New Advancement in Fiber Optic && Its Contribution in the Development of Modern Information Technologies, Systems and E-services

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ABSTRACT

There is an increasing and continuous demand for optical fibers of various types and in various fields, whether communications, medicine, industry, computing within fibers, artificial networking, the Internet of Things, and many others. Where all development sectors are witnessing an increasing demand for more optical fibers to be employed in new applications, and there is an urgent need to innovate and develop new types of them to meet the requirements of development in providing more luxury, time and effort with the highest quality and best possible performance. There are now a lot of advances in the optical fiber industry, a lot of modern applications, as well as a lot of ratings and contributions to the international development clock, in addition to some developments in the scientific research arena. The main objective of this paper is to demonstrate the contribution of fiber optics to the development of information technology, information systems and electronic services. Thus, this study states the conclusion and proof of the important role played by fiber optics in this regard by reviewing a number of advanced applications that have employed and benefited from the great progress in fiber optics. In addition to focusing on studying indicators of infrastructure development and electronic services in countries with levels of penetration, development and spread of optical fibers within them.

KEYWORDS

Optical Fiber, Information Technology, Information System, E-services, Development

1. INTRODUCTION

In 1970, Corning Incorporated invented low-loss optical fibers, which developed over time and became one of the best and most powerful means of transmitting information from one place to another over long distances with high efficiency and without losing information. Today, traditional optical fibers are still the most common way to transmit data—one basic channel that carries information. Despite the many advantages and facilities offered by these optical fibers, the huge increase in data generation makes information systems reach the limits of information transmission capacity. Thus, there is a constant need to focus on research and finding new ways to take advantage of the full potential of fibres. In this research, we aim to clarify the contribution of fiber optics to the development of information technology, information systems and electronic services. Thus, this study states a conclusion and proves the important role that fiber optics plays in this regard. The ultimate goal is to demonstrate the contribution of FO to development in various sectors including industry, communication networks, medicine, computing, physics, space, sensors, etc.

Previous studies in the field can be general, of course, so our research focuses on advanced services and their bandwidth needs, reliable connections. This study will lead to the conclusion and proof of the important role played by FO in the development of information technology, information systems and electronic services, which reflect positively on the general international climate. This paper studies the relationship between the spread of optical fibers and the development of information technologies and modern electronic services. Historical study has been cut and part of unrelated chapters has been reduced.

Chapters will be presented on new advances in optical fibers and new information technologies by reviewing a number of fiber optic applications in many modern fields and their contribution within them. The role and contribution of fiber optics within these systems and electronic services will be discussed and compared between them. Graphical comparisons and tables will show the relationship between the FO score between countries with regard to infrastructure and electronic services. The modern internal structure of the fiber optic will be examined by reviewing the modern applications and approaches in signal generation and transmission through these advanced media.

2. RESEARCH BACKGROUND

In the past few decades, the production and use of optical fibers has contributed effectively to improving the quality of human life greatly. The applications of optical fibers have expanded significantly until they entered many fields such as sensing, lasers and medicine [1, 2, 3]. One of the main success factors that contributed to the success of these applications is the one-dimensional (1D) optical fiber structure, which is very suitable for long-distance transmission and excellent optical transmission performance with low loss [4, 5].

Since its invention, optical fibers have witnessed great developments at an accelerated pace, making them reach advanced stages of modernity and efficiency. This distinctive launch and the great developments of optical fibers made it enter into many industries and applications of the real world and contribute effectively and effectively to the development of these fields significantly, whether in the areas of information technology, information systems or electronic services. Through this paper, we review a number of areas in which the enabling of optical fibers contributed to raising the level of its progress, productivity and effectiveness. We find optical fibers involved in real-world applications and industries such as: Communication Physics [7], Artificial Intelligence and Robotics [1], and [6] Deep-space Optical Communication. Multi-functional Tasks (disease diagnosis, intra-fiber computing, energy harvesting and storage, inter-fiber communication, etc.) [2], Wireless Networks, Optical Fiber Densor Networks (OFSNs) [3], and Optical Sensor Fibers [8], enable very high transmission power In sixth generation (6G) radio access networks [4], Optical Fiber Sensors and their applications within the sectors of biotechnology, space science, and law enforcement security applications such as digital imaging [5].

3. LITERATURE REVIEW

In this work [9], the ICFO team used phase-detached Anderson-finding fibers to engineer an optical setup with the goal of quantum light transmission, and a SPAD two-photon array camera was used as a receiver to detect the arrival of this light; Where the SPAD matrix contributed to the recognition and detection of pairs of photons as pairs due to the arrival of those pairs coincidentally at the same time and is also very sensitive so that it can detect single photons with very low noise; It also has a very high time resolution, so that the arrival time of single photons is known with high accuracy. The researchers' work principle relied on the idea of quantum correlation of pairs of photons. Knowing where one photon was detected helps determine the location of the other photon. Finally, the researchers carried out their experiment and verified this quantum correlation of pairs of photons before and after sending quantum light through PSF, and the results proved that the spatial anti-photon correlation was successfully preserved. The ICFO team concluded their study by attaching a map to improve their findings in future work. The approach adopted began with a scaling analysis to find the optimal size distribution of elongated glass filaments for the quantum light wavelength of 810 nm. Classical light was then used to perform a comprehensive analysis of the phase-separated fibers to identify current limitations in those fibers and suggest improvements to their fabrication, which will ultimately contribute to reducing resolution loss and attenuation during the transmission process.

In this research [10], the researchers (who are Cornell University engineers) created a soft robot that can identify and detect when and where it was damaged, and then inform the mechanisms of self-healing itself immediately. The principle on which the researchers relied is the great development in the field of artificial intelligence and the large spread of robots, which have become performing many tasks, whether on a simple daily level, up to the most complex of electronic, medical and industrial services, etc.; This is what necessitates the work of these robots for long periods, and therefore the damage may accumulate, hence the motive to search for mechanisms that allow the robots to discover the damage within them, repair them, and deal with them in the appropriate manner. The contribution of this research is complemented by making robots more agile and more endurance, which makes them work with more capabilities, better efficiency, and for longer periods. The methodology pursued in this paper is to develop stretchable fiber optic sensors for use in soft robotics and related components - from skin to wearable technology. The researchers explain that an essential first step is to get the robot to be able to determine if there is damage or something that needs to be fixed. After that, work was done to discover the subtle changes that occur on the surface of the robots by devising a technology that uses optical fiber sensors in addition to LED lights. Finally, the optical fiber sensors were combined with an elastomeric polyurethane containing hydrogen bonds to achieve rapid recovery of the robot. The experiment was carried out within Shepherd's Organic Robotics Lab. The researchers' results show that the resulting SHeaLDS technology - self-healing optical guides for dynamic sensing - contributes to the production of a soft, damage-resistant robot that can identify damage within and achieve self-healing of wounds at room temperature without any external interference. A future approach is to combine machine learning algorithms with SHeaLDS technology to allow recognition of tactile events and thus help create "a highly durable robot that has self-healing skin but uses the same skin to sense its environment to be able to perform more tasks."

In this work [11], the researchers focused on the NASA Deep Space Optical Communications (DSOC) technology demonstration project. The researchers' goal with this project is to develop and test new advanced laser sources for deep space optical communication. The proposed demonstration system consists of two aviation laser transceivers and two ground laser transceivers. The work's primary contribution is providing the ability to conduct optical communications free from space throughout the solar system that is beyond the capabilities of the radio communication systems in use today; Thus, there will be enough bandwidth for future space missions to transmit large amounts of data, including high-resolution video and images. This work is a quantum leap forward in the field of optical communications in deep space. It will allow verification of the validity of such communications and will use similar resources to the latest radio frequency communications to provide the possibility of re-streaming high-resolution images during the automated and manned exploration of planetary bodies.

In this paper [12] the researchers focus on optical sensing and give a more comprehensive overview of the basic principles of optical sensing and show the diversity of its different real-world applications and the advantages that these applications have. The methodology in this research is based on a discussion of the optical architecture to integrate wireless networks and sensor networks (WSNs) to obtain the benefits of each of these networks more efficiently. First, the different types of optical fiber sensors, their characteristics, and operating principles were described, after that, optical fiber sensor networks (OFSNs) were studied; Where the characteristics of multi-point and distributed sensing were presented, then the high potential of OFSNs was highlighted, especially its ability to carry out simultaneous measurements over a continuous and long range of optical fibers, after that the value of the parameters that use the same sensing element was emphasized as great features for monitoring environments or Structures or large structures within which it is difficult or impossible to use or deploy other sensing technologies. The contribution of this paper lies in providing a comprehensive and effective review of the literature and discussing the principles, properties, applications and properties of optical sensing that make this technology unique. The results of the researchers clearly showed that OFSNs can be applied in many different fields, such as mechanical civil engineering, environmental monitoring and other concrete examples presented and evaluated.

In this research [13], the researchers focused on the trends in the application of information technologies in the field of civil infrastructure, which has been growing rapidly in recent times. The aim of the study is to study the current development trend in this field and to give a future view of the direction of research. The approach adopted was based on collecting 204 research papers as samples from the literature published in the past decade between 2010-2020. Then the progress and development of information technologies in different stages were discussed to provide a critical analysis of the application of current information technologies, which included: fiber optic sensors (FOS), wireless sensor networks (WSN), radio frequency identification (RFID) and building information modeling (BIM). and other advanced information technologies. Finally, the results concluded that the future of civil infrastructure is more sustainable and smarter. By demonstrating the potential for using digital twins as tools for planning and managing smart next-generation infrastructure.

In this paper [14], the researchers discuss an industrial use case of a RoF-based DAS network experimentally to measure its ability to accommodate both 5G and 6G terahertz services. The approach adopted in this study is based initially on using 256-QAM and a new 5G radio signal experimentally over a 10km single-mode optical fiber link to broadcast the single-wave 6G modulated signal. This 6G signal is then received through a 3-meter wireless medium in the 6G RAU. Next, the experiment was carried out and performance was evaluated in terms of EVM and

CSR. The dynamic range of the RF input power allowed for a 6G signal was 10dB, while the dynamic range for a 5G waveform signal was 18dB. The BER rate also improved significantly as a result of the promotion of corporate social responsibility. The paper's contribution lies in emphasizing the necessity of photonic integration as a critical tool for the coexistence of 5G and 6G services, which can be achieved using silicon photons, especially with the many photonic components used in this experiment.

In this work [15], the researchers demonstrate the importance of OFSs. The work method used in this work was initially based on giving an overview of OFSs and their operating principles and main components and classifying them according to different categories, then the advantages of OFSs were mentioned as FOSs have many advantages compared to traditional sensors, so they are developed and the range of applications is increased (one of the most prominent and recent applications contributed to the development of biotechnology, space science, and law enforcement security applications such as digital imaging).

Reference	Year	FO Applications	FO contribution
[9]	2022	Communication physics (quantum imaging or quantum communication).	This study contributes to providing an effective approach for application within scalable manufacturing processes in various real-world applications in quantum imaging or quantum communication, especially in the fields of quantum key distribution, entanglement distribution and high-resolution spectroscopy.
[10]	2022	artificial intelligence and robotics.	Creating a soft robot capable of detecting when and where it was damaged and then healing itself on the spot. The contribution of this research is complemented by making robots more agile and more endurance, which makes them work with more capabilities, better efficiency, and for longer periods.
[11]	2023	Deep Space Optical Communications (DSOC).	Demonstrating new laser systems for deep-space optical communication; Where the ability to conduct optical communications free of space

			throughout the solar system was provided, which exceeds the capabilities of the radio communication systems in use now; Thus there will be enough bandwidth for future space missions to transmit large amount s of data, including high-resolution video and images.
[12]	2022	Wireless networks and optical fiber sensor networks (OFSNs) and their use in environmental monitoring and in civil and mechanical engineering.	Provide a comprehensive and effective literature review and discuss the principles, characteristics, applications and properties of optical sensing and optical fiber sensing networks (OFSNs) The researchers' findings clearly show that OFSNs can be applied in many different areas to develop new sensor products and develop efficient approaches to sensing many parameters.
[13]	2022	Fiber Optic Sensors (FOS).	The results conclude that the future of civil infrastructure that uses the following modern information technologies (FOS, BIM, WSN, RFID and CV) is more sustainable and smarter.
[14]	2023	Enable very high transmission power in sixth generation (6G) radio access networks.	Emphasizing the necessity of optical integration as a critical tool for the coexistence of 5G and 6G services.
[15]	2022	Biotechnology, space science, and law enforcement security applications such as digital imaging.	Emphasizing the important role of sensors in providing the correct information that countries need at the required time, and thus reflecting positively on the general climate internationally.

Table 1. Comparison of Previous Applications of Fiber Optic && its contributions in different Development Fields

4. COUNTRIES ADVANCEMENT VS. FO EXPANSION

Many studies have indicated that the indicators of infrastructure development and electronic services in countries are linked to the levels of fiber penetration and development (FDI); In this section we will review the deployment and development of fiber across 88 countries and measure how it relates to the progress of infrastructure in these countries.
Studies have indicated that investment in optical fibers is vital to providing all data services with high quality, and there is a wide range of measures of investment in fibers, including the following [16]:

- Fiber to the household (FTTH) penetration
- Fiber to the premises (FTTP) coverage
- Advanced WDM technology investment Mobile cell site fiber penetration
- Fiber to the business (FTTBusiness) penetration

The extent to which these standards are applied is reflected in: Median download speed, Median upload speed, Median latency, Median jitter Increasing levels of efficiency and quality of services provided by optical fibers, which stimulates further innovation, proves the importance of high-speed broadband not only in achieving consumer satisfaction but also in its positive contribution to national economic indicators, with additional GDP growth of 0.25% to 1.5% for every 10% increase in household broadband penetration and a further 0.3% increase for every doubling of speed.
The golden key to improving countries' growth potential lies in maximizing investment in access to the next generation, which is what fiber-optic technology possesses, which is the cornerstone for achieving that investment, whether it is in the access or connectivity network.
Governments around the world are aware of the importance of broadband networks, and are now working to promote broadband goals and increase focus on investments in fiber-based infrastructure, which has great implications for the development and progress of these countries in the future.
Countries seeking to develop and advance should focus on achieving good quality broadband connectivity as it is vital and important for many digital applications - such as video conferencing, gaming and video streaming - to function well as they require high speed, reliable, highly consistent networks and low latency.
When developing investment plans these characteristics should be considered: higher overall quality of service (QoS), lower maintenance costs, lower energy costs, and smaller physical infrastructure requirements.
Investing in advanced broadband and cutting-edge technologies such as fiber optic networks will bring vital social and economic growth to the entire country; Optical fibers are proof of a more sustainable future. Governments should realize this point and the amount of benefits to the wider society from investing in a larger amount

of optical fibers that brings benefits to network operators, end users, network operators and society as a whole. The broadband industry underpins the broader ICT industry which typically accounts for between 2% and 7% of a country's GDP and supports a wide range of industries, from manufacturing to health institutions to educational facilities, as well as supporting more social aspects such as well-being and social equality [[16]].

In addition to all this, an end-to-end optical fiber network is essential to digital transformation. Increasingly, companies will use time-critical networks to improve their performance, and the reach network in leading regions will expand deep into customer premises.

It is important for governments to legislate to enable gigabit societies; It must be ensured that the telecommunications infrastructure can be deployed efficiently so that all new developments/properties are equipped with micro ducts, fiber, in-building access points or other physical infrastructure with the aim of accelerating the deployment of that infrastructure and reducing the cost of offering.

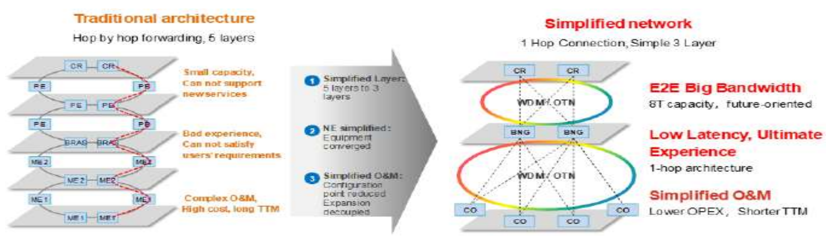

Figure 1. Moving to a flat optical network for optimized efficiency

Increased fiber deployment should be encouraged by best practice policies. The global broadband subscription market alone reached more than $356 billion at the end of 2021 [16].

The benefits of broadband spread to an educated population increasing the chance of getting jobs by 7-13% when they have access to fiber optic infrastructure.

Governments' drive to enable and expand deployment of optical fibers within their infrastructure has contributed to reducing the number of the world's connected population from 45% in 2019 to 27% by 2026. The more mature a country's broadband, the greater its ability to further digitize the product and increase its impact. The economist. An advanced set of Internet applications can increase the country's wealth and increase public efficiency [16].

In developed countries large portions of the population receive high-speed broadband connections in excess of 500 Mbps. In less developed areas, availability of high-speed broadband access is minimal. And those areas will be at a disadvantage if they don't catch up quickly, especially when the world of apps like XR and the metaverse moves into them [16].

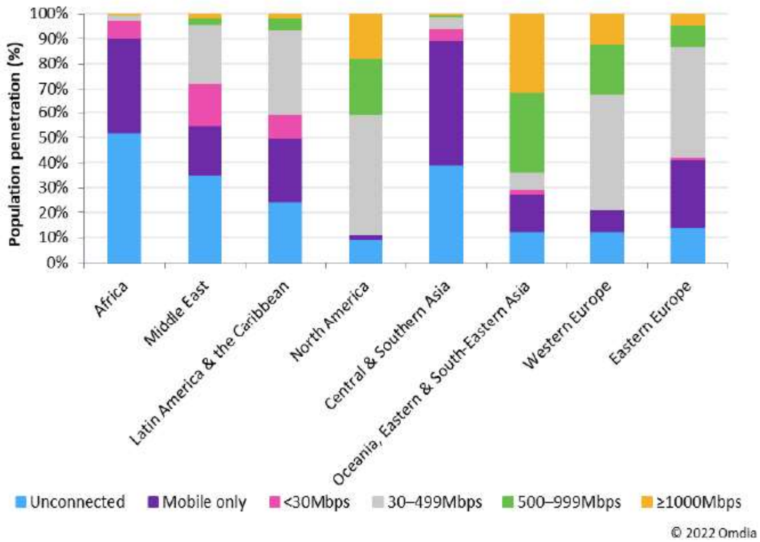

Figure 2. Percentage of connected population, by fixed broadband speed, by region, 2026

Fiber is the Ultimate Broadband Technology As discussed in the Fiber Development Index Analysis: 2021 Report, end-to-end fiber optic networks outperform all other broadband technologies in all quality of service (QoE) metrics. As the results of the statistics and FO investment indicators at the country level show, Singapore once again leads the FO direct investment index for the year 2022, (photo 3,4), as it achieved maximum scores in seven out of nine approved measures, followed by South Korea, then China, then the United Arab Emirates, then Qatar, then Japan [16].

All of those countries in the leading group benefit from high-speed services and strong national broadband plans provided by optical fibers, which are supported by generous government grants or subsidies.

Therefore, to compare individual results, the Fiber Development Index splits territories into three different country clusters [16]:

- Cluster 1: Countries with highly developed fiber-based broadband networks.
- Cluster 2: Developed broadband countries that are moving toward greater fiber broadband adoption.
- Cluster 3: Emerging broadband countries that have a low level of broadband household penetration.

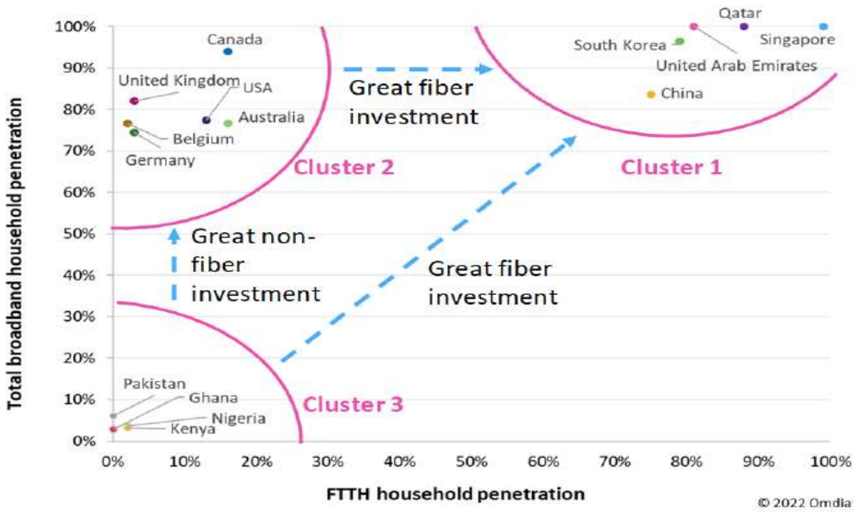

Figure 3. Fiber development clusters enable more focused recommendations

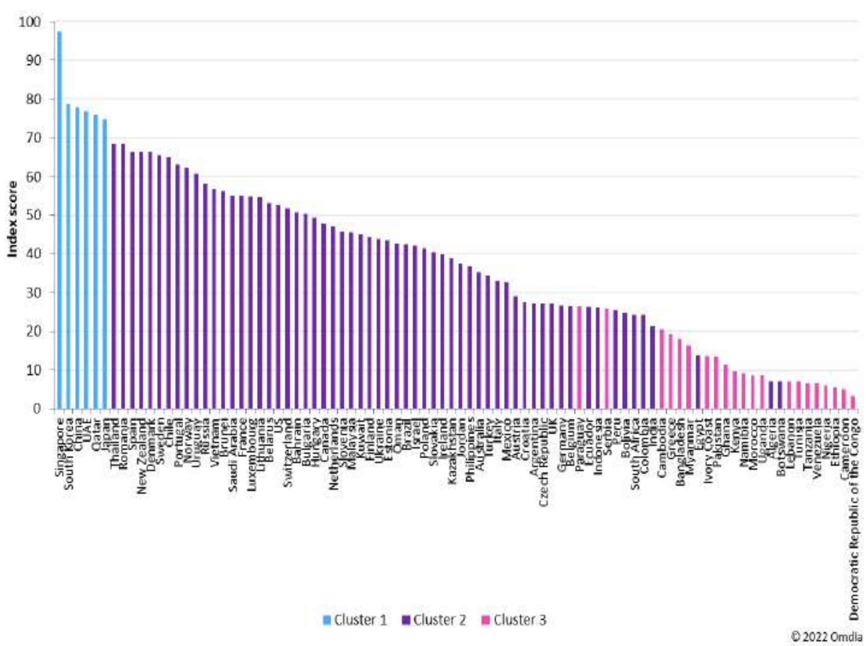

Figure 4. Fiber Development Index 2022 ranking

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Rank	country\territory	rank change 2021-22	2020 index score	2021 index score	2022 index score	cluster
1	Singapore	0	85	86	98	Cluster 1
2	South Korea	0	74	72	79	Cluster 1
3	China	1	69	69	78	Cluster 1
4	UAE	-2	69	71	77	Cluster 1
5	Qatar	0	68	69	76	Cluster 1
6	Japan	0	60	65	75	Cluster 1
7	Thailand	1	52	57	68	Cluster 2
8	Vietnam	-2	46	50	57	Cluster 2
9	Saudi Arabic	3	44	45	55	Cluster 2
10	Bahrain	-6	39	46	51	Cluster 2
11	Malaysia	4	36	37	46	Cluster 2
12	Kuwait	3	28	35	45	Cluster 2
13	Oman	1	25	31	42	Cluster 2
14	Kazakhstan	-12	34	38	39	Cluster 2
15	Jordan	0	26	31	38	Cluster 2
16	Philippines	0	21	30	37	Cluster 2
17	Australia	1	27	28	35	Cluster 2
18	Indonesia	-8	21	23	26	Cluster 2
19	Bangladesh	0	15	16	18	Cluster 3
20	Myanmar	-4	18	18	16	Cluster 3

21	Pakistan	1	7	8	13	Cluster 3
22	Lebanon	-4	6	7	7	Cluster 3
23	Brunei	5	41	45	56	Cluster 2

Table 2. Group 1 Results and Changes in the Fiber Development Index Ranking

Rank	country\territory	rank change 2021-22	2020 index score	2021 index score	2022 index score	cluster
1	USA	6	37	38	53	Cluster 2
2	Canada	6	36	37	48	Cluster 2

Table 3. Group 1 Results and Changes in the Fiber Development Index Ranking

Rank	country\territory	rank change 2021-22	2020 index score	2021 index score	2022 index score	cluster
1	Chile	15	26	39	65	Cluster 2
2	Uruguay	2	48	48	61	Cluster 2
3	Brazil	5	25	31	42	Cluster 2
4	Mexico	1	22	25	33	Cluster 2
5	Argentina	4	18	21	27	Cluster 2
6	Ecuador	8	14	17	26	Cluster 2
7	Bolivia	-3	17	21	25	Cluster 2
8	Colombia	3	14	17	24	Cluster 2
9	Paraguay	5	16	19	27	Cluster 3

Table 4. Group 1 Results and Changes in the Fiber Development Index Ranking

Rank	country\territory	rank change 2021-22	2020 index score	2021 index score	2022 index score	cluster
1	South Africa	-2	18	20	24	Cluster 2
2	Egypt	2	7	10	14	Cluster 2
3	Algeria	2	6	7	7	Cluster 2
4	Cambodia	-3	18	19	20	Cluster 3
5	Ivory costa	-1	6	12	14	Cluster 3
6	Ghana	-2	11	11	11	Cluster 3
7	Kenya	1	8	7	10	Cluster 3
8	Namibia	-2	7	8	9	Cluster 3
9	Morocco	1	6	7	9	Cluster 3
10	Uganda	5	5	6	9	Cluster 3
11	Tunisia	-3	7	7	7	Cluster 3
12	Tanzania	-1	8	6	7	Cluster 3
13	Nigeria	-1	4	6	6	Cluster 3
14	Cameroon	-1	7	4	5	Cluster 3
15	Congo	0	3	3	3	Cluster 3

Table 5. Group 1 results and changes in the classification of the Fiber Development Index

Rank	country\territory	rank change 2021-22	2020 index score	2021 index score	2022 index score	cluster
1	Romania	1	54	56	68	Cluster 2
2	Spain	1	55	55	66	Cluster 2
3	New Zealand	5	50	52	66	Cluster 2
4	Denmark	0	50	54	66	Cluster 2
5	Sweden	-5	59	58	65	Cluster 2
6	Portugal	-2	51	54	63	Cluster 2
7	Norway	-1	52	53	62	Cluster 2
8	Russia	-4	52	53	58	Cluster 2
9	France	5	34	41	55	Cluster 2
10	Luxembourg	-5	45	49	55	Cluster 2
11	Lithuania	-1	46	46	55	Cluster 2
12	Belarus	-4	45	47	53	Cluster 2
13	Switzerland	-1	41	41	52	Cluster 2
14	Bulgaria	-9	45	47	50	Cluster 2
15	Hungary	5	35	37	49	Cluster 2
16	Netherlands	6	35	36	47	Cluster 2
17	Slovenia	-3	36	39	46	Cluster 2
18	Finland	-2	35	38	44	Cluster 2
19	Ukraine	-9	40	40	44	Cluster 2
20	Estonia	-7	36	39	43	Cluster 3
21	Poland	-1	29	34	41	Cluster 3
22	Slovakia	0	29	31	41	Cluster 3
23	Ireland	0	28	31	40	Cluster 3
24	Turkey	-1	26	28	34	Cluster 3
25	Italy	1	23	25	33	Cluster 3
26	Austria	2	20	23	29	Cluster 3
27	Croatia	4	20	22	28	Cluster 3
28	Czech Republic	-5	26	27	27	Cluster 3
29	UK	4	19	21	27	Cluster 3
30	Germany	-2	20	22	27	Cluster 3
31	Belgium	-2	22	22	27	Cluster 3
32	Greece	2	13	14	19	Cluster 3

Table 6. Group 1 Results and Changes in the Fiber Development Index Ranking

5. RESULTS AND DISCUSSION

Through the previously reviewed works, we find that optical fibers are of great importance in many fields:

a) Within the field of **telecommunications physics and quantum communication**: Optical fibers have successfully transported two-photon quantum states of light through phase-separated Anderson localization optical fibers (PSF), as confirmed by a study published in the Journal of Communication Physics by ICFO researchers; Where an optical fiber was created that can spread multiple optical beams into a single optical fiber with minimal spacing between them by harnessing Anderson localization, and this contributed to the transmission of quantum information as efficiently and effectively as possible through Corning's phase-separated optical fibers.

b) In the **AI and robotics** sector: researchers have developed stretchable fiber optic sensors for use in soft robotics and related components - from skin to wearable technology; Thus, the use of optical fibers has contributed to making robots more agile and more enduring, which makes them operate with more capabilities, better efficiency, and for longer periods.

c) In the field of **optical communications in deep space**: the development of new laser systems for deep-space optical communication contributed to providing the ability to conduct optical communications free of space throughout the solar system, which exceeds the capabilities of the radio communication systems used now; It provides enough bandwidth for future space missions to transmit large amounts of data, including high-resolution video and images; This work is considered an advanced qualitative leap in the field of optical communications in deep space, as it will allow the verification of the validity of these communications and will allow an automated exploration of planetary bodies using resources similar to the latest radio frequency communications to provide the possibility of re-streaming high-resolution images or craters.

d) **Multi-functional Tasks (disease diagnosis, intra-fiber computing, energy harvesting and storage, inter-fiber communication, etc.)**: Researchers have confirmed that advanced functional optical fibers have a significant role in greatly expanding and enriching current information technology as they help in accomplishing complex functions including manipulation. With neural activity, disease diagnosis, computing within fibers, energy harvesting and storage, as well as communication between fibers, multifunctional optical fibers thus play an important role in achieving progress and development in information applications today.

e) **Wireless networks and optical fiber sensor networks (OFSNs)** and their employment in environmental monitoring and in civil and mechanical engineering: The results of the integration of optical fiber sensors and sensor networks WSNs showed real contributions to the development of new sensor products and the development of effective approaches to sensing many parameters, for example , water levels, temperature, presence of chemicals (pH, DNA, ammonia, etc.)

f) **Fiber Optic Sensors (FOS)**: The study showed the growth of trends in the application of information technologies in the field of civil infrastructure, which has taken a rapid pace in recent times; The current development in this field was studied, and the results concluded that the future of civil infrastructure that uses the following modern information technologies (FOS, BIM, WSN, RFID, and CV) is more sustainable and smarter; Especially when digital twins are used as tools for planning and managing smart infrastructure of the next generation, and this contributes to the outcome in raising the level of infrastructure and the efficiency of its services.

g) Enabling a very high transmission capacity in the **sixth generation (6G) radio access networks**: where the researchers emphasized the importance of photonic integration as a crucial tool for the coexistence of 5G and 6G services, which in turn achieves a very high transmission capacity in the sixth-generation radio access networks (6g).

h) **Optical fiber sensors and their applications within the sectors of biotechnology, space science, and security applications for law enforcement such as digital imaging**: The results showed a significant increase in demand for optical fiber sensors because they have many advantages compared to traditional sensors, so they are developed and the range of applications is increased (Among the most prominent and recent applications that have contributed to the development of biotechnology, space science, and security applications for law enforcement such as digital imaging). But just as OFSs have many advantages, they are a double-edged sword that may carry many security and privacy risks. Some negative effects may arise because of them, such as the rapid spread of misinformation and the increase in unemployment rates. Hence, it is possible to analyze and measure the impact of the advancement of optical fibers on the infrastructure of countries. Now countries rely heavily on data to plan for the future and highly accurate studies are being built on that data. Obtaining accurate data will lead to the optimal and correct use of the state's resources, building accurate and effective future plans and studies that lead in the right directions, as well as preserving the environment to provide a better climate for its citizens, and this is what will ultimately contribute to reducing spending on sectors such as health and the Corona pandemic.

In conclusion, we find many studies that indicated the correlation of indicators of infrastructure development and electronic services in countries with the levels of fiber penetration and development (FDI); Investing in fiber is an essential measure for network operators, government organizations and other stakeholders such as the media and businesses. The strength of optical fiber is that it is a broadband access technology that provides improved quality service that is highly sustainable and future-proof. All this progress and the superior level of quality that optical fibers achieve makes them essential for the development of future digital applications and services across all sectors including (but not limited to) education, entertainment, smart cities, health, work at home, corporate services and more. In conclusion, for countries to transition to a greener future, optical fiber-based communications must be part of their future investment plan included.

6. CONCLUSIONS

The ultimate goal of this work is to elucidate the contribution of FO to development. The great development and progress in the fiber optic industry was reviewed and the employment of these advanced versions within a wide range of modern fiber optic applications that included many fields, including industrial, scientific and technical. The paper examined the relationship between the spread of optical fibers and the development of information technologies and modern electronic services and showed the new and accelerating progress in optical fibers, and new information technologies. Many modern applications of Fiber Optic within the various sectors of development were reviewed, and the effective and real contribution of Fiber Optic in the development of the systems of those sectors was greatly highlighted. The score part was finally developed further and the strengths were discussed more clearly and a table was developed comparing the relationship and contribution between the FO score within different applications. Finally, the influence and relationship between FO within countries with regard to infrastructure and e-services is demonstrated. In summary, we found that OFSs have many advantages, but they are a double-edged sword that may carry many security and privacy risks, such as the rapid spread of misinformation and the increase in unemployment rates. Hence the relationship between the degree of FO on the infrastructure of countries can be studied and analysed; Now countries rely heavily on data to plan for the future and highly accurate studies are being built on that data. In conclusion, the important role of sensors is clearly shown in providing the correct information that we need at the required time, and thus positively reflecting on the general climate internationally. There are many directions towards further development of fiber optics in order to achieve higher levels of efficiency when enabling it within the various applications and development systems that form the basis of the future for individuals, countries and the world at large.

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