International Journal of Advance and Applied Research
www.ijaar.co.in
ISSN – 2347-7075 Impact Factor – 7.328
Peer Reviewed Bi-Monthly
Vol.9 No.6 July – Aug 2022

INVESTIGATION OF COHERENCE LENGTHS AND FRINGE SYSTEMS OF MATERIAL SOURCES BY DC GLOW DISCHARGE

K.P. Kadam
Department of Physics,
Arts, Commerce & Science College Arvi. Dist. Wardha, Maharashtra, India.
E-mail: kpkadam1964@gmail.com
***Corresponding Author* - K.P. Kadam**
DOI- 10.5281/zenodo.7737706

Abstract:

Fourier transform spectroscopy can be used to investigate the coherence lengths and fringe systems of material sources. We investigate the coherence lengths of a light source by DC glow discharge of various 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 coherence time and fringe width (spectral width) of the 11 sources has been calculated from the measured respective coherence length.

Keywords: Coherence length, fringe width, Fourier, elements, material

Introduction:

Study of optical coherence theory [1] and experiments is currently an area of active research. Coherence of light [2, 3, and 4] is the property of wave-like states that enables them 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 [5] 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 and a have duration on the order of 10-8s to 10-9s [2]. 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 [5]. 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 Δν rather than one single frequency and it is given [5] by $\Delta v = \frac{C}{Lc}$, where L_c is the coherence length.

E.B.M. Steers and A.P.Thorne applied [6] 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 [7] the transition element spectra by using high resolution Fourier transform spectrometry. In 1995 A.P.Thorne [8] 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 [9] 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 [10] 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. [11] are mostly photon noise limited and it is possible to apply Fourier transform spectrometry as shown by Broekaert et al. [12].

Electrical and spectral characterization of the glow discharge [1-7] of the material helps in studying the chemical composition of the material. The elements in the material may be excited in the plasma [8, 9.12] produced between liquid and solid interface. Recently, research on the use of plasma has very much interest, since they are environment friendly [13]. The DC glow discharge plasma system is a popular technique [14]. With the help of this technique determination of coherence length of a source can be done by using a Michelson Interferometer. A narrow bandwidth results in a longer coherence length and a broad bandwidth results in a shorter coherence length [15]. Characterizing the coherence of a source is important, as it is indicative of the lights ability to interfere [15].

With this background of dc glow discharge system, in this paper a little attempt has been made to study the Coherence Lengths and Fringe Systems of Material Sources by DC glow discharge of different electrolytic solutions in the interface of solid and liquid with the help of Fourier Transform Spectroscopic method.

Materials and Method:

The view of the experimental arrangement for 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, is shown in figure (1). 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 as shown in figure 2. 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, while other arm contains a movable mirror. 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 movable mirrors and fixed mirror 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 movable mirror. When the path difference between the two rays is zero the well-defined fringe system is obtained. As the movable mirror 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 23 glow discharges were carried out and used the respective sources for the measurement of Coherence lengths. Out of 23 glow discharges, 11 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 11 sources using the Fourier Transform Spectroscopic method were measured and listed in table 1.

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 movable mirror is continuously moved back and its effect on the visibility of fringes is observed. As the movable mirror 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. Out of 11 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 11 sources has been calculated from the measured respective coherence length and the details are tabulated in table (1) 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. Moreover in case of 8 glow discharges the change in color was observed when the discharge current is increased. In order to investigate the change in color we computed the difference in the ionization potential of neutral species and singly ionized species and tabulate in table (2). It clearly shows that when difference in the ionization potential is low the change in color of glow discharge observed with more probability but for greater difference change in color not observed when discharge current is increased.

Conclusion:

The measurement of coherence lengths of the 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.

References:

[1] Optics (fourth edition) by Eugene Hecht, Adelphi University, pp.314

[2] file://C:\My Documents\ftr\Fourier transform spectrscopy-wikipedia,the free encyclopedia.htm

[3] http://www.astro.livjm.ac.uk/courses/phys362/notes/

[4] C.C.Homes,Fourier Transform Infrared Spectroscopy, Department of Physics, Brookhaven National Laboratory, June 24 2003 (infrared.phy.bnl.gov/pdf/homes/FIR.PDF)

[5] Optics (fourth edition) by Eugene Hecht, Adelphi University, pp.314

[6] E.B.M. Steers and A.P.Thorne, J.Anal.At.Spectrom.8, pp.309-315, 1993

[7] J.E.Murray, J.C.Pickering, G.Nave, R.C.M. Learner and A.Thorne, NIST special publication 850, 154-155, 1993

[8] A.P.Thorne, Elsevier Science, pp.355-367, 1995

[9] E.B.M. Steers and A.P.Thorne, Fresenius J.Anal.Chem. 355, pp. 868-872, 1996

[10] Anne Thorne, Journal of Analytical Atomic Spectrometry, Vol. 13, pp. 407-411, May 1998

[11] M.R.Winchester, J.C.Travis and M.L.Salit, Spectrochim. Acta, Part B, Vol. 48, pp. 1325, 1993

[12] J.A.C. Broekaert, K.R.Brushwyler, C.A.Monnig and G.M.Hieftje, Spectrochim. Acta, Part B, Vol. 45, pp. 769, 1990

[13] Eliston, L., Martinu M., Wertheimer J., 1992.

[14] V.Anusha Devi and K.A. Vijayalakshmi, Study of Discharge Plasma of Various Metal Oxide Nano Particles Doped Semiconductor Films. Int. J. Adv. Sci. Eng. (IJASE) Vol. 4 No.2, 667-672 (2018), ISSN 2349 5359

[15] Coherence Length Measurement System Design Description Document ASML / Tao Chen Faculty Advisor: Professor Thomas Brown, Pellegrino Conte (Scribe & Document Handler) Document Number 00007 Revisions Level G, pp.5-6, Date 5-06-2018

Table 1: Observed Coherence Lengths of Few Sources of Light during discharge

Sr.No.	Electrolytic Solution	Coherence length in cm L_c	Coherence time in sec	Fringe width in Hz $\Delta\nu$
1	0.5 N $MgSO_4.7H_2O$	1.004	3.3467×10^{-11}	0.2988×10^{11}
2	0.5N $Cd(NO_3).4H_2O$	0.9884	3.2947×10^{-11}	0.3035×10^{11}
3	0.5 N NaCl	0.9108	3.0360×10^{-11}	0.3294×10^{11}
4	0.5 N KNO3	0.8048	2.6827×10^{-11}	0.3728×10^{11}
5	0.05 N $AgNO_3$	0.4990	1.6633×10^{-11}	0.6012×10^{11}
6	0.25 N SeO_2	0.4891	1.6305×10^{-11}	0.6133×10^{11}
7	0.5N Cu $Cl_2.2H_2O$	0.4052	1.3507×10^{-11}	0.7404×10^{11}
8	0.25 N $ZrOCl_2.8H_2O$	0.3994	1.3313×10^{-11}	0.7511×10^{11}
9	0.25 N $LiNO_3$	0.2932	0.9773×10^{-11}	1.0232×10^{11}
10	0.5 N $BaCl_2$	0.2876	0.9587×10^{-11}	1.0431×10^{11}
11	0.5 N $NiSO_4$	0.1014	0.3380×10^{-11}	2.9586×10^{11}

Table 2: Investigation of color change of glow

Sr.No.	Electrolytic Solution	I.P. I eV	I.P. II eV	I.P. II – I.P. I eV	Color Change
1	0.5 N $BaCl_2$	5.210	10.001	4.791	Yes
2	0.25 N $ZrOCl_2.8H_2O$	6.95	14.03	7.08	Yes
3	0.5 N NaCl	5.138	47.29	42.152	No
4	0.5 N KNO3	4.339	31.81	27.471	No
5	0.05 N $AgNO_3$	7.524	21.48	13.906	Yes
6	0.25 N SeO_2	9.75	21.5	11.75	Yes
7	0.5N $CuCl_2.2H_2O$	7.724	20.29	12.566	Yes

8					
9	0.25 N $LiNO_3$	5.390	75.6193	70.2293	No
10	0.5N $Cd(NO_3).4H_2O$	8.99	16.904	7.914	Yes
11	0.5 N $NiSO_4$	7.633	18.15	10.517	Yes
	0.5 N $MgSO_4.7H_2O$	7.644	15.03	7.386	Yes

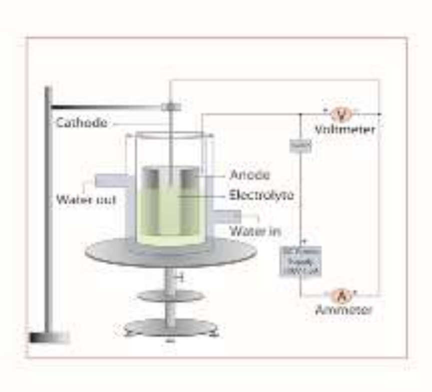

Fig. 1: DC glow discharge system

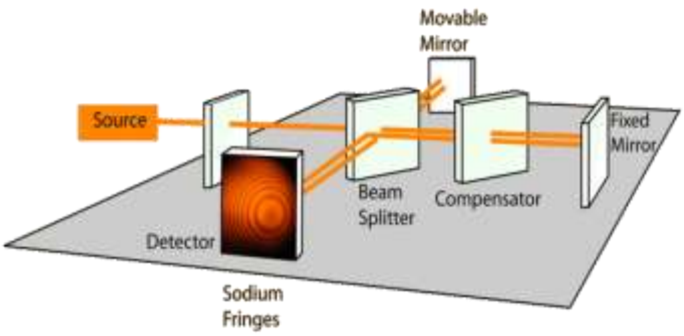

Fig. 2: Michelson's Interferometer