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REVIEW

REVIEW on PhD Dissertation

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Optical properties and development of flat-surface nanostructured gradient index micro-optical vortex phase components

General Remarks

The present thesis reports on new technique of manufacturing optical components for optical vortex generation. The proposed method involves stacking large number of rods made of two different glasses into a complex structure according to the precise design. Such a bundle is drawn to make the single glass rod thinner than light wavelength. In that way two different refraction indexes are combined into some value depending on the local index variation. Finally, such a fiber is cut into a number of thin slices, each being the separate optical element. Thus, the GRIN optical elements can be produced in large volume with the desire refractive index distribution. I consider this technique as promising and its particular application to manufacturing the vortex component as being interesting with sound application perspectives. For these reasons I think that the subject of the present thesis is important. The results are both interesting and promising.

The present work as being focused on special element manufacturing has experimental character with important numerical part. The author had good support including the cooperation with special glass manufacturer which could support her with custom glasses.

The amount and quality of scientific work is high and sufficient for PhD degree.

The dissertation is validated by six publications and eight conference reports. The publications were published in top optical journals; three of them in Optics Express, two in Optics Communications and one in Optics and Laser Engineering. I conclude that this publication record is highly satisfactory.

The thesis is well organized, figures are carefully edited, text is clear. Below I present my detail remark concerning the dissertation.

Chapter 1

In this short chapter the dissertation outline and the thesis are presented. In page 1 one can read: "The OVBs are subset of Laguerre-Gauss beams".

My comment: Not all LG beams are vortex beams, so it could be rather: Some of LG beams (modes) belong to the vortex beam family

Chapter 2

Chapter 2 is a brief introduction to optical vortices. The basic OVs properties are described as well as the method for their generation and detection. Finally optical vortex applications are presented.

- The text under eq. (2.4) is somewhat unclear: "....(z) and w0 are the beam radius of z and beam waist." As I guessed it should be w(z) and w0 are the beam radius at z plane and at waist plane.

- Fig 2.4. The orientation of the fork fringes (up or down) cannot be used as reliable test of vortex sign. When changing the reference plane inclination, the fork like fringes can change their orientation regardless of the true sign of the optical vortex.

- Section (2.4), Reference (8) does not concern STED

Chapter 3

In this chapter the proposed technology is discussed. Also, the way in which vortex structure were design is presented. In section "Materials" the author focused on new glass pairs designed specifically for this project by Łukasiewicz Center. This was an important support for the thesis. The relation between vortex charge, wavelength and VPM structure thickness for the given glass pair was derived.

The diameter of the VPMs structure is about 20 microns which as I understood is a matter of great number of glass rod which must be assembly. But authors could explain explicitly why this particular size of the designed structure.

Chapter 4

This chapter concerns the numerical studies of the optical performance of designed VPMs. The author introduced her own parameter named Q for evaluation the vortex spot quality, which seems to be well defined. The main problem of the designed VPM structures is waveguide effect, which breaks the vortex beam symmetry. Here critical parameter is VPM thickness. The thicker VPM has greater waveguide effect. On the other side the thickness of elements cannot be too large for optical and mechanical reasons. As author has shown the waveguide effect can be partially compensate by changing the refractive index distribution versus azimuthal angle from linear to nonlinear. Author has identified the optimal nonlinear refractive index distribution and designed the proper glass rods pattern to produce the corrected VPM element. The numerical simulations have shown that the waveguide effects can be partially compensate in this way.

In the last part the performance of the VPMs with higher topological charge were calculated. Generally, the generated beam quality is lower, which results from stronger waveguides effects. Elements generating higher optical vortices must be thicker. Also, the higher order vortices split into a constellation of single one, which is well described effect. These single vortices move away from the beam center at larger range than in case of spiral phase plate (SPP). The light intensity distribution becomes more non-uniform. Actually, we do not have a ring like structure but rather dotted ring. The quality of the beam with optical vortex having topological charge 4 or higher can be insufficient for most applications.

Chapter 5

Chapter 5 concerns numerical and experimental test of the VPM elements. In particular the vortex element of the first and second order are tested. The test covers various environments: air, water, and ethanol. Results of both experimental and numerical test are in good agreement. As was expected the results are independent of the environment which is an important advantage of the technology under study.

There is some mismatch between Figure 5.3 and text. According to the Figure the best results are for 20 microns incident beam while in text the 18 microns case is written to be optimal.

Chapter 6

In this chapter the question of VPMs integration with optical fiber is investigated. The new structure is named "fiber-based vortex converter." The integration technique is described. Next the numerical simulations are performed in order to confirm the main idea and find the best parameters for optimal integration. After finding the desire parameters the fiber-based vortex converter has been made and successfully tested. It was also shown that the system works in desired way in case of bend fiber and anti-resonant fiber

- Figure 6.9. Capture: It should be 0, 40, 85 and 120 microns
- Figure 6.10. The number of extra vortices in the dark area is larger in case of water environment. They also are closer to the bright area. Is the explanation for this effect?

Chapter 7

In chapter 7 the possibility of manufacturing achromatic VPMs is investigated. First the concept of such a design is discussed. Next the proper glass pair was identified and manufactured. Finally, the sample achromatic VPMs were prepared and measured. The measurements were performed at the wavelengths from 532 nm to 1550nm. For such a wide range of wavelengths there is also a question of the influence of the microscopic objective dispersion on the presented results. The presented results, in particular the fact that the minimum of the working distance is at the middle of the wavelength range, shows that the concept of the achromatic VPMs is correct and can be realized with the method being the subject of this dissertation.

In next subsection the other achromatic design was presented and tested in numerical simulation. The general concept was to correct the chromatic aberration for two wavelengths. The new pair of glasses has been proposed, but not manufactured. The numerical test proofed that in principle the proposed solution may work in the desired way.

It would be nice to see one more case in Figure 7.10, i.e., the case for some wavelength between 633nm and 1010nm; 800nm for example. The high quality of the generated optical vortex at this wavelength could be a visual proof of correct performance of this achromatic VPM. I also wander what is a reason for such a remarkable difference in vortex spot size in Figure (7.13). Moreover, the spiral center is located at different positions which means that the single achromatic VPMs can be used for generation of good quality OV using various wavelengths separately. However, its applicability for white light must be more carefully analyzed.

Chapter 8 concludes the work

Author summarized that all the thesis have been proofed. I agree with this statement.

Final conclusions

On the basis of the presented dissertation, I conclude that the candidate has the required theoretical knowledge in the field of optics and has demonstrated the ability to work on scientific problems. The subject of the dissertation is the original solution of a scientific problem

I conclude that the presented doctoral dissertation, meets the criteria resulting from the regulations on academic title and degrees and may be the basis for applying for the degree of Doctor of Physical Sciences. I recommend the thesis to the public defense.

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