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Number of Claims for Evaluation of Individual Patent Based on LiDAR Technology

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***Abstract*—Patent quality measurement is very important, many quantitative indicators express the importance, strength, or value of a patent. This article explores the relationship between two indicators, one is number of claims, the quality of the patented document itself, another is number of citations, the value of invented technology. A worldwide popular and developing technology, light detection and ranging system, was selected to demonstrate the analysis based on US patents. Individual patents of six sub-technologies are shown on two dimensional bubble diagrams. Traditional patent strength indicators are collected as total strength to be bubble size.**

The results show that the number of claims as an indicator of patented document is highly influenced by legal framework and excess fee, the number of citations as an indicator of invented technology is representative, a roughly positive relationship between the two indicators, and extreme cases with special meaning should be noticed.

Keywords— patent strength; patent map; patent indicators; number of claims; LiDAR.

I. INTRODUCTION

In the era of knowledge economy, the speed of knowledge update is getting faster and faster. It is important activity for companies to apply patents for research and development results to obtain exclusive rights protection. According to statistics from the World Intellectual Property Organization (WIPO), the total number of patent applications worldwide in 2020 reached 3.3 million [1]. The value of so many patents varies greatly, patent strength evaluation or patent quality measurement are very important research fields but still very difficult to quantify comprehensively in current research. Patent strength, patent value, patent quality, patent scope, and patent novelty, are all terms often used to assess the importance, impact, value, or significance of a patent. Any quantitative indicator is to extract the data on patent bulletin, no anyone indicator can fully express the value of a patent, to add up multiple indicators from different aspects to total strength is normal in industrial evaluation. So many indicators can be roughly divided into two categories. One is the value related to patent applications, which based on the cost of the applicant's patent application, or the quality of the patented document itself, mainly including number of claims, scope of claim, and size of patent family. Another is the value of invented technology, which is the quality of patented technology itself, mainly including patent forward and backward citation, and broadness of patent classification. The former related to the subjective investment in patent fees and cost of the applicant, and the latter is an objective technical value. Whether subjective value and objective value are related, and if so, what is the relevance? In particular, the two most representative indicators, number of claims and citations. This study will explore it by case study.

A hot technical topic, light detection and ranging, or LiDAR, is the subject of this study. In response to the rapid technological evolution and the expected rapid growth of the market, 3D laser scanning technology has been a hot research topic in recent years. This technology is mainly used to scan object and provide distance information. Its applications are from satellite telemetry, auto drone, autonomous driving, and facial recognition. The most popular in the last ten years is medium-distance static and dynamic object detection for autonomous vehicles or robots [2], the LiDAR uses light pulses or frequency modulated and receives reflected signals from objects. Optical interference or coherent technology calculates the distance of objects, from traditional beam steering or flash lighting form, mechanical rotating type, evolve into solid-state module type. Technology developers are very interested in the most important patents in order to formulate advanced R&D proposals. Patent strength indicators can also be used to quickly identify important patents from database for them instead of labor search. This article will use indicators to identify extreme patent cases and examine their value from the perspective of experts.

II. LITERATURE REVIEW

Many patent strength indicators have been proposed in the past. The number of patent citations is most often used to evaluate the strength or quality of a patent from a technical point of view. The basic concept is the higher number citing former, or cited by later filing patents or technical documents, the higher

technical value of the patent. Important inventions are usually developed on more prior technical documents and are also cited by more patent applications. Any invention is based on prior arts, and patent citations in the patent gazette show high relevance prior patents or technical papers of the issued patents. The use of citation documents to evaluate patent strength has been around since the 1990s, long literature will not be discussed here. Tseng (2011) [3] has divided the patent indicators developed by previous scholars in 13 papers into different types according to attribution and purpose, and classified these indicators into three stages according to purpose, including motives, technological strategy, and value-produced. It has been validated by empirical study that more frequently cited patents have higher technological and economic impacts (Fisher, 2014) [4]. Patent strength analysis can be applied to the strength of patent cases, and the strength of patent portfolios held by competing companies and Institutes. A fundamental patent in a technical fields usually has the highest number of citation as prior art by subsequent patents, Liu (2014) [5] obtained basic patents for various types of additive manufacturing technology. Alvarez-Meaza (2019)[6] evaluated patent value and impact on further developments of additive manufacturing technology of competitors by forward citation and the size of patent family.

Citations are mainly patent documents, but more and more patents citing scientific papers, United States Patent and Trademark Office (USPTO) patents before 1980 has less than one citation to science on average, but more recently the average has been more than four citations per patent (Marx 2020)[7]. In general, more valuable patents are cited more, but using novel revenue data held by non-practicing entities (NPEs), Abrams (2018)[8] found that the relationship between citations and value forms an inverted-U, with fewer citations at the high end of value than in the middle. Kwon (2021) [9] empirically examines the prevalence of weak patents in the United States and whether or not the current patent system is capable of correcting weak patent issues, and propose a method to identify weak patents by using patent citation information in conjunction with the textual similarity between citing and cited patents, to get 13% of U.S. patents filed from 2001 to 2010 are weak patents. Higham (2021) [10] utilize applicant forward citations and examiner forward citations to get relative importance and evaluate patent quality.

The size of patent family is another indicator of patent strength, a patent family is a set of patents taken in various countries to protect a single invention. The larger size of family, the higher value of the patent, because the applicant attaches great importance to the invention and is willing to spend the cost to obtain more national patents. Some previous papers have used members of a patent family to evaluate its strength. Harhoff (2002) [11] has ever evaluated the value of patents not only by citations but also family size, which can represent worldwide patent strength. However, the market covered in a country may be quite different from another country, an invention with a larger patent family size may cover narrower market than a smaller one. A family could be a simple family, complex family, or extended family, depend on the priority documents share[12], the definition of patent family has to clarify to determine the patent strength (Liu, 2014) [13].

The number of words of claim can evaluate patent strength, Kuhn (2019) [14] introduced a way of measuring patent scope according to the length of the patent's first claim, who points out longer claims producing narrower scope, and extensively validate this measure agrees with qualitative pronouncements by practitioners, patent evaluations by patent attorneys, and the behavior of applicants. The author find that previously proposed measures of patent scope, including counting the number of patent classes, counting the patent's citations, and counting the number of claims in a patent, are all either misleading or uninformative, the number of patent classes is negatively correlated with scope, the citations to a patent are so weakly related scope as to be of no use to patent scholars, the number of claims in a patent is correlated with patent scope, but this relationship is quite weak. Marco (2019) [15] developed and validate two measurements of patent scope: independent claim length (ICL) and independent claim count (ICC), obtained the kernel densities for the distributions of ICL and ICC for application years 2001-2014, the examination process narrows the ICL scope and increases the mean ICL form 106 words at publication to 156 words, and the mean ICC of grant patent is 3.08 claims.

Lee (2015) [16] developed a novelty-focused patent identification map by combining the novelty indicator together with the number of patent citations and the number of patent claims. A case study of the patents about thermal management technology of light emitting diode is exemplified. The patents having higher citation counts are classified as influential, having higher number of patent claims are categorized inimitable. Sven (2019) [17] defined a normalized technological patent scope indicator through a semantic patent analysis of patent claims. The linear regressions between the patent scope and several indicators of the three technologies DVD, HD-DVD and Blu-ray disc are provided.

Patents can be used two indicators as coordinate axes to draw on a 2D patent map and divided into four quadrants, to visualize some valuable information by their locations. Kim (2021) [18] shows Dyson's patent products on design innovation and technology innovation map, to get whether innovation design or technology driven. Liu (2020) [19] has ever collected them as total strength to get leaders of LiDAR competitors, and visualize different aspects on 2D diagrams.

It can be seen from the above literature that there are many patent strength indicators for various

aspects, simple indicators are taken directly from bibliographic information. All simple indicators commonly used in the past will be collected as traditional indicators and sum up as total strength in this study. It is a reasonable presumption that the total strength is more representative than a single indicator or a few indicators. The total strength of individual patents will show on 2D map, and the number of claims and citations as the two coordinate axes, we can get the correlations between two coordinate indicators, and find out if individual indicator positively related to the total strength. Furthermore, this article will explore the results from a legal point of view that was rarely used in the past, and the aforementioned important literature results or conflicts also be reviewed and discussed.

III. Data Collection and Methodology

A. Selected indicators of patent strength

There are seven simple indicators were selected in the following, and sum them after normalization to get traditional total patent strength for individual patent:

A1 Published members of one patent family: patent documents based on exactly the same priority, including continuous and divisional application.

A2 Issued members of one patent family: members issued of one patent family.

A3 Independent claims: the average numbers of independent claims for one application.

A4 Numbers of IPC subclasses: the numbers of technologies finished by one applicant based on International Patent Classification classes.

A5 Classifications: the numbers of technologies finished by one applicant based on the concept of technical experts.

A6 Cited numbers: cited families of every patent family in year average.

A7 Citations: average numbers of citations for one patent family, including patent and non-patent citations.

B. Patent pool and overview of LiDAR technology

Under the expert opinion, LiDAR technology including six sub-technologies: Solid State LiDAR, Optical Phase Array, Optical Beam Steering, Tunable Laser, Hybrid Laser, and Silicon Photonics Optical Coupling. The mechanical rotating LiDAR has restricted structure, volume, and receiving efficiency due to physical properties, on the other hand, Solid State LiDAR is based on optical phase array, has become a hot spot in technology research and development in recent years.

The search strategy is six topics separately in the USPTO official database (USPTO AppFT) and combine them. Using these six technical themes as keywords in title or abstract, publication date between January 1, 2001 and December 31, 2020. The search quires and results are shown in Table 1. Number of documents obtained from 41 to 778.

We combined them to get 1923 documents in total, some documents are appeared in multiple topics, as LiDAR patent pool.

Table 1 Search quires of this study (PD/20010101-20201231)

Topics	Search string	hits
Solid state LiDAR	((TTL/"solid state$" OR ABST/"solid state$") OR (TTL/"solid-state$" OR ABST/"solid-state$")) AND (TTL/"LIDAR" OR ABST/"LIDAR")	41
Silicon photonics optical coupling	((((TTL/"Silicon photonics$" OR TTL/"optical coupling$") OR (ABST/"Silicon photonics$" OR ABST/"optical coupling$") OR (SPEC/"Silicon photonics$" OR SPEC/"optical coupling$")) AND (TTL/"LIDAR" OR ABST/"LIDAR")) OR ((TTL/"optical coupling" OR ABST/"optical coupling") AND (TTL/"photonics" OR ABST/"photonics"))) AND PD/20010101->20201231	121
Hybrid laser	((((TTL/"hybrid laser$") OR (ABST/"hybrid laser$") OR (SPEC/"hybrid laser$")) AND ((TTL/"LIDAR") OR (ABST/"LIDAR") OR (SPEC/"LIDAR"))) OR (TTL/"hybrid laser" OR ABST/"hybrid laser"))	105
Optical beam steering	((((TTL/"beam steering$") OR (ABST/"beam steering$") OR (SPEC/"beam steering$")) AND (TTL/"LIDAR" OR ABST/"LIDAR")) OR (TTL/"beam steering$" AND ABST/"beam steering$" AND (SPEC/"LIDAR" OR SPEC/"light detection and ranging" OR SPEC/"light")))	471
Optical phase array	((((TTL/"optical phase array$" OR TTL/"optical phased array$") OR (ABST/"optical phase array$" OR ABST/"optical phased array$") OR (SPEC/"optical phase array$" OR SPEC/"optical phased array$")) AND (TTL/"LIDAR" OR ABST/"LIDAR")) OR (SPEC/"optical phase array" OR SPEC/"optical phased array"))	650
Tunable laser	((((TTL/"Tunable Laser$") OR (ABST/"Tunable Laser$") OR (SPEC/"Tunable Laser$")) AND (TTL/"LIDAR" OR ABST/"LIDAR")) OR (TTL/"Tunable Laser" OR ABST/"Tunable Laser"))	778

Fig.1 is the trend of LiDAR technology patent applications in the United States in the past two decades. Looking at the overall application trend, it remained stable before 2010, except for a slightly higher level in 2004, during 2011 to 2015 is a slow growth period. After exceeding 100 applications for the first time in 2016, it enters a period of rapid growth. The 2019 and 2020 applications have not yet been wholly published, because the publication date is 6 to 18 months behind the application date. We can predict that there will be about 340 in 2019, and 456 in 2020, based on published percentage.

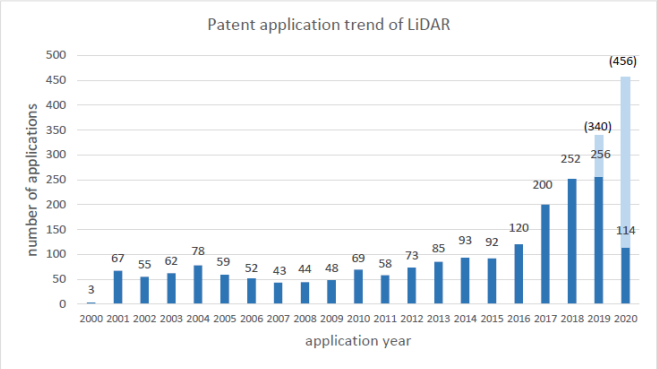

Fig.1 Patent application trends of LiDAR

IV. ILLUSTRATION

A. Number of citations and claims correlated to total strength

We visualize all LiDAR patents as bubbles on 2D map in six sub-technologies separately, the horizontal axis is normalized number of claims, the vertical axis is normalized number of citations, and the bubble size is proportional to the normalized traditional total strength. Lee (2015) [16] called it novelty-focused patent identification map, the patents having higher citation counts are classified as influential, and the patents having higher number of patent claims are categorized inimitable.

Fig. 2 is the correlation map of 41 Solid State LiDAR patents, we can observe that the bigger the bubble, the farther away from the origin. It means that the total strength and is positively correlated with citations and number of claims.

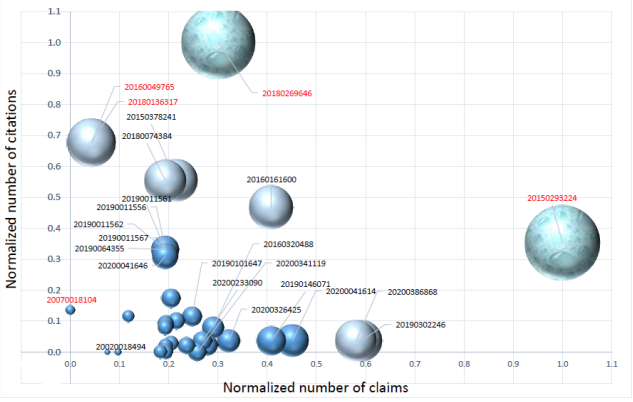

Fig.2 Correlation map of 41 Solid State LiDAR patents

The US20150293224, which title is solid state optical phased array lidar and method of using same, has the largest number of 95 claims, but only 49 citations. On the other hand, the US20180269646, solid-state laser for lidar system, has the most 139 citations but only 30 claims. The count of claims mostly concentrate between 0.2 to 0.3, equivalent to 20 to 25 claims, which should be affected by excess fees for each claim in excess of 20 charged 100USD, and each independent claim in excess of three charged 480USD (USPTO fee schedule, effective January 2, 2021) [48]. The minimum number of claims is US20070018104 with only 2 independent claims, the next two patents are US20160019764 with 7 and US20180136317 with 6, the latter is a continuation application of the former.

Fig. 3 is the correlation map of 121 Silicon Photonics Optical Coupling patents. The distribution of bubbles can be divided into three concentric circles from origin, most of them concentrated in the inner circle, medium size in the second circle, the top five total strength patents in the third circle are far away from the origin. The top number of claims is 112 owned by US2018102442, the next is US20060231771 with 97 claims but only 11 citations. On the contrary, US20150153453 has only 3 independent claims. The top three citations are US20200064476 with 266 citations, US20190179015 and its continuous application US20190187284 with 227 citations.

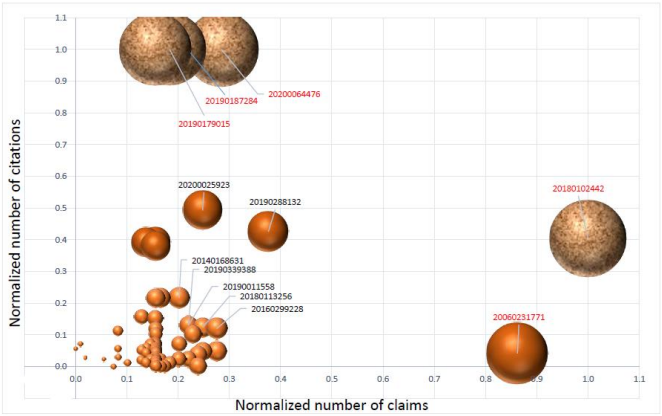

Fig.3 Correlation map of 121 Silicon Photonics Optical Coupling patents

Fig. 4 is the correlation map of 105 Hybrid Laser patents. Its distribution pattern is similar to Solid State LiDAR and Silicon Photonics Optical Coupling. Small bubbles gather below (0.4, 0.4), in this cluster, some bubbles on the line near x=0.22, which is 20 claims, it is clear in the map that many applications are affected by claim excess fees. Of course, there are still some applications that are willing to pay excess fees, but

most of them are not higher than 30 claims (normalized 0.33), and the largest one is 91 claims of US20050030540.

Big bubbles gather at a higher position on the vertical axis, there are many patents with high citations, and they are also high total strength patents. The number of citations is positively correlated with the total traditional patent strength. The highest one is US20120187096 with 130 citations but 15 claims, this case is an application from Germany, and may be subject to the excess fees for more than 15 claims in EPO [49], and apply for US patent with the same specification.

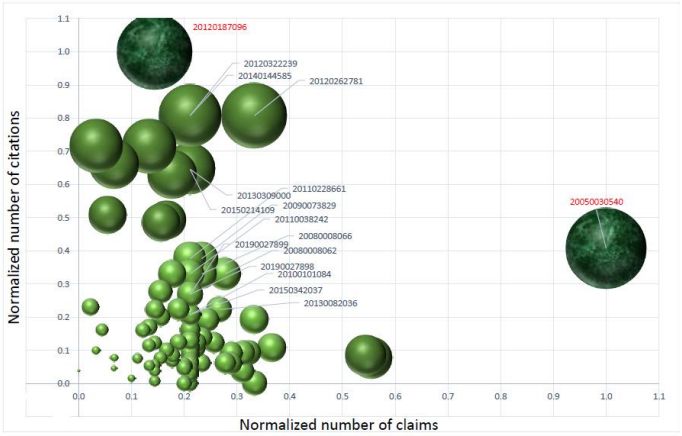

Fig.4 Correlation map of 105 Hybrid Laser patents

Fig. 5 is the correlation map of 471 Optical Beam Steering patents. It is interesting that all the bubbles are almost concentrated in the area less than 0.3, except two bubbles are far away origin, one is US20030024912, micro-machining system employing a two stage beam steering mechanism, with huge claims as 728, which needs excess fees of 70,800USD today. The other is US20180003805, holographic waveguide lidar, with 749 citations but only 20 claims.

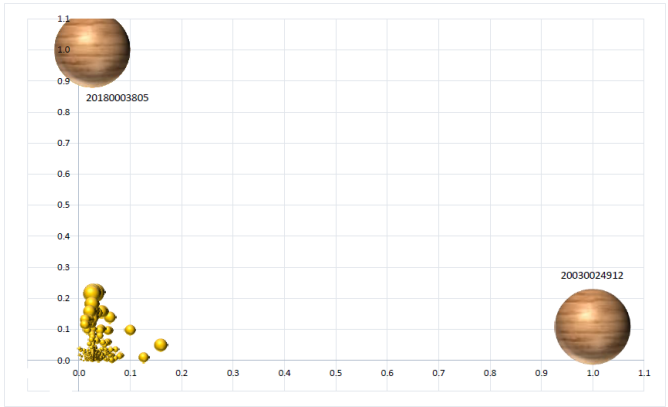

Fig.5 Correlation map of 471 Optical Beam Steering patents

Fig.6 is partial enlarged view of Fig.7, it shows two similar distribution with Fig.7, one is clustered on the line of 20 claims, the others have positive relationship between total strength and number of citations.

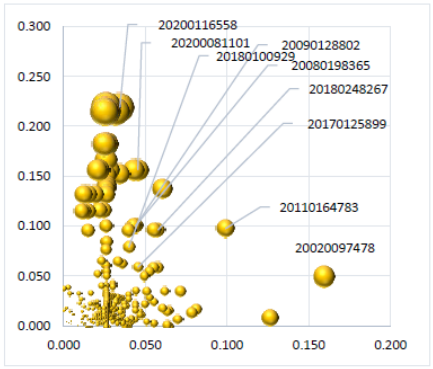

Fig. 6 Partial enlarged view of the correlation map of 471 Optical Beam Steering patents.

Fig. 7 is the correlation map of 650 Optical Phase Array patents. It can be observed that many small bubbles gather in the block between normalized claims 0.1 to 0.2 and normalized citations less than 0.1. The largest bubble on the right hand side is US 20030063484, which has 160 claims but only 14 citations. The density of the bubbles between normalized claims 0.1 to 0.2 is much higher than 0.2 to 0.3, most patents have 20 to 30 claims again. It is very rare that the US20200191916 has only one claim but 176 citations, it is the fourth generation of continuation application, parent applications are unlikely to have only one claim.

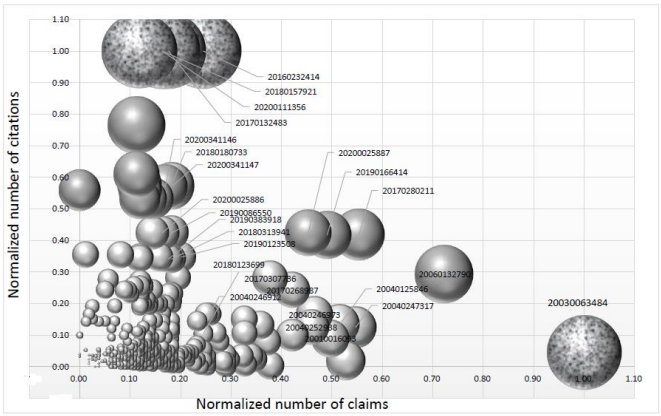

Fig.7 Correlation map of 650 Optical Phase Array patents

Fig. 8 is the correlation map of Tunable Laser patents, there are as high as 744 patents on this map, the highest number in six technical fields, but the phenomenon is similar. The biggest two bubbles US20030034538 has 158 claims, and US20090225325, continuation of US20050231729, has 267 citations.

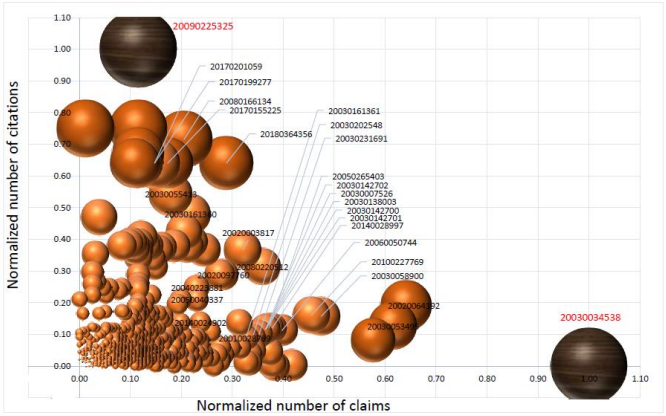

Fig.8 Correlation map of 778 Tunable Laser patents

B. Review of extreme cases

After discussing six technologies in LiDAR, the number of patents from 41 to 778, we can get that the total patent strength is positively correlated to claims, and the number of citations, these results are consistent with literature researches. It is interesting that all sub-technologies have extreme cases. The all extreme cases are collected in Table 2, only one assignee, Luminar Technologies Inc., is one of sixteen main assignee.

Table 2 Extreme cases of LiDAR patents

Publication No	Sub technologies	Assignee/Applicant	No. of claims	Citations
20150293224	Solid State LiDAR	Quanergy Systems Inc.	95	49
20180269646	Solid State LiDAR	Luminar Technologies Inc.	30	139
20070018104	Solid State LiDAR	Parviz Parvin (IR)	2	19
20180102442	Silicon Photonics Optical Coupling	W&Wens, Devices Inc.	112	108
20060231771	Silicon Photonics Optical Coupling	Science & Engineering Services LLC	97	11
20150153453	Silicon Photonics Optical Coupling	Arete Associates Inc.	3	15
20200064476	Silicon Photonics Optical Coupling	Soraa Laser Diode, Inc.	35	266
20050030540	Hybrid Laser	Robert L., Thornton	91	53
20120187096	Hybrid Laser	V&M Deutschland Gmba (DE)	15	130
20030024912	Optical Beam Steering	Orbotech Ltd. (IL)	728	80
20180003805	Optical Beam Steering	DigiLens Inc.	20	749
20030063884	Optical Phase Array	Duane D. Smith	160	14
20200191916	Optical Phase Array	Gerard Dirk Smits	1	176
20030034538	Tunable Laser	Motorola Inc.	158	(abandon)
20090225329	Tunable Laser	Clark Alexander Bendall	20	267
20090141748	Tunable Laser	Finisar Corp.	4	200

For cases with a very low number of claims, we can say that the applicant does not pay too much attention to it, the value of this kind of patent is of course low even its high citations. High citations usually come from continuation ancestors, for example, US20200191916 is the fourth generation of continuation, the first generation, US20170176575, has 20 claims. Continuation cases have the same specification and the same number of citations, but different claims. On the contrary, cases with a huge number of claims can be considered high strength, but how to explain it with low citations. Abrams (2018) [8] has ever used novel revenue data for tens of thousands of patents held by non-practicing entities, and found two kinds of patent, in the case of productive patents, patent value and forward citations are positively correlated, and then strategic patents are allowed, patent value and forward citaions are negatively correlated. The patent with high claims but low citations is similar to the strategic patent, the applicant have high expectations that it will become a high-value patent, but there is still a test of technogy follow-up and market expasion. This kind of patent can at least be said to have high value of cost and potential.

C. How the claim affects the strength of the patent

Although the number of claims is related to the total strength but highly affected by official fees, the critical number is 20 in USPTO. Fig.9 is the scale of claims for six technologies.

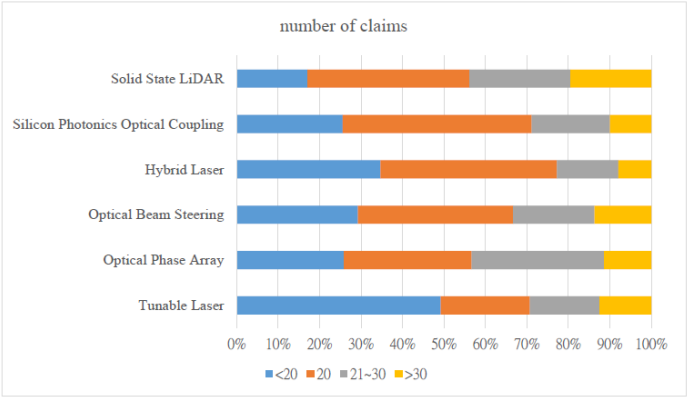

Fig.9 scale of claims for six LiDAR technologies

We can divide it into three sections to discuss separately. The first part is more than 30 claims, accounts for 10 to 20 percentage, the inventions are very important to the applicant, who is willing to pay high excess official fees, and applications with huge claims should be considered technically important, because it needs variant embodiments, and an invention with low technical level is unlikely to write so many claims. The second part is applications with 20~30 claims which occupy the highest proportion, 57 to 63%, and exactly 20 of them is 30 to 45%, only tunable laser is lower. The remaining part is less than 20 claims.

Many researchers regard number of claims as a good indicator for patent strength. Kuhn (2019) [14] found that the number of claims is correlated with patent scope, but this relationship is quite weak and explains little variation, it provides virtually no information across the patents with which most scholars work. However, this study believes that although the number of claims has a positive relationship to strength, it is not linear proportional. It is necessary to divide the number of claims into three parts as above, because they are quite different, which leads to different weighting results. Lee (2015) [16] regarded the high number of claims as inimitable instead of strength. In a single company, this linear

relationship will not be distorted, because a single company usually has a main claim strategy.

Another indicator is the number of independent claims, which affected by legal framework. The EPO only allows one independent claim in on category, unless there are exceptions [20]. Hikkerova (2014) [21] analyzed about 22,700 European patents, to look for the factor that influence the renewal of a European patent, the number of independent claims is not an important factor. In USPTO, there is no limit to the number of independent claims, but an excess fees for more than three, no wonder Marco (2019)[15] found the mean independent claim count of grant patent is 3.08. The number of independent claims is larger, the broader the scope, which is beyond doubt under the legal interpretation of the scope of patent rights in the United States.

V. CONCLUSIONS

This study review the number of claims as an indicator of patent strength or patent scope by US patents in LiDAR composed of six sub-technologies. We believe that it must be reviewed from the legal point of view, because obtaining a patent is to get an exclusive right and enforce it. This article presents legal viewpoints that were rarely discussed in the past. The following conclusions are only in the legal framework of the United States.

It is a bedrock principle of patent law that the claims of a patent define the invention to which the patentee is entitled the right to exclude. In patent litigation, the patentee always uses the broadest independent claim to enforce patent right. This is not to say that dependent claims with narrower scope are useless, when an independent claim is declared invalid by Court or UPSTO, the valid dependent claims can still enforce. Under the all limitations rule of claim words, the more words of an independent claim, the smaller the scope, the number of words of an independent claim in line with the legal point of view, but the number of claims does not, because the scope will not be larger for more dependent claims, an indicator of patent scope defined based on the levels of dependent claims does not, either [17]. The number of claims can still be used as an indicator for patent strength, it should be noticed that the number of 3 independent claims and 20 total claims are critical. We can also infer that in Europe the critical number is 15, the EPO charge a high excess fee. This results in only under a thousand-scale research, but under the legal framework it can be inferred that the number of ten thousand or more is a similar result.

The number of citations commonly used in the past can be used to measure the technical value of patents, there is no difference in the results of this article. However, when analyzing the individual patent, a patent with high claims but low citations could be a strategy patent, these patents are not important patents in the eyes of the experts in this study, and it can only be said that they may have future potential. To sort out the extreme cases during statistics will be advisable, which are less likely to cause statistical distortion. The abnormal situation caused by continuation cases is worth noting and is also a topic for future research.

Patent is an intangible property right whose value is difficult to assess. Over the years, the efforts of researchers have made some evaluation tools available for practical use. This article verifies the indicators and proposed some legal points, hoping to give users more confidence in assessing the strength of patents.

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