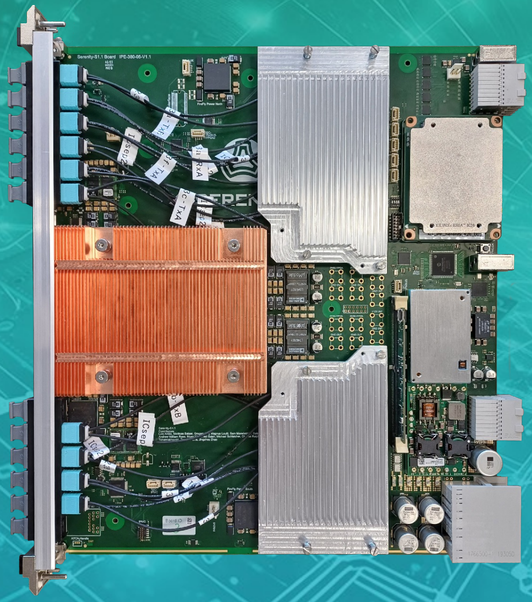


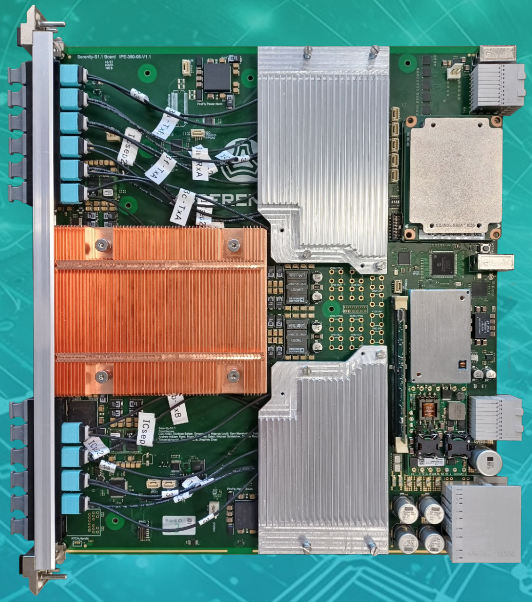
Detector Technologies and Systems (MT-DTS) Preparations for PoF V

Frank Simon

MT-DTS Strategy Meeting Kassel, 05/2025

Content

1. Structural Context – DTS in PoF V
2. KIT Plans – In broad Strokes
3. Selected Details – ST by ST
4. Facilities – Infrastructures in DTS Context
5. Additional Material: Project Details



Structural Context
DTS in PoF V

Chapter 1

FoPoZis: konkrete Ziele mit KIT Beteiligung / Verantwortung

DTS

- **Halbleiterdetektoren** und analog-digitale integrierte Schaltkreise bei höchster Integrationsdichte sind ein primäres Ziel von DTS. Die Etablierung von hochkompakten 2,5D und 3D **Integrationstechnologien**, die auch die direkte optische Kommunikation über eingebettete photonische Strukturen ermöglich, sollen in den Aufbau eines vollständig integrierten Demonstrationssystem münden (DESY, GSI, **KIT**; **2031**).

- Der Zugang zu disruptiven Technologien, wie **kryogene Quantensensoren** als Zukunftstechnologie, ist für die Helmholtz-Gemeinschaft zu sichern. Dies beinhaltet die Weiterentwicklung innovativer Sensorkonzepte inklusive der skalierbaren Auslese von großflächigen Sensoren mit tausenden bis Millionen von Pixeln, sowie die Bereitstellung von Produktions- und Testkapazitäten (DESY, **KIT**; bis **2030**).

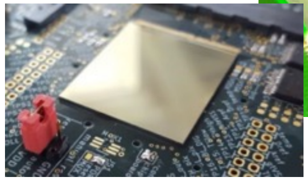
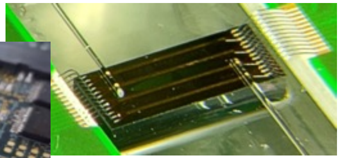
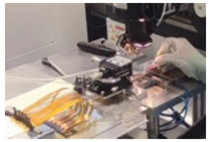
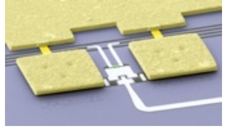
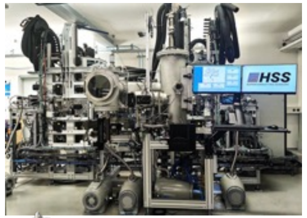
- Technologien- und Methoden für den automatisierten Betrieb und die Datenanalyse von Instrumenten z.B. in der Hochdurchsatzmessung in den Material- und Lebenswissenschaften sind anhand konkreter **Hochratendetektorsysteme** für den Einsatz an Photonenquellen wie PETRA IV mit integrierter Auslese zu entwickeln (DESY, **KIT**; **2035**).

Strategy – Detector Technology
Preparing the Future

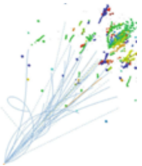
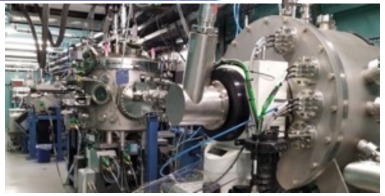
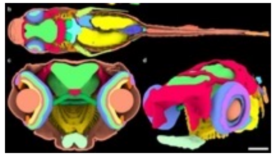
Development of cutting-edge technologies, realisation of unique detector systems ...

Interlinked strategic fields of development

- Sensors, Photonics, Interconnects ***FoPoZi***
- Superconducting Quantum Sensors ***FoPoZi***
- Multidimensional Detection Methods and Applications, integrating Photon Science Methods ***FoPoZi***
- Data Acquisition, Transmission, Processing Technology



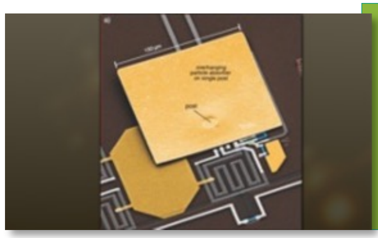





... addressing performance needs of instruments, driving experiment design, and enabling discovery.

Structuring research in MT - DTS

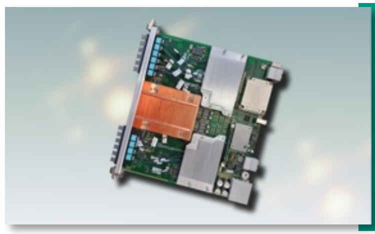
From PoF IV — *to PoF V*

From PoF IV



Detection and Measurement
Intelligent & compact granular detectors with high space and time resolution

ST1



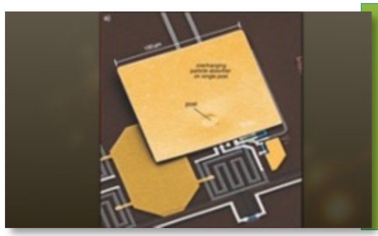
System Technologies
Critical technologies for coping with the data deluge

ST2

Science Systems
Build & characterize demonstrator systems ready for science

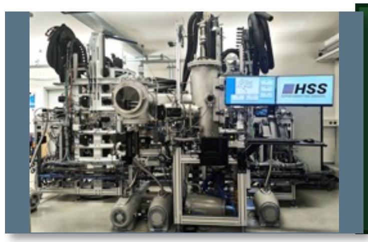
ST3

to PoF V



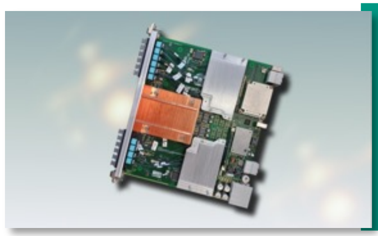
Sensing and Detecting Technologies
Realize intelligent and compact granular detectors with high space and time resolution

ST1



Quantum Technologies
Establish highly pixelated quantum sensors with ultimate energy resolution

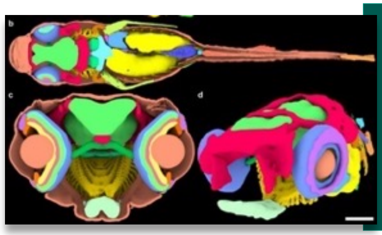
ST2



System Technologies
Build sustainable detector systems and cope with drastically increasing data rates

M M L

ST3



Detection Methods
Integrate advanced detector systems into multidimensional modalities for scientific discovery

M M L

ST4

KIT Plans for PoF V
In broad Strokes

Chapter
2

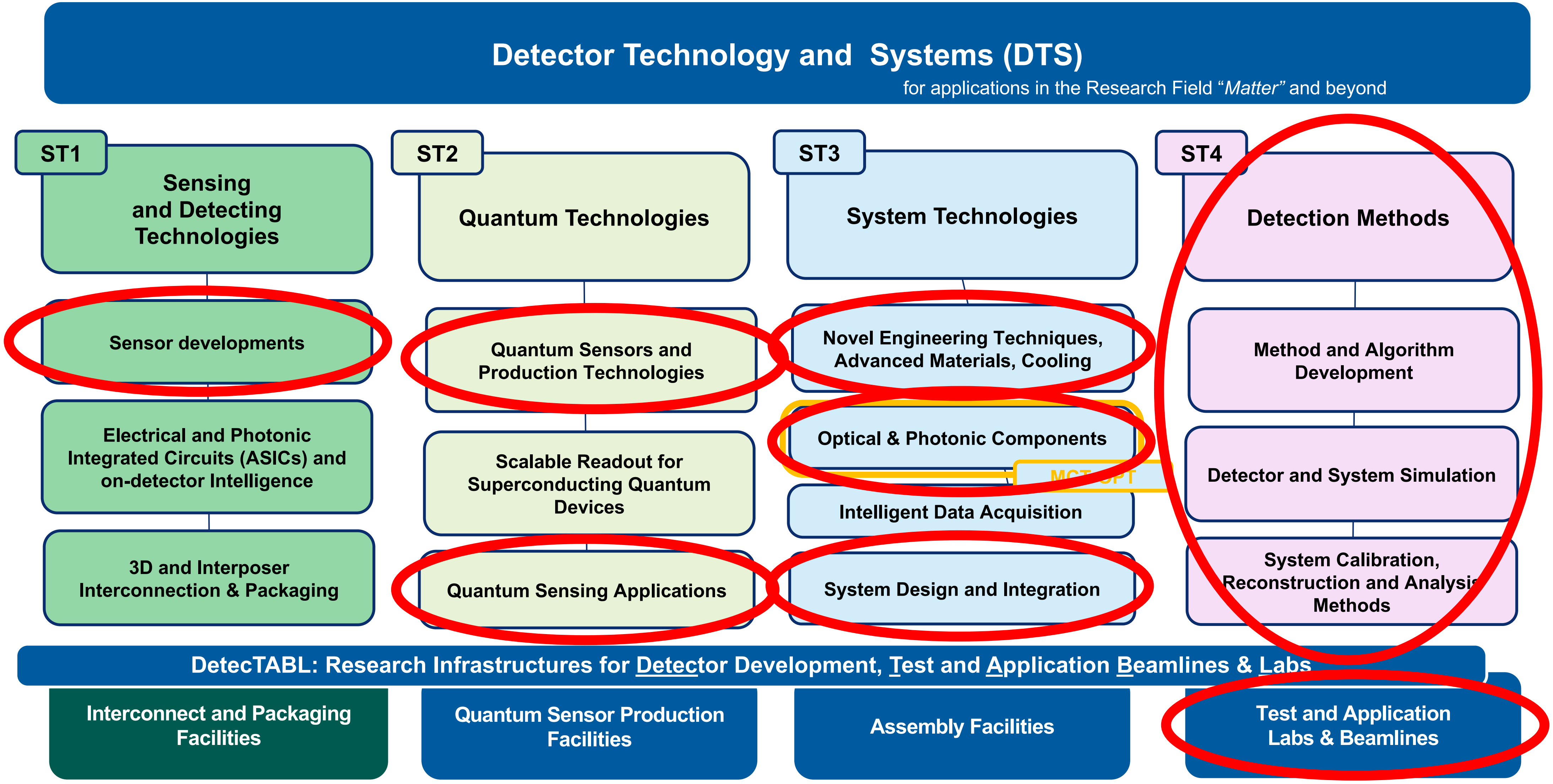
MT-DTS in PoF V at KIT

- Three research groups
- Cross-cutting technologies
- Activities in applications bejond RF Helmholtz Matter, Technology transfer
- Continuous training of young scientists
- This reflects the topic structure

ST1	ST2	ST4
Large-scale detector systems, sensors, interconnects and silicon photonics for high-energy physics	Superconducting quantum sensors for astroparticle physics and dark matter searches, ...	Detectors, instruments and methods for photon science
Simon / Peric	Kempf	Baumbach / Heske

ST3: High-performance DAQ systems, intelligent algorithms for online trigger and reconstruction, AI

Transition of MML activities to MT-DTS



KIT

Main Activities – High Energy Physics
The wider Context

LHC Phase IIb Upgrades – LS4 2034-35

- LHCb MightyTracker and Upstream Pixels: HVCMOS MightyPix Sensor
- ALICE3 Main Tracker modules – packaging and interconnects

EIC – Construction start 2026

- HVCMOS AstroPix sensor for highly granular ECAL

Next CERN Flagship – CDRs/TDRs early 2030ies, Operations from ~2045

- Ambition to contribute significantly to one experiment:
  - Calorimetry
  - Tracking
  - DAQ / data transmission

CMS, Belle II

- DAQ operation & development (CMS HGCAL, Tracker; Belle II PXD, possible Belle II upgrade)

Key technologies

- Semiconductor sensors, in particular HVCMOS
- Silicon photonics
- Packaging, interconnect technology
- High-performance DAQ, on- and off detector processing, system design
- High-speed links, intelligent front-ends

Strongly connected to implementation of ECFA Detector R&D roadmap:

- DRD3 – Semiconductor Sensors
- DRD6 – Calorimetry
- DRD7 – Electronics and On-Detector Processing
- Possibly in addition
  - DRD8 – Mechanics & Cooling

Main Activities – Precision Experiments
The wider Context

KATRIN++ – R&D phase during PoF V, Operations ~ 2035

- Multi-million quantum sensor array
- Windowless coupling to a room-temperature spectrometer ("cold chicane")
- Sub-eV resolution to push neutrino mass measurement to ultimate limit

DELight – dark matter detection with superfluid helium, in proposal and R&D phase

- Large-area, large-pixel sensors

BULLKID – dark matter detection with KIDs on silicon, construction of first phase ongoing

- Readout system for 1000s of quantum sensors, complex online triggering for background suppression

XLZD – Dark Matter Detection Collaboration

- Liquid Xenon TPC

Key technologies

- Quantum sensors, in particular MMCs
  - Achieve sub-eV resolution
  - Operation in magnetic fields
  - Emphasize scaling and large-scale production
- Quantum sensor readout technology
- Liquid Xenon technology

Strongly connected to implementation of ECFA Detector R&D roadmap:

- DRD5 – Quantum Technologies
- Possibly in addition:
  - DRD2 – Liquid Detectors
  - DRD4 – Photon Detectors

Main Activities – Photon Science
The wider Context

Creation of unique and challenging experimental environments for the development of novel detection approaches

- HIKA as first phase beamline B23 at PETRA IV
- Beamlines and labs at the KIT Light Source within the Clusters for
  - Spectroscopy (X-SPEC beamline)
  - Scattering (NANO beamline)
  - Imaging (IMAGE and HIKA beamlines)
- Multidisciplinary KIT research infrastructure for natural and engineering sciences
- Complementary experimental stations at low-emittance photon facilities
- Radionuclide Materials Observed with Soft X-ray Spectroscopy (ROXS) at X-SPEC

Key technologies

- Quantum-sensor based calorimetric superconducting detectors
  - High rates & harsh environments
  - Operation in magnetic fields
- AI-supported beamline concepts for autonomous large-scale digitization and analysis of 3D morphology
- Automated beamline operation
- Bragg (de)-magnifiers

KIT's new activities in MT-DTS

- KIT proposes to strengthen MT-DTS by further contributions in ST1-3 and in a fourth subtopic, jointly with DESY
  - ST4 will support system conception, design, characterization, and application
- KIT's beamlines and labs will extend the DTS "Research Infrastructures" portfolio
  - System implementation and application tests as important steps in technology development

Main Activities – Beyond Matter
The wider Context

Quantum Computing

- Connecting to *Helmholtz Information*
- Contributing to large consortia focusing on quantum computers using solid-state cryogenic qubits
- Primary focus: Readout technology

Energy Technology

- Connecting *to Helmholtz Energy*
- Power electronics for electromobility, photovoltaics

Ultrasound diagnostics

- Technology transfer – health technologies
- Lean wearable ultrasound diagnostic systems
  - Goals: cost effective, easy to use, patient-friendly
  - Exploiting MT technologies

Key technologies

- High-performance readout systems
  - Qubit readout and control
  - DAQ for medical applications
- Cryogenic CMOS
- Packaging and interconnects
- System integration

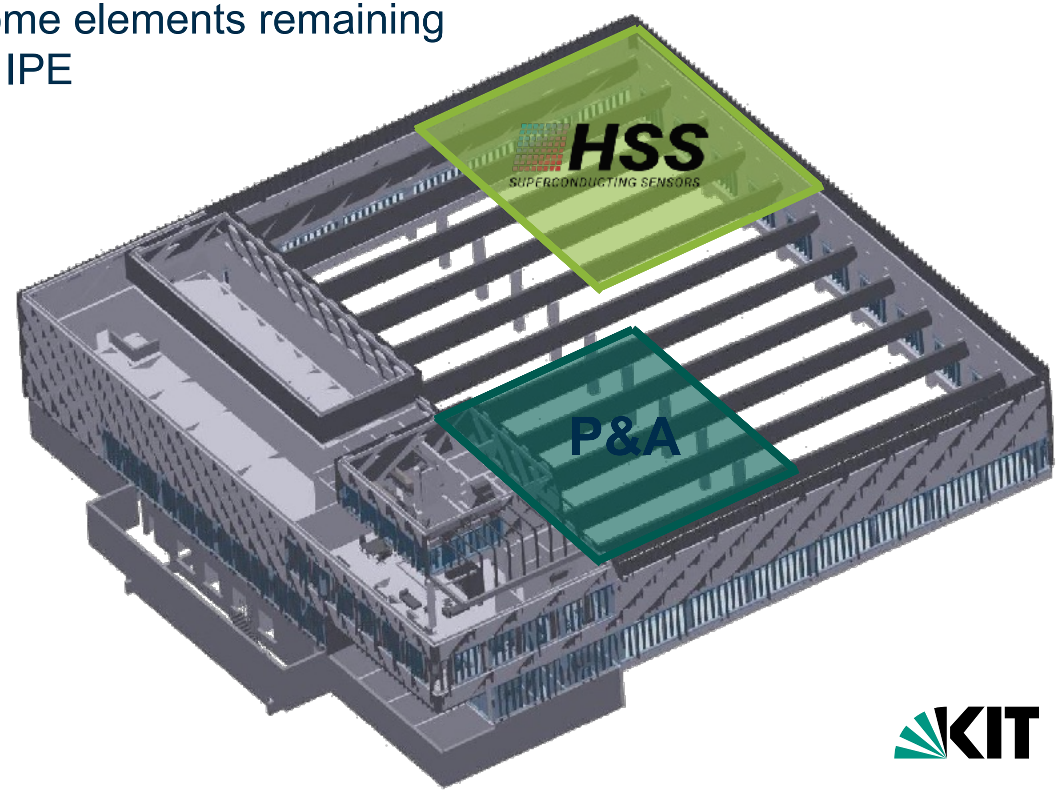
KCOP & HSS
Key Infrastructure

Competence Center on High-resolution Superconducting Sensors (HSS)

- strategic HGF investment: significant infrastructure built up
- addresses the ever-increasing need for large-scale / large-volume QS arrays
- three pillars of HSS:
  - QS development
  - QS prototype and batch fabrication
  - QS application
- allows to compete with internationally renowned facilities, e.g. MIT-LL, NASA/GSFC, NIST, …
- continuous equipment extensions and technology (r)evolutions to enable next generation QS development

Karlsruhe Center of Optics and Photonics (KCOP)

- Cleanroom center currently in construction – operational 2026
- Two DTS-relevant “technology clusters”:
  - HSS will be fully integrated once cleanroom available
  - Packaging and assembly – partially to move to KCOP, some elements remaining at IPE



Personnel

- Expected personnel in PoF V (HGF core funded), based on resources in 2024

PoF V subtopics	DTS "Core team" Scientists	DTS "Core team" Support	New (former MML) Scientists	New (former MML) Support	Total Scientists	Total Support	Total Sum	Network
ST1	6,5	1,5	1,5	0,5	8	2	10	10
ST2	2,5	0,5	1,5	0,5	4	1	5	30
ST3	7	3	12	6	19	9	28	20
ST4	1	0	12	6	13	6	19	10
Sum	17	5	27	13	44	18	62	70

Allocation of personnel in 2024

MT-DTS relevant environment at KIT beyond core funding

- Third party funding IPE
- Personnel FIS KCOP/HSS
- Synergies with quantum computing in RF Information
- Synergies with KATRIN++ detector team in MU
- AG Kempf, quantum sensors
- Cooperation with UNSAM / ITeDa; Argentina, quantum sensors and readout
- Supervision of PhD at CERN by Simon, Peric
- AG Biondi, Liquid Xe – Technologies
- Cooperation Uni Freiburg, High-Z sensors
- AG Baumbach, LAS
- AG Heske, U Nevada Las Vegas

Approx. 70+ FTE

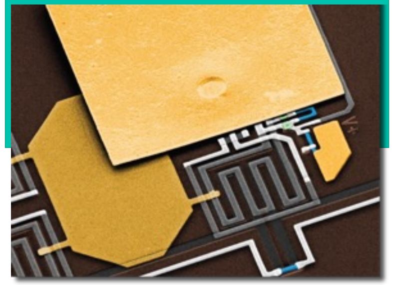
Proposal for a detector innovation platform

Detectors are a cross-cutting and enabling technologies for Helmholtz Matter and beyond

Four pillar structure

Organize according according ECFA detector R&D roadmap structure

Coordinate the German contribution to the implementation of the detector R&D roadmap

Cutting-edge infrastructure Operation, maintenance, replacement, upgrades, …	ASIC design hub for German com munity + intern. exper. Engineering staff, design tools, submission costs	High-tech experts Attract engineers for large-scale experiments, offer career perspectives	Links to academia / university groups Provide services and adopt new technologies
			

Selected Details
Subtopic by Subtopic

Chapter
3

ST1: Bringing Intelligence to the Front-End
Advanced packaging: AI, FPGA, Photonics-on-Detector

Leveraging novel small, compact FPGAs/eFPGAs, together with Silicon Photonics, for the conception of *intelligent* detector modules that integrate compact, high-speed logic, low-power and AI capabilities

1. Active or passive silicon interposers featuring TSVs, RDLs, and flip-chip, as well as ultra-light polyimide/Al large-area hybrids by FBK within DRD 7.6b
2. NDA (KIT & Efinix) access to 16 nm TSMC for novel class of ultra-compact FPGA
3. Silicon-Photonic InnoPool (DRD 7.1)
4. No-BackEnd electronics, enabling direct data streaming to commercial off-the-shelf (COTS) devices (DRD 7.5)

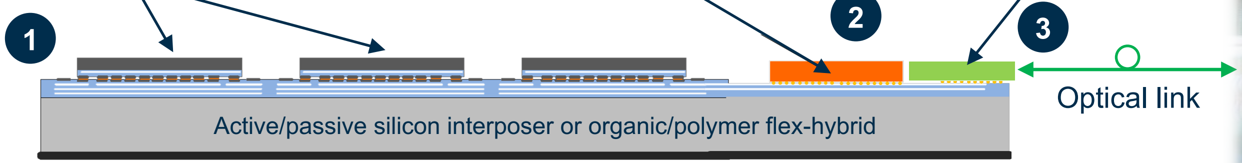
LHCb upgrade / ALICE 3
MVD-CBM upgrade, photon science, many others …

Active/passive sensors
Front-end chip

On-detector processing by
bare-silicon FPGA / RISC V

Silicon Photonic
Chip

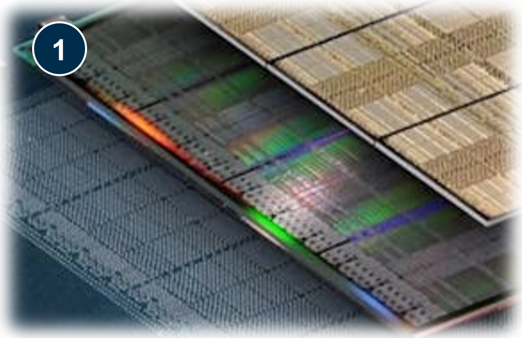
COTS Ethernet



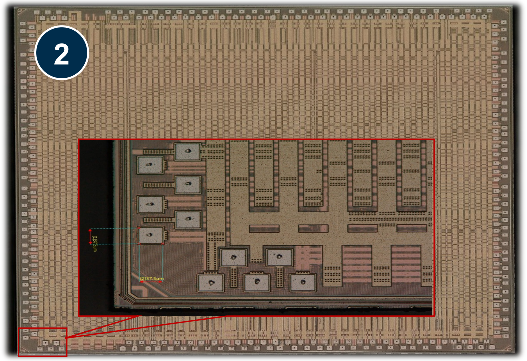
Detector module active region

Detector module periphery

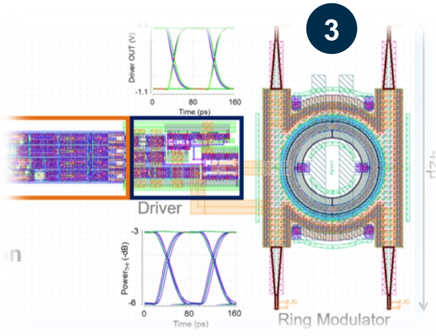
No BackEnd



High-density interconnection technologies (DESY, GSI, KIT)



Ultra-light, ultra-compact and ultra-low-power FPGAs for HEP



SOPHIE InnoPool (DESY, GSI, KIT)

ST1: ASIC Development
KIT ADL Activities

Monolithic sensors – large area sensors, thin sensors – investigating a range of technologies

- Large area: 12 inch wafer technology, for example 130nm and 55nm BCD technologies of TSMC and Globalfoundries
- Thin sensors: technology with 25µm epi layer or with gain layer – ex.: XS018 process of XFAB (also offers stitching)
- High time resolution: SiGe or a nm-scale technology with small pixel size (28nm, 16nm FinFET…).
- High spatial resolution: nm scale technology

Radiation-hard readout ASICs for future experiments at hadron colliders

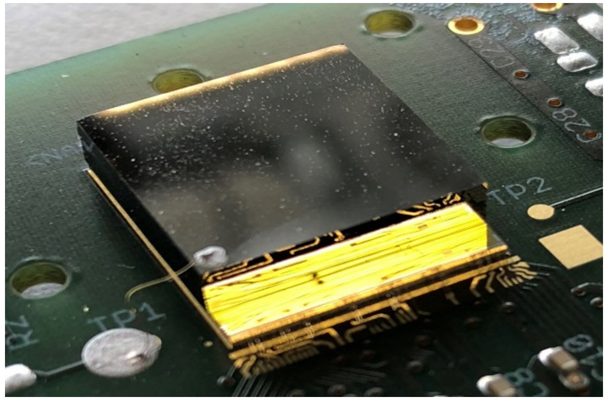
- FinFET or GAA (nanowire) nm technologies may offer high radiation tolerance. SiC as a potential technology for rad-hard circuits

Cryogenic applications

- Investigating 130nm SiGe BiCMOS technology of IHP - design kit for temperatures down to 4K available.
- SOI technologies for quantum dot transistors and single carrier transistors: Qubit implementation – also possible in similar FinFET technologies. Combination with readout circuits on same die: monolithic quantum processors

ST1: High-Z Sensors
Sensors for Photon Science

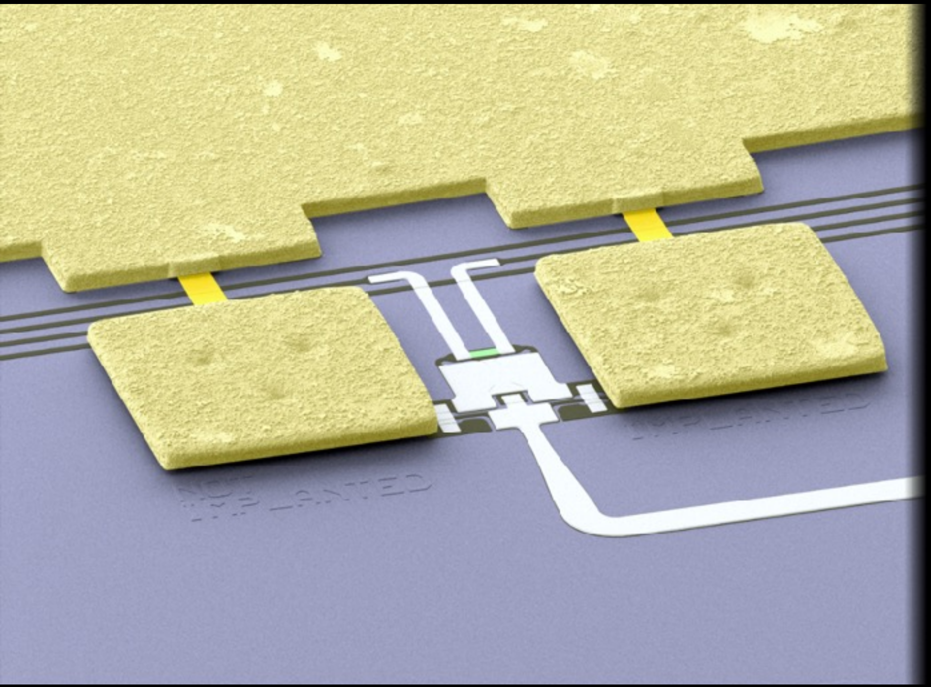
- **CdZnTe/GaAs (collaboration with U-Frei, …)**
  - Development of CdZnTe/GaAs sensor technologies from crystal growth towards detector production



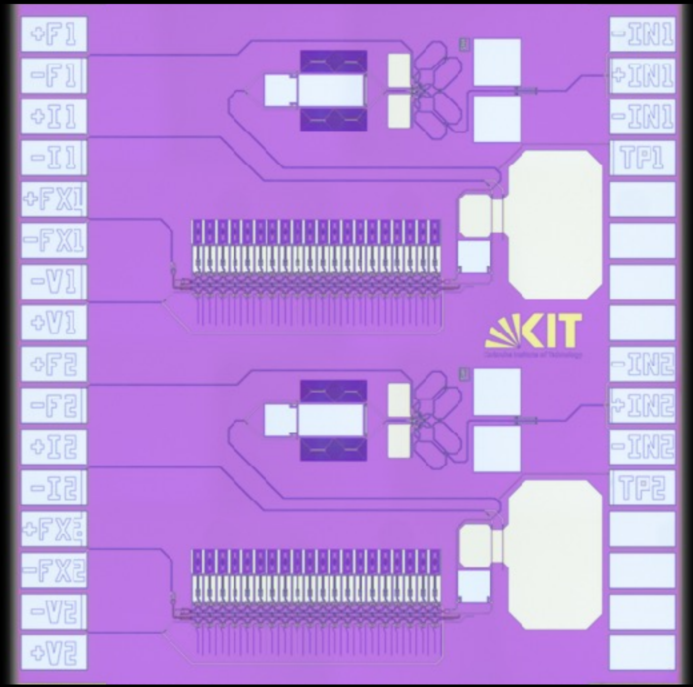
- **Perovskites**
  - New class of semiconductors: Perovskite semiconductors (promising photovoltaic materials)
  - Perovskite materials are a promising alternative regarding availability, toxicity, and low production costs, compared to conventional high-Z materials like CdZnTe or GaAs

ST2: Quantum Sensors
Covering the full Chain: From Sensor to Data on Disk

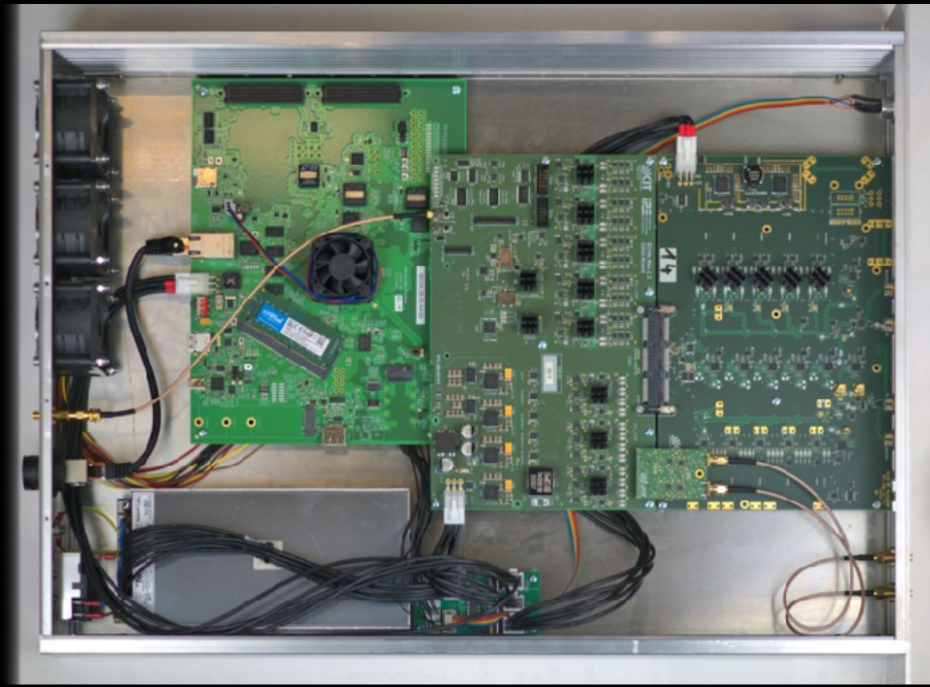
Superconduncting quantum sensor arrays require outstanding sensor + readout technology, large-volume fabrication capabilities, and scalable, customized cutting-edge high-speed DAQ readout electronics



QUANTUM SENSOR →



QUANTUM ELECTRONICS →



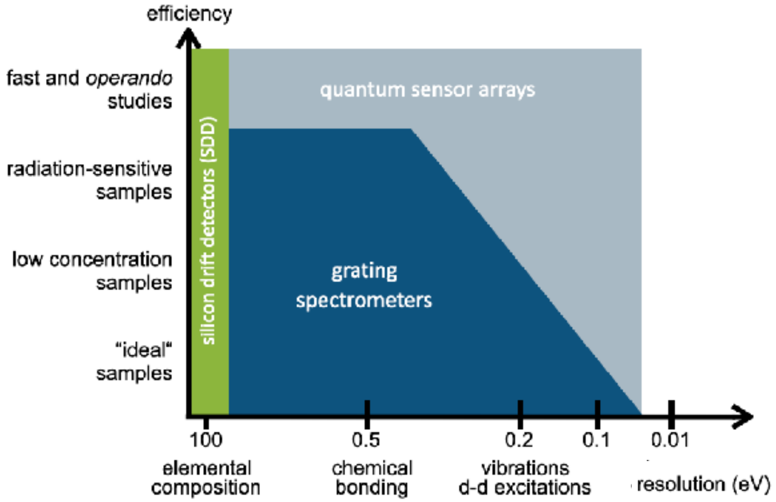
SCALABLE DAQ ELECTRONICS

➡ pushing physical limits and developing high-tech

ST2: Quantum Sensors: Lighthouse experiments
(Order does not reflect importance, impact etc.)

MT DTS + MML Materials

High transmission and efficiency detector for X-SPEC beamline at KIT Light Source

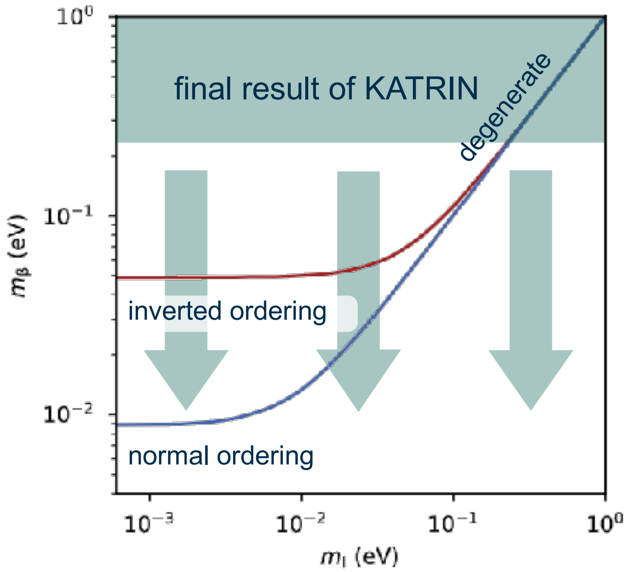


➡ Large-scale QS array
(high-transmission IR filters, high photon flux, harsh environment, …)

QUASY - Quantum Sensor Platform for Synchrotron X-ray Spectroscopy

MT DTS + MU MRU

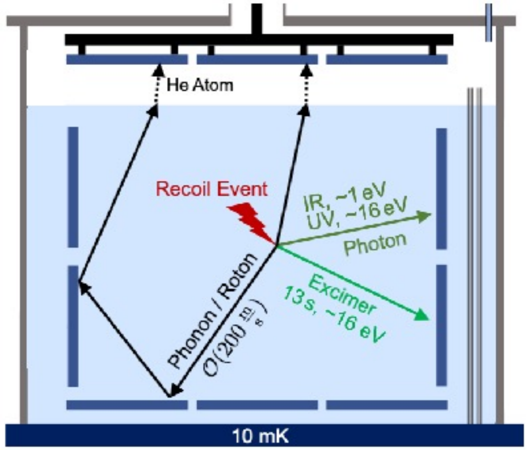
KATRIN++ | The ultimate (tritium based) neutrino mass experiment



➡ Large-scale QS array
(10^5-10^8 channels, *B*-field tolerance, interface to warm spectrometer, …)

MT DTS + MU MRU

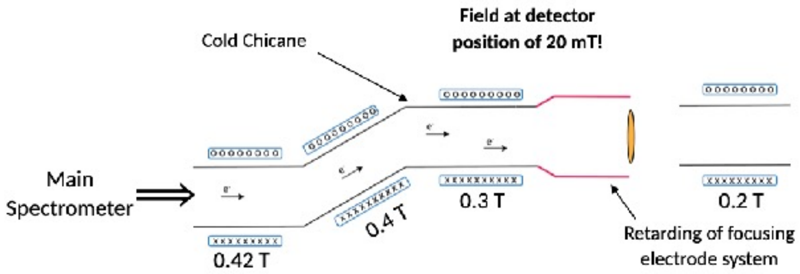
DELight | Direct search experiment for Light Dark Matter using superfluid Helium

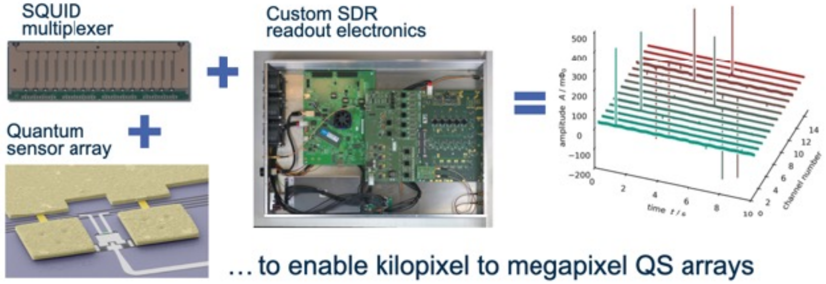


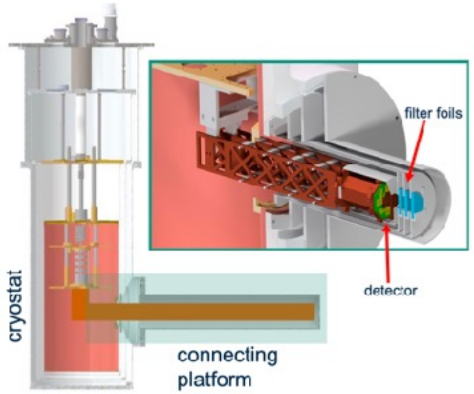
➡ Large-scale array of large-area QS
(full-wafer detectors, athermal phonon detection, spatial separation, radiopurity …)

ST2: Quantum Sensors
Scientific Goals and Challenges

- Development of quantum sensors (cryogenic microcalorimeters) with (deep) sub-eV energy resolution (KATRIN++, beamline endstations, e.g. X-SPEC)
- Maturing and advancing readout for kilo- to megapixel quantum sensor arrays: Cryogenic SQUID multiplexers, high-speed and scalable DAQ electronics, (quantum amplifiers?), …
- Detector development for harsh environmental conditions: Proximity to accelerators, Operation in static of dynamic magnetic background fields, …
- Development of source-coupling techniques:
  - High-transmission coupling of warm photon sources to cryogenic detectors („windowless“)
  - Coupling of warm electron sources to cryogenic detectors („cold chicane“)
- Enhancing technology-readiness level (TRL): Easy-to-use, reliable, and robust quantum sensors allowing for commercialization
- Adressing the ECFA detector roadmap







ST3: System Technologies
High-performance DAQ, Integrated Systems

High-performance DAQ exploiting state-of-the-art FPGAs and heterogeneous devices – often driven by experiment requirements

- High-throughput DAQ boards, online processing: CMS Serenity
- Scalable quantum sensor readout – with applications also in quantum computing
- Exploiting AI-enabled SoC devices
- Sustainable design – reuse, common standards, scalability and flexibility of component selection

Novel DAQ concepts

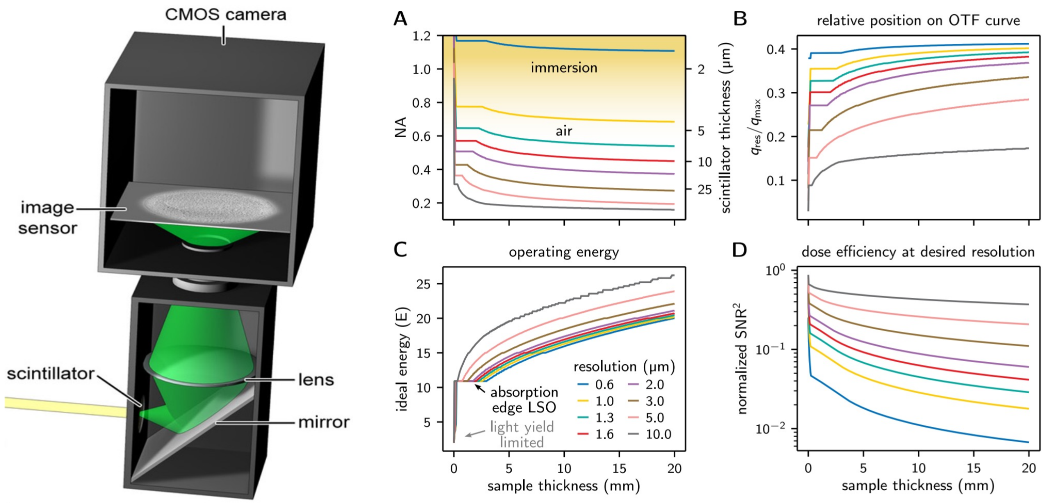
- Integration of intelligence in front-end (-> ST1); use of standard protocols early in readout chain; enabling COTS systems downstream.
- Alternative detector front-end data transmission using silicon photonics (-> ST1)

Detector system design

- For example: HEP (sub-)detector systems for present and future collider experiments: CMS HGCAL, Tracker; Higgs Factory Calorimeters, Trackers and DAQ concepts; AI-based reconstruction and design techniques

ST3 – System Technologies:
Advanced Materials
Optical & Photonic Components (MCT-OPT)
System Design and Integration

Simulating properties of a high-resolution indirect X-ray camera system

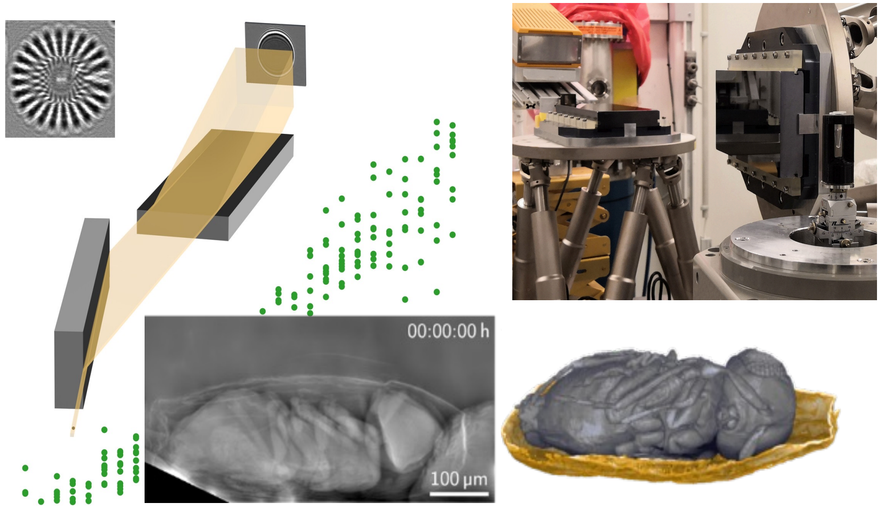


Detector and System Simulation

High fidelity simulation of detecting systems

- Dose efficiency
- Direct and indirect converting X-ray detection systems
- … and their involved components (X-ray optics, converting sensor, light optics, read-out electronics, …)

Illustration of dose-efficient coherent near field imaging



Integrating Optics and Detectors in powerful Detecting Systems

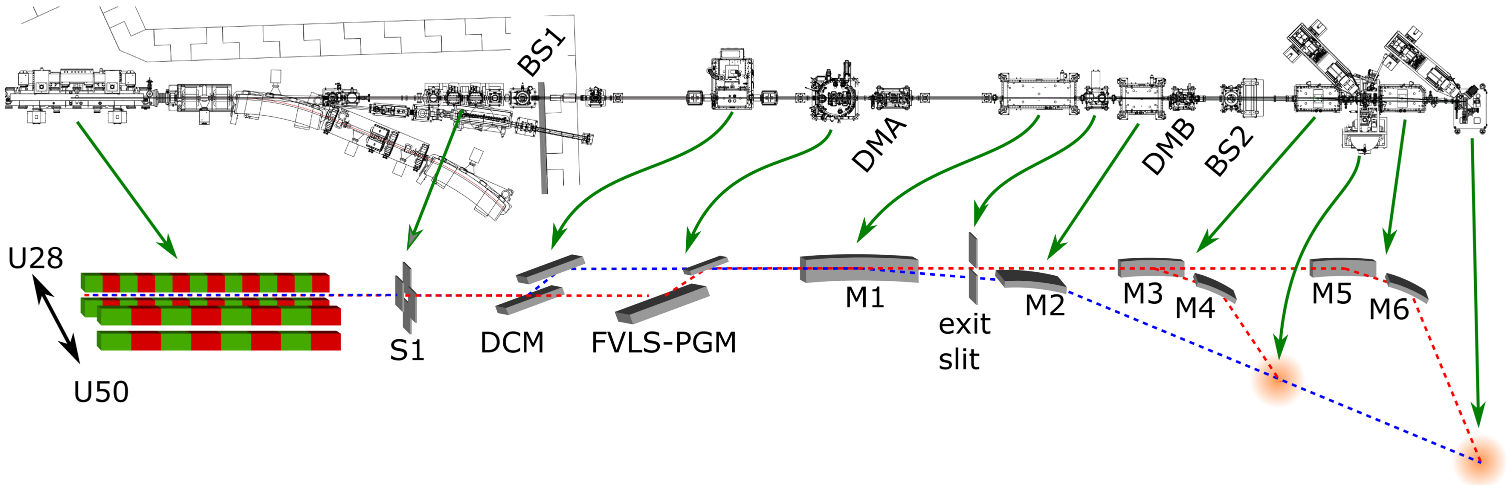
- Integration of high-Z Single Photon Counting Detectors (SPCDs) and Bragg-Magnifiers (BMs) for dose-efficient high-resolution imaging

ST4 – Detection Methods:
Development for serial, *in situ*, *in vivo*, *operando* Applications

Advanced multidimensional synchrotron method developments
→ trigger new detector developments

- High dose efficiency and short exposure times towards *operando* soft x-ray detection systems
- Combination of powerful optics (e.g., gratings) and pixel array detectors
- On-the-fly component integration from source (undulator), mono-chromator, and focusing optics, to sample, analyzer optics, and (soft x-ray) photon detection systems
- Spectroscopy, Scattering, Imaging

Example: The X-SPEC Beamline at the KIT Light Source



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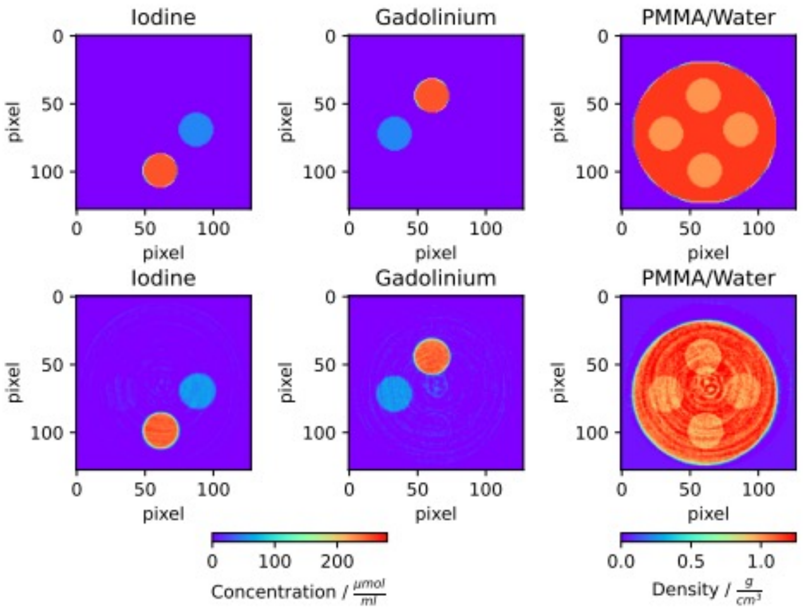
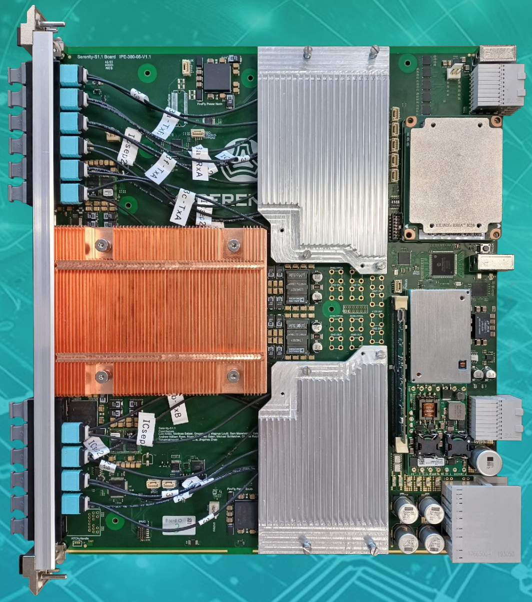
ST4 – Detection Methods:
Multidimensional Method and Data Analysis

- **Systems Integration of novel Detectors:** Integration in versatile X-ray pipelines (Hard- and Software) at synchrotron beamlines and X-ray tube-based laboratory setups
- **Dedicated method developments based** on novel detectors and combinations with optics & smart analysis
  - Dose-efficient phase contrast imaging, hierarchical imaging, serial CT, Cine-tomography, MHz-imaging …
  - Spectroscopic X-ray imaging with machine learning based material decomposition …
  - Rapid RIXS: On-the-fly component integration from undulator to optics and soft x-ray photon detection systems
- **Application Tests:** Quality measure for imaging properties evaluating exemplary applicability in life science, materials research, …
- **MT-DTS-ST4 connects to other Helmholtz Programs and Research Fields**



Material-specific spectroscopic CT-slices of a test phantom. Top: ground-truth, bottom: measurement, Medipix3RX with 2mm CdTe in charge-summing-mode

PhD-thesis Marcus Zuber



Facilities: Infrastructures in DTS Context

Chapter 4

Competence Center for High-resolution Superconducting Sensors (HSS)

exploitation of full HSS potential
(experiments + commercialization)

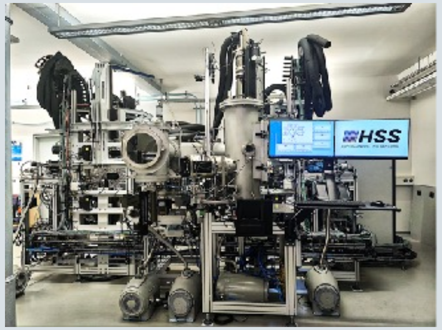
- strategic HGF investment
- addresses the ever-increasing need for large-scale / large-volume QS arrays
- three pillars of HSS:
  - QS development
  - QS prototype and batch fabrication
  - QS application
- allows to compete with internationally renowned facilities,
  e.g. MIT-LL, NASA/GSFC, NIST, …
- continuous equipment extensions and technology (r)evolutions to enable next generation QS development

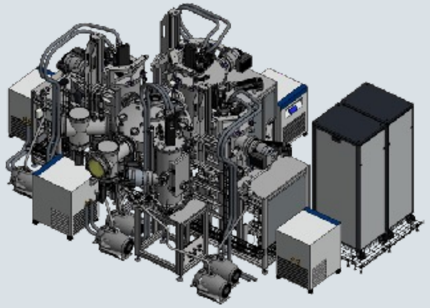
HSS
SUPERCONDUCTING SENSORS

Photolithography

photoresist processing,
direct laser lithography

UHV material deposition cluster





magnetron sputtering, e-beam evaporation, in-situ oxidation, ion-based substrate cleaning

ICP-PECVD **3 x ICP-RIE**

TEOS + silane based insulator deposition

F- and Cl-based RIE of metals, dielectrics, and Si

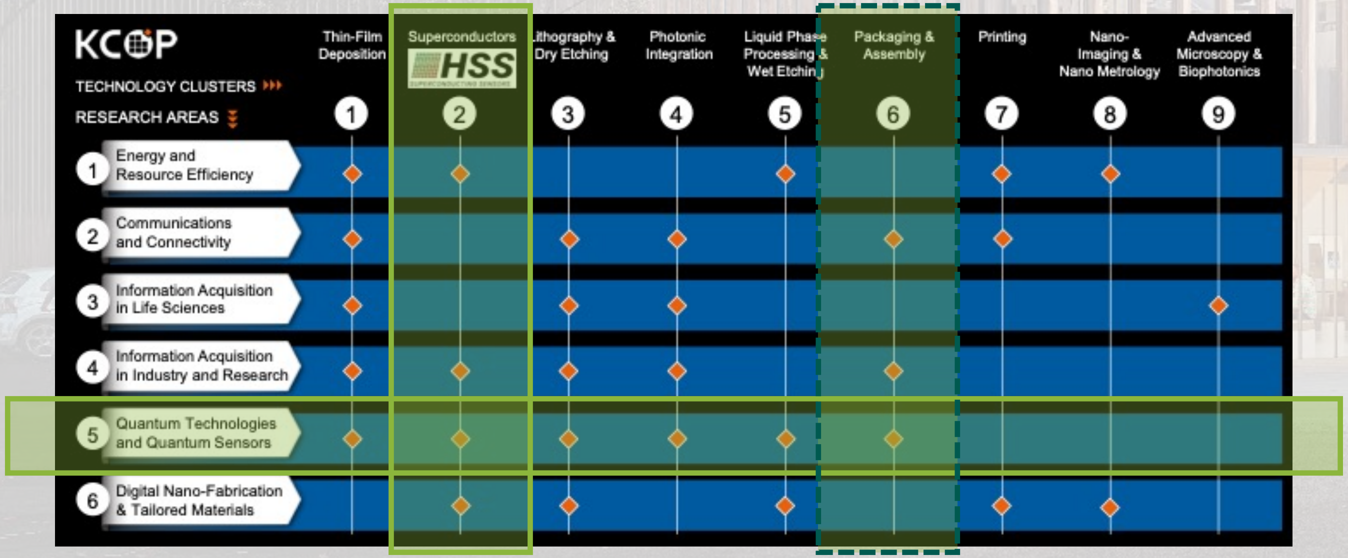
CMP technology

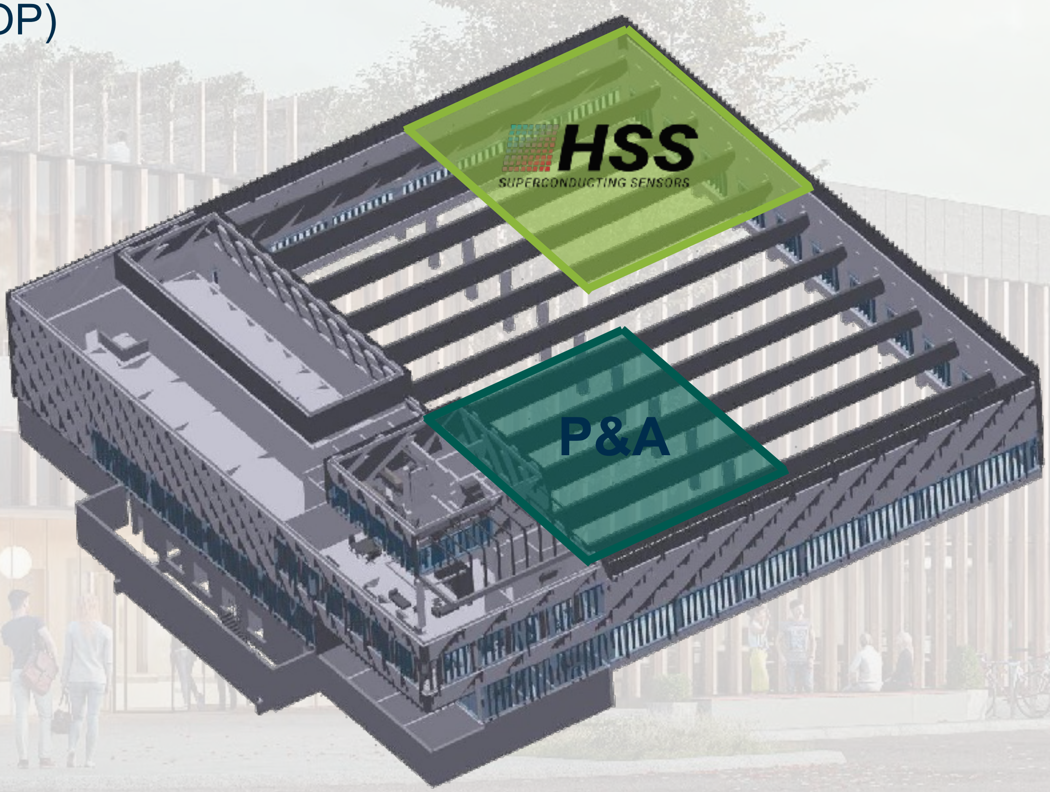
Wafer polishing for multi-layer supercond. structures

KCOP: Karlsruhe Center for Optics and Photonics

Large-scale research infrastructure

- Integration of HSS in Karlsruhe Center for Optics and Photonics (KCOP)
- HSS forms independent technology cluster (TC) and is main driver of research area (RA) “Quantum Technology and Quantum Sensors”
- Close collaboration with TC “Packaging and Assembly (P&A)” (operated by MT-DTS) for sensor module packaging





KIT

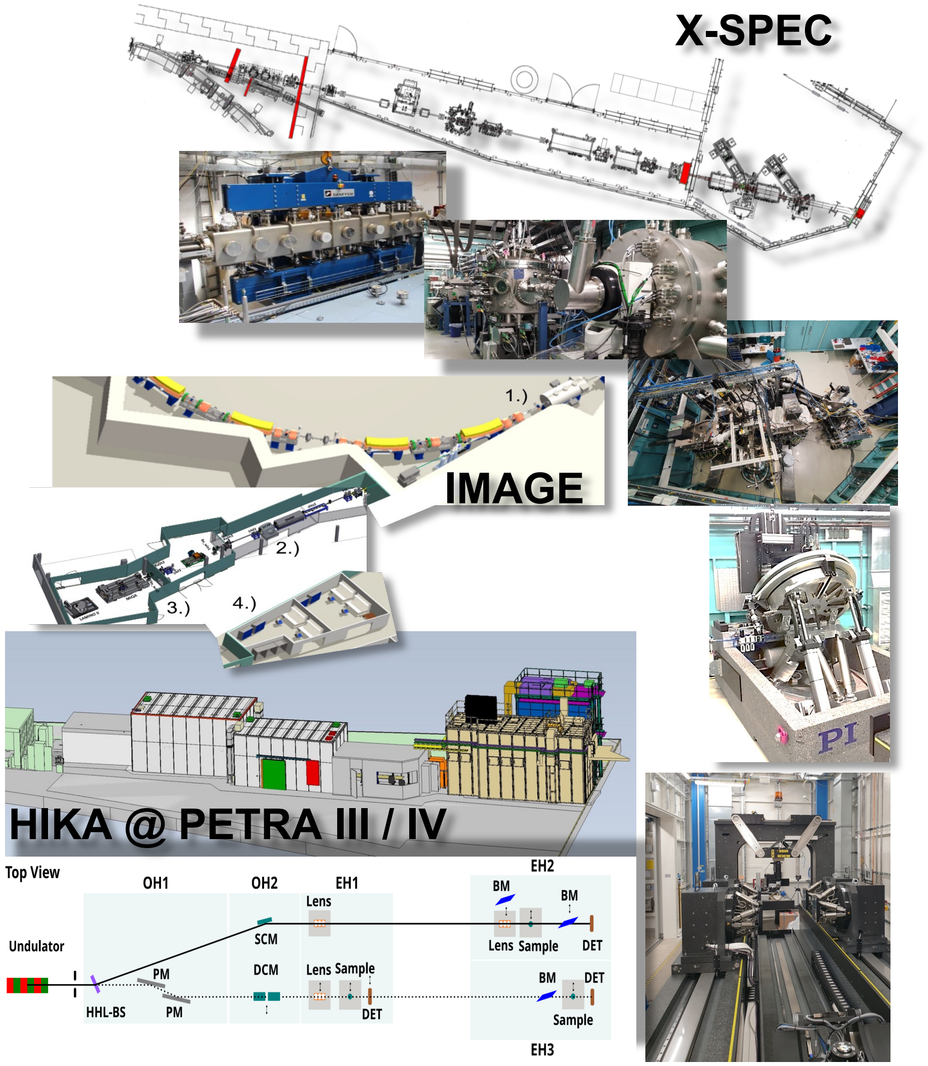
Beamlines and Imaging Laboratories
Research Infrastructures

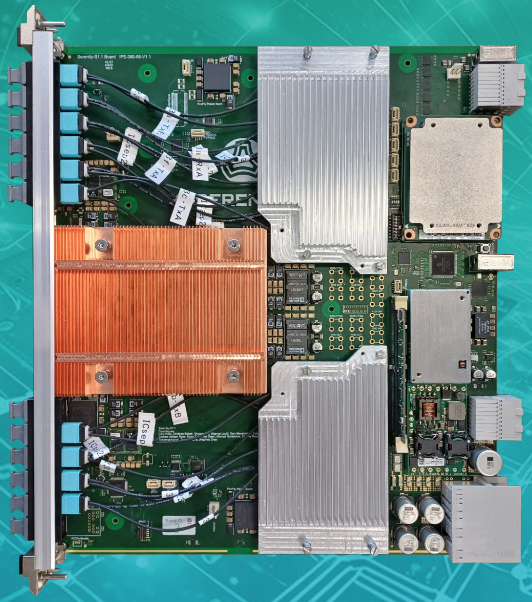
Test and Application Beamlines & Labs

- Beamlines for Characterization, Detection Performance Tests, Method & System Development for Multidimensional Data Modalities & Application

  - **IPS Spectroscopy, Scattering & Imaging Cluster to convert multidimensional data into information for scientific discovery**
    - Multidimensional data acquisition & processing
    - High throughput, *operando, in situ & in vivo* data acquisition
    - X-SPEC for cutting-edge soft and hard x-ray spectroscopy development
    - IMAGE & HIKA: unique portfolio for laminography, hierarchical imaging, and serial tomography for large-scale comparative studies

  - **Methods Development & Application for**
    - Sensor characterization & detector performance
    - CL-CT-Det-Lab: Laboratory-based X-ray Development Platform for quality assurance of optics and detectors & method development
    - Synchrotron based sensor characterization, detector performance tests
    - Development of methods of multidimensional modalities and application to real-world challenges





Additional Material: Project Details

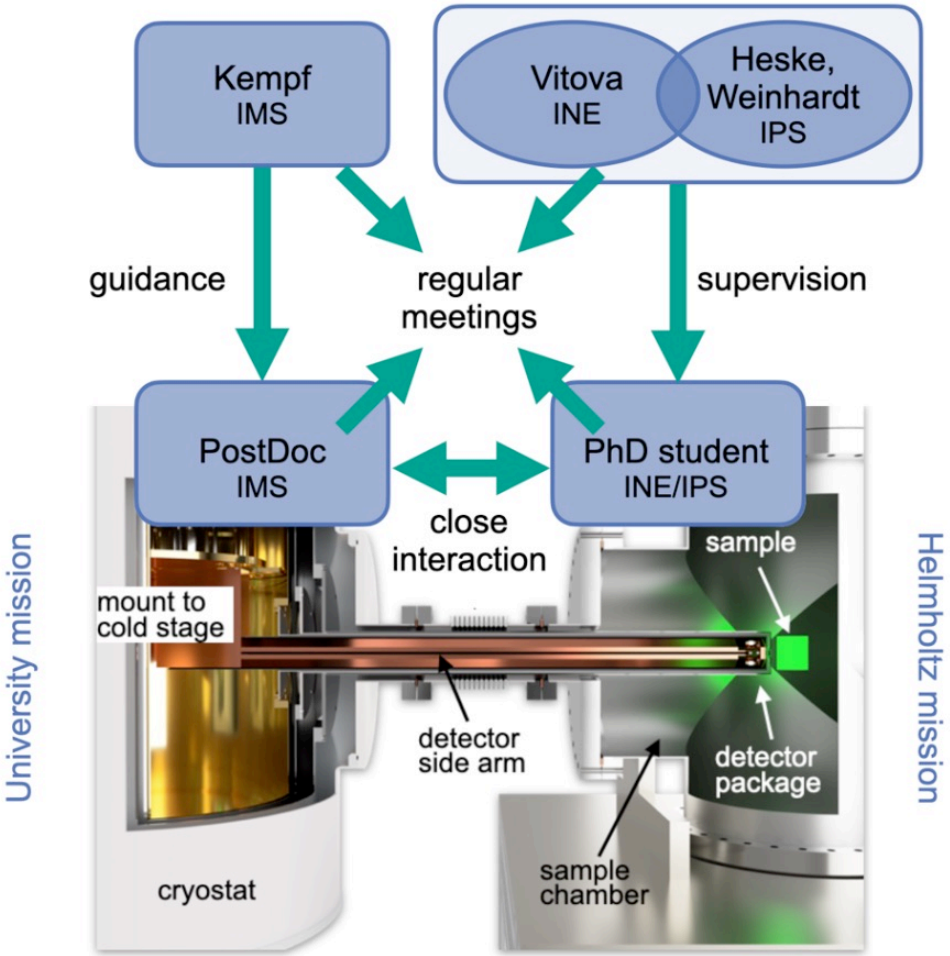
Chapter 5

Quantum Technologies in Photon Science Applications

QUASY - Quantum Sensor Platform for Synchrotron X-ray Spectroscopy

- **Magnetic Microcalorimeters – MMCs**
- For various beamlines in the IPS Spectroscopy Cluster
- Energy resolution **orders of magnitude better** than for conventional EDX detectors
- Part of InnoPool project QS4Physics

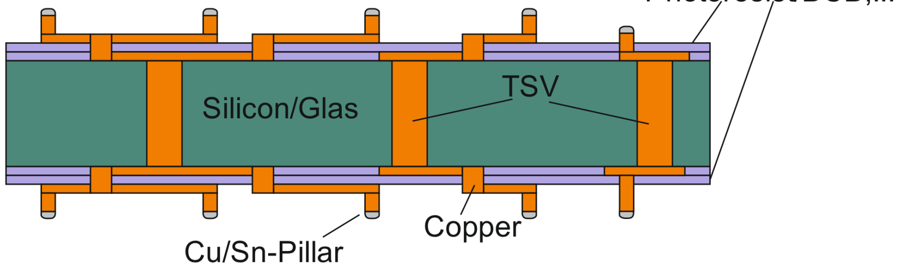
Collaboration with S. Kempf (IMS), T. Vitova (INE)



Packaging and Interconnect Technologies
IPE AVT

Development of Interposer technologies

- On 6” glass and silicon wafers, and other materials using laser drilling and deep reactive ion etching (DRIE) technology. Selected challenges & goals:
  - Line and spaces down to 5µm
  - Multilevel redistribution layers (e.g., 4 layers, each layer with a thickness of ~ 15-20µm)
  - Highly accurate and controlled glavanic processes, incl. Cu-Sn copper pillar bumps (diameter ~ 10 µm; solderable in reflow process)



Cable technology development

- Fine Pitch Flex-Cable (CBM, …) development by roll-to-roll lamination of photosensitive resist films (see DIT).
- Laser processes to ablate Cu or Al metal but keep the PI
- Optimization of galvanic deposition processes on flex PCBs for microcables

New interconnect technologies

Material structuring in Si, SiC and other materials

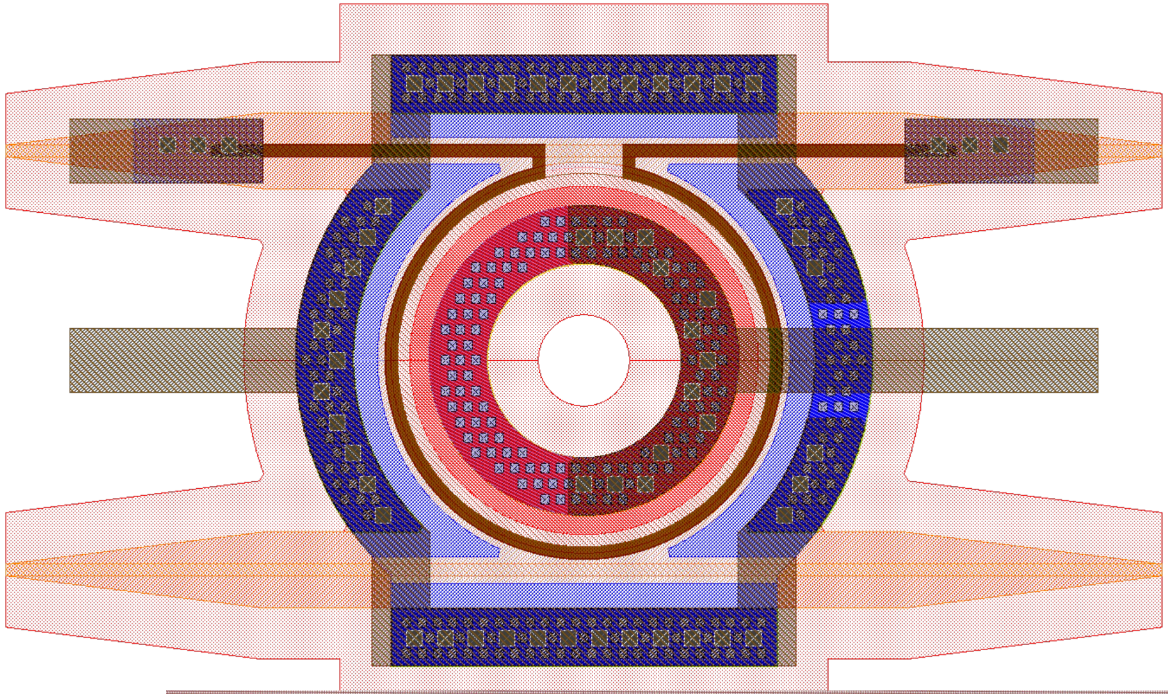
Silicon photonic transceivers in PoF V at IPE

- Ring Modulator (RM) based
- RMs with drop port and photodiode (PD) and heater for working point control
- PD can also be used for data reception on working wavelength
- Bi-directional transceiver
- Required: Driver ASIC with working point control logic
- Wavelength division multiplexing transceiver systems with cascaded RMs
- TSVs for contacting with interposer/driver/read-out-chip
- Fiber-Chip-coupling using grating couplers and quartz glass fiber holders
- Fiber-Chip-coupling using edge couplers and fiber ribbons (questionable approach)

Silicon Photonics

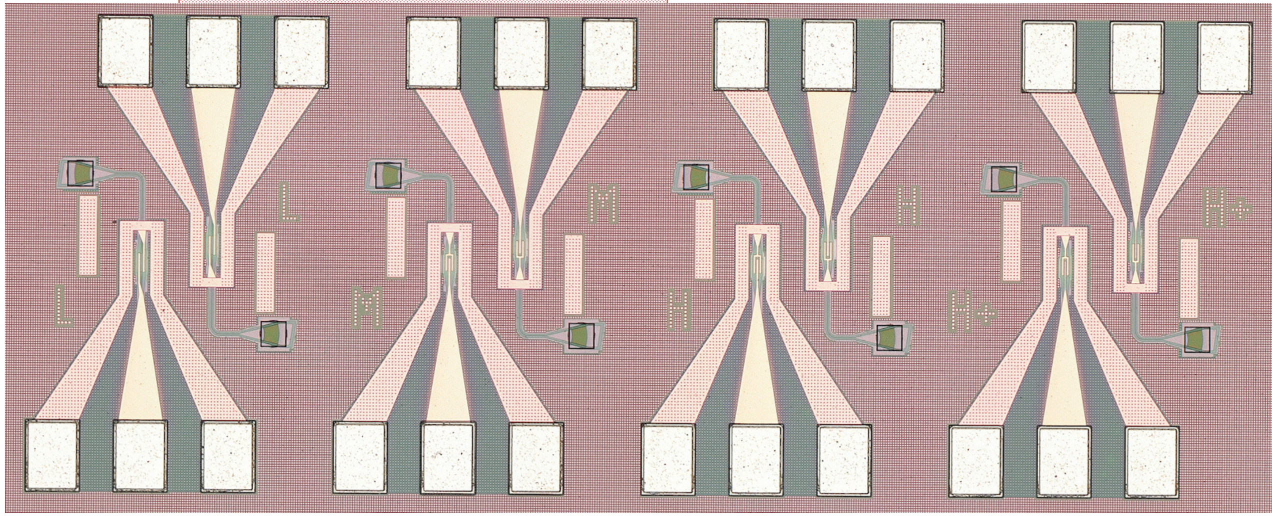
New ring modulators

- Bus-waveguide and Drop-waveguide
- Integrated heater
- Radiation hardened design



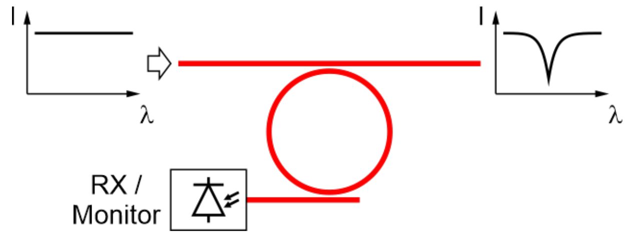
Germanium based photodiodes (imec)

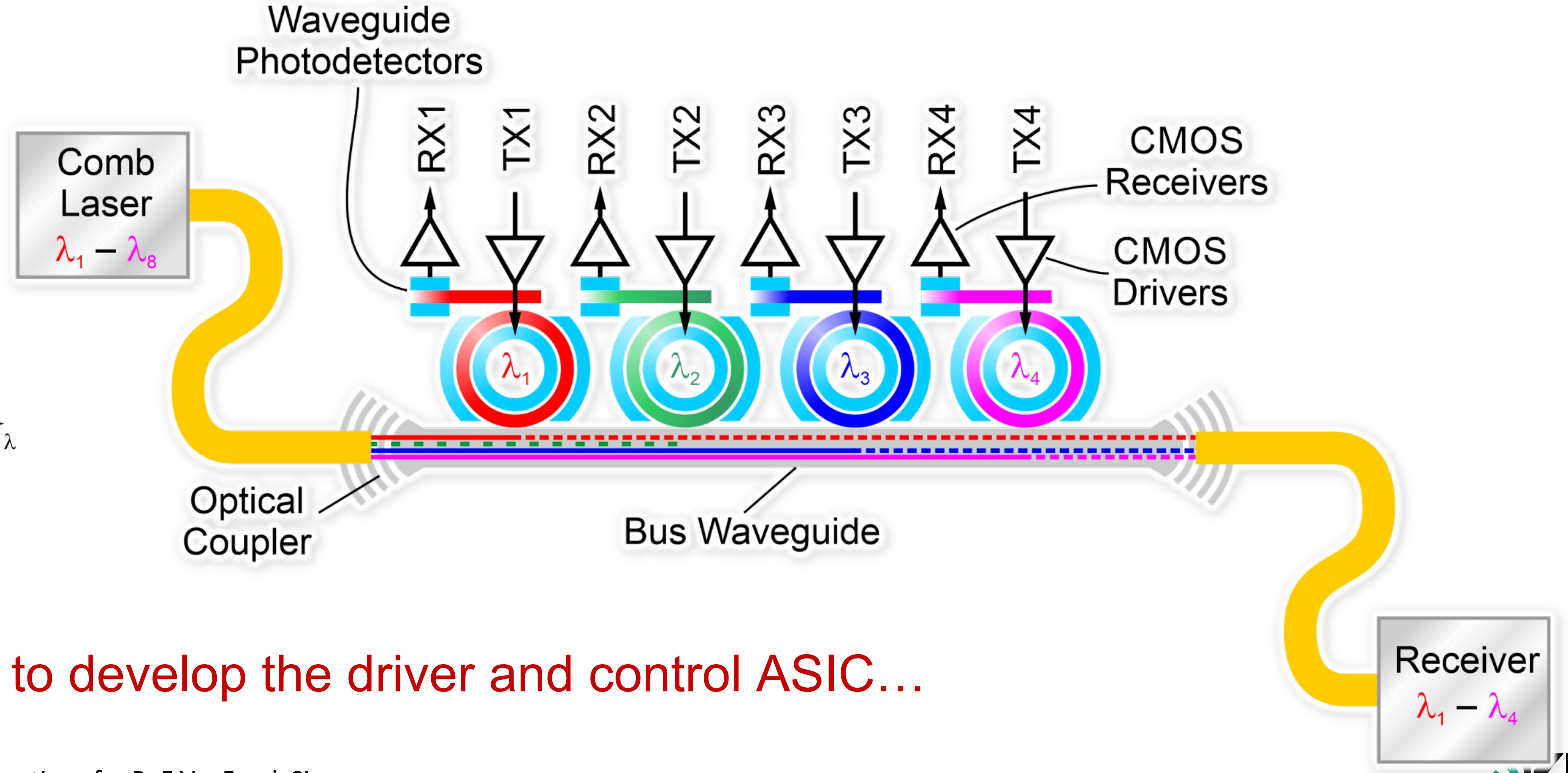
- 4 different types to choose from
- Connect to drop port
  - Monitor diode for working point control
  - RX-PD for data reception (>40 Gbps, ASIC-limit?)



Transceiver system

- One ring modulator with photodiode can operate as transmitter or receiver
- Receive function inherently present due to working point control
- Resonance tunable through heater ➔ wavelength division multiplexing through cascading of RMs



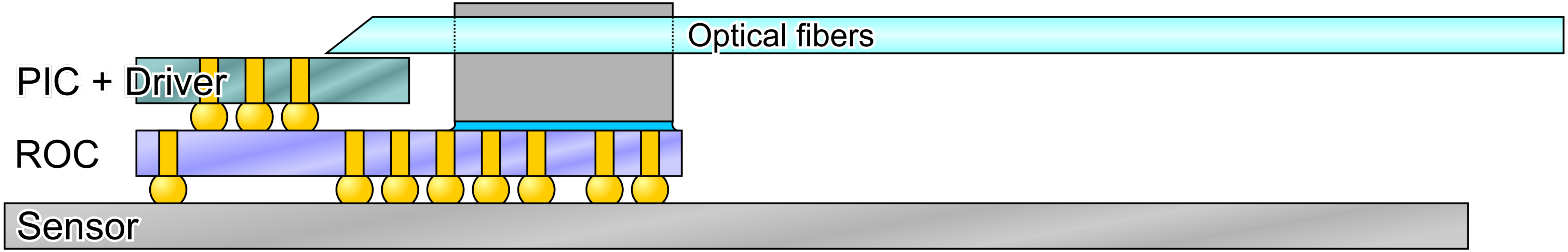


- We need someone to develop the driver and control ASIC…

Packaging

System setup and fiber-chip-coupling

- TSVs for contacting with interposer/driver/read-out-chip
- Fiber-Chip-coupling using grating couplers and quartz glass fiber holders
- Fiber-Chip-coupling using edge couplers and fiber ribbons (questionable approach)



Transfer: lean wearable USCT technology

Transfer MT-DTS technology to lean wearable ultrasound diagnostic systems

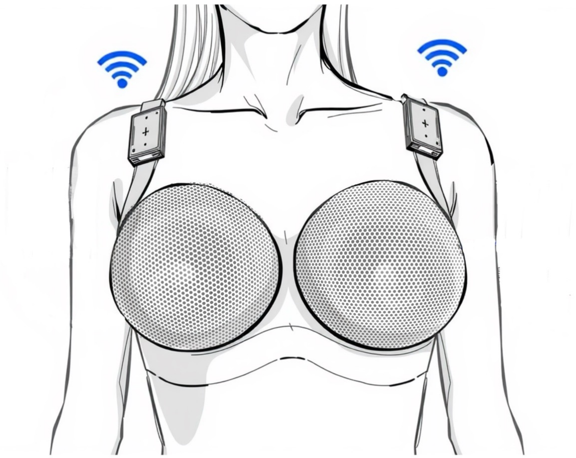
- Enabled by compact sensor design and readout

Advantages:

- Very cost effective
- Easy to use, readily available, patient friendly
- Simple to transfer to other fields of application, e.g. brain, joint and abdominal imaging
- Fast imaging will allow additional imaging modalities, e.g. Doppler, Photoacoustics, Elastography

Aim:

- Enable full diagnostic potential of ultrasound tomography imaging



Wearable USCT technology:
Examples for breast and brain imaging