Abstract of the Ph.D. Thesis

Effect of Spatial Coherence on the Spectra of Wave Fields

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The lines observed in the spectra of radiation that reaches earth from astronomical objects are shifted relative to those observed in the spectra from the same elements on earth is a well known fact. The lines are either shifted towards the longer wavelengths which are called redshift or, in some cases, they are shifted towards shorter wavelength called blueshift. From these observations, the understanding of the structure of the universe is studied by astronomer who has far reaching consequence. Three well known causes of these shifts, i.e., (i) shift due to relative motion of the source and the observer known as the Doppler's shift (ii) due to the expansion of the whole universe known as the cosmological shift and (iii) the shift due to gravitation. The gravitational redshift is observed when the light passes through a strong gravitational field, e.g., when light passes in the neighborhood of a dense star such as a neutron star. The discovery of quasi-stellar objects quasars and their links with galaxies but the amount of redshift shown by the galaxies and quasars being different posed problems in astronomy. These problems could not be explained on the basis of existing theories. Although the majority of astronomers do not consider that there can be other mechanisms of redshifts except the existing mechanisms, but a few well-known astronomers, on the other hand, consider the possibility that there could be some other explanations to these puzzles. About one and half decade ago, Wolf showed that there is a mechanism which is deeply rooted in present day physics which has nothing to do with the Doppler Effect, expanding the universe or gravitation and which can nevertheless generate redshift of spectral lines. This mechanism is the correlation-induced spectral shift.

Incoherent and coherent sources are two well defined categories of light sources. A thermal source emits in disordered manner therefore is said to be an incoherent or chaotic source. A well stabilized laser on the other hand is a highly ordered and said to be coherent source. Incoherent and coherent sources represent two extreme cases in statistical sense however in practice we encounter the sources which do not represent these extremes and are termed as partially coherent sources. The degree of coherence (correlation) that exists within a source or wavefield produced by the source can be described in terms of various correlation functions. Classical scalar theory describes the correlation function, that characterize the statistical properties of the sources and of partially coherent field they generate, in the space-time or in the space-frequency domain. Spectrum is an intrinsic property of radiation and it was assumed until recently that it does not change on propagation of radiation in free space. This assumption may not always hold, was suggested by Mandel in an early investigation. Later on, Wolf discovered the spectrum of light, which originates in an extended source whether a primary source (a set of radiating atoms or molecules) or a secondary source (obtained by allowing the radiation from a primary source to pass through an aperture) depends not only on the source Spectrum but also on the degree of spatial coherence of the source. Wolf also predicted that the spectrum of light will, in general, be different at different points in space. In recent times the '*Wolf effect*' is one of the most significant discoveries in modern optics.

The developments that took place during the past few years after the discovery of correlation-induced spectral changes i.e. the '*Wolf effect*', is the inspiration for taking up further studies to verify experimentally certain theoretical predictions and also to show some applications of the phenomenon of correlation-induced spectral shift. Special emphasis has been given to study the spectral changes that take place during propagation of electrical signals through a propagating medium namely the telephone wires. Random electrical signals have the analogy with the ordinary optical signals (fields). The stationary random processes and the theories related to optical fields can be applied to random electrical fields.

In chapter 1 "Introduction" a brief description of the historical progress and the basic concepts of optical coherence theory in space–time domain to understand the nature of partially coherent fields has been given. To formulate these basic concepts of the theory of partially coherent light, the polarization properties of the electromagnetic field were ignored and it was treated as scalar field. Radiation from model sources, the scaling law and the theoretical and experimental studies on spectral changes due to source correlation are described about optical wavefields/signals.

In chapter 2 "Correlation-induced spectral shifts in random electrical signals" an experimental study has been made to clearly demonstrate the spectral changes that take place due to correlation between two propagating electrical signals. These two random signals were generated by designing electronic circuits. In this experiment the dependence of emitted field spectrum on the correlation properties of the source have been tested. For this we produced two randomly fluctuating electrical signals. These two signals were produced by adding and subtracting an electrical signal with its delayed component. $S_1(\omega)$ and $S_2(\omega)$ are the power spectra of two signals generated by adding and subtracting an electrical signal X(t) with its delayed component Y(t) respectively, Since the signals are randomly fluctuating, applying Wolf's prediction based on correlation theory it is shown that the spectrum of the radiated field changes on propagation depending on the correlations between the two source points.

In chapter3 "Reconstruction of source intensity profile using the space frequency principle in Young's double slit experiment" has been studied experimentally. In this experiment the reconstruction of source intensity profile by the space-frequency equivalence principle in Young's double slit experiment has been used. The effect of single and double grating monochromator on the coherence properties of light field is studied experimentally in detail by measuring the degree of coherence of field at the entrance and exit slits of the monochromator. The spectral degree of coherence (SDC) at the exit slit of double monochromator is found to be more than the SDC at the exit slit of single monochromator. The advantage of the proposed experiment is only two slits are required and by using the spectrum over a large no. of frequencies. This may be utilized for automated nondestructive inspection.

In chapter 4 "Experimental observation of phenomenon of spectral switch for a class of partially coherent light" has been described. Within Fresnel approximation, experimental investigations of the spectral characteristics are carried out in the near zone when partially coherent light passes through a rectangular or a circular aperture. It is seen that at a critical value of z (the distance between the aperture and the on-axis observation point), the gradual change in the spectral shift shows a rapid spectral switch. Experimental results are compared with the theoretically expected results.

Experimental observations of the phenomenon of spectral switching are made for a class of partially coherent light incident on a circular aperture. The on-axis spectrum of the light in the far-field is different from the spectrum of the light at the aperture. It is shown that, depending on the value of the parameter $\frac{a}{\overline{L}(\omega)}$ (a is the radius of the aperture and $\overline{L}(\omega)$ is the effective correlation length of the light at the aperture at the central frequency ω_0 of the source spectrum), the spectral shift shows a gradual change but for a particular value of $\frac{a}{\overline{L}(\omega)}$ the spectral shift exhibits a rapid transition and the phenomenon of spectral switching occurs. The generation of many spectral lines, from a single spectral line, in the far-field is also demonstrated.

In chapter 5 "Determination of correlation properties of moving diffuser by studying the spectrum of the scattered light emerging from two pinholes" has been undertaken. Correlation properties of light scattered by a moving diffuser are determined by studying the spectral characteristics of the light that emerges from two pinholes placed behind the diffuser. The amplitude and the phase of the spectral degree of coherence are determined experimentally from spectral measurements in Young's interference experiment. These properties are used for determining the correlation functions of the heights of diffuser surface and the speed with which the diffuser moves.