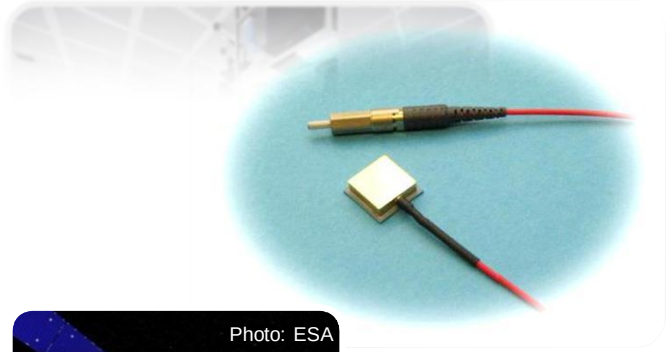
VTT TECHNICAL RESEARCH CENTRE OF FINLAND LTD



Fiber-Optic Transceivers for Space

Intra-satellite Fibre Optic Links Workshop, at ESTEC, 10 Dec 2015

Mikko Karppinen (mikko.karppinen@vtt.fi)

VTT – Technology for business

VTT Technical Research Centre of Finland Ltd is the leading research and technology company in the Nordic countries. We provide expert services for our domestic and international customers and partners, and for both private and public sectors. We use 4,000,000 hours of brainpower a year to develop new technological solutions.

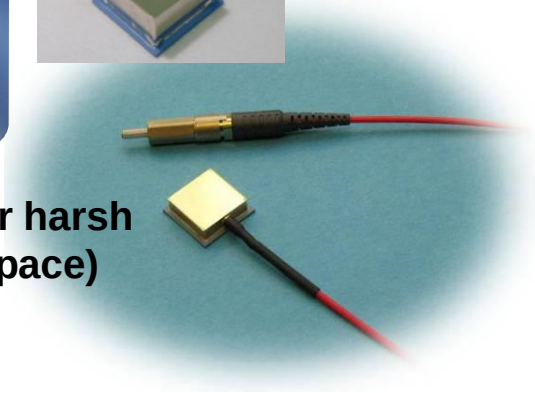
We develop new smart technologies, profitable solutions and innovative services. We cooperate with our customers to produce technology for business and build success and well-being for the benefit of society.

VTT is a non-profit organisation and a crucial part of Finland's innovation eco-system. VTT operates under the mandate of the Ministry of Employment and the Economy.

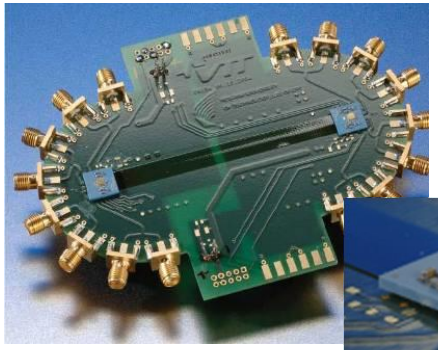
- Turnover 277 M€ (VTT Group 2014), personnel 2,600 (VTT Group 1.1.2015)
- Unique research and testing infrastructure
- Wide national and international cooperation network

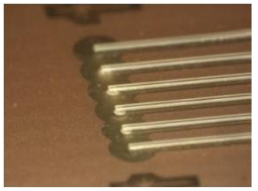
*) Source: Roles, effectiveness, and impact of VTT, VTT & Technopolis Group, 2013.

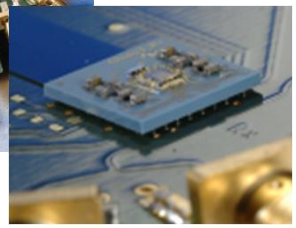
VTT Technologies for Optical Connectivity

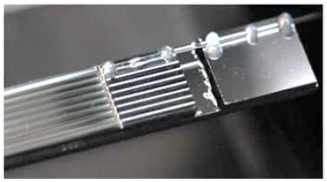


Optical transceivers for harsh environments (aerospace)

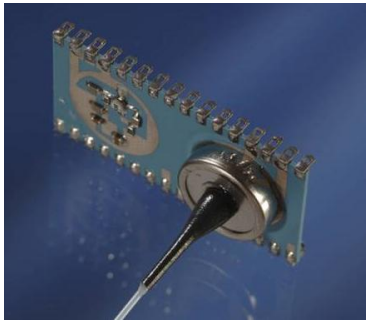




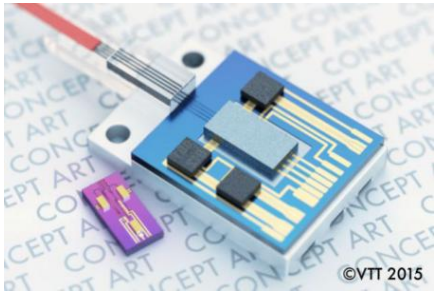


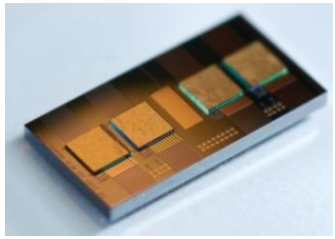


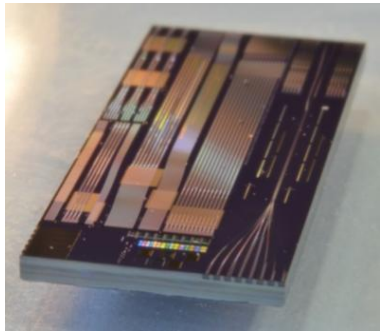
Optical interconnects on printed circuit board, and polymer waveguides



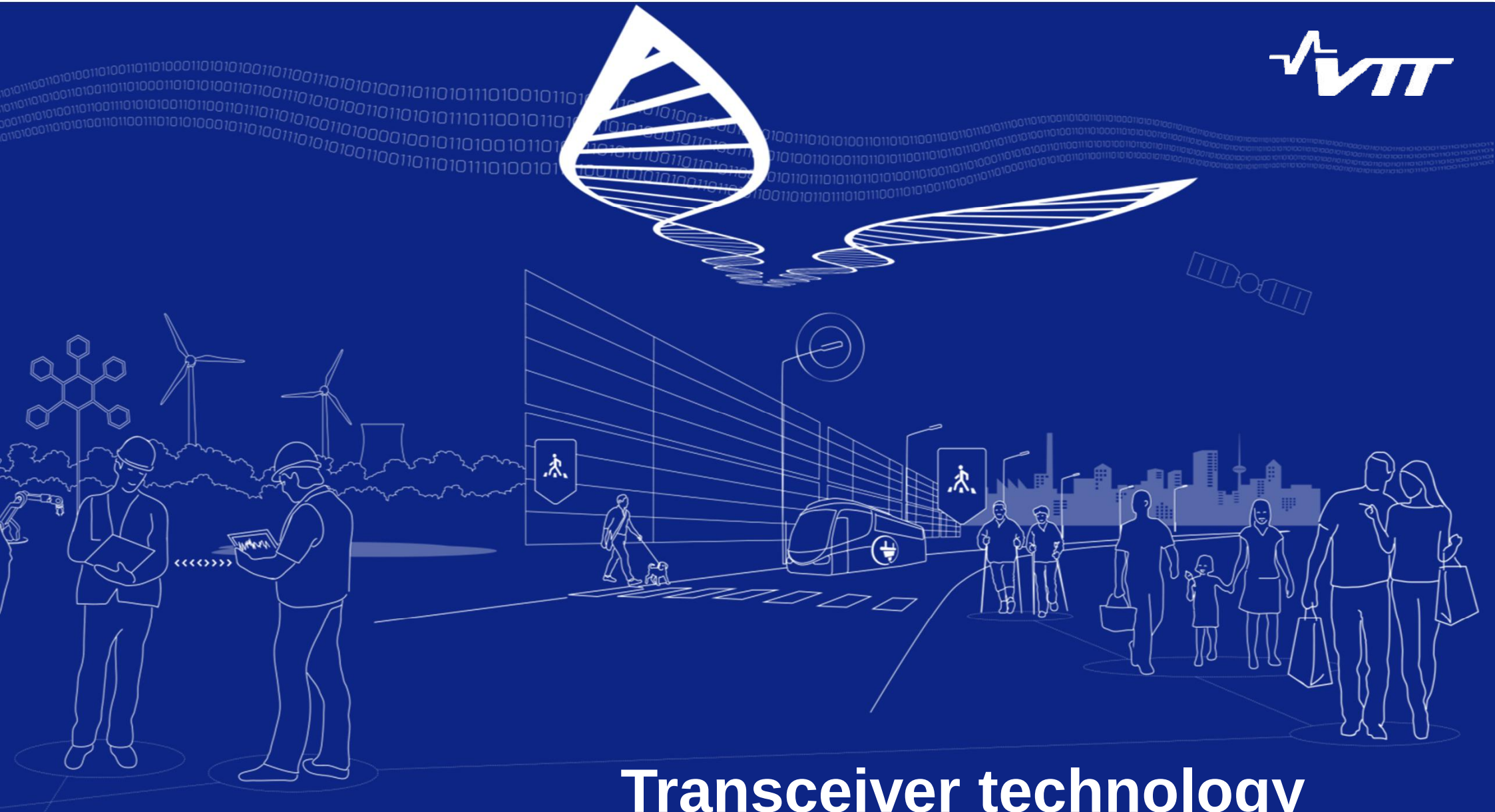
Fiber-optic modules (e.g. for radio-over-fiber)







Silicon photonics

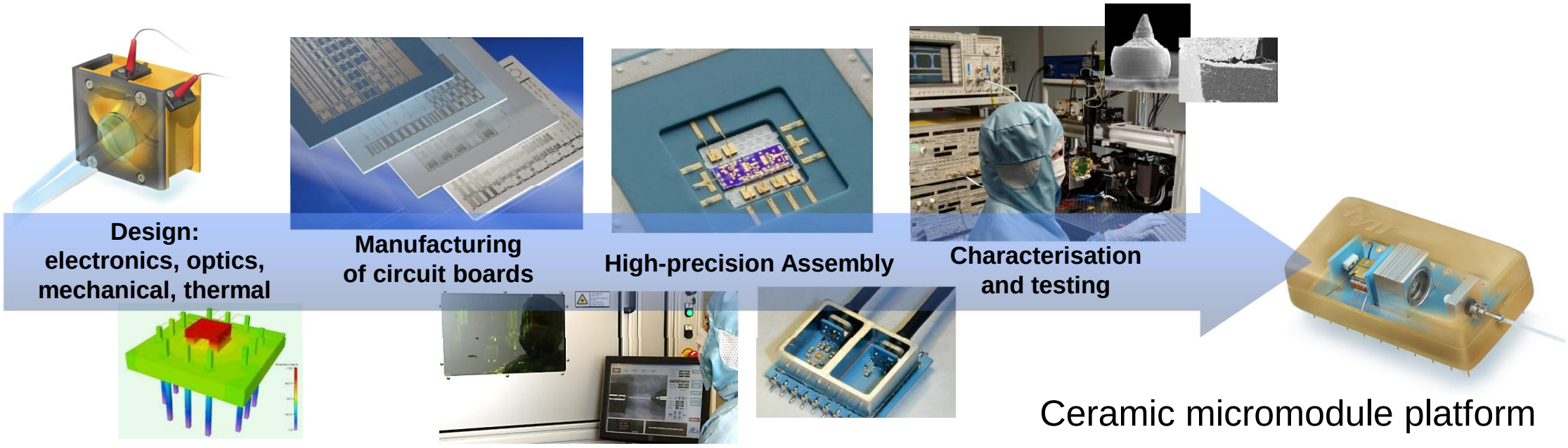


Transceiver technology

Optoelectronics for harsh environments

VTT's photonics integration & packaging competences include:

- High-speed electronics integration
- Robust metal-ceramic photonics packaging
- In-house facility for prototyping and small series manufacturing

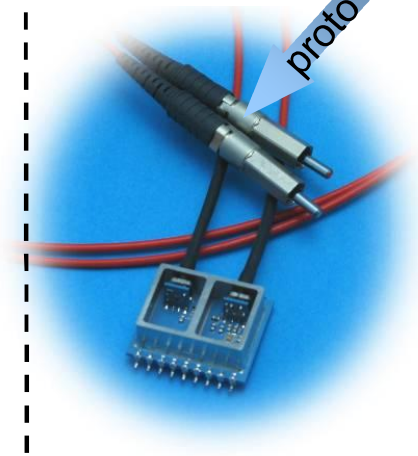


Overview of VTT's transceiver activities for intra-satellite links

2004 2010 2016

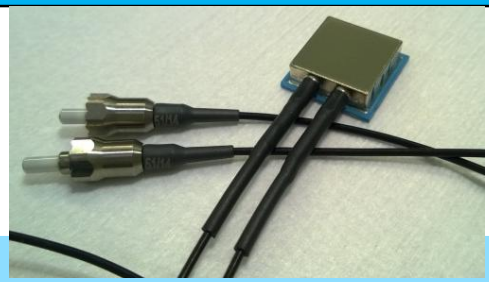
SpaceFibre study

proto



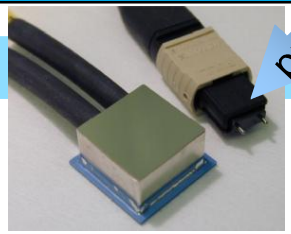
SpaceFibre Eng. Model

3rd-gen SolidOpto SPFI



Interboard Optical Links

proto

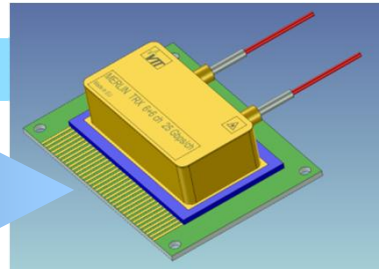


ADC/DAC with Optical Links

proto

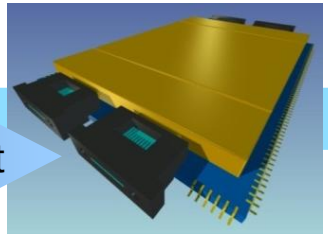
Multicore transceiver (MERLIN project)

target



Interchip Optical prestudy

concept



SpaceFibre – High-Speed Fibre-Optic Link

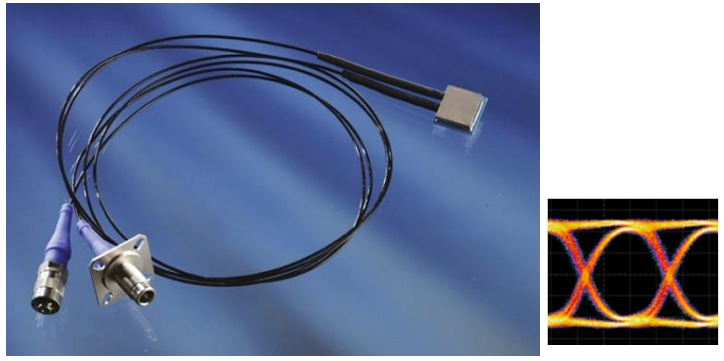
SpaceFibre is a high-speed extension to SpaceWire standard:

- Objective is to provide symmetrical, full-duplex, point-to-point communication with 1…10 Gbps data rates over 100 m.

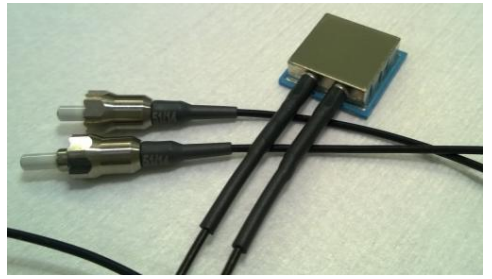
VTT has developed transceiver components for SpaceFibre, based on:

- 850-nm VCSEL lasers: Lowest power-per-bit efficiency of the short range links; high integration density; mature; reliable; radiation tolerant
- 50/125 µm silica fiber: enough bandwidth, rather easy optical coupling

1st gen (3 Gbps) SpaceFibre prototype



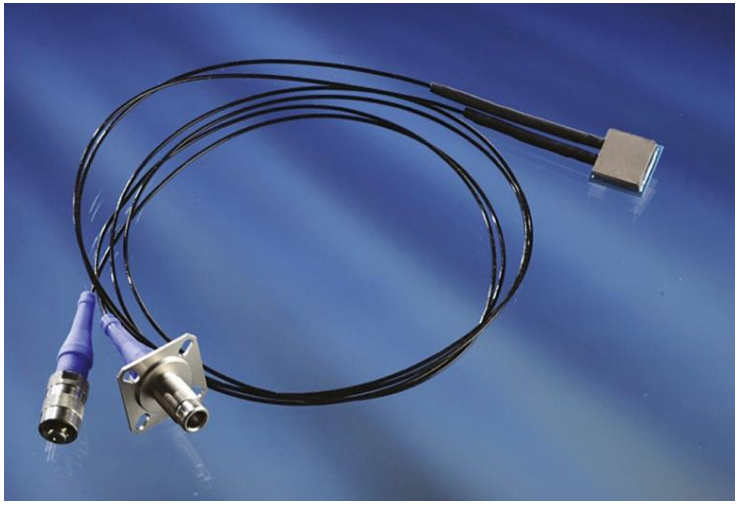
Engineering Model of (6.25 Gbps) SpaceFibre transceiver



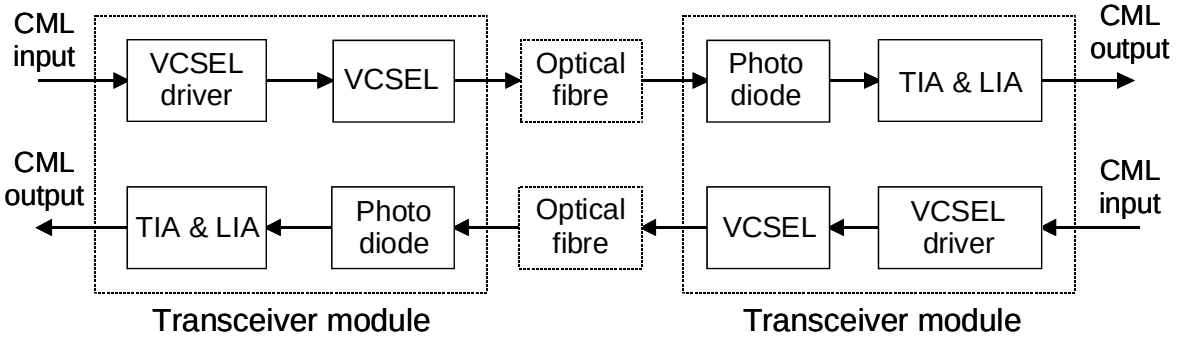
3rd Gen(6.25 Gbps) SpaceFibre transceiver

VTT's SolidOpto SPFI-(003)-6G – 6.25 Gbps 850-nm Transceiver for Harsh Environment

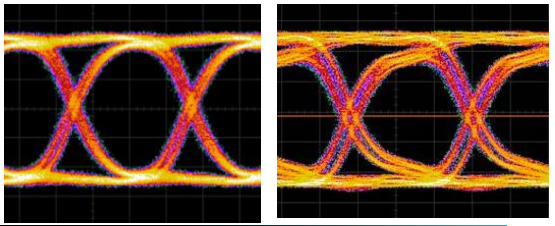
- Up to 6.25 Gbps full-duplex data link for short range applications
- Protocol independent; but compatible with *SpaceFibre* physical layer
- Power consumption 210 mW (typical)
- 50/125 µm multimode fiber pigtails



SolidOpto SPFI transceiver
with Radiall LuxCis connectors



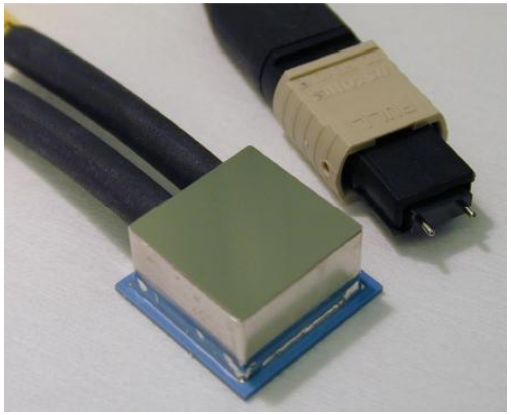
Data link functional diagram



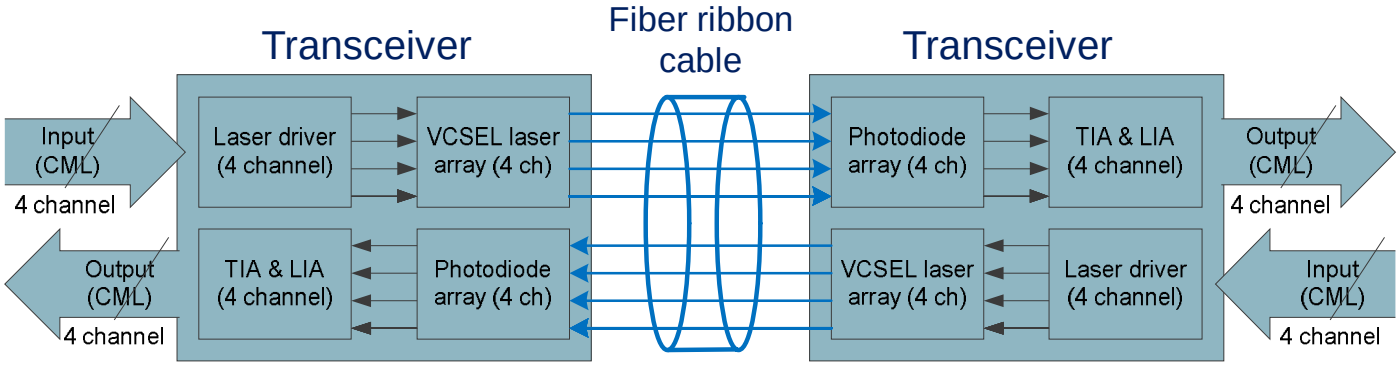
Link eyes at +25 ºC and at +90 ºC

Parallel Optic (4+4 ch) Transceiver – SolidOpto OI2

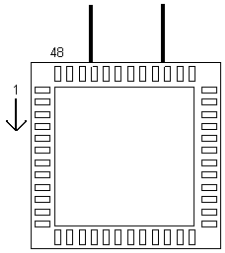
- Up to 4x10 Gbps full-duplex data link for short distances
- Protocol independent; e.g. inter-board interconnects in on-board processor
- Power consumption ca 750 mW (=19mW/Gbps)
- Dimensions 17 x 17 x 9 mm^3
- Hermetic package with multimode fiber ribbon pigtail



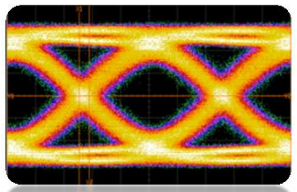
SolidOpto OI2 transceiver with 8-fiber MTP connector



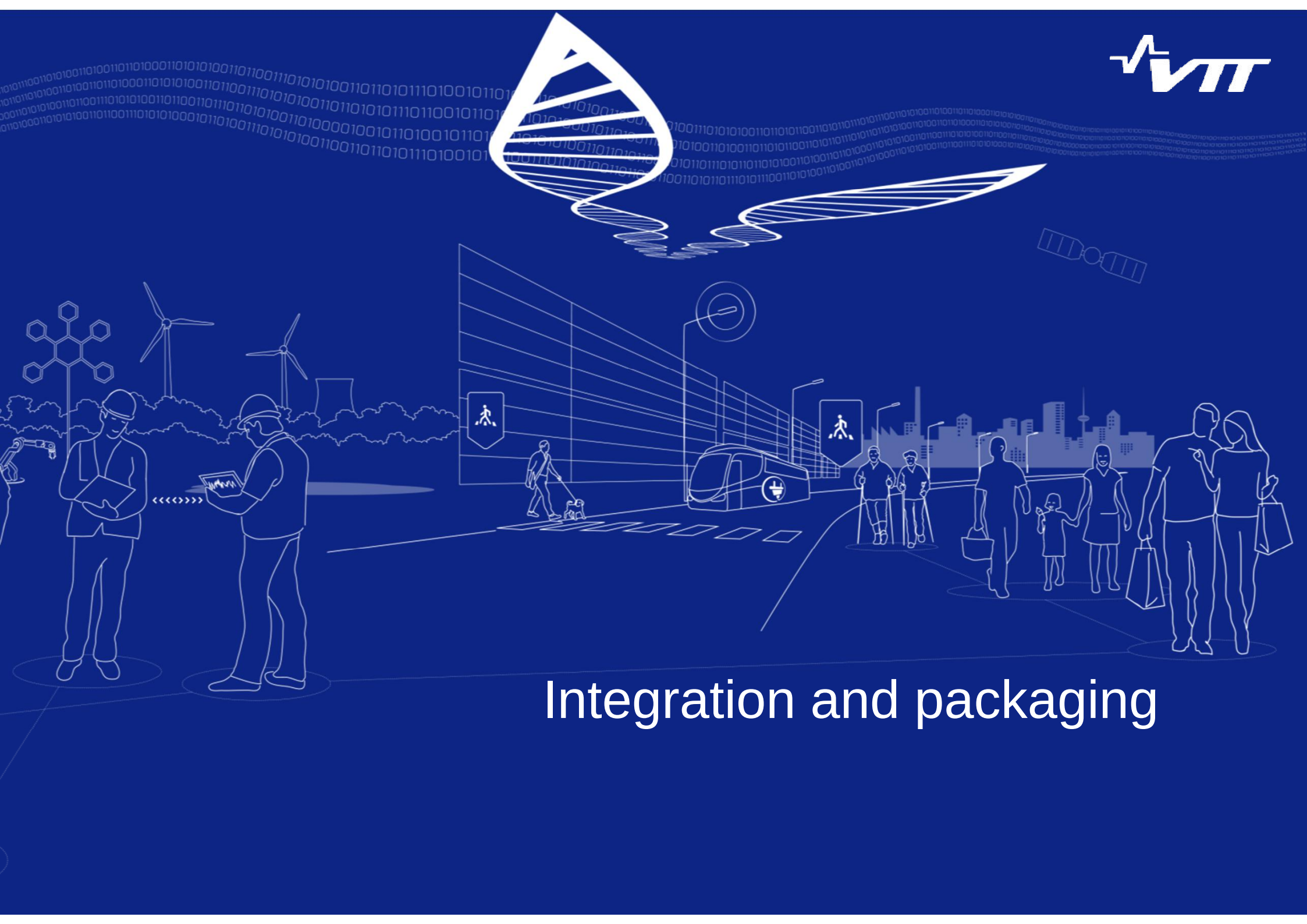
Functional diagram



PCB footprint

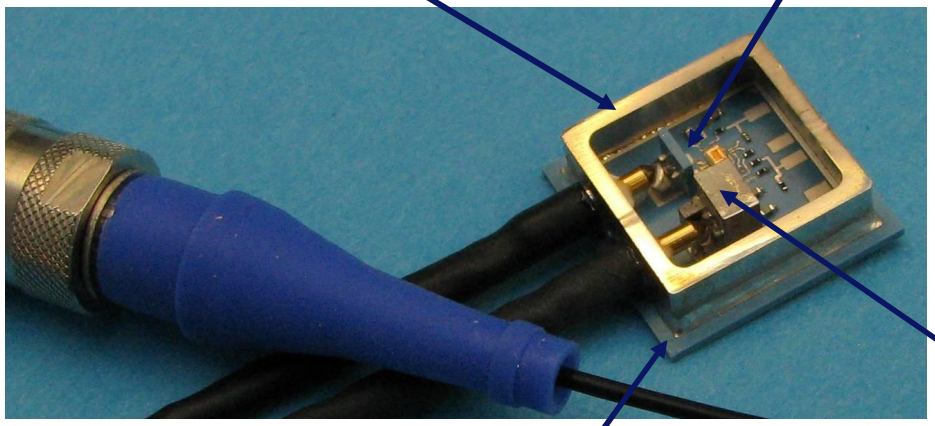


10 Gb/s

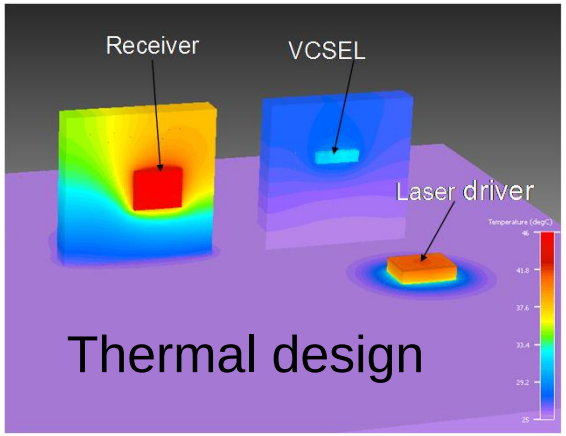


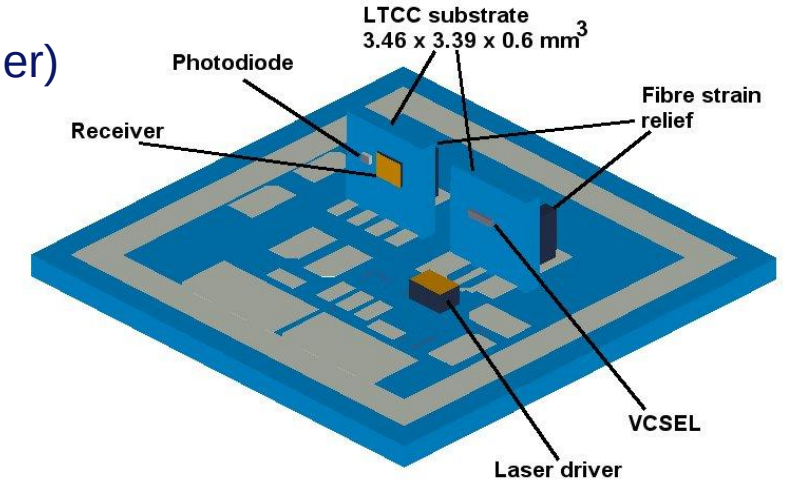
Integration and packaging

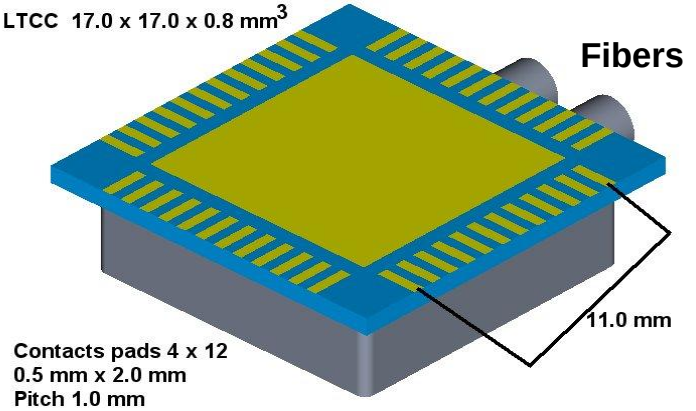
6.25 Gbps *SpaceFibre* Transceiver Structure



SolidOpto SpFi Transceiver without metal lid



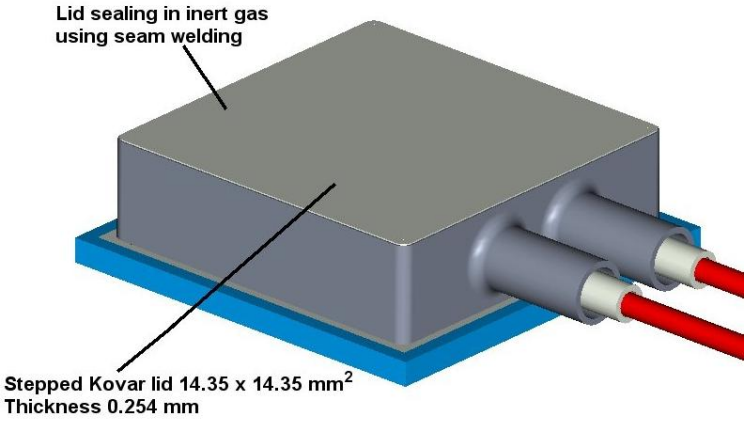




Bottom side of transceiver package (dimensions 17 x 17 x 5 mm^3)

Hermetic transceiver packaging and reliability

- Kovar frame and lid soldered to ceramic carrier
- Glass-metal fiber feedthrough using solder glass preform



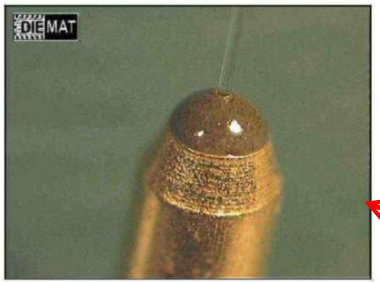
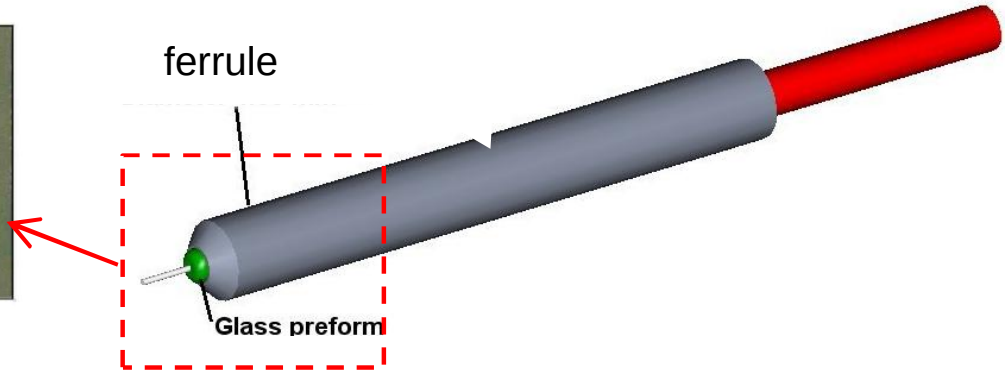


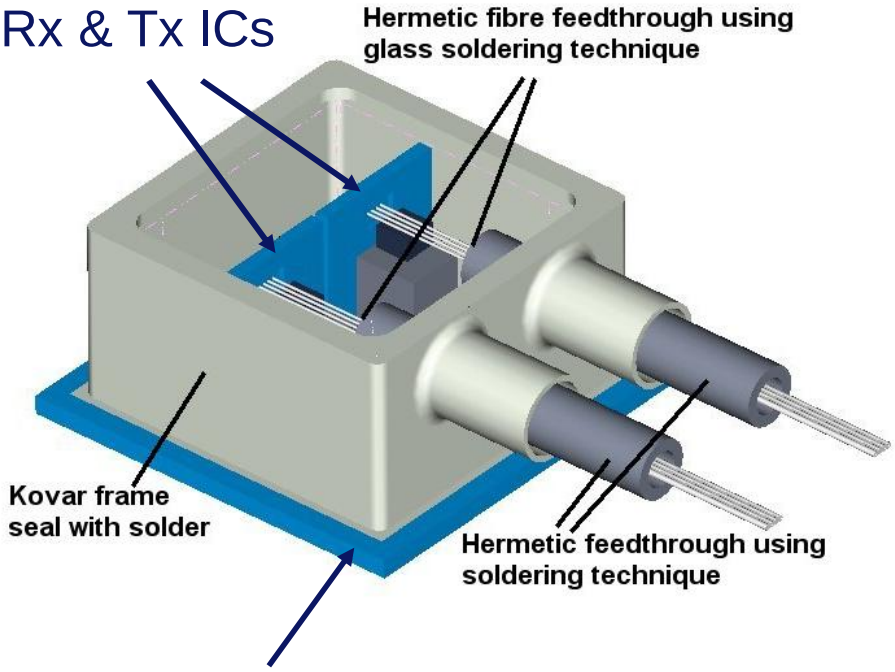
Photo by Diemat Corp



- Sealed packages passed the helium leak tests after been stressed with temperature cycling -55…+125 °C up to 1000 cycles

Parallel Optic (4+4ch) Transceiver – Packaging

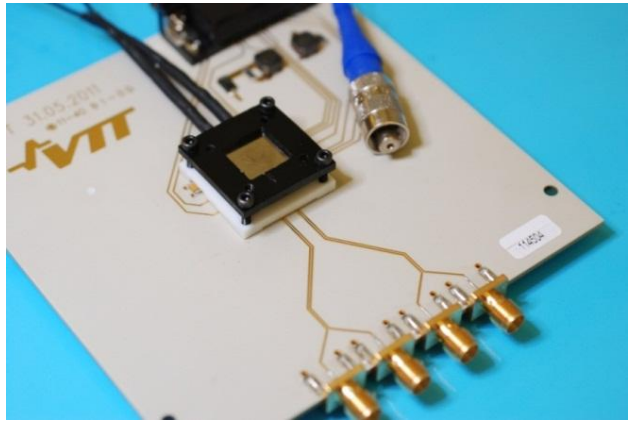
TOSA & ROSA
with 4-ch
Rx & Tx ICs

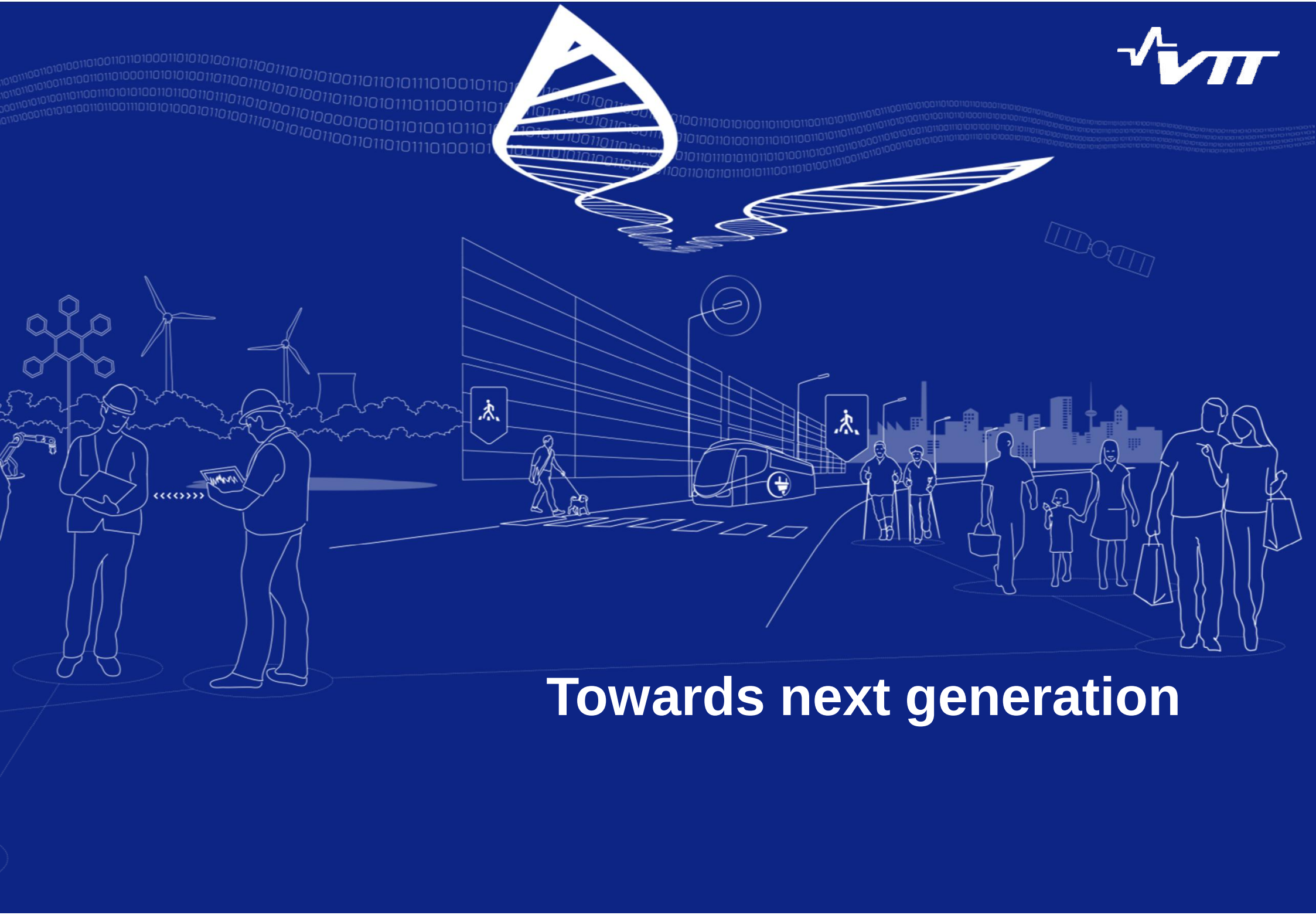


Ceramic carrier (LTCC)

More environmental reliability – *SpaceFibre* TRx

- **Radiations**
  - Passed specified **total dose** tests:
    - Gamma radiation up to 100 krad
    - Proton fluence 10^{12} p/cm^2 (@ 60 MeV)
  - Laser drivers used in the EM model showed tendency to latch-up effects at high dose of heavy ions (LET >35 MeV/mg/cm^2), however, the laser driver IC has been changed after that.
- **Mechanical testing**
  - Vibrations: passed 50 g_{rms}
  - Shock: passed 3,000 g
- **Thermal vacuum –** passed -45…+85 °C
- **ESD –** Receiver part max ±150 V





Towards next generation

Towards inter-chip optical I/O

- Studied: Interchip-Optical Communications and Photonic PCBs for Next Generation On-Board Processors (ESA TRP, 2008 – 2011)
- Optical interface should be as close as possible to ASIC/FPGA, in order to minimize overall power dissipation and complexity
  - From hybrid integration up to chip-level
  - Proposed 1st generation solution:
    Integrate multi-channel fiber-optic I/O into the IC package

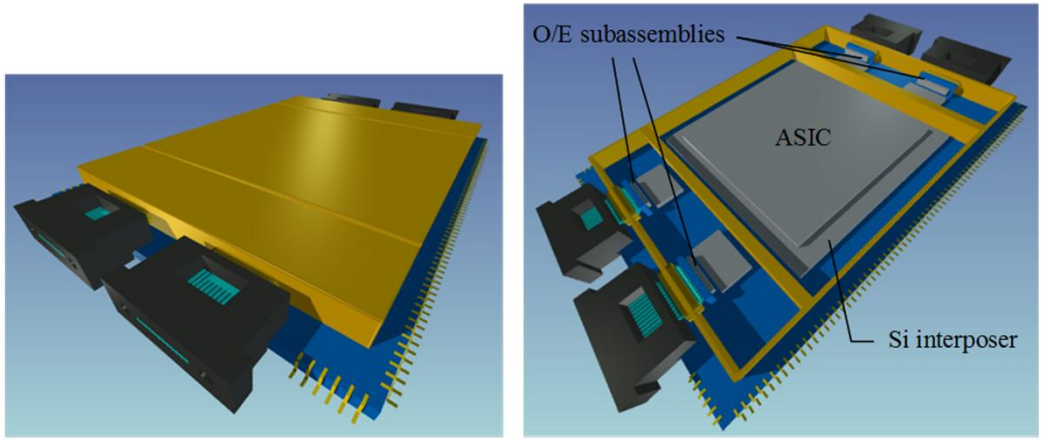
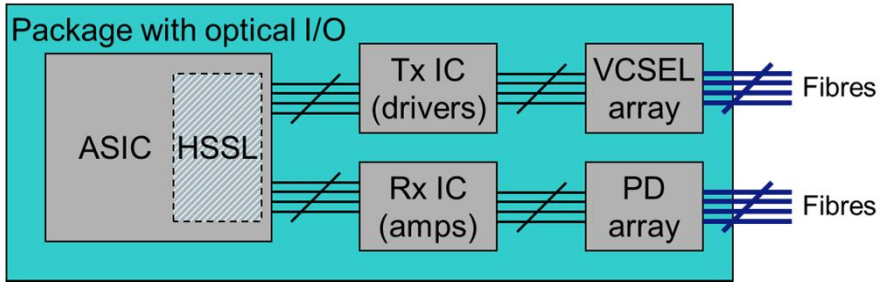


Illustration of space-grade ASIC package with fibre-ribbon I/O's



Functional diagram of I/O's

MERLIN
space transceivers

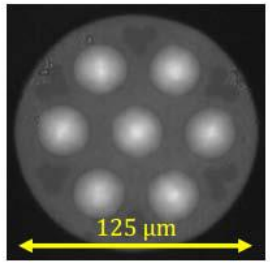
SEVENTH FRAMEWORK PROGRAMME

VTT

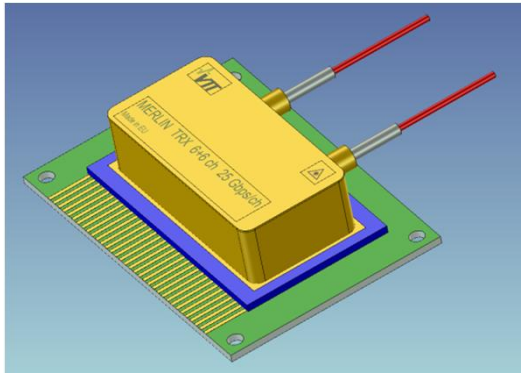
Multi-Gigabit, Scalable & Energy Efficient on-board Digital Processors Employing Multicore, Vertical, Embedded Optoelectronic Engines

Project objectives include:

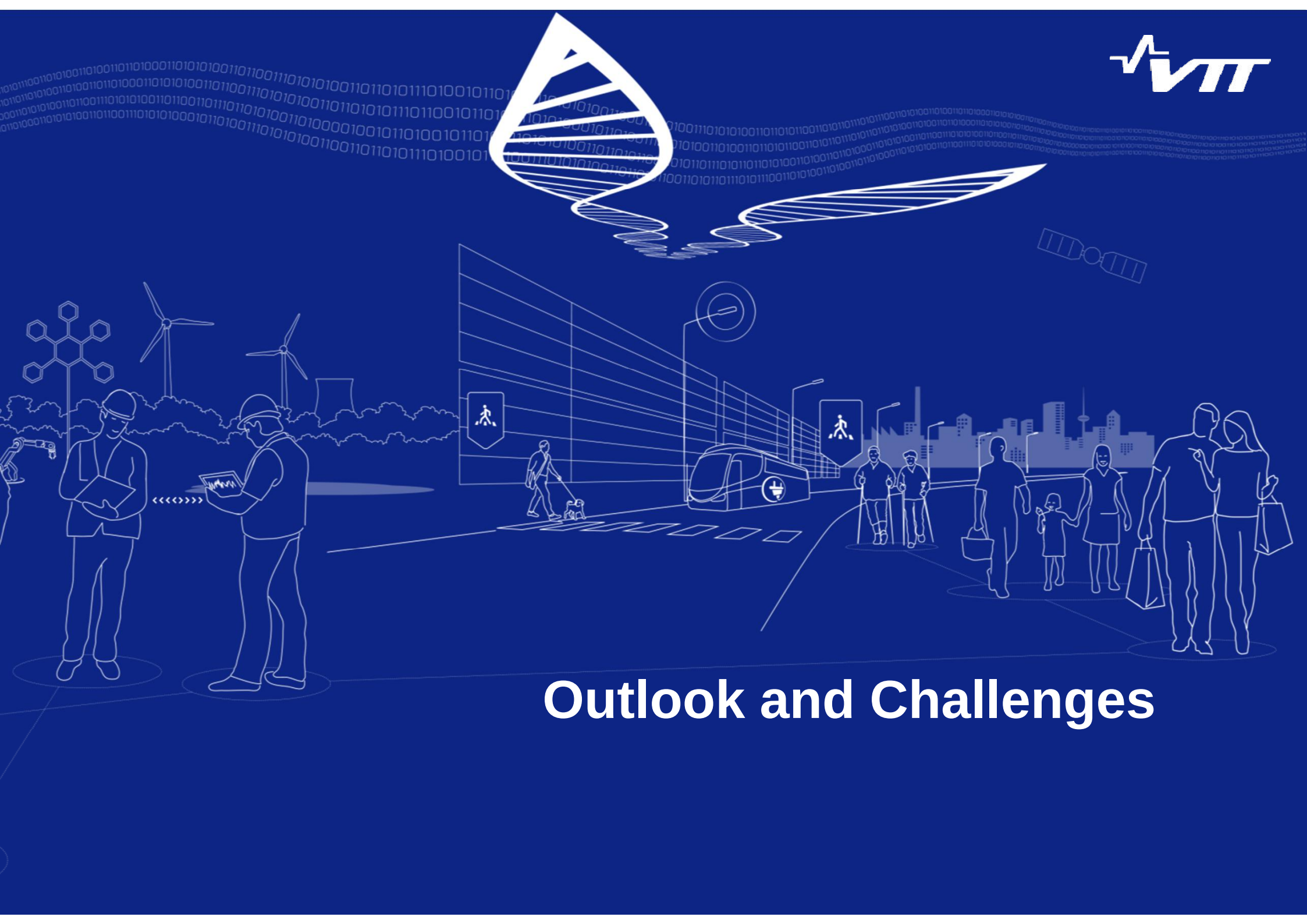
- Ruggedized optical transceiver “engines” with
  - Record-high data rate of 150 Gb/s, per fiber
  - Very wide temp range, rad-hard, low power
- Very dense integration by the use of:
  - Novel multicore fibers
  - Custom VCSEL & PD arrays
  - Custom multi-channel ASICs



Multicore fiber (©OFS)


Transceiver Vision

G&H ENABLING PHOTONIC TECHNOLOGIES
ThalesAlenia Space
U·L·M PHOTONICS
ofs A Furukawa Company
ihp
CHALMERS
VTT



Outlook and Challenges

About component selections

- So far used commercial off-the-self photonics and IC devices:
  - Can exploit advances in datacom technology (e.g. power efficiency)
  - Inexpensive compared to custom devices (space is small market)
  - Screening for e.g. radiation, wide temp range, material outgassing
- Mature 850nm GaAs-based VCSEL and PD technology:
  - Low power and good scalability
  - Reliability; also shown good radiation tolerance
- Silica multimode fibers (50/125 µm)
  - Rad-hard fibers available from a few manufacturers
  - More limited availability of suitable aerospace cabling (e.g. by W.L. Gore and by OFS)

Summary

- VTT developed high-bit-rate data links for satellite payloads with transceivers based on:
  - Advanced metal-ceramic photonics packaging
  - 850-nm VCSELs and multimode fibers
- Components developed for intra-satellite communications:
  - “SpaceFibre” fibre-optic transceivers (6.25 Gb/s)
  - Parallel optical transceivers (4+4 x 10 Gb/s)
- Developing higher speed and more inter-chip/package interconnects:
  - Next-gen ASIC packaging with integrated optical I/O
  - High-density, multi-channel, up to 150 Gb/s
- Pursuing full commercialization

For further information please contact:

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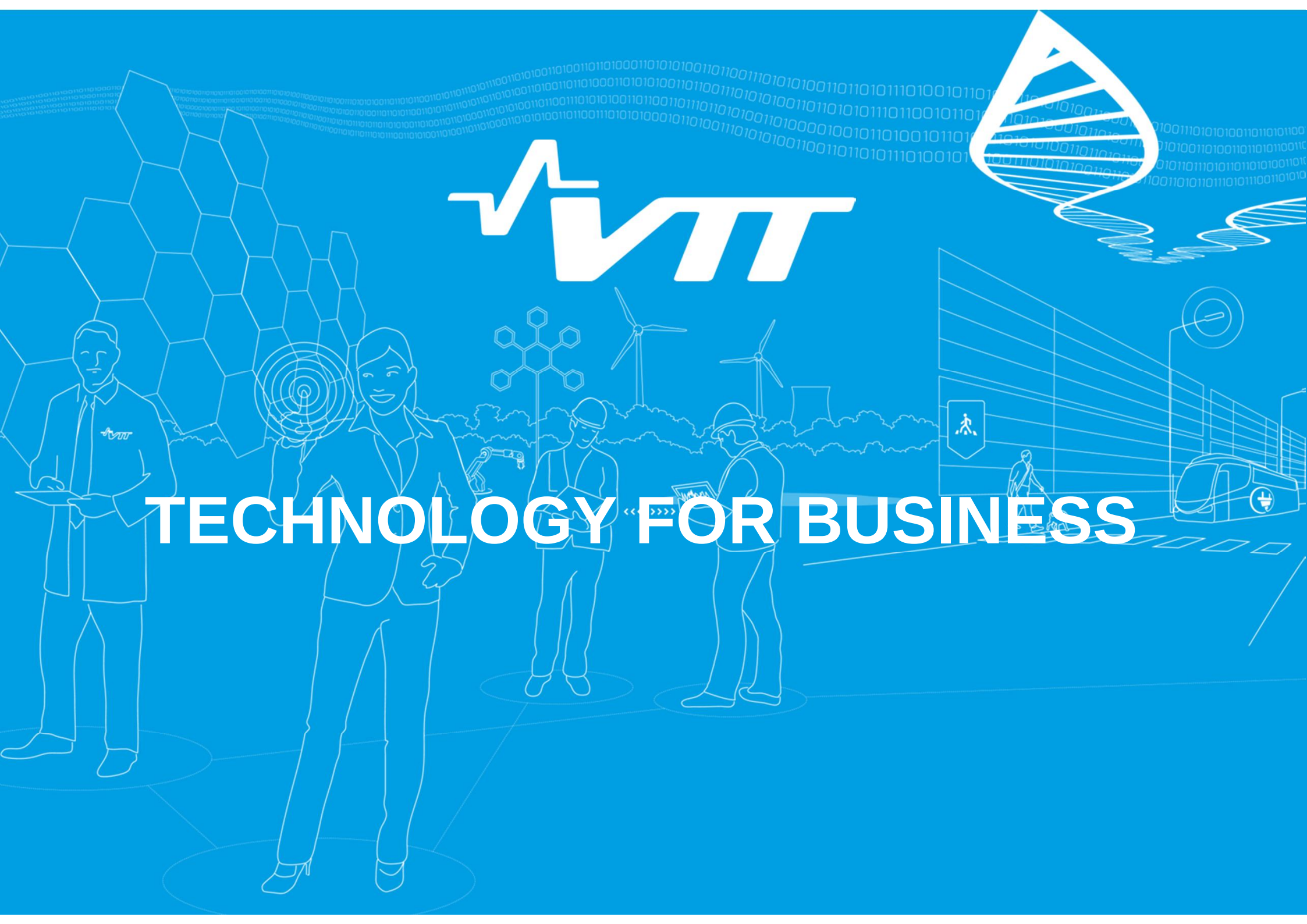
TECHNOLOGY FOR BUSINESS