

Discussion on the Development Path of China's Laser Industry

Xiaoyan Li¹, Mrs. Di Li²

¹Faculty, ²Undergraduate,

^{1,2}School of Information, Beijing Wuzi University, Beijing, China

ABSTRACT

Since the formation of China's laser industry, it has maintained a good momentum of development, the industrial scale has maintained steady growth, the industrial structure is mature, the technical strength is constantly enhanced, and the industry application is gradually expanded. In the future, China's laser industry will further develop rapidly, but affected by the macro environment, there may be risks such as the increase of R & D costs and the short-term fracture of the industrial chain. The industry will also face the problems of intensified competition and lagging key technologies. In this paper, the SWOT analysis method is used to determine the internal strengths, weaknesses, external opportunities, and threats of China's laser industry development, and the AHP analysis method is used to quantify and visualize the factors affecting the development of China's laser industry. It can be concluded that China's laser industry should attach importance to technological innovation, strengthen the vertical integration ability of industry, and actively participate in international cooperation to promote the development of China's laser industry.

KEYWORDS: Laser technology, industry chain, SWOT analysis, AHP analysis, development strategy

INTRODUCTION

The laser is the light produced by the stimulated radiation of atoms. It has become one of the basic technologies of modern high-end manufacturing because of its strong monochromatic light source, high brightness, and directional luminescence. Although China's laser industry market started late, it has developed very rapidly under the influence of national policy support and the progress of manufacturing technology. As early as 2006, China issued the outline of the national medium and long-term science and technology development plan (2006-2020), in which laser technology was listed as one of the 21 key areas of advanced manufacturing high-tech industrialization that should be given priority. The emergence of "industry 4.0" and "made in China 2025" marks that China's manufacturing industry has entered a new stage, paying more attention to the innovation and development of advanced manufacturing technology, which is also an important measure to promote China to become a manufacturing power. In "made in China 2025", the development of "high-end CNC machine tools and basic manufacturing equipment" is highlighted, and the high-end CNC machine tool is a kind of laser equipment. This paper studies the current environment and problems of China's laser industry and discusses the specific strategies for the future development of China's laser industry.

Development status of laser industry in China

A. Industrial scale

With the transformation and upgrading of China's manufacturing industry, as well as the emerging industrial application scenarios with the development of science and technology, laser equipment with its advantages of good

performance and low price has attracted more and more attention of relevant industries, and the growth and expansion speed of the whole laser industry is faster and faster. According to the data statistics of the prospective industry research institute, in 2018, the market scale of China's laser industry reached 144 billion US dollars, with a year-on-year growth of 22.14%. The laser equipment market in the middle reaches occupies the largest market share of the laser market, the market share of components and materials market in the upstream and processing service market in the downstream accounted for 20% and 38% respectively.

After several years of rapid development, the laser industry has generally slowed down since 2019. However, compared with traditional processing, laser processing technology has incomparable advantages. At the same time, the domestic laser manufacturing technology and application level are constantly improving. In terms of industrial upgrading and import substitution, the laser industry will have good development opportunities and market prospects.

B. Industrial chain structure

China's laser industry has now formed a complete and mature industrial chain. The whole industry chain presents a pyramid-like distribution relationship between upstream and downstream industries, and most laser enterprises are concentrated in the downstream laser market.

Located in the upstream market of laser industry are the suppliers of laser materials and supporting core optical

How to cite this paper: Xiaoyan Li | Mrs. Di Li "Discussion on the Development Path of China's Laser Industry" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-4 | Issue-5, August 2020, pp.602-609, URL: www.ijtsrd.com/papers/ijtsrd31905.pdf



IJTSRD31905

Copyright © 2020 by author(s) and International Journal of Trend in Scientific Research and Development Journal. This is an Open Access article distributed under the terms of the

Creative Commons Attribution License (CC BY 4.0) (<http://creativecommons.org/licenses/by/4.0>)



components, as well as some manufacturers of supporting power supply and CNC module; optical devices such as chips, optical fibers, high-power fiber gratings and heat sinks in the upstream link are important raw materials for laser products.

The development of the upstream market needs the driving of the downstream application market to a great extent. With the continuous improvement of the technology of China's upstream enterprises, domestic leading enterprises located in the middle reaches of the country also pay more attention to the purchasing proportion of their core components in domestic enterprises. In terms of the amount of imported raw materials, the proportion of Chuang Xin laser's import procurement decreased from 41.6% to 23.7% in the first half of 2017-2019, and the proportion of imported raw materials of JPT decreased from 48.2% to 29.3%. Fu Jing technology is a leading enterprise in the upstream market. As of 2018, Fu Jing technology has achieved a business income of 491320700 yuan, an increase of 8.29% over the same period of last year, and a business profit of 171.9916 million yuan, an increase of 7.15% over the same period of last year. At present, LBO crystal and BBO crystal occupy 70% and 50% of the global market respectively.

The midstream laser market mainly includes lasers and complete sets of equipment. As early as 2015, China replaced Europe for the first time and became the largest consumer market of lasers. The market scale accounted for 29% of the global market scale, reaching about 2.8 billion US dollars. According to the report on the development of China's laser industry, the total sales volume of China's laser market in 2018 accounted for 64.9% of the global market size, exceeding 8.3 billion yuan. According to the data of strategies unlimited, the market size of industrial lasers has shown a rapid growth trend in recent years, from \$2.866 billion in 2015 to \$5.058 billion in 2018, with a compound growth rate of 20.8%. Among them, the growth rate of fiber laser is faster. The market scale of the whole fiber laser has increased from the US \$1168 million in 2015 to the US \$2.603 billion in 2018, with a compound growth rate of 30.6%. At the same time, the proportion of fiber lasers in industrial lasers has also increased from 40.8% in 2015 to 51.5% in 2018, which is the industrial laser with the largest market share.

At present, the low power section of domestic laser has been replaced by import, and the domestic and imported laser at medium power end is equally matched. In terms of fiber lasers, from 2013 to 2017, domestic low-power fiber lasers developed rapidly, and in 2018 domestic medium power fiber laser sales increased at a compound annual growth rate of more than 200%, from 200 in 2013 to 12500 in 2018, with the localization rate of 52.1% in 2018. In terms of high-power lasers, import substitution space is still broad, international manufacturers still occupy a certain advantage in the field of high-power lasers, and domestic fiber lasers only occupy about 34.5% of the market share. However, it is expected that with the technical progress and upgrading of domestic laser manufacturers, combined with the advantages of local cost advantages and convenient after-sales service, domestic lasers will gradually enter the high-power laser market and change the monopoly pattern of international manufacturers on the Chinese market. Among the domestic enterprises, Rui ke laser and Chuang Xin laser have emerged, occupying the majority of low and medium power lasers in the domestic market, with market share of

24.3% and 11.9% respectively, while IPG market share is 41.9%. In the high-power laser control system market, international manufacturers still occupy absolute advantage.

In the downstream of the laser industry, laser equipment such as laser application products, consumer electronics, and instrument equipment are the main products. According to the statistics of China's laser industry report in 2019, the scale of China's laser equipment market in 2018 was 60.5 billion yuan, as shown in Figure 3, more than half of the global market, including 30 billion yuan in the industrial sector. In the industrial field, the market scale of laser cutting and marking is expected to be 25 billion yuan, and the welding market is expected to be 5 billion yuan. The vigorous development of laser downstream market is closely related to the emergence of the upstream laser market and its downstream emerging application scenarios. The combination of price reduction and import substitution in the midstream laser market accelerates the application and promotion of the downstream laser market. The price of laser core devices is in line with Moore's law, and the price can be reduced to a certain extent every year under the condition of continuous improvement of performance. At the same time, the market share of foreign laser manufacturers in China has been gradually replaced by domestic laser manufacturers represented by Rui Ke laser and Chuang Xin laser. Take Rui Ke laser as an example, its market share increased from 12% in 2017 to 17% in 2018, and IPG share decreased from 52% to 49% in the same period. Therefore, the promotion of laser cost reduction and localization substitution boost the development of the laser industry, making many laser enterprises complete the accumulation of industrial capital in a short period.

The competition pattern of laser equipment in China is relatively scattered. Due to the characteristics of regional and downstream discrete manufacturing enterprises, it is difficult for the laser processing market in the pan manufacturing field to form a more centralized competitive pattern. There are more than 300 laser processing equipment enterprises engaged in the laser cutting field in China. Among many enterprises, Han's laser and Hua gong technology have emerged, occupying most of the domestic market share. Based on the domestic laser equipment market scale of 60.5 billion in 2018, the market share of Han's laser and Hua gong technology is 18% and 8.6% respectively, while the market share of Trumpf in China is only 6%. However, in the field of high-end high-power equipment, due to the factors of technological innovation, domestic enterprises still have a certain gap with the global leading German Trumpf and other enterprises.

SWOT analysis of laser industry in China

A. Analysis of the strengths of laser industry in China

Regional maturity (S_1)

China's laser industry has formed mature industrial belts in the Pearl River, Yangtze River Delta, Bohai Rim, and central China. These four industrial zones have their division of labor. The Pearl River Delta region is dominated by small and medium-sized laser processing machines, the Yangtze River Delta region is dominated by high-power laser cutting and welding equipment, the Bohai Rim region is dominated by high-power laser cladding and all-solid-state laser, and central China is led by Wuhan, covering large, medium and small laser processing equipment.

Technological breakthrough (S₂)

In terms of technology development, the state has also focused on supporting many R & D institutions and supporting many R & D projects in recent years. According to the statistics of China Science and technology strategy, as of the beginning of 2018, there were 5 national engineering research centers authorized by the national development and Reform Commission (NDRC), 10 institutions licensed by the Academy of science and technology engaged in laser technology research and industrialization, and 14 national key laboratories related to optoelectronics. Meanwhile, the Wuhan National Research Center for optoelectronics has become the only interdisciplinary exchange focusing on the field of optoelectronics Cross-national science and technology innovation base. In terms of projects, in 2017, the National Natural Science Foundation of China supported 415 laser-related projects with funding of nearly 300 million yuan and 172 research institutions. In terms of patent publication, the number of laser-related patents in China has also shown a rapid growth trend in recent years. According to the statistics of China's laser industry development report, from 2010 to 2015, there were 32905 laser technologies in China, accounting for about 70% of the total patents in 1992-2009. In 2016, 14768 laser related technologies were added, and in 2017, 17386 new laser technologies were added, showing an accelerated growth trend.

Therefore, domestic scientific research institutions have made many breakthroughs in basic laser technology, as shown in Table 1, which provides technical support for domestic laser and laser technology applications.

Table 1 basic laser technology for breakthrough

Breakthrough technology	brief introduction
The world's strongest ultra violet laser	A single picosecond laser pulse can generate 140 trillion photons, making it the world's brightest and fully tunable EUV free electron laser source
Large scale laser high precision diffraction grating ruling system	It is the largest high-precision medium step grating in the world
Ultra short laser	Laser output of 5 beats successfully
Ultrashort pulse laser processing	The laser pulse reaches femtosecond level
Remote manufacturing technology of high beam quality laser beam	High power laser with flexible beam transmission and fiber manufacturing, transmission and coupling technology
Double beam laser welding	Improvement of laser welding, metallurgy and laser welding defects

Good sales network and brand image (S₃)

China's laser industry has formed a sound industrial chain, so through the continuous improvement of its core technology, production, and service capabilities, the situation of monopoly by overseas companies since the production period has been broken, and the brand advantage of China's laser enterprises have been established. Through continuous cooperation, China's laser enterprises

have formed a stable cooperative relationship with their main industrial customers and distributors, and also established a professional marketing team and perfect international sales channels. At the same time, with a variety of laser products, enterprises also put forward a new one-stop procurement service for customers, which reduces the procurement cost of customers and enhances customer stickiness.

B. Analysis of the weaknesses of China's laser industry

Serious homogenization of laser products (W₁)

With the development of the laser industry, the enhancement of technology maturity, the gradual increase of competitors in the market, the strength of competitors, and other factors lead to the decrease of market share and the decline of product price of related enterprises in the laser product market. Although this has played a positive role in promoting the development of the whole industry, it is not ruled out that some enterprises deliberately lower the price of products to compete for market share, causing price war and other vicious competition which is not conducive to the development of the industry. The sales and profit level of the whole laser industry may fluctuate to a certain extent due to the above factors.

At present, the market for low-end laser equipment is in the stage of fierce competition. The gross profit rate of laser equipment for enterprises has dropped sharply. At present, the competition of low-power laser and equipment in China is fierce, and the product homogeneity is serious. For example, the laser cutting and marking equipment in the market of laser processing equipment have entered the Red Sea stage, and the market has reached saturation. If the enterprise cannot make a breakthrough in the field of high-power, and cannot keep up with the needs of high-quality customers, the long-term profits of laser enterprises may face the risk of decline, which is bound to affect the overall development of the laser industry.

Insufficient R & D capability of key devices (W₂) In the production process of laser equipment, the technical level of the core optical devices used directly determines the laser output power level and performance parameters. According to the feedback from the prospectus of Chuang Xing laser, optical devices account for 40% - 60% of the cost of fiber lasers. Therefore, it is of great significance to master the R & D and production technology of core optical devices for manufacturing fiber lasers.

According to the investigation and feedback of Rui Ke laser, the traditional pump source accounts for 60-70% of the cost of the fiber laser, which can be reduced to 20-30% after self-made; the special optical fiber accounts for about 20% of the cost of the whole optical module; the imported transmission optical cable is expensive, about 20000-30000 yuan per piece, and the cost decreases rapidly after self-made, and the cost proportion is about single digit. There are also some optical components, such as high-power beam combiner, after self-made, combined fiber Bragg grating accounts for several percents of the cost. The main cost of the remaining fiber laser is the cost of mechanical parts, which is difficult to reduce again, accounting for about 20-30% of the total cost.

Domestic manufacturers have mastered most of the device manufacturing technologies, but although the fiber media,

high-power laser chips, and fiber grating core components have some self-made ability, or some domestic supply chain manufacturers have certain supply capacity in related fields, the components corresponding to fiber lasers in a certain power range still mainly rely on imports, while foreign lasers are the leader IPG and coherent rely on the integration of the whole industry chain and the advantages of leading technology to achieve low cost and high-performance stability. Therefore, the independent research and development of laser core components are very important for fiber lasers in terms of stability, cost reduction, expansion of competitive advantages, and acceleration of domestic substitution.

Lack of professionals (W₃)

In recent years, with the increasing competition in the laser industry, talents with rich technical experience and R & D ability have increasingly become the focus of industry competition. Laser products are highly dependent on employees in the post-processing stage. Laser enterprises are generally faced with the problem of "difficult employment", and labor costs are rising, which may increase the operating costs of the company.

C. Opportunity analysis of laser industry in China

Policy support (O₁)

The laser industry has always been a development industry supported by the state. In recent years, national policy support has accelerated. Many policies have been implemented by both the state and the local governments, among which the national level mainly encourages and supports the application of laser technology in the manufacturing industry, and the local level mainly supports the construction and development of industrial parks. Since the State Council issued "made in China 2025" in 2015, the State Council, the national development and Reform Commission, the Ministry of industry and information technology, and the Ministry of science and technology have successively promulgated a series of supporting policies, and the industrial policies related to lasers have been accelerated, such as the special plan for scientific and technological innovation in the field of advanced manufacturing technology during the 13th Five Year Plan period in April 2017 and the action plan for high-end intelligent remanufacturing in October 2017. The development direction of laser technology has been clearly defined in the plan (2018-2020). At the local level, in recent years, many provinces and cities have issued many matching policies to support the development of the laser industry. At the same time, several industrial parks have been built in the four laser processing industrial belts of Pearl River Delta, Yangtze River Delta, central China, and Bohai rim, which has formed scale effects.

Market demand and technology development fit (O₂)

The demand for laser technology in the new application market also promotes the development of downstream laser equipment. In addition to the traditional cutting and welding applications in sheet metal, the laser has generated a large number of application markets in automotive, 3C, lithium battery, aviation, and medical fields. For example, in automobile manufacturing, laser technology is involved in both mainline welding and off-line parts processing. Domestic major automobile enterprises, such as SAIC, GAC, and Geely, have gradually accelerated the popularization of

laser technology. According to the statistics of Zhi Yan consulting data, the market space of China's automobile manufacturing equipment is estimated to be more than 150 billion yuan, of which the automobile welding automation equipment accounts for about 25% of the total equipment investment, and the market scale is more than 40 billion yuan.

The development of manufacturing industry needs laser-assisted reform (O₃)

In recent years, China has vigorously promoted the development of the high-end equipment manufacturing industry, and China's traditional manufacturing industry is in the accelerated transformation stage. Compared with traditional cutting and welding equipment, laser equipment has obvious advantages. Taking metal welding as an example, laser equipment realizes the non-contact welding process, reduces cutting material loss, and does not need to carry out follow-up treatment, which helps to improve work efficiency and greatly reduce manufacturing costs. At this time, the cost of laser equipment materials is also decreasing, the existing laser processing technology is gradually mature, the emerging laser technology is constantly pushed to the market, the outstanding advantages of laser processing are gradually reflected in various industries, and the market demand of laser processing equipment keeps growing.

D. Threat analysis of laser industry in China

Technology R & D costs rise (T₁)

At present, China's macroeconomic situation is reflected in an unbalanced state. But this kind of state generally has two characteristics: the first appears is the domestic demand insufficiency, manifests in the domestic demand especially. Under the risk of the financial crisis in the world, the weakness of domestic aggregate demand also leads to an economic downturn.

On the other hand, China is now in a period of supply inflation pressure. Although there is no big change in the market demand, the cost of manufacturing products by suppliers has increased, resulting in the rise of product prices. The direct result of this phenomenon is that the cost of technological research and development progress is higher than that under normal economic conditions. Economy and core technology progress promote each other. Technology serves the market demand. However, with the increase of technology R & D cost, the investment and risk of independent R & D have increased. The problem that laser enterprises are facing now is that they need to increase R & D investment for technological innovation, which may lead to the decline of demand due to the price increase, or the profits of laser enterprises are not as expected, which will further slow down the development of the industry.

Industrial chain defects exposed by the outbreak (T₂)

The outbreak of novel coronavirus pneumonia will undoubtedly impact our economic development in the short term. At the same time, due to the long-term shutdown caused by the epidemic, the global manufacturing industry chain may break in the short term. For the laser industry, the most serious impact is the supply of key chips and core components. Because of its dispersed distribution and many-core devices rely on imports, the risk of industrial chain fracture may occur in the short term.

Periodicity of customer demand (T₃)

As the leading producer of laser equipment in the downstream market of the laser industry is laser equipment, which belongs to fixed assets. Customers' investment in fixed assets is cyclical, so there is great uncertainty in the time and quantity of equipment purchased. For the whole market, there is a risk that the same market will be oversaturated or the growth rate of sales volume will decline in the future. At the same time, combined with the current national macro-control policy for fixed asset investment, it may also have a direct impact on the purchase demand of laser products.

SWOT analysis of laser industry in China

A. Basic methods and steps of the study

Through the SWOT analysis method, the qualitative factors affecting the development of China's laser industry are determined, and the internal conditions and external conditions affecting the development of China's laser industry are determined. In this paper, the qualitative factors are analyzed quantitatively by AHP. The advantages and disadvantages of China's laser industry as well as the opportunities and threats faced by the laser industry are taken as the standard of strategy selection. The data hierarchy model is designed and the corresponding judgment matrix is constructed. The factors at all levels are calculated and the consistency test is carried out. Then, the important process of each influencing factor on the

development of China's laser industry is analyzed. To provide a reasonable and accurate development strategy for the laser industry, the paper establishes a quadrilateral for the strategic development of the laser industry and determines the strategic positioning.

B. AHP-SWOT analysis of laser industry in China

Based on the need of AHP analysis method, this paper takes the internal advantages (S), internal disadvantages (W), external opportunities (O) and external threats (T) of China's laser industry as the criteria layer, and selects the influencing factors in each group as the index layer, and constructs the hierarchical structure model of China's laser industry development strategy (see Table 2).

To quantitatively analyze and evaluate the influencing factors of SWOT group and basic criteria, the 1-9 digital scale method (see Table 3) and Delphi method are used to construct the criteria layer judgment matrix A, S (strength) judgment matrix, W (weakness) judgment matrix, O (chance) judgment matrix and t (threat) judgment matrix (see tables 4 to 8).

According to the AHP analysis method, the judgment matrix is analyzed by hierarchy, and the weight of each level in the model is obtained by hierarchical ranking analysis (see Table 9). Among them:

Table 2 hierarchical structure model of laser industry development strategy in China

Decision target layer	Layer criterion	Index layer
Development strategy of laser industry in China	S: Strength	S ₁ : a mature industrial chain cluster has been formed
		S ₂ : major breakthrough in technology
		S ₃ : good sales network and brand image
	W: weakness	W ₁ : serious homogenization of laser products
		W ₂ : insufficient R & D capability of key devices
		W ₃ : lack of professionals
	O: Opportunity	O ₁ : policy support
		O ₂ : market demand meets technology development
		O ₃ : manufacturing development and reform promote technological progress
	T: Threats	T ₁ : technology R & D costs increase
		T ₂ : industrial chain defects exposed by epidemic
		T ₃ : customer demand changes periodically, industry income is lower than expected

Table 3 standard degree of judgment matrix of level 1-9

assignment	meaning
1	It means that the two elements are equally important
3	The former is slightly more important than the latter
5	The former is more important than the latter
7	The former is more important than the latter
9	The former is more important than the latter
2,4,6,8	Represents the intermediate value of the above adjacent judgments
reciprocal	The ratio of elements to importance is

Table 4 criteria layer judgment matrix

A	S	W	O	T
S	1	3	2	3
W	1/3	1	1/3	2
O	1/2	3	1	3
T	1/3	1/2	1/3	1

Table 5 S (strength) judgment matrix

S	S ₁	S ₂	S ₃
S ₁	1	1/3	2
S ₂	3	1	4
S ₃	1/2	1/4	1

Table 6 W (weakness) judgment matrix

W	W ₁	W ₂	W ₃
W ₁	1	1/5	1/3
W ₂	5	1	2
W ₃	3	1/2	1

Table 7 o (opportunity) judgment matrix

O	O ₁	O ₂	O ₃
O ₁	1	1/5	1/4
O ₂	5	1	3
O ₃	4	1/3	1

Table 8 T (threat) judgment matrix

T	T ₁	T ₂	T ₃
T ₁	1	2	1/3
T ₂	1/2	1	1/5
T ₃	3	5	1

Table 9 consistency test and weight analysis

Decision objectives	Layer criterion	Consistency ratio Cr	Maximum eigenvalue λ Max	Layer criterion	Index layer	Consistency ratio Cr	Maximum eigenvalue λ Max	The weight of each element in the index layer	The weight of each element of index layer to "decision target"
Development strategy of laser industry in China	S	0.044	4.121	0.439	S1	0.015	3.018	0.2385	0.1048
					S2			0.6250	0.2746
					S3			0.1365	0.0600
	W			0.146	W1	0.003	3.003	0.1095	0.0160
					W2		0.5816	0.0852	
					W3		0.3090	0.0453	
	O			0.310	O1	0.074	3.085	0.0936	0.0291
					O2		0.6267	0.1947	
					O3		0.2797	0.0869	
	T			0.103	T1	0.003	3.003	0.2297	0.0238
					T2		0.1220	0.0126	
					T3		0.6483	0.0671	

Geometric mean of each row :

$$\bar{w}_i = \sqrt[n]{\prod_{j=1}^n a_{ij}} \quad i, j = 1, 2, 3, 4$$

The geometric mean values were normalized:

$$w_i = \frac{\bar{w}_i}{\sum_{i=1}^n \bar{w}_i} \quad i, j = 1, 2, 3, 4$$

Maximum eigen value :

$$\lambda_{max} \approx \bar{\lambda} = \frac{1}{n} \sum_{i=1}^n \frac{(\sum_{j=1}^n a_{ij} w_j)}{w_i} \quad i, j = 1, 2, 3, 4$$

To ensure the accuracy of the results, it is necessary to check the consistency of the above five judgment matrices. among:

consistency indicator (CI):

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

consistency ratio (CR):

$$CR = \frac{CI}{RI}$$

(when CR < 0.1, it is considered that the inconsistency degree of judgment matrix is within the allowable range; when CR > 0.1, it is considered that the inconsistency degree of judgment matrix is not within the allowable range)

Through calculation, the consistency ratio CR of all matrices is less than 0.1, and the analysis results are reasonable through the consistency test.

C. Strategic orientation of laser industry development in China

First of all, the strategic quadrilateral of China's laser industry is established to judge the future development

trend of the laser industry. Through the analysis of the calculated data, the weights of S, W, O, and T groups on China's laser industry development strategy are 0.4393, 0.1464, 0.3107, and 0.1036 respectively. Taking SW as x-axis and OT as the y-axis, a coordinate system is constructed. Takings and o as positive values of x-axis and y-axis respectively, the strategic quadrilateral is obtained. The center of gravity coordinates $P(x, y) = (0.1221, 0.1381)$ of China's laser industry development strategy is located in the first quadrant. Therefore, the development of China's laser industry has more advantages than disadvantages, and opportunities outweigh threats. Therefore, it can be inferred that both the internal and external environment of China's laser industry is promoting the development of the industry.

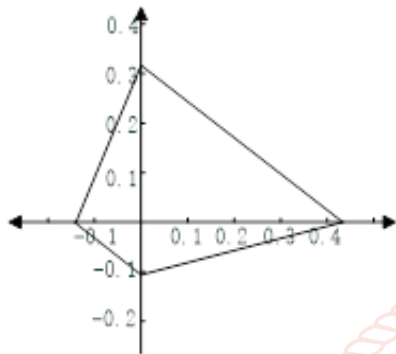


Figure 1 Strategic quadrilateral

According to the factor analysis of the criterion level, the weight of China's laser industry development strategy from high to low is $W_i(S) = 0.4393$, $W_i(O) = 0.3107$, $W_i(W) = 0.1464$, $W_i(T) = 0.1036$. Therefore, when formulating the development strategy of China's laser industry, we should focus on grasping its internal advantages and the convenience brought by external opportunities, and pay attention to the internal disadvantages and external threats appropriately.

From the analysis of the index layer, the weight proportion of group S from high to low is $S_2, S_1,$ and S_3 respectively. Therefore, in the superior group, we should focus on S_2 and S_1 , and consider S_3 as appropriate; in group W, the weight proportion from high to low is $W_2, W_3,$ and W_1 . Therefore, in the inferior group, we should focus on overcoming W_2 and W_3 , and pay a little less attention to W_1 ; in group O, the opportunity group, we should closely grasp the opportunities of O_2 and O_3 ; finally, in the T group, the weights from high to low are $T_3, T_1,$ and T_2 . Therefore, in the threat group, we should try our best to avoid the threat caused by T_3 and T_1 .

The weight of each element of the index layer on the "decision-making objective" is listed in the table. $S_2, S_1, O_2,$ and O_3 rank in the top four, which is very important. We should pay more attention to the development of China's laser industry. We should give full play to the internal advantages of S_2 and S_1 , seize and utilize the external opportunities of O_2 and O_3 , and combine the two to promote the development of laser industry. In addition, as an unfavorable factor for the development of China's laser industry, the weight of $W_2, T_3, W_3,$ and T_1 is more than 0.02. In the process of the laser industry development, preventive plans should be formulated in time, and measures should be taken to make up for the deficiencies, to ensure the positive development of China's laser industry.

Table 10 weight ranking of each factor of index layer to "decision objective"

Index layer	The weight of each element of index layer to "decision target"
S_2	0.2746
O_2	0.1947
S_1	0.1048
O_3	0.0869
W_2	0.0852
T_3	0.0671
S_3	0.0600
W_3	0.0453
O_1	0.0291
T_1	0.0238
W_1	0.0160
T_2	0.0126

After calculation, $S_{\Delta SAO} = 0.0682$, $S_{\Delta OAW} = 0.0227$, $S_{\Delta SAT} = 0.0228$, $S_{\Delta TAW} = 0.0076$, $S_{\Delta SAO} > S_{\Delta SAT} > S_{\Delta OAW} > S_{\Delta TAW}$. Therefore, the development strategy of China's laser industry should focus on so strategy and implement ST strategy, WO strategy, and WT strategy at the same time.

Development strategy of laser industry in China

A. Vertical integration of industrial chain

At present, the technical level of China's laser industry has entered a stage of rapid development, and it has a certain position in the international market. Even in the middle and low-end laser market, there is a large space for other laser equipment to import and replace. Therefore, domestic laser enterprises need further vertical integration of the industrial chain, which can make China in the international laser market invincible. The industrial chain pattern of China's laser industry is relatively scattered. If we want to vertically integrate the industrial chain, we should first let the enterprises in the middle and lower reaches of the industrial chain integrate their existing production technologies, and investigate other key technologies for research and development, to find the most matching upstream enterprises for merger and acquisition, to form the whole industrial chain. In this way, enterprises can better control and reduce the cost of products, have more bargaining power and competitiveness in the international market, and promote the occupation of the international market.

B. Realize the localization of the whole industry chain

When the global industrial chain can operate normally, the problem of insufficient domestic substitution in China's laser component market can be made up in time. However, the current serious epidemic situation in foreign countries has affected the integrity of the industrial chain. It is very important to improve the independent production of core components and master the core technology of the whole industrial chain.

At present, China has realized the complete localization of semiconductor laser pump source, optical fiber isolation output head, and end cap. However, China's laser enterprises need to continue to increase investment, cooperate with scientific research laboratories, develop industrial-grade devices such as chips, beam combiners, and gratings, to realize the complete localization of key laser devices, and help enterprises reduce costs and improve the market competitiveness.

Therefore, although the short-term laser enterprises will have the problem of reducing the shipment, in terms of long-term development, the improvement of the industrial chain will further break the monopoly position of foreign enterprises in China, drive the profit recovery ability of enterprises, and improve the quality of operation.

C. Foreign cooperative merger and acquisition

To make a faster breakthrough in laser technology, the cooperation between laser enterprises and international enterprises with advanced laser technology is also essential. In light of the weak links in the industrial chain of China's laser industry, we should strengthen cooperation and exchanges in the fields of fiber coupling technology, domestic semiconductor chips, high-power lasers, etc. Not only that, but also to guide foreign enterprises to set up research and development bases in China, to drive the development of domestic laser technology as a whole, and to fully integrate and digest foreign advanced technological achievements in combination with China's situation. In addition to the introduction of advanced international technology, China's laser enterprises should also actively enter the international market, carry out mergers and acquisitions, equity investment, venture capital investment and establish overseas research and development centers, so that China's laser enterprises can also have strong competitiveness in the international market.

D. Expand market and increase demand

Science and technology are closely related to the market economy. The old idea of "R & D and production before supply and sale", which is divorced from market demand, has been difficult to adapt to the upgrading of consumption structure in the modern market. In the future, market demand-oriented research and development has become a development trend. For example, in the field of industrial robots, it has become one of the top ten key areas to promote and break through the development of China. The policy focuses on the layout of the robot and the automation industry. The key technologies related to the robot field in the laser downstream market include harmonic reducer, laser sensor, etc. Laser enterprises need to increase the

research and development of laser technology related to the robot field.

Acknowledgement

This paper is supported by "Practical Training Plan for High-level Cross-training of Talents in Beijing Institutions of Higher Learning". The name of the project is "An analysis of business trends in the laser manufacturing industry".

References

- [1] Oliver, E. Williamson. Strategy research: Governance and Competence Perspectives [J]. Strategic Management Journal, 20(12):1087-1108
- [2] Boonyarat Phadermrod, Richard M. Crowder, Gary B. Wills. TEMPORARY REMOVAL: Importance-Performance Analysis based SWOT analysis [J]. International Journal of Information Management, 2016.
- [3] Muhammad Azeem Akbar, Arif Ali Khan, Abdul Wahid Khan, Sajjad Mahmood. Requirement change management challenges in GSD: An analytical hierarchy process approach [J]. Journal of Software: Evolution and Process, 2020, 32 (7).
- [4] Khine Mi Mi Hmu Tin, Henry Lau. A business process decision model for client evaluation using fuzzy AHP and TOPSIS. 2020, 35(1)
- [5] Zhe Huang, Cherifi Ahmed, Gardoni Mickael. A model for supporting the ideas screening during front end of the innovation process based on combination of methods of EcaTRIZ, AHP, and SWOT. 2020, 28(2):89-96.
- [6] Chengjiang Li, Michael Negnevitsky, Xiaolin Wang. Prospective assessment of methanol vehicles in China using FANP-SWOT analysis [J]. Transport Policy, 2020.
- [7] Luis E. Quezada, Eduardo A. Reinao, Pedro I. Palominos, Astrid M. Oddershede. Measuring Performance Using SWOT Analysis and Balanced Scorecard [J]. Procedia Manufacturing, 2019, 39.