

Microelectronics enabling Large Scale Quantum Computing Technologies

EPIC Workshop

01.12.2021

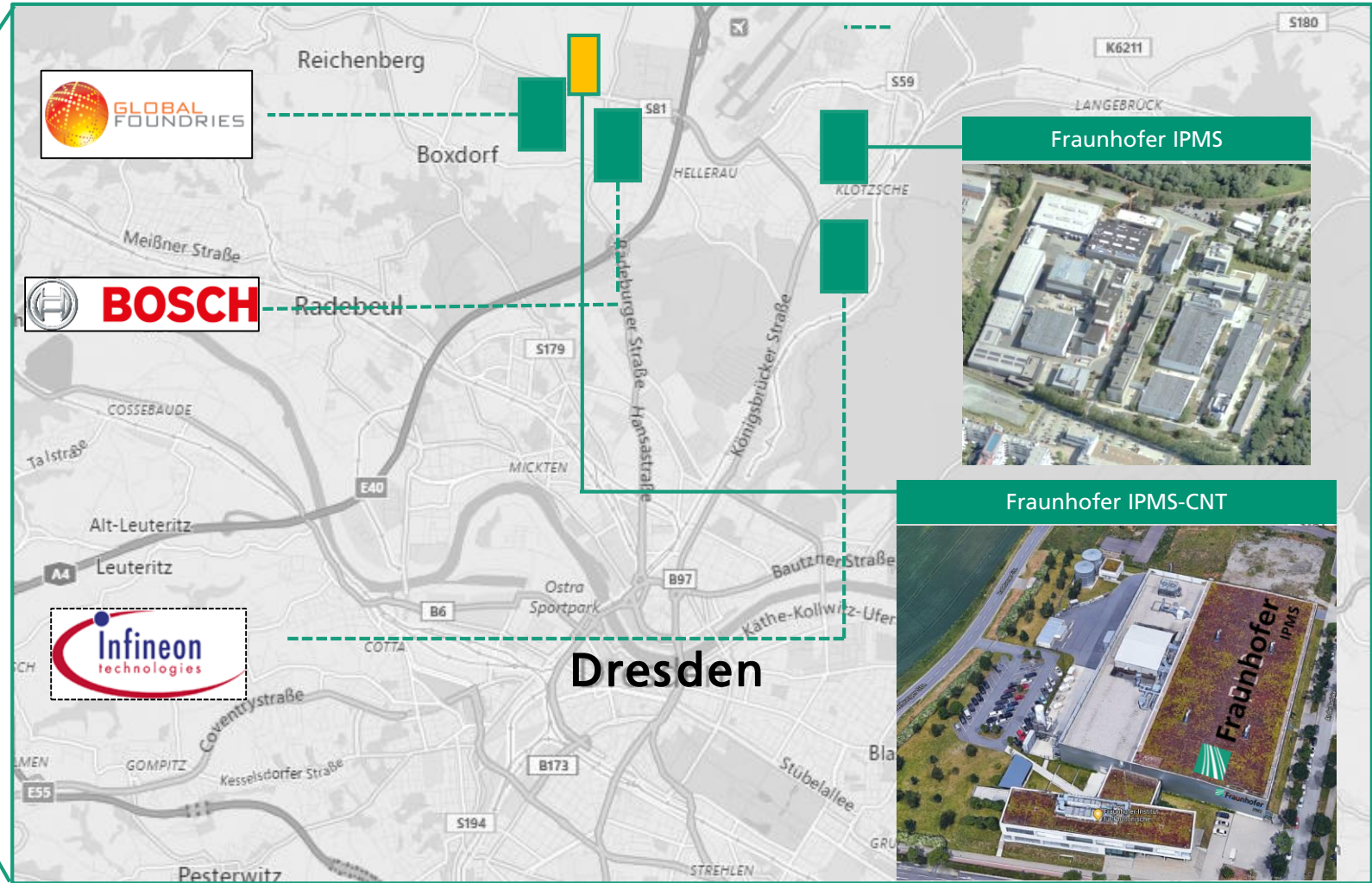
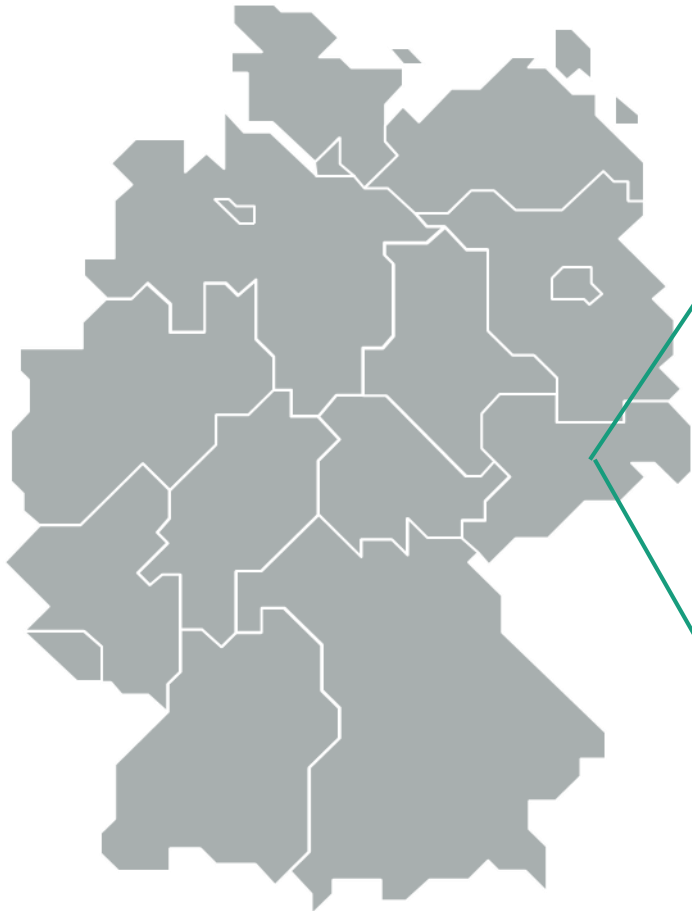
Dr. Benjamin Lilienthal-Uhlig

NGC Next Generation Computing

Benjamin.lilienthal-uhlig@ipms.fraunhofer.de

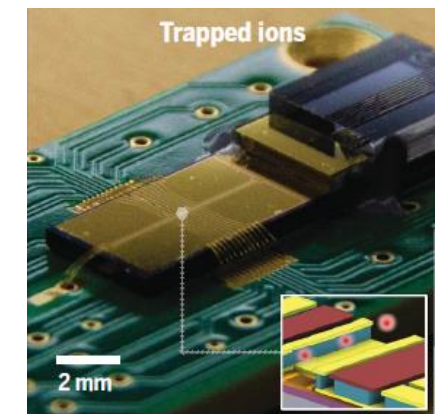
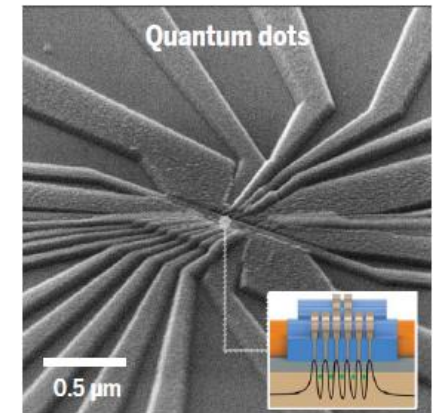
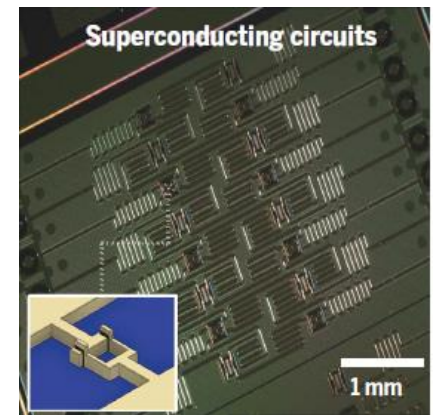
www.ipms.fraunhofer.de

FRAUNHOFER IPMS in Dresden, Silicon Saxony



Modern Semiconductor Manufacturing is needed for (large scale) Quantum Computing !

- Number of qubits
 - Error correction, size of quantum algorithms
- Variability, process control and yield
 - Improve qubit uniformity, coherence time and gate fidelity
- Interconnects
 - Spatial limitations, thermal budget, wiring ,apocalypse'
- Interface to classical electronics
 - CMOS control electronics, Advanced packaging, variability control, FDSOI, ...
- Applicable to most platforms (SC, spin, ion trap, photonics, ...)
- Relevant players also focusing on 300 mm semiconductor manufacturing
 - Intel, imec, CEA, PsiQuantum (with Globalfoundries), ...



Some Examples



Advanced CMOS cleanroom processes on 300mm for super conducting and Si/Ge quantum dot based qubits

■ Nanopatterning

- High definition e-beam gate patterning
 - down to 25 nm, flexible prototyping
- Atomic layer etch
 - Damage free patterning, Ultra precise profile etch control

■ Advanced films deposition

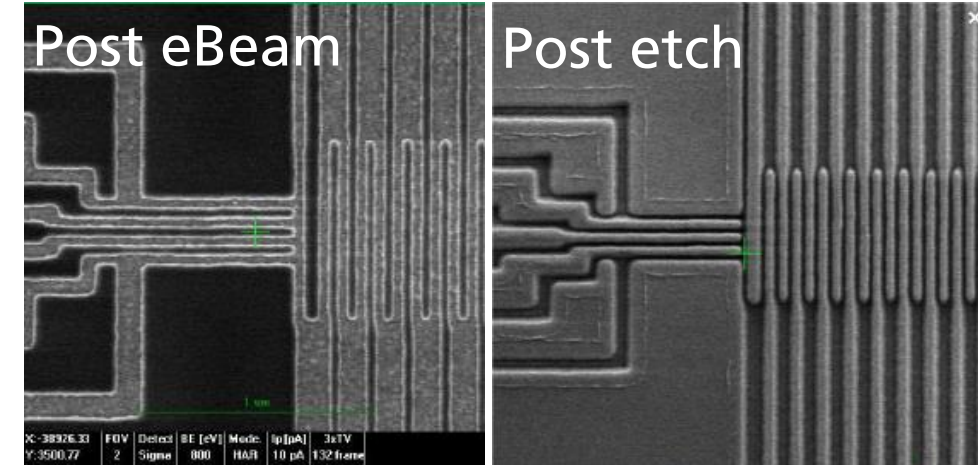
- Multi target PVD for superconducting devices and qubits
 - new materials (TaN, CoSi, NbN, AlX, ...)
 - advanced process control and uniformity
- Fabrication of Micro magnets

■ Cryogenic electrical characterization

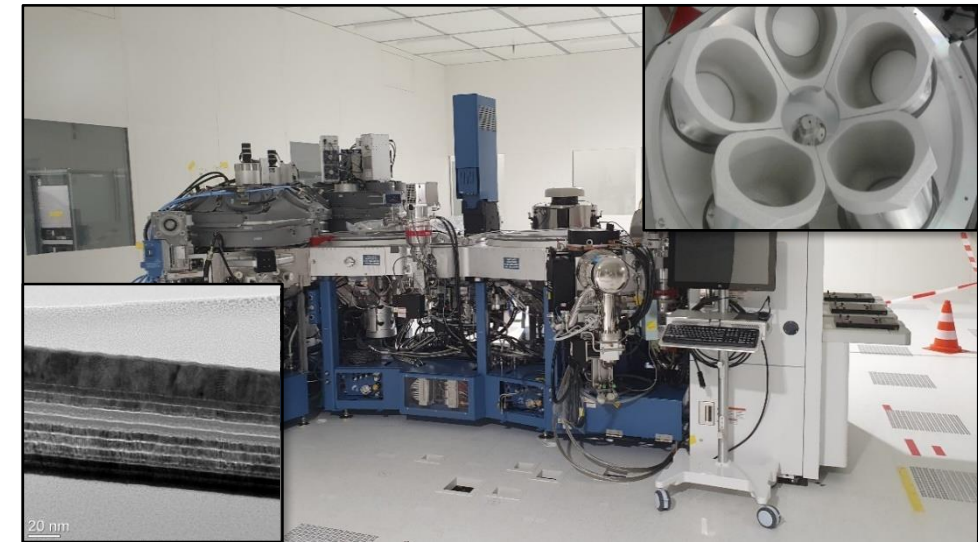
- Down to 1.7 K
- Up to 7 T magnetic field
- RF capability



fine pitch gate patterning

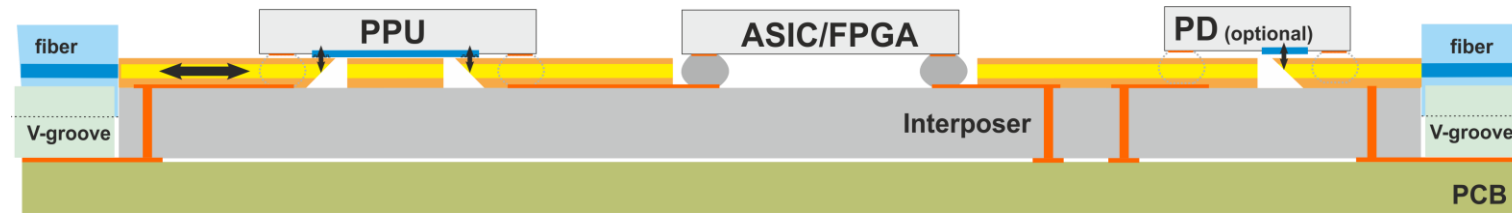


300 mm UHV cluster PVD



Silicon photonics at IPMS

Photonics as key to the quantum world

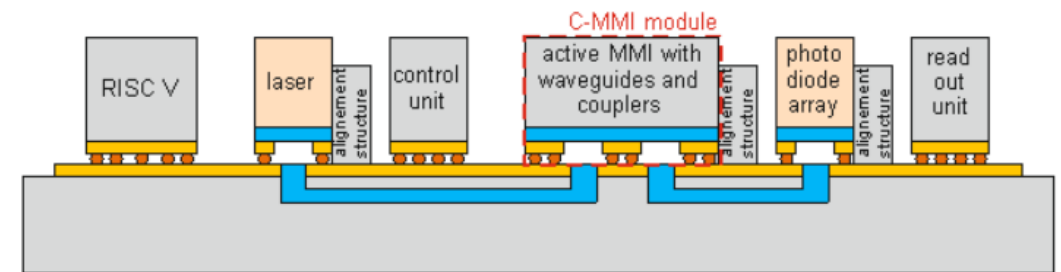


■ Currently in development: electro optical co-integration platform

- Easy access to photonic components (PPU) from a generic electrical domain (ASIC)
- Addressing silicon or silicon nitride based PPUs
- Hetero integration of LASER diodes, photodiodes, electrical, and optical elements
- Fiber and fiberless solutions
- RISC V integration

■ Applications:

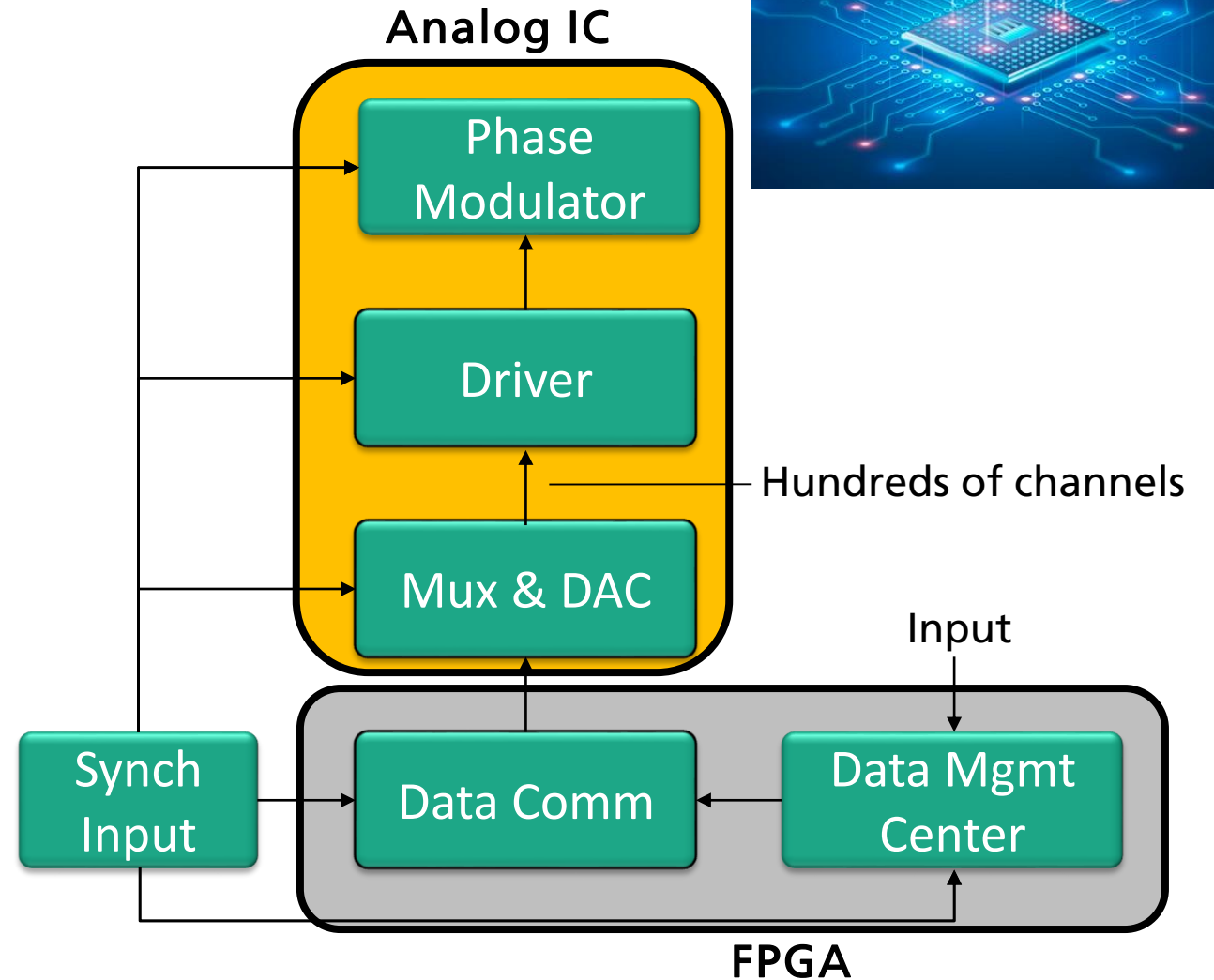
- Quantum based random number generators
- Security key generation
- Cryptographic multi mode interferometers (C-MMI)
- ... and much more



Crypto MMI module

Integrated circuits for control systems of photonic QCs

- Analog control of phase modulators (PM) or similar (capacitive, resistive, inductive drive)
- IC Development of PM drivers, DAC, ADC, TIA, OPA using cutting-edge CMOS
- Control of hundreds of PM driver channels in parallel
- Synchronize channels
- High speed data flow management



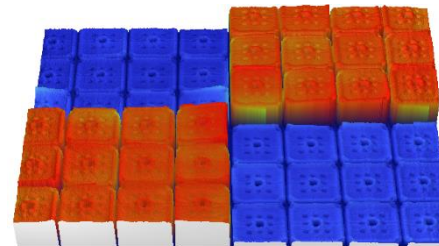
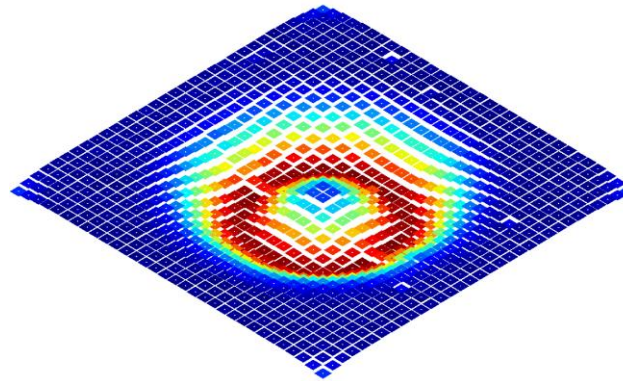
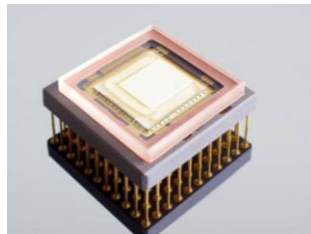
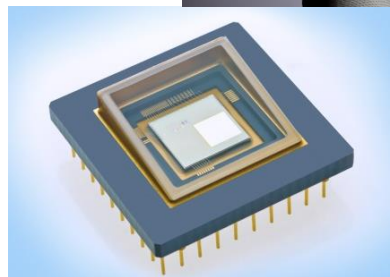
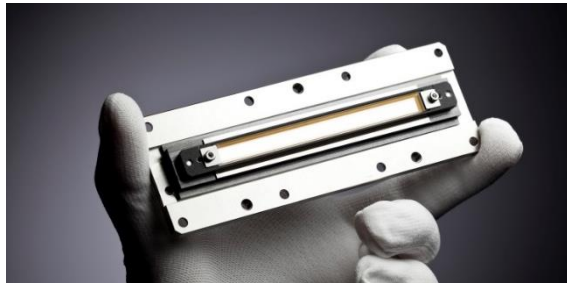
High Precision Light Modulation by Micro Mirror Arrays (MMA)

for Neutral Atoms QC

Fraunhofer IPMS SLM/MMA

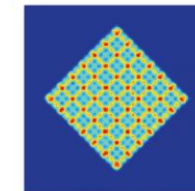
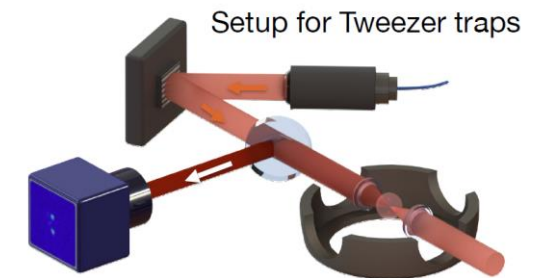
- Application specific MEMS based Spatial Light Modulator (SLM) development
- Spatially resolved high speed phase / amplitude modulation

Examples

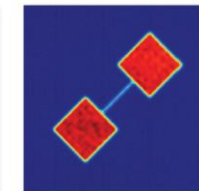


SLM Application Potential for Quantum Technology

Prof. Dr. I. Bloch, Max Planck Institute of Quantum Optics
DLR Austauschforum QC - 10 September 2021



Programmable Lattices



Quantum Wires



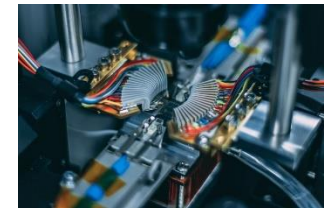
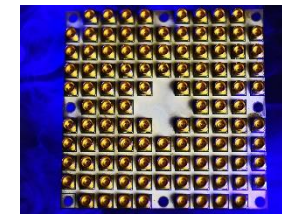
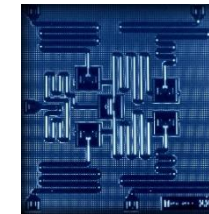
Box Potentials

Almost Arbitrary Light Patterns Possible!



Take Away Message

- Need access to semiconductor manufacturing infrastructure?
 - 300 mm CMOS, 200 mm MEMS
 - want to build new quantum computer hardware ?
 - improve your technology towards large scaled systems ?
 - look for open QC pilot line and prototyping platform ?
 - establish a manufacturing supply chain ?
- Fraunhofer IPMS in Dresden 😊



Different quantum processors (IBM, Intel, PsiQuantum)

