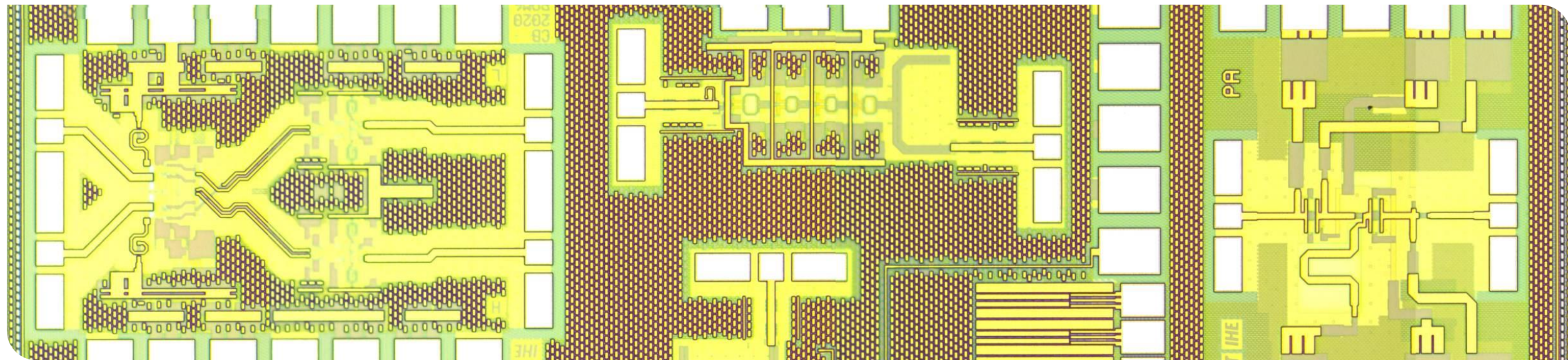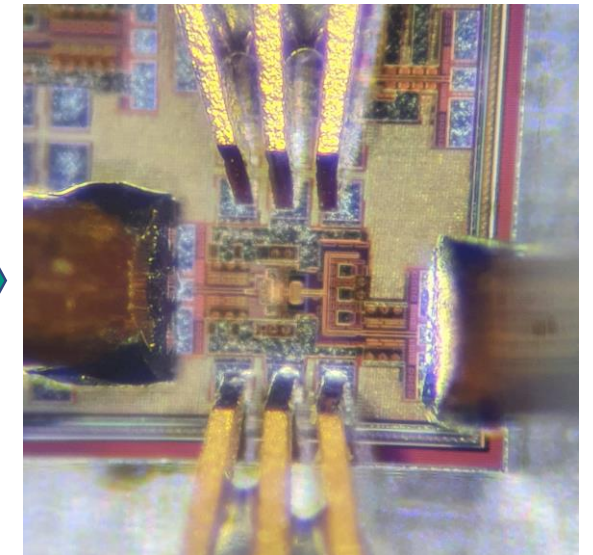# Teaching Circuit Design at KIT

Going from Zero to Tape-Out
Joachim Hebeler
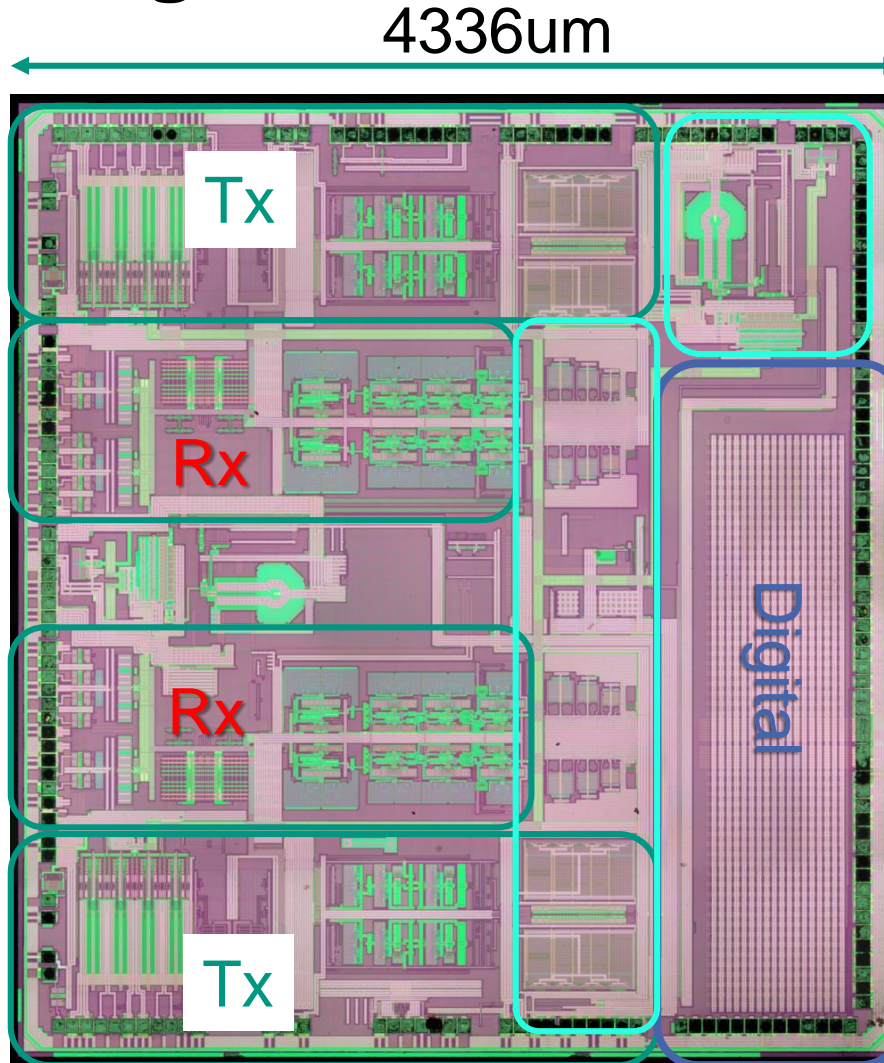
Introduction

Measurement?

Schematic Layout Chip

What is Circuit Design?

4336um

4730um
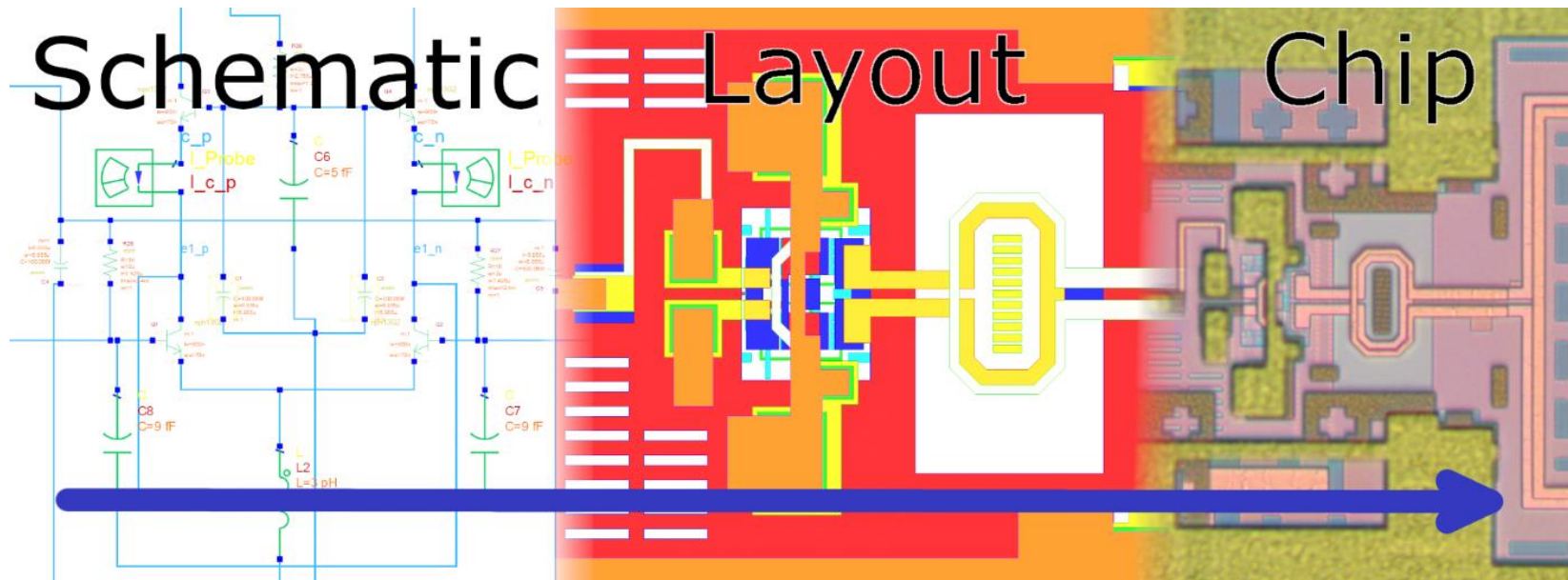
RFIC/MMIC
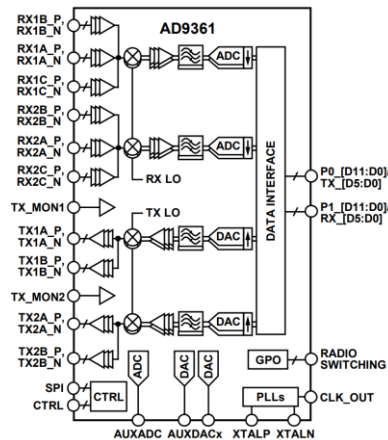
Analog/ Mixed Signal

Digital Design

Tx

Rx

Rx

Tx

Digital

https://zeptobars.com/en/read/AD9361-SDR-Analog-Devices-DAC-ADC-65nm

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What is Circuit Design?

4336um

4730um
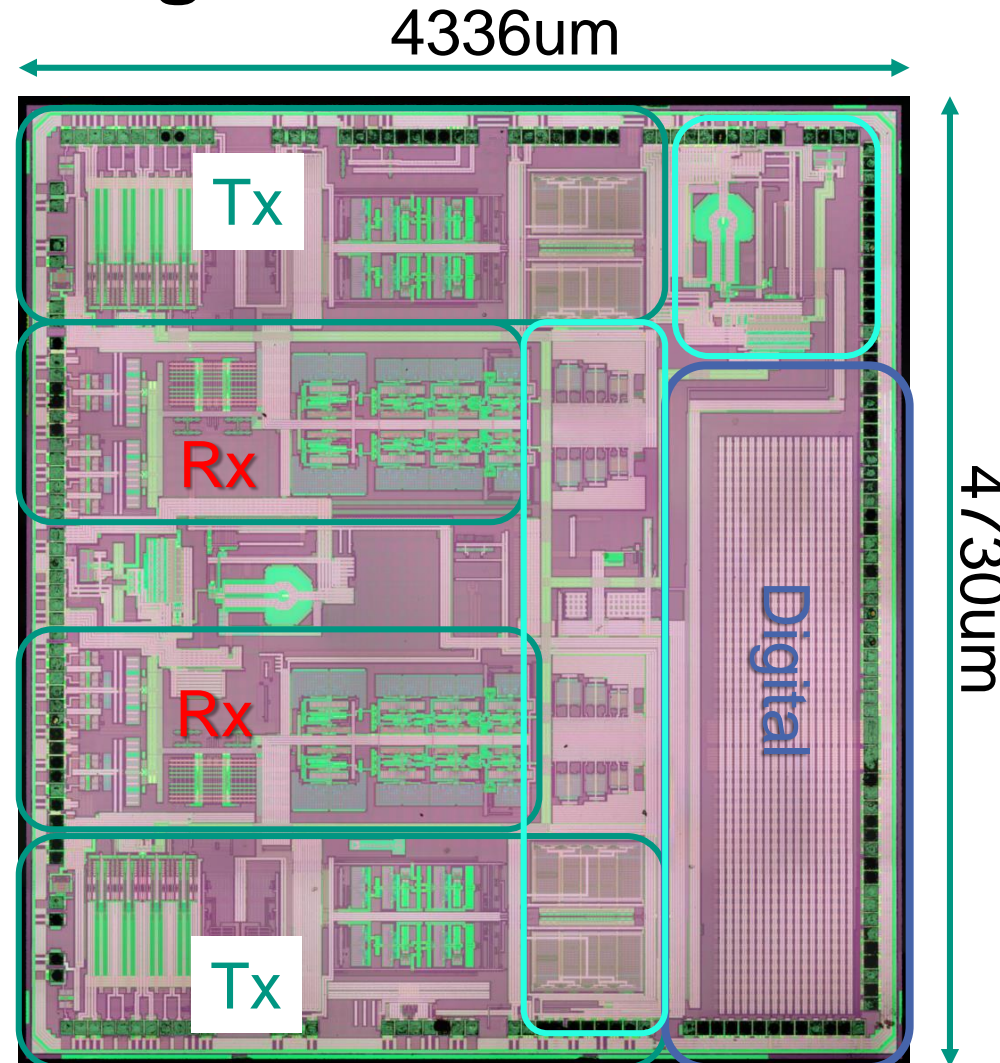
Tx

Rx

Rx

Tx

Digital

- Schematic Design
- Layout
- Design Verification
- Functional Verification
- EM Simulation
- Process Specifics

- System Design
- Floorplan
- Measurement
- Packaging
- Interfaces
- Workflows

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Introduction

- Circuit Design is an exhaustive topic
- How to introduce students into the world of semiconductor design?
- Curriculum:

ES - Intro into electronics

RFE - Intro into RF electronics

RFICs - Intro into RF-IC

MMICDL - Intro into MMIC Design

- Mixed-Signal IC Design
- Moderne VLSI Technologien
- Semiconductor Process Technologies

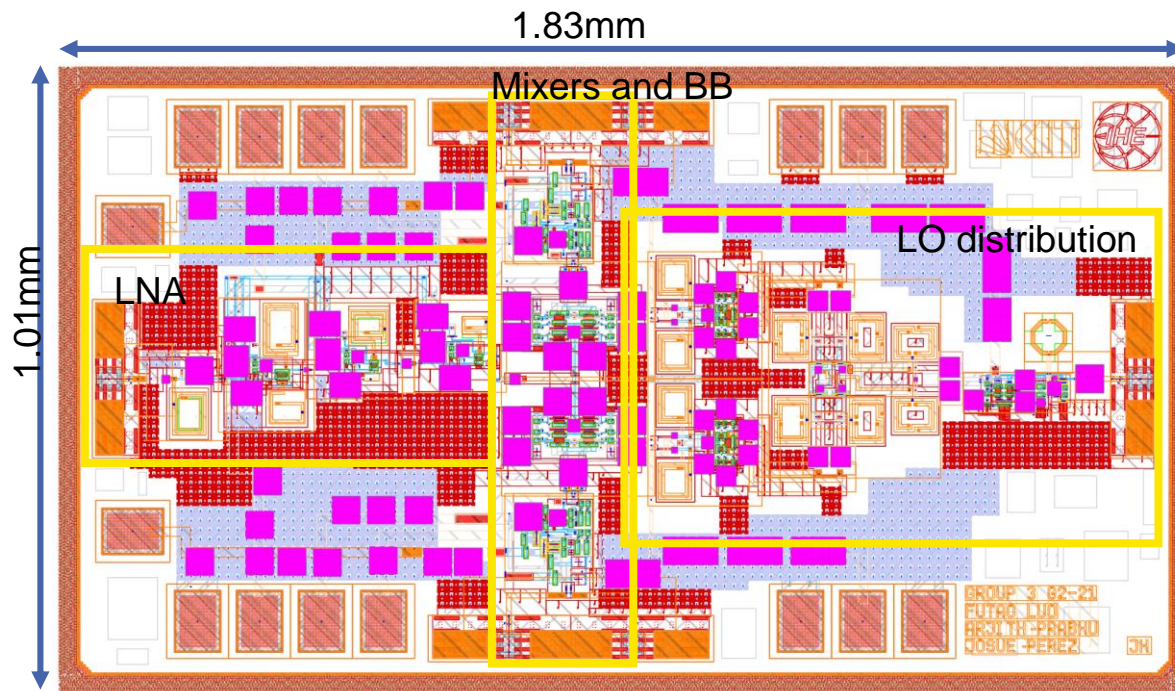Institute of Radio Frequency Engineering and Electronics

Aims

- Introduce Students to RF concepts, ideas and circuits
- Teach them with the tools they will encounter in their later career
- Teach them with current generation technologies
- Teach them with current topics
  - 5G basestation
  - RADAR
  - Next gen communication

→Teaching real world engineering
→Let students design real world circuits

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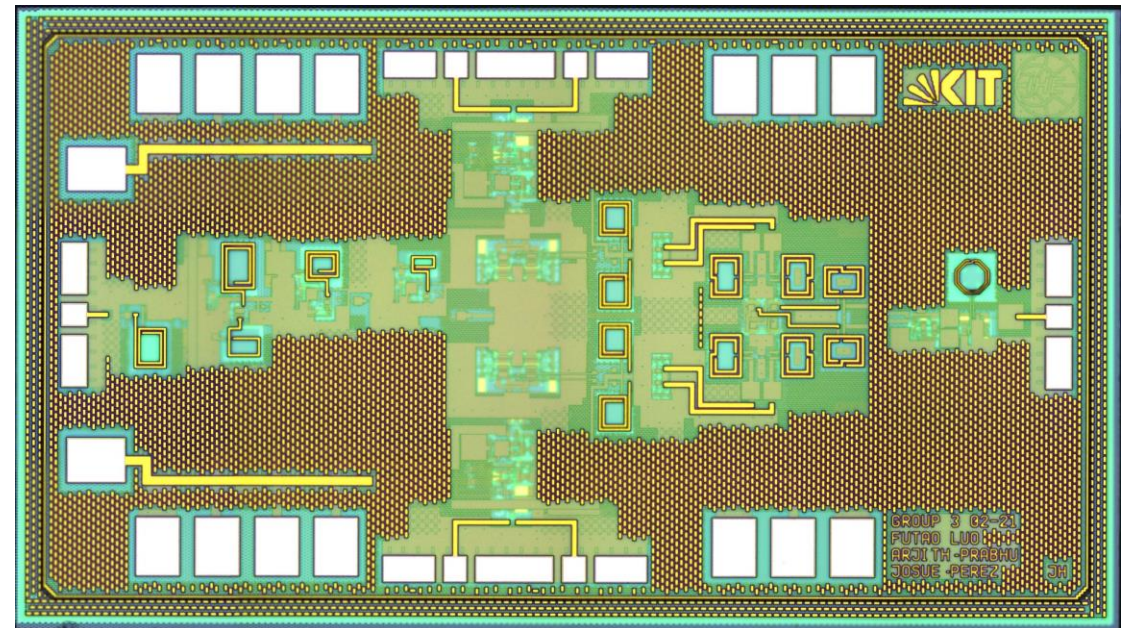
MMIC Design Lab Curriculum

- RF System Aspects, Topologies, Use Cases
- Understanding Differential Circuits and Circuit Analysis
- Introduction to Layout and Manufacturing of RFICs
- Theoretical and Practical Aspects of EM Simulation
- Theory of Small Signal Simulation
- Theory of Large Signal Simulation
- Passive Components, Inductors, Capacitors, Antennas, Transmission Lines
- Substrate Effects
- Common Circuit Components
- RF Components, Floorplanning, ESD Protection
- Digital Design, Mixed Signal Design, Tapeout Procedures

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Results 28GHz Receiver

1.83mm

1.01mm

LNA

Mixers and BB

LO distribution

Homodyne IQ Receiver

SG25H3

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Results 28GHz Transmitter

- Homodyne Tx

1.46mm

1.11mm

LO Distribution
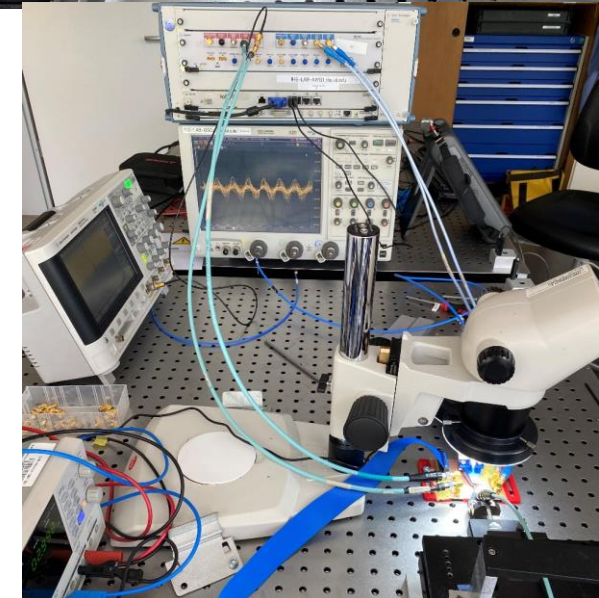
PA

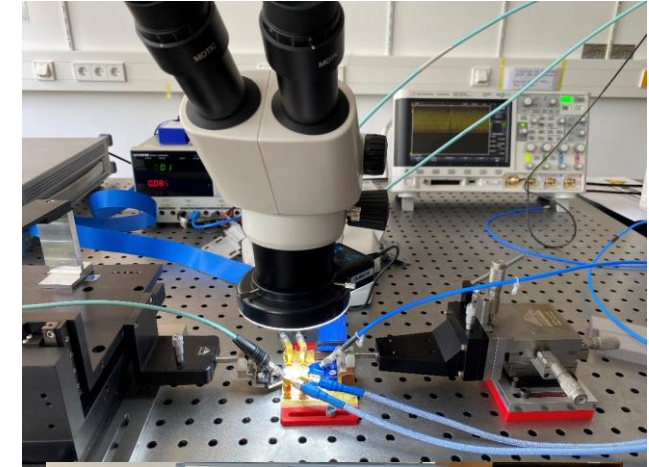SG25H3

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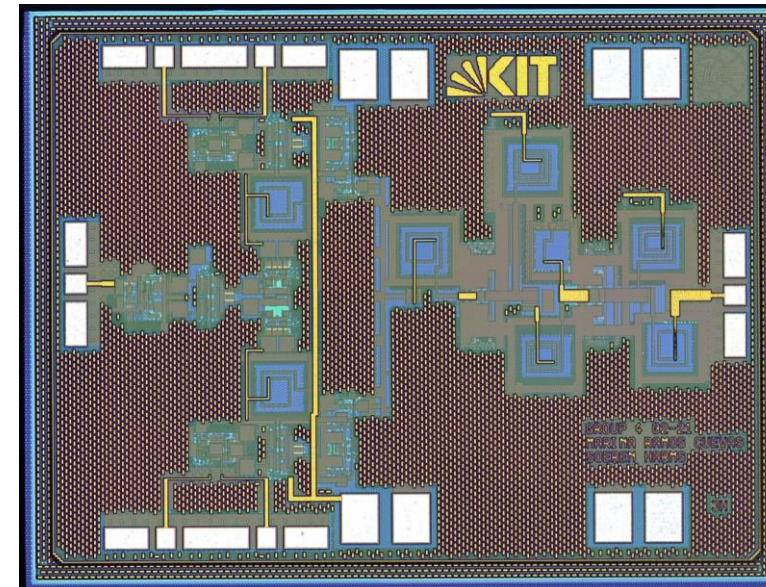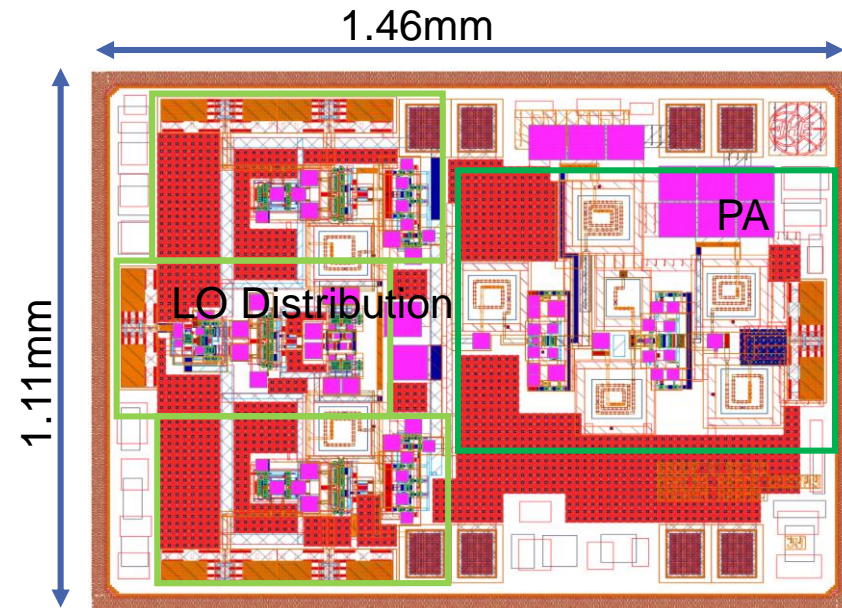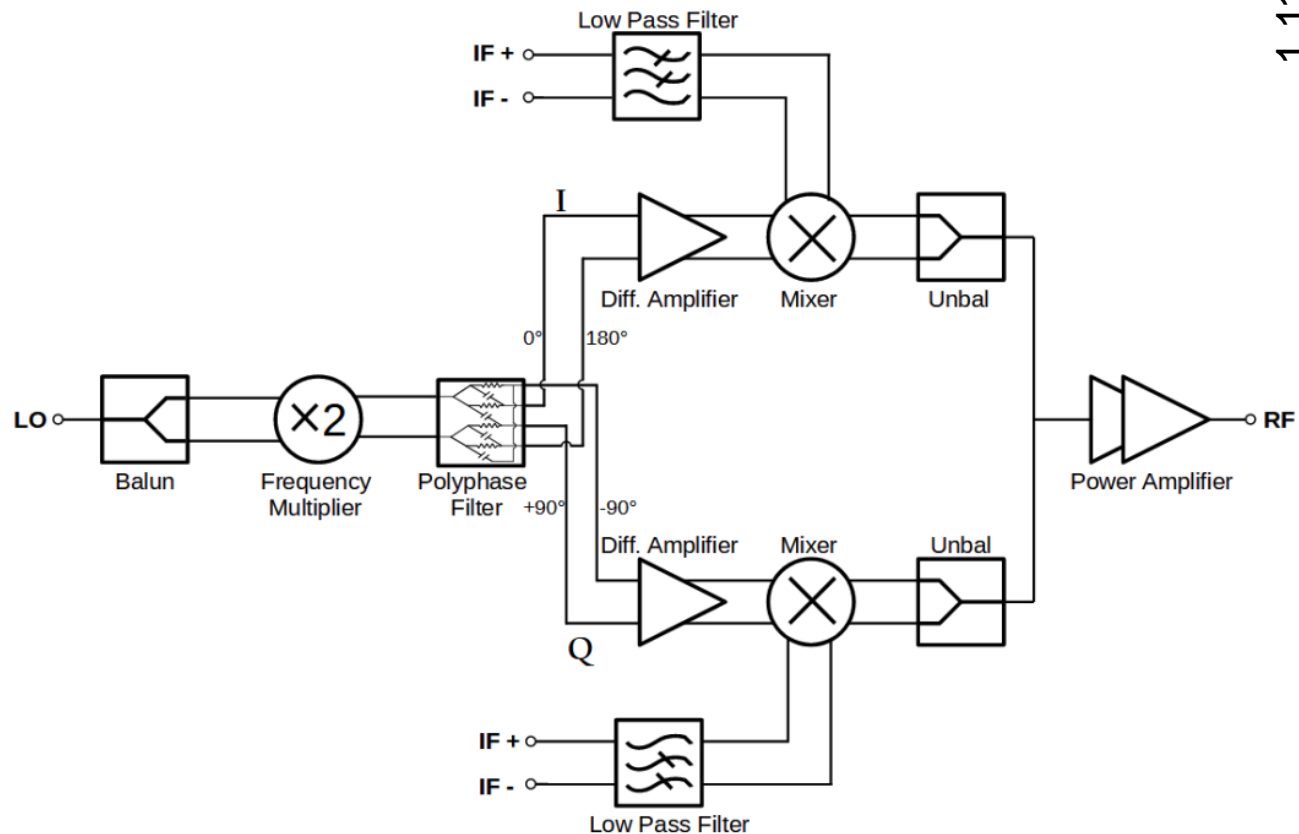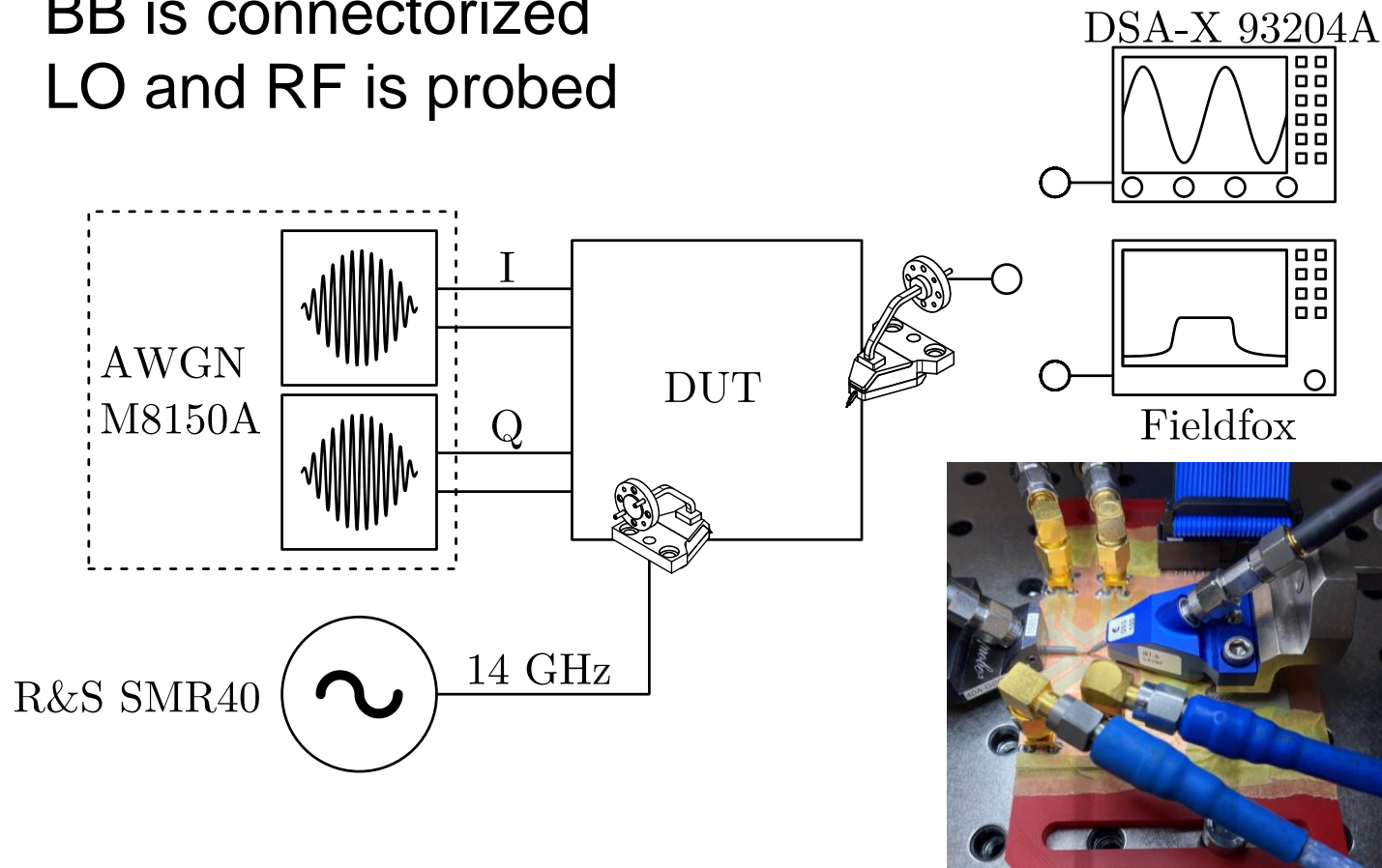
Measurement Setup

MMIC on custom PCB
BB is connectorized
LO and RF is probed

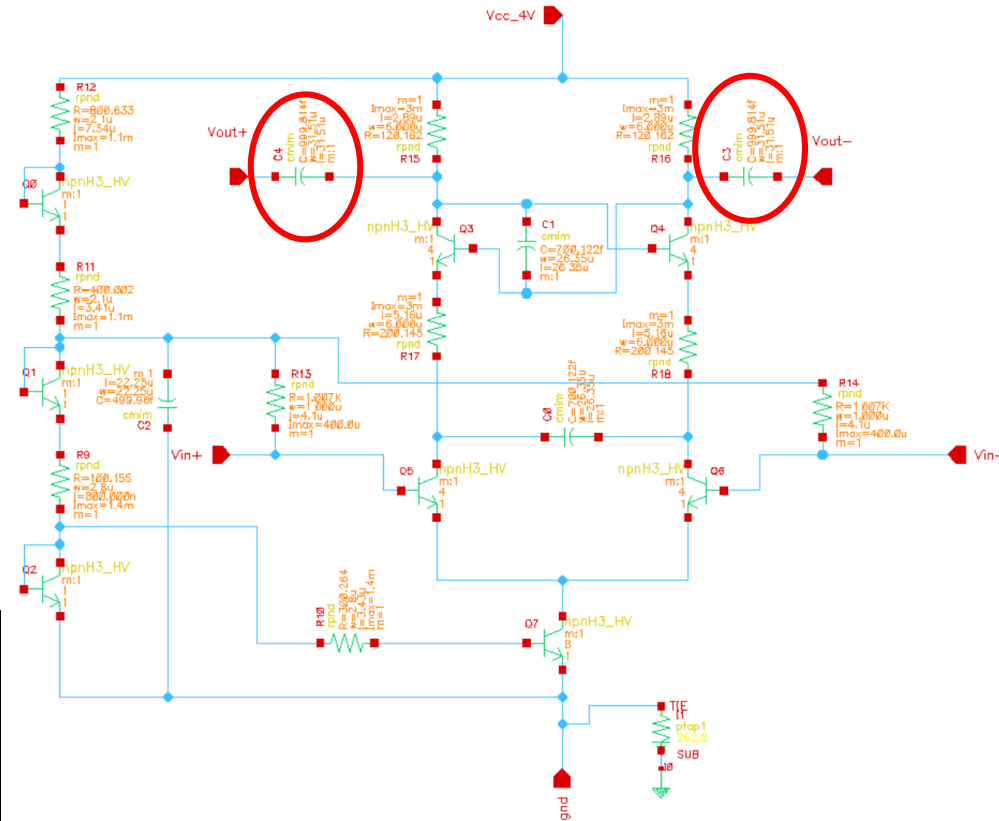June 26, 2023   Joachim Hebeler – Teaching Circuit Design at KIT

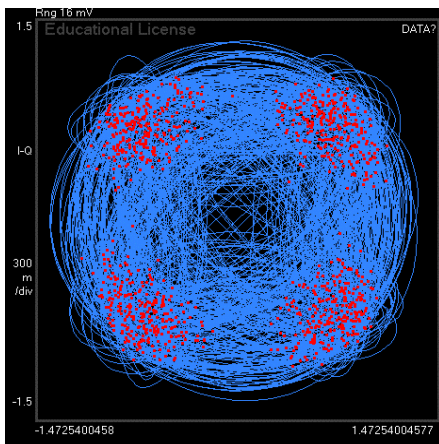Institute of Radio Frequency Engineering
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Measurement Results
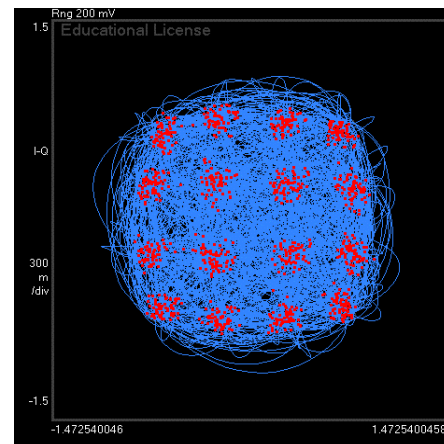
- High-pass response in the BB path
- Cause: AC coupling in the BB path
- Oversight during design
  Input is DC coupled, however to the
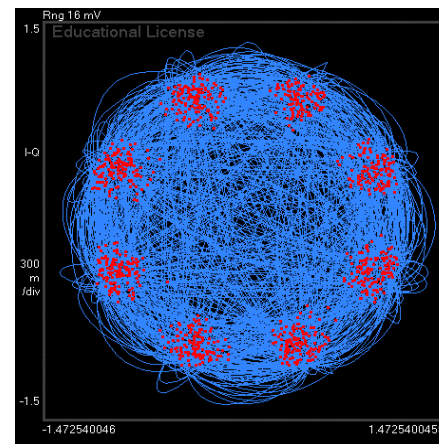 next stage AC coupling was used

800MBaud QPSK   120MBaud 16-QAM   70MBaud 8-PSK

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Measurements

Receiver

Transmitter

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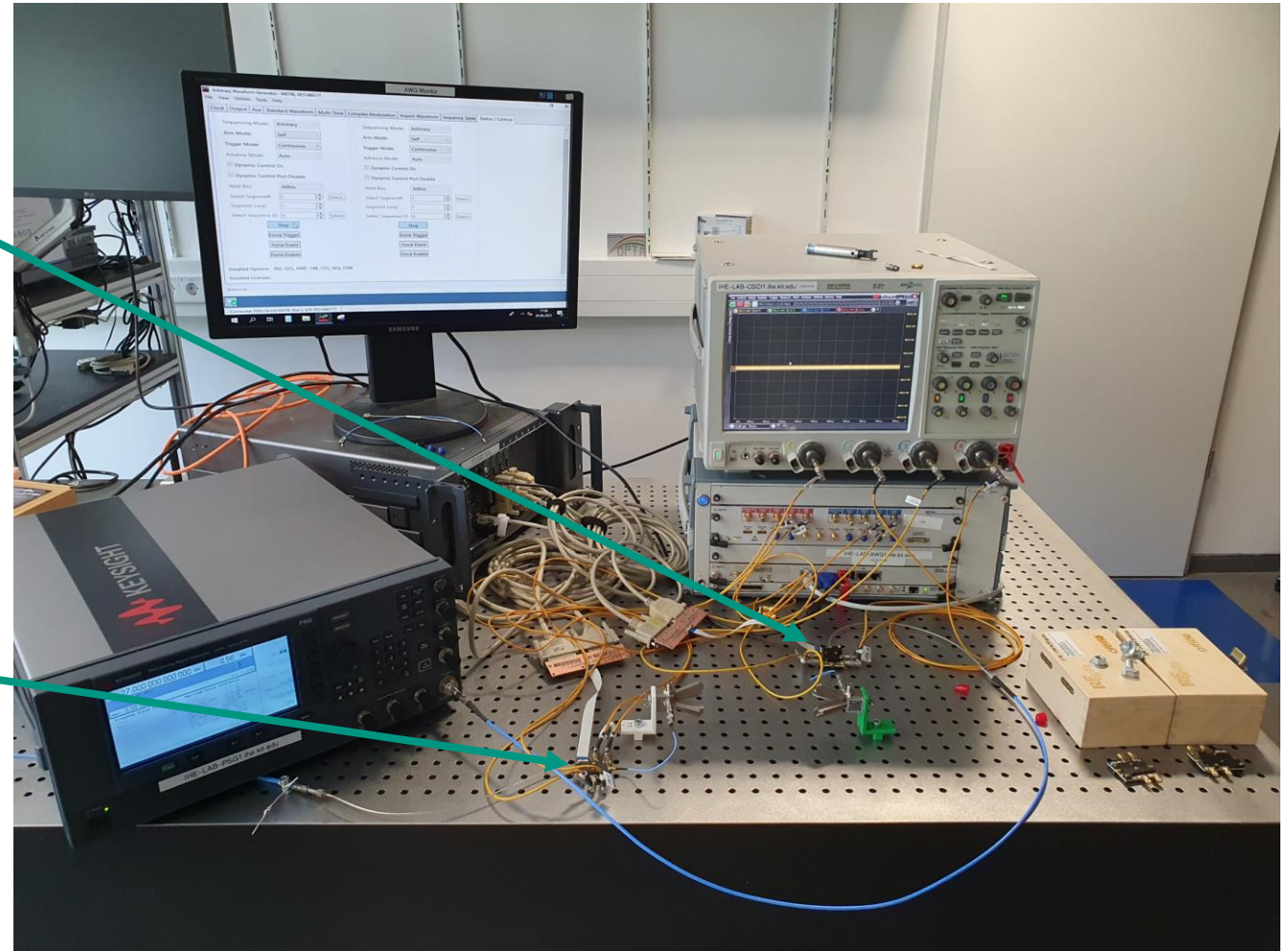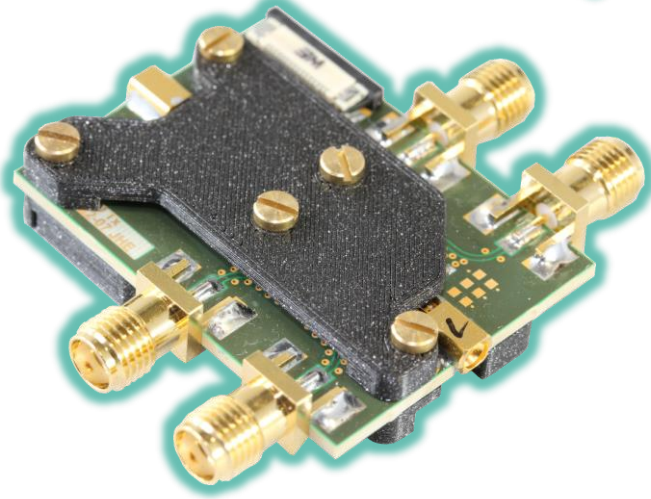and Electronics
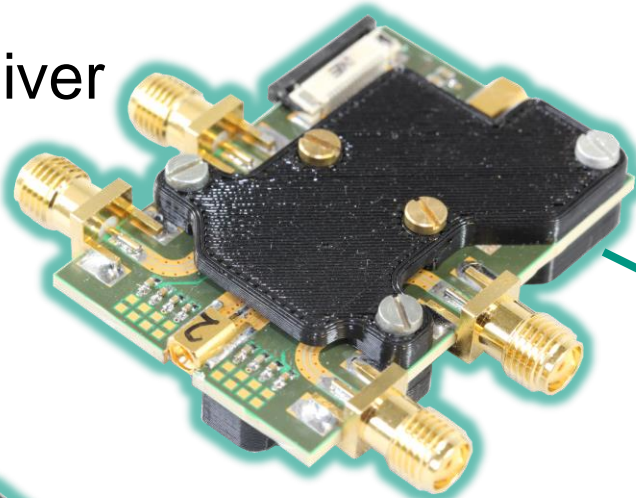
Measurement Results

- Output power is low
- Measurements show -20dBm to -30dBm signal levels
- Cause: First stage of PA has an issue and does not amplify
- Output signal is feedthrough of first stage plus gain of second stage

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Open Source in Teaching

- Design Tools usage is driven by availability and relevance
- Currently provided by Europractice:
  - Cadence Virtuoso
  - EMX
  - Mentor Calibre
- Other Tools:
  - Keysight ADS
  - CST Microwave Studio
- Which tools are used in research and industry?
- What can replace some of the commercial tools or workflows?

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Open Source Design Tools Requierements

- Circuit Design
  - Easy PDK integration
  - Schematic Capture
  - Spice like circuit solvers, time and frequency domain
  - Non-linear solvers, Harmonic Balance, Envelope
- Layout design
  - Integration of schematic and layout tool
  - LVS, QRC extraction
  - EM Simulator integration
  - Proper PDK integration
  - DRC Checks!

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Wishlist

- Python integration for automation of tasks
  - Simulation, parameter sweeps, data processing
  - Programmable layout generation
  - User expandable features/plugins
- Interoperable Formats
  - No complicated export/import processes for different tools
  - Integration in commercial tools and workflows
  - Automated and clearly documented workflows for exchange
- Integrated Environments
  - Not a collection of different tools with different interfaces, design methodologies, workflows or file formats

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Thank you for your attention
Questions?

Contact:
joachim.hebeler@kit.edu

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