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Method for optimizing fiber optic interferometer for quantum systems

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Abstract. A method for optimizing the parameters of a two-arm fiber-optic interferometer is proposed. To increase the OSNR at the interferometer output, a step-by-step method for aligning the lengths of the interferometer arms using a time delay meter is proposed. A high (83%) contrast of the interference pattern is achieved, which increases the sensitivity of the system and allows recording optical signals in a large dynamic range.

Keywords: fiber-optic communication system, interferometer, optical fiber, laser

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Метод оптимизации волоконно-оптического интерферометра для квантовых систем

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Аннотация. Предложен метод оптимизации параметров двухплечевого волоконно-оптического интерферометра. Для повышения OSNR на выходе интерферометра предложен пошаговый метод выравнивания длин плеч интерферометра с помощью измерителя временной задержки и последующего включения линии задержки. Достигнут высокий (83%) контраст интерференционной картины, что повышает чувствительность системы и позволяет регистрировать оптические сигналы в большом динамическом диапазоне.

Ключевые слова: волоконно-оптические телекоммуникационные системы, интерферометр, оптическое волокно, лазер

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Introduction

Fiber-optic systems have wide applications in different areas: telecommunications, aerospace, astronomy, security, and scientific research.

Fiber-optic communication systems (FOCS) using quantum technologies provide a high degree of protection of transmitted data from unauthorized access. However, these technologies impose special specifications for their components: lasers, photoreceivers, optical fibers, and others. One of the components of quantum systems is an interferometer used to register a quantum key. For reliable registration of the quantum key at high speed, it is necessary to ensure equality of the lengths of the interferometer arms, the state of polarization of the transmitted signal, and minimal losses.

Experimental results and discussion

Coherent high-speed DWDM fiber-optic systems are characterized by a low optical signal detection threshold. A key feature of coherent systems is the interference superposition of optical signals at the photodetector input. This technology places increased demands on the polarization characteristics of all data transmission system components.

The proposed method for aligning the optical travel time of signals along different arms of the interferometer is characterized by simplicity of implementation, visibility of control, high accuracy (up to 20 ps), and the possibility of use with a high bit rate (up to 50–100 GBit/s).

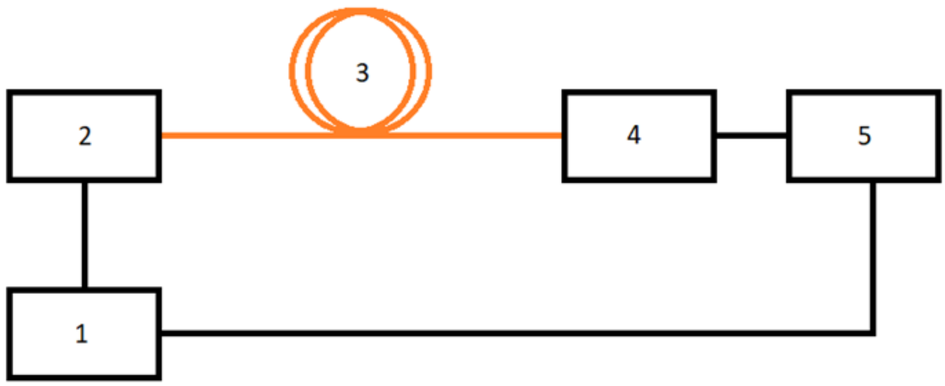

Fig. 1. Block diagram of experimental setup for measuring the delay in optical fiber: pulse generator *1*, laser *2*, optical fiber *3*, photodetector *4*, time interval meter *5*

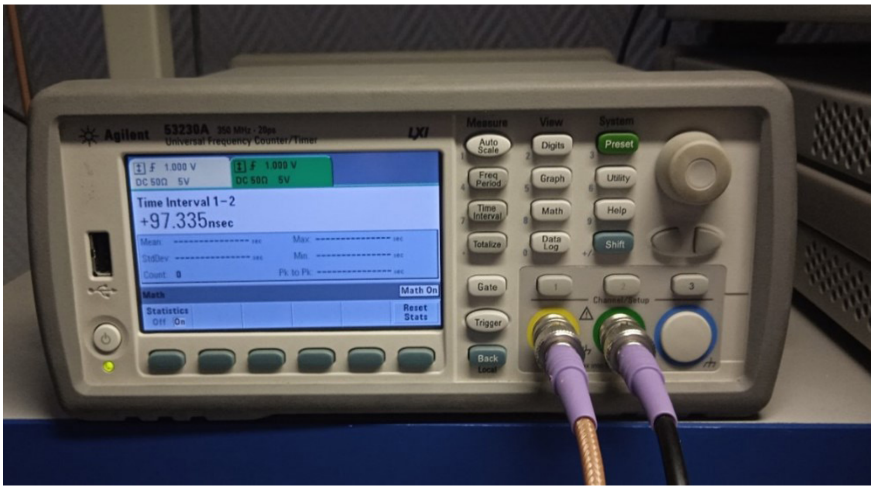

Fig. 2. Measuring the delay between the first and second pulses using an Agilent 53230A frequency counter

The experimental study was conducted using typical DWDM telecommunications equipment. The block diagram of the experimental setup is shown in Fig. 1. The signal from a narrowband laser source was modulated by a rectangular pulse generator. A sequence of optical pulses at a wavelength of λ = 1550 nm of nanosecond duration was introduced into a 1:2 coupler and then into two single-mode optical fibers. Optical signals at the ends of the fibers were recorded using photodetectors and fed to the inputs of an Agilent Technologies 53230A dual-channel frequency counter and an Agilent Technologies MSO-X-3052A oscilloscope. This Agilent Technologies 53230A frequency counter was used as a time interval meter (Fig. 2). To increase the contrast of the interference pattern, the delay between pulses should be minimal.

The envelope shape and pulse duration were monitored using an Agilent Technologies MSO-X-3052A oscilloscope (Fig. 3). These parameters depend on the laser type, parameters, and length of the optical fiber.

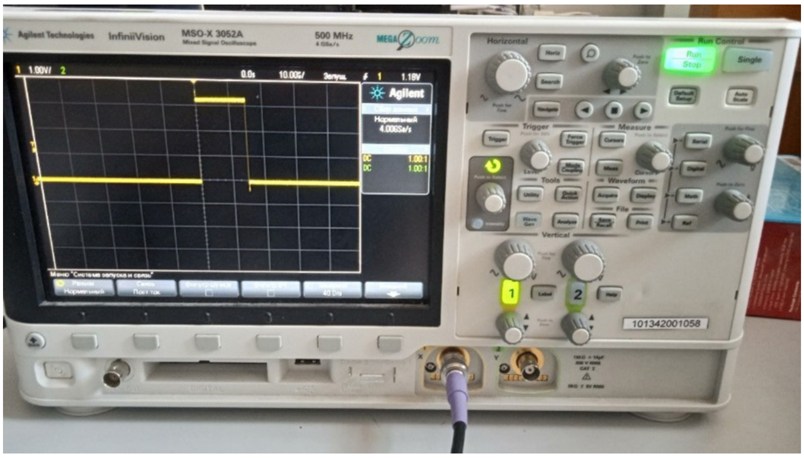

Fig. 3. Optical pulse at the end of optical cable at Agilent oscilloscope

To check the accuracy of the interferometer adjustment, a modulator was included in one of the interferometer arms. The contrast depth of the interference pattern at the interferometer output reached 83%, which indicates that the time delay of the optical signal passing through the optical fibers included in the interferometer arms is equal.

The polarization state was also monitored during the experiment by a polarimeter THORLABS PAX1000 (Fig. 4). The result of measuring the state of the optical pulse polarization using the polarimeter is shown in Fig. 5.

The achieved interference pattern contrast of 83% with an interferometer arm length of about 5 m made it possible to measure the optical signal in a dynamic range of more than 80 dB.

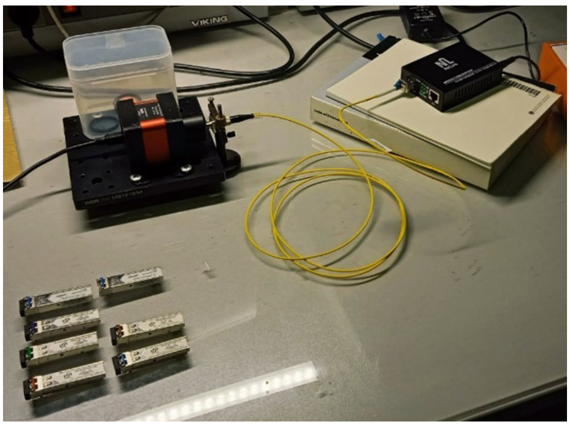

Fig. 4. Experimental stand for the polarization state monitoring

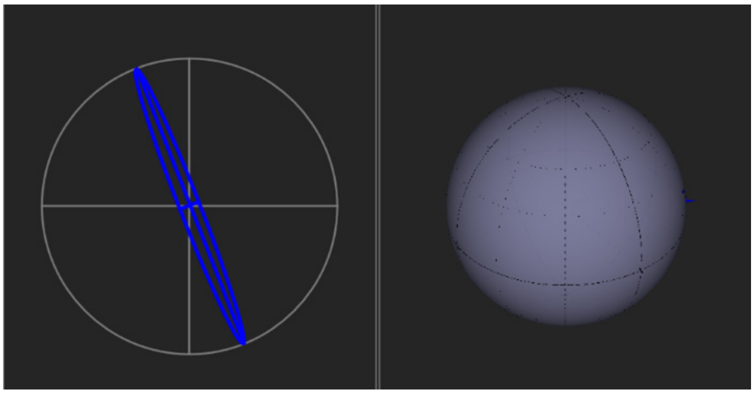

Fig. 5. Result of measuring the state of the optical pulse polarization using a polarimeter

Conclusion

Thus, the method of equalizing the lengths of the interferometer arms using a time-delay meter between pulses passing through different arms of the interferometer has been experimentally confirmed. The possibility of controlling the delay time to 20 ps and less has been demonstrated. Aligning the lengths of the interferometer arms (up to 5 mm) increases the sensitivity of the interferometer and allows recording signals in a large (80 dB) range.

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