iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 Issue: XII Month of publication: December 2020

DOI: https://doi.org/10.22214/ijraset.2020.32349

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue XII Dec 2020- Available at www.ijraset.com

A Highlight on the Development of Christiansen Effect

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Abstract: The Christiansen effect concerns with an optical technique to produce optical spectral filtering. This effect has lots of applications in diverse field of science and technology. The present paper is concerned with some salient features of Christiansen phenomenon and highlights of its development.

I. INTRODUCTION

The Christiansen effect is a very important tool in the research of material science. In 1884 C Christiansen [1,2], while studying particle-liquid mixtures in an attempt to determine the refractive indices of various crystals, noticed that if a suspension of particles in a liquid medium have a refractive index whose rate of change with wavelength is different from that of the liquid, and if the refractive indices of particles and liquid are equal at a particular wavelength, then the medium will transmit perfectly at that wavelength. At all other wavelength, scattering will occur and the suspension will transmit less than perfectly (Fig. 1). Christiansen discovered this effect for the first time and he designated this wavelength as Christiansen wavelength λ_c.

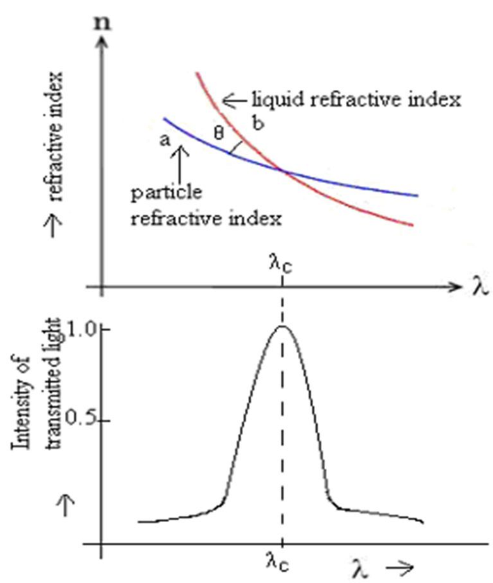


Figure 1: Curve a represents the dispersion curve of a crystal, and b that of a transparent medium. The two intersect at an angle θ at the point λ = λc

II. HIGHLIGHTS OF ITS DEVELOPMENT

In 1889, Lord Rayleigh [16] published a paper entitled “On an Improved Apparatus for Christiansen’s Experiment” where the experimental arrangement was rapidly improved by him. In 1929 Weigert and his co-workers [6] published a series of papers in which attention was directed to the fact that with proper temperature control and regulation such filters could be used quantitatively for the production of monochromatic light. By correct choice of the substances involved, λ_c may be shifted from the visible to the ultraviolet or infrared regions of the spectrum. In 1933 Kohn and von Fragstein [13] implemented a Christiansen cavity that transmitted ultraviolet light. By correct choice of the substances involved, λ_c may be shifted from the visible to the ultraviolet or infrared regions of the spectrum. In 1936 Barnes and Bonner[20] proved the universal principle of this optical filtering method, since they even extended it to the infrared range. They build some suitable IR filter with some crystalline powders like quartz; MgO, NaCl, calcite etc. dispersed in air or in organic liquid.

Historically, Raman and coworkers [3-4], may be considered as pioneers in giving a model of Christiansen effect. There were no serious attempts to explain the observations of Christiansen effect. In 1949 Raman came back to the subject, offering adequate explanations to the phenomenon through a series of papers published during 1949 to 1955. The theory which Raman advances is concerned with the concept of wavefront corrugation and is analogous to the earlier work by Ramachandran on clouds [7], except that instead of air and water, one has here two media of refractive indices n_1 and n_2. Using wave front corrugation concept, Raman is able to explain not only the intensity of transmitted spectrum but also aspects of the diffraction halo. Raman and Viswanathan extended their model to birefringent solid particles, and incorporated in their model the influence of the "packing properties" of the solid particles.

1973 Cloupeace and Klarsfeld [18] originated another new important application for the first time in the study of natural convection problem in porous media. Using the Christiansen effect, he demonstrated a method for the study of two-dimensional thermal phenomena in saturated porous media making possible the visualization of a certain numbers of isotherms as bright lines of different colors. After a parametric study of the passband of Christiansen filters, Charrier – Mojtabi (1993) [5] mentioned also its implementation to natural convention in annular process media.

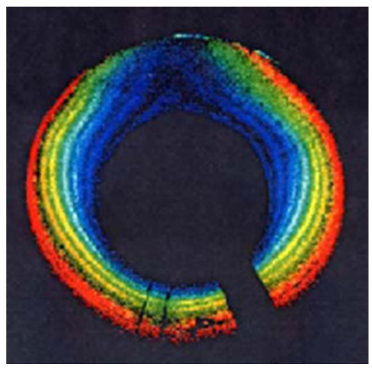


Figure 2: The use of an arc lamp makes it possible to visualize separated isothermal lines for example in annular natural convection - From Charrier-Mojtabi(1993)

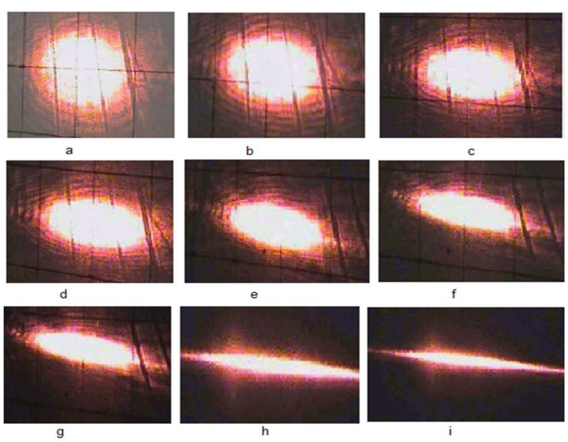
During the second part of last century, many workers did more optically-oriented studies in different field using Christiansen effect technique. These works are mainly on IR studies determination of refractive indices of solid and liquids in the infrared and investigation of multi-component system, mineral studies , investigation of the homogeneity of glass , dye laser timing and to investigate heat transfer and flow through porous media and the related problems.In 1960 Shelyubski [25] originated a new important application of the Christiansen effect for the quantitative measurement of the homogeneity of a glass by the application of Raman's theory. Homogeneity is one of the most important factors in quality control in the glass industry and Christiansen effect was found very suitable to measure the homogeneity. In 1986 Z Tiziara [27] extended Shelyubski theory to an important application; mineral study.

Until the eighties, Christiansen filters were in widely used for infrared down to UV wavelengths. . In 1987 Wajak *et al.* [24] did an important study on the Christiansen filer for the ultra violet with a new light. The development of laser sources in the far UV down to the limit of the vacuum UV (KrF and ArF lasers) had led to many uses where spectral filters in the far UV were required. Interference filters were really not the best solution if wavelengths around 250 nm and below were of interest as these filters for this spectral range can only be obtained with reduced transmission and bandwidths much broader than values possible in visible range. Wajak and his co-workers built some Christiansen filters for this spectral range using LiF powder with some alkenes such as hexane which were clearly superior to commercially available interference filter.

A new type of Christiansen filter referred to as Solid matrix Christiansen filter were designed by Z Milanovic *et. al.* [26] in 1991. Instead of classical solid in liquid system, these filters had been fabricated with host matrices by mixing finely ground optical glass powders with pellets of optical grade resins and injection molding the combination into planar filters of various sizes. These filters transmit unscattered light of the intersection wavelength and incoherently scatter light of other wavelengths. Balasubramanium *et. al.* [14] in 1992 also fabricated some solid-in-solid filter. It was observed that the performances of solid CFs were very good and had narrow band width. They reported that with the proper choice of media such solid Christiansen filters could function in practice as sensors or switches.

The nonlinear Christiansen filter was first developed by SD Vartak and NM Lowandy [23] in 1996, for the first time. Vartak and Lawandy demonstrated the cross-switching effect in the nonlinear CF and use it to ascertain the difference between switching that is due to nonlinearly along and switching that is due to combined effects of nonlinearly and scattering. Using thermal non-linearity they performed experiment on the CF in both the transient and the steady-state regimes to create an intensity dependent index of refraction. In 2002 Liu Xiao- Dong [17] discovered an interesting effect known as “reversed Christiansen effect”, when they investigated into the mid-infrared Christiansen effect of the dispersive materials. It was found to occur in the KBr pellets in which powder of the dispersive material α-SiC was dispersed. The KBr pellet technique is commonly used for infrared transmission (or absorption) spectroscopy of powders. When a large (not small as usual) amount of alpha-SiC powder is dispersed into KBr powder, the resulted pellet has an infrared transmission spectrum with a sharp peak at the position of 1,052.33 cm^{-1}. They observed that this new phenomenon is very interesting, and looks contrary to the usual Christiansen effect, but can be explained with Lorentz dispersion model accurately together, so they termed it as reverse-Christiansen effect. Exactly at this frequency, the refractive indices of these two materials are equal, and absorption coefficients are very small. This new phenomenon is very useful for making a new type of mid-infrared band-pass filter.

Recently Mahanta and Baruah [20-22] have carried out a study on the role of diffusion on the nature of chromatic patterns associated with the Christiansen effect in detail. When we have adjusted the refractive index of liquid of Christiansen cell by varying the concentration of saturating liquid phase it has been observe that diffusion acts as an important key factor on the chromatic pattern associated with the Christiansen effect. In our experiment Laser radiation (5mW, 675nm) is allowed to fall on the thermostatized Christiansen cell containing two suitable liquids through an iris and the chromatic patterns are observed on a white screen. Video camera has been used to photograph the chromatic patterns under different circumstances. When laser radiation is allowed to pass through the boundary separating the two liquids miscible through diffusion, beautiful circular fringe is observed on the screen. The pattern changes with time. At the beginning of the experiment, approximately circular fringe is observed and as time evolves, the fringes become more and more elliptical. They are reproduced in Fig 3. It is worthwhile to note that the circular fringe appear on the screen only when the light is transmitted through diffusion region. This gives additional information to the development of Christiansen filter theory.



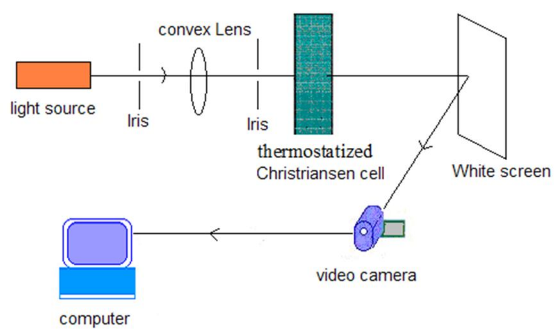


Figure 3: Time evolution diffusion fringe pattern in Christiansen cell – From Mahanta & Baruah (2009) Figure 4: The Christiansen effect experiment setup - from Mahanta and Baruah [21]

III. APPLICATION OF CHRISTIANSEN EFFECT

This effect has found its applications in diverse field of science and technology. It has been seen that recently Christiansen effect has been widely used in atmospheric study[7], to build optical power limiter and sensor[9,11], colloids and polymer study[15], and in microgravity research [13] in addition to its conventional uses like in glass technology[10], mineral study[28] and IR study, etc.

Recently Christiansen effect has found lot of application in atmospheric physics. H.R. Carlon first drawn [10] the attention of atmospheric Physicists and I.R system designers by reporting that Christiansen effect can occur in dust or particulate clouds in the atmosphere. An interesting example of Christiansen effect occurs near 7.4 μm, on the lower wavelength edge of the 7-13μm IR atmospheric window, for powdered quartz (silica) particle in air. Silica and related compounds including silicates are major constituents of soil derived atmospheric dust.

Thus, if precipitated films of silica dust in air can be shown to exhibits Christiansen effect, atmospheric clouds of silica dust could also exhibit this effect, with enhanced optical transmittance near 7.4 μm compared to other wavelength, because of the optical band pass characteristics of such dusts in air. There is the possibility that such wavelengths may be favored for optical transmission and that they may thus be optimum wavelengths for transmission through dusty atmospheres, e.g., in the designing a new laser system.

Now a day's Christiansen effect has also used in colloid and polymer study. More recently, a novel coloration phenomenon in a colloidal dispersion with an amphiphilic polymer was found by K Okoshi *et.al.* [15]. The dispersion consists of tetrahydrofuran (THF), an aqueous solution of sodium thiosulfate and hydroxypropylcellulose (HPC). The dispersion was emulsified by HPC as an amphiphilic polymer, so that the aqueous phase was confined in droplets in the THF matrix. It typically appeared bluish violet at room temperature and turned into blue with increasing temperature.

IV. CONCLUSION

The Christiansen effect is a very important tool in the research of material science.

This effect has found its applications in diverse field of science and technology. Day by day the applications of this effect have spread in diverse field.

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