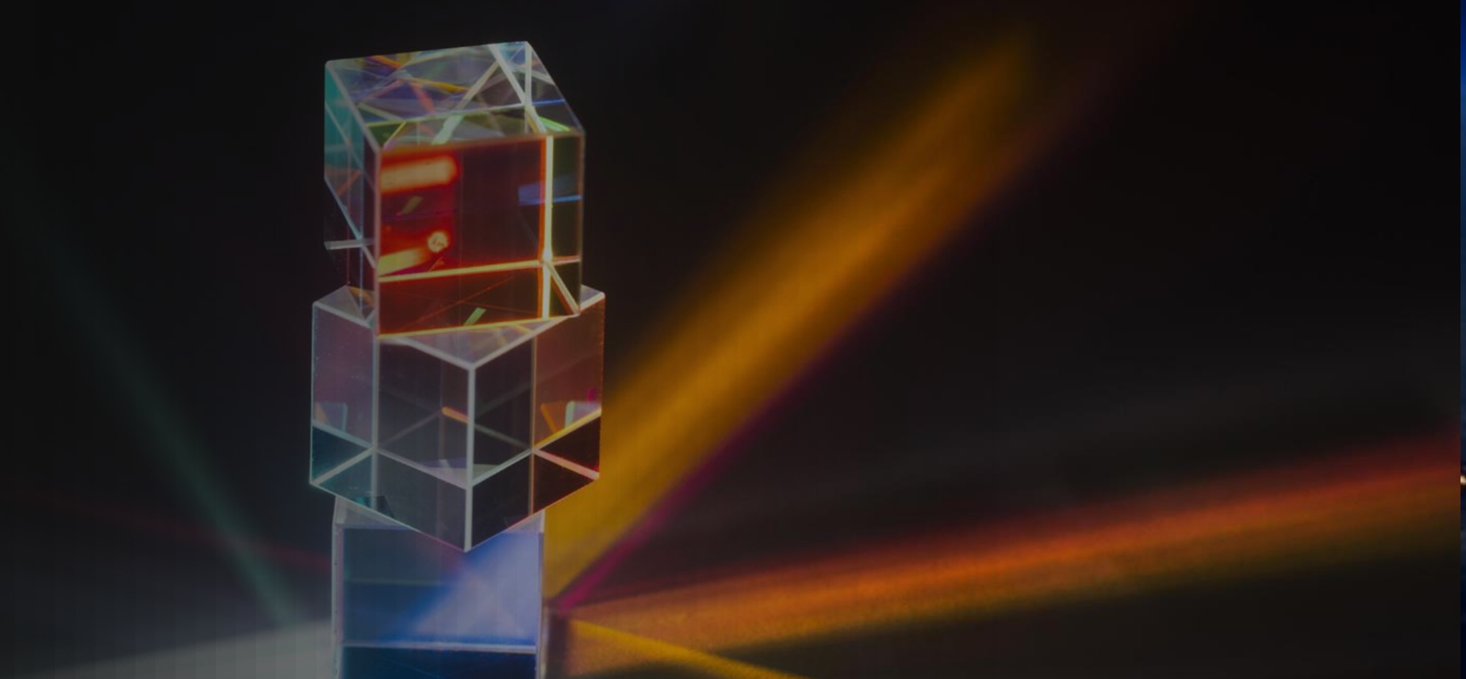


Space Photonics Unified Roadmap

Airbus Space Systems Initiative

SPUR Team (V.Fernandez, S.Mariojouls, D.Kokkinos)

EPIC Meeting on Photonics for Space: Opening New Horizons

21-22nd of September 2023

AIRBUS
DEFENCE & SPACE

AGENDA

- **Introduction to Space Photonics Unified Roadmap (SPUR)**
  - Domains
  - Objectives
  - Photonic building blocks

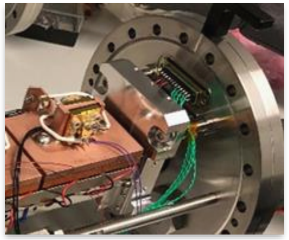
- **Synthesis of the photonic needs for selected future applications**
  - Intra-sat coms
  - Cold Atom Interferometry
  - Frequency Combs
  - LIDAR laser

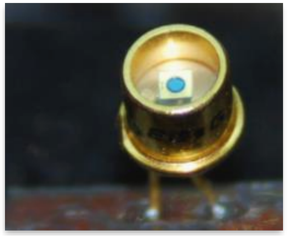
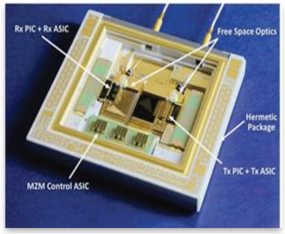
- **Way forward**

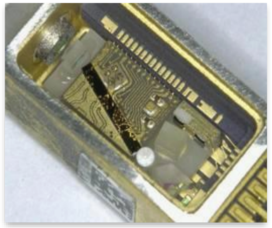
INTRODUCTION TO SPACE PHOTONICS UNIFIED ROADMAP (SPUR)

- SPUR is the 1st photonic roadmap initiative in Airbus.
- Has been triggered by the good foundation initiated through the informal and spontaneous photonics networking across the group in the past few years.
- The key objective is to address all applications across Space Systems where photonics are active or can make a difference, and liaise in a coherent manner with colleagues in other Program Lines and Divisions developing and building on photonic technologies.





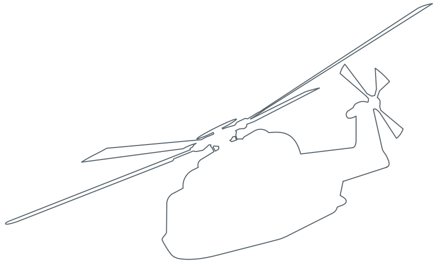





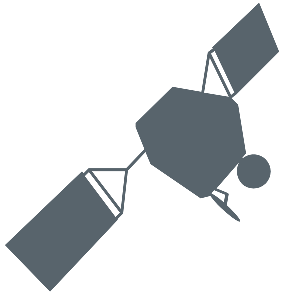
EPIC Meeting on Photonics for Space: Opening New Horizons

INTRODUCTION TO SPUR: DOMAINS

Commercial Aircrafts



Helicopters and Military Aircrafts



Space

Active sensors
(LIDAR, Gyroscopes, magnetometers, Encoders, Fiber optical sensing)

Passive sensors
(Star trackers, sun sensors, navigation cameras)

Optical com's
(HSSL, Microwave Photonics, Free Space Optics)

Quantum
(cold atom interferometers, QKD, Atomic clocks)

LASERS
(Opto Pyro, laser weapons, calibration, OGSE)

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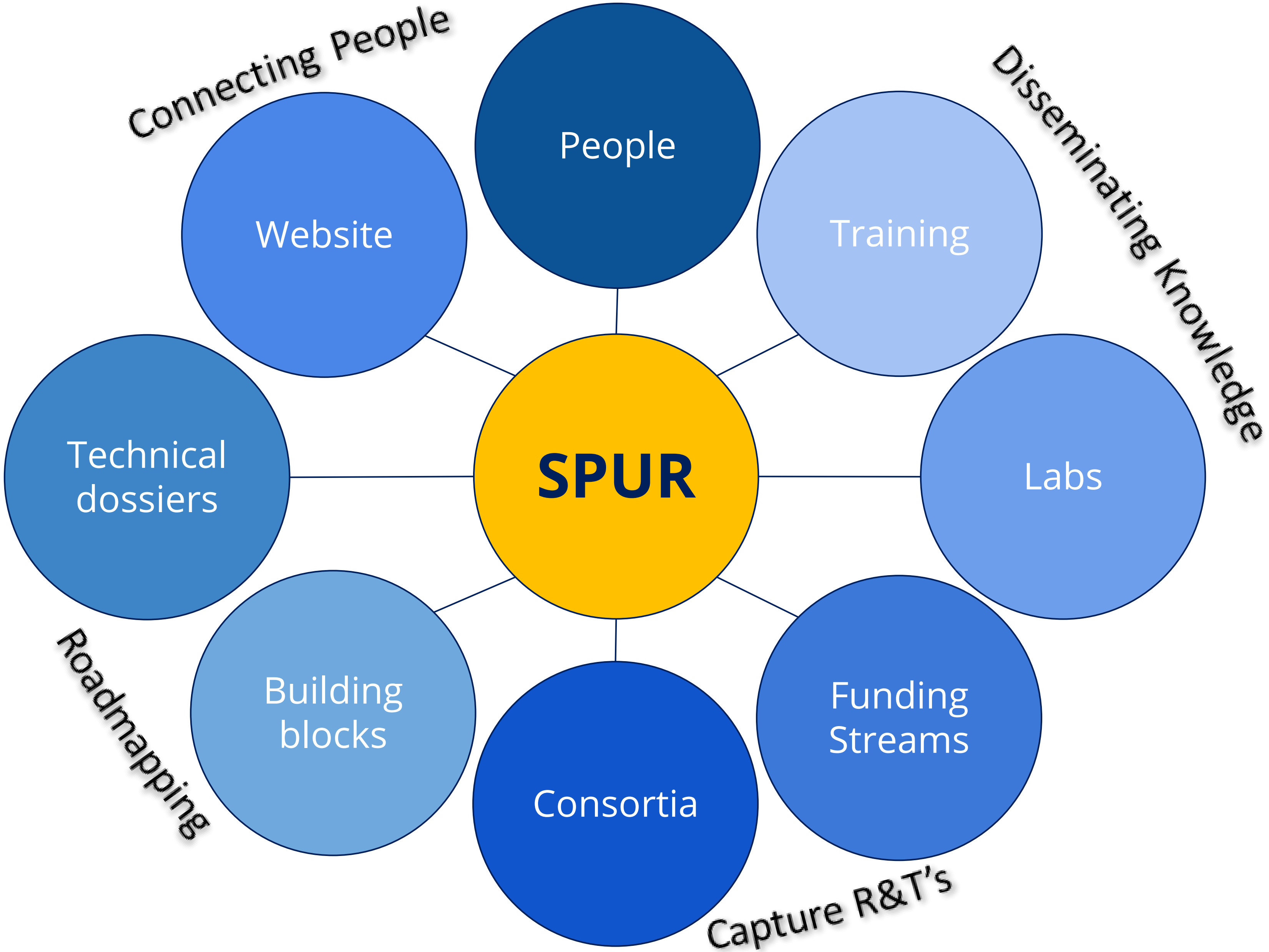
INTRODUCTION TO SPUR: OBJECTIVES



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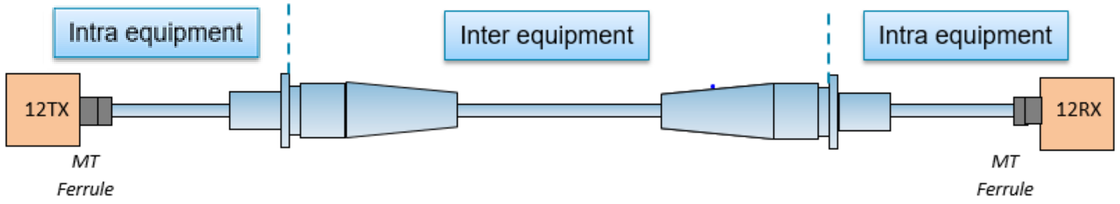
INTRODUCTION TO SPUR: PHOTONIC BUILDING BLOCKS CATALOGUE

The objectives of this database is to :

- Distribute the information across all divisions, of each photonics component used or required in Space Systems
- Map heritage, qualification data, supply chain
- Avoid redundancies, duplications, save time & money, optimize the knowledge
- Highlight the ‘must-have’ components & technologies, and identify priorities (for R&D or Group synergies)
- Offer toolbox and new opportunities to photonics architects

INTRA-SATELLITE PHOTONICS: MOTIVATION



Digital optical links has been so far the most successful application of photonics for intra-satellite comms, used to interconnect different equipment modules thanks to the **higher data rates**, the **lack of EMI in fibers** and the **flexibility in the accommodation** on the spacecraft they enable.

However, beyond the high speed serial links (HSSLs) application, **photonic processing (under the scope of microwave photonics)** is an important candidate to revolutionise the way on-board processing of RF signals is done. Key benefits:

- ✓ Can process large amounts of band-width with low power (like RF; unlike digital).
- ✓ High dynamic range (like RF; unlike digital)
- ✓ Photonic processing elements can be re-used at different bands or even for optical feeders (like digital; unlike RF)
- ✓ Light weight, flexible interconnect (like digital (optical SERDES); unlike RF)

As a processing technology, photonics perhaps most closely resembles RF analogue and it is foreseen as an eventual replacement for it—delivering similar benefits (low power, good scalability with band-width), but with better scalability with number of ports, all the *fiber vs copper* advantages plus the frequency agnostic operation they allow.

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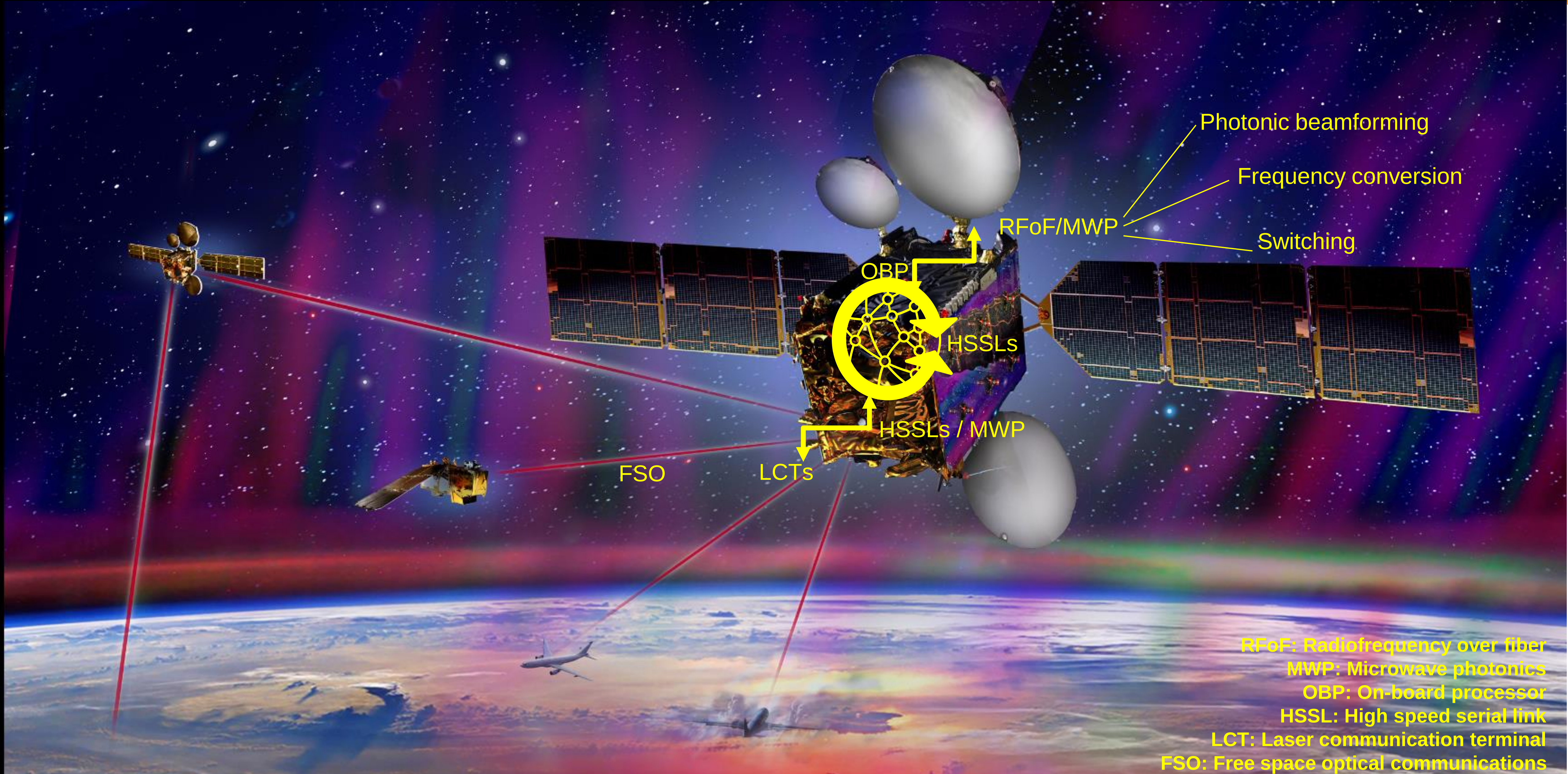
INTRA-SATELLITE PHOTONICS: NEXT



RFoF: Radiofrequency over fiber
MWP: Microwave photonics
OBP: On-board processor
HSSL: High speed serial link
LCT: Laser communication terminal
FSO: Free space optical communications

INTRA-SATELLITE PHOTONICS: NEXT

NEED	PAYLOAD BENEFIT
ASIC/FPGA with co-packaged optics capable of running at 56/112G	HSSLs power can be reduced to 1/3 of current figures
Multi-channel RFoF SMT modules	Fiber optics benefits over copper for antenna to processor interconnects
Optical frequency generation units	Exploiting frequency conversion in the photonics domain can halve the power required to do RF up-/down conversion with currently employed technologies
Optical amplifiers with integrated splitters for point-to-multipoint signal distribution	
Photonic beamformers	Lowest power, frequency agnostic and highest scalable beamformers.
Large optical switch	High density (hundreds to thousands of I/O), low loss and low power optical switches will be required to maximise the flexibility and power efficiency of our payloads.
Fully-photonic ADC & DAC	Simplify the signal path while leveraging the photonics high bandwidth and low latency

PICs

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COLD ATOM INTERFEROMETRY

Objectives:

- ➢ Transition from Experiment to Instrument
- ➢ Instrument Maturation to TRL 5 using Engineering Model
- ➢ Test of critical technologies
- ➢ Industrialization of Development

Industrial Team:

- o Airbus France: Instrument Development Lead
- o Airbus Germany: Physics Package
- o exailFrance: Laser System
- o TELETEL, Greece: IPCU Simulator
- o LEONARDO, Italy: HF-Source

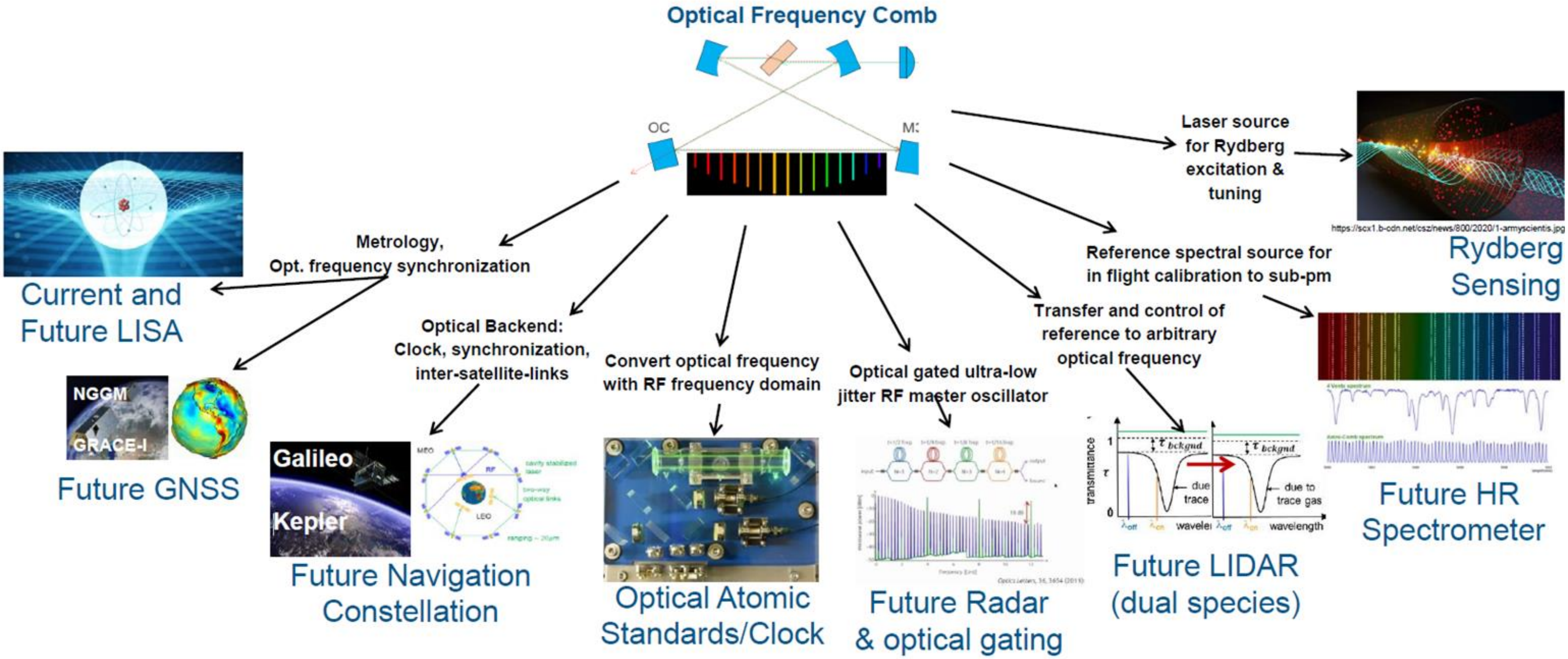
Photonics needs (in the Physics Package):

- ➢ Fiber coupled collimators, piezo actuator, fiber splitters, etc.

ADS contact:

Stephan Seidel (stephan.s.seidel@airbus.com)

FREQUENCY COMBS AS ENABLING TECHNOLOGY



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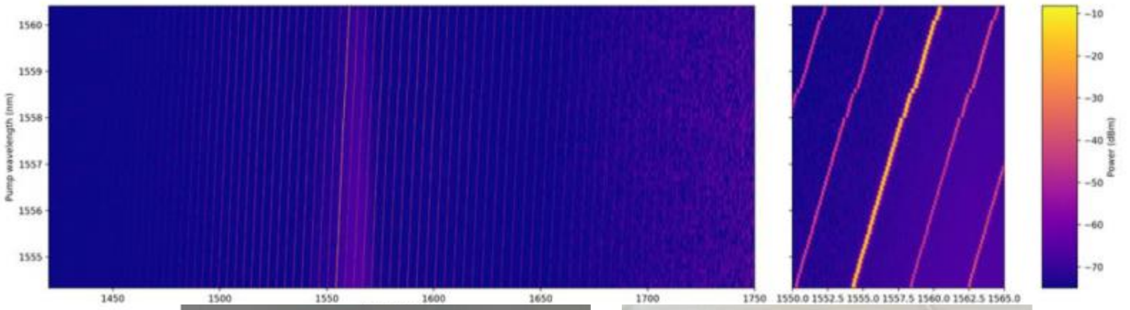
MICRO-FREQUENCY COMBS

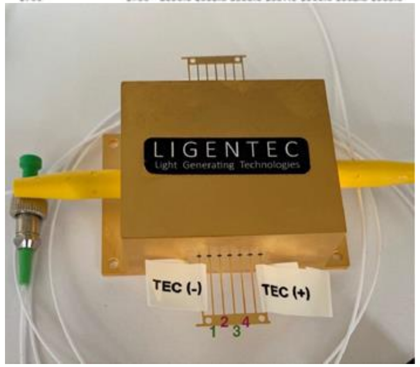
Objectives:

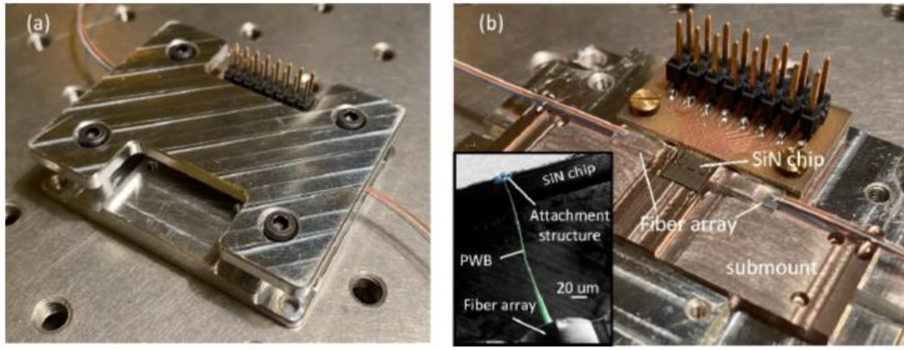
- ➢ Disruptive Si3N4 on-chip microcomb (100µm-diameter resonator) provide the required multi spectral line source to outperform current spectrographs (target TRL 4)
- ➢ Stability, tunability, throughput and compactness are key parameters provided by this new technology, enabling in-space operation

Industrial/Academic Team:

- o Ligentec (CH) - cavity
- o Max Planck Institute for the Physics of Light (DE)
- o Karlsruhe Institute of technology (DE) – fiber attach
- o Iloomina (SE) – chip architecture
- o ADS Ottobrunn test facilities







Photonics needs:

- ➢ PIC, tunable laser source, erbium-doped fiber amplifier, etc.

ADS contact:

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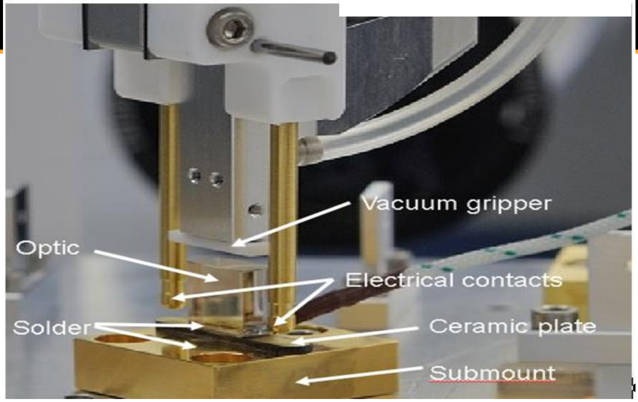
LIDAR LASER COMPONENTS & LASER AIT

Pick&Align



Objectives:

- ➢ Ultra precise (<< arcsec), adhesive-free and compact mounting of the optical components (Target TRL 9)
- ➢ Compensation of the different thermal expansion coefficients between base plate and optical components

Industrial/Academic Team:

- o Mounts and Laser AIT: Fraunhofer ILT (DE)
- o Faraday Isolator: STI (DE)
- o Oscillator pump modules: TESAT (DE)

Photonics needs:

- ➢ Pump modules, Faraday Isolator, Pockels Cell, Photonic crystals, Optical Parametric Oscillator (OPO), amplifier, Piezo actuators, fiber feedthroughs etc.

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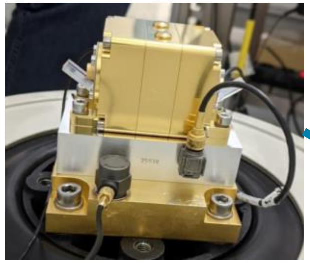

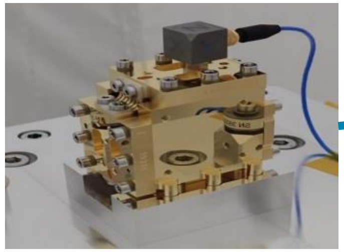

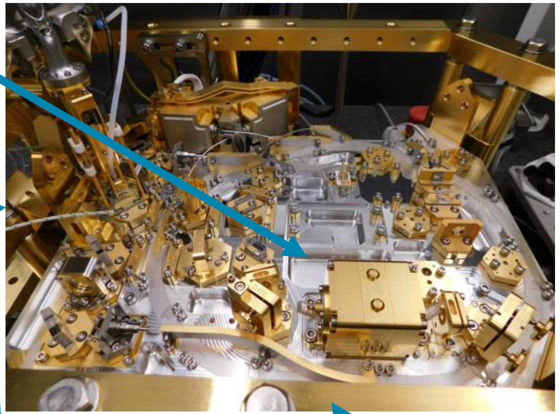

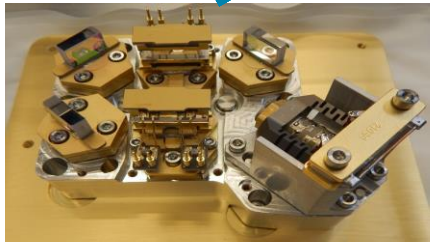

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SPACE PHOTONICS UNIFIED ROADMAP: WAY FORWARD

- ❑ Extend SPUR coverage to more applications and increase awareness internally
- ❑ Promote synergies inside Airbus to make stronger business cases
- ❑ Improve understanding of funding sources and support ADS photonic communities in seeking them
- ❑ Communicate externally photonic developments at ADS in order to foster industrial relationships

✓	✓			✓		Not yet addressed				✓		✓					Not yet addressed			
Optical Coms						Optical Sensing						Quantum based Instruments					Laser Systems			
FSO Coms	Intra Com			Quantum Coms		Local Sensing	Position Sensors			Remote Sensing		Future Local time generation	Magnetometer	Accelerometer	Gravimeter	Ultra Stable Frequency reference	Opto pyro	Laser warfare	Calibration	Metrology
All types	HSSL (Data Transfer/ Digital Datacom)	Photonics processing	µwave Photonics	QKD	Quantum Internet	Stress, T, pressure via Fiber Sensing	Sun sensors & startrackers	Inertial Wheel	FOG	LIDARs (*) (*) detection excluded	Laser Ranging	Uncooled Optical atomic clocks	Cold atom inteferometers based - NV centers			Future Laser Ranging	Optopyro	Laser warfare (Laser Weapons, countermeasures)	Calibration	Metrology

Thank you

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