Low SWaP modulating retroreflectors for asymmetric free space optical communication applications

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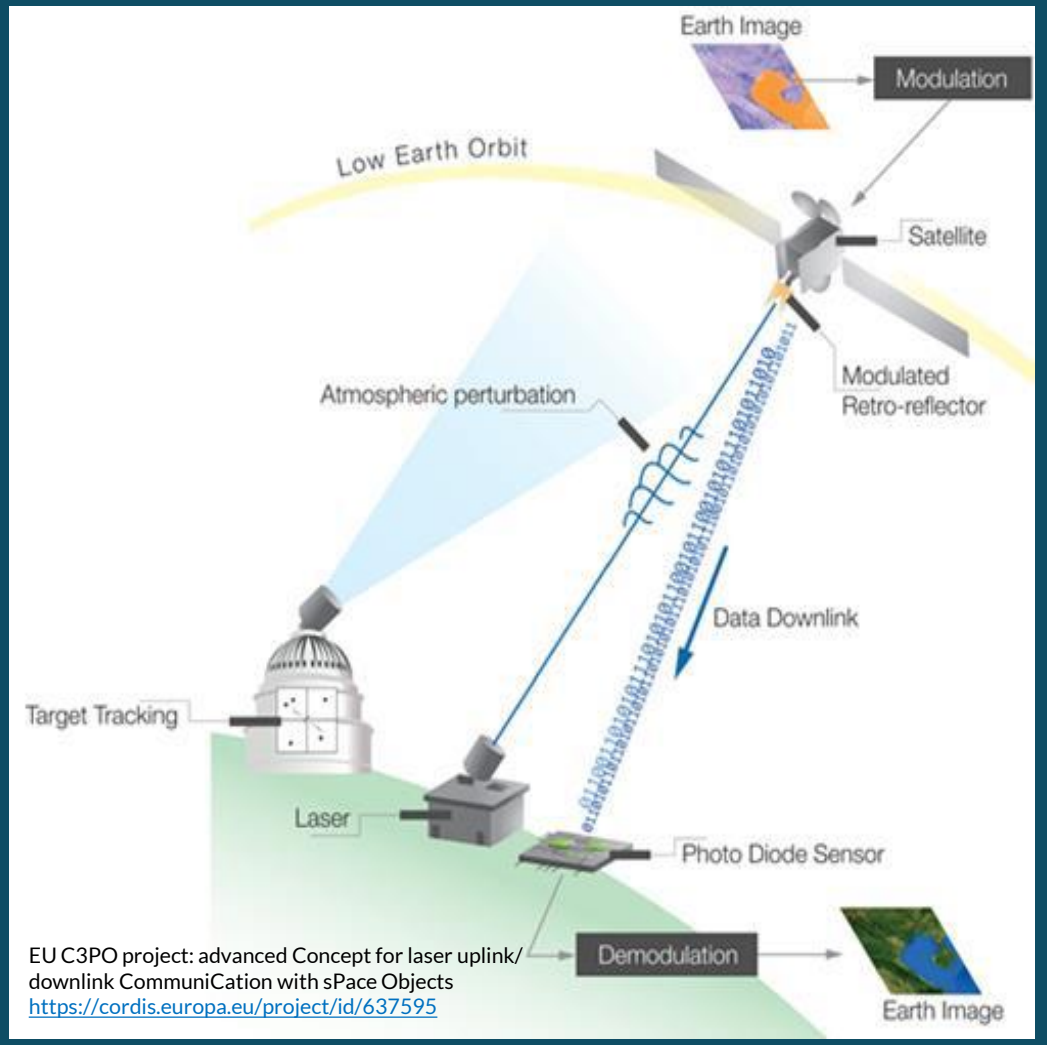
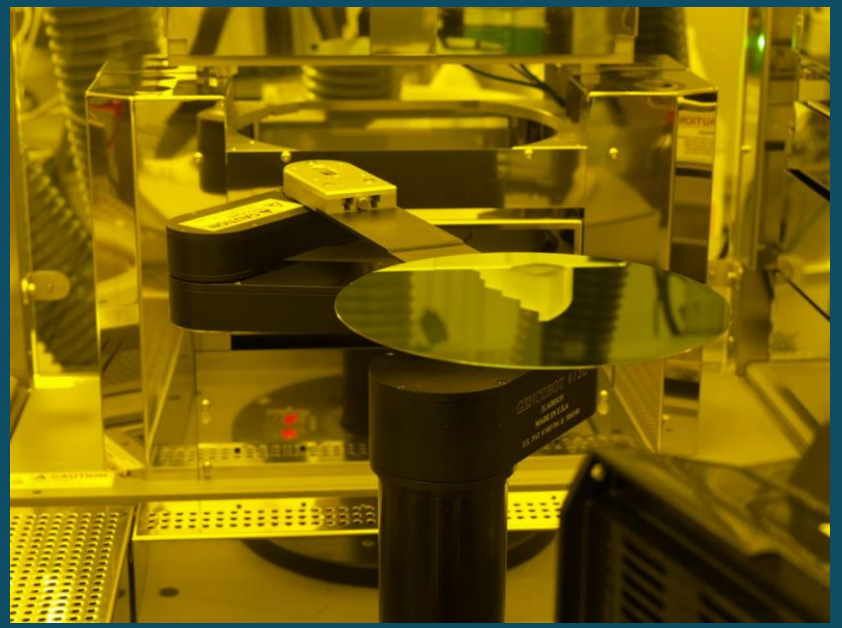


EU C3PO project: advanced Concept for laser uplink/ downlink CommuniCation with sPace Objects
https://cordis.europa.eu/project/id/637595

Outline

1. Team and acknowledgements
2. RISE and Smart Hardware in brief
3. R&D&I activities on MRRs at RISE
4. EAM for other space applications and publications
5. Partnership for EU calls
4. Contact info for future collaborations



1. Team and acknowledgements

- Colleagues from RISE Acreo: Bertrand Noharet, Stephane Junique, Susanne Almqvist, Olof Oberg, Darius Jakonis, Mikael Karlsson, Xiaoyu Piao, Adrien Chopard, Raphael Bellossi, Duncan Platt, Ingemar Petermann and Michael Salter
- Dr. L. Sjöqvist, Dr. E. Hällstig and J. Öhgren from the Swedish Defence Research Agency for the modulator characterization in their free-space optical communication links.
- Profs. and students from KTH, Lund, colleagues through EU projects
- International collaborations, Airbus, ESA, Thales, NLR (Netherlands Aerospace Centre), DLR (German Aerospace Center) etc.
- The Swedish Defence Photonics Research Program (FMV), the Swedish Defence Research Agency (FOI), the Swedish Knowledge Foundation (KKS), Swedish Agency for Innovation Systems (Vinnova), and several EU projects such as Labels, Iphobac, Sandra and C3PO.

RI.
SE

2. Research Institute of Sweden RISE in brief

130+

Testbeds and demonstration environments

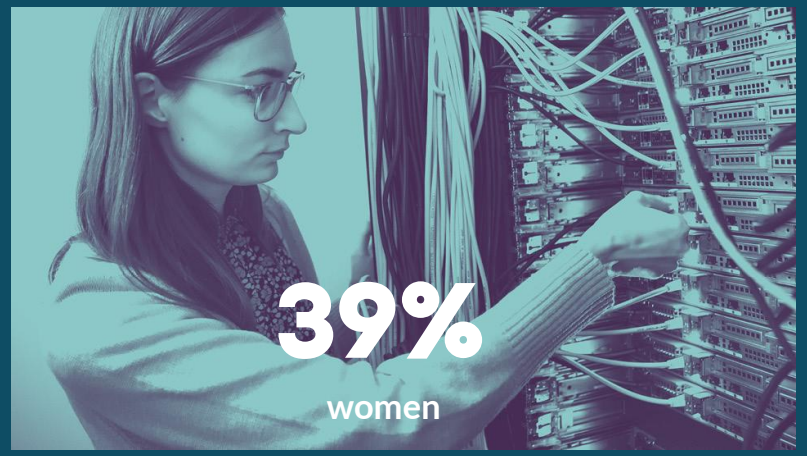
Approx.

3,000

employees

94%

of our projects were declared for sustainability in December 2021

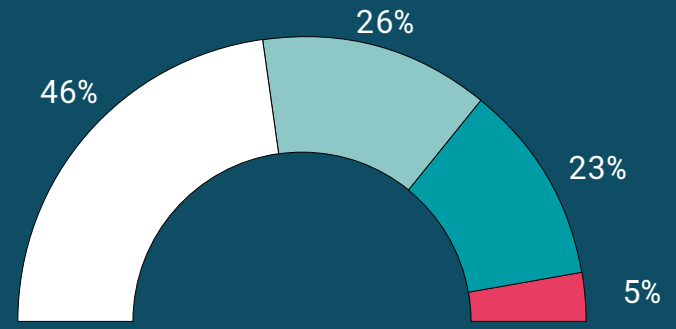


2025

The year when RISE becomes climate neutral

3,618

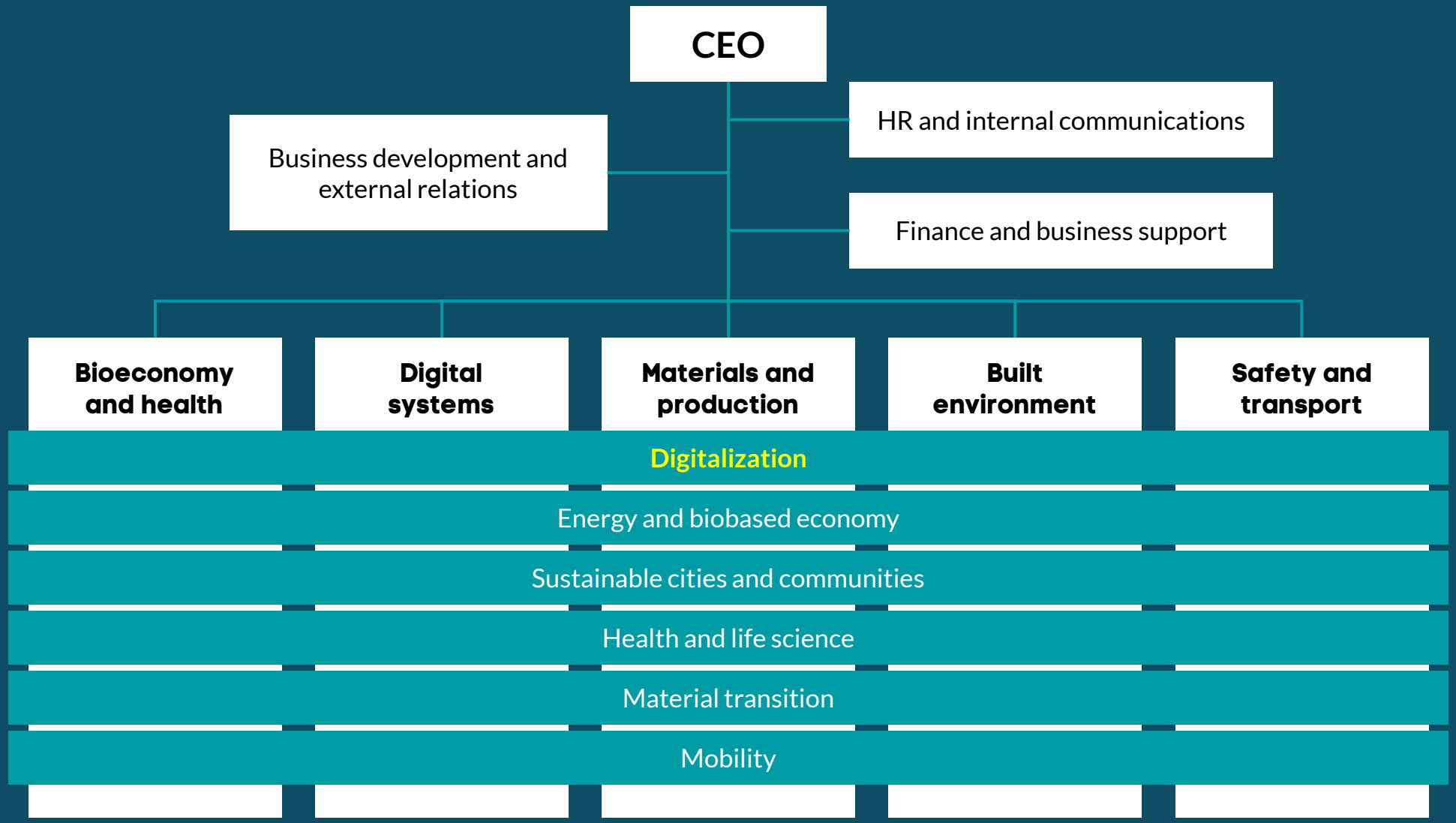
SEK million, net sales



Distribution of net sales

Business sector	1,651 MSEK
Public funds	954 MSEK
State funds	827 MSEK
EU funds	186 MSEK

All figures refer to 2021.


CEO
Business development and external relations
HR and internal communications
Finance and business support
Bioeconomy and health
Digital systems
Materials and production
Built environment
Safety and transport
Digitalization
Energy and biobased economy
Sustainable cities and communities
Health and life science
Material transition
Mobility

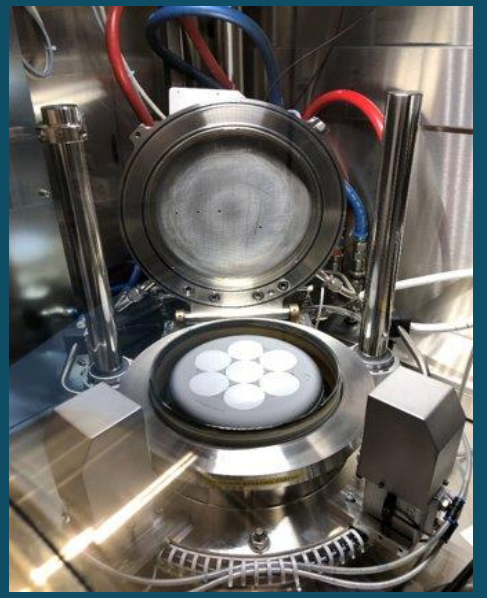
3. R&D&I activities on MRRs at RISE

Graphene for thermal management

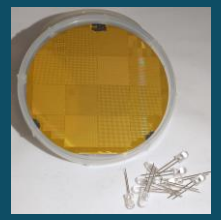
Nano Technology Unit

- Focus on electronic/photonic devices and systems based on semiconductor materials including GaAs, InP, GaSb, GaN, SiC, Ga_2O_3, and ZnO that create new functionalities and allow for further integration and miniaturization giving higher performance at reduced cost.
- Specialize in the areas of nano/micro fabrication, MEMS/NEMS nanoelectronics/photonics for applications for imaging, bio & life science, sensors & actuators, power electronics and high-speed optical communications.

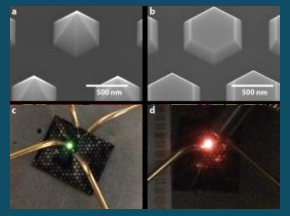
ISO-9001 certificated clean-room facilities and various characterization tools/setups at Kista and Lund



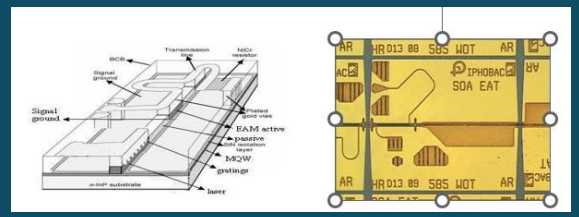
Aixtron CCS Group III-Nitride MOCVD System



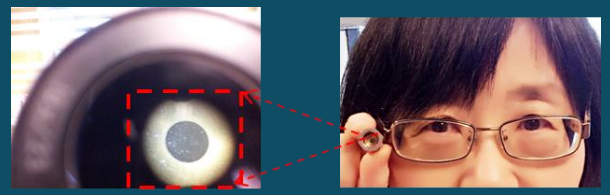
Wafer-scale component design and fabrication for small-scale production



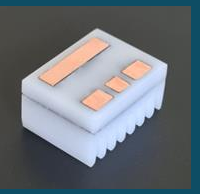
III-N Nano pyramid/ platelet based RGB LEDs



PIC, TW EAM + laser or SOA



SiC-based high temperature and high-pressure sensors

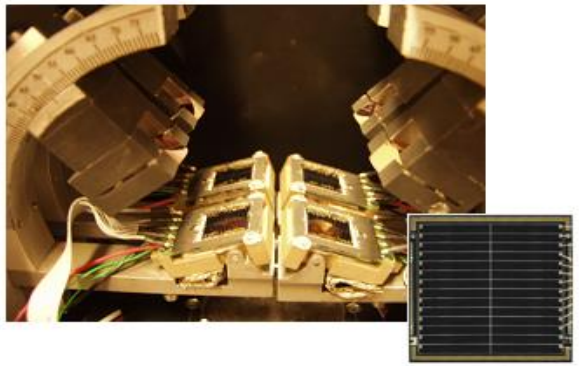


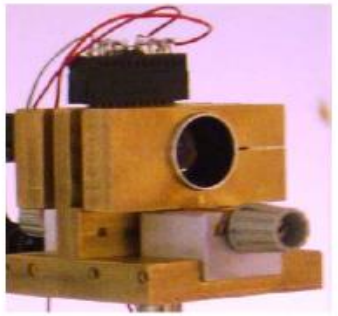
Graphene for thermal management

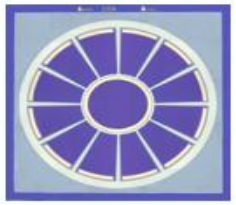
3. R&D&I activities on MRRS at RISE
Background and State-of-the-Art

Surface normal modulators and arrays for free-space optical communication links at 850 nm, and 1550 nm

- III-V semiconductor microfabrication
- Wafer scale process
- Good uniformity and yield
- Monolithic and hybrid integration
- Start-of-the-art performance







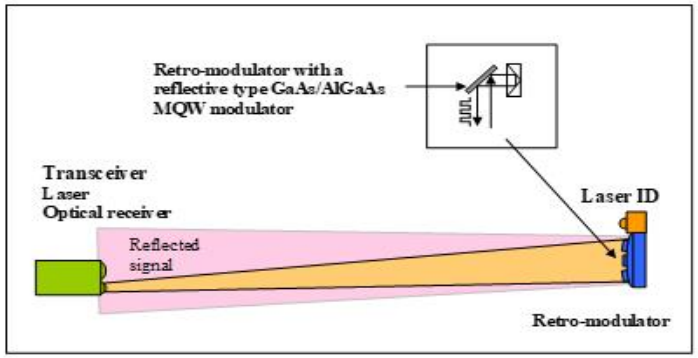
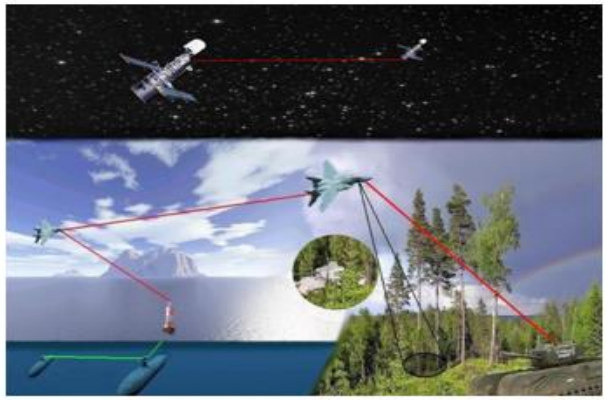


Fig. 12 Sample image from the live video transferred via the optical link.



Retrokom phase 1, 2, operating wavelength 860 nm, and then 1550 nm collaborating with FOI, and funded by FMV since 2000

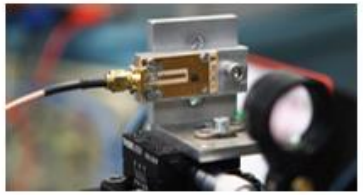
3. R&D&I activities on MRRS at RISE

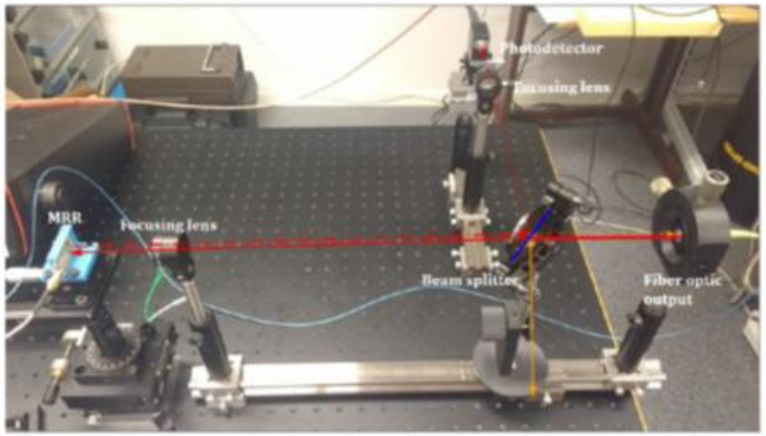
Background and State-of-the-Art

Year	Group	Speed	Range	BER	CR	Aperture size	FoV	Structure
2021	RISE	500 Mbps	560 m	7.6×10^{-4}	1.5~4	11 mm	6.4 deg.	Cat's eye
2017		150 Mbps	200 m	1.22×10^{-6}	1.25	20 mm	2.8 deg.	Cat's eye
2005		8 Mbps	100 m	7×10^{-3}	4(Max. 40)	1 mm	6 deg.	Cat's eye
2018	NRL	Max. 100 MHz	-	-	15 dB	6.3 mm	5.0 deg.	Corner cube
2007		45 Mbps	7 km	-	2	16 mm	10 deg.	Cat's eye
2004		10 Mbps	1 km	-	2	16 mm	16 deg.	Cat's eye

3. R&D&I activities on MRRS at RISE, in door demo

1550 nm EAM

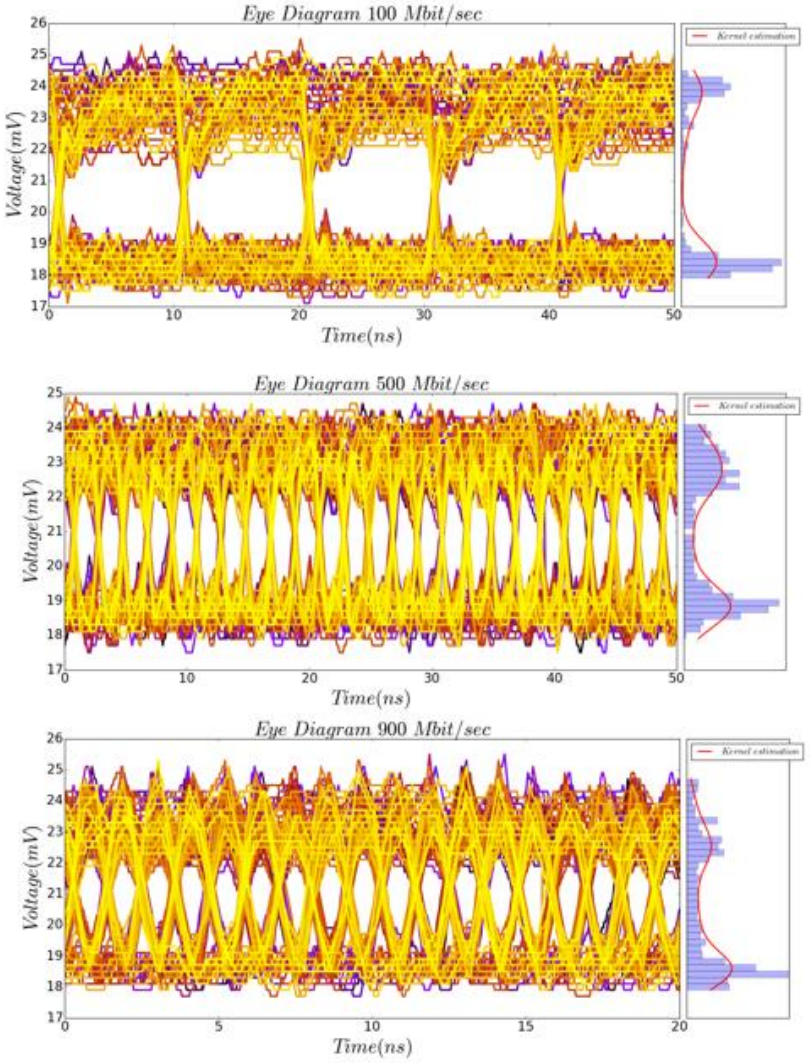




https://www.youtube.com/watch?v=I5Gyw9dMtCA

Frequency($Mbit.s^{-1}$)	Q	BER
100	5.5	$1.7\,e^{-8}$
300	4.9	$3.7\,e^{-7}$
500	4.3	$7.1\,e^{-6}$
750	4.2	$1.5\,e^{-5}$
900	3.8	$8.5\,e^{-5}$

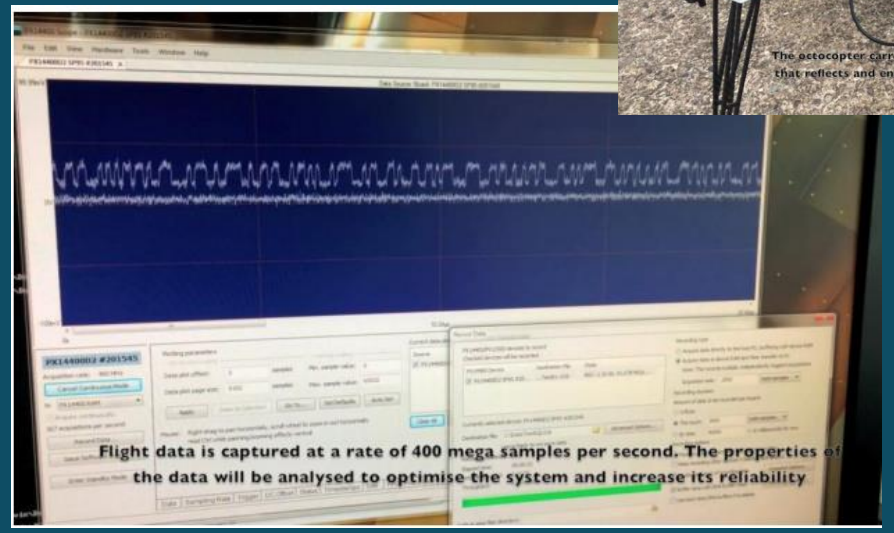
Pseudo Random Sequences



3. R&D&I activities on MRRS at RISE, 2014, field test

- A retro-reflective laser modulation system was demonstrated at the Pershore Trials Range. A random sequence was successfully transmitted from an octocopter UAV both on the ground and in flight at an altitude of 25m and at ranges of 75, 500m and 1200m.
- The data rate achieved was 20Mbps. The signal received was clearly visible on an oscilloscope and recorded with a capture card. This allowed the calculation of a BER of 4x10-3 at a range of 75m and 2x10-2 at a range of 500m.
- FOV, 10-degree,
- Further develop retro-reflective technology to achieve data rates in the order of 1Gbps.

Modulated retro-reflector based on MQW technology provided by RISE (Acreo)



DAZZLE project: UAV to ground communication system using a laser and a modulated retro-reflector, by Yoann Thueux, Nicholas Avlonitis, Gavin Erry Airbus Group Innovations, Newport, Wales, Proc. of SPIE Vol. 9248, 92480P · © 2014 SPIE doi: 10.1117/12.2062610

3. R&D&I activities on MRRS at RISE, field test.

EU H2020 project: C3PO based on electro-absorption modulator arrays produced at Electrum cleanroom

https://www.acreo.se/projects/advanced-concept-for-laser-uplink-downlink-communication-with-space-objects-c3po

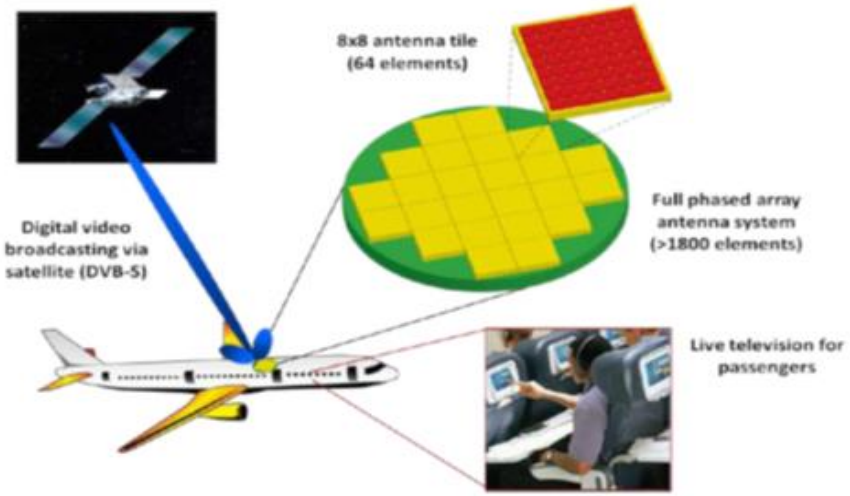
- Design and implementation of a high bandwidth MQW based MRR.
- The system uses a pixelated electro-absorption modulator (EAM) modulating retro-reflector (MRR) to establish a data link operating at 500 Mbps at a range of 560 m and a bit error rate (BER) of $7.6 \cdot 10^{-4}$.
- The MRR provides an effective aperture of 11 mm and full field of view (FFOV) of 6.4°.
- To the best of our knowledge, this is the fastest demonstration of an outdoor link of this type.

C. Quintana, Q. Wang et al, IEEE Photonics Technology Letters, DOI 10.1109/LPT.2017.2680842
C. Quintana, Q. Wang et al, IEEE Lightwave Technology in revising A high speed retroreflective free space optics links with UAV

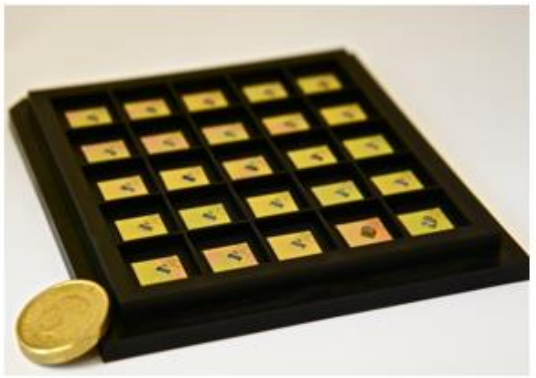
1. C. Quintana, Q. Wang, et al. "High Speed Electro-absorption Modulator for Long Range Retroreflective Free Space Optics", IEEE Photonics Technology Letters, Vol. 29, No. 9, p. 707-710, 2017
2. C Quintana, Q Wang, et al, 'A high speed retroreflective free space optics links with UAV', IEEE Journal of Lightwave Technology, ISSN 0733-8724, E-ISSN 1558-2213, **2021** DOI: 10.1109/JLT.2021.3091991

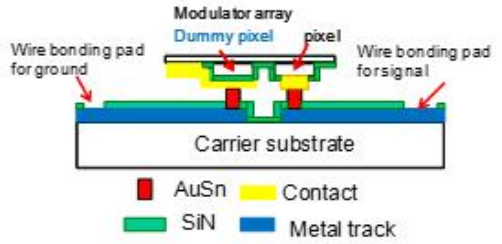
4. EAM for other space applications and publications

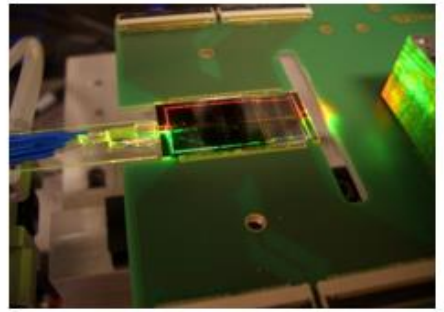
EU Sandra project, FP7



In order to provide airplane passengers with live television channels, a phased array antenna system is used for reception. The antenna consists of antenna tiles of 64 elements.







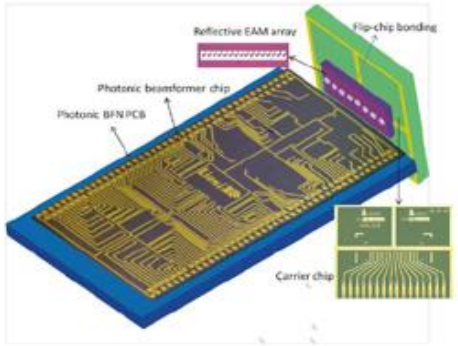
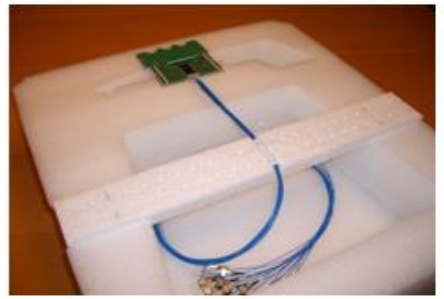


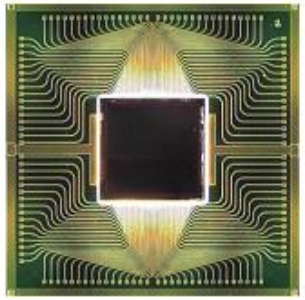
Figure 6. An artist impression of a possible photonic integration scheme between the photonic BFN chip and the EAM array.

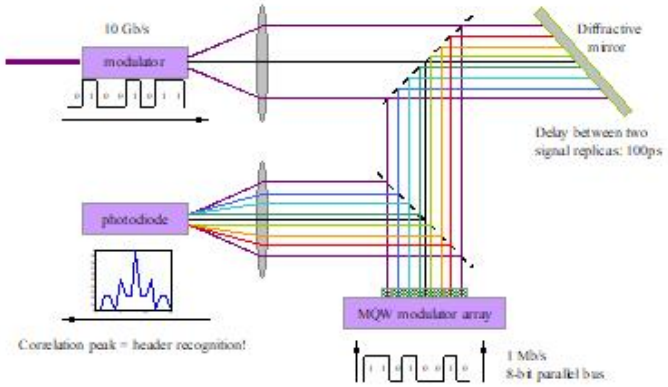


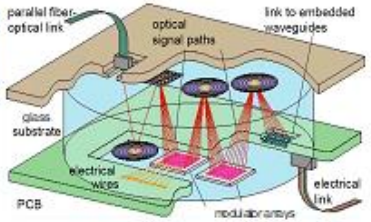
4. EAM for other space applications and publications

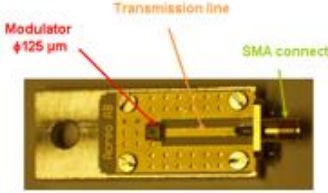
Hybrid integration approaches

Lightwave architectures for the processing of Broadband Electronic Signals (LABELS)
EU Project:, 3 years and 6 countries and ESA project
Lenslet project

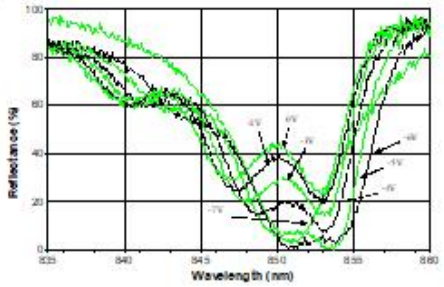


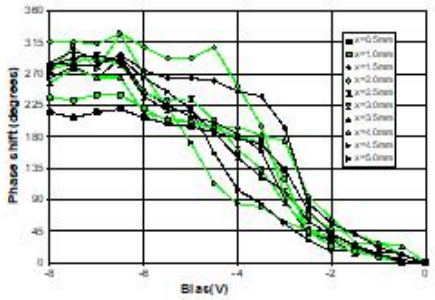


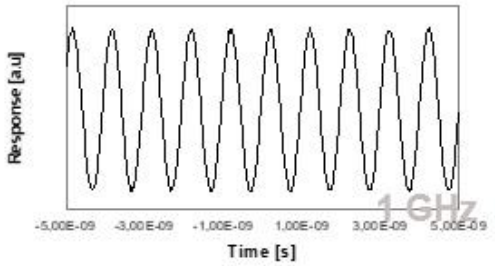


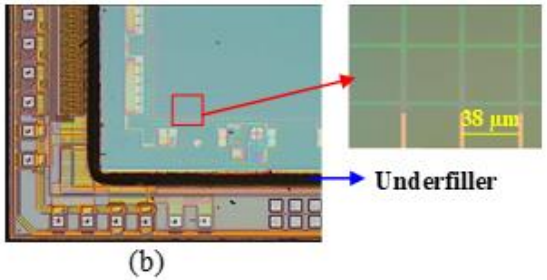


Amplitude and phase modulator array









(b)

SLM flip-chip bonded on ICD

4. EAM for other space applications and publications

(1) C Quintana, Q Wang, D Jakonis, O Oberg, G Erry, D Platt, Y Thueux, A. Gomez, G. Faulkner, H. Chun, M. Salter, and D. O'Brien, 'A high speed retroreflective free space optics links with UAV', IEEE Journal of Lightwave Technology, ISSN 0733-8724, E-ISSN 1558-2213, **2021** DOI: 10.1109/JLT.2021.3091991

(2) Hedlund, C., Öberg, O., Lim, J.-K., Wang, Q., Salter, M., Hammar, M. "Hedlund, C., Öberg, O., Lim, J.-K., Wang, Q., Salter, M., Hammar, M. "Trench-confined epitaxial regrowth", Phys. Status Solidi A, 1700454, 2018

(3) Q. Wang, S. Junique, A. Chopard, M. Karlsson, I. Petermann, O. Öberg, "Optoelectronic components for optical information processing and communication in 850nm/1060nm/1550nm regimes", SPIE Photonics West 10524-6, 2018

(4) C. Quintana, Q. Wang, D. Jakonis, X. Piao, G. Erry, D. Platt, Y. Thueux, A. Gomez, G. Faulkner, H. Chun, M. Salter, and D. O'Brien, "High Speed Electro-absorption Modulator for Long Range Retroreflective Free Space Optics", IEEE Photonics Technology Letters, Vol. 29, No. 9, p. 707-710, 2017

(5) Benoît d'Humières, Bruno Esmiller, Yann Gouy, Emilie Steck, Crisanto Quintana, Graham Faulkner, Dominic O'Brien, Fabian Sproll, Paul Wagner, Daniel Hampf, Wolfgang Riede, Michael Salter, Qin Wang, Duncan Platt, Darius Jakonis, Xiaoyu Piao, Mikael Karlsson, Olof Oberg, Ingemar Petermann, Aneta Michalkiewicz, Jerzy Krezel, Anna Debowska, and Yoann Thueux, "The C3PO Project: a laser communication system concept for small satellites", SPIE Photonics West 2017, SPIE Proceedings Volume 10096: Free-Space Laser Communication and Atmospheric Propagation XXIX

(6) Yann Gouy, Qin Wang, Benoît d'Humières, Crisanto Quintana Sanchez, Dominic O'Brien, Duncan Platt, Jerzy Krezel, Michael Salter, Aneta Michalkiewicz, Paul Wagner, Emilie Steck, Yoann Thueux, Sebastien Vourc, Wolfgang Riede, "Advanced Concept for laser communication system for micro and nanosatellites", Symposium 4S (Small Satellites Systems & Services), 30 May - 3 June 2016 Valletta, Malta, http://esaconferencebureau.com/docs/default-source/16a02_docs/4s-2016-programme5813EEC7A377.pdf?sfvrsn=2

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(8) Noharet, B., Wang, Q., Platt, D., Junique, S., Marpaung, D., Roeloffzen, C., "Arrays of Surface-Normal Electroabsorption Modulators for The Generation and Signal Processing of Microwave Photonics Signals", 2011 IEEE International Topical Meeting on Microwave Photonics, 2011

(9) Marpaung, D., Zhuang, L., Burla, M., Roeloffzen, C., Noharet, B., Wang, Q, Beeker, W. P., Leinse, A., Heideman, R., "Photonic Integration and Components Development for a Ku-Band Phased Array Antenna System", IEEE International Topical Meeting on Microwave Photonics, 2011

(10) J. Verpoorte, H. Schippers, P. Jorna, A. Hulzinga, C. G. H. Roeloffzen, D. A. I. Marpaung, B. Sanadgol, R. Baggen, Qin Wang, B. Noharet, W. Beeker, A. Leinse, "Development of the SANDRA antenna for airborne satellite communication", IEEE Aerospace Conference, 978-1-4244-7351-9, 2011

(11) Marpaung, D, Zhuang, L., Burla, M., Roeloffzen, C., Verpoorte, J., Schippers, H., Hulzinga, A., Jorna, P., Beeker, W.P., Leinse, A., Heideman, R., Noharet, B., Wang, Q., Sanadgol, B., Baggen, R., "Towards a Broadband and Squint-Free Ku-Band Phased Array Antenna System for Airborne Satellite Communications", IEEE Proceedings of the 5th European Conference on Antennas and Propagation (EUCAP), 978-1-4577-0250-1, p2623 – 2627, 2011

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(13) Junique, S., Wang, Q., Noharet, B., Almqvist, S., Wang, K., and Andersson, J. Y., "Multiple quantum well surface normal modulators for free-space optical communication links", OASIS konferens, Tel-Aviv, 2007

RI. SE

4. EAM for other space applications and publications

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RI. SE

5. Partnership for EU calls

Call partner(s) on MRR packaging

Spec.

- Temperature control/stabilize
- Optic design and alignment and FOV
- Date rate to Gb/s
- Light weight and robust housing
- Cost-effective

C3PO_2.0?

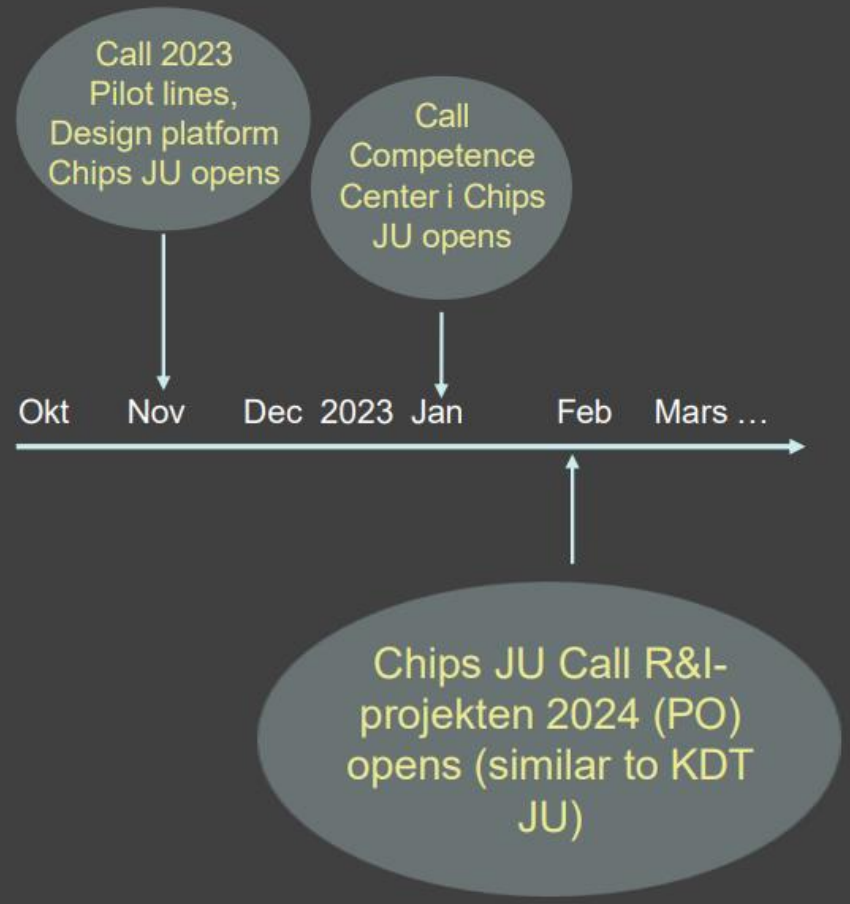
EU call: Smart photonics for joint communication & sensing and access everywhere (Photonics Partnership) (RIA), the call will open in Nov. 2023

EU call: Quantum sensing and metrology for market uptake (IA), the call will open in Nov. 2023

Chip-Act, JU

5. Partnership for EU calls

Timeplan KDT JU + Chips JU (pillar 1 in Chips Act)



Preliminary timeplane for the first calls within Chips JU – Chips for Europe Initiative

- CALL 2023 DEP PILOTLINES: Expression of interest (EoI), (Nov 2023 – Oct 2024)
- CALL 2023 DEP DESIGN PLATFORM (Nov 2023 – Sept 2024)
- CALL 2023 DEP COMPETENCE CENTER (Jan 2024 – Sept 2024)
- Call on SKILLS i EU DIGITAL program: 11th May 2023-26th September

Chips JU's first calls for research and innovation projects

- Chips JU CALL 2024 – Research and Innovation Actions och Innovation Actions. (Feb 2024 – Nov 2024)
- Bottom up-call according to SRIA 2023 and Focus Topics

Thank you and Welcome collaborations

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