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China's Fibre Optic Cable Development: Spatial Layout, Strategic Importance, and Future Challenges

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China's Fibre Optic Cable Development: Spatial Layout, Strategic Importance, and Future Challenges

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Abstract. This article explores China's leadership in the field of optical cable technology and its key role in promoting progress in various fields, including the economy, technology and military. As of 2024, China boasts the world's longest fibre optic cable network, with substantial investments made in access networks and local trunk cables. This study also explored China's "East Data, West Computing" plan, which is a project that aims to improve the efficiency of data transmission nationwide, meet domestic infrastructure needs and international communication demands. The study also examined China's involvement in submarine optical cable projects and highlighted the contribution of China to global digital connectivity and the Belt and Road Initiative (BRI). In spite of these accomplishments, challenges like restrictive trade policies, technological divides, and uneven regional development persist. However, emerging innovations such as 5G, artificial intelligence (AI), and Big Data have also created new development opportunities. This paper posits a conclusion wherein it is asserted that the People's Republic of China has achieved substantial progress, thus becoming a global leader in the realm of fibre optic infrastructure. Furthermore, it is contended that the country has secured access to significant global resources through the medium of international cooperation. Nevertheless, the challenges of trade protectionism, regional development gaps and reliance on certain foreign technologies endure and persist. To ensure maintenance of China's competitive advantage in the Fourth Industrial Revolution, it is imperative that the nation focuses on the acceleration of innovation, talent development and market diversification, while ensuring sustainable infrastructure growth against a backdrop of geopolitical uncertainty.

INTRODUCTION

The People's Republic of China has become one of the global leaders in the field of fibre optic cable technology, playing an essential part in fostering progress in multiple sectors, including commercial and military communications. By 2024, China have completed the world's longest fibre optic cable network, reflecting its leading position in this sector. The strategic investments made by China in pivotal sectors such as access networks and local relay cables underscore its preeminence in this field. The "East Data, West Computing" project is a significant initiative aimed at enhancing data transmission across China, thereby strengthening global communication and addressing the challenge posed by domestic infrastructure within China. This study investigates the geographical spread, technological characteristics, and future directions of China's fibre optic infrastructure. In addition, the article examines China's expanding involvement in submarine cable initiatives, which are pivotal for global digital connectivity. While there have been notable achievements, challenges like trade protectionism (such as the imposition of tariffs, non-tariff barriers, and trade quotas by key economies, which hinder the free flow of goods and services, especially in sectors like technology and manufacturing), technological differences (including the disparity in technological capabilities between China and certain advanced economies, with challenges in accessing cutting-edge technologies, as well as the need for more innovation in areas like artificial intelligence, semiconductors, and green technologies), and uneven infrastructure development across regions still endure (with some regions in China, particularly the western and rural areas, still lacking adequate digital infrastructure, posing challenges for nationwide data transmission and the equitable distribution of technological benefits). As China continues to invest in advanced technologies such as 5G, artificial intelligence, and renewable energy, it will shape the future of global digital connectivity and infrastructure.

LAND PORTION

The progress of optical cable laying in China is shown in Figure 1. As of the end of September 2024, the total length of optical cable lines in China has reached 71.83 million kilometers, ranking first in the world. Among them, access network optical cables account for 60.8%, local network relay optical cables account for 37.7%, and long-distance optical cable lines account for 1.6% [1]. Eight major hub nodes of the national 'East Data West Calculation' project have been preliminarily connected, including the Beijing Tianjin Hebei hub, the Yangtze River Delta hub, the Guangdong Hong Kong Macao Greater Bay Area hub, the Chengdu Chongqing hub, the Inner Mongolia hub, the Guizhou hub, the Gansu hub, and the Ningxia hub [2]. The high-speed transmission channels between each hub and surrounding major cities and key provinces have been greatly improved in terms of transmission bandwidth, ultra-low latency, and network capacity.

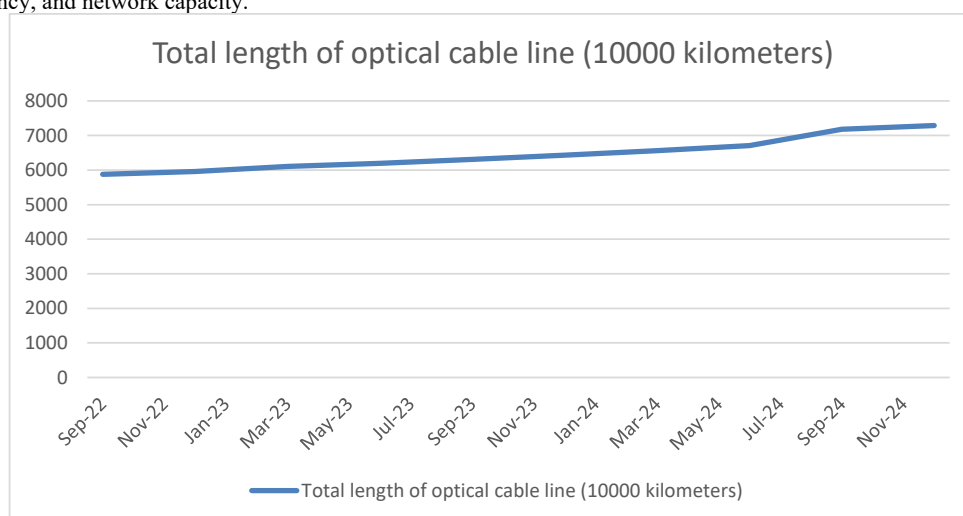


FIGURE 1: Changes in Optical Cable Length in China from September 2022 to December [3]

The Strategic Reasons for the "East Calculation West Calculation" Project

Presently, the majority of China's data centres are situated in the eastern region. However, due to resource constraints, the large-scale development of data centres in this region is difficult to sustain. Projections indicate that from 2024 to 2030, the average annual growth rate of electricity consumption in data centres nationwide will reach approximately 20%, which is significantly higher than the growth rate of electricity consumption in the overall society. Associate Professor Yong Zhen Wang from Beijing Institute of Technology has indicated that by 2025, the electricity consumption of data centres in China will account for 2.4% of the national electricity consumption, with some node cities and regions accounting for more than 20%. The Report on Comprehensive Energy Consumption and Flexibility Prediction of Data Centres indicates that by 2030, the electricity load of data centres in China will reach 105 million kilowatts, and the total electricity consumption of data centres in the country will be about 525.76 billion kilowatt hours, accounting for 4.8% of the total electricity consumption of the whole society [4]. In order to maintain the development of China's information industry, it is necessary to transfer data centres to the western region, which is particularly rich in renewable resources, to ensure the processing needs of data in the eastern region.

The Implementation Method of the "East Calculation West Calculation" Project

The plan proposes to build data centre clusters in regions such as Beijing Tianjin Hebei, Yangtze River Delta, Guangdong Hong Kong Macao Greater Bay Area, and Chengdu Chongqing, while Guizhou, Inner Mongolia, Gansu, Ningxia, and other regions rely on abundant renewable energy to undertake large-scale data processing and storage needs. Through the mechanism of "East Data, West Computing", cross regional computing power scheduling and

optimization can be achieved, enhancing the computing capacity of the western region and promoting the balance of data demand and efficient use of resources in the eastern region[5].

The basic idea of this project is based on resource complementarity, and its implementation plan specifies the direction of green and intensive construction. In the construction of data centres, advocating energy conservation and consumption reduction, promoting the application of green technologies, and striving to reduce energy consumption and improve energy utilization efficiency. At the same time, relying on renewable energy, support the collaboration between data centres and energy plants such as wind and solar power to ensure the green and sustainable development of data centres. In addition, the plan strengthens energy consumption monitoring and management of data centres, promotes unified planning of energy efficiency indicators, and promotes energy efficiency sharing and cooperation among different regions[5].

In promoting technological innovation, the plan emphasizes the importance of independent innovation and breakthroughs in key core technologies. By strengthening the research and application of big data infrastructure, supporting technological breakthroughs in software and hardware products, promoting independent and controllable technologies such as cloud computing, data storage, and distributed computing, and enhancing the innovation capability of China's entire big data industry chain. Especially in terms of data circulation, application, and governance, the plan focuses on promoting effective circulation and utilization of data resources through technological model innovation, improving data circulation efficiency, and ensuring data security and privacy protection[5].

In addition, the "East West Calculation" project can enhance the interconnectivity of computing power networks. This plan proposes to build a high-speed data transmission network, connect national hub nodes, improve cross regional computing power scheduling level, and promote integrated services between cloud computing platforms and data centres. By implementing a reasonable network settlement mechanism and optimizing bandwidth configuration, the cost of long-distance transmission can be reduced, ensuring efficient integration between data centres, cloud platforms, and enterprises[5].

Finally, the country has also strengthened cooperation and promotion among various departments through policy support, funding guarantee, and organizational coordination measures. Local governments formulate specific implementation plans based on the national framework, promote the green and intensive construction of data centres, provide policy support, and facilitate the implementation of technology pilot and demonstration projects. These measures provide strong guarantees for the comprehensive implementation of the project[5].

OFFSHORE SECTION

TABLE 1: Optical Cable Data Built in China by 2018 [6]

Serial Number	Direction	CABLE	Login Station	Operator
1	The US	TPE	Qingdao, Chongming	China Telecom, China Unicom
2		NCP	Chongming, Nanhui	China Telecom, China Mobile, China Unicom
3	Southeast Asia	EAC	Qingdao	China Unicom
4		APG	Chongming,Nanhui,HongKong	China Telecom, China Mobile, China Unicom
5		APCN2	Chongming,Shantou	China Telecom, China Mobile, China Unicom
6		C2C	Nanhui	China Unicom
7		SJC	Shantou,HongKong	China Telecom, China Mobile, China Unicom
8	Europe	FLAG	Nanhui	China Telecom, China Unicom
9		SWM3	Chongming,Shantou	China Telecom, China Unicom
10		AAE-1	HongKong	China Telecom, China Unicom

Overview: As shown in Table 1, as of 2018, China's submarine optical cable construction mainly depends on international cooperation, including the "the Belt and Road" and other international cooperation. The global sea area

accounts for 71%. There are few land connections between major economies, and large-scale submarine optical cables are needed to realize cross-border Internet communication. By the end of 2021, 440 submarine optical cables in use around the world have a total length of more than 1300000km, carrying 99% of the world's international information and communication exchanges [7].

The Belt and Road Initiative

The Belt and Road aims to achieve a higher level of cooperation, achieve higher input-output benefits, achieve higher supply quality, and achieve higher development resilience of the fourth line [8]. Under the framework of the the Belt and Road Initiative, China and countries along the Belt and Road jointly promote submarine optical cable projects, aiming to improve the level of international communication connectivity and promote the development of the digital economy. For example, the Asia Direct (ADC) submarine cable project connecting China, Japan, the Philippines, Singapore, Thailand, and Vietnam; The Cambodia West Port China Hong Kong submarine cable project is expected to be completed by July 2025.

Participate in the Construction of Submarine Optical Cables for Other International Collaborations

In addition to the "the Belt and Road" initiative, China has also participated in other international submarine cable projects, such as the New Trans Pacific Submarine Cable (NCP), Asia Europe No.3 International Submarine Cable (SEA-ME-WE3), Asia Pacific Direct Submarine Cable (APG), Asia Pacific No.2 Submarine Cable (APCN-2), etc.

THE ACHIEVEMENTS OF CHINA'S OPTICAL FIBRE CABLES

The People's Republic of China has made significant achievements in the field of optical cable technology, with the total length of domestic optical cables ranking first in the world and a wide coverage area. Notably, the "East West Calculation" initiative has led to the optimization of national data centre layout, thereby augmenting the computing and storage capabilities in the western region. Moreover, China has played an active role in international submarine cable projects, promoting cooperation through initiatives such as the "Belt and Road" initiative, thereby enhancing global connectivity in the field of information and communication.

CHALLENGES FACED BY CHINA'S FIBRE OPTIC CABLES

Global Trade Protectionism and the Slowdown of Chinese Investment in Europe and the United States

In recent years, the rise of global trade protectionism, especially the U.S.-China trade dispute, the Russian-Ukrainian conflict, and global inflation, has increased the external risks facing the Chinese economy. China's outward foreign direct investment (OFDI) has gradually slowed down, especially in the United States and the European Union, where foreign investment is increasingly scrutinized. The U.S. has implemented a series of policies, such as the Bipartisan Infrastructure Act and the Chip and Science Act, that place greater restrictions on Chinese investment. 2023 The Biden administration has even placed restrictions on investments involving semiconductors, artificial intelligence, and other technology sectors. The European Union has also strengthened its foreign investment review since 2019, especially when it comes to critical infrastructure and corporate acquisitions, adding multiple review mechanisms such as "anti-foreign subsidies" and "anti-trust," which makes it more difficult for Chinese companies to invest in the EU [9].

Historically, the fibre optic cable sector has depended on global markets, especially in Europe and the U.S., for technological collaboration and business growth. However, Chinese fibre optic cable firms now face a more challenging investment landscape in these regions due to tightening regulations. The U.S. government has intensified scrutiny over national security-linked infrastructure, imposing strict limits on Chinese companies in critical tech fields like fibre-optic communications. These measures have severely hindered cross-border M&A activities and tech partnerships for Chinese players in the industry. At the same time, Europe's stricter foreign investment screening,

including the Foreign Subsidies Regulation, has made it significantly harder for Chinese businesses to pursue mergers, acquisitions, or investments in the EU market.

These restrictions not only weaken the international competitiveness of China's fibre optic cable enterprises, but also has a far-reaching impact on its global supply chain. To cope with this challenge, China's fibre optic cable enterprises need to accelerate independent innovation, enhance core technology capabilities, while diversifying market strategies to find new export channels, but also to strengthen cooperation with the "Belt and Road" along the countries, in order to reduce the dependence on the European and American markets. In addition, actively promote the growth of domestic market demand, strengthen the domestic 5G and data centre construction, is also China's fibre optic cable enterprises to cope with external pressure is an important way.

Weaknesses in Synthesis

On the whole, the comprehensive strength of China's state-owned high-tech enterprises is relatively weak. On the one hand, due to the special nature of state-owned enterprises, both government departments and enterprises themselves are keen to use administrative means to protect the development of state-owned enterprises, excessive policy dependence, making most of the self-development ability of state-owned enterprises continue to weaken, and even gradually lost[10].

China's scientific and technological level has reached the world's advanced level in many fields after more than half a century of progress, but it still faces the problems of restricted core technology, insufficient innovation capacity and poor transformation of achievements. At the same time, resource constraints and the disappearance of the demographic dividend make it difficult to maintain the economic model of relying on cheap labor and capital expansion, but may bring long-term risks. Therefore, it is necessary to develop technology-intensive high-tech industries, driven by innovation, and to promote industrial upgrading through science and technology and advanced management in order to achieve successful economic transformation and stable development.

Imbalanced Distribution of Industries

China's fibre optic cable industry faces an imbalance in industry distribution in the overall development of the technology sector. Despite the significant progress made in the electronic communications industry, the enhancement of independent innovation capacity, and in cutting-edge areas such as 5G at the forefront of the world, the technological innovation and industrial expansion of the fibre optic cable industry is relatively lagging behind. Although fibre-optic communication technology is the core to support China's communication infrastructure construction, the performance of the optical cable industry in terms of innovation investment and output value enhancement is still insufficient compared to other technology-intensive industries. The fibre optic cable industry has insufficient independent R&D and technological breakthroughs, especially in the manufacturing and application of high-end products, and still relies on external technical support. In addition, although China's fibre optic cable manufacturers are gradually expanding their market scale, the increase in market share has not been effectively transformed into the production and application of high value-added products due to the limitation of core technology[11].

Wide Regional Disparities

The development of China's fibre optic cable industry in the regional gap is also more obvious. Due to the developed economy, technology concentration and abundant human resources in the eastern region, enterprises in the fibre optic cable industry can obtain more policy support and capital investment, which promotes the development of the industry and the gradual improvement of technology. However, the development of the central and western regions in this regard is relatively lagging behind, especially in the production and research and development of fibre optic communication equipment, weak infrastructure and insufficient market demand, resulting in constraints on the technological innovation ability of enterprises. Despite the potential for capital investment and economic spending in these regions, the pace of development is still slow compared to the eastern region. The Northeast region, in particular, is constrained in its innovation and efficient transformation of the fibre optic cable industry due to its over-reliance on state-owned enterprises and its historically over-expansive economic development model [12].

Slow Technological Progress

The status quo of slow technological progress in the fibre optic cable industry is mainly manifested in the lagging of technological research and development and insufficient innovation power[12].The government's support policy for the fibre optic cable industry is more general, and focuses on the front end of production and operation and R & D, but lacks in-depth support for the technological upgrading of the industry. Many state-owned enterprises lack effective management and supervision, resulting in capital investment is difficult to match with technological innovation. Enterprise R & D personnel are mostly grass-roots-type labor force, the lack of high-end composite talent, especially experts to master the world's leading technology is more scarce. Coupled with the management of many enterprises are mostly administrative officials, the lack of innovation and market risk-taking spirit, resulting in the industry in the high-end fibre optic technology as well as new applications of R & D progress is slow. Therefore, the optical fibre industry is difficult to break through the technological bottleneck, promote technological progress and industrial upgrading.

POLICY RECOMMENDATIONS AND FUTURE PROSPECTS

Based on the current situation and challenges faced by China's fibre optic communication industry, the following policy recommendations and future prospects are proposed. Firstly, the government should strengthen its support for innovation driven development and encourage fibre optic communication enterprises to increase their research and development investment, especially in the independent research and development of high-end fibre optic products and core technologies. By promoting industry university research cooperation, attracting top talents, cultivating more internationally competitive technical experts, and further narrowing the gap with the global leading level. In addition, the intellectual property protection system should be improved to ensure effective protection of innovative achievements, motivate enterprises to accelerate the transformation of technological achievements, and enhance technological barriers and market competitiveness.

Secondly, policies should further support the internationalization of optical fibre communication enterprises, especially under the framework of the "the Belt and Road" initiative, to promote more transnational cooperation. For enterprises affected by global trade protectionism and international investment restrictions, the government can provide guarantees through financial support, tax reduction policies, and other measures to help enterprises diversify their market strategies, reduce dependence on European and American markets, and open up new international markets. Moreover, it is recommended to strengthen cooperation with some third World Countries in the field of fibre optic communication technology, promote low-cost and efficient communication infrastructure construction, promote global information interconnection, and enhance China's global visibility.

In terms of regional development, it is the responsibility of the Government to implement differentiated policies, especially to narrow the technology gap between the eastern and western regions. In regions such as the central and western zones, where natural resources are limited, government guidance should be employed to foster the development of fibre-optic industry clusters and enhance local technological innovation and industrial competitiveness. The formulation of targeted policies, such as tax incentives and financial subsidies, is recommended to attract high-tech enterprises and research institutes to the region. Furthermore, the government should strengthen infrastructure development and improve the quality of transportation, communication and other infrastructure to support innovation. Furthermore, local governments should be encouraged to promote cooperation between high-tech enterprises and research institutions through political support and economic guidance, as this is an important source of technological innovation in these areas.

In the long run, the future development of China's fibre optic communication industry will highly rely on continuous technological innovation and green development. The country should continue to promote the construction of green data centres and promote the use of renewable energy nationwide to reduce electricity consumption and minimize environmental impact. Concurrent with the ongoing development of next-generation communication technologies, including 5G and the forthcoming 6G, the fibre optic communication industry is poised to experience significant new growth opportunities. To this end, it is incumbent upon China to proactively establish the requisite technical standards and to nurture the development of its industrial ecosystem. This will serve to enhance China's voice and influence within the global communication industry.

CONCLUSION

China has achieved remarkable advancements in optical cable infrastructure, establishing itself as a global leader in both domestic and international communication networks. To improve resource distribution and boost data

processing capacity in western regions, the government has launched key national strategies like the "East Data, West Computing" project. These efforts not only address rising energy needs but also support sustainable technological growth. Additionally, China has actively participated in global submarine cable projects, particularly through the Belt and Road initiative, strengthening worldwide connectivity and accelerating the expansion of the digital economy.

Despite these successes, China's fibre optic industry faces obstacles that could impede its long-term growth. Rising global trade protectionism, especially in key markets like the U.S. and Europe, creates barriers for Chinese firms seeking overseas investments and technical partnerships. Domestically, regional imbalances persist, with eastern provinces benefiting from greater resources and policy advantages compared to less-developed central and western areas. Additionally, the sector struggles with slow innovation and ongoing dependence on foreign technology for high-end products, weakening its global competitiveness.

To sustain and enhance its global market leadership, China needs to prioritize three key areas: boosting technological innovation, developing skilled professionals, and strengthening R&D capacity. Equally crucial is government backing for eco-friendly data center development, along with strategic expansion into diverse markets. These measures will fortify the Chinese fiber optic cable sector's ability to withstand geopolitical pressures while maintaining its international competitiveness.

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