Computer Modelling Based Empirical Study on Coherence-Induced and Diffraction-Induced Spectral Changes

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Abstract

This thesis contains the results of some experimental work and computer modelling based empirical studies on coherence-induced and diffraction-induced spectral changes of spatially partially coherent light.

It was shown long ago that on propagation of light radiation through space, the correlation property of the optical fields change, this is the well known van-Cittert Zernike theorem. About two decades ago, it was shown that the change in the correlation properties of the light fields leads changes in the spectral properties of the source. This is the well know *Wolf effect*. This effect states that if the correlation property of a light source violates the so called scaling law (this law states that any change in the correlation property of the source by change in the wavelength of the light source if, is compensated by the change in the position vector of the two source points between which the correlation property is being measured), the spectral properties change during propagation.

The phenomenon that the spectral changes come from the spectral correlation of the source is also termed as the correlation-induced spectral changes. It was also shown when a field that satisfies the scaling law and is incident upon an aperture, the diffraction of the field by the aperture will make the spectrum of the light in the diffraction field (in the far zone) different from that at the aperture. It is the diffraction effect that causes the spectral changes; therefore these kind of spectral changes are more suitable to be defined as the diffraction-induced spectral changes. Recently, it has been shown that when a field that satisfies the scaling law, is diffracted by a circular aperture, the spectral changes occur in the diffraction field, and at one side of special distances, a spectral line becomes red-shifted, becomes blue-shifted at the other side, and break into two lines at the special distances. This phenomenon was termed as *spectral switching*. More recently, the spectral switches that take place in the far field were discovered. This prediction for spectral switches has already been verified experimentally. In addition, the spectral switches in the Young's experiment were also studied.

Meanwhile, topological singularities of wave-front dislocation have received considerable attention and a completely new field called *singular optics* has emerged. The domain of singular optics has been extended to polychromatic fields. In particular, it was predicted that appreciable spectral changes may occur in the vicinity of phase singularities (i.e., point of zero intensity of certain frequency components) of focused, spatially coherent polychromatic wavefield. Not long ago, Foley and Wolf analyzed the phenomenon of spectral switches in the domain of phase singularity. They have demonstrated that the spectral switching phenomenon has a natural interpretation in the framework of singular optics with polychromatic light and that should be regarded as being primarily a manifestation of diffraction-induced spectral changes rather than the correlation-induced spectral changes. The field is still open for discussion.

In this multidisciplinary (optics, computing and communication) work we have not only studied the coherence-induced and the diffraction-induced spectral changes of spatially coherent light but have also explored the possibility of information encoding, information hiding and information transmission with the spectral anomalies of diffracted light. The results may provide new way of optical information encoding, information hiding and free-space optical communication with spectral changes (spectral switching).

The main concept has been taken from the fundamental optics but the over all study explores some new possibilities and applications of spectral switching in the field of information encoding and free-space optical communication.
Some significant aspects of the work are listed below:

- A new technique for information encoding, information hiding, and information transmission is proposed and analyzed on the basis of the theoretical and experimental studies carried out so far for spectral anomalies shown by spatially coherent light on diffraction.
- Two novel types of communication models are proposed for free-space optical communication and computer algorithms are developed for the newly proposed system.
- A detailed study is carried out for the anomalous behavior of spatially partially coherent polychromatic light after passing through an optical system and some significant applications are explored in the field of optical computing and free-space optical communication.
- A prototype of computer modeling (GUI based) is developed to study the anomalous behavior of diffracted light. The system might be very useful for the researchers involved in the field of singular optics, optical signal processing and free-space optical communication.