Acoustic sensor based on few-mode optical fibers

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The application of few-mode optical fibers as a sensing element was considered in a number of works [1-3]. In this paper the results of a study of an acoustic impact sensor based on the basis of an optical fiber, operating in a few-mode regime, are represented.

An experimental setup for studying acoustic effects on the parameters of light propagating in a few-mode fiber is shown on Fig. 1. A laser diode (LD) with a center wavelength of 980 nm and an output power of 5 mW was used as a radiation source. A polarization controller (PC) was used to control the state of polarization. The mode controller (MC) was used to control the higher order mode excitation. In experimental setup Corning SMF-28e+® optical fiber, total length of 5.9 km, was used as a sensor. The acoustic impact was applied on the short section of the optical fiber at a distance of 4.9 km. A p-i-n photodiode with a transimpedance amplifier (PD/TIA) is used for detection.

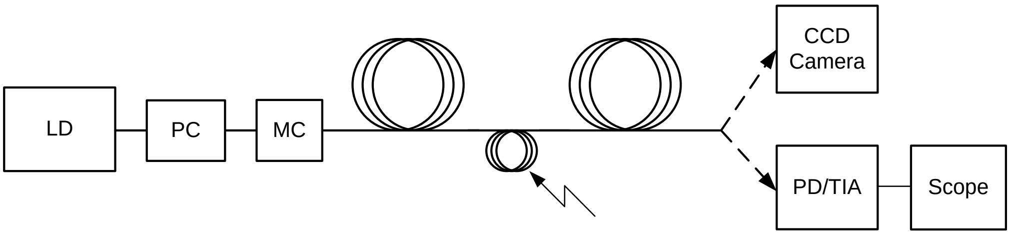

Fig. 1. Experimental setup

As a result of theoretical calculations, it was determined that when using a radiation source with a wavelength of 980 nm, the optical fiber supports the propagation of two modes LP_{01} and LP_{11}. A digital CCD camera was used to experimentally study the mode composition in the optical fiber. In Fig. 2 the distributions of the optical field obtained at various settings of the mode controller are shown.

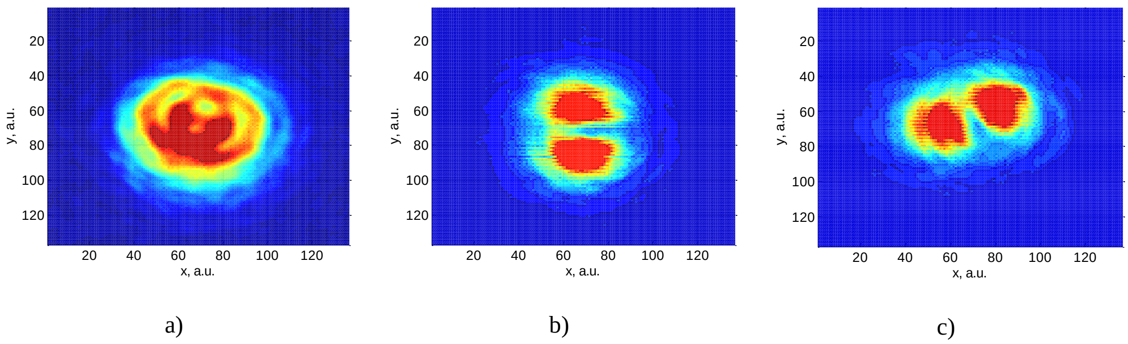

Fig. 2. Optical field distributions at different settings of the mode controller: a) total field; b) LP11a; c) LP11b

The study of acoustic effects was carried out with various configurations of the sensor element and its orientation in relation to the acoustic field. A speaker with a diaphragm diameter of 40 cm was used as a source of acoustic impact. The following configurations were investigated: a coil of 4 turns of an optical fiber with a diameter of 50 cm with vertical orientation; coil of 4 turns of optical fiber with a diameter of 50 cm with horizontal orientation; a straight section of the fiber with a length of 40 cm, located above the speaker diaphragm.

For acoustic isolation and prevention of parasitic influences, the interrogation system and a sensitive element with a speaker were placed in different rooms. A sinusoidal signal with a frequency in the range of 500 - 10000 Hz was supplied to the speaker, while providing an acoustic exposure level of 60-70 dBa for the range 800 - 2400 kHz. Examples of measurement results for a frequency of 1.7 kHz are shown in Fig. 3.

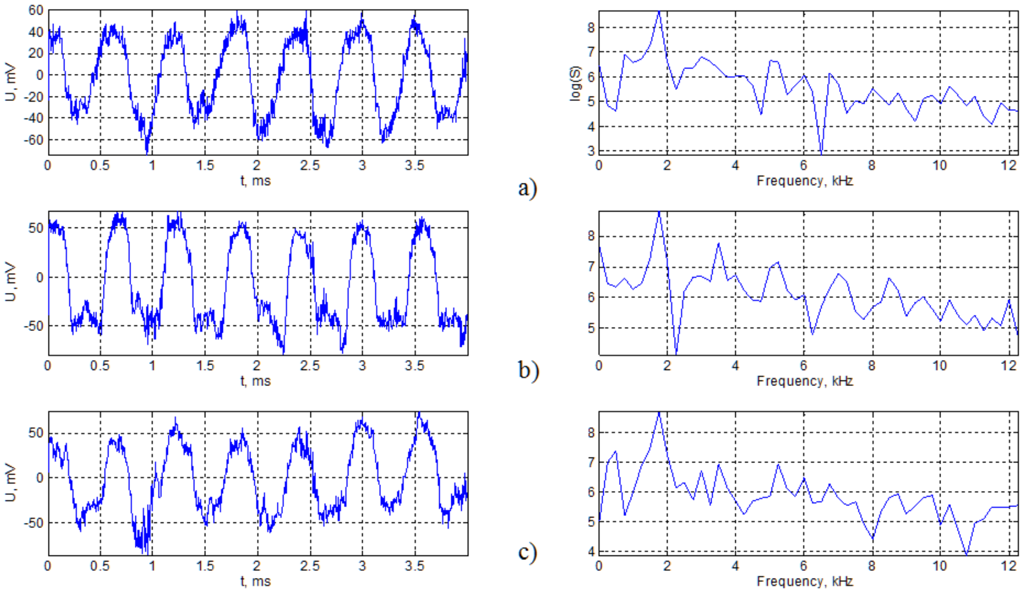

Fig. 3. Detected signal and spectral characteristics: a) fiber coil, horizontal; b) fiber coil, vertical; c) straight fiber section

Thus, the ability to identify the impact and determine its characteristics was demonstrated. It was noted that the amplitude of the detected signal largely depends on the settings of the mode controller and the polarization controller.

References

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