
creotech
ARTIQ
DIO-BNC
8x TTL IO
Mirny
Quad PLL
RF0
RF1
RF2
RF3
EXT
IO1
IO3
IO5
IO7

New developments in the time and frequency synchronization systems based on atomic clocks and White Rabbit at Creotech

Contact: pawel.zienkiewicz@creotech.pl

creotech

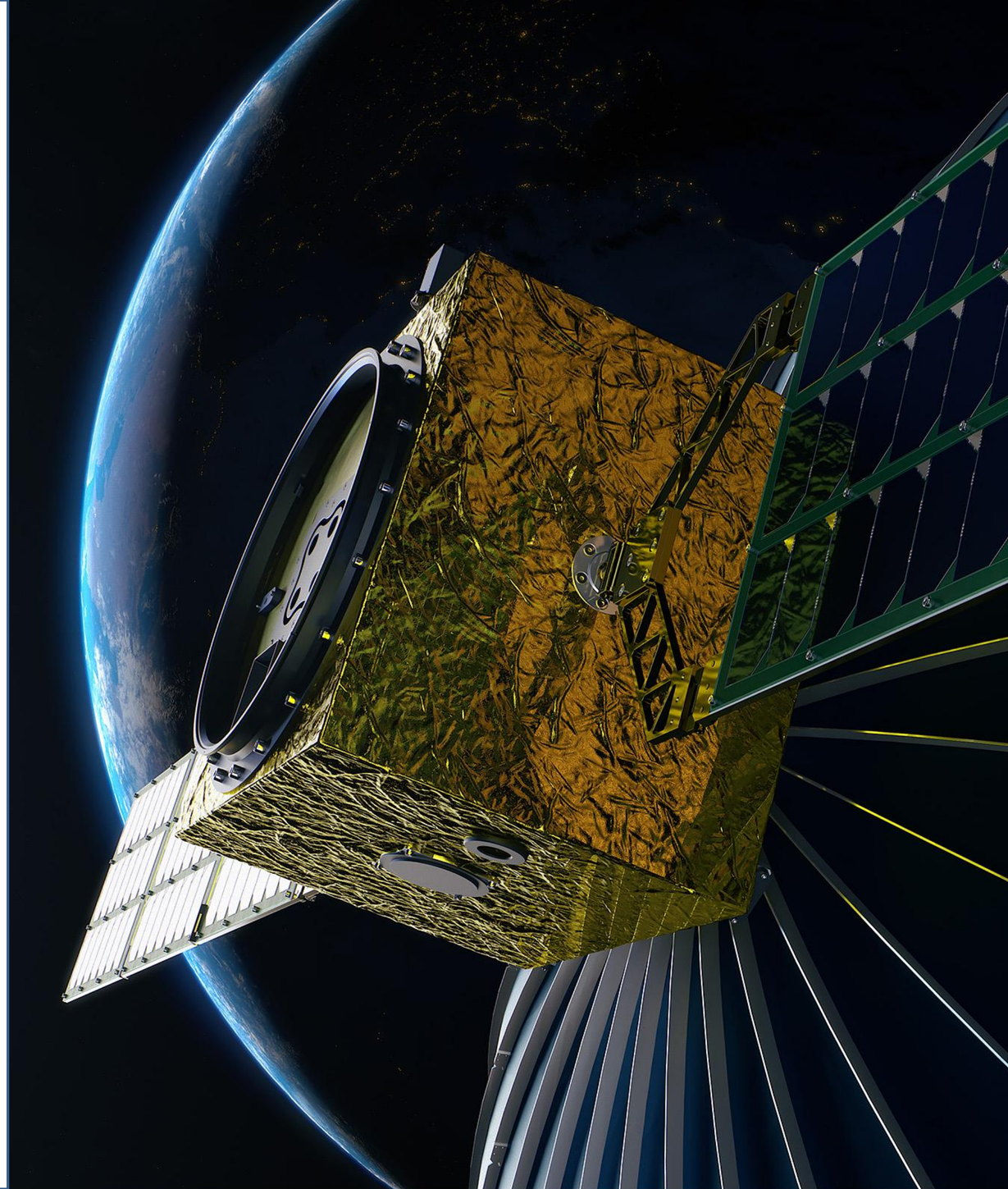
Creotech Instruments S.A.

Established in 2012
Headquarters in Piaseczno, Poland
~200 employees
~80% R&D

EuIC European Quantum Industry Consortium
Member

- Certified (automotive, medical, Space) manufacturing services
- Systems for Space, satellites (>25 ESA projects)
- Cameras, drone tracking, EO
- Hardware and systems for Big Science facilities
- Control systems for Quantum Technologies
- R&D, electronics engineering consultancy services

www.creotech.pl



Infrastructure and production capabilities

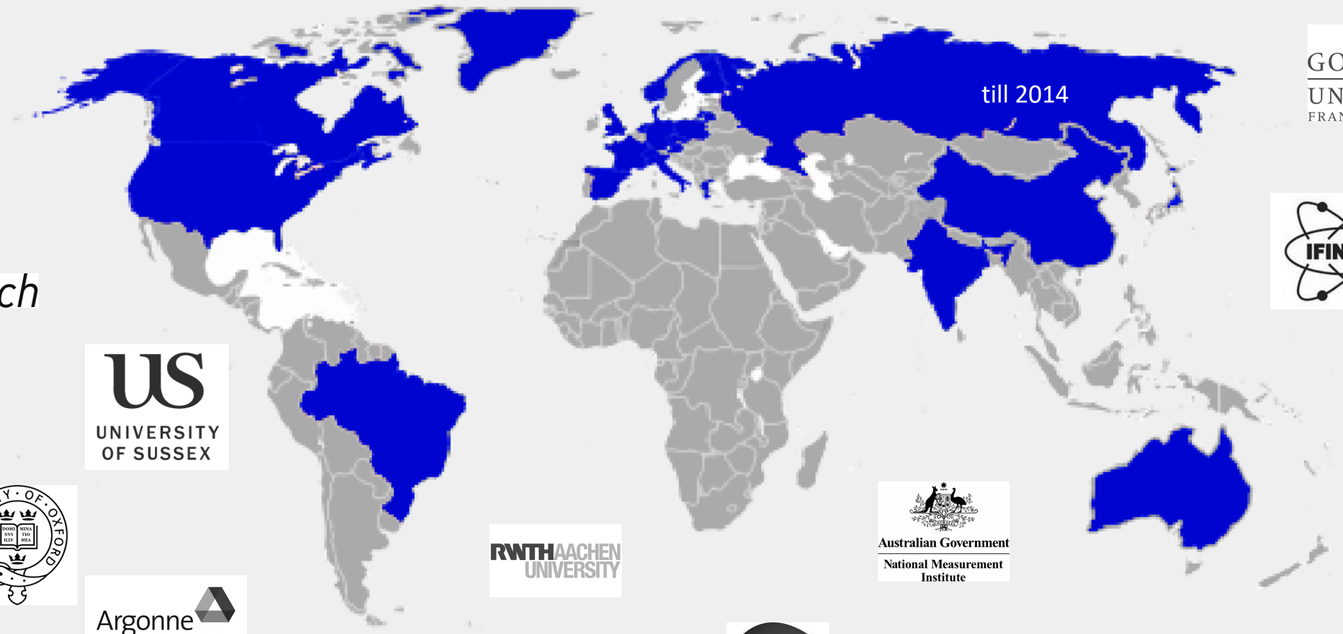
PRODUCTION CAPABILITIES

- Clean-rooms ISO7-8
- ESD protection area, temperature, humidity and cleanliness control
- Three Surface Mount Technology (SMT) lines with Juki technology
- Through Hole Technology(THT) with Selective Soldering Machine (ERSA) and 10 stations
- Inspection with AOI MEK PowerSpector done by ESA certified inspectors
- Other: rework, cleaning, conformal coating, press-fit, electrical tests, climate chamber testing, component lead forming, cable stipping
- New investment on-going – X-ray, vacuum oven, ionic contamination tests
- Production of electronics for NewSpace, ie. ICEYE, ENPULSION, THORIUM
- Now in the proces of realocation to new premises

QUALITY MANAGEMENT SYSTEM

- QMS certified according to **ISO 9001:2015** since 2015
- Project specific qualification of electronic manufacturing according to ECSS standards
- Ongoing general qualification of electronic manufacturing for deep space missions according to ECSS standards performed by European Space Agency
- ECSS qualified assembly operators, ECSS qualified inspectors

Selected international customers of Creotech



Quantum and time synchronisation systems

Quantum computers are the most promising area for the development of computing and digital technologies.
We develop specialized systems that control qubits and quantum computers.

Together with the CERN laboratory, we are implementing the White Rabbit standard for sub-1 nanosecond time synchronisation - currently in demand in research centres, but the first deployments in telecommunications and energy systems are underway.

Together with Oxford University we are working on the Sinara standard. It allows to assemble control and measurement systems from simple electronic "building blocks", e.g. for quantum computers. Currently, we have implemented into production >30 electronic systems in the Sinara standard.

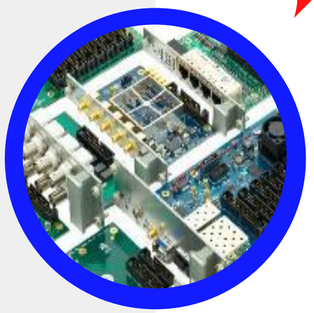
In May 2022, we were invited (in the consortium led by Innsbruck U.) to build the first large-scale quantum computer for the European Union

In October 2022, we were selected to join the group of entities that will create the European Union's quantum computer network. The first Polish quantum computer will be built in Poznan. The project is being carried out in cooperation with the Polish Academy of Sciences.

Estimated CAGR (2017-25): 29.5%
(Persistence)

BETTER TIME SYNCHRONISATION

The White Rabbit standard allows to achieve a factor 100 better synchronisation than today.
Application area: telecommunications (5G), power grid synchronisation, air navigation control, autonomous cars.



SYSTEMS FOR QUANTUM COMPUTERS

The Sinara standard allows for a factor of 20 improvement in the efficiency of creating quantum systems - standardised operation, efficiency, low power consumption, small volume, simplicity of connections.

CONTROL SYSTEMS

From November 2020, we also started to supply entire systems that control quantum processes.

Sinara/ARTIQ project for Quantum Technologies

- Bottom-up initiative of the ion trap community
- Modular control and measurement hardware ecosystem, tailored to the needs of ion-trap experiments
- Compatibility with ARTIQ open software
- ~70 modules in EEM format
  + 3 MTCA cards

QUARTIQ

M-Labs

creotech

opticlock

NIST

PTB
Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin

Leibniz Universität Hannover

UNI FREIBURG

UNIVERSITY OF OXFORD

Oxford Physics

NQIT Networked Quantum Information Technologies

UNIVERSITY OF MARYLAND

ARL

JOINT QUANTUM INSTITUTE

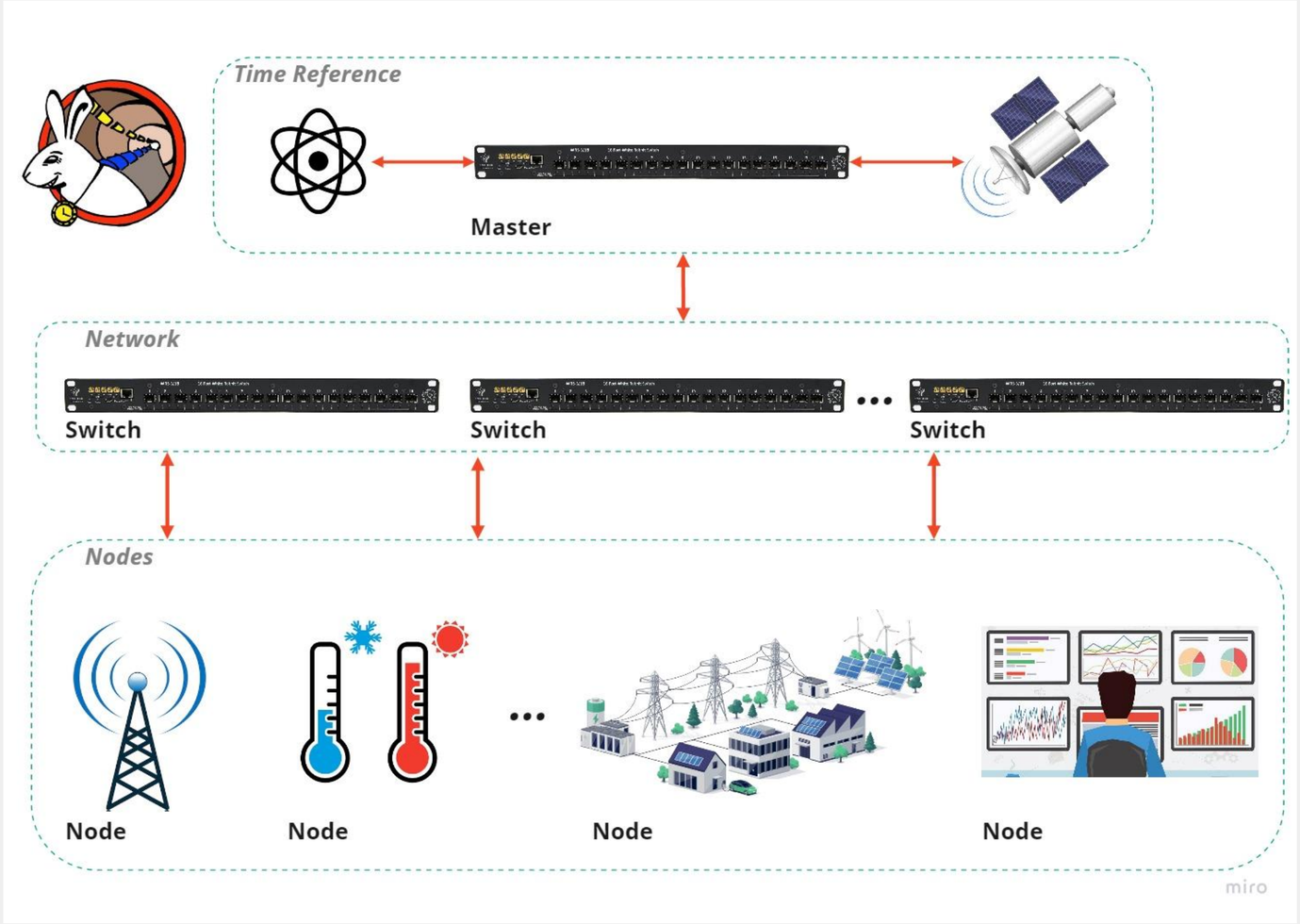
White Rabbit

Hard Real Time System

- External event to system response time is guaranteed
  (a few microsecond scale)
- Transparent, modular and extensible system

White Rabbit System

- Scalable sub-ns time and event transfer with picosecond precision
- Time synchronization over large distances (~100km)
- Accurate timestamping
- Frequency reference with low jitter (1PPS and 10MHz)



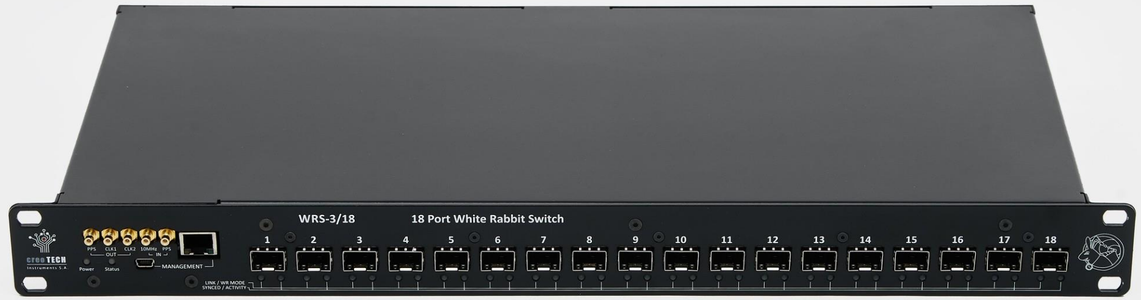
PTP

White Rabbit is now
IEEE1588-2019 High Accuracy Profile

White Rabbit Switch

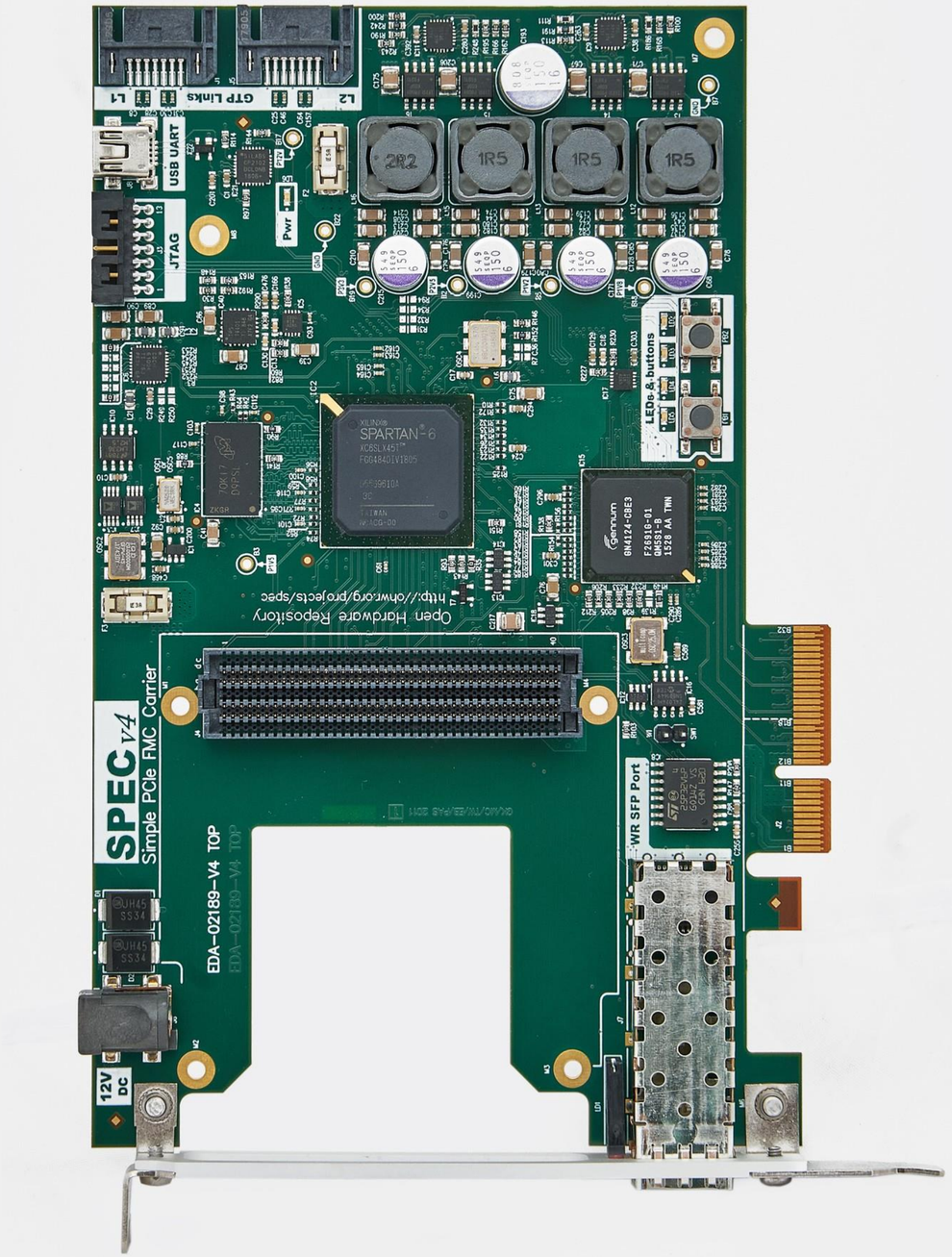
- The key component of the White Rabbit System that provides precision timing and high accuracy synchronization in an Ethernet-based network. WRS distributes the clock of a WRS master (or its internal clock) to all the nodes in the network using a hierarchical architecture.

A new White Rabbit Switch tailored to the needs of telecommunication applications is under development.



Simple PCIe FMC Carrier – SPEC

- The FMC PCIe Carrier is an FMC carrier that can hold one FMC card and an SFP connector. This board is optimised for cost and is usable with most of the FMC cards. It can be used as a cost-effective node in a White Rabbit network.



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The AFC Family of AMC FMC Carrier Cards

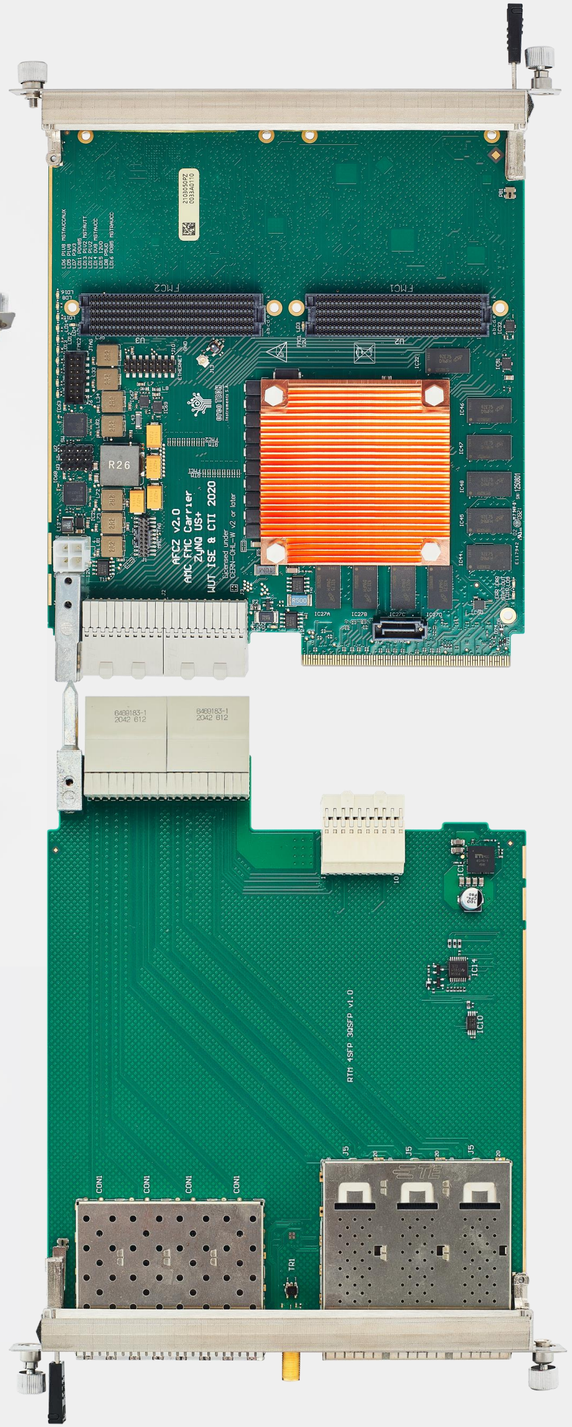
- **AMC FMC CARRIER Zynq – AFCZ**
  Xilinx Zynq UltraScale+ ZU7EV SoC FPGA

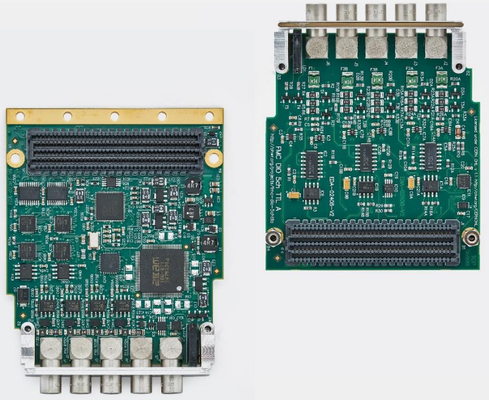
- **AMC FMC CARRIER Kintex Ultrascale – AFCKU**
  Xilinx Kintex UltraScale KU035 FFVA1156 FPGA

- **AMC FMC CARRIER Kintex – AFCK**
  Xilinx Kintex-7 325T FFG900 FPGA

- **AMC FMC CARRIER – AFC**
  Xilinx Artix-7 200T FFG1156 FPGA

All modules offer a very flexible clocking circuit, customizable gigabit transceiver configuration and support White Rabbit time synchronization.





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White Rabbit – Low Jitter version

Laboratory tests using Microchip 5071A reference

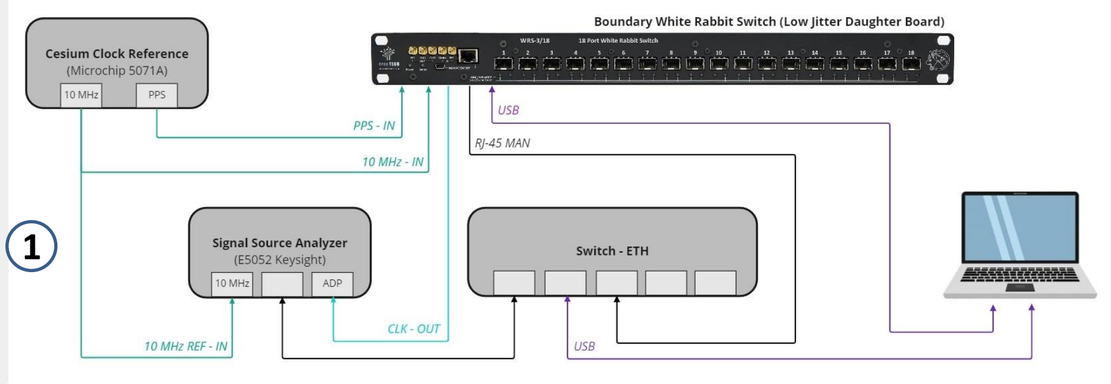
For testing purposes, **cesium clock** reference and **WR Switches** interconnected with **10km standard fibre optics** were used. The quality of the time synchronization is assessed by Signal Source Analyzer.

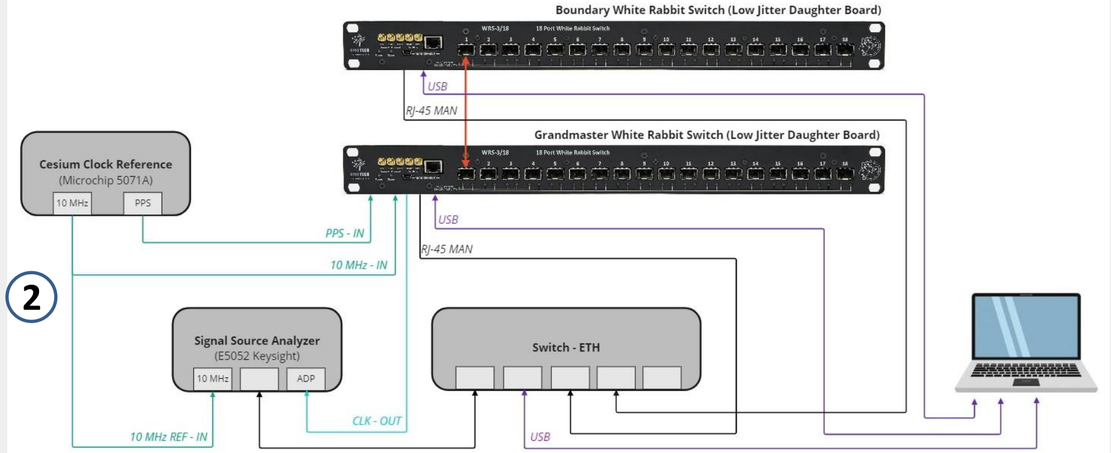
Type 1 - single White Rabbit Switch (WRS). Ideally, it should be equipped with Low Jitter Daughter Board (LJ).

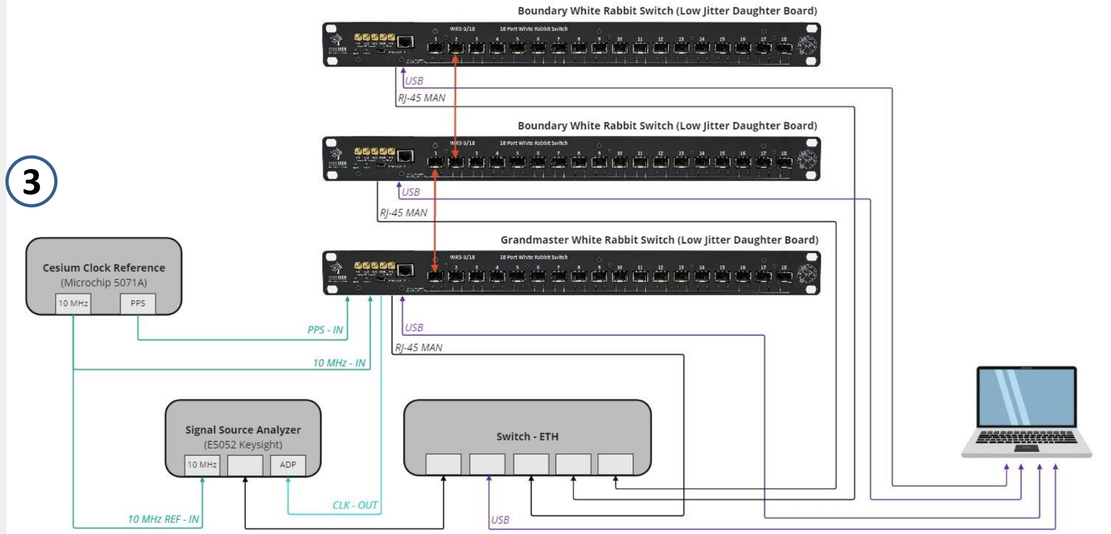
Type 2 - a cascade of **two White Rabbit switches**: the **Grandmaster** and the **Boundary** White Rabbit Switch. To maintain ultra-precise time synchronization, both devices should be equipped with Low Jitter Daughter Boards.

Type 3 – expanded WR network**, three WR switches** connected using fiber optic link: **1x Grandmaster** White Rabbit Switch and **2x Boundary** White Rabbit Switches. To maintain ultra-precise time synchronization all White Rabbit Switches should be equipped with Low Jitter Daughter Boards.

No.	Configuration type	Clock Reference type	Grand Master	First stage slave	Second stage slave	Number of averages	Jitter RMS [ps]	
							from 10Hz	from 1Hz
1	1	Cs	WRS	-	-	16	6.37	9.29
2	1	Cs	WRS-LJ	-	-	16	1.23	1.80
3	2	Cs	WRS	WRS-LJ	-	16	5.36	8.73
4	2	Cs	WRS-LJ	WRS	-	16	3.49	5.29
5	2	Cs	WRS-LJ	WRS-LJ	-	16	1.40	2.03
6	3	Cs	WRS-LJ	WRS-LJ	WRS-LJ	16	1.63	2.12







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White Rabbit - summary

Applications:

- 5G, 6G telecom (at least 100x better accuracy than PTPv2) and quantum communication (QKD)
- Synchronization and syntonization of control of multiple control and measurement subsystems or even full systems (already implemented at CERN, GSI and other big science labs)
- Synchronization of GPS signals and clocks (supplements single time source or satellite weaknesses)

Features:

- Sub-nanosecond accuracy synchronization with picosecond precision for large distributed systems
- Expandability to thousands of nodes at typical distances of 10km between nodes (works up to 400km)
- Reliable Ethernet (local area network) data transfer at gigabit speeds (10gbps soon)
- Precise time-stamping of transmitted data measured by the system
- Easy triggering of data downloads in large installations

NImSoQ project – just launched

New Imaging and control Solutions for Quantum processors and metrology

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INSTITUT ZA FIZIKU

MAX-PLANCK-INSTITUT FÜR QUANTENOPTIK

- **New camera with built-in cutting-edge image processing techniques and algorithms integrated into a low-cost modular control system solution**
- **Modular and real-time control system that can be scaled alongside the experiment**
- **Data processing and control solutions for Quantum Technologies that can improve the experiments outcome and thus drive further technological development**

QUANTERA

NCBR National Centre for Research and Development

VDI Technologiezentrum

HrZZ

Novel strontium state readout techniques – MPQ

MAX-PLANCK-INSTITUT
FÜR QUANTENOPTIK

- **Novel strontium state readout techniques (of both 3P0 and 3P2 state populations) relevant for higher fidelity of readout and future implementation of error correction protocols in quantum computing, developed at MPQ**

- Strong reduction in the latency time between the measurement and the image analysis so that quantum information can be read out quickly and can then be used within a quantum algorithm

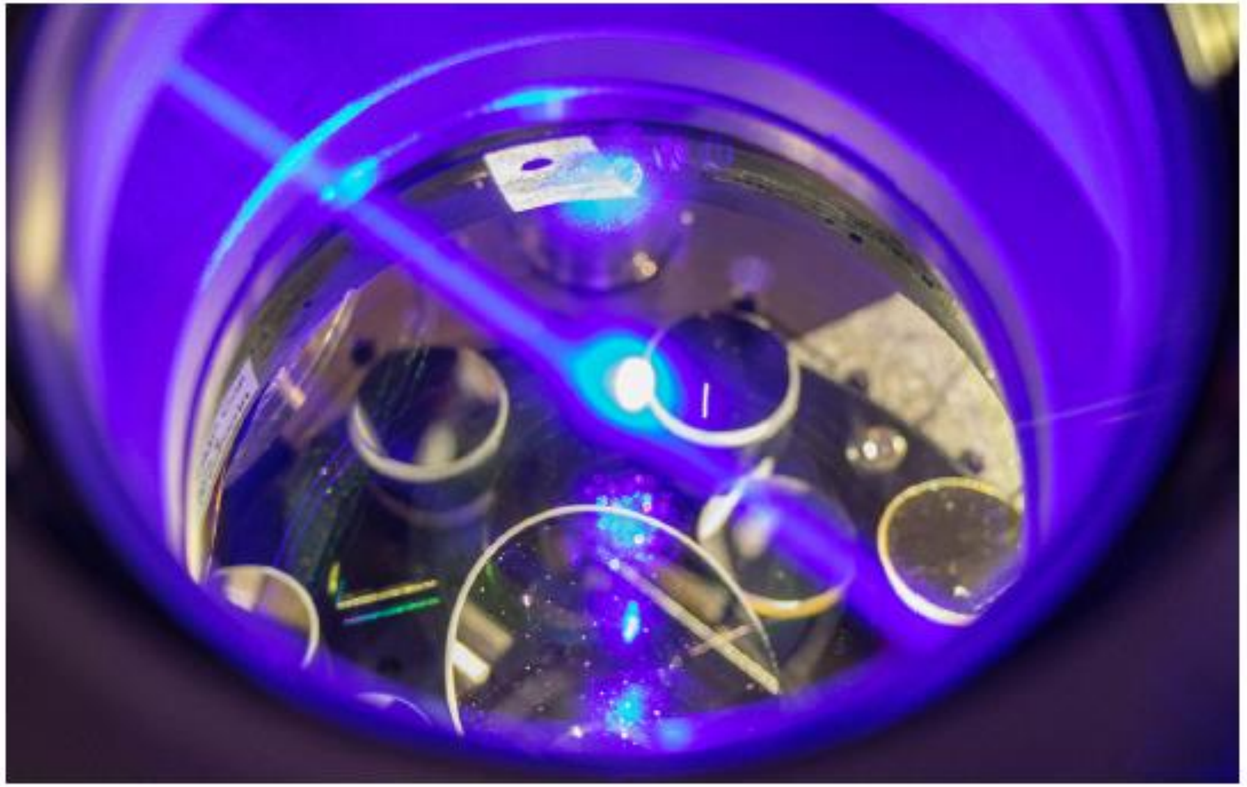
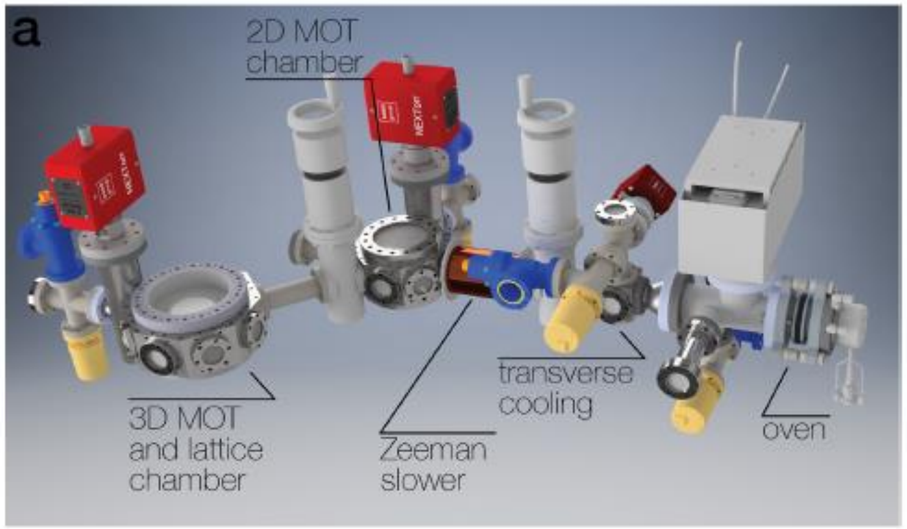


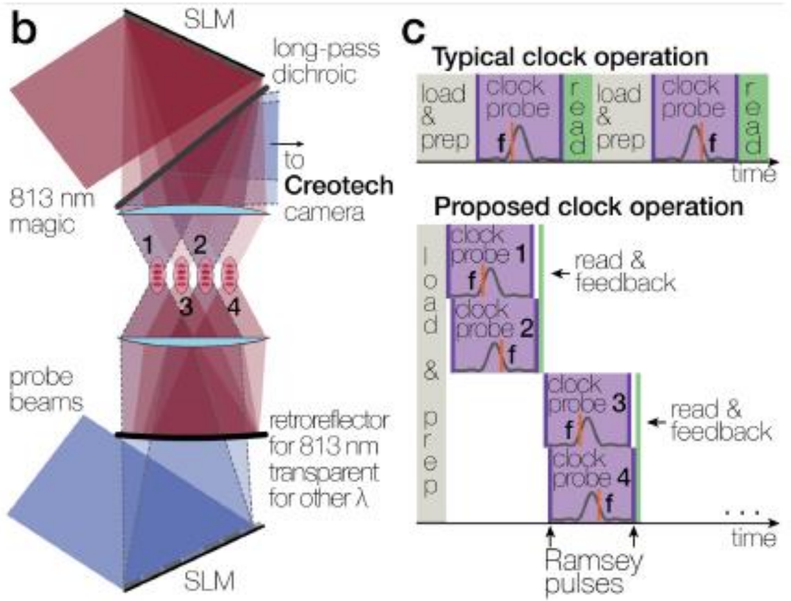
Image: magneto-optical trap for strontium atoms
Copyright: Sebastian Blatt, Max-Planck-Institute of Quantum Optics

QUANTERA NCBR National Centre for Research and Development VDI Technologiezentrum HRZZ

Novel interrogation scheme of a hybrid atomic clock – IFS

INSTITUT ZA FIZIKU





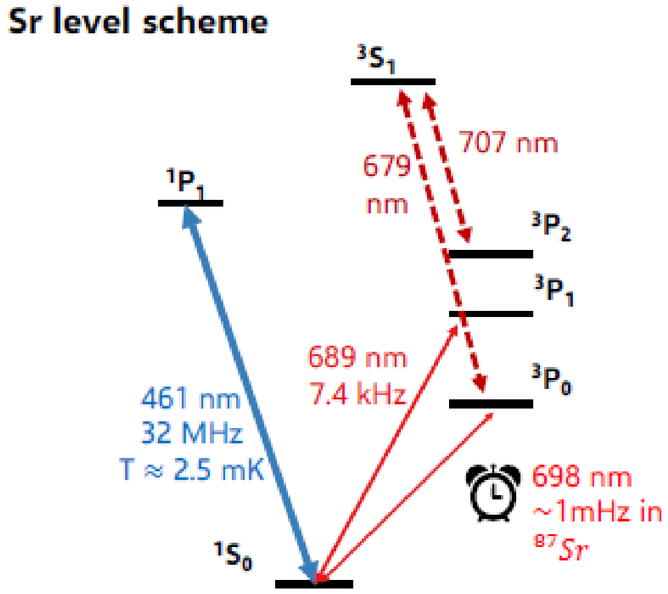


Image: a) the planned vacuum system
b) schematic of the future multiplexed strontium optical atomic clock
c) comparison of the timelines in a typical current optical clock and the proposed clock showing a dramatically reduced readout and feedback enabled by the Creotech camera

- **This experiment will demonstrate and benefit from the low-latency optical qubit readout enabled by the camera developed by CTI. This newly developed optical clock aims to significantly improve the short-term stability compared to current limits set by the optical resonator used.**

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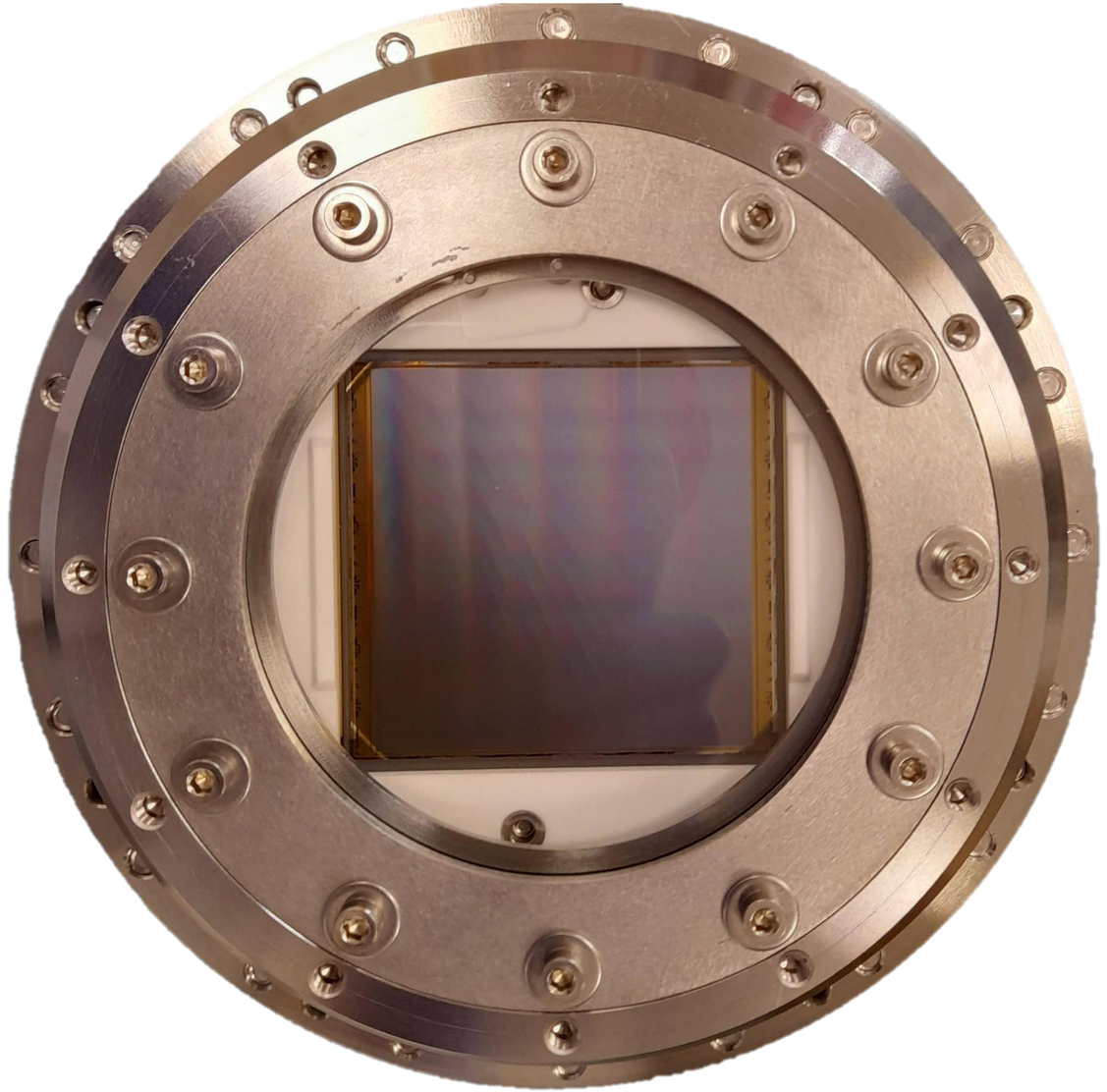
NImSoQ camera parameters

- Sensor capable of reading selected areas at a rate of at least 5,000 times per second
- QE for the 450-500nm range maximum (80%+), allowing to capture a photon flux of about 10 photons per 10us
- Photon counting capability
- Sensor control implemented in FPGA
- Implementation of real-time algorithms with output directly to the loop hardware controlling the experiment in an analog manner
- Ability to simultaneously download image data for further analysis
- Liquid cooling - required by the optical table environment
- Adaptable to microscope optics
- Noise lower than 2.5e (we aim to be in the 1.6e to 2e region)



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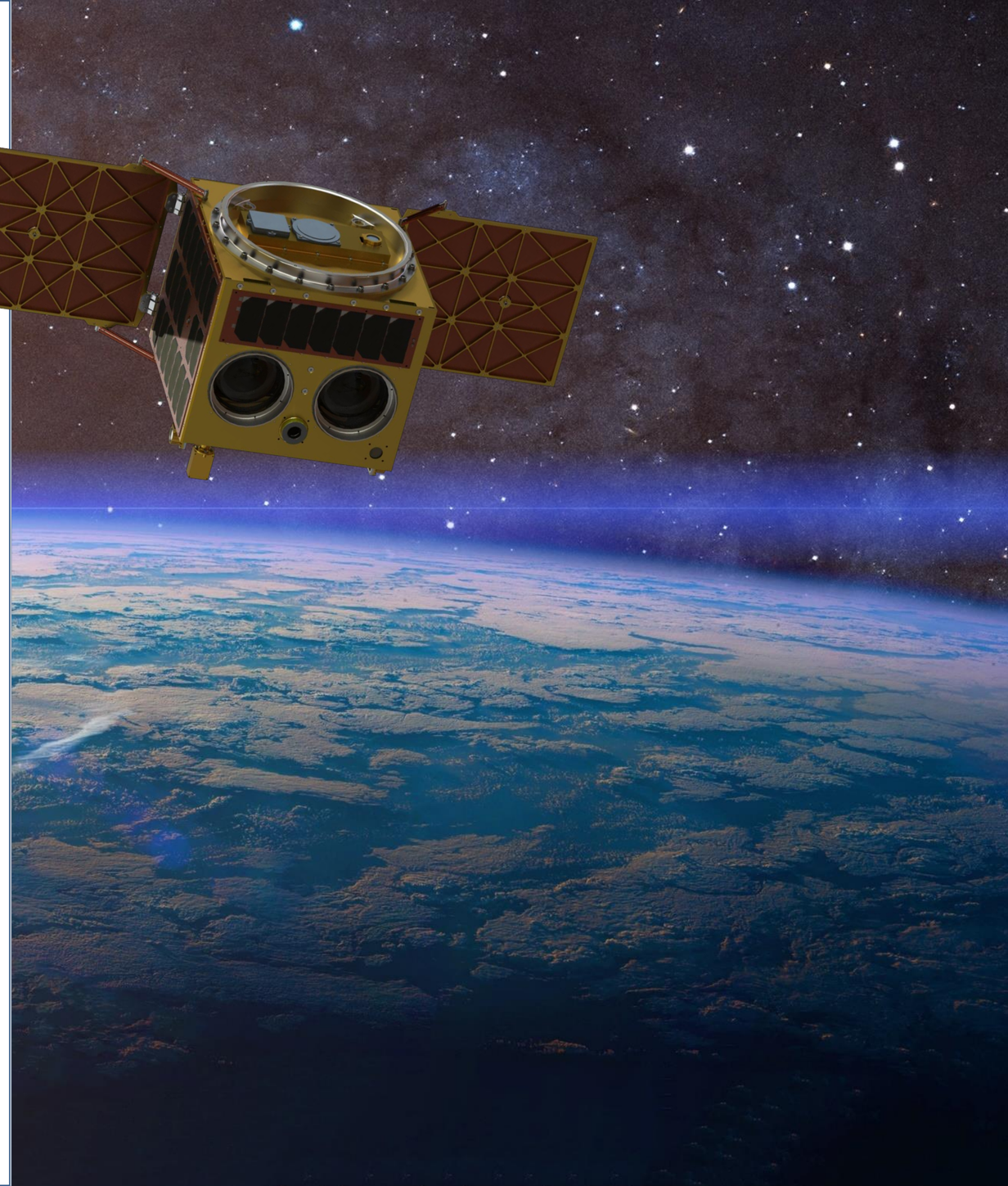
Creotech projects

- 1000 qubit quantum computer R&D project Millenion (Quantum Flagship) in a consortium led by Innsbruck U. with AQT as the commercial partner
- QuantERA NImSoQ project for qubit readout camera with MPQ Munich and Zagreb U.
- PL/DE bilateral AI-ARTIQ project for ultra-integrated laser subsytems with Quartiq, FBH Berlin and Warsaw U.
- EuroHPC JU project for QC @HPC, led by PSNC in Poznań, Poland
- Several satellite missions, electronics design for CERN, …
- Always looking for interesting collaborations ☺



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