

Towards the neW era of 1.6 Tb/s System-In-Package transceivers for datacenter applications exploiting wafer-scale co-integration of InP membranes and InP-HBT electronics



# TWILIGHT Project Presentation



[www.photonics21.org](http://www.photonics21.org)

**Call identifier:** H2020-ICT-2019-2

**Topic:** ICT-05-2019: Application driven Photonics Components

**Scope:** Photonics System on Chip/System in Package for optical interconnect applications

**Type of Action:** Research and Innovation Action

**Contract No:** 781471

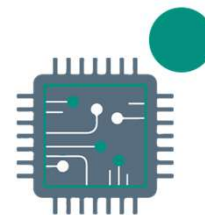
**Duration:** 48 months

**Start Date:** 1<sup>st</sup> December 2019

**End Date:** 30<sup>th</sup> November 2023

**Requested EC contribution:** € 5,080,621.25

**Website:** <https://ict-twilight.eu/>



# Consortium

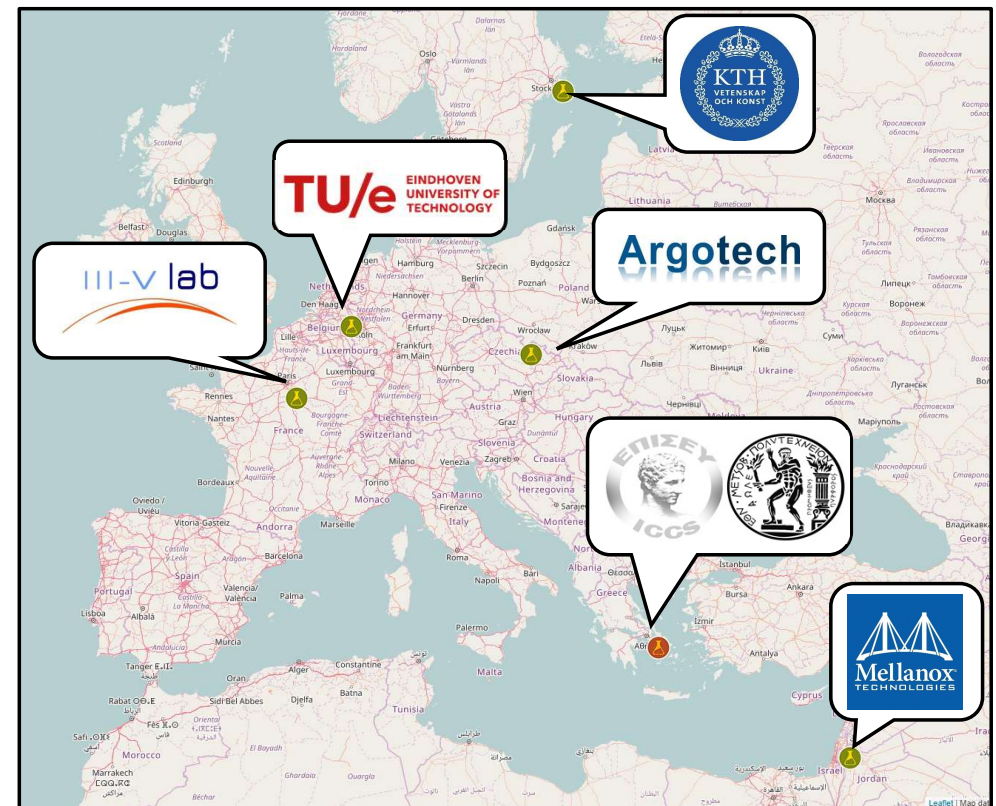


## 6 partners

- **Project Coordinator:** Institute of Communications & Computer Systems, **ICCS (GR)**
- Technische Universiteit Eindhoven, **TU/e (NL)**
- III-V Lab, **III-V LAB GIE (FR)**
- Kungliga Tekniska Högskolan, **KTH (SE)**
- Argotech, **AT (CZ)**
- Mellanox Technologies LTD, **MLNX (IL)**



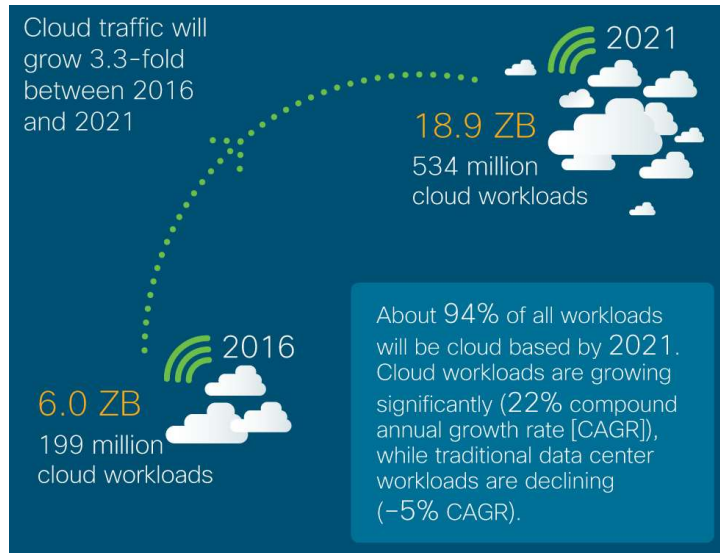
## 6 countries



# The challenge



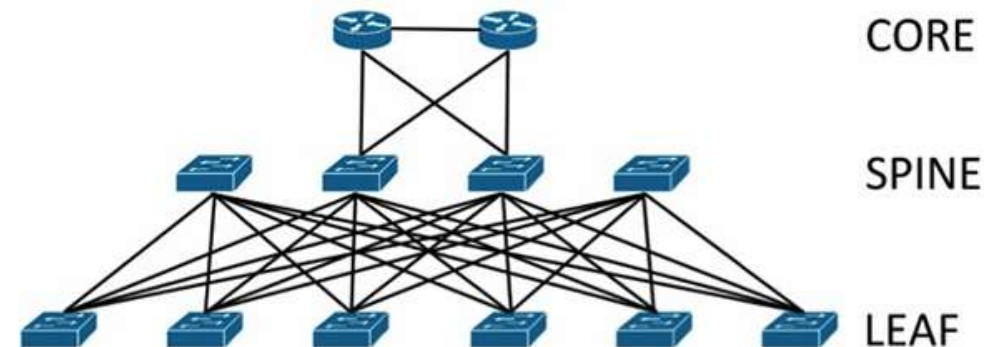
## Global Internet traffic trends



Source: Cisco Global Cloud Index (GCI) 2016-2021 forecast  
<http://business-technology-roundtable.blogspot.com/2018/02/hybrid-it-demand-fuels-multi-cloud.html>

- Cloud datacenter (DC) traffic will reach 19.5 ZB per year by 2021 ramping up from 6 ZB in 2016
- 71% of this traffic stays within the datacenter

## Datacenter Architecture



- Increasing number of endpoint connections
- Stringent latency constraints from modern IoT applications

# The path to 1.6T



*“ TWILIGHT will develop high capacity optical transceivers for intra- and inter- datacentre connectivity over 2, 10 and 40 km; that is two generations ahead with respect to existing 400GbE technologies”*

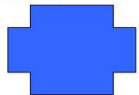
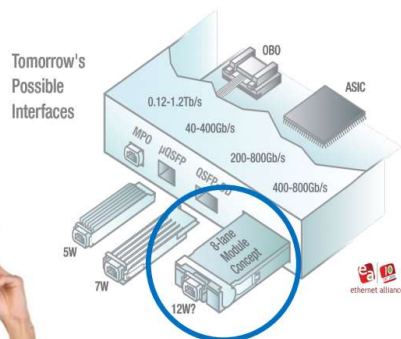
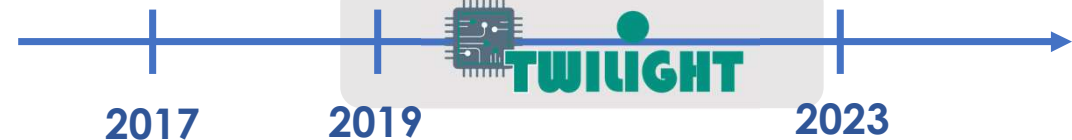
## 400GbE pluggables (QSFP-DD, OSFP)

- ✓ 2017: 28G EMLs, 8 lanes
- ✓ 2019: 56G EMLs, 4 lanes

**400GbE**  
Standard ratification

**800GbE**

**1.6T**



**100 Gb/s Signaling**

802.3 NEA Ad hoc, IEEE 802 March 2017 Plenary,  
Vancouver, BC, Canada

## 800GbE: Stepping stone to 1.6T

- ✓ Possible with existing 56G technologies i.e. 100 Gb/s signalling based on PAM4 and 8 lanes

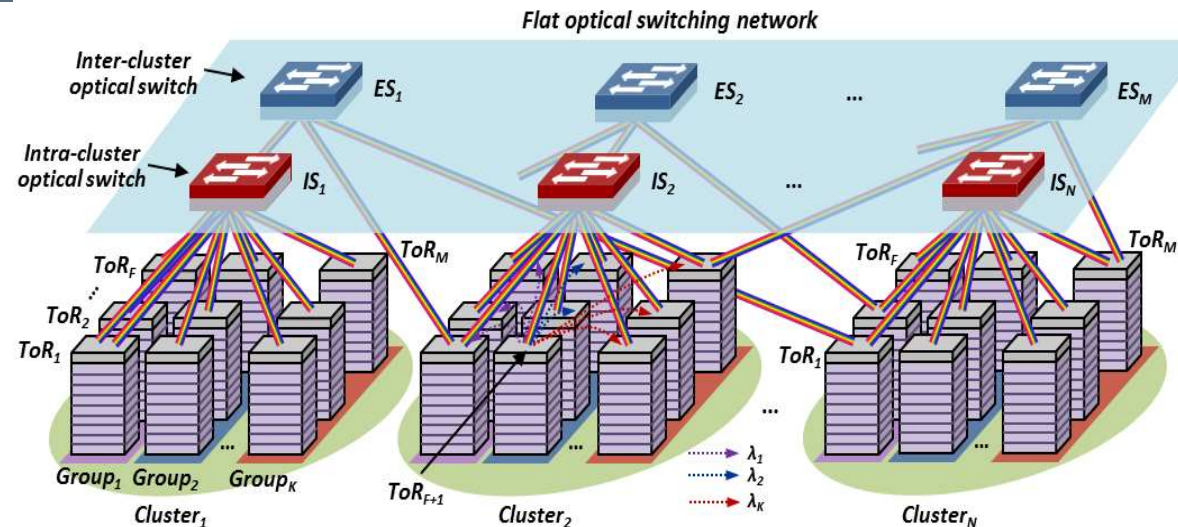
## 1.6T (Multi-Chip-Modules)

- ✓ 112 Gbaud per lane
- ✓ Intimate co-integration of photonics & electronics
- ✓ End of pluggable form factors & advent of Multi-Chip-Modules

# Towards all-optical datacenter architectures



*“ TWILIGHT will develop ultra-fast & scalable optical space switches for intra-datacentre connectivity ”*



- Datacenter architectures evolved from typical fat tree to leaf-spine topologies.
- Flat optical architectures increase switching efficiency and minimize latency.
- Optical space switches for the interconnection of 100s of Top-of-Rack (ToRs) and 10s of board-level switches required:
  - Large port count
  - Nanosecond switching speed

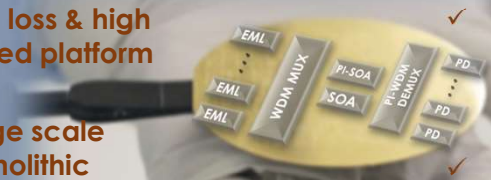
# TWILIGHT vision



Scaling transceiver speed to 112 Gbaud per lane  
Novel co-integration & co-packaging approach

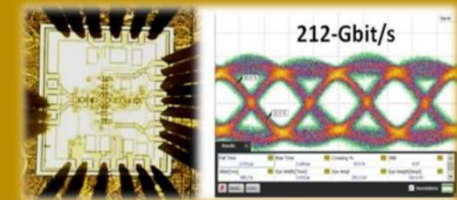
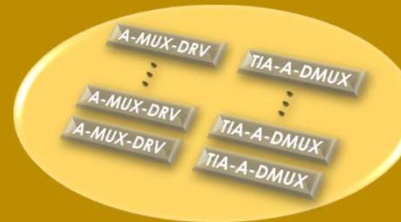
## InP membrane technology system-on-chip photonic platform

- ✓ Low loss & high speed platform
- ✓ Large scale monolithic integration enabling PICs with advanced functionalities
- ✓ Compact optical routing on chip
- ✓ 100 GHz electro-absorption modulated lasers (EMLs) & Photodiode arrays
- ✓ Ultra-fast Polarization insensitive semiconductor optical amplifiers
- ✓ Passive wavelength Mux & DeMux



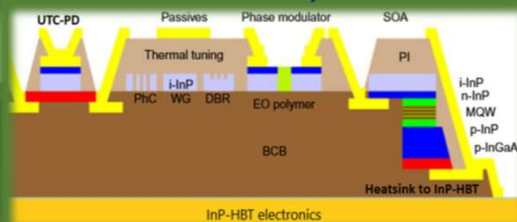
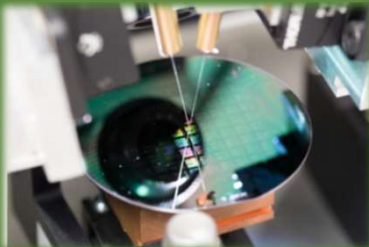
## InP-DHBT electronics technology

- ✓ Analog time-domain electrical multiplexing and demultiplexing
- ✓ Linear amplification with gain peaking
- ✓ 100 GHz Driver Amplifiers and Transimpedance Amplifiers with built-in analog MUX and DeMUX



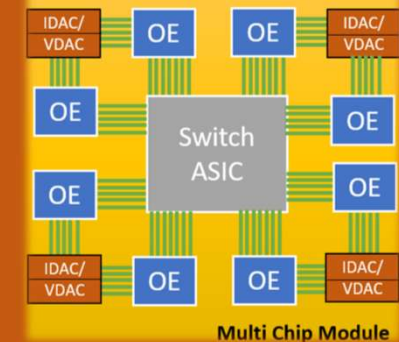
## Wafer-level bonding

- ✓ Intimate interconnection of photonics and electronics (10-20  $\mu\text{m}$ )
- ✓ Thermal vias for passive heat dissipation from the photonics to the electronics layer



## System-in-Package demonstrators

- ✓ 800 GbE and 1T optical transceivers at 1310 nm for intra-datacenter 2 and 10 km
- ✓ 800 GbE and 1T optical transceivers at 1550 nm for short inter-datacenter links up to 40 km
- ✓ 4x4 and 16x16 scalable & compact optical space switches for low latency intra-datacenter connectivity



# TWILIGHT objectives



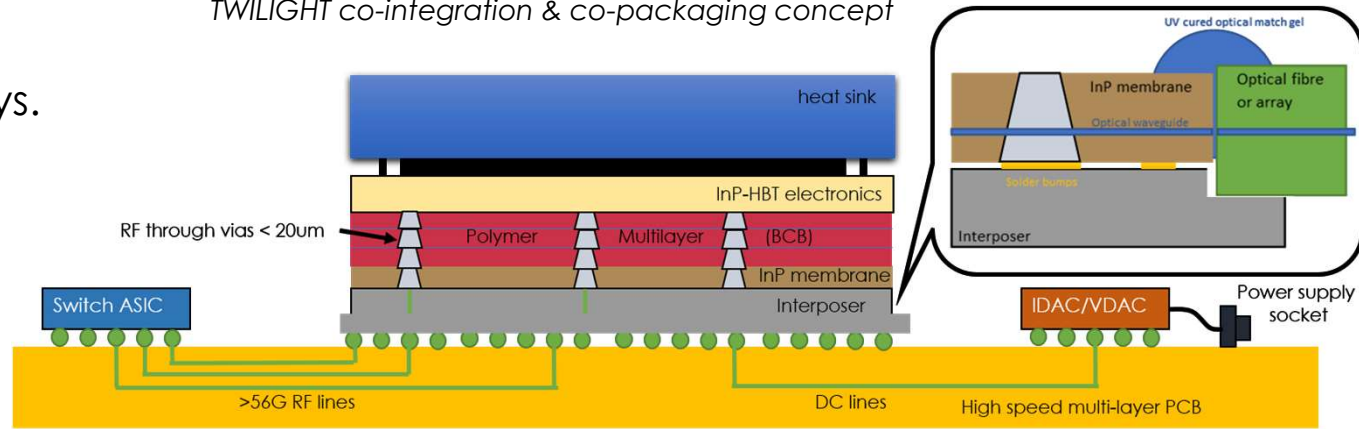
- Scale the symbol rate of optical transceivers to **112 Gbaud per lane**.
- Exploit **InP membrane technology** for the **development of high speed photonic components**.
- Enable **advanced system-on-chip photonic functionalities** via large scale monolithic co-integration of actives and passives.
- Develop **high speed electronics ICs on InP-DHBT platform**.
- **Wafer-scale bonding of photonics and electronics** at unprecedented close distances.
- Develop **Multi-Chip-Modules** via co-packaging optoelectronic engines with ASIC chip.
- Develop programmable compact and scalable **optical space switches** for intra-datacentre interconnection.
- Demonstrate up to **1Tb/s transmission over 2, 10 and 40km** via laboratory experiments and real network conditions using commercial datacentre equipment.
- Demonstrate **low latency all-optical intra-datacentre connectivity** within a host-to-host all optical switching testbed interconnecting multiple NICs

# TWILIGHT transceiver modules & demonstrators



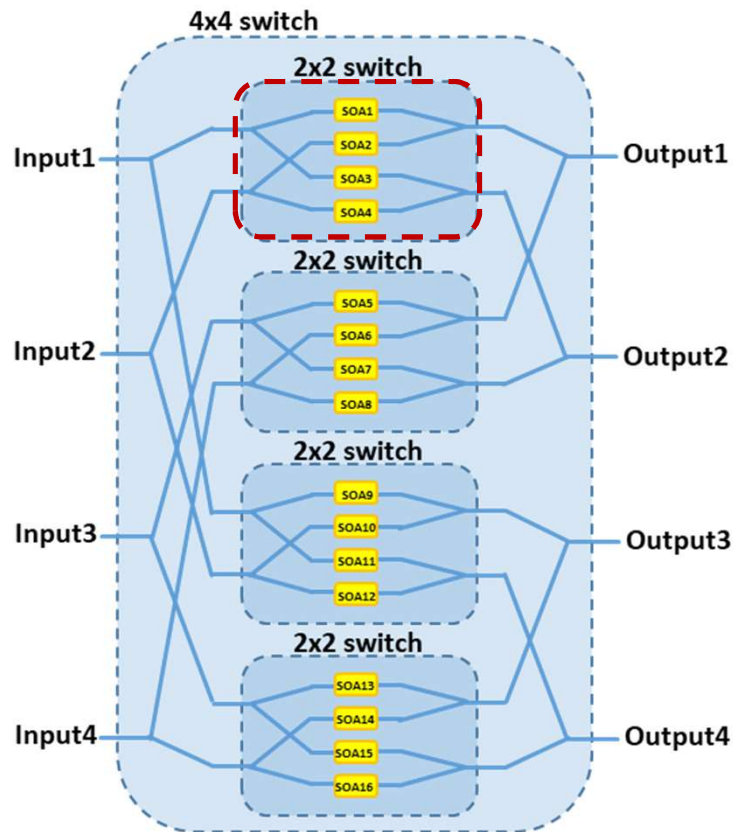
- Selective Area Growth & butt-joint process for bandgap optimization of WDM EML arrays.
- Polarization insensitivity via optimization of the gain medium.
- Flexible optical and RF routing on chip to minimize interconnection distance of photonic and electronic components.
- Material-compatible photonics and electronics platforms yielding high accuracy alignment down to the instrument limit ( $\sim 1\mu\text{m}$ ).
- Polymer multi-layer for wafer bonding fits various chip and wafer sizes.

*TWILIGHT co-integration & co-packaging concept*



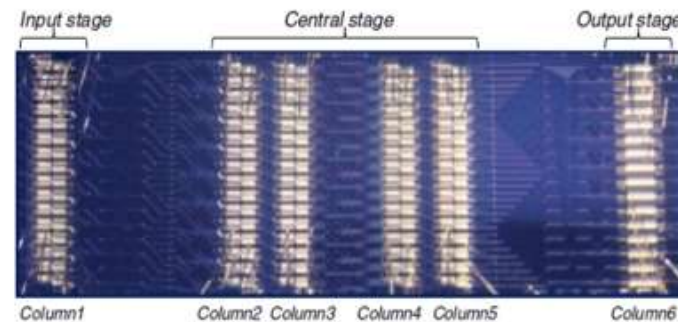
Type	Total Capacity [Tb/s]	No. Lanes	Operating Band	Target application
Module 1, Tx	0.8	4	C-band DWDM	40km, Inter-DC
Module 2, Rx	0.8	4	C-band DWDM	40km, Inter-DC
Module 3, Tx	0.8	4	O-band LAN-WDM	2, 10km, Intra-DC
Module 4, Rx	0.8	4	O-band LAN-WDM	2, 10km, Intra-DC
Demonstrator 1, TxRx	1.6	8	C-band DWDM	40km, Inter-DC
Demonstrator 2, TxRx	1.6	8	O-band LAN-WDM	2, 10km, Intra-DC

# TWILIGHT 4x4 and 16x16 optical space switches



Concept of TWILIGHT optical space switch SOA-based architecture

- Modular architecture based on a 2x2 switch element
- PI-SOAs and PI passive elements (MMIs)
- System-in-package integration with programmable current and voltage sources for controlling switch I/O port



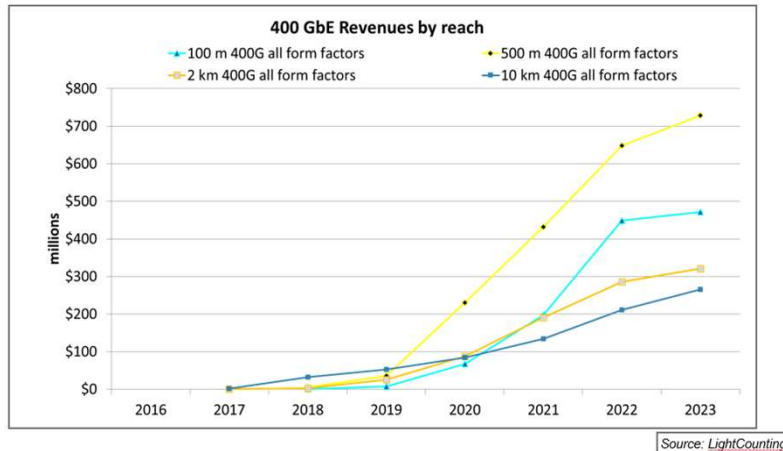
Picture of a 16x16 optical switch chip based on multi-stage architecture developed on the generic InP photonic platform

Optical Space switch	Size	Switching time	Building blocks	Operating Band	Target application
Module 5	4x4	10s of ns	PI-SOA PI-MMIs	O-band	Board-level interconnection, intra-DC
Demonstrator 3	16x16	10s of ns	PI-SOA PI-MMIs	O-band	TOR-to-TOR, Intra-DC

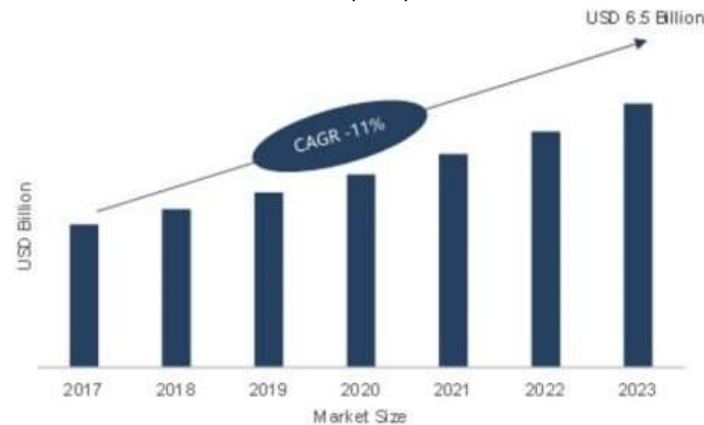
# Impact



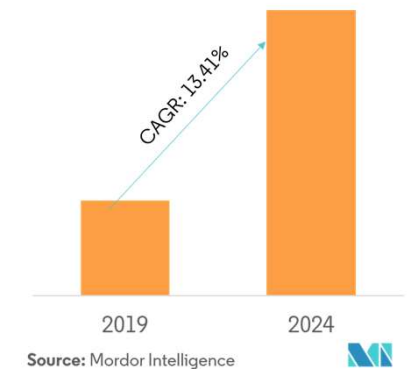
TWILIGHT technologies will penetrate high value markets...



Datacenter Interconnects (DCI) Market



Optical Switches Market



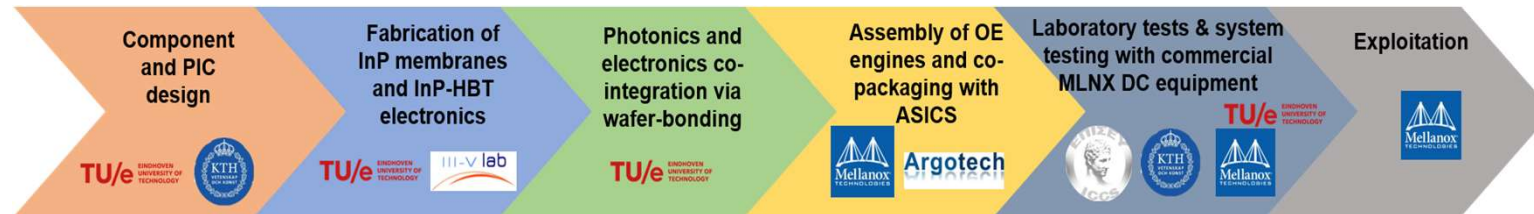
... and will leverage significant power & cost reductions & footprint savings

- **TWILIGHT intra-DC demonstrator** leverages **4-fold power consumption reduction** with respect to 56G EML-based solutions and **72% power savings** with respect to silicon photonics, for 2 and 10 km links.
- **TWILIGHT inter-DC demonstrator** exhibits **74% power consumption benefits** with respect to 28G EML-based solutions and **3 times less power consumption** compared to silicon photonics, for 40 km short DCI links.
- The cost of **TWILIGHT 1.6 transceiver demonstrators** considering volume production is estimated **0.89€/Gb/s** matching with industry requirements in the 2023-2025 timeframe.
- **TWILIGHT ultra-fast 16x16 optical space demonstrator** is scalable to large I/O ports exploiting the benefits of monolithic integration and **reduces footprint by more than 50%**.

# Exploitation

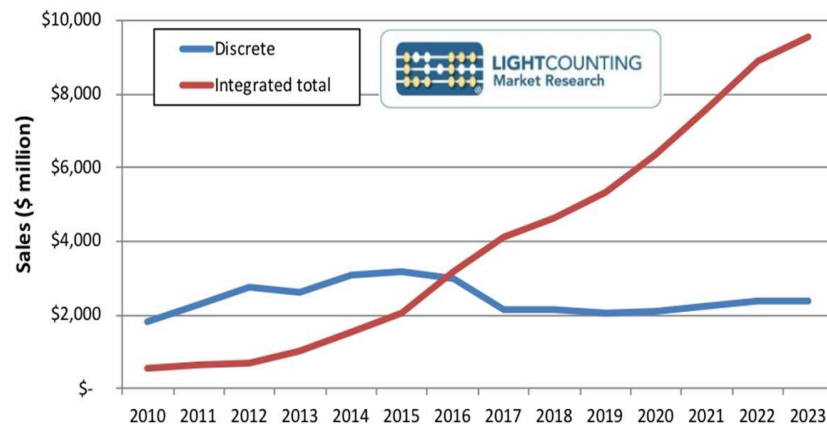


## TWILIGHT will ensure European industrial leadership



- ✓ Secure pathway to market
- ✓ Industrially compatible technology platforms
- ✓ Addresses the whole value chain

## TWILIGHT foregrounds will be exploited in new market opportunities



- Next generation passive optical networks (EMLs, PDs)
- 5G Fronthaul (EMLs)
- Sensing (Polarization insensitive components)
- Low latency optical switching for metro/core networks and 5G (Optical space switches)
- 600T and 1T coherent optical transceivers (InP-HBT electronics)

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# Contact

**Project Coordinator:** Hercules Avramopoulos  
Professor, ICCS/NTUA  
**Email:** hav@mail.ntua.gr  
**tel:** +30 210 772 2076

<https://ict-twilight.eu/>

