Indium phosphide industry moving into consumer applications

Ali Jaffal of Yole Intelligence outlines how the indium phosphide market is evolving, including challenging gallium arsenide.

According to our latest InP analysis , a global increase in the indium phosphide (InP) photonics market from US$2.5bn in 2021 to more than US$5.6bn in 2027 is forecast, with a compound annual growth rate (CAGR) of 14%. Originally developed for solar cells in the 1960s, InP is garnering considerable interest for fiber communications and wireless equipment. Its multi-functional role as a light source, modulator, amplifier and detector at 13xx- and 15xx-nanometer wavelengths makes it the primary material for the fabrication of current and future optical devices in telecom and datacom. With the need for higher transmission data rates and longer communication distances generated by the explosion of social networks, cloud computing and IoT, the future of InP is well secured. In addition, this semiconductor compound is starting to make eyes at several evolving consumer and automotive applications. This could elevate it from its niche market and propel it to a prominent position.

InP industry boosted by new needs in several applications

- **The well-established datacom & telecom sector**

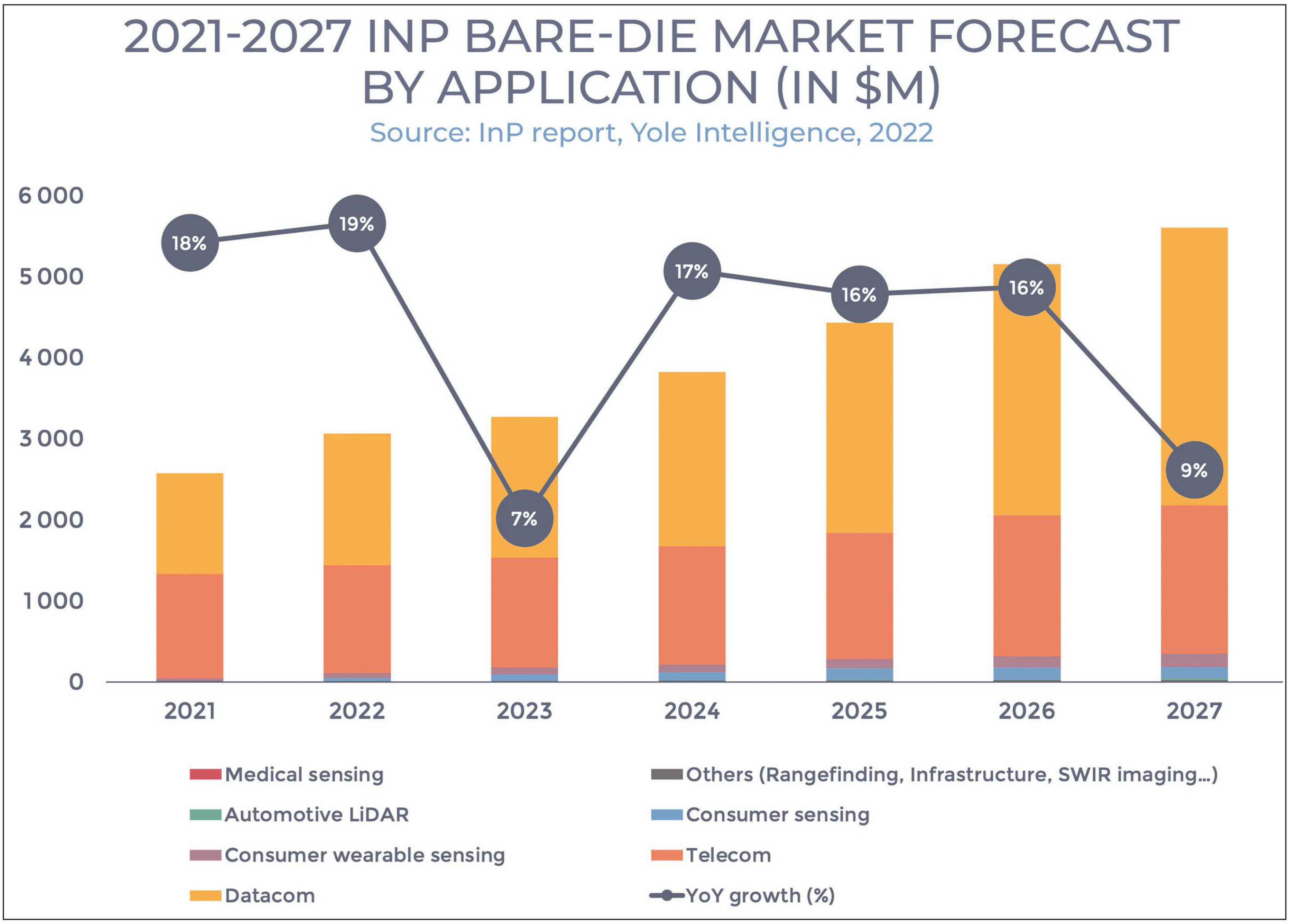
With the capacity to emit and detect at wavelengths above 1000nm, InP has been considered a key technology in datacom and telecom applications for over 30 years. In perfect accordance with the optimum operating range for fiber-optic transmission (13xx & 15xx nm), InP is mainly used for high-power and high-frequency optoelectronic devices such as lasers and photodetectors. Its outstanding structural and electronic properties — high electron mobility, low dielectric constant, and direct bandgap — leave little room for other semiconductors to support the exploding demand for higher data rates and increased range. Technological development efforts tend to focus on optical transceivers that will deliver 100Gb/s, 400Gb/s, 800Gb/s and even 1.6Tb/s data rates, for which InP is the best option. The use of emerging coherent transmission technology to carry considerably more information through a fiber-optic cable will mean moving to integrated photonic solutions where InP photonic integrated circuits (PICs) also have a role to play.

- **Mobile: under-display 3D sensing for smartphones**

Beyond the telecom and datacom markets, the consumer industry also seems interested in InP solutions. The first submarket segment to mention is smartphone sensing. Integration of InP-based short-wave infrared (SWIR) sensors in late 2021 in Apple's AirPods 3 paved the way for the penetration of InP for under-display 3D sensing in smartphones. Apple's iPhone roadmap confirms the committed development to enlarge the screen to the total size of the phone, reducing the current notch (for imaging, proximity sensor, flood illuminator, and dot projector functionalities) first to a smaller pill-shaped hole and then to a tiny punch-hole. It implies a shift from 940nm to 13xx nm or 15xx nm wavelengths which are organic light-emitting diode (OLED) transmissive, and therefore from gallium arsenide (GaAs) to InP sensors. A transition phase has already begun with the release of the iPhone 14 Pro model this year that combines a SWIR proximity sensor and an InP edge-emitting laser (EEL) placed under the screen, with GaAs vertical-cavity surface-emitting lasers (VCSELs) squeezed into a small pill-shaped opening. The pill shape is expected to remain for the next 3–4 years for the next standard and pro iPhone models before the eventual integration of the complete set of sensors under the screen in 2025–2026.

- **Consumer wearable sensing: from well-being to health monitoring**

Wearable devices are already widely available to consumers for monitoring well-being parameters in real time. However, the use of optical sensors to track multiple vital signs non-invasively is gaining ground, pushed by the development of telemedicine. Limited by the detection capabilities provided by visible and near-infrared LED-based sensors, wearable sensing technologies could turn increasingly towards InP to benefit from its mid-IR wavelength range and track a wider variety of biomarkers in blood, such as glucose, lactate and alcohol. There is still a long way to go, however. To date, Rockley Photonics seems to be the only player developing silicon photonic solutions



incorporating an InP-based laser and detector targeting this specific market segment. Although at the very early stages of a discussion with certain OEMs for the next generations of smartwatches, the company will certainly still need 2–3 years before its technology is available for consumer-wearable sensing applications.

● **Automotive-grade LiDAR: on the way for autonomous driving**

A flurry of interest in automotive-grade light detection & ranging (LiDAR) was stimulated four years ago after Valeo opened up the field with the implementation of its Scala 3D laser scanner in a commercialized car. This sensor, combined with cameras and radars, is gradually leading the driving experience to the highest levels of autonomy and safety.

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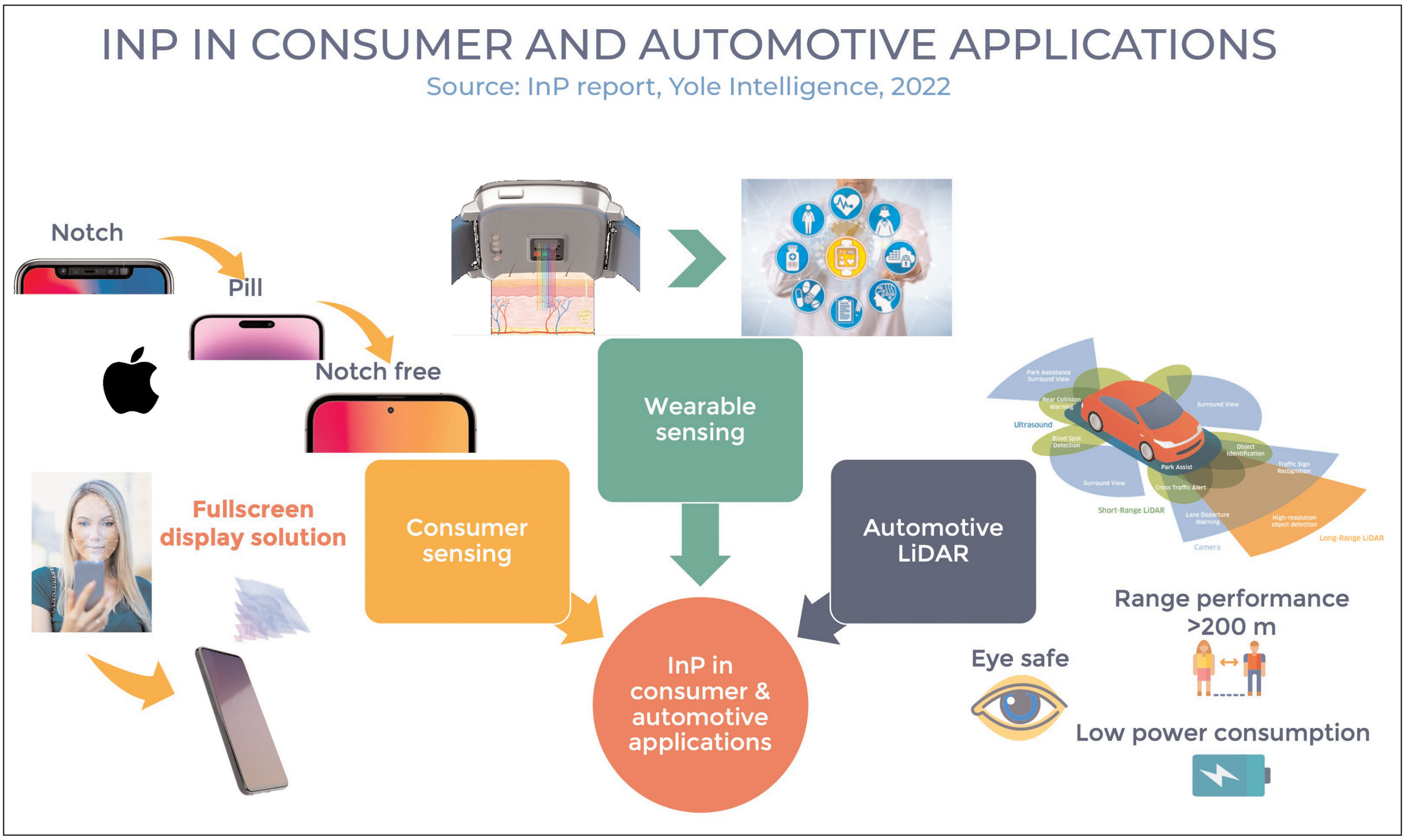
There are at least two reasons why InP-based lasers are considered a premium choice for LiDAR. First, their capacity to accurately map the vehicle's environment at a longer range (> 200m) than conventional lasers. Second, they are eye safe: with mid-IR wavelengths, power for long-range detection can be increased without risking pedestrian eye injuries.

Its penetration into LiDAR remains very limited because of the cost of the InP lasers and the continuous development of the well-established GaAs lasers. So far, it is only being promoted by Luminar, which uses a 1550nm fiber-coupled laser and InP-based InGaAs photodetectors to manufacture its system. It could, however, be boosted by the adoption of a different ranging approach. Indeed, current LiDAR technologies are 100% based on the time-of-flight (ToF) method using narrow light pulses to detect the distance and direction of objects. With future LiDAR (SiPh/InP laser) generations employing a frequency-modulated continuous wave (FMCW) approach, velocity could also be measured, increasing accuracy and, therefore, safety.



Global view of marketplace projections and business opportunities

According to the Compound Semiconductor Monitor Module III Q3 2022, at Yole Intelligence we expect the InP bare die market to grow from US$2.5bn in 2021 to about US$5.6bn in 2027, with a CAGR of 14%. The growth is mainly driven by datacom and telecom applications, for which InP seems to be the best material to achieve the high data transmission rates and longer distances required in data centers and 5G base stations and to provide high-bandwidth, low-latency, low-power fiber communications in data-center interconnects (DCI). The consumer sensing market, at US$31m in 2022, is predicted to reach US$151m in 2027, with a 37% CAGR, due to the evolution of the iPhone's under-display sensor configuration. With a modest US$33m in 2021, the consumer-wearable sensing market should grow steadily thanks to current and future models of Apple's AirPods. A jump is forecasted from 2025 with the possible adoption of InP in smartwatches, bringing the market to US$159m in 2027 with a CAGR2021–2027 of 30%. Because of high competition with GaAs, InP is not expected to penetrate the automotive LiDAR market before the take-up of FMCW systems planned in 2026–2027.

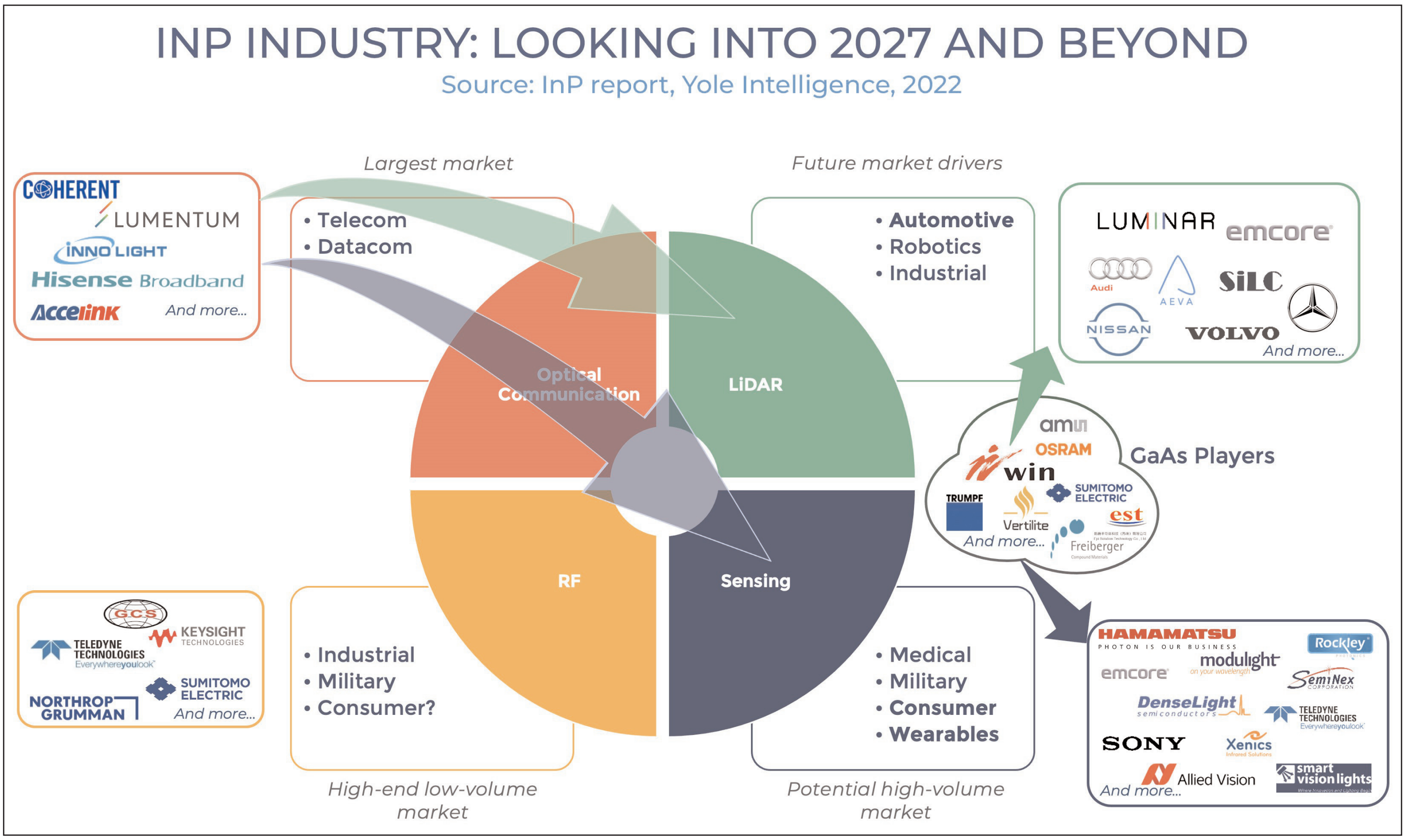
In terms of business opportunities, the established datacom-telecom players – including Lumentum, Coherent Corp (formerly II-VI Inc), Accelink, and Hisense – endowed with InP know-how and manufacturing equipment, may be tempted to enter consumer markets. As InP and GaAs share the same epitaxy process and equipment, GaAs VCSEL/EEL companies such as Trumpf and ams OSRAM could also find an interest in moving towards the LiDAR and sensing markets. A few other players, like the foundry WIN Semiconductors, already has a foot in the door. This is just a small sample of the companies that could contribute to the changing of the InP industry landscape once the green light is given.

Considering alternative scenarios

The story (and the numbers above) could be rewritten if one considers InP's limitations for entering a mass market and the potential competition from another III–V semiconductor that could slow down InP's penetration.

● Cost: the sinews of war

Despite its superior electrical properties compared with silicon and GaAs, semiconductor players keep in mind that the industry is cost driven. And therein lies the rub: InP costs more not only in terms of wafers (3–4 times the price of GaAs) but also in terms of device manufacturing. InP laser manufacturing suffers from low yield, which in turn significantly increases the cost of the die. The trend for advanced laser technologies for longer reach and higher speed in telecoms and datacoms will amplify the issue: the electro-absorption modulated laser (EML) technology needed to fulfill these requirements involves extra epitaxial growth steps and a higher probability of generating an even lower yield. In addition, the InP technology platform is currently 2″, 3″ or 4″ in diameter, whereas GaAs is 4″ or 6″ and silicon is 8″ or 12″. With InP's potential to penetrate the consumer market, the industry will need to move to larger wafer sizes, which is not anticipated before 2024–2025.



InP versus GaAs: a fierce competition

New technology developments are being made to overcome GaAs' limited bandgap energy (9xx nm). For smartphone under-display 3D sensing, epiwafer foundry IQE is currently working on a very promising new laser technology based on dilute-nitride GaAs, targeting a 13xx nm wavelength. However, this technology could take a few years to enter the market, leaving InP enough time to establish itself comfortably in this field. The competition between InP and GaAs also extends to LiDAR. Lumentum and Hesai have designed GaAs multi-junction VCSEL (905nm) arrays based on the ToF approach which, when powered with very short pulses, reach extremely high peak power with no danger to the eye. This makes them an ideal solution for long-range LiDAR systems with a range of up to 200m. Thanks to the use of a new generation of components like VCSELs and ultra-sensitive silicon photomultiplier (SiPM) detectors, ToF LIDARs increased their performance and should still be used for several years. In parallel, FMCW InP-based LiDARs are in the development phase and are expected on the horizon 2026–2027.

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And the final word goes to...

Relegated to niche applications until now because of cost and technology control difficulties, will InP's performance opportunities for consumer and automotive use offset these disadvantages? The answer is Apple. Apple's interest in InP-based solutions has begun to spread throughout the whole supply chain, which is now taking a closer look at this industry. Whether InP moves into a position of prominence in the marketplace depends on Apple's strategy, which will obviously take into account cost, performance and supply chain security. ■

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Sources:

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