Industry Report
Methodologies

Report Methodology

Underpinning all light-enabled products and services are fundamental (or core) optics and photonics components, which range from raw materials to image sensors, and from light emitting diodes (LEDs) to lasers. The SPIE Optics and Photonics Industry Report provides an in-depth assessment of the global industry that produces these core components. The Industry Report also provides an overview of the end-use marketplace for the light-enabled products.

The methodology used for the Core Components industry analysis is different from that used to assess the end-use (or enabled) marketplace. Both methodologies are outlined below.

Developing the components industry profile

The biennial Optics and Photonics Industry Report is based on industry research carried out at SPIE over several years by a team of industry experts. With a knowledge base that includes the most current and comprehensive database of photonics organizations in the world, combined with many years of industry experience and actual revenue data from the companies, the SPIE team has developed a reproducible and transparent methodology to characterize the global production of photonics components.

The components industry profile involves four basic steps, starting with creating a list of companies that are active in photonics. Firms that do not actually make and ship core components are then removed, with the result being a list of core components producers worldwide. Using actual company data, revenues and employment are then determined for each firm. The final step involves an assessment for each company larger than $10 million in annual revenues as to the percentage of revenues that are attributable to photonics components production. The sum of the resulting revenues and employment data provides the final industry profile.

The four steps of this process are illustrated in more detail below:

1. **Compile a list of commercial entities active in photonics**
    Any entity that exhibited at one or more of ~40 optics and photonics events worldwide is included in this list.

| Companies | Manufacturer? | Sales & Jobs | Data Review |

Commercial entities active in photonics

- Exhibited at one or more optics + photonics events
- In 2014, 2015, 2016 (one or more)
- Names de-duped (i.e., only counted once)
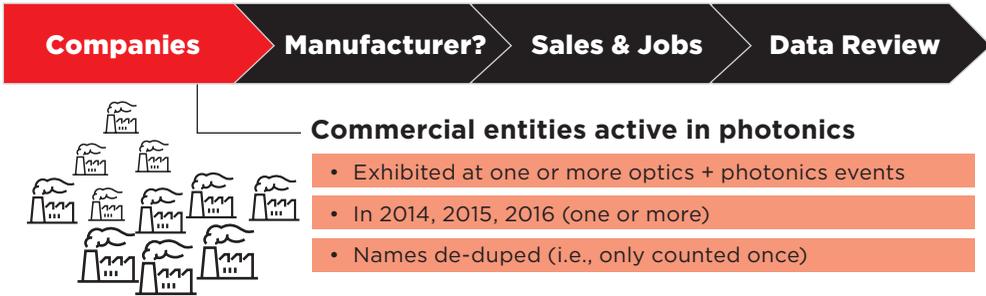
2. **Exclude any entity that does not make and ship photonics components**
    Publishers and media outlets, lawyers and consultants are examples of entities that are excluded from the list because they do not make and ship core components.

| Companies | Manufacturer? | Sales & Jobs | Data Review |

Do they make and ship photonic components?

Excluded Entities

- Publisher and media outlets
- Associations, societies, non-profits
- Distributors and reps
- Educational institutions
- Government labs
- Consultants and law firms

3. Compute revenues and employment for each company

Actual company data is obtained from various sources including Dunn & Bradstreet, company annual reports, SPIE database, websites, or using regional statistical benchmarking.

Companies	Manufacturer?	Sales & Jobs	Data Review

Compute total sales and jobs

- Sales & employee data obtained from Dunn & Bradstreet
- If no D&B, public information is combined with regional statistical benchmarks derived from D&B

Data imported to SPIE database
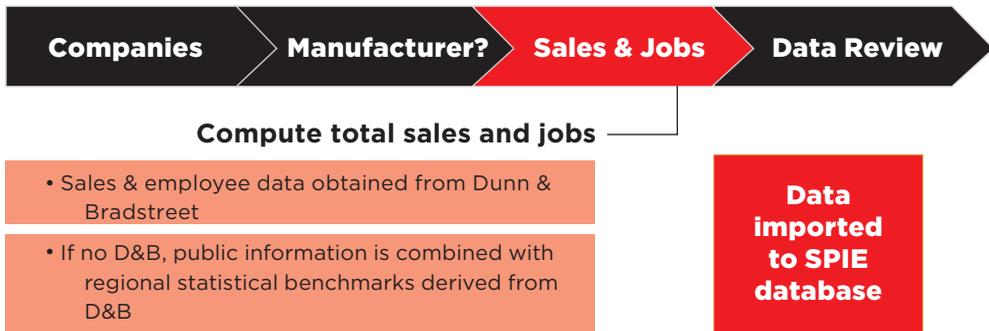
4. Review photonics revenues and apply a "photonics factor"

For each company revenues and employment information is pro-rated based on expert estimates of actual photonics-related sales. The sum of these data provides the industry totals.

Companies	Manufacturer?	Sales & Jobs	Data Review

SPIE Data Analysis Team

- Sales factored on est. actual photonics-released sales
- Firms with sales < $10 M assumed to be 100% photonics
- "Out of range" or anomalous data reviewed in-depth

"Photonics Factor" applied
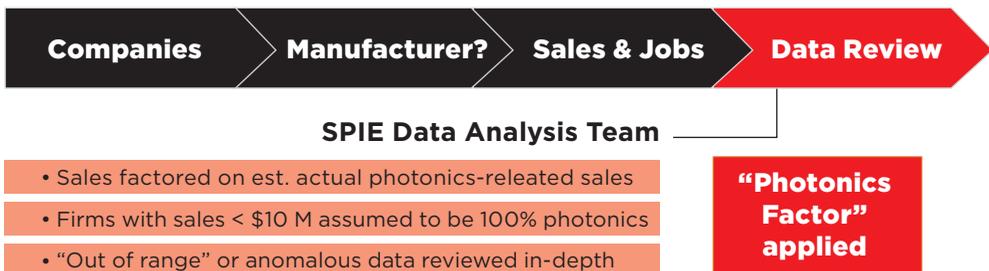
Developing the components industry forecast

Professional stock analysts research public companies and their markets for their investor clients. These analysts generally follow public companies that are important to their client base. The analysts track company revenues, income, and other financial indicators, as well as the rest of the market, with the goal of assessing company performance as compared to its peers and the likely impact on stock prices. This information is typically public and provides insight as to likely company performance over the near term (12-18 months).

SPIE has developed a model that aggregates all the available professional revenue forecasts for the public companies in its core components database. These companies represent about 80% of the total global component revenues.

We believe that the aggregated company revenue forecasts provide a reasonable indicator of likely industry performance.

To test this assumption, we compared our industry assessments for 2012, 2014, and 2016 with what the analysts were forecasting at the time in each of the relevant years. We found generally good agreement between the analysts' predictions and actual company performance.

Our forecast uses the same methodology to project the likely revenue trend in the near term. We will continue to update the forecast as new information is made available.

Notes and key assumptions

Company count: The SPIE core components company database resulting from the methodology described is a reflection of the dynamic photonics marketplace. Annual changes to the companies included in the list occur for several reasons. Growing companies may decide to exhibit when they have not done so previously, for instance; startups may fail or be created; or because of mergers and acquisitions. We track and account for these and other factors.

Repatriated revenues: Few large multinational companies report their revenues in detail by region and product line. The SPIE core components company database assumes, therefore, that all revenues originate at the location of the company headquarters. For the larger companies, this will affect some of the regional revenue distribution shown in the Industry Report.

Foreign exchange: All revenue information in the SPIE core components company database is maintained in US$. However, the original information may have been in local currency, converted to US$ at the rate prevailing at the time. Due to significant foreign exchange rate variations over the period of the studies, the currency conversion to US$ may obscure trends that would otherwise be evident if reported in local currency.

Developing the "enabled markets" profile

Most people not in the Photonics Industry interact with photonics as enabled products: displays, cell phones, LED lighting, to name a few. The health and growth of the enabled product markets and applications create demand for the core products. Understanding the size, growth, and employment of the enabled products facilitates the core industry's investment, opportunities, and policy issues, which may impact these businesses.

The enabled market profile relies heavily on industry and application expertise. Updates to applications, emerging technologies, and the key players in each area are usually undertaken on a two to three-year cycle. SPIE has developed a process that leverages the expertise of industry experts, is consistent from analysis year to analysis year, and is global in nature.

The methodology comprises five basic steps starting with development of the list of photonic-enabled applications. From the list of applications, various sources are consulted and compared to develop a revenue value per application. A comprehensive list of companies that serve each application is then developed from which employment estimates are derived. Finally, a review of growth ensures that the sources used are consistent and that the underlying application data is consistent from one analysis year to the next.

1. Compile a list of photonic applications

More than one hundred and twenty applications are included in the enabled market profile. The applications are reviewed with new applications added as they become appreciable. For example, the 2012 analysis listed several emerging applications that were too small to be followed by analysts or were still in the process of tech-transfer from laboratory to commercial deployment. By 2016 several applications such as wearables, Li-FI, and AR/VR were sizeable enough to attract market analysis.

The applications are grouped into segments. There are ten segments:

Advanced Manufacturing Tools
This segment comprises tools and equipment used primarily to manufacture products, such as laser cutting, marking, and welding, as well as 3D printing and additive manufacturing technologies.

BioMedical Systems and Applications
The theme for this segment is whether a device or system is medical in nature. This segment includes diagnostic tools such as endoscopes, microscopes, and pulse oximeters, as well as therapeutic tools such as medical lasers and intense pulse light therapeutics. Biometrics such as iris or fingerprint scanning are security tools by nature and are included in the Defense, Safety, and Security segment.

Consumer and Entertainment Devices
The overarching commonality for this segment is whether the device was sold directly to consumers, such as smart phones, eyewear, and gaming systems. This segment has the most sensitivity to price compression over time. The revenue value for this segment is ex-factory (the value the factory sold it for) not the price the consumer pays.

Defense, Safety, and Security
The largest applications in this segment are the security technologies such as anti-counterfeiting, biometrics, and video surveillance. This segment comprises more than thirty-five unique applications.

Displays

Display technology is overwhelmingly migrating into photonic-enabled products, as display signage in stores and restaurants move to dynamic displays, billboards in metro areas convert to dynamic on-demand-messaging, and even the dashboards in our cars migrating from needle guages to representations of vehicle performance on an LCD display. Displays are sold to OEMs such as automobile companies or ATM kiosk manufacturers in addition to consumers for home entertainment systems and demonstrates a mix of consumer and OEM behaviors.

Lighting

The entire segment of lighting, by definition, is photonic. There are many reports that feature the explosion of LED lighting luminaires. However, the most accurate analysis includes all lighting technologies from older technologies such as incandescent and fluorescent to the new LEDs. This segment includes lighting for automotive applications (interior and exterior), residential, and shop or office lighting.

Communication, Information Processing, and Data Storage

This segment includes the components of fiber optic transmission (from the transmission lines to the equipment at the ends) as well as the newly emerging Li-Fi and visible light communication equipment.

Semiconductor Processing Equipment

Manufacturing equipment that is specifically dedicated to the processing of semiconductor devices is contained in this highly cyclical/volatile segment.

Sensing, Monitoring, Measurement, and Control

This category is a mix of complete systems and sub-systems. A sub-system would be the sensor used with the garage door opener where the value of the garage door is not included in the revenue assessment (the garage door is still a door without a sensor). A complete system would be a high-pressure liquid chromatography (HPLC) system, which uses light to detect when molecules are passing through the column; without the light detector the system cannot function.

Photovoltaic Solar Products

This category includes solar panels integrated into consumer applications (such as landscaping lighting) as well as the large solar installations that energy companies deploy across the world.

2. Estimation of revenue

Applications ▸ **Revenue** ▸ Companies ▸ Employment ▸ Data Review

For each identified application, a source for determining application revenue is identified, for example a trusted marketing report. It is key that the revenue source uses a consistent methodology from year to year. Some of the applications are part of larger markets or industries such as test and measurement or aerospace. Depending on the application, or revenue source, further analysis must be carried out to capture only the photonics-enabled revenue.

3. Identification of manufacturing companies

Applications ▸ Revenue ▸ **Companies** ▸ Employment ▸ Data Review

For each application, a comprehensive list of companies that manufacture products for that application are developed. Some companies produce products for a variety of enabled-photonic products. Company data is then compiled for annual tracking. Company data includes country, revenue, employment, and ownership.

4. Employment estimates

Applications ▸ Revenue ▸ Companies ▸ **Employment** ▸ Data Review

The company data is used to create an application-specific employment estimate. Different applications are naturally highly automated and have fewer employees per dollar of revenue realized. Other applications may require complex assembly and testing and require more employees per dollar of revenue.

5. Data review

Year-over-year analysis of each application, companies, and employment ensure a high degree of consistency in the revenue and employment estimates. Outliers are investigated with multiple data sources being consulted to ensure consistency and accuracy of significant changes.

Developing the enabled-products forecast

The enabled-products forecast is highly dependent upon commercially available market reports, which are easier to sell if the market predictions are optimistic. Therefore, some market forecasts are "irrationally exuberant" about the future growth. Other forecasts are more conservative as their constituency is highly skeptical after decades of boom-bust cycles. This mix of optimism and skepticism produces an interesting future forecast with some applications over-delivering and others woefully deficient. SPIE has developed a forecast model that dampens the over-exuberance and yet allows for proven high-growth applications to forecast rational revenue growth.

We will continue to update the forecast as new information is made available and with time our models will improve.

Notes and key assumptions

Application count: The enabled market analysis is highly dependent upon the initial applications and the definition of photonic-enabled. For example, the use of photonics in an automobile is expanding significantly from year to year. However, the automobile is (and was) an automobile first, and utilizes photonics to improve performance, safety, and design. Therefore, within the automobile, applications are identified such as lighting, backup cameras, dashboard cameras, collision sensors, safety lighting. The whole value of the automobile is not included, just the photonic parts.

Foreign exchange: Revenue sources for every application are converted to US$. Nearly all sources are already converted to US$ at time of publication.

SPIE is the international society for optics and photonics

MOVING TECHNOLOGY TO MARKET.

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