

Transmission of large amounts of scientific data using laser technology

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Abstract. Currently, the volume of figures generated by different research scientific projects (the Large Hadron Collider (Large Hadron Collider, LHC), The Square Kilometre Array (SKA)), can reach tens of petabytes per day. The only technical solution that allows you to transfer such large amounts of scientific data to the places of their processing is the transfer of information by means of laser technology, using different propagation environment. This article discusses the possibility of data transmission via fiber-optic networks, data transmission using the modulation binary stream of light source by a special LED light source, the necessity to apply laser technologies for deep space communications, the principle for an unlimited expansion of the capacity of laser data link. Also in this study is shown the need for a substantial increase in data transfer speed via a pre-existing communication networks and via the construction of new channels of communication that will cope with the transfer of very large scale data volumes, taking into account the projected rate of growth.

1. Introduction

Recently, the rapid development of various scientific fields (such as radio astronomy, bioinformatics, climatology) has lead to appearance of scientific projects, which form massive volumes of the order of tens of terabytes of figures in a short time period. This leads to an extreme increase of the volume of transmitted information in data networks. Therefore, we are faced with the necessity of the solution of the problem of a strong increase of the volume of figures transmitted in the local and regional data networks in contemporary world. It already causes the exhaustion of available resources, and the real needs of requirements indicate the continuation of the growth of information flows tenfold and hundredfold in some cases [1].

2. Current situation

Let's consider some of the largest Russian and foreign research projects that operate with massive data arrays.

Nowadays the radio telescope RT-22 (figure 1) is used as a tracking station for the project "Radiostron" of Physical Institute Astro Space Center. PN Lebedev (ASC FIAN). The goal of this project is to conduct scientific observations using radio astronomy telescope, which was established in



the scientific-production association Lavochkin [2] and is mounted on the spacecraft "Spektr-R". The daily stream of figures from this radio astronomy center is just over 1.28 terrabytes. This project uses communication channel of 1Gbps bandwidth for its operations, which connects the tracking station and a buffer data center, and located on the territory of the Pushchino Radio Astronomy Observatory, and the center of the processing of scientific information Astro Space Center in Moscow [3].



Figure 1. Radiotelescope RT-22 [4].

Research related to the human genome, provide a wealth of information also. For example, the data center of the Beijing Genomic Institute, consisting of more than 500 nodes, each day produces about 10 terabytes of "raw" data [5].

Fluorescence microscope IsoView, created in the Howard Hughes Medical Institute, is able to visualize the cellular dynamics in all three dimensions in large organisms with a resolution of up to the definition of individual cells structure. A typical experiment fluorescence microscope lasts more than one hour. Four cameras transmit approximately 3.2 gigabytes of data per second, resulting in about 10 terabytes of raw data [6].

Another project that generating huge amounts of data, is an array of telescopes, LOFAR (LOW Frequency ARray - «low-frequency antenna array»). Radio telescope explores the low-frequency radio waves to search for the first stars and galaxies in our Universe, the potential signals of extraterrestrial intelligence, as well as studying black holes and pulsars. The project connects about 20,000 radio antennas located throughout Europe. LOFAR generates about 138 terabytes of data per day [7].

Nowadays for the high-speed transmission of this vast amounts of information are widely used laser technology, where as a carrier information signal, the electromagnetic radiation in the optical range. The ubiquitous distribution in the commercial and scientific exploitation has optical fiber communication. It uses special optical cables as the transmission medium, comprising filaments of optically transparent material (glass, plastic) that serve to transfer light internally by total internal

reflection. Widespread this systems received due to a number of advantages, such as high bandwidth and low attenuation of the signal, as compared to transmission systems using copper cables or radio broadcast as the transmission medium, and in days.

Existing commercial communication line speed at this time is usually no more than 10 Gbps. However, the possibilities for transmitting in scientific data networks are higher. For example, the internal rate of scientific network of the US Department of Energy's ESnet (Energy Sciences Network) is 100 Gbps [8], it will be coupled by the channels with the European scientific and educational GEANT network. Transatlantic expansion will provide users the capacity of 340 Gbps and it can serve dozens of scientific collaborations [9].

3. Investigations and possible solutions

It should be noted that the existing data transmission speeds insufficient for the growing needs of science. It is necessary to constantly upgrade the existing communication channels, communication equipment, data transmission protocols, as well as the running of new communication channels and the launch of new data transmission technologies.

The research on this issue is constantly carried out and progress has been made in this field, allowing to look optimistically into the future. Based on these results it can be concluded that a fiber-optic connection can cope with the transfer of a large amount of scientific data. Further, the article describes some of the research groups of scientific capabilities of fiber-optic communication.

In 2014, a joint team of researchers from the University of Technology Eindhoven (Eindhoven University of Technology) and the University of Central Florida (CREOL) has created a new type of fiber optic cable capable of transmitting on one strand fiberglass data at a rate of 255 Tbps [10].

In early 2014, the British company Alcatel-Lucent and British Telecom were able to achieve a data rate of 1.4 Tbps on a standard fiber optic cable that was laid quite a long time, using a set of standard communication equipment. This speed was achieved by means of a unique hardware solution - new protocol called "Flexigrid", which allows you to overlay multiple independent signals to each other and transmit it over a single optical cable [11].

And the absolute record of fiber optic data transmission speeds currently achieved by Nippon Telegraph and Telephone Corporation (NTT) Japanese companies. They worked together with three partner organizations, company Fujikura Ltd., Hokkaido University and the Danish University of Technology (Technical University of Denmark, DTU). Their experiment in September 2012 showed a record speed of information transmission over a single fiber. During the test of a new line of communication, specialists recorded data rate of 1 Pbps over fiber optic cable with 12 channels, and a light guide length of 52.4 kilometers. This is orders of magnitude greater than the rate cables are now in commercial operation [12].

Russian company "T8" has established several world records on the fields of data rate transfer. For example, in 2014 on a sector of 500.4 km length with a channel speed of 100 Gbps was achieved speed 1Tbps due to amplifiers with remote pumped ROPA and simultaneous transmission of 10 channels of information. In 2013, the successful transmission of signals at 100 Gbps was achieved over a distance of 4,000 kilometers in the current link in the "Volga" equipment. And now T8 is developing a high-speed WDM platform (DWDM) with total capacity of 25 Tbps [13].

It should be noted that currently there exists a development of high-speed data transmission by means of laser technology in the air. For example, in 2014 a group of Russian companies "Stins Coman" introduced a wireless local area network "Beamcaster", which uses data transmission by laser beam in the air, and the data rate which can be up to 40 Gbps by virtue of this technology [14].

National Aeronautics and Space Administration (NASA) proposes to use laser beams to transmit information in a vacuum, because the wavelength of visible light is much shorter than that of radio waves, therefore so the use of the optical transmitter will transmit much more of figures. In addition, the laser is much better "hover" at the target, therefore transfer requires less energy. In the current experiment in 2013 LADEE probe (figure 2), came to a circular orbit at an altitude of 235 kilometers above the lunar surface and spent laser communication session between the Moon and the Earth by an

on-board device Lunar Laser Communication Demonstration (LLCD). The authors of experiment said that the data rate at a distance of 385,000 kilometers between the Moon and the Earth was a record 20 Mbps, and between the Moon and the Earth - 622 Mbps.



Figure 2. Spaceprobe LADEE [15].

Featured data rate appeared to be several times higher than the transmission speed of the radio waves by the spaceships reached the surface of the moon ever before. Furthermore, the signal receiver in Earth have four antennas 30 cm in diameter. This size is orders less than that of the antennas receiving data over radio waves from space. In the future, NASA is planning to develop this information transmission system, and it allows you to send and receive high-definition images of probes and 3D video from deep space. Also, NASA is planning an another long-term experiment on the LCD (Laser Communications Relay Demonstration) laser communications, which will be launched in 2017 [16].

The development teams for several years experimenting with the new data transfer technology, the LEDs in the fluorescent. The project is called "light fidelity", or "li-fi". With this technology, the Mexican company Sisoft together with scientists from the Autonomous Technological Institute of Mexico in 2014 reached a data rate of 10 Gbps [17]. And at Oxford University are developing a transceiver, which receives the signal from the optical fiber, amplifies it and transmits the room at a speed of 224 Gbps by means of this technology [18]. The data rate is much higher than the maximum data transfer speeds via Wi-Fi technology.

Recently the newest technology have appeared, enabling virtually unlimited bandwidth to expand the data. We are talking about the use of one of the quantum characteristics of photons, namely their "twist" - the orbital angular momentum of photons relative to their direction of propagation. This very property helps photons to implement the transfer of information not by classical "zero" and "one", but by the qubits in a quantum superposition. This makes it possible for us to realize for the unit the transmission of information an infinite number of states, describing arbitrary points of the multidimensional space. Despite the apparent high noise immunity of this communication channel, recent experiment was carried out by a group of scientists under the guidance of professor Zeilinger [19]. This experiment has proved its high reliability even when the transfer of information id effected through the atmosphere. The experiment revealed that, despite the high number of atmospheric

turbulence the quantity of incorrectly transmitted information does not exceed one percent. This allows to conclude about the high reliability of this transmission channel. Transfer rate was 4 pixels per second, but no optimization was carried out. This experiment showed that at large distances the turbulence of the atmosphere in the process of transfer has no significant impact on the reliability of data transmission. It also revealed the prospect of this method when sending large amounts of information, including for communicating with interplanetary spacecraft. In the future, announced the establishment of a channel with 11 states twist [20].

4. Conclusion

To date, the available communication links cope with the flow of large volumes of scientific data, and providing remote access of researchers to the complex scientific equipment and computing resources in real-time. However, due to the ever increasing volume of scientific information generated by the scientific projects there is the need for a fundamentally new technological solutions, using laser technology to increase the scientific data rates.

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