Patent Analysis of The Global Laser Technology Development

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Abstract: Laser technology has a wide range of applications in modern industry. However, most existing studies have focused on the technical or application aspects, lacking of studies highlighted the technical development trend and competitive landscapes of laser technologies from the big picture. Therefore, this study presents a detailed analysis of patent documentation in Laser technology around the world, identifying research and development activities happening globally. As a result of the research, the publication trend of patent activity, the leading countries, the top patent holders in the considered technological field are identified. It also highlights a competitive landscape indicating the main competitive players in the laser technology market. Further analysis of the main technological segments and research hotspots landscape of the field of laser technology provide a detailed understanding of emerging innovations in the area.

Keywords: Patent Analysis, Laser, Technology Development, Patent Information, Competitive Analysis

1 INTRODUCTION

Laser term stands for light amplification by stimulated emission of radiation. The laser is often grouped with the transistor and computer as landmark inventions of the mid-20th century. Laser technology has a wide range of applications in optical communication, astronomy, laser processing, medicine, surgery, and health. Due to the cheap cost of manufacture and simplicity of utilization, laser plays an important role in almost every aspect of life and has enormous applications in lots of fields. Laser also acts as a key role in delivering encouragement for the emerging technological innovations. In this regard, the task of identifying the technical development direction of the innovation activity around the world, as well as analyzing the current competitive landscapes in the global market of laser technology, is relevant.

Patents are the tangible products of R&D efforts, which reflect the current innovative developments and direction of inventive activities in modem technology. 80% of technology information can be found in patent information which successfully identify technology

ICICA 2022, December 02-04, Chongqing, People's Republic of China

DOI 10.4108/eai.2-12-2022.2327993

opportunities[1]. Bloom and Van Reenen[2] proposed that patents act as key factors not only in exploiting knowledge, but also in improving a firm's productivity and increasing product differentiation. Patent are the foundation of longer-term competitive advantage. Patent analysis can enhance the understanding of the competitive behaviour of the industrial enterprises and assist to identify which countries/industrial firms are the loci of innovation activity[3]. Scientometrics studies dealing with patent literature have been reported recently[4-9]. Specially, scientometric study of the laser patent literature was presented by GARG[3]. Myers[10] provided a careful study of patent claims for deciding invention priority. On the basis of academic patents analysis, a technology network model was constructed [11] to reveal the development direction of laser technologies.

The present study aims to undertake a scientometric study of the laser patent literature around the world, exploring the technical development direction of laser technologies, forming a foundation for enlightening technical development direction and building protection strategies in the laser technology. Based on the patent analysis, this research has contributed to enlighten the laser technology development and competition ability around the world, which could serve as a reference for acknowledging current technological competition in a specific field.

2 DATA

IncoPat was used as patent information retrieval and analysis platform to analyze the patent of the global laser technology. Specially, competitor analysis was performed via Innography. The business data from Innography can help assess the company's market value and scale, help to analyze and compare the comprehensive strength of the patentee, and understand the market competition situation and trend[12-13]. The retrieval time of the paper is: June 16, 2022. Both the characteristic keywords and the corresponding categories of the IPC were used to search the ducumentation, and the search formula is: (TIAB = (laser) OR (lasers)) AND (IPC = (B25B) OR (B25J) OR (B28D) OR (B29C) OR (B29L) OR (B33Y) OR (B41C) OR (B41J) OR (B41M) OR (B42D) OR (B44B) OR (B60K) OR (B60Q) OR (B60R) OR (B60T) OR (B60W) OR (B65B) OR (B65G) OR (B82Y) OR (C01B) OR (C03B) OR (C03C) OR (C04B) OR (C08K) OR (C08L) OR (C09K) OR (C21D) OR (C22C) OR (C23C) OR (C23F) OR (F21K) OR (F21S) OR (F21V) OR (F21W) OR (F21Y) OR (F42B) OR (G01B) OR (G01C) OR (G01D) OR (G01J) OR (G01K) OR (G01L) OR (G01M) OR (G01N) OR (G01R) OR (G01S) OR (G01W) OR (G02B) OR (G02F) OR (G03B) OR (G03F) OR (G03G) OR (G03H) OR (G05B) OR (G05D) OR (G05F) OR (G06F) OR (G06K) OR (G06N) OR (G06T) OR (G08G) OR (G11B) OR (G11B) OR (G16H) OR (H01C) OR (H01F) OR (H01L) OR (H01M) OR (H01R) OR (H01S) OR (H02G) OR (H02J) OR (H02M) OR (H03B) OR (H03C) OR (H03D) OR (H03F) OR (H03K) OR (H04B) OR (H04L) OR (H04N) OR (H05G) OR (H05K) OR (B26F) OR (H01J) OR (F21S) OR (C07D) OR (C08G)) AND (PD=[20010101 TO 20211231]). Based on the retrieval function of IncoPat, 571,545 patents were acquired after merging application No. On this basis, 489,282 inventor patents related to laser technology was choose to carry out the patent analysis.

3 PATENT ANALYSIS OF GLOBAL LASER TECHNOLOGY DEVELOPMENT

3.1 Global Laser Patent Publication Trend

The publication trend of laser technology from 2001 to 2021 is shown in Figure 1. The overall dynamics of the global publication trend is characterized by a negative trend in the first decade (2001-2010) and a positive trend in the second decade (2011-2021). The publication trend of China was consistent with that of global patent publication since 2011, and China has surpassed Japan and the United States become the major contributors to the growth of the laser technology patent publication since 2012. It can be seen that China has the largest number of inventions, indicating that China has flourished in the field of laser technology, and China embodies a strong competitive strength. However, both the industrial and academical organizations in China began the research of laser technology later than foreign countries, which leaded to gap between China and other advanced countries in the field of laser regarding the key technologies, such as core components, laser light source, laser device and etc.

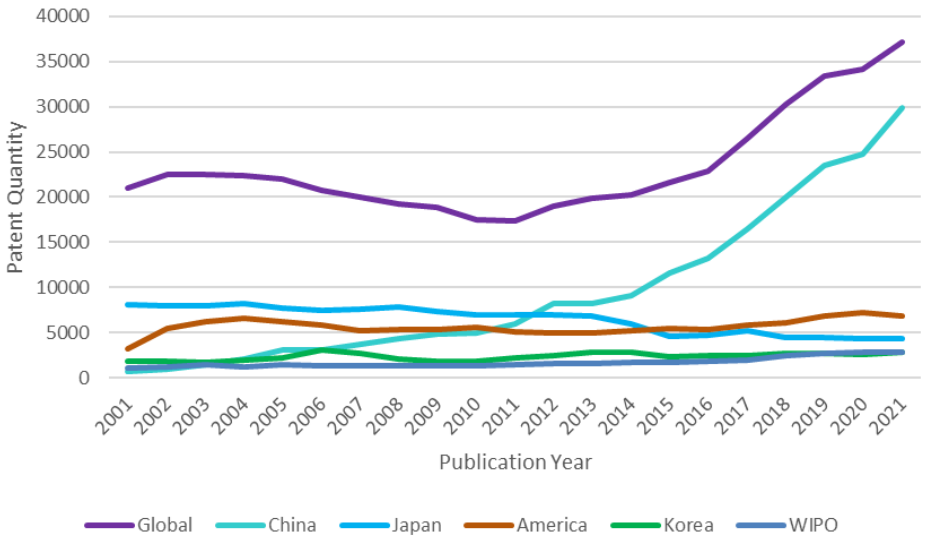

Figure 1. Publication trend of laser technology from 2001 to 2021

3.2 Regional Analysis

On the basis of Regional Analysis, the Global Laser Technology Innovation Market is classified into Asia Pacific, North America, Europe and Rest of the world. The Asia Pacific, represented by China, Japan and South Korea, is estimated to account for the largest market size. Among all the counties, China(29%), Japan(21%) and America(16%) are the major contributors to the growth of the Laser Technology Innovation Market (Figure 2). China is the leading country holding 143,495 patents in the area of laser technology, followed by Japan with 102,010 patents, and the United State holds 76,634 patents. The continuous investments

in research and development activities, huge population base, growing demand for cost-effective and fast processing laser machine tools are boosting the market for these countries.

The patent priority system was originally established for the Protection of Industrial Property by the Paris Convention in 1883, which aims at assisting applicants in filling a subsequent application in another contracting state after filing their first application in their own country. Figure 3 shows the number of priority patent application in domestic and foreign countries or regions. The number of priority patent application in foreign countries or regions represents the market value of patent rights. In general, if a patent is filed in several different foreign countries or regions, it represents the patents with a high market value. Because the number of priority patent applications reflects the efforts and cost incurred by the patentees in order to protect their rights within a broader geographical scope .

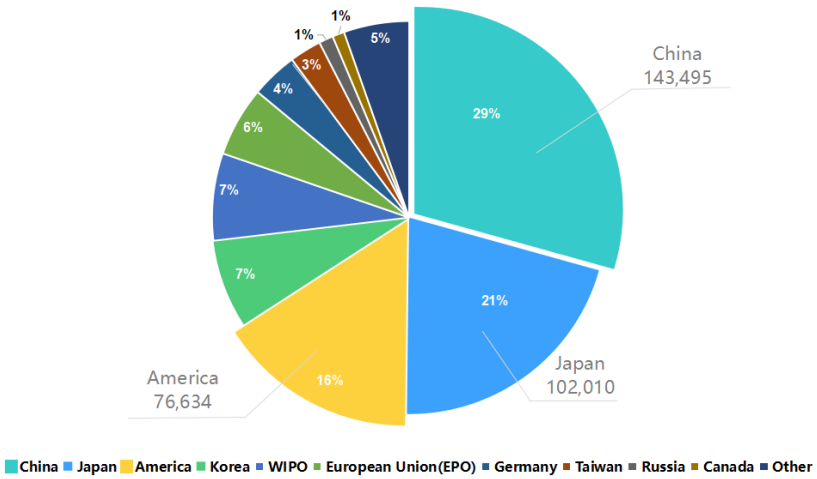

Figure 2. Global Region Ranking (Publication Country/Patents Quantity)

Japan is the most active country in filling priority patent application in foreign countries or regions in the laser area, followed by Germany and the U.S., indicating the main competition players globally. Due to the advantage of entering the laser industry earlier, the laser technologies of Japan are relatively mature. Thus, Japan has the highest rates of priority patent application in foreign countries or regions. Especially, although the total number of laser patents in Germany is a lot less than China, Germany attach great importance to the overseas patent layout. On the contrary, China holds the largest number of laser patents, while China has the lowest rate of priority patent application in foreign countries or regions. This analysis results showed that China has not paid enough attention to overseas patent layout, which will lead to the risk of patent infringement when Chinese players get involved into the global laser market competition.

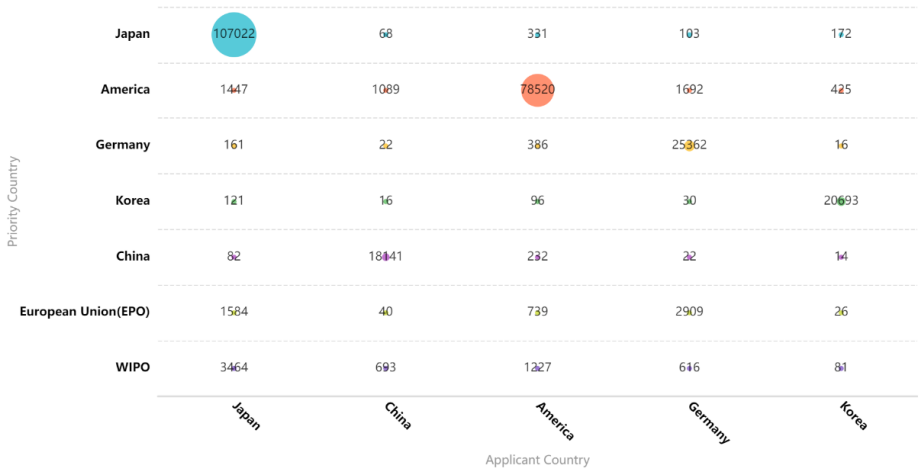

Figure 3. The number of priority patent application in domestic and foreign countries or regions

3.3 Applicant and Competitor Analysis

The analysis to identify the Top 10 applicants in the field of laser technology was also conducted, and the results are presented in Figure 4. The South Korea company "Samsung Electronics Co. Ltd." ranks first with 4,325 published patents in the field of laser technology globally. Except for Samsung, the rest of the major applicants in laser technology are Sony Corp., Matsushita Electric Ind Co. Ltd., Fuji Photo Film Co. Ltd., Mitsubishi Electric Corp., Canon KK, Ricoh KK, Sharp KK, Seiko Epson Corp., Toshiba Corp. Among the top 10 applicants in the world, there are 9 industrial firms from Japan, which shows that Japan is the leading country filling patents in the area of laser technology.

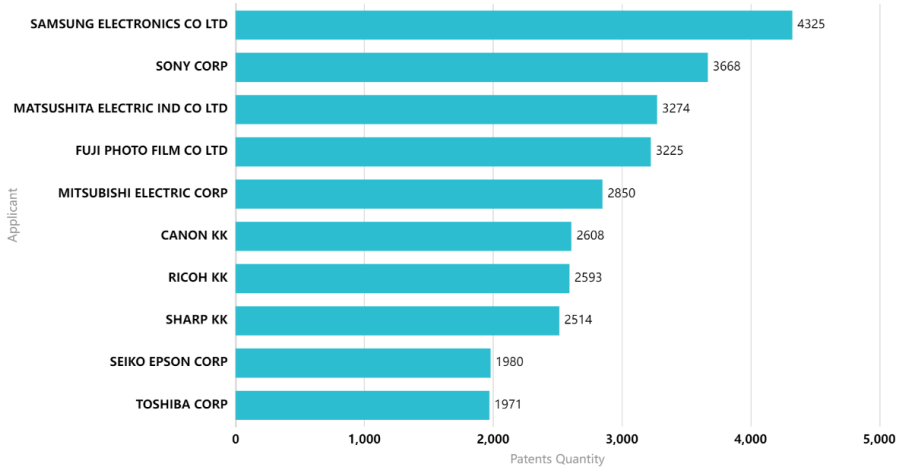

Figure 4. Number of published patent cases for the Top 10 applicants in laser technology

Innography's patent applicant's bubble analysis chart is an excellent way to create useful, competitive landscapes [14]. By integrating a resources (vertical) axis and a technological (horizontal) axis into the plane coordinate system, reflecting the comprehensive economic strength and the technical gap among the patent applicants directly. The number of patents was represented by the bubble size. And the horizontal axis represents the applicant's technological index, related to the proportion of patent, patent classification and citations, the larger the abscissa of the patent technology patent applicant is stronger. The ordinate represents the enterprise strength index, related to the patent applicant's revenue, litigation and locations, ordinate the more that the applicant has the stronger economic strength [15]. The competitive positions of the top 5 patentees from China, Japan and the United State is shown in Figure 5, in order to performing competitor analysis among the 3 most competitive countries all over the world. As shown in Figure 5, there are 9 patentees from the industry and 5 patentees from the academia. Among these top patentees from these 3 countries, the patentees from Japan and the U.S. are mainly enterprises, such as Sony, Panasonic, Coning. Specially, Sony Group Corporation holds the largest number of patent technology of the strongest in the field of laser. However, the top 5 Chinese patentees are all from academia, indicating that there is a gap between industry and technology innovation. Both Sony Group Corporation and Panasonic Corporation located in the upper right quadrant area, indicating that these two enterprises are powerful leaders in the global laser technology. However, the top 5 pantentees from China are all located in the area of lower right quadrant, reflecting that China lacks of competitive organizations in laser technology area.

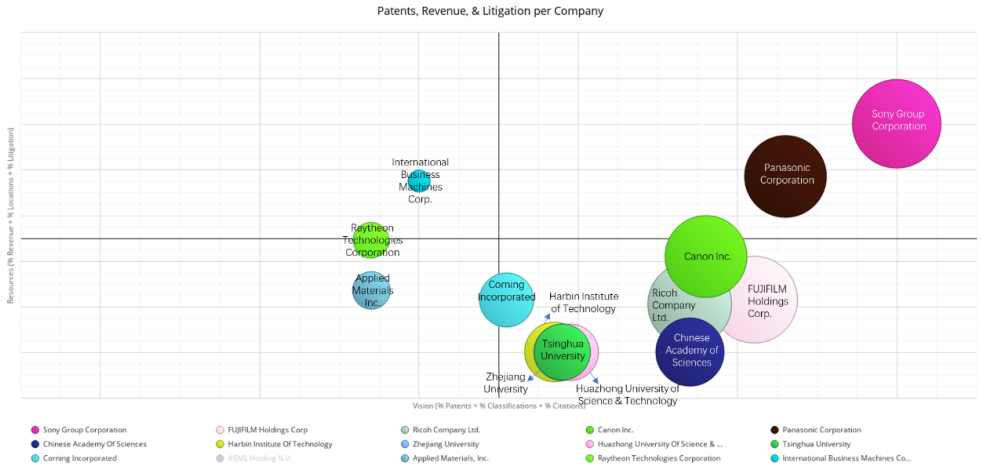

Figure 5. Competitive position of top 5 patentees from China, Japan and the U.S. respectively

3.4 Patent Strength analysis

Scherer and Harhoff revealed that the top 10% of the most valuable patents account for 48% to 93 % of the whole patent value [16], which indicated that more attentions to analysis the high value patents to dig out research hotspots and technology development in laser area should be attached. Patent strength, as a new patent evaluation indicator of Innography, includes more than 10 key factors, such as forward citation, backward citation, claim and family numbers, patent licensing revenue, etc. According to the scale for patent strength

developed by Innography, patents with the patent strength 80-100% represents as core patents. The patent strength 30-80% is classified as an important patent in the technology field, while the patent strength of 10-30% is classified as the general patent in the technology field. By setting the patent strength from 80% to 100%, 8926 patent families were retrieved after simple (EPO) family reduction. As shown in Figure 6, top 20 patentees regarding the number of core patents being held is concerned. Semiconductor Energy Laboratory Co., Ltd.(Japan) outstrips other patentees, with 281 core patents, followed by Honeywell International Inc.(142, the U.S.), ASML Holding N.V.(113, Hoodlan), II-VI Inc.(113, the U.S.), MSK Instruments Inc.(109, Japan), Panasonic Corporation(107, Japan), Corning Incorporated(106, the U.S.), Samsung Electronics Co., Ltd(99, Korea), Western Digital Corp.(95, the U.S.), Coherent, Inc.(82, the U.S.) and Hamamatsu Photonics K.K.(82, Japan). According to the top 20 patentee' licensing revenue, the 10 patentees from the U.S. accounted for 9.87% of the total core patent families, while Japan ranked in the second place with 6 patentees. Europe has 3 assignees and Korea has 1 assignees.

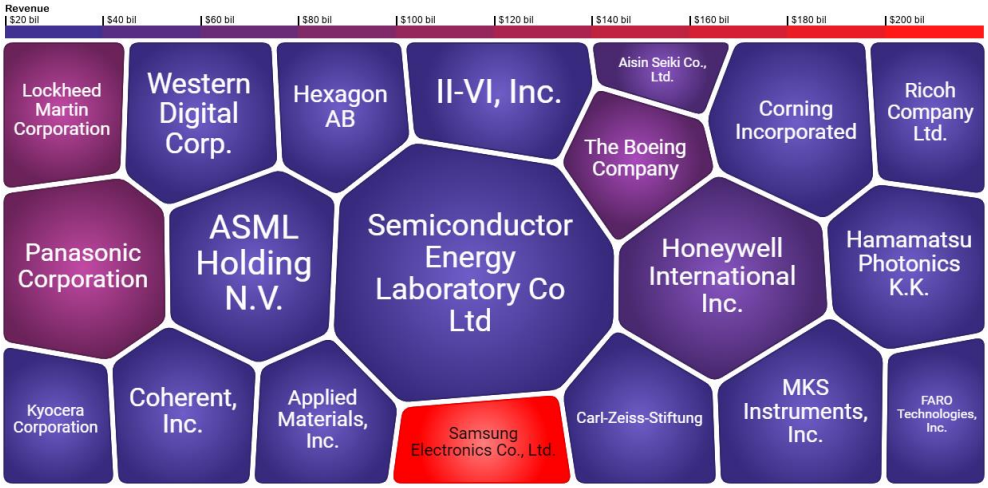

Figure 6. Heat chart of top 20 patentees regarding the number of core patents being held

3.5 Technology Analysis

The distribution of the patent quantity in the Top 10 technology areas is shown in Figure 7, and the definition of IPC code was displayed in Table 1. Results in Figure 7 indicate that the technologies mostly lie in the H01S3, H01S5, B23K26 and H01L21 category. According to the IPC classification system, H01S3, H01S5 and H01L21 represent laser and semiconductor devices; B23K26 represents laser processing, laser welding, laser cutting, laser boring etc. It can be seen that the innovative activities of laser are mostly focused on the laser device development represented by H01S3 and H01S5, as well as the laser processing technology represented by B23K26.

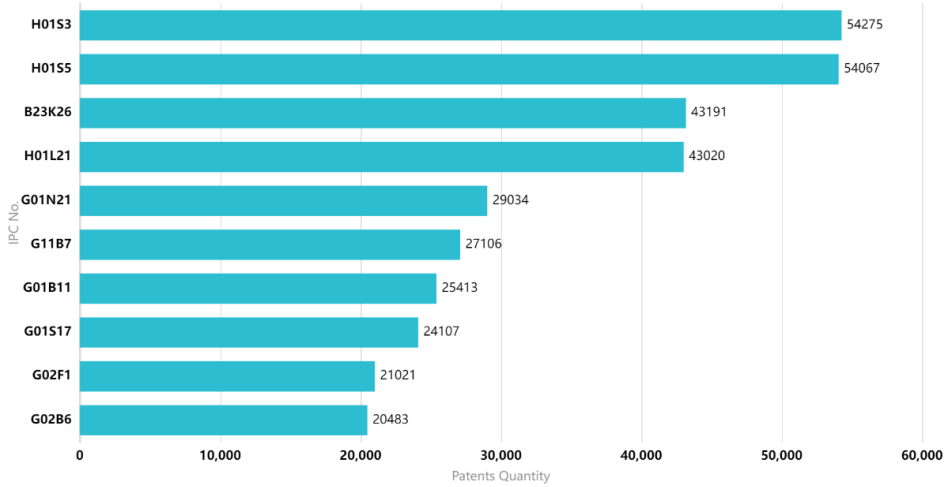

Figure 7. Frequency distribution of the Top 10 technical domains

Table 1. The definition of the Top 10 IPC codes

IPC No.	Notes
H01S3	Lasers, i.e. devices using stimulated emission of electromagnetic radiation in the infrared, visible or ultraviolet wave range
H01S5	Semiconductor lasers
B23K26	Working by laser beam, e.g. welding, cutting or boring
H01L21	Processes or apparatus specially adapted for the manufacture or treatment of semiconductor or solid state devices or of parts thereof
G01N21	Investigating or analysing materials by the use of optical means, i.e. using sub-millimetre waves, infrared, visible or ultraviolet light
G11B7	Recording or reproducing by optical means, e.g. recording using a thermal beam of optical radiation, reproducing using an optical beam at lower power; Record carriers therefor
G01B11	Measuring arrangements characterised by the use of optical means
G01S17	Systems using the reflection or reradiation of electromagnetic waves other than radio waves, e.g. lidar systems
G02F1	Devices or arrangements for the control of the intensity, colour, phase, polarisation or direction of light arriving from an independent light source, e.g. switching, gating or modulating; Non-linear optics
G02B6	Light guides; Structural details of arrangements comprising light guides and other optical elements, e.g. couplings

To better understand the development trends of laser technology, further analysis of the yearly changes of H01S3, H01S5, B23K26, H01L21, G01N21, G11B7, G01B11, G01S17, G02F1 and G02B6 technology domains in the patents of laser technology was presented. As Figure 8 shown, the results indicate that laser lidar system represented by G01S17 have been developed quickly as a popular technology since 2016. On the contrary, laser recording technology

represented by G11B7 reach its peak in 2006 and has gradually faded out of the main technology category.

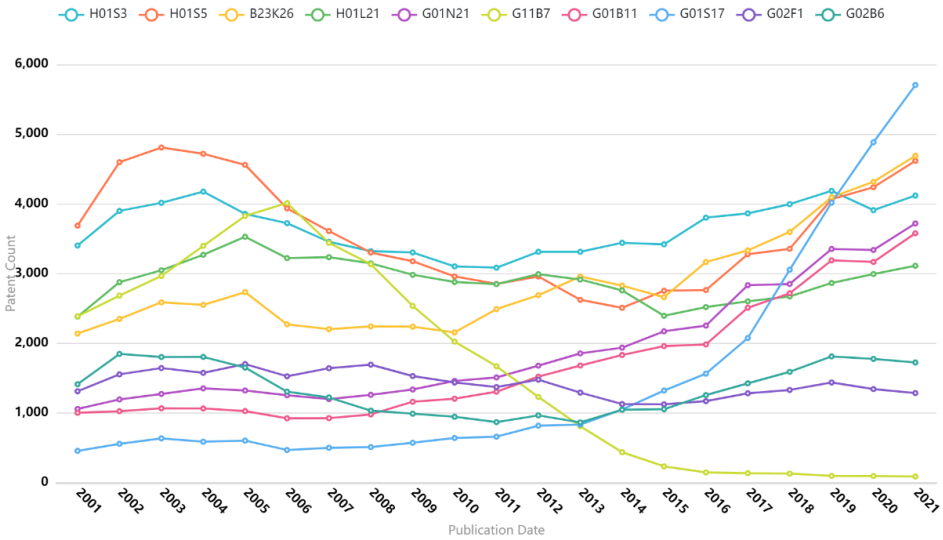

Figure 8. Development trends of the key technical domains in the laser technology

It can be seen that patent publication of laser device represented by H01S3 and H01S5 mainly originate from China, Japan and the U.S., while Japan lead the world regarding the patent number of the semiconductor lasers represented by H01S5 and laser processing represented by B23K26. As shown in Figure 9, China lack of patents of laser recording technology (G11B7) which has gradually faded out of the main technology category, while China attach great importance to the laser lidar related patents (G01S17) layout by holding the largest patent fillings. In another word, China is expected to build technical barriers in laser lidar technology through global patent layout.

Figure 9. IPC classification distribution of top 5 countries or region

3.6 Research Hotspots Analysis

In order to reveal the research hotspots and technology opportunities of laser technology, we used Innography to make a text clustering analysis of 69111 patent families which is acquired by screening the active utility patents with patent strength larger than 30% after simple (EPO) family reduction. As Figure 10 shown, patent technology research is mainly concentrated in 15 core areas: Laser Light Source, Point Cloud, Laser Radar, Laser Device, Optical Signal, Resonant Cavity, Structured Light, Gain Medium, Measuring System, Semiconductor Layer, Laser Irradiation, Femtosecond Laser, Reflecting mirror, Laser Processing, 3D Printing, etc. And the core ares cover the upstream (optical components), midstream (laser device) and downstream (laser processing) of laser industry.

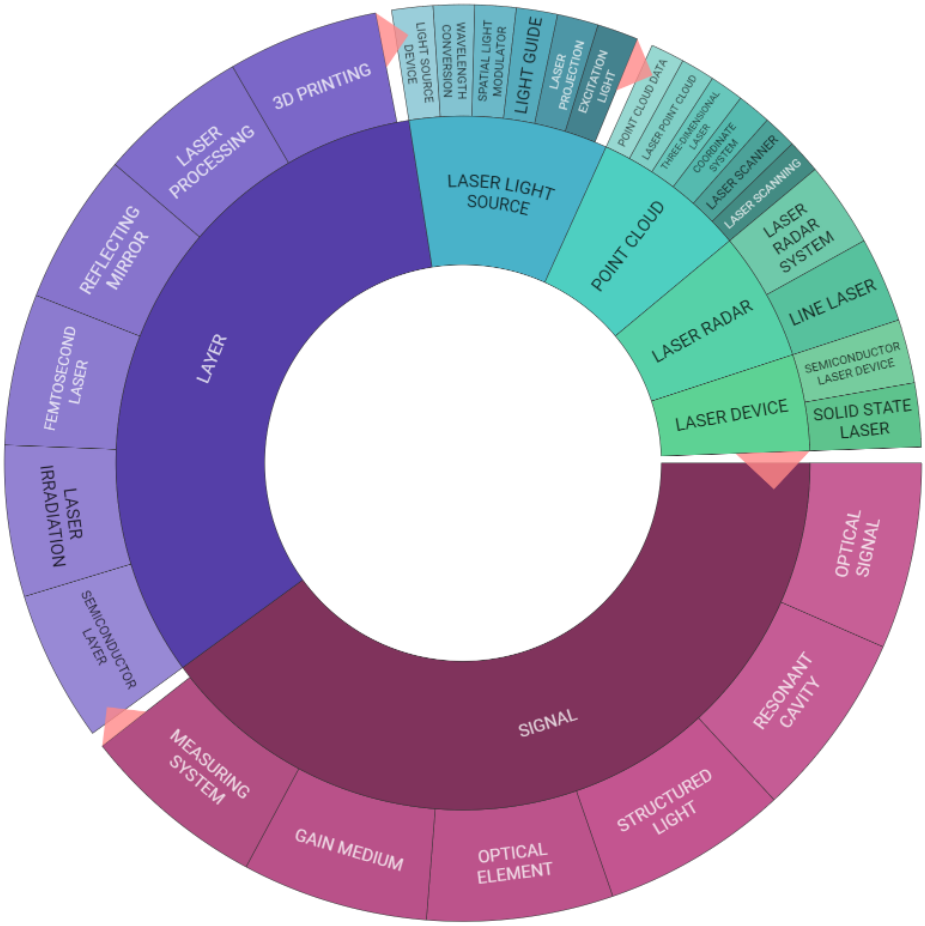

Figure 10. Clustering analysis of important and core utility patent families

4 CONCLUSION

This study serves as a scientometric research in the area of laser technology based on patent analysis. In the past decade, the increasing patent quantity indicates that more and more academic researchers and industry practitioners have focused on the laser technology development. Taking the bias and noise into consideration, proper patent indicators, including the publication trend, regional analysis, patent applicant and competitor analysis, patent strength, technology and patent hotspots were seleted to study the global development of laser technology. As for patent quantity, China is the leading country filling 143,495 patents in the field of laser technology. However, indicators evaluated patent quality, including the competitive position analysis of top assignees and numbers of core patent with high patent strength, shown that there are still a great gap between China and Japan or the U.S.. Further analysis of the main technological segments and research hotspots landscape of the field of laser technology revealed that the laser lidar is an emerging innovation, and China attach great

importance to the laser lidar related patents layout by holding the largest patent fillings. Based on the patent analysis, this research has contributed to enlighten the laser technology development and competition ability around the world, not only acknowledging technological competition in the field of laser technology currently, but also inspiring the future directions.

ACKNOWLEDGMENT. This research was funded by The National Social Science Fund of China (Grants No. 19BTQ074).

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