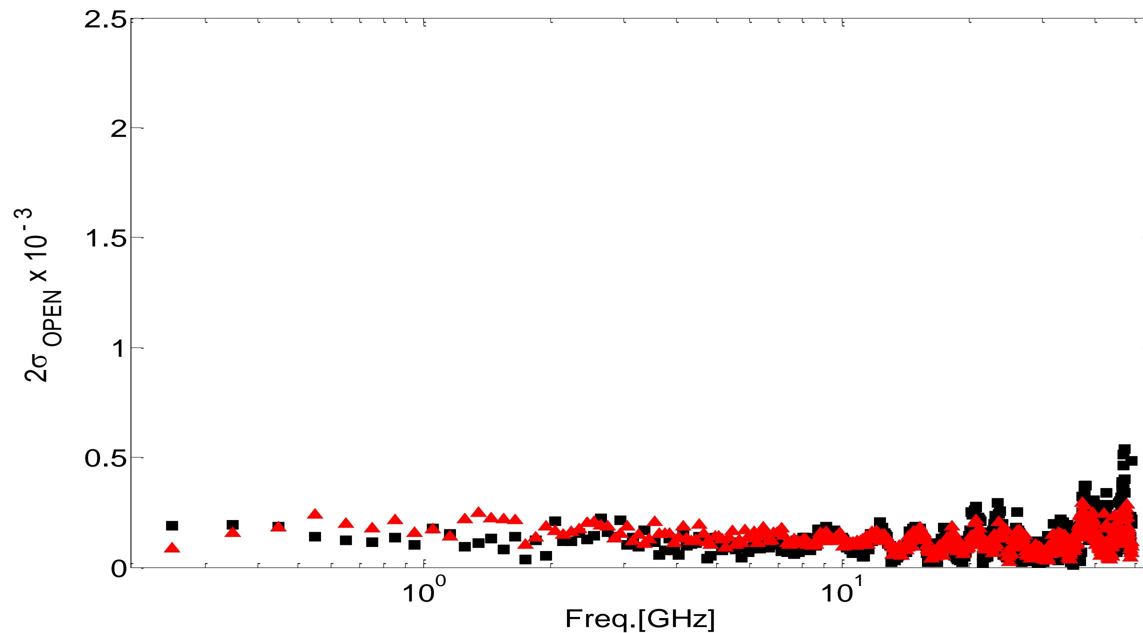




RF wafer probing with improved contact repeatability using nanometer positioning
DAFFÉ K., DAMBRINE G., VON KLEIST-RETZOW F., HADDADI K.
Proceedings of 87th ARFTG Conference, May 2016.

Results and Discussion 2/3

- The Open standard is not a contacted device
- The Standard Deviation is not influenced by this experimental comparison



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Results and Discussion 3/3

- Mean value of the relative errors over the frequency range
  - Significant improvement for Nano-positioner are shown below 20 GHz.

	0.05 – 20 GHz		20 – 50 GHz	
	Manual	**Piezoelect.**	**Manuel**	**Piezoelect.**
Short	**0.23 %**	**0.06 %**	**0.44 %**	**0.18 %**
Load 50Ω	**0.35 %**	**0.1 %**	**0.42 %**	**0.16 %**

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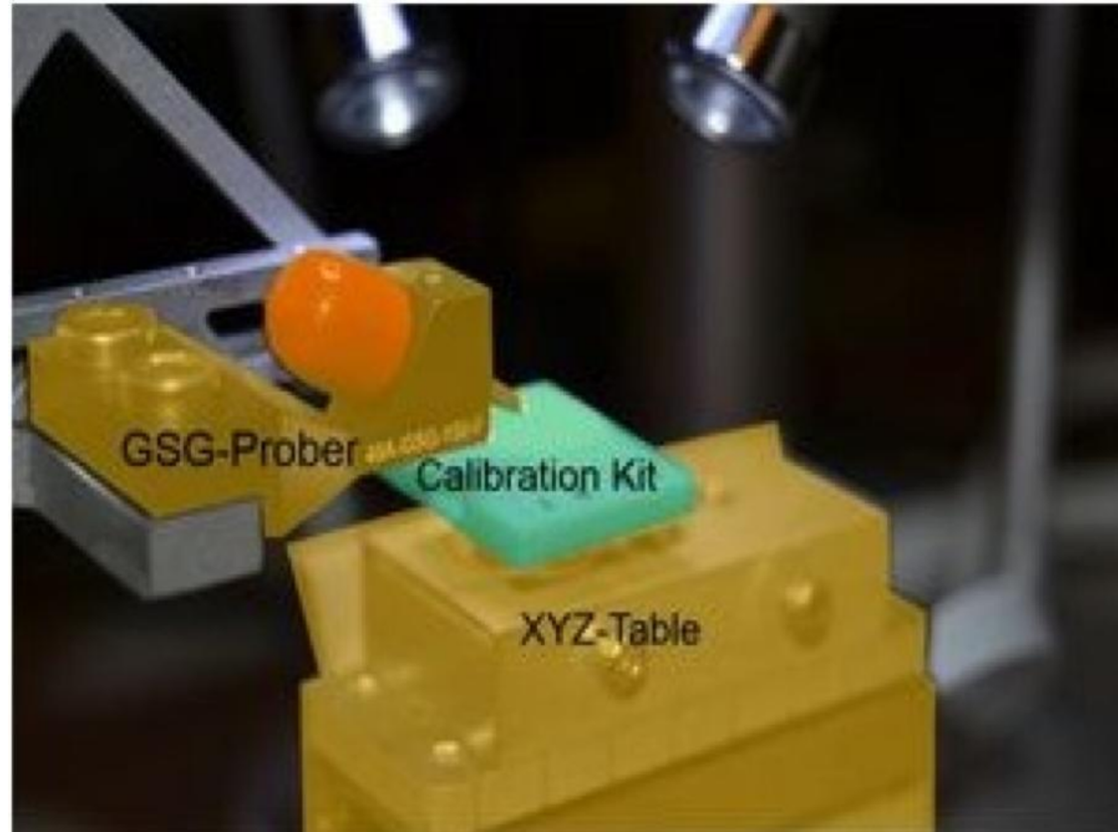
Conclusion

HF on-wafer based characterization remains challenging and needs to develop new instruments.

Probe/Pad positioning inaccuracy is one causal of random error,

Nano-robotic based positioners (with nm resolution) are a solution to reduce it significantly up to 15-20 GHz,

Nano-robotic based on-wafer station is a reality for on-line test of microelectronic.



fabian.von.kleist-retzow@uni-oldenburg.de

https://www.uni-oldenburg.de/en/computingscience/amir/research/research-group-microwave-nanoscopy-and-nanorobotics/

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Thank You

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