

# UK-Taiwan Technology Showcase for Compound Semiconductors: Optical Telecom Networks

Virtual event  
Tuesday 20<sup>th</sup> October 2020  
9:00 – 11:00 UK time  
16:00 – 18:00 Taiwan time

**CATAPULT**  
Compound Semiconductor Applications



**ITRI**  
Industrial Technology  
Research Institute





[www.kubos-semi.com](http://www.kubos-semi.com)

# Overcoming the Green Gap in Light Emitting Diodes

Prepared for UK-Taiwan Technology Showcase

20<sup>th</sup> October 2020

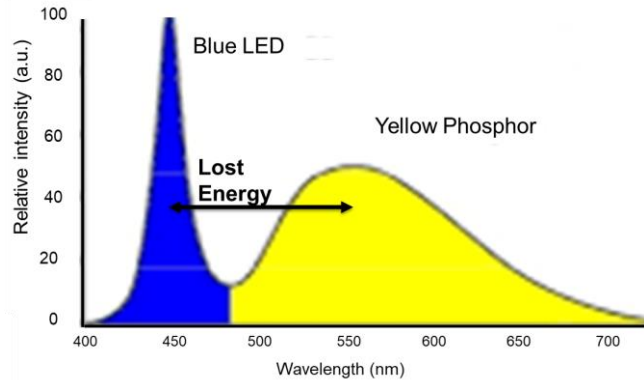
By: Caroline O'Brien, CEO

- Conventional Light Emitting Diodes (LEDs) emitting in the green and amber parts of the spectrum suffer from very low efficiency (<20%) when compared with red and blue devices – an effect known as “The Green Gap”
  - Red and blue LEDs have efficiencies >80%
- The US Department of Energy (DoE) has a target for green LEDs to reach >50% efficiency
  - To produce pure white light (from RGB LEDs) more efficiently
  - Connected LED Lighting will increase >14% if achieved
- Kubos can solve this problem with a novel technology
  - And a process that fits seamlessly into existing LED production lines
  - Saving an estimated 22 million tons of CO2 emissions over 5 years



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# Solid State Lighting – The Problem



- Conventional Solid-State lighting mixes blue LED light with yellow light from a Phosphor
  - Energy lost in converting Blue light to Yellow light limits efficiency

- Ideally white light for solid state lighting is generated by mixing Red, Green and Blue (RGB) LEDs
  - Gives maximum efficiency
  - Also allow tuning of the light to mimic day light
    - There is significant interest in the health impact of artificial light



## Kubos is completing the colour palette for LEDs

- By producing more efficient solutions and producing a natural white light
- Brighter white and pure **Green** and **Amber** colours for lighting and displays
  - Tuneable across the wavelengths (no green or red gap)

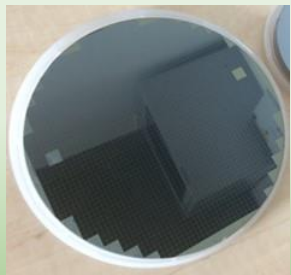


- Our mission is to deliver a transferrable technology for the next generation visible light
  - Increase the uptake of LEDs by improving efficiency
  - We have adopted an IP licensing/royalty model

# The Kubos Business Model

## Kubos Research and Development

Substrate



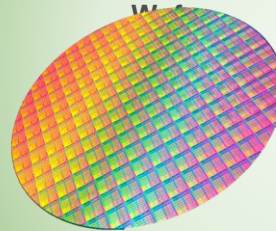
Kubos' Technology - growth of epi-layers



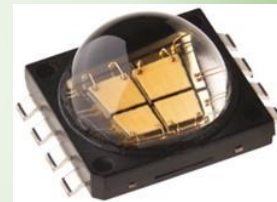
License to Tier 1 LED manufacturers

## LED manufacturer

Processed Cubic-GaN LED



Packaged LED



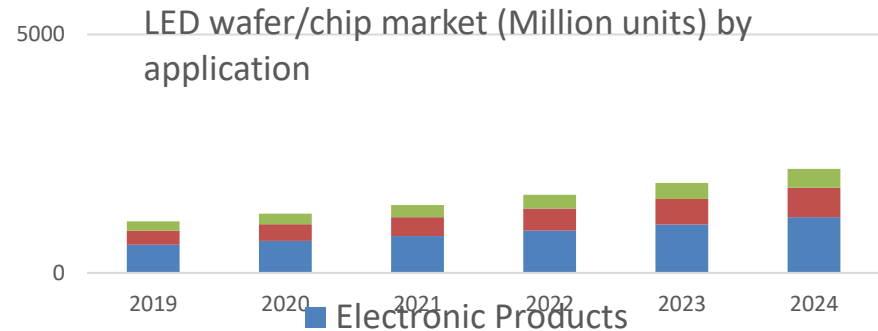
- Licensing/Royalty model targeting Tier 1 LED manufacturers
  - Early engagements with development and evaluation contracts
  - Fabless Semiconductor model to supply small quantities of wafers

# Market Sizes and Estimated Share



- Total Market size USD 5,534 Million in 2018 (USD 13,639 Million by '24)
  - Initial target market is a subset of Electronic Products (EP)
  - Size of EP market in 2024 is approx. 1,168 million units
    - Green LEDs in lighting (est. 400m units)
    - Mini and micro LEDs for displays
    - But, the market is 100% addressable by Kubos' technology
  - Interest already received from major manufacturers in the target sector

- Plan to engage 1<sup>st</sup> licensee by 2023
  - Joint development agreements
  - Licensing agreements

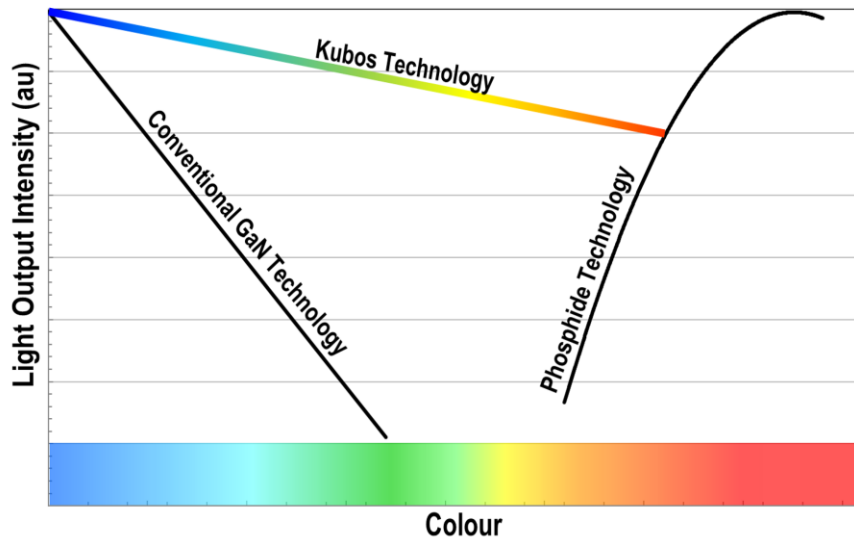


Source: Fior Markets Report 2019: Global LED Wafer and Chip Market 2024. [www.fiormarkets.com](http://www.fiormarkets.com)

# Current vs. Kubos technology

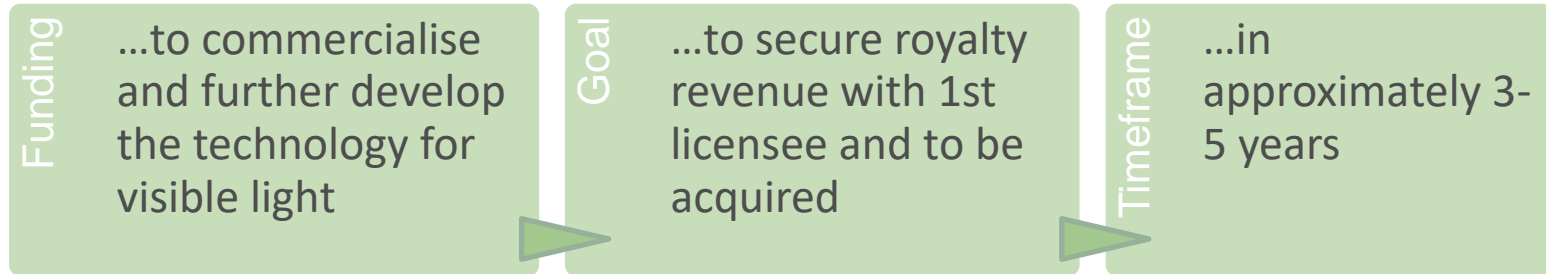
Current Technology		Kubos Technology
Poor	Power Consumption	Good
✓	Scalable/Compatible production	✓
Limited	Colour Spectrum	Wide
X	Response Times	>3X
=	Cost	=

Kubos operates more efficiently in the green and amber regions





- Kubos can demonstrate
  - The technology produces efficient green LEDs
  - Compatible and Scalable manufacturing
  - A protected IP base
- We are seeking



- The Exit plan
  - Acquired in 3-5 years

# Contact Details and Questions?



Caroline O'Brien

CEO

[caroline.obrien@kubos-semi.com](mailto:caroline.obrien@kubos-semi.com)

+44 7538 864445



Our mission:

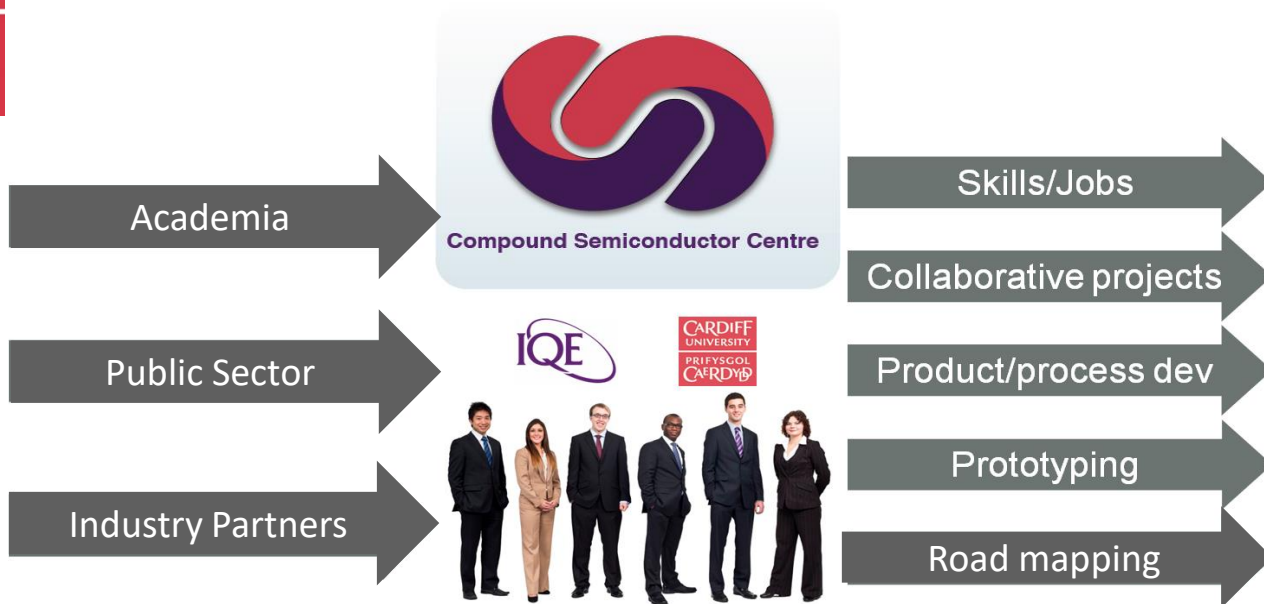
- *To Deliver a transferrable technology for the next generation visible light*

# Compound Semiconductor Centre

Wyn Meredith



## Formal JV: 50:50 Cardiff University: IQE Plc



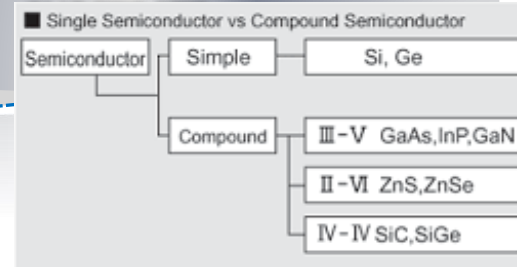
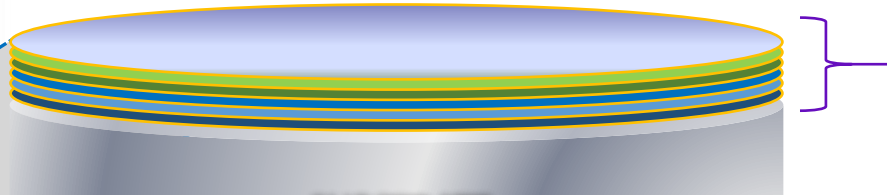
**MISSION: Translation of R+D to commercialisation activity**



# What is a Compound Semiconductor ?

## Epitaxy - engineering advanced materials

Nanotechnology:  
Atomically engineered epitaxial films of compound  
semiconductors  
(up to 300 films)



■ Combinations on the Periodic Table of the Elements

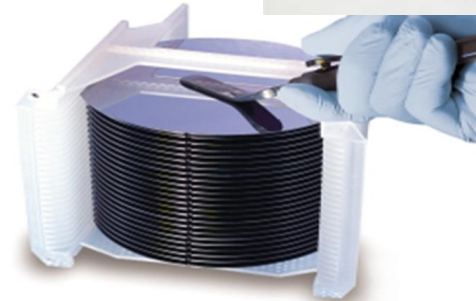
II	III	IV	V	VI
	B	C	N	
	Al	Si	P	
Zn	Ga	Ge	As	Se
Cd	In	Sn	Sb	Te



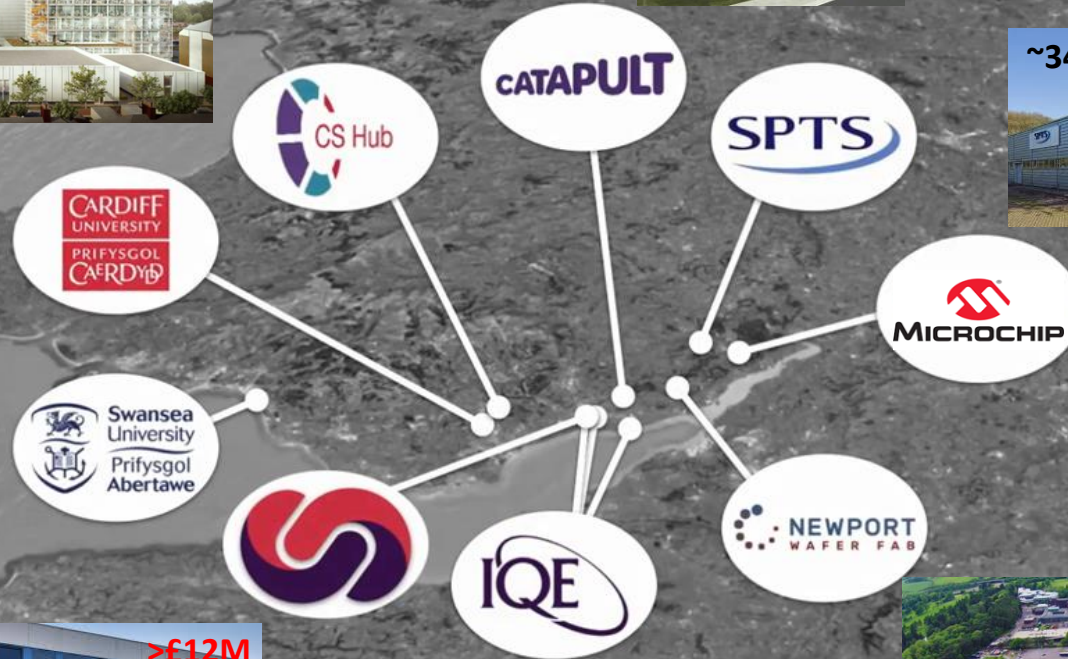
# Key Facts



- Operational since November 2015
- Co-located with IQE @ St Mellons, Cardiff, UK
  - 15 x Metal Organic Chemical Vapour Deposition (MOCVD)
- Materials focus: GaAs, InP photonics, GaN RF/Power
- Primary delivery mechanisms:
  - **Collaborative R+D (CRD) programmes**
  - **Contract epitaxial materials supply (early stage)**
  - **Exploitation of CRD outcomes**



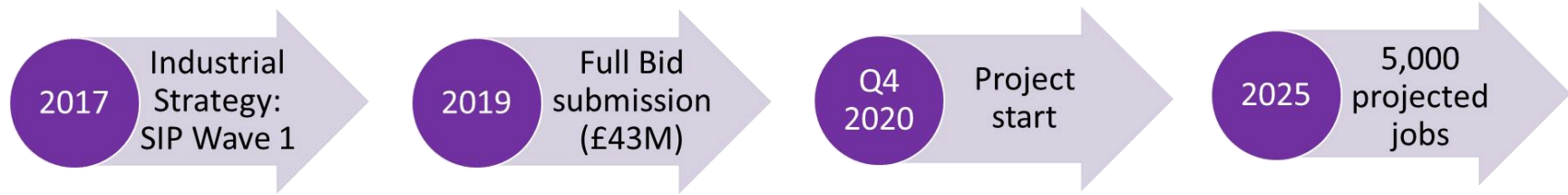




# £43M project announced in June 2020



*“The Strength in Places Fund (SIPF) will bring together research organisations, business and local leadership to drive significant economic impact, job creation and regional growth”*



*“CSConnected will aim to translate our regional strength in Advanced Semiconductor Technologies into a renaissance of high value-add product manufacturing in South Wales”*



<https://www.ukri.org/funding/funding-opportunities/strength-in-places-fund/>

Home of enabling technologies



# High efficiency manufacturing and scale up

- Diode Laser manufacturing process using Nano-imprint lithography
  - Development of 'commodity' Distributed Feedback Lasers
- High speed InP components for next generation PON
  - Development of 'commodity' 10-25Gb/s photodiodes
- SUPER 8: A scalable 200Gb/s Super-thermal CWDM architecture
  - Next generation, ultra-high speed datacentre interconnect technology

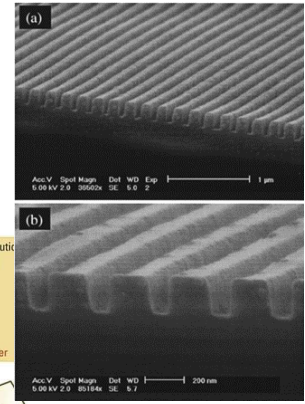
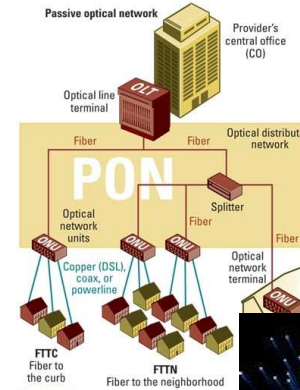


FIGURE 1. The many varieties of FTTx. As bandwidth demands increase, networks will evolve toward



**ICS** Integrated Compound Semiconductors Ltd



8	•Technology Readiness Level
9	•Commercial Readiness Level
<2	•Years to Market

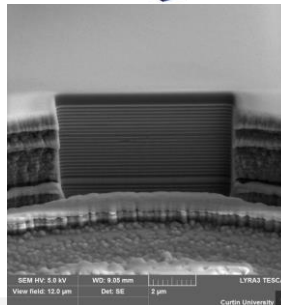
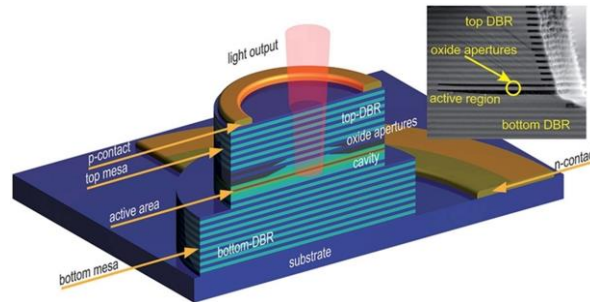
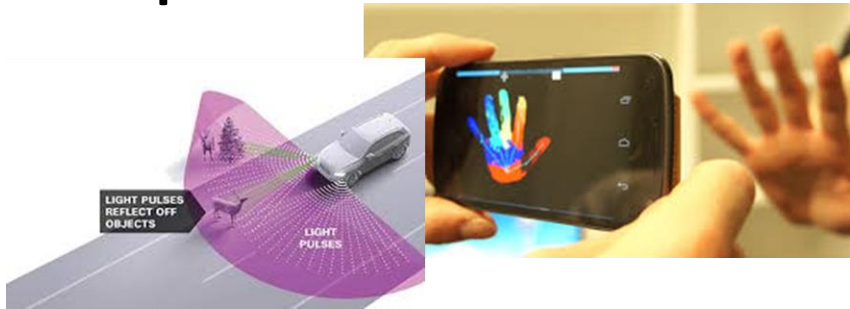


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# High efficiency manufacturing and scale up

- **High Efficiency Manufacturing of VCSELs**

- Development of 6" VCSEL process technology
- 6" VCSEL epitaxy
- High uniformity ICP etching
- Qualification of 6" VCSEL process
- Applications:
  - 3D imaging, LIDAR, rapid thermal sources
  - Short range optical data links



8-10

•Technology Readiness Level

10

•Commercial Readiness Level

<1

•Years to Market



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# Next generation products: Quantum Technologies

## *A SIGNIFICANT CHALLENGE EXISTS FOR QUANTUM APPLICATIONS*

*Lack of robust, reliable and volume supply of quantum photonic components (QPCs) present a major barrier to the return on the UK's £270M investment in Quantum Technologies*

### PROBLEMS:

#### Cost to taxpayer of CRD

Majority of UK QT programmes include semiconductor device manufacturing, @ to ~20-30% of total cost

#### Cost-driven market traction

Significant R&D to drive down cost of quantum components.

#### Lack of data for R&D studies

Semiconductor industry needs mid-volume data to drive up yield and reliability



### SOLUTION:

## **QuantumFOUNDRY**

*Creating the conditions for a UK Quantum Systems Industry:*

- ✓ Fully optimised custom components
- ✓ Turnkey QPC design for Manufacture
- ✓ Rapid prototyping for new QT applications
- ✓ Critical Sovereign Capability
- ✓ Trailblazing global standards



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## ***Interested in collaborations to develop 'custom' CS components:***

- Telecomms/ datacomms applications
  - VCSELs, InP lasers and detectors
  - Active components for SiPhotonics
- Quantum Technologies:
  - Eg: Single photon emitters/detectors
- RF, GaN, power devices
- Participation as an epitaxial materials partner
- Gateway to UK partners in chip processing and packaging
- New applications and device architectures

<http://www.compoundsemiconductorcentre.com/>  
<http://csconnected.com>



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**CATAPULT**  
Compound Semiconductor Applications



**smiths interconnect**  
bringing technology to life

## Platforms and Technology; *An overview of our Technology Development & Product Innovation*

Hasan Uppal, Jorge Pacheco et al., Smiths Interconnect  
*Presented at CSA/ITRI UK-Taiwan Technology Showcase / Oct 2020*





# Smiths Interconnect Global Markets Served; *High-Power/High-Speed Platforms and Technologies*



## Commercial Aerospace

- Avionics Equipment
- Engine Systems
- Power Distribution
- SATCOM Broadband Connectivity



## Defense

- Radar
- Electronic Warfare
- Intelligence, Surveillance and Reconnaissance (ISR)
- Communications



## Space

- GEO/MEO Satellites
- LEO Satellites
- Launchers
- Manned Space Flight
- Ground Support Equipment



## Semiconductor Test

- Area Array Test
- Package on Package Test
- Wafer Level Test
- Peripheral Package Test



## Medical

- Surgical and Monitoring Systems
- Imaging Systems
- Disposables



## Industrial

- Heavy Equipment / Machinery
- Servo Drives and Encoders
- Factory Automation
- Power Supplies



## Railway

- Rolling Stock
- Signalling
- Infrastructures



## Test & Measurement

- Electronics Testing
- Automotive Testing
- Telecommunications

# Smiths Interconnect/Reflex Photonics; *technology specialist in ruggedized high-speed optical transceivers and embedded optoelectronic products for space, defense, commercial aerospace, industrial applications*



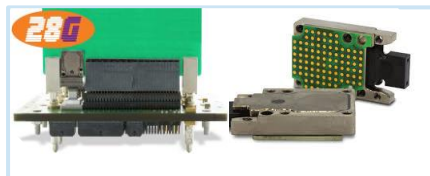
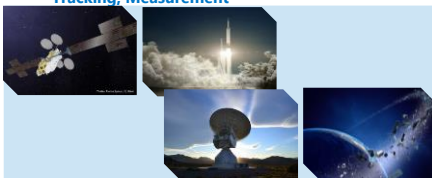
**Defense**  
*Rugged, MIL-Spec, onboard 150 Gbps embedded optical transmitter and receiver with high I/O density for the most demanding environment*

- LightABLE™/LightCONEX™ optical embedded transceivers/interconnects OT/OI
- Extremely ruggedized for higher performance/bandwidths > 150Gbps chips parts
- OI for military aircraft sub-systems
- OT for 100/140µm aircraft optical cabling
- Active electronically scanned array radars
- High resolution surveillance, computation, security



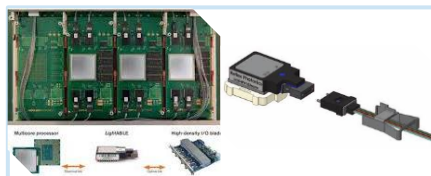
**Space**  
*Onboard embedded optical transmitter and receiver modules offering radiation hardness, robustness, longevity, high I/O density optical interconnects*

- SpaceABLE™ radiation-resistant/hardened optical interconnect OT for space vehicles
- Radiation hardness, Heavy-ion tested, Gamma rays tested, Protons tested, ECSS acceptance
- OI for within space vehicles in low-earth orbit
- OI for within space vehicles in geo orbit
- Launch vehicles, Ground stations, Data intensive radars, RF transmitters/receivers, Detection, Tracking, Measurement



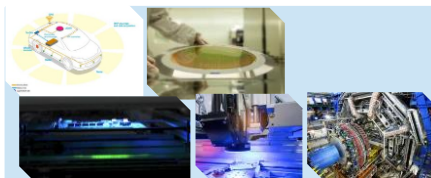
**Commercial aerospace**  
*Affordable, reliable, high-performance embedded optical transceivers with bandwidth up to 150Gbps*

- SNAP12/LightVISION™ families of optical embedded transceivers/interconnects
- OI for High-bandwidth commercial aerospace
- OI for highest quality uncompressed data communication, integrated aircraft wiring system, weight, advanced fault diagnostics, enhanced EMI/EMC, lightning tolerances
- In-flight entertainment and connectivity IFEC
- Embedded Multiprocessors, Inter-board comms



**Industrial**  
*Affordable, reliable, high-performance embedded optical transceivers with bandwidth up to 150Gbps*

- High bandwidth industrial OT/OI with optical modularity and integration offering flexible agile solutions for electrical/optical coupling
- Industrial performance LightVISION™ provides embedded and extremely rugged industrial transceivers > 150 Gbps under Operating temp: -40°C to 100°C, Storage temp: -57°C to 125°C



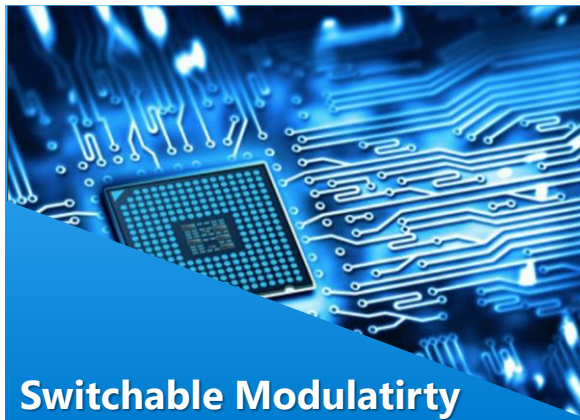
# Advanced Applications – SMARTConnectors

*Integrating 'smart' technologies into the next generation connectors*



## RF over Fiber Optics

- Development of an integrated connector with signal conversion capabilities. Drastically decreasing the overall size and weight seen with current conversion solutions.



## Switchable Modularity

- Allowing rerouting on the fly to bypass damaged signal pathways, redundancy for improved robustness of fiber in rugged applications.



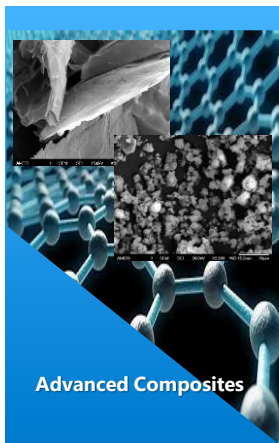
## Mil-Spec Compliance

- Integration of 'SMARTConnector' technology into military compliant connector platforms, designing ruggedized systems and functionality in the harshest environments.



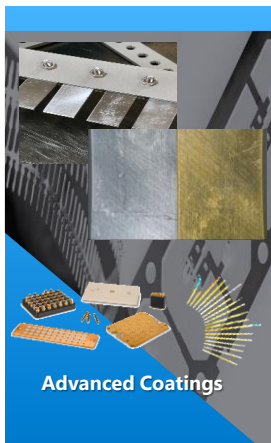
# Advanced Materials / Processing

*Developing new materials with enhanced thermal, electrical, thermoelectric/thermoresistive properties*  
*Rapid prototyping, hybrid manufacturing, innovative and disruptive technologies for materials/testing*



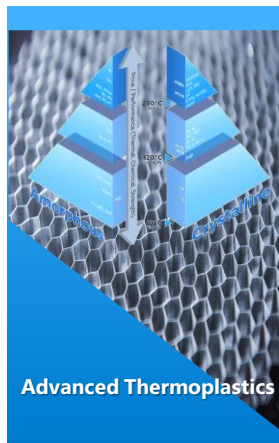
Advanced Composites

- Development of *Graphene-based nanocomposites* with excellent thermal conductivity balanced with enhanced electrical conductivity.



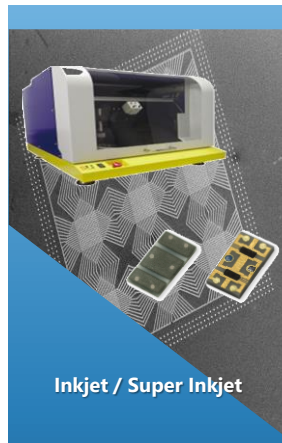
Advanced Coatings

- Development & characterization of *hybrid conductive materials* as a corrosion resistant protective coatings



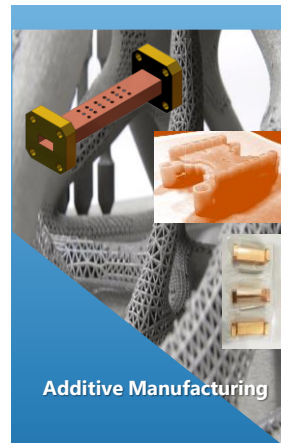
Advanced Thermoplastics

- Research & Development of *high-performance thermoplastics insulators* for HPHT applications in Connectors & Interposers (MicroMachined, Molded & 3D/AM Hybrid Printed).



Inkjet / Super Inkjet

- R&D prototyping using *functional/formulated nanodispersive-inks deposition/patterning techniques* (SuperInkJet SiJ printing for large-area, low-cost rapid processing)



Additive Manufacturing

- R&D evaluation *Additive Manufacturing AM techniques* to drive technology innovation for Smiths Interconnect products (rapid prototyping and hybrid product design capabilities)

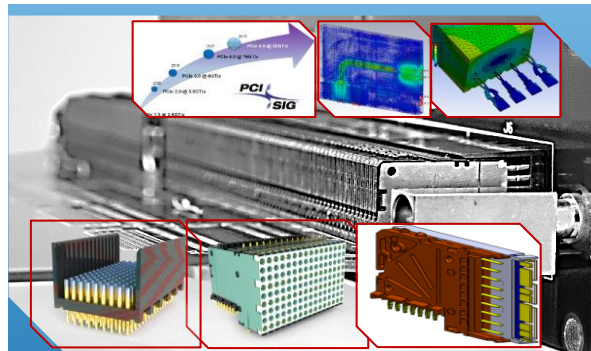


Advanced Mechanical Testing

- Analytics of comprehensive *material database* to leverage realistic performance of material in product design, modelling, simulations and prototyping lifecycle

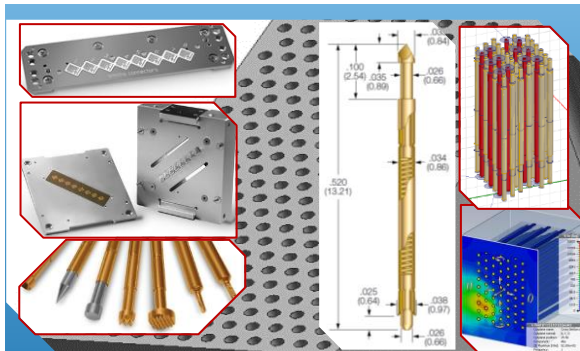
# High-Speed/Frequency Signal/Data Integrity

Backplane Orthogonal, IDI MultiPin Differential, SMPM COAX Microform Connectors, and beyond ...



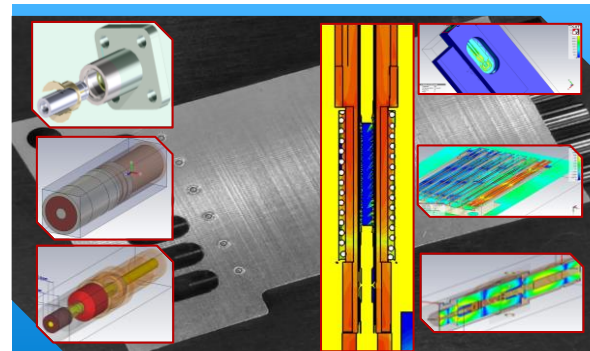
## High Speed 32/56Gbps Backplane Connector; **R&D Innovation**

- Smiths Interconnect next generation high-speed backplane connector  $\geq 32/56$  Gbps (PCIe Gen 5, NRZ/PAM-4), EMI/EMC Compliance
- KVPX footprint, hybrid chassis, Solderless termination to PCB  $>50A$  current capacity
  - ESD Protection EN 61000-4-2 Level 2 ( $<4$  KV)
    - Temperature Range  $-55^{\circ}C$  to  $+125^{\circ}C$
- NASA/ESA (ESA 3401) Space Compliance for high-speed, small-form, performance-driven technology



## High-Frequency IDI MultiPin Differential; **Assemblies**

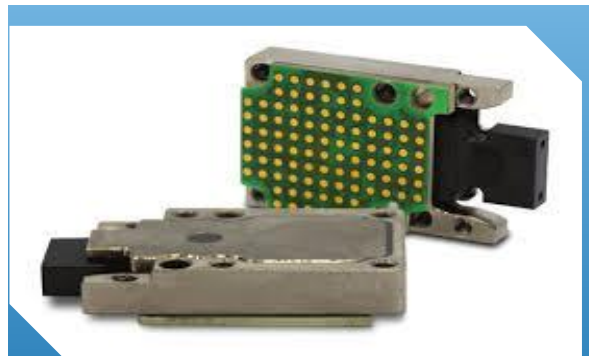
- Smiths Interconnect transformational IDI MultiPin Differential Pairs (Hyperboloid, SpringProbes)
- Digital IDI B2B HighDensity Interposers; High speed 20/30+Gbps/40/60+GHz digital CCAs
- SmallForm Interposers; SpringProbes/PogoPins with wafer I/O pitch 250-350um, probe depth 2.5/2.9mm, probe travel 150-300um,  $<50/70m\Omega$ , 2/3A, InsertionLoss 10-20GHz @ -1dB (i.e. Volta Series)
- Rapid IDI prototyping & innovative designs for harsh environment performances i.e. HTHP, condensing, shock & vibration, aero-space, space-orbital



## Signal Integrity RF/Digital Simulations; **R&D Prototyping**

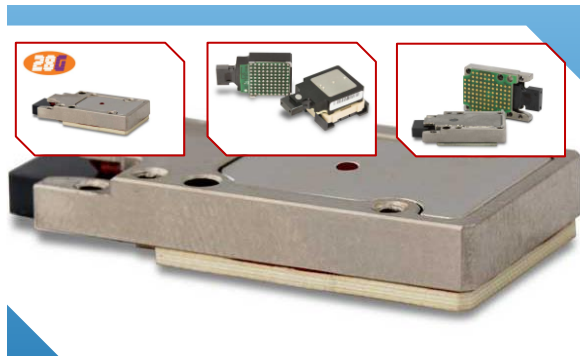
- Smiths Interconnect innovative CST/HFSS Simulation workflow (InterposerCOAX, MicroSMP Connectors)
- Large Array B2B Interconnects for high/ultrahigh performance electromagnetics (thermal/power)
- Optimal alignment / tolerances / design/ right angle / edge launch / blind mating / Low Mass / Low cost /
- GEO/LEO satellites; miniaturized blind-mate locking space/commercial connectors i.e. SpaceNXT™ Q
  - Achieving performances upto  $\sim 65/75/100GHz$  bandwidth, x 100 times integration, VSWR:  $<1.15/1.50$
- (Thermal, Shock, Vibration, Corrosion; MIL-STD-202)

# Smiths Interconnect/Reflex Photonics; *technology specialist in ruggedized high-speed optical transceivers and embedded optics products for space, defense, commercial aerospace, industrial applications*



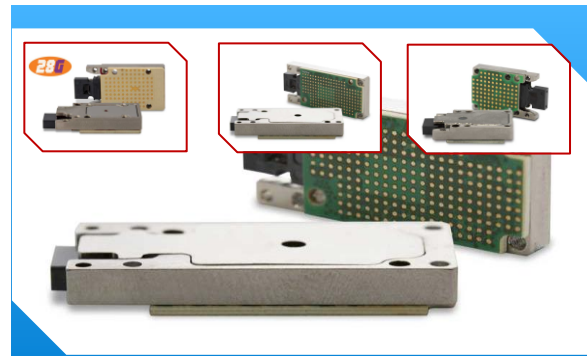
Embedded transceivers; **chip-sized on 850 nm VCSEL offering bandwidth  $\leq 300$  Gbps at short reach applications  $< 300$  m**

- Transceivers soldered or socketed to pcb with small compact form high density I/O, low power consumption, harsh environment compliance
  - SpaceABLE SL and SM
  - LightABLE LL
- LightABLE LM (with or without microcontroller)
  - LightABLE LH and LA
  - LighVISION VM
  - SNAP12



SpaceABLE SL and SM; **radiation resistant transceivers are engineered to withstand radiation doses  $> 100$  krad (Si)**

- SpaceABLE SM embedded optical modules for rugged device integration 8 lanes of  $\geq 12.5$  Gbps bandwidth
- Chip-size package featuring either SMT or Meg-Array connector for low profile screw-in modularity (4.5mm)
- Surface mounts to the board as LGA connectors with full bandwidth/speed guaranteed for full modularity at  $-40$  to  $100$  °C at ultra-low bit error rates of  $10^{-12}$ 
  - SpaceABLE28 SL 100G (full duplex) and 300G
  - SpaceABLE SL 50G (dull duplex) and 150G
  - SpaceABLE SM 150G

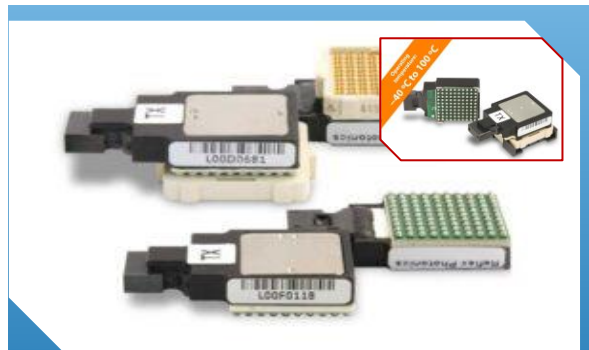


LightABLE LL; **rugged, low profile screw-in modular mounts to pcb via LGA connector utilizing at 12.5 Gbps or 28 Gbps per lane**

- LightABLE28 LL low profile screw-in module (4.5 mm) mounts to board via an LGA connector
- (4+4)-lane transceiver (100G full-duplex) 12-channel transmitter/receiver modules (300G half-duplex pair)
- 28 Gbps per channel  $-40$  to  $85$  °C at ultra-low BER of  $10^{-12}$
- Rugged: MIL-STD 883 shock and vibration qualified
  - Sealed: Moisture and thermal shock resistant
- Sensitivity:  $-9$  dBm BER  $10^{-12}$ , Power: 180 mW/lane
  - 12 TX 12-channel transmitter (300G)
  - 12 RX 12-channel receiver (300G)

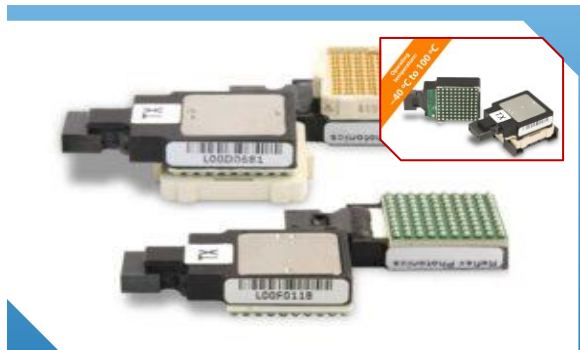


# Smiths Interconnect/Reflex Photonics; *technology specialist in ruggedized high-speed optical transceivers and embedded optics products for space, defense, commercial aerospace, industrial applications*



**LightABLE LM (with or without microcontroller); rugged, low profile screw-in module with LGA connector, performances at 12.5Gbps/28Gbps**

- LightABLE™ LM Series 12-lane transmitter/receiver operational at full bandwidth/speed of 12.5Gbps/lane industrial compliance temperatures (micro-controller)
- Small: <5mm high (SMT version), Rugged: MIL-STD 883
- Sealed: Moisture/shock resistant, Storage : -57to125°C
  - Sensitivity: -12 dBm for BER 10<sup>-12</sup>, Power: 100 mW/lane
  - 4 TRX (4+4)-lane per device (50G, full duplex)
    - 12 TX or 12 RX lane per device (150G)
  - Specialty: Aerospace and defense applications



**LightABLE LH and LA; 12-lane transmitter/receiver, (4+4)-lane transceiver performances for commercial and industrial**

- LightABLE™ LH low profile optical transmitter/receiver as a 4 lane (50G) or 12 transmit/receive lanes (150G) in a parallel fiber configuration or a MEG-array config
  - Multimode 850 nm wavelength laser
  - Over 100 m reach on OM3 ribbon fiber
- Surface mountable or pluggable, RoHS or tin-lead
  - Monitoring: LOS, RSSI, temperature etc.
    - 4 TX or 4 RX lanes per device (50G)
    - 12 TX or 12 RX lanes per device (150G)
- Specialty: Commercial and Industrial applications



**LighVISION VM and SNAP12; screw-in, robust industrial, RoHS optical module with LightSNAP interface with MPO pluggable optical interface**

- LightVISION VM as a 2-12-lane transmitter/receiver, 12.5Gbps, ultra-low BER 10<sup>-12</sup>, sensitivity -9 dBm,
  - Multimode 850nm, OM3 ribbon fiber
- MPO parallel fiber, LOS, RSSI, Int. microcontroller
- Data rate : 10.3125Gbps, 6.25Gbps/3.125Gbps per lane
  - 100 mW/lane typical power consumption
- Card edge mountable, MPO/MTP interconnect
  - OM3 and OM4 multimode fibers support
- Bandwidth from 25G (2TX/2RX) to 150G (12TX/12RX)
- Specialty: High-speed/temp Industrial applications

# RD&T Investment Strategy and Collaborative Exploration

Researching and applying new and developing technologies & capability to enable innovation in the form of value-added Smiths' customer solutions

## ▪ Leveraging Expertise @ Smiths

- Learnings across Smiths served industries
- Identify leverage tangent technology applications
- Continuous drive for innovative technologies
- From Next Gen to Transformational products

## ▪ Developing Collaborative Partners

- Throughout the full value chain productivity
- Academic CrossFunctional (Partnerships & Internships)
- Government Funding; Innovate UK, KTP/KTN, Catapults
- Innovative '*SMART functional*' differentiated solutions



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Tel: 01633 373121

Email: [info@csa.catapult.org.uk](mailto:info@csa.catapult.org.uk)

Twitter: @CSACatapult

Website: [www.csa.catapult.org.uk](http://www.csa.catapult.org.uk)

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