

Multiplexing and demultiplexing of the complex signal in the singular beams propagating in a few-mode optical fibers: an experiment

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Abstract. We have experimentally demonstrated the possibility of multiplexing and demultiplexing the complex signal in the singular beam propagating in a few -mode fiber. Stokes polarimetry method conducted field analysis of the structure at the outlet of a few-mode fiber. The possibility of identifying each of the input signals of the wavelengths and orbital angular momentum. It is found that in the radiation field at the exit of a few-mode fiber, C-points each of which corresponds to the input beam polarization. The topological index of these C-points corresponding to the initial charge of the beams.

1. Introduction

The main tasks of modern optics include: - the creation of instruments and devices for high-speed data transmission over long distances; - increasing data capacity of communication channels; - encoding and decoding transmitted signals [1-3]. Recently, as a communication channel commonly used optical fibers. In [4-6] were shown the processes of propagation of singular beams with unique properties in optical fibers. This propagation is accompanied by screwing a helical beam wave front in the fiber environment, and between fields of their own beam mode energy is exchanged. Singular beams are of fundamental interest in finding methods of increasing the transmittance of optical fibers. By the process of applying the transmitted signals include multiplexing, and the separation of signals – demultiplexing. A number of studies [7-10] have been highlighted principles of multiplexing and demultiplexing of signals in optical fibers. The proposed experimental design allows for: multiplex and demultiplex composite signal in the optical-mode fiber; analyze the field at the exit of a few-mode fiber by Stokes-polarimetry for different combinations of folded signals, depending on the signs and magnitudes of topological charges of optical vortices and direction of the circularly polarized components.

2. Multiplexing signal

To investigate the signal multiplex in the few-mode fiber used in the experimental setup shown in Figure 1.



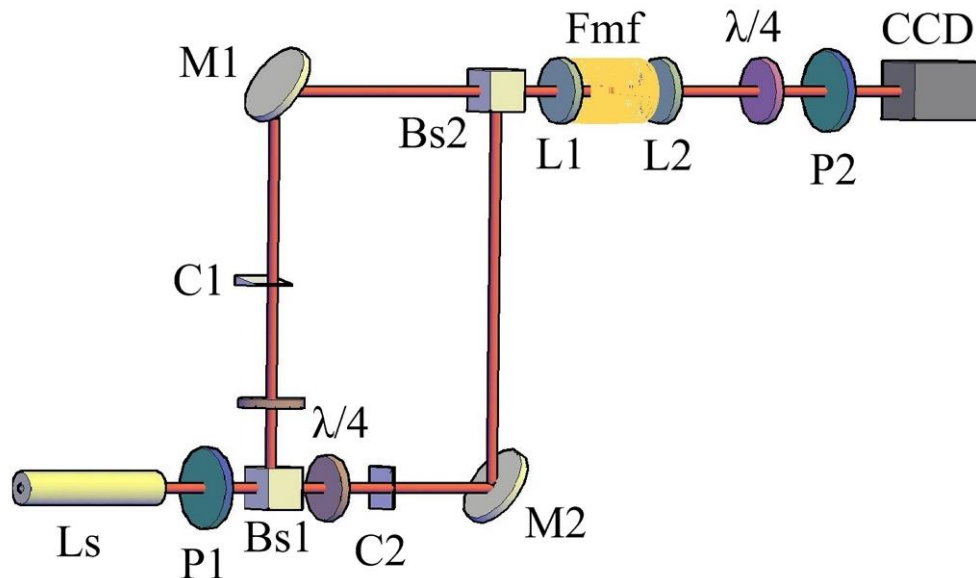


Figure 1. Schematic of the experimental setup: (Ls) Laser, (P) polarizer, ($\lambda/4$) quarter-wave plate, (Bs) beam splitter, (L) lens, (M) mirror, (C) dielectric wedge, (Fmf) few-mode fiber ($V = 3.4$), (CCD) camera.

The linearly polarized Gaussian beam from the light source Ls with a wavelength $\lambda = 0,63\text{mkm}$, the beam is split into two with a beam splitter Bs_1 . Using records $\lambda/4_{1,2}$ from the resulting beams distinguish orthogonally directed circularly polarized components - right and left. Then, placing the optical path of the beams, dielectric wedges $W_{1,2}$ generate singular beams with given values of topological charges $l = \pm 1$ [11, 12]. The second beam splitter Bs_2 collect beams, thereby setting the complex signal. Further, already multiplexed signal is transmitted is wound few-mode fiber Fmf . Analysis of the multiplexed signal is produced at the output of the fiber mode field for the state. The identification of each of the superimposed beams can be made from the values of the orbital angular momentum. Also, the state received the total field at the output of the fiber, the method of Stokes-polarimetry, we can identify each of the input signals.

We have a number of possible combinations of signal multiplexing have been implemented in the inlet mode fibers:

- 1) Multiplexing of the beams with the same values and different signs of topological charges of optical vortices;
- 2) Multiplexing beams with identical and orthogonal directions of circular polarization.

The resulting intensity distribution maps and polarization multiplexing in the process of the composite signal at the output of a few-mode fiber, shown in Figure 2.1-3.

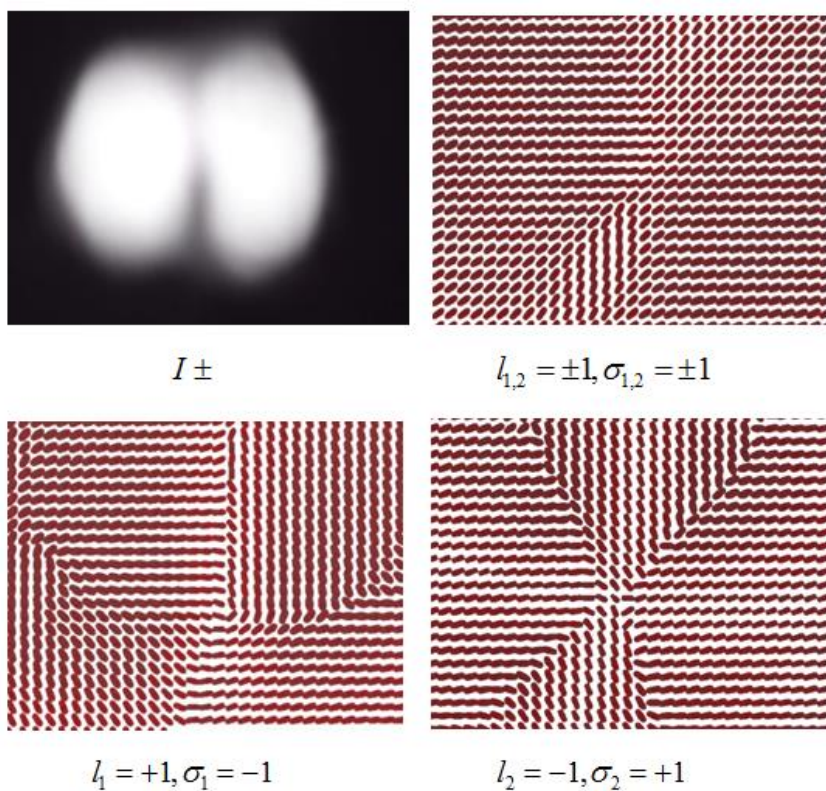


Figure 2.1.

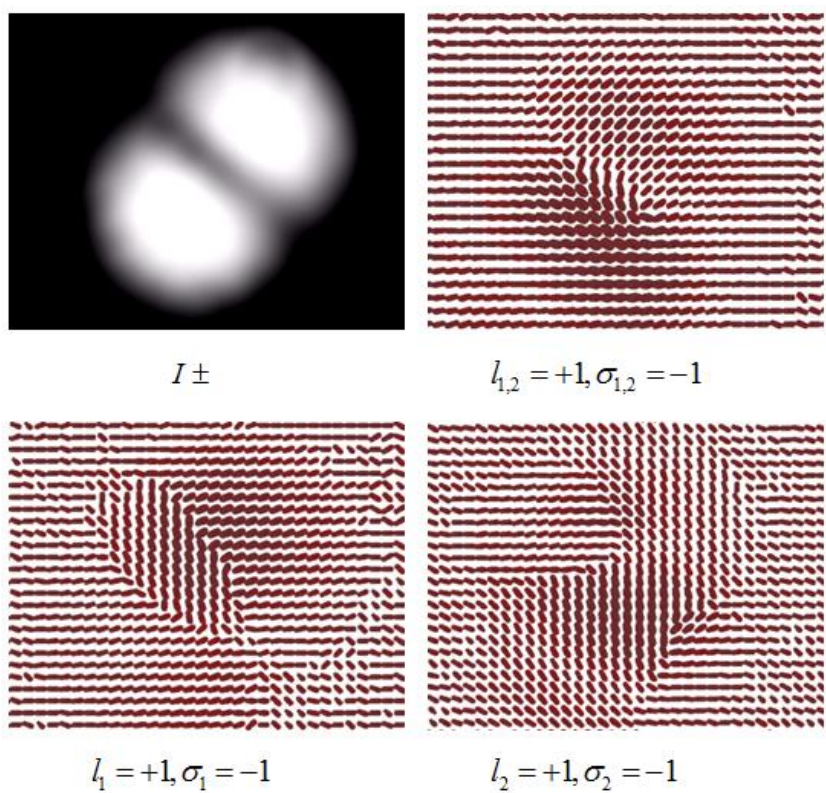


Figure 2.2.

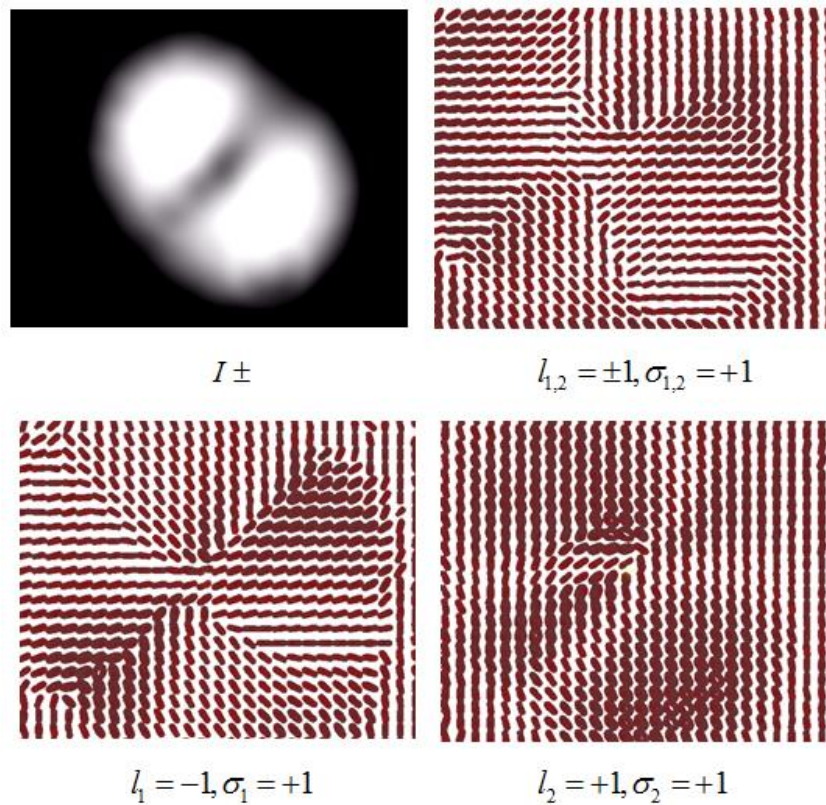


Figure 2.3.

Figure 2.1-3. Maps of the intensity distribution and polarization multiplexing in the composite signal at the output of a few-mode fibers: (1) the distribution of the intensity and polarization of the beam with a wavelength $\lambda = 0,63\text{mkm}$, topological charges, $l_1 = +1$ and $l_2 = -1$, left $\sigma_1 = -1$ and right-circular $\sigma_2 = +1$ polarisations; (2) the distribution of the intensity and polarization of the beam with a wavelength $\lambda = 0,63\text{mkm}$, topological charges $l_1 = +1$ and $l_2 = +1$, left-circular $\sigma_{1,2} = -1$ polarisations; (3) the distribution of the intensity and polarization of the beam with a wavelength $\lambda = 0,63\text{mkm}$, topological charges $l_1 = -1$ and $l_2 = +1$, right-circular $\sigma_{1,2} = +1$ polarisations.

3. The signal demultiplexing

Investigation signal demultiplexing process was carried out on the experimental setup, shown in Figure 3.

Gaussian beam emitted from the light source LS_1 with a wavelength $\lambda_1 = 0,63\text{mkm}$ using a polarizer P_1 and a quarter wave plate $\lambda/4_1$ is converted into right-circularly polarized beam. Further, during the passage of the dielectric wedge W_1 beam is converted into a singular, carrying an optical vortex with a given value of the topological charge. The second Gaussian beam emitted from the light source LS_2 with a wavelength $\lambda_2 = 0,53\text{mkm}$ of passing through a polarizer P_2 and a quarter wave plate $\lambda/4_2$ is converted into left-circularly polarized beam. Two beam from the light source LS_1 and LS_2 going to fission Bs and dice fall to the end of the wound-mode fiber Fmf . The output from the fiber by means of beams share the prism space. We perform an analysis of states separated beams by Stokes-polarimetry. In the process of demultiplexing identify each of the original beams and the

wavelength λ_1 and λ_2 mode composition, in a complex signal. Research demultiplexing process is also performed for a variety of signal multiplexing combinations (for the same values and different signs of topological charges of optical vortices with identical and orthogonal directions of circular polarization).

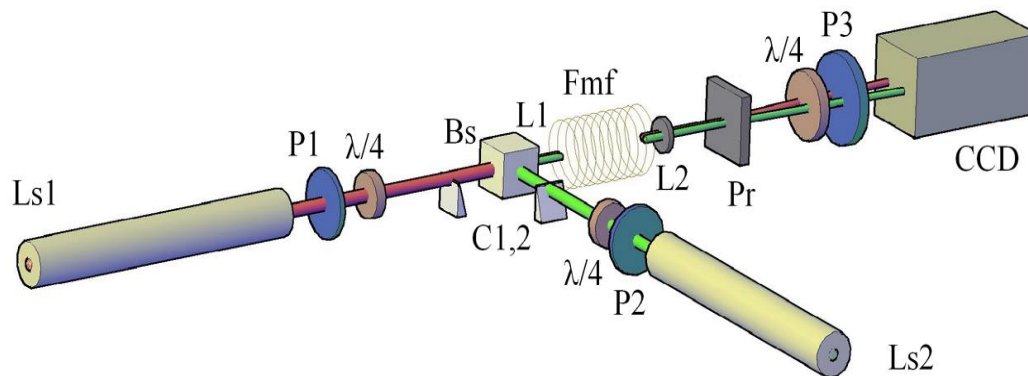


Figure 3. Schematic of the experimental setup: (Ls) Laser, (P) polarizer, ($\lambda / 4$) quarter-wave plate, (C) a dielectric wedge, (Bs) beam splitter, (L) lens, (Fmf) few-mode fibers ($V = 3.4$), (Pr) prism, (CCD) camera.

The resulting polarization distribution maps in the process of demultiplexing the composite signal at the output of a few-mode fibers, are shown in Figure 4.1-3.

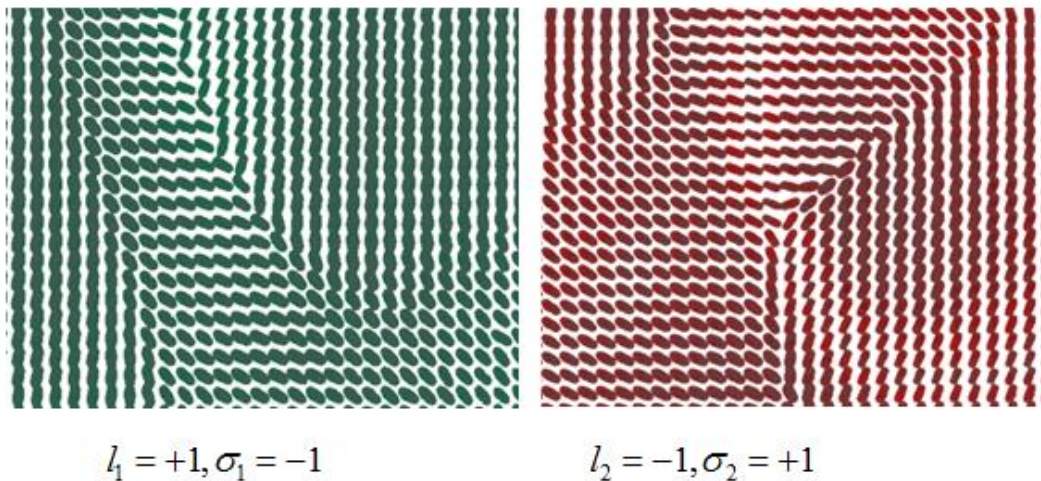


Figure 4.1.

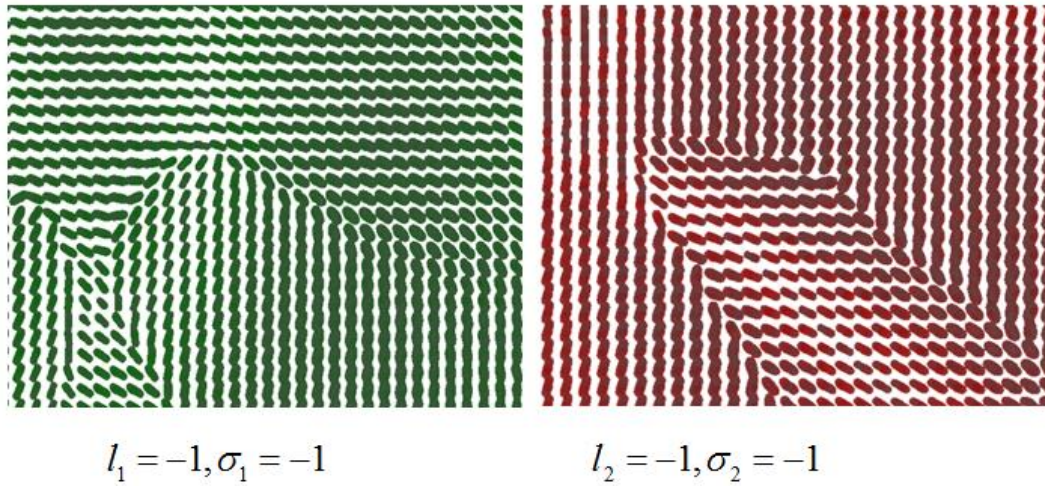


Figure 4.2.

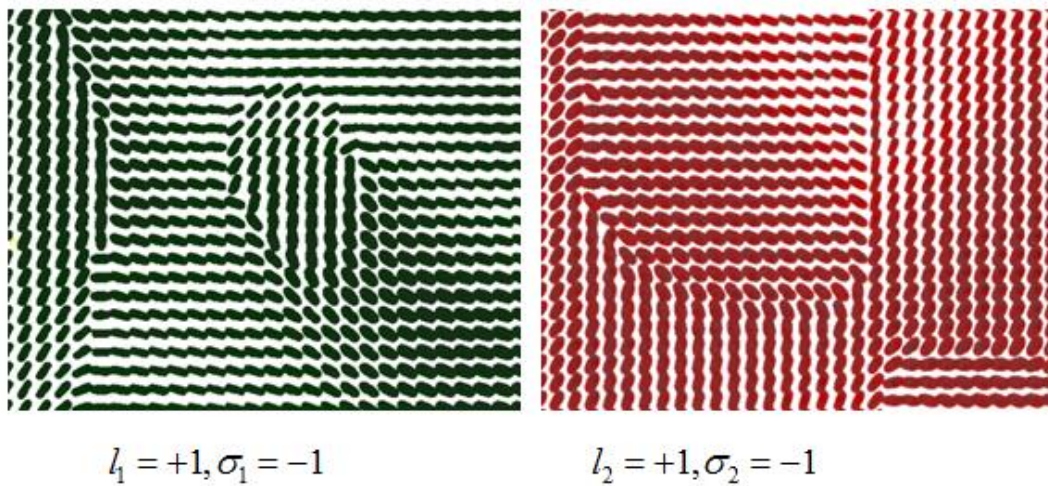


Figure 4.3.

Figure 4.1-3. Maps polarization distribution in the process of demultiplexing the composite signal at the output of a few-mode fiber, green - light beam with a wavelength of $\lambda_1 = 0,53\mu m$, red - light beam with a wavelength $\lambda_2 = 0,63\mu m$: (1) the polarization distribution for beams with topological charges $l_1 = +1$ and $l_2 = -1$, left $\sigma_1 = -1$ and right-circular $\sigma_2 = +1$ polarisations; (2) the polarization distribution for beams with topological charges $l_1 = -1$ and $l_2 = -1$, left-circular $\sigma_{1,2} = -1$ polarisations; (3) the polarization distribution for beams with topological charges $l_1 = +1$ and $l_2 = +1$ left-circular $\sigma_{1,2} = -1$ polarisations.

4. Conclusion

We have experimentally demonstrated the possibility of multiplexing and demultiplexing the complex signal in the singular beam propagating in a few -mode fiber. Stokes polarimetry method conducted field analysis of the structure at the outlet of a few-mode fiber. The possibility of identifying each of the input signals of the wavelengths and orbital angular momentum. It is found that in the radiation field at the exit of a few-mode fiber, C-points each of which corresponds to the input beam polarization. The topological index of these C-points corresponding to the initial charge of the beams.

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