LUMENTUM

Response to the 1st Stakeholder Consultation – Questionnaire for indium phosphide (CAS 22398-80-7; EC 244-959-5)
Annex: InP Devices, their applications, alternatives and impacts in the optical communication

InP Device	Where used	Application	Alternatives	Impact of InP device on consumer	Example component manufacturer	Example equipment manufacturer	Example network operator	Services impacted
Tunable lasers	ITLA modules	Light source for DWDM coherent fiber optic communications systems. Typically used with an external modulator and integrated into optical modules or line cards for Metro and Long Haul telecom transmission applications.	No viable alternative for semiconductor lasers.	Tunable lasers integrated into ITLAs are used as the light sources for Long Haul and Metropolitan fiber-optic communications networks (e.g. those operated by Orange, Deutsche Telecom) to provide very high data capacity connectivity: - Between countries for Submarine networks - Between cities for long haul networks - within metropolitan areas for Metro networks All internet traffic between cellular networks, consumers, businesses and datacenters are multiplexed up to high aggregate data rates and transported over these networks to form the internet.	Lumentum Neophotonics Oclaro Finisar Furukawa	Ciena Coriant Cisco Nokia ADVA Huawei Etc.	Orange, Telecom Italia British Telecom Verizon China Telecom Deutsche Telecom Google Etc.	Backbone fiber optic network
Tunable lasers with integrated Mach-Zehnder (MZ) modulators	10G TOSAs for TXFP modules	10G pluggable modules for DWDM Metro and Long Haul fiber optic communications systems.	Alternate modulator technologies exist, but there is no viable alternative for the laser (e.g. InP laser co-packaged with Silicon Photonic modulator). Severe size constraint also demands monolithic integration of the laser and MZ on a single material system (InP).	As above for tunable lasers. 10G pluggable DWDM transceivers are typically used closer to the edge of networks where the highest capacity is not needed, for example connecting cellular networks to the main backbone network, or within cable TV networks where data is carried from the backbone into the neighborhoods.	Lumentum Oclaro Finisar	All of the above	Orange, Telecom Italia Verizon China Telecom Deutsche Telecom Google Comcast Cox Etc.	Backbone fiber optic network, Connections to cellular network
Narrow linewidth tunable laser with integrated IQ modulators and SOA's	100G to 600G ICT and IC-TROSA components for integration into telecom transmission modules	100G - 600G transponders and transceivers for high capacity DCI, Metro and Long Haul DWDM fiber optic communications links	No viable alternative for tunable laser source. Modulator can be implemented in SiP or LiNbO3 and co-packaged with the InP laser. LiNbO3 is physically much larger and requires higher drive voltage. Silicon Photonic modulators are more complex to control and have much higher losses, as well as higher drive voltage. Neither LiNbO3 or Silicon Photonic modulators allow integration of SOA amplification, requiring bulky and expensive external amplification in high power applications such as long haul and metro networking	As above for tunable lasers. These devices represent the cutting edge of optical networking technology where the modulation function is integrated onto the tunable laser, as well as optical amplification with SOA technology. This results in smaller, faster and ultimately cheaper optical networking equipment and allows network operators to keep up with ever increasing traffic demands at reasonable cost and without increasing the space and power requirements of the networking equipment.	Lumentum Oclaro Finisar	All of the above	Orange, Telecom Italia British Telecom Verizon China Telecom Deutsche Telecom Google Etc.	Backbone fiber optic network
Standalone InP modulators	No current Lumentum program, but other vendors implement this technology for HB-CDM components	Displacing LiNbO3 modulators in high performance fiber optic communications applications from 100G to 600G due to smaller footprint, lower drive voltage and ability to integrate optical amplification monolithically with the modulator structure.	LiNbO3 modulators (physically significantly larger, higher drive voltage requirements). Silicon Photonic modulators (similar size but more complex to control, higher losses, and higher drive voltage requirements). Neither of these alternatives allow the integration of SOA optical amplifiers monolithically with the modulator structure.	The highest performance long reach and high capacity networking applications require very linear, low loss modulator components. Traditionally these modulators have been made from Lithium Niobate (LiNbO3). Recent advances in technology have allowed equivalent performance to be achieved from InP modulators, which are significantly smaller and require lower drive voltage than LiNbO3, allowing network equipment manufacturers to keep up with ever increasing traffic demands within the size and power footprints of existing communications network nodes.	Oclaro Neophotonics Fujitsu	All of the above	All of the above	Backbone fiber optic network
Fixed wavelength O-band lasers (directly modulated)	Client and DCI pluggable modules from 10G to 200G such as XFP, SFP+, CFP2, CFP4	Short reach (<10 km) high volume optical interconnect within a data center or to connect client services to telecom transmission equipment using single mode fiber	VCSEL technology can be used for the shortest reach applications (usually on multi-mode fiber). Some efforts have been made to productize 1310 nm VCSELs, but so far unsuccessfully due to insufficient optical output power in the fiber.	This type of laser is used in optical transceivers used to connect client services to the metro or backbone network. They are also used within data centers to connect severs and switches together. Since they are used near the edge of the network the volume is very high.	Lumentum Oclaro Finisar Multiple Chinese suppliers	All of the above	All of the above	Connection to the backbone network, cloud data centers, enterprise etc.
Fixed wavelength O-band lasers with integrated external modulators (EML or MZ)	Longer reach 10G client and DCI interfaces (40 and 80 km) as well as high speed arrays for 100G and 400G modules	Intra data center switch interconnect, and connecting client services and routers to telecom transmission equipment.	No alternative to InP.	This is a higher performance version of the line above, allowing longer reach and faster connectivity	Lumentum Oclaro Finisar Multiple Chinese suppliers	All of the above	All of the above	Conection to the backbone network, cloud data centers, enterprise etc.
High power 1480 nm and Raman pump lasers (1420 nm to 1495 nm wavelengths)	Pump laser components used in EDFAs and Raman fiber optic amplifiers	Optical amplifiers enabling long haul fiber optic transmission	No alternative to InP.	Optical amplifiers are used in networks to boost the signal power to allow a signal to go further, or to propagate through a high loss element like an optical switch. Optical amplifier technology has revolutionized fiber optic networking since without it, the signal must be regenerated back to electrical data, recovered, and then re-transmitted back as optical data. In a DWDM network with many wavelengths of data on the fiber this is orders of magnitude more expensive than optical amplification.	Lumentum II-VI O-Net Etc	All of the above	All of the above	Long haul and metro networks
O-band, C-band, L-band Photodiode arrays	Photonic detectors used in optical receivers for all single mode fiber optic applications from data center interconnect to Long Haul	All optical interconnects from 10's of meters to thousands of km	Germanium-on-Silicon waveguide photodiodes are potential replacements for InP-based waveguide photodiodes in O-band and C-band (but not L-band), where the optical beam is edge-coupled to the die. Germanium is not suitable for component architectures requiring normal-incidence surface or backside illumination which have looser alignment tolerances.	Photonic detectors are needed at all levels of the optical network (submarine, long haul, metro, client, data center interconnect, etc.) to detect the incoming photons of the optical signal and turn these into electrons that can be amplified and process to recover the original electrical data stream.	All of the above	All of the above	All of the above	All of the above
S-band photodiode arrays	Short reach applications using multimode fiber interconnect	Intra-data center server and switch connectivity	Potential alternatives such as Germanium, Indium Gallium Arsenide multiple quantum well and Indium Gallium Arsenide Nitride have much lower performance and are not suitable replacements for InP.	As above. Although the laser in the transmitter for 850 nm multi-mode applications can be made out of GaAs instead of InP, at high data rates (100 Gb/s or above) the receivers still use InP.	All of the above	All of the above	All of the above	All of the above