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Investigation of Temporal and Spatial Coherence of Radiative Materials by Fourier Transform Technique

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Abstract: Fourier transform spectroscopy has progressed in research area like molecular structure examination and analyses. The particularly rapid increase in this type of spectroscopy in recent years is related to the availability of high-speed computers. This type of spectroscopy is a measurement technique in which spectra are collected with respect to the measurements of the temporal coherence of radiative materials. We investigate the Coherence lengths of a light source, which is obtained by dc glow discharge of different electrolytic solution in the interface of solid and liquid with the help of Fourier Transform Spectroscopic method. The variation of coherence length of respective elements with corresponding color of the fringes has been investigated. The respective coherence time and fringe width (spectral width) of the 16 sources has been calculated from the measured respective coherence length.

Key word: Radiative materials, dc glow discharge, Coherence length, Fringe width

Introduction

Study of optical coherence theory [4] and experiments is currently an area of active research. Coherence of light [1,2,3] is the property of wave-like states that enables to exhibit interference phenomenon. This parameter of light quantifies the quality of interference (known as degree of coherence). It can be stated that the coherence is a measure of the correlation between the phases of the wave measured at different points and it depends on the characteristics of its source. Coherence of light waves distinguishes two types of coherences such as 1) Temporal coherence and 2) Spatial coherence. The former relates [4] directly to the finite bandwidth of the source, the latter to its finite extent in space.

The electron transitions responsible for the generation of light have duration on the order of 10-8s to 10-9s [1]. Because the emitted wave trains are finite, there will be a spread in the frequencies present, known as the natural line width. Moreover, since the atoms are in random thermal motion, the frequency spectrum will be altered by the Doppler Effect [4]. In addition, the atoms suffer collisions that interrupt the wave trains and again tend to broaden the frequency distribution. The total effect of all these mechanisms is that each spectral line has a bandwidth $\Delta\nu$ rather than one single frequency and it is given [4] by

$$\Delta \nu = \frac{c}{\Delta L_c}$$

where L_c is the coherence length.

Coherence length [7] is a very useful measure of temporal coherence because it tells us how far apart two points along the light beam can be, and remain coherent with each other.

Spatial coherence is a measure of the correlation between the phases of a light wave at different point's transverse to the direction of propagation [6]. It has been experimentally observed that the light waves produced by a laser always have high temporal and spatial coherence [1].

Review: The coherence property of the laser is an important aspect for the understanding of the optical Physics [5]. Using Michelson Interferometer and reversible shear interference P.D.Shukla and co-workers reported the measurement of temporal and spatial coherence of laser [5]. The spatial coherence width of the copper vapor laser (beam size ~ 45 mm) measured approximately as 8 mm and temporal coherence of the CVL measured as 8 cm. They also reported the temporal coherence of the He-Ne laser as 15 cm using Michelson interferometer. Lasers can have very long coherence lengths [1]. LED are less monochromatic ($\Delta\lambda \approx 50$ nm) than the most monochromatic lasers and tungsten filament lights are less monochromatic ($\Delta\lambda \approx 300$ nm) and so these sources have shorter coherence time than the most monochromatic lasers [1].

E.B.M. Steers and A.P.Thorne applied [8] high resolution Fourier transform spectroscopy to the study of glow discharge sources. They record the spectra from glow discharge source with and without supplementary microwave excitation and also recorded true line profiles. The contribution of charge exchange processes to the excitation of ionic lines was discussed in detail. J.E.Murray and co-workers investigated [9] the transition element spectra by using high resolution Fourier transform spectrometry. In 1995 A.P.Thorne [10] published the Calibration of Line width standards and Lamp intensities using FT-UV Spectrometry. High resolution FTS studies of Glow Discharge spectra Line-profiles and Line-widths were done by E.B.M. Steers and A.P.Thorne [11] and published in 1996. They described the high resolution Fourier transform instrument to study Line-width and Line-profiles for Fe and Ti using microwave boosted GD source. Anne Thorne have studied [12] high resolution Fourier transform spectrometry in the visible and ultraviolet regions and described the suitability of FTS for upgrading databases, both for atomic emission spectroscopy and for astrophysical and atmospheric physics applications. DC glow discharges, as discussed by Winchester et al. [13] are mostly photon noise limited and it is possible to apply Fourier transform spectrometry as shown by Broekaert et al. [14]. The measurement of temporal coherence can be done by Fourier transform spectrometer i.e. Michelson Interferometer in which wave is combined with a copy of itself that is delayed by time t [1].

Method

The measurement of Coherence lengths of a light source, which is obtained by dc glow discharge of different electrolytic solution in the interface of solid and liquid with the help of Fourier Transform Spectroscopic method. When dc glow discharge of an electrolytic solution is initiated, the emitted light beam is collimated by lens and made incident on the beam splitter of the Michelson Interferometer. The light beam is divided by it into two parts: partially as reflected beam and partially as transmitted beam. One arm of interferometer consists of fixed mirror M2, while other arm contains a movable mirror M1. Both the beams are recombined at the beam splitter (compensating plate) and produce an interference pattern after having been reflected once and transmitted once and then proceed to the sample area and detector. The interference condition for the two rays is determined by their path differences. When

mirrors M1 and M2 are exactly made perpendicular to each other the interference pattern of the bright and dark concentric circular fringes is obtained. When the amplitudes of the two light beams are equal, the intensity of dark fringe is zero and the intensity of bright fringe is maximum consequently the clear interference pattern of concentric circles is obtained. The distinctness of the fringes depends upon the position of the mirror M1. When the path difference between the two rays is zero the well-defined fringe system is obtained. As the mirror M1 is moved a very clear interference pattern is observed while optical path difference is small, but if the path difference is increased to a distance of several millimeters, the bright circular fringes becomes more and more indistinct and finally completely disappear. The circular fringes remain distinct for a limiting value of the optical path difference. This limiting value is the coherence length of the source of radiation. In this way the distance over which the fringes are obtained can be measured and the coherence length of source of light is measured. It was observed that when optical path difference is increased, the fringe visibility decreases.

Result and Discussion

By the above-mentioned procedure the measurement of 28 glow discharges were carried out and used the respective sources for the measurement of Coherence lengths. Out of 28 glow discharges, only 16 sources could give the respective colored well-defined fringes showing monochromacity and coherence of the light emitted by the discharge and the remaining 12 sources could not give the fringe system. The coherence lengths of the 16 sources using the Fourier Transform Spectroscopic method were measured and listed in table.

Using Fourier Transform Spectrometer i.e. Michelson interferometer the well-defined interference pattern of circular fringes has been obtained. The interference pattern is very clear and well defined when the path difference between the rays is zero. The mirror M2 is continuously moved back and its effect on the visibility of fringes is observed. As the mirror M2 moves back the visibility of the fringes is influenced and a stage comes when the fringe system disappears. This reading is noted. Now the mirror is moved in opposite (forward) direction. Initially fringe system start appearing and we may get well-defined fringes. The mirror is moved still ahead so that fringe system once again disappears. This reading is noted and the coherence length of the source is found. A table shows that the coherence length lies between 0.1014 - 1.004 cm. Out of 16 sources the coherence length is maximum for the glow discharge of $MgSO_4$ electrolytic solution and minimum for $NiSO_4$ solution. The respective coherence time and fringe width (spectral width) of the 16 sources has been calculated from the measured respective coherence length and the details are tabulated in table. The study of the observations shows that as the coherence length or coherence time is decreased, the fringe width increases. Furthermore, the product of coherence time τ_c and fringe width $\Delta\nu$ is equal to unity. If the fringe width is narrowed by a filter the coherence length of the source may increase.

Conclusion:

The measurement of coherence lengths of the material sources and the study of the fringe system shows that many sources can be used as monochromatic sources and the fringe system may be obtained and studied. The correlation between the coherence length and the properties of the sources may be obtained.

Sr. No	Electrolytic solution	Coherence length in cm	I.P. in eV		Coherence time in sec	Fringe width In Hz
			I	II		
1	0.5 N $MgSO_4.7H2O$	1.004	7.644	15.03	$3.3467x10^{-11}$	$0.2988x10^{11}$
2	0.5 N $Cd(NO_3)_2.4H_2O$	0.9884	8.99	16.904	$3.2947x10^{-11}$	$0.3035x10^{11}$
3	0.5 N NaCl	0.9108	5.138	47.29	$3.0360x10^{-11}$	$0.3294x10^{11}$
4	0.5 N NaOH	0.9058	5.138	47.29	$3.0193x10^{-11}$	$0.3312x10^{11}$
5	0.5 N KNO_3	0.8048	4.339	31.81	$2.6827x10^{-11}$	$0.3728x10^{11}$
6	0.5 N KOH	0.8038	4.339	31.81	$2.6793x10^{-11}$	$0.3732x10^{11}$
7	0.5 N K_2SO_4	0.7978	4.339	31.81	$2.6593x10^{-11}$	$0.3760x10^{11}$
8	0.5 N KCl	0.7952	4.339	31.81	$2.6507x10^{-11}$	$0.3773x10^{11}$
9	0.05 N $AgNO_3$	0.4990	7.524	21.48	$1.6633x10^{-11}$	$0.6012x10^{11}$
10	0.25 N SeO_2	0.4990	9.75	21.5	$1.6633x10^{-11}$	$0.6012x10^{11}$
11	0.5 N $CuCl_2.2H_2O$	0.4052	7.724	20.29	$1.3507x10^{-11}$	$0.7404x10^{11}$
12	0.5 N $CuSO_4.5H_2O$	0.4044	7.724	20.29	$1.3480x10^{-11}$	$0.7418x10^{11}$
13	0.25 N $ZrOCl_2.8H_2O$	0.3994	6.95	14.03	$1.3313x10^{-11}$	$0.7511x10^{11}$
14	0.25 N $LiNO_3$	0.2932	5.390	75.6193	$0.9773x10^{-11}$	$1.0232x10^{11}$
15	0.5 N $BaCl_2$	0.2876	5.210	10.001	$0.9587x10^{-11}$	$1.0431x10^{11}$
16	0.5 N $NiSO_4$	0.1014	7.633	18.15	$0.3380x10^{-11}$	$2.9586x10^{11}$

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