The unique properties of the interference field produce by the three plane waves interference and their meaning for the optical vortex interferometer

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The regular net of optical vortices can be generated by the interference of three plane waves. The resulting interference field has a number of unique properties, which are discussed in brief. The optical vortex interferometer is a new optical system which is based on such vortex net. The advantages of the optical vortex interferometer, which results form the special properties of the vortex net are also discussed.

Optical vortices are point phase singularities (line singularities when considering three dimensional picture). They have a number of interesting properties. They are stable, generic, carry non-zero angular momentum and the singular point (vortex point) is perfectly dark [1]. The regular net of optical vortices, can be generated by the three plane waves interference [2,3] (Fig.1). Such a net is a base for Optical Vortex Interferometer (OVI) [3,4]. The optical body of the OVI may be very simple. Any system that brings three plane waves to interfere under small angles can be considered as OVI. When one or more of the interfering waves are disturbed, due to the sample, which is measured the geometry of the vortex net changes. By measuring this change one can determined the physical properties of the sample. For this purpose the localization of vortex points must be known precisely. The localization procedure are discussed in [3,5].

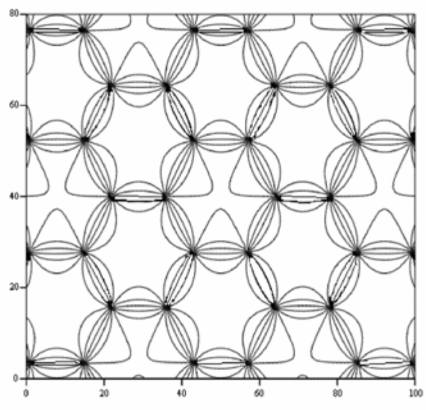

Fig. 1. *Equiphase line for the field generated by three plane waves interference*

The OVI is special instrument due to special properties of three plane waves interfering field. Now we describe these special properties. It is important to emphasis here that the vortex net can be generated by interference of four or more plane waves. However, the special properties described in this communication are lost when more then three waves interfere.

- The optical vortex net can be divided into two subnets consisting of positive and negative vortices. The vortex points distribution in a subnet does not depend on the amplitude of interfering waves
- The internal geometry of vortex points depends on interfering wave amplitudes only. By internal geometry we understand the figure that results from adding complex amplitude vectors representing three interfering waves. This fact can be easily proofed as shown in Figure 2a. Figure 2b shows that four or more waves lead to more complicated picture.
- The change in phase of one or more interfering waves does not change the vortex point distribution, neither the vortex internal geometry. This is not valid in case of more then three wave interference field.
- The energy flow in the three plane wave interference field is smooth, contrary to more waves case.

What is the meaning of these properties for the OVI? The second property allows determining the relative phase angle among the interfering waves. There are also simple calibration procedures that enable the vortex point topological charge determination. This means that the phase angle between interfering waves can be found without ambiguity (phase unwrapping problem). To give an idea on other properties of the OVI, in such short text, a specific example must be considered. Figure 2 shows the OVI system for the angle of optical wedge measurement. Analyzing the possibility of such a system one can conclude that:

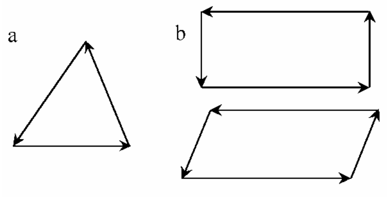

Fig. 2. Three vectors form a triangle in unique way, contrary to four or more vectors case.

- The angle can be read in respect to two perpendicular axis of the coordinate system (in fact two angles can be measured in on measurement)
- Introducing the optical wedge into one of the beam lowers its amplitude. This effect does not lower the OVI accuracy
- The linear vibrations of the optical wedge does not lower the measurement accuracy, the resolution of the system is better than 0.5 second of arc (the active area of the beam has diameter of 7mm)
- There is no ambiguity in data interpretation
- OVI is a simple system.

Conclusions

The optical body of the OVI is simple and can be setup in various ways. Although it looks as simple extension of the classical two beam interferometry this is not a case. The OVI is a new instrument based on the special properties of the three plane waves interference field. As a new instrument the OVI posses some specific technical problems, as optical vortex localization problem, but gives new possibilities in optical measurement. Some of them were presented above. The possible applications of the OVI are very wide. It can be treated as an extension of two beam interferometry (we can consider OVI as two beam interferometer with two object or two reference beams) or specifically as three beam interferometer. In the last case the advantages of the OVI can be fully explored. The other possible application of the OVI, which were considered by the authors are: Small-rotation angle measurement [3,6], wavefront reconstruction, superresolution microscopy, 3D scanning interferometry, small linear displacement measurement.

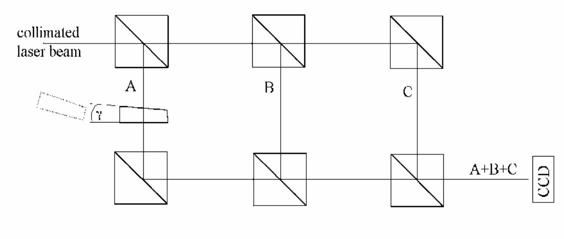

***Fig 3.** Optical scheme of the optical vortex interferometer with measured optical wedge introduced into one of the interferometer's arm. The three plane waves are obtained by the six cubic beamsplitters mounted on the adjustable tables. By rotating the optical wedge an additional tilt of the wave A can be introduce with high accuracy. This is a simple way for testing the OVI resolution.*

References

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Acknowledgements

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