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INFLUENCE OF SELECTED FACTORS FOR LOCALIZATION ACCURACY IN THE OPTICAL VORTEX INTERFEROMETER

Optical vortices were intensively studied during the last decade. In the literature there are papers presenting applications of the optical vortices. The regular net of optical vortices generated by the three plane waves interference allows for the new kind of the interferometer – the Optical Vortex Interferometer (OVI). The precision of the OVI depends on the localization accuracy and the phase reconstruction. The localization methods lead to errors if we use beamsplitters with coatings changing the polarization state of the light. There are six beamsplitters used in this interferometer. In the setup we used non-polarizing coatings. We observed a pleochroism effect which occurs in these coatings. It is the cause of errors in the localization of optical vortices. In this paper we study the effect of pleochroism and we show the way to avoid errors in the localization of optical vortices in the OVI.

Keywords: optical vortices, interferometry

1. INTRODUCTION

Optical interferometry is one of the most interesting domains of optical measurement techniques [1]. The new kind of the interferometry – the Optical Vortex Interferometry (OVI) uses a net of vortices. An Optical Vortex (OV) – an isolated point of a singularity in a wavefront phase distribution – is an example of an interesting and unique type of such a marker [2, 3]. In many papers one can find a lot of methods with which the light beam containing Optical Vortices (OVs) can be generated, for example: synthetic holograms [4, 5, 6], spiral wave plates [7, 8], non-linear optical phenomena [9, 10]. And also another method of OVs regular net generation based on the three plane waves interference is presented by J. Masajada [11]. In this paper only tree beams interferometer OVI are discussed. The measurement precision of the OVI depends on vortex points localization accuracy [12]. The precision of the optical vortices localization depends on the optical elements that are used to build the OVI. When improper elements are used to build the OVI the method of OVs localization does not work. If non-polarizing beamsplitters, that are used to build the interferometer, are changing the polarization state of the light, we are able to observe errors in the localization of the optical vortices. In this paper the cause of these errors is discussed. The precision of the optical vortices localization depends on the accuracy of positioning of the vortex points, which requires more than one interferogram (fringe pattern), so the influence of the laser beam's frequency stability is important. This problem is solved and described [13].

2. POLARIZATION EFFECT

The non-polarizing beamsplitters that we used for measurement are changing the polarization state and the intensity of the light. Figure 1 shows the arrangement for measuring the dependence between the azimuth angle α and the change in azimuth angle $\Delta\alpha$ of the transmission or reflection of the light and intensity of this light.

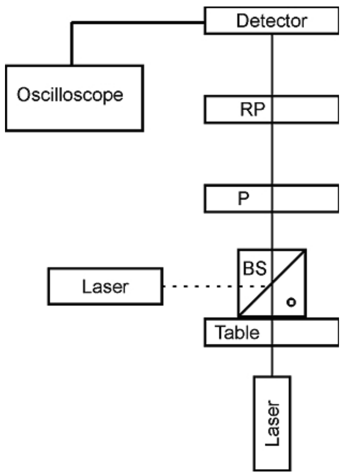

Fig. 1. The arrangement to measure the dependence between the azimuth angle α and the change in azimuth angle $\Delta\alpha$ transmission or reflection of the light and the intensity of this light – on the left.

A laser emits a linearly polarized beam. At first we set the polarizer RP to the oscilloscope, we see a constant signal and now we put the beamsplitter on the table. Polarizer P rotates with a frequency of 40Hz. If the beamspliter does not change the polarization state of the light, we will see the constant signal on the oscilloscope. If the beamspliter changes the polarization state of the light, we will be able to see a sinusoidal signal. The rotation table with the angular steps with the beamspliter allows searching for the position when on the oscilloscope we see a constant signal. If we cannot find this position, it means that the light has not a linear polarization but that it has an elliptical polarization. Six beamspliters were measured with the arrangement that is shown in Fig. 1. We obtained similar results for all the beamsplitters. Figure 2 shows the results of the measurement of one selected beamsplitter.

Figure 2 shows the dependence between the change azimuth angle $\Delta\alpha$ and the azimuth angle α for the transmitted and the reflected light. The azimuth angle can change about ±30

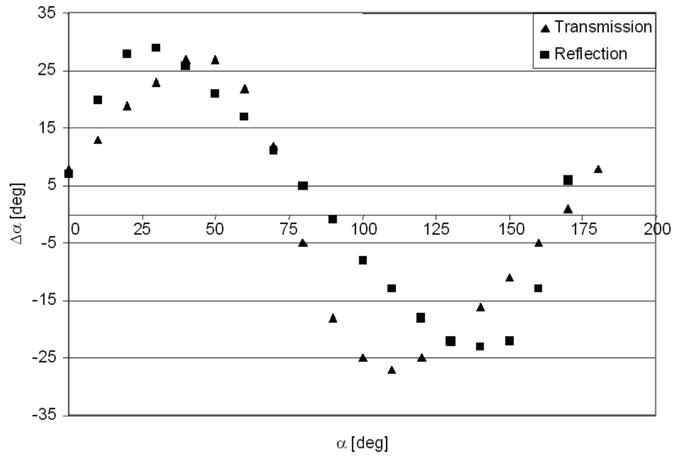

Fig. 2. Dependence between the change azimuth angle Δα and the azimuth angle α for transmitted and reflected light.

degrees depending on the azimuth angle of the incident light. It is a very significant value. When the azimuth angle of the incidence light equals about 90° or 170°, the output azimuth angle is not changing. Change of the azimuth incident light causes changes of the intensity of the transmitted and the reflected light. Figure 3 shows the dependence between the azimuth angle α and the normalized intensity light for the transmission and the reflection light. Maximal measurement value of the output normalized intensity is 1, minimal measurement value of the output normalized intensity is 0.1. It is again a very significant value. Normally the non-polarizing beamsplitters divide the input light with a ratio of 50/50 % ± 5%.

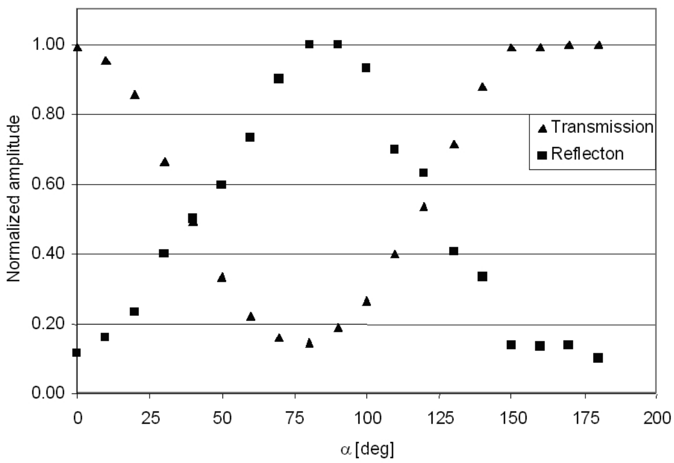

Fig. 3. Dependence between the azimuth angle α and the normalized intensity light for the transmission and the reflection light.

The unfavourable effect of the change of the azimuth angle and the intensity of the transmitted and the reflected light makes the localization of the Optical Vortices impossible, because the frequency stabilized laser which we use for measurements has two orthogonal modes. With one mode we can generate one network of optical vortices points. If there is a second mode a different network of optical vortices points or other singularities are added to the interferogram. This is a problem and solution of them is described below. Of course, the first way is to order new beamsplitters (more expensive, with better coatings), but more interesting is second way. This solution allows to use not perfect beamsplitters but requires symmetrical arrangement.

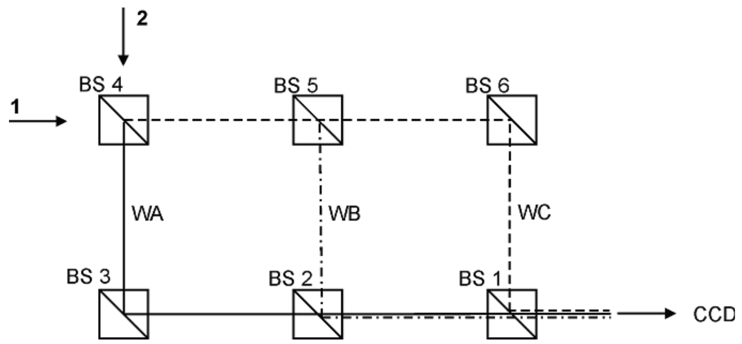

Fig. 4. The symmetrical (1) and the asymmetrical (2) arrangement of the Optical Vortex Interferometer.

Figure 4 shows two ways to pass the beam on the first OVI's beamsplitter. Depending on the configuration of these ways they are called the symmetrical and the asymmetrical. In the symmetrical arrangement every wave crosses through two beamsplitters and reflects also from two beamsplitters. In the asymmetrical arrangement not all the waves have the same number of reflections and crossings. On the basis of measurements, shown in Figs. 2 and 3, numerical simulation was done. The result of the simulation is shown in Fig. 5.

In Figure 5 is easy to see that the change of the azimuth angle is almost the same in both arrangements. The differences are only in the amplitudes of the waves after passing the beamsplitters set. In the symmetrical arrangement it is possible to find the azimuth angle so that all the amplitudes are equal. In the asymmetrical arrangement it is not possible. From the simulation it is known what arrangement and what azimuth angle should not be used. As it is mentioned above we use a laser with two orthogonal modes. When we try to use the asymmetrical arrangement the vortices are not generated. The result of using the laser and the symmetrical arrangement is shown in Fig. 6.

The simulation result presented in Fig. 6 contains vortex points marked by 'o' generated from one mode interference and other singularities marked by '+' generated by the second mode interference. Only one mode with the azimuth angle 90 deg (see Fig. 5a) should be used to obtain the right hexagonal regular network of OVs.

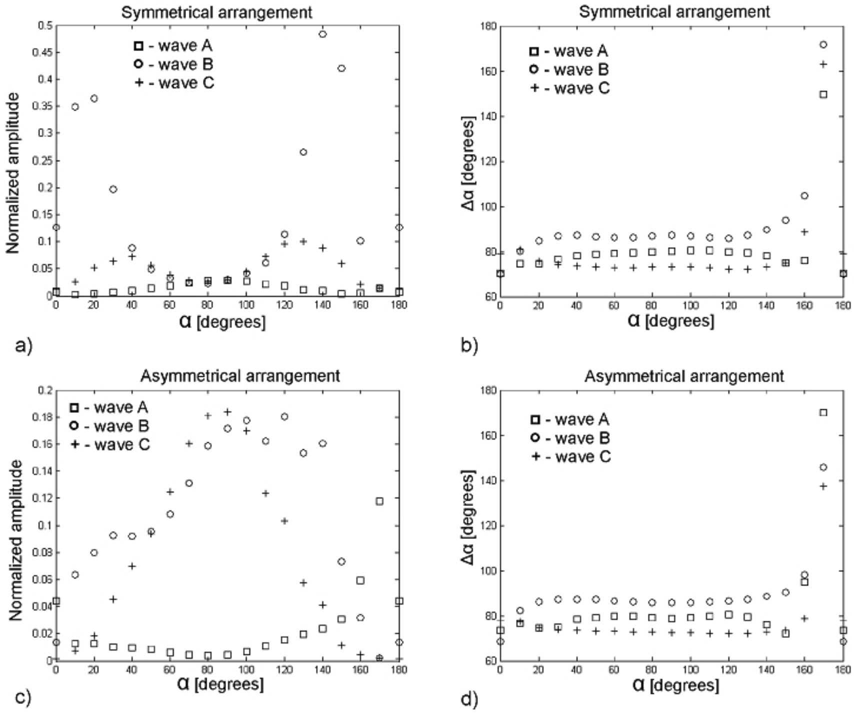

Fig. 5. Result of simulation in the symmetrical and the asymmetrical arrangement.

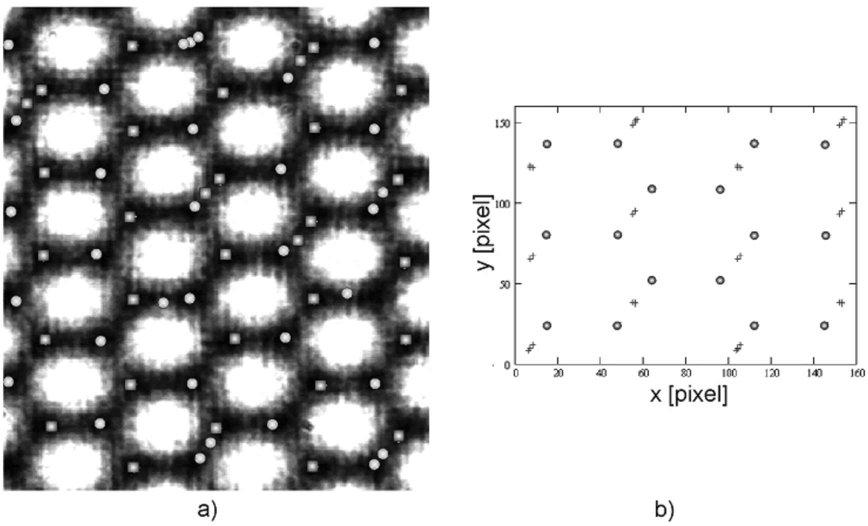

Fig. 6. The result of using the laser and a symmetrical arrangement: a) experiment, b) simulation.

3. CONCLUSION

In arrangement of OVI polarization affects can not be passed over even when non-polarizing beamsplitters are used. Standard non-polarizing beamsplitters available on the market may not be suitable for OVI because of changing the polarization state of the light on the coatings. These beamsplitters may be used if it is necessary but as is described in this paper it is essential to take into account changes in the polarization state of the light. It is very important to choose the best azimuth angle for measurement and to use proper optical arrangement. The method to reduce influence of polarization effects may be helpful for all who need building OVI.

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