Trends in semiconductor and optoelectronic technologies

Author: Rokas Klioštoraitis

2023 11 08

Table of Contents

Technology trends

Global trends

Currently, our society is steadily progressing towards a more interconnected and digitized way of life. The universal utilization of sensors in various aspects of our technology, coupled with the ongoing AI revolution, demands a substantial investment in both software and hardware solutions. This trend is reflected in the technology landscape of 2023, determined by the McKinsey Consulting Group[1]. It states that there are 15 trends in the technology sector:

1. Applied AI
2. Industrializing machine learning
3. Generative AI
4. Next-generation software development
5. Trust architectures and digital identity
6. Web3
7. Advanced connectivity
8. Immersive-reality technologies
9. Cloud and edge computing
10. Quantum technologies
11. Future of mobility
12. Future of bioengineering
13. Future of space technologies
14. Electrification and renewables
15. Climate technologies beyond electrification and renewables

EU trends

The European Union identifies sixteen priority advanced technology branches[2]. Advanced technologies are defined as recent or future technologies that are expected to substantially alter the business and social environment. These technologies include:

1. Advanced materials
2. Advanced manufacturing
3. Artificial Intelligence
4. Augmented and Virtual Reality
5. Big data
6. Blockchain
7. Cloud technologies
8. Connectivity
9. Industrial biotechnology
10. Internet of Things
11. Micro- and nanoelectronics
12. IT for Mobility
13. Nanotechnology
14. Photonics
15. Robotics
16. Security

The European Commission highlights nine industries where Europe is competing with other players and in only three of those sees itself as a global leader. These industries can be seen in Figure 1. Europe is the key player in Advanced manufacturing, IoT, and Mobility sectors. All of them are closely interconnected and bear strong similarities. Germany is the main driving force behind these advancements and dominates all sectors of advanced technology innovation in Europe.

[1] McKinsey Technology Trends Outlook 2023 | McKinsey

[2] ATI Final Report on technology trends and technology adoption.pdf (europa.eu)

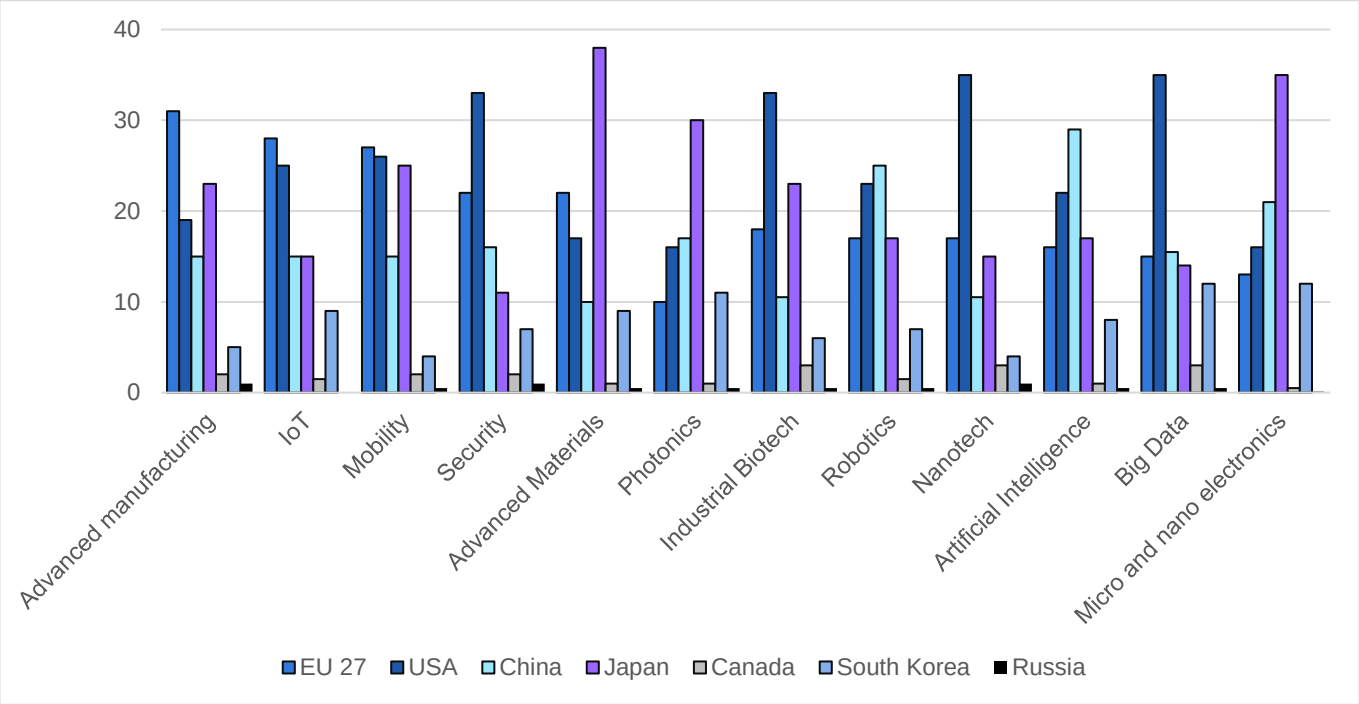

Figure 1. Share of global patent applications in the EU27 and competing economies in 2018 (last available year with complete patent data)
Source: ATI Final Report on technology trends and technology adoption.pdf (europa.eu)

Semiconductors and Optoelectronics connection to global trends

Since semiconductors are the foundation of modern electronics, starting with being used as resistors, transistors, diodes, and similar components and ending with being the main material for sensor and chip fabrication. Currently industry's main trends come from increased demand for semiconductor chips from:

- Automotive industry – electrification, driving assistance, advanced autonomous driving,
- Computing – data centers and cloud servers

According to the forecast of University4Industry and McKinsey increase for semiconductor demand is 6-7% per year[3]. This increase is shown in Figure 2.

As noted above, many, if not all, of these technologies require an increasing quantity of semiconductors for data processing and storage. Semiconductor chips must continually be refined and enhanced, surpassing the capabilities of their predecessors in various aspects.

[3] University4Industry

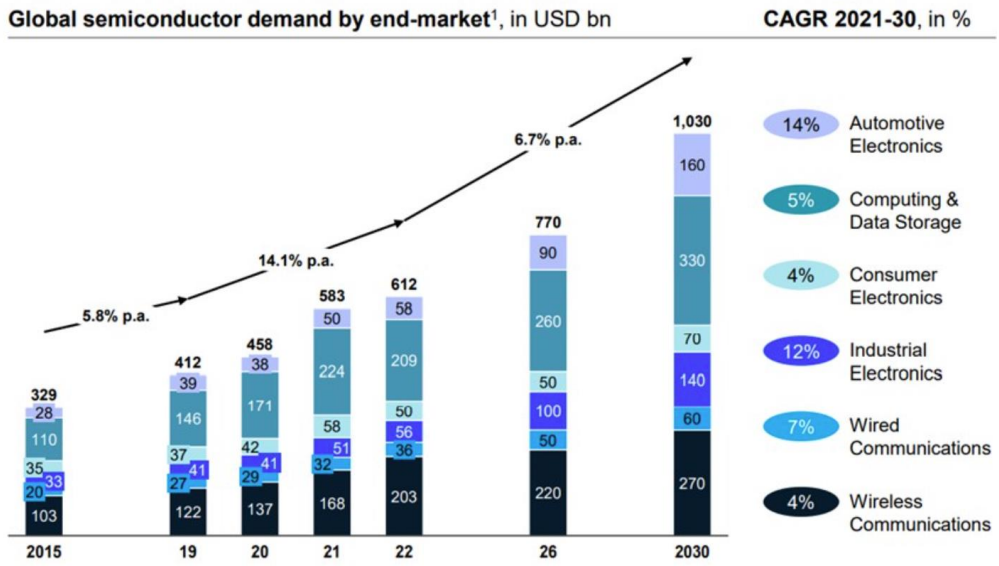

Figure 2. Global semiconductor demand over the years[4]

Additionally, other technologies rely on sensors, often fabricated from semiconductor materials, which harness light waves for detection. These sensors typically necessitate dedicated companion chips, contributing to an exponential surge in the demand for semiconductors and chips alike. Such sensors usually interact with light waves and are treated as a product of optoelectronics. Light sensor market is set to increase almost 8.4% CAGR from 2023 to 2032 in the US alone (Figure 3) [5].

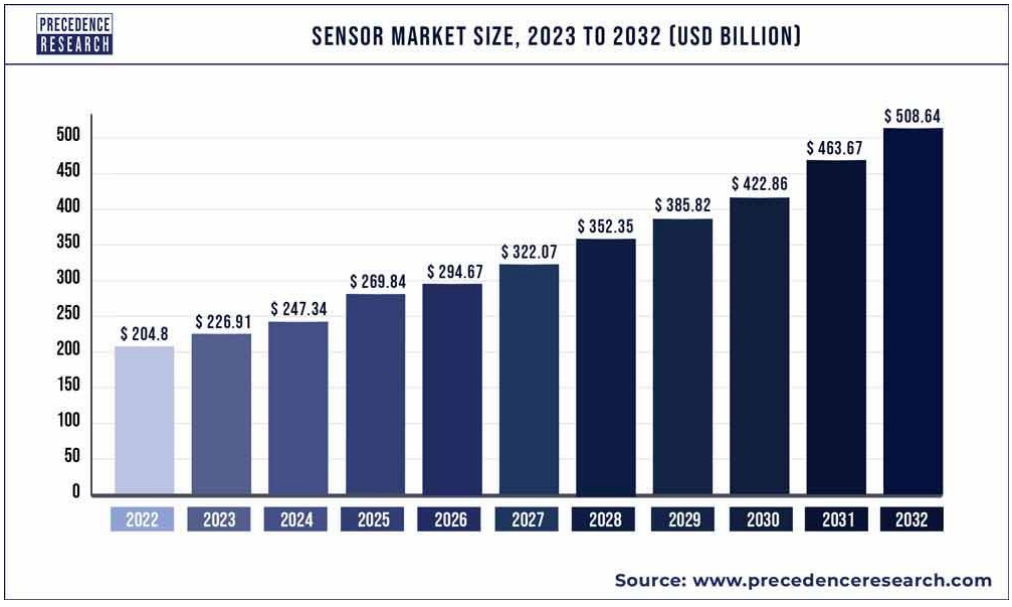

Figure 3. Global sensor market size.
Source: [Sensor Market Size To Hit Around USD 508.64 Billion By 2032 (precedenceresearch.com)]

[4] University4Industry

[5] Sensor Market Size To Hit Around USD 508.64 Billion By 2032 (precedenceresearch.com)

With these trends, our consumption of energy and electricity is set to grow significantly. The proportion of power generated from solar sources is steadily rising year by year (Figure 4) [6]. These evolving technologies heavily depend on the optoelectrical properties of semiconductors to transform light into energy. Thus, semiconductors and their optoelectrical properties are pivotal for a range of applications, including data storage and computing, sensing technologies, and the advancement of green energy solutions.

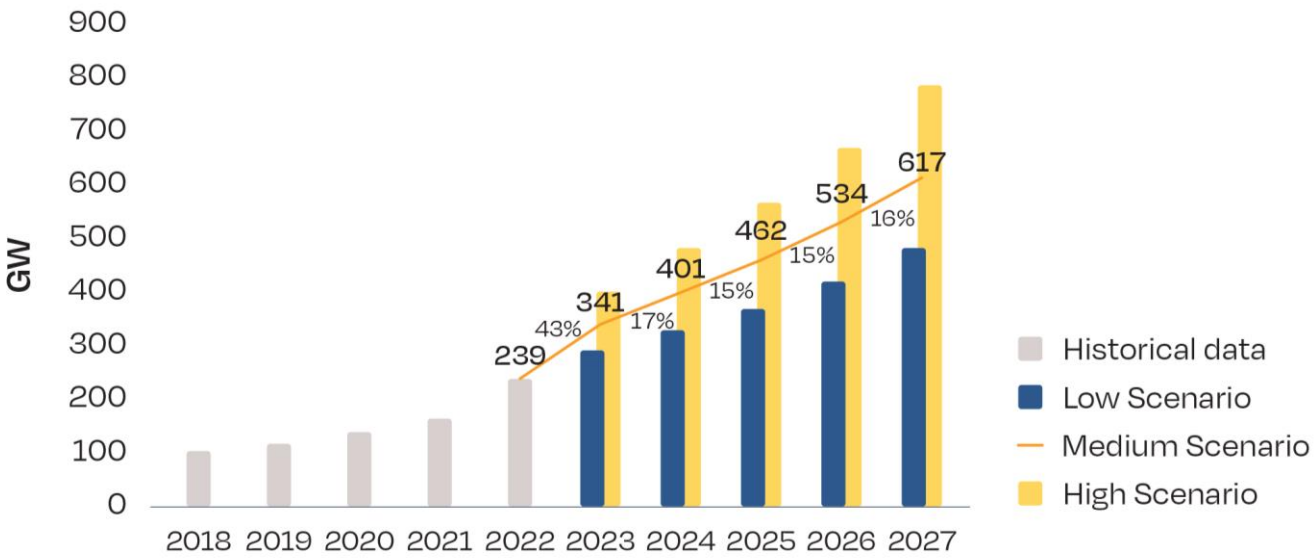

Figure 4. World Annual solar power market scenarios.
Source: Global Market Outlook For Solar Power 2023 - 2027 - SolarPower Europe

Specific semiconductor and optoelectronics technology trends

Semiconductor trends

Although semiconductors play a crucial role in modern technology, their manufacturing is a highly resource-intensive and intricate process. No single country possesses the capability to handle the end-to-end production of these devices. Typically, nations focus on specific segments within the semiconductor value chain (Figure 5)[7]. For instance, the USA concentrates its industry on chip design (fabless model) and electronics design. They are also a huge player in electronics where they are integrating a substantial number of semiconductor devices into their products. Taiwan, on the other hand, adopts a distinct approach, specializing in chip manufacturing (foundries) as well as the testing and packaging of these chips. Europe participates across various segments of the value chain but lacks the scale of these operations while significantly relying on external imports. This implies that Europe does not have such a deep know-how in these sectors and cannot compete with the main players. The only segment where the EU leads is equipment manufacturing thanks to ASML (Netherlands) and Aixtron (Germany). The

[6] Global Market Outlook for Solar Power 2023 - 2027 - SolarPower Europe

[7] Strategies to lead in semiconductor world | McKinsey

countries within the “Rest of world” label are mainly Japan and South Korea and their focus is on wafer fabrication and device integration. Raw materials for the semiconductor manufacturing are mostly supplied by China[8].

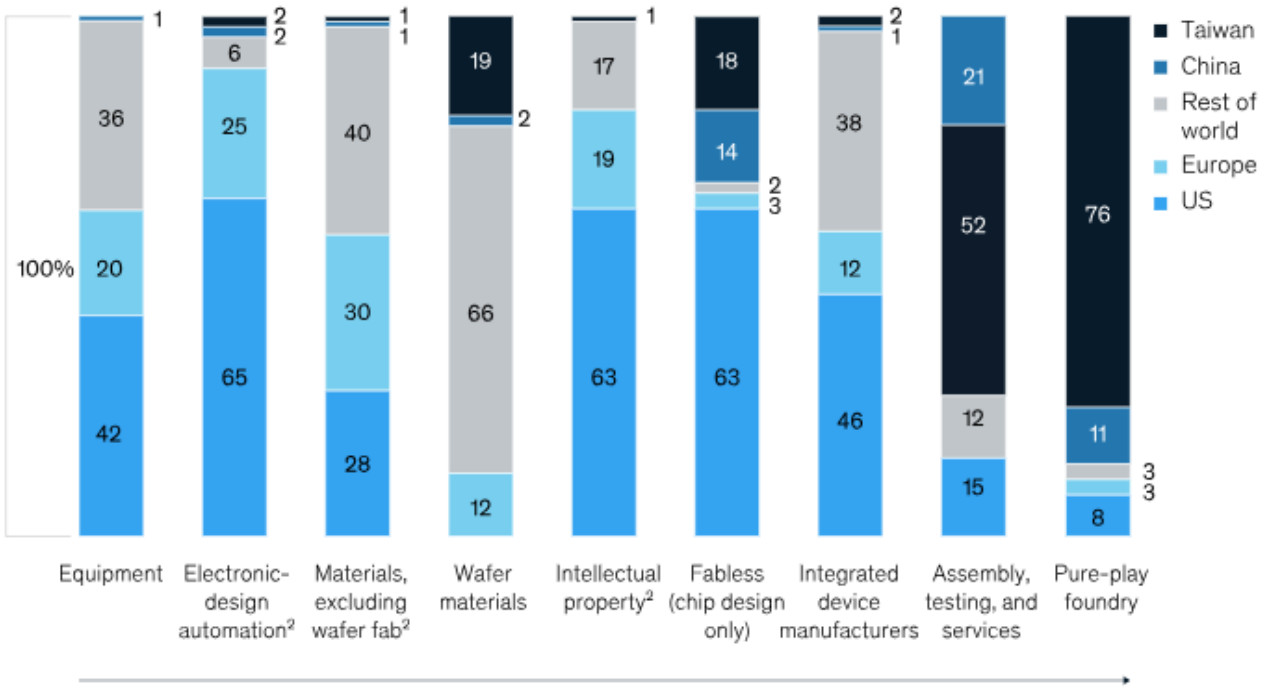

Figure 5. Semiconductor sales along the value chain.
Source: Strategies to deal with the semiconductor shortage | McKinsey

Let's explore the key sectors driving the latest trends and understand why they play such a crucial role.

More than Moore

Moore’s law is a historical observation by Gordon Moore that the semiconductor market will be able to double the transistor (bit) number on a chip every two years. This “self-fulfilling” prophecy has been a consistent trend for the past 40 years. However, we are currently approaching the physical constraints of this law, prompting the industry to explore innovative approaches to enhance the performance and density of new chips without reducing transistor size. This evolution, known as the "More than Moore" trend, enables performance improvements through chip stacking, migrating capabilities from chip to packaging or onto the chip itself, and implementing advanced algorithms. It empowers us to compete with key market players without necessitating the use of the most cutting-edge equipment and know-how, while still producing chips with comparable capabilities to bleeding-edge counterparts[9].

AI and computing

The field of Artificial Intelligence advanced a lot in recent years, demanding heightened storage and computing capabilities. However, conventional solutions found in other devices are becoming bottlenecks for the continued progression of AI. To solve this problem semiconductor companies are producing memory, data storage, and logic hardware solutions tailored for this task.

[8] Semiconductors - Key Inputs - Business Executives for National Security (bens.org)

[9] 2021 IRDS More than Moore (ieee.org)

Forecasts indicate that in the upcoming years growth for AI semiconductors is expected to be five times greater than the remainder of the market (Figure 6). Even though the highest projected growth is in storage, most opportunities for value creation will arise from computing[10].

Furthermore, another trend is that a big part of computing is set to shift to edge and data centers. Edge computing is executed directly at the device with an embedded chip. It is bound to happen that a significant portion of the computing will be done on site instead of large cloud data centers[11].

These shifts are an upcoming opportunity for new semiconductor design and usage approaches within the industry. Utilizing an upcoming market and providing tailored solutions to key players will be crucial for semiconductor companies to capitalize on these trends.

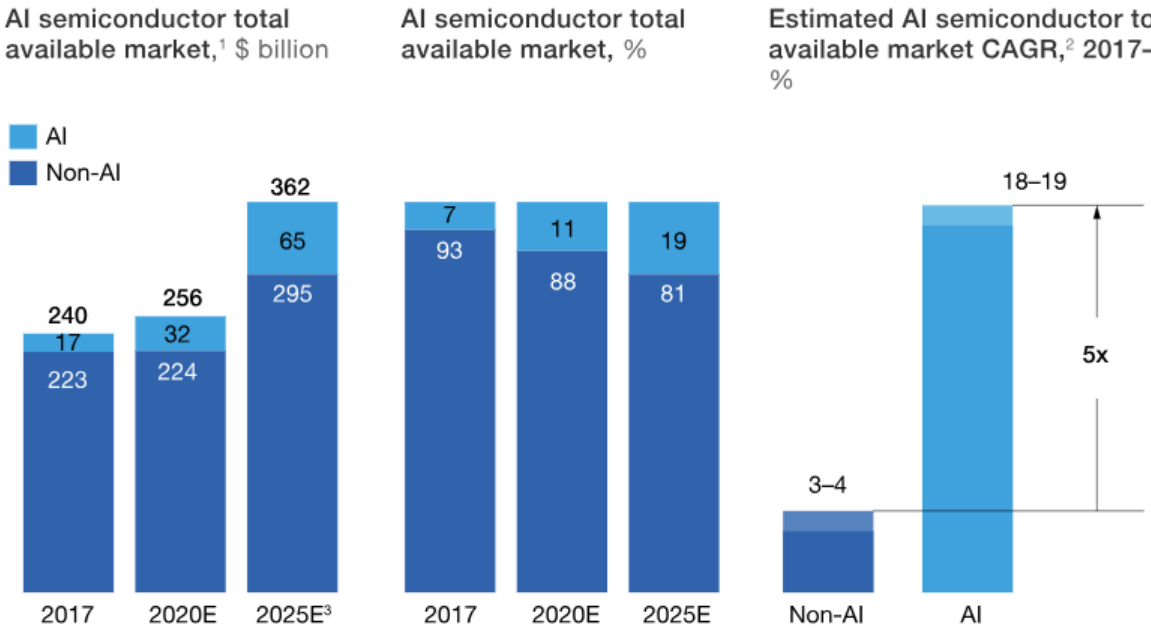

Figure 6. Growth for semiconductors related to AI in comparison to the global semiconductor market. Source: AI hardware: Value creation for semiconductor companies | McKinsey

Automotive

The recent rise in advanced driver-assistance systems and the emergence of autonomous vehicles is requiring an ever-increasing number of semiconductor chips within the automotive industry (Figure 7). These chips, often customized for specific purposes, are encouraging a lot of companies to shift their design in-house to increase the performance of the chips, reduce development timelines, and shorten the value chain[12].

Similarly, as was said before, a substantial portion of these semiconductors will be accompanied by various sensors in a car. Customizing these chips for specific tasks becomes crucial to optimize data transfer speed between sensors and chips, facilitating real-time calculations. While these are the current challenges of the

[10] AI hardware: Value creation for semiconductor companies | McKinsey

[11] Edge computing architecture: IBM's POV - IBM Cloud Architecture Center

[12] Automotive semiconductors for the autonomous age | McKinsey

industry, they also present opportunities for companies to strengthen their market positions or for startups to emerge with innovative solutions. This dynamic environment calls for strategic agility and a keen focus on tailored solutions to stay ahead in this evolving automotive technology landscape[13].

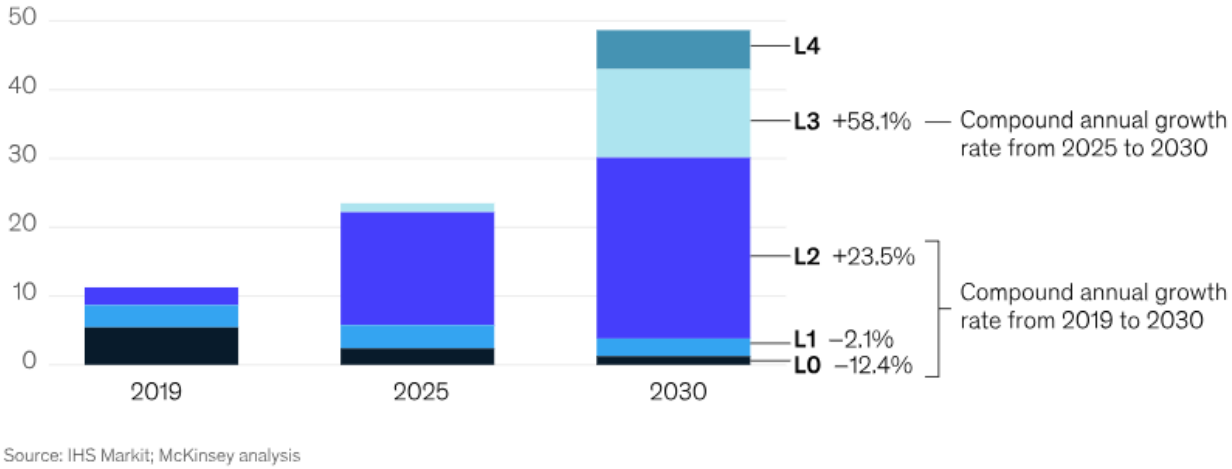

Figure 7. Autonomous semiconductor market. (L0-L4 shows the autonomy level of the vehicle). Source: Automotive semiconductors for the autonomous age | McKinsey

IoT

With the rise of autonomous cars, smart wearable devices, and Industry 4.0 being the target of the 21st century Internet of Things is becoming a more and more important topic in our world[14]. The Internet of Things connects AI, sensors, and edge computing in one package. It enables businesses to work more efficiently to track data and increase revenues. Businesses starting to understand IoT's value and it is used in around 25% of them[15]. These trends show us that IoT is only going to become more important in our world and we will be using more devices to improve the quality of life and businesses.

Optoelectronics trends

According to the latest forecast, North America is likely to maintain its domination in the sector with Japan and South Korea following closely and Europe trailing slightly behind. The growing adoption of high-end devices and increased investments in semiconductors are significant contributors to the expansion of optoelectronics sector. An insightful perspective is offered by “The Photonics 100” which nominates a hundred of most influential and innovative people in photonics sector. Most of them come from western countries, mainly from the USA, Germany, UK, and the rest of Europe[16].

The sector is dominated by large-medium scale enterprises which are actively investing in R&D and innovations to stay relevant in the market. A large number of smaller players are acquired by these industry giants in order to enhance regional presence and expand their product networks[17]. Now, let's delve into the key trends shaping the optoelectronics sector.

---

[13] mck_on_semiconductors_08_2021.pdf (mckinsey.com)

[14] What is industry 4.0 and the Fourth Industrial Revolution? | McKinsey

[15] Growing opportunities in the Internet of Things | McKinsey

[16] The Photonics100 2024: Where are they based? | Electro Optics

[17] Optoelectronics Market Size, Share, Growth Forecast by 2031 (transparencymarketresearch.com)

Sensors

Optoelectrical sensors represent approximately 16% of the broader sensors market. These sensors are set to achieve 9 percent of annual growth until 2025, reaching $44 billion in revenue[18]. Most of this growth is driven by a few key sectors:

- Automotive – sensors of high precision, resolution and rapid response times are used in ever increasing quantities to assist the growth of driving assistance and autonomous vehicles.
- Infrastructure – a significant portion of these devices come from smart home appliances and measurement of physical properties of infrastructure (strain, vibrations, etc.). Additionally, IoT integration in process automation and growth of Industry 4.0[19] contribute substantially to this growth.
- Aero and defense – growth mainly comes from expanded applications and automation for technology and other remote sensing tools.

To sum up, this kind of sensor is usually used for LiDAR, spectroscopy, machine vision, defense applications, proximity, and parameters of material. They are comparably cheap and with a capacity for large-scale deployment which makes them a preferred solution for various industries. As demand continues to surge, these sensors are poised to play a pivotal role in shaping the technological landscape in the years to come.

Laser market

Current laser market was valued $21.3 billion in 2021 and is up 22% from 2020[20]. Despite this growth some numbers suggest that the laser industry is slowing down. This can be seen in the number of filled patents in the US (Figure 8), which is a leading country in this sector.

Another trend in this sector is that the technology of lasers is shifting. Previously the main technology in the laser market was CO2 based lasers because of their relatively low price and diversity. Nowadays fiber lasers are getting more and more important accounting for 45% of all filled patents. Fiber technology has an edge because of its ability to focus the beam down to the micro level and generate more power from a more compact device.

[18] The next wave of innovation in photonics | McKinsey

[19] Four things to know about the Fourth Industrial Revolution | EY - US

[20] 2021 Laser Market Data – Optech Consulting (optech-consulting.com)

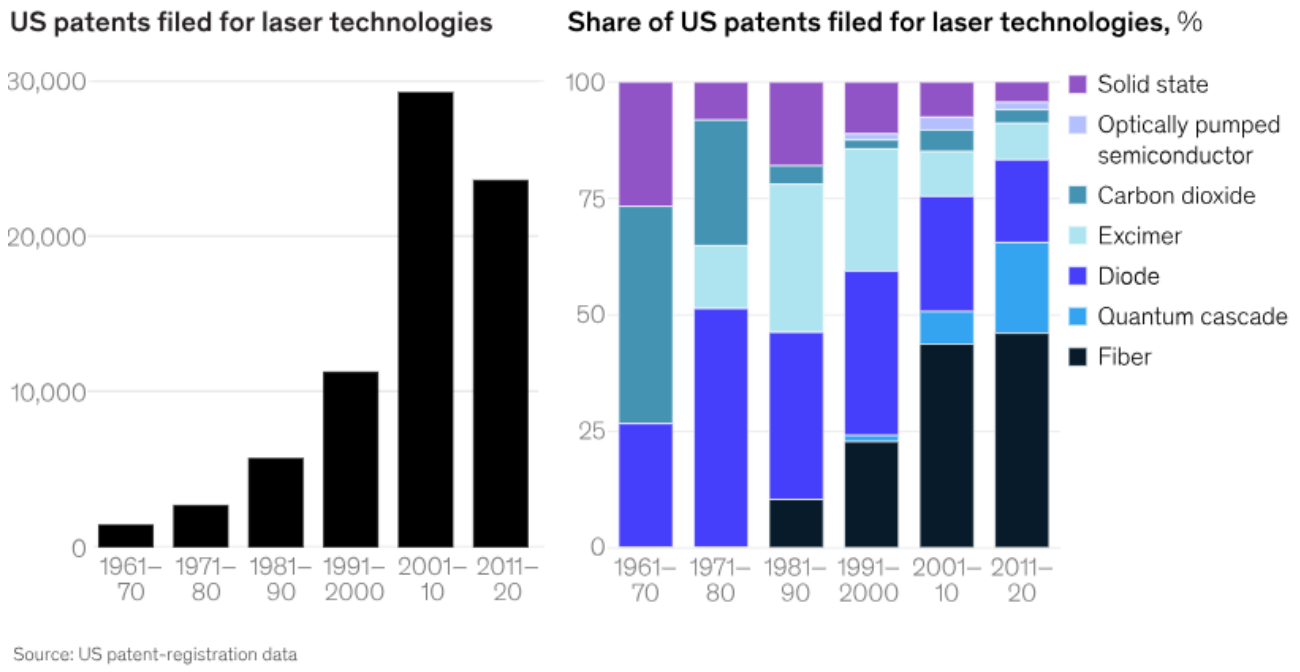

Figure 8. Number of new patents filled in the US.
Source: The next wave of innovation in photonics | McKinsey

Fiber communications

With data traffic expected to grow at a rate of 25% until 2028, there's a rising need for faster and reliable transfer methods[21]. Fiber stands out as the only broadband technology capable of delivering these vast amounts of data. Interestingly, millions of households still lack a connection to the fiber network, presenting opportunities for future investments. With the rise of IoT and other digital technologies the need for faster data transfers is only going to become more important in the imminent future[22].

Photovoltaics

With increasing demand for electricity renewables are coming up as a possible solution. One of the types of it is photovoltaics more widely known as solar cells. They are made from semiconductor material and convert light into electric energy.

With the advancements in solar cell efficiency and their dropping in price, more and more electricity is being produced from solar (Figure 9)[23].

[21] Ericsson Mobility Report June 2023

[22] Investing in fiber cable: Four broadband opportunities | McKinsey

[23] Solar Technology Got Cheaper and Better in the 2010s. Now What? | Greentech Media

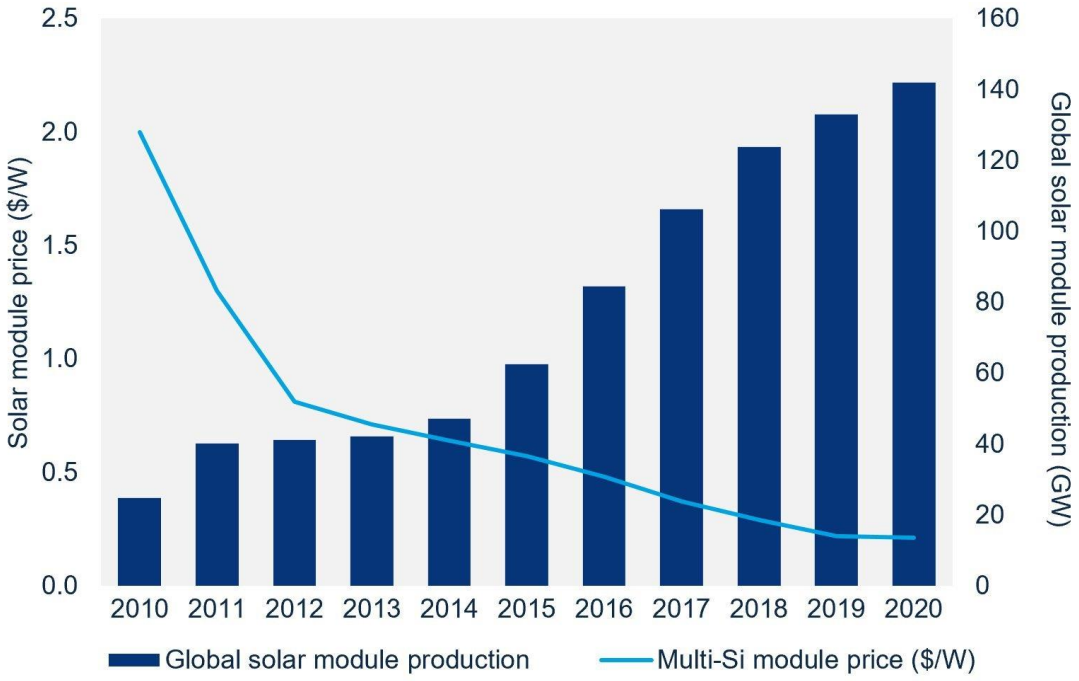

Figure 9. Global solar manufacturing capacity vs module price.
Source: [Solar Technology Got Cheaper and Better in the 2010s. Now What? | Greentech Media]

Rokas Klioštoraitis
Projektų vadovas

+370 690 88059
rokas.kliostoraitis@kurklt.lt

Upės str. 23,
08128, Vilnius,
Lithuania

www.kurklt.lt