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# Computation of Refractive Indices of Corona Viruses through Reverse Calculation

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The present paper computes the refractive indices of different corona viruses (H5N1, H5N2, H9N2, H4N6, FAdV and IBV) through reflectance analysis of a virus solution. The computational analysis indicates that the refractive indices of all viruses are negative at the signal of 412 nm. Further the numerical output shows that the infectious bronchitis viruses (family of novel corona viruses, COVID-19) have higher negative refractive indices as compared to other corona viruses. Finally refractive indices of the family of COVID-19 are investigated with respect to the EID (Electronic infusion Device) concentration of the viruses, showing that the refractive index which ranges from "-0.96725 to -0.999998" corresponds to '0.01 to 10000' EID virus concentration.

*Keywords* : Refractive indices, Corona viruses, Zirconium quantum dots solution, Reflectance
*OCIS codes* : (240.5698) Reflectance anisotropy spectroscopy; (350.2450) Filters, absorption

## I. INTRODUCTION

Today's world has been facing a momentous complication since December 2019 when corona virus disease 2019 (COVID-19) was identified in the city of Wuhan, China. The spreading of such viruses is pandemic nowadays throughout the world. Primarily such viruses are spread between two bodies during the close contact via droplets which are produced by coughing, talking and sneezing [1]. Apart from this, animals may be infected by touching a contaminated surface and then touching their face (nose, mouth and ear, etc.). The common symptoms of these diseases are cough, sneezing, fever, tiredness, breathing problems, and the loss of smell, etc. Besides these, pneumonia and respiratory distress syndrome are complications due to such diseases [2]. The time of exposures of such diseases is typically around five days but may range from two to fourteen days. Since no proper medicine has been discovered so far, some preventive measures (frequently hand washing with soap, covering mouth while coughing and sneezing, maintaining distance from other animals or people, wearing a face mask in public setting and self-isolation for human or animals who are suspected of having these diseases for fourteen days) have been recommended. Basically it is a group of RNA viruses that cause diseases in mammals and birds. The common cold is a basic symptom. However, all common colds are not the symptoms of novel corona viruses (COVID-19). They may be in the category of other flus (H5N1, H5N2, H9N2, H4N6, FAdV) [3]. However the category of infectious bronchitis viruses (IBV) is different from the aforementioned viruses and they resemble the COVID-19 as novel corona viruses belongs to the family of the IBV [4, 5]. Keeping the importance of the corona viruses in mind pertaining to health issues, the present paper computes the optical parameter (refractive indices) of the above mentioned viruses with respect to the analysis of transmission, absorption and reflection. The outcomes of the paper could be utilized to envisage different sensing applications. As far as different recent work on sensing applications is concerned; reference [6] discusses the cloaking sensor where metasurface based graphene strips play a vital role to realize the cloaking of a dielectric cylinder pertaining to the terahertz signals. Similarly in reference [7], authors discuss a perfect absorber using

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graphene based plasmonic material at the signal of the terahertz regime. In this research six layers of graphene sheets have been considered. The proposed absorber has a certain primacy with respect to the higher order modes. Further reference [8] designs an optofluids laser sensor with the help of two polydimethylsiloxane. In this research, single mode based an optofluidics ring generator is successfully demonstrated. Again reference [9] describes different photonic nanosensors for the investigations of various cancers and viruses. Here authors focus on the proposed structures and applications (breast cancer and cervical cancer). In reference [9], the principle of detection is based on the field distribution in two dimensional photonic crystal structures. As in reference [9], in the reference [10], authors describe an optical nanosensor for streetlight applications using graphene based materials. In this research authors establish a numerical formulation of different aspects of graphene properties with the help of a transfer matrix method. Moreover a nano biosensor is proposed in the reference [11] using a unidirectional reflectionless propagation effect. In this research a coupled mode theory is discussed using both a finite difference time domain method and analytical treatment. The output of this research detects different biomaterials including Quinoline, ethyleneglycol, and chlorobenzene.

## II. BASIC MATHEMATICAL EXPRESSION

The mathematical expression for refractive index of corona viruses is a function of the wavelength and it can be expressed as [11, 12]

$$\text{Refractive index (wavelength)} = \left[\frac{4\times\text{reflectance}}{(\text{reflectance}-1)^2} - \text{extinction coefficient}^2\right]^{\frac{1}{2}} - \left[\frac{\text{reflectance}+1}{\text{reflectance}-1}\right]. \tag{1}$$

Basically, the refractive indices of materials are complex quantities at a certain signal (wavelength). For example; it is a combination of real and imaginary refractive indices. The real refractive indices control the reflected signal while imaginary refractive indices control the absorbance of the materials. So from Eq. (1), it is realized that the refractive indices of the corona viruses rely on the reflectance as well as the extinction coefficient. The extinction is an imaginary part of the refractive index which controls the absorption coefficient. Further the relation between the extinction coefficient and absorption coefficient is expressed as [13]

$$\text{Extinction coefficient} = \frac{\text{absorption coefficient}\times\text{wavelength of signal}}{4\pi}. \tag{2}$$

Here the imaginary part of the refractive index (extinction coefficient) relies on the operational wavelength, which is taken as 412 nm. Moreover the absorption coefficient can be expressed as [11]

$$\text{Absorption coefficient} = \frac{1}{\text{thickness of the speciman}}\log_e(\text{transmittance}). \tag{3}$$

The transmittance of the signal corresponding to each virus is obtained from the experimental result which is found from reference [3]. In reference [3], authors discuss the absorbance and photoluminescence intensities of the different viruses through a quantum dot solution. So knowing the values of the transmittance, the absorption coefficient and subsequently the extinction can be determined. Furthermore, the reflectance can be obtained using the generalized equation as [13]

$$\text{Reflectance} = 1 - \text{absorbance} - \text{tansmittance}. \tag{4}$$

After computing the extinction using Eqs. (2, 3) and reflectance using Eq. (4), the refractive indices of the different viruses can be computed using Eq. (1).

## III. RESULT AND DISCUSSION

Before going to discuss the result and interpretation, let us focus on the Eqs. (3, 4), where the reflectance relies on both absorbance and transmittance of the signal, which can be determined from the analysis of photoluminescence intensities of the virus based ZrQD solution. Again realizing the same, reference [3] discusses the method of preparation of such solutions. A brief part of the same is shown in Fig. 1.

In this process zirconium nanoparticles are mingled with the ascorbic acid and form Zr quantum dots. Then antibody conjugation is formed from ZrQD particles which are obtained through the process of autoclaving at 120°C for 1 hour. Again a targeted virus is applied after the formation of antibody conjugated magnetic plasmonic nanoparticles (MP NPs). Further photoluminescence intensities are measured after applying an external magnetic field and the process of supernatant. Finally the refractive indices of the targeted viruses are determined from the analysis of the luminescence intensities. We in this paper focus on the computation of the refractive indices of the different viruses with the help of the Eqs. (1-4). Although the current paper concentrates on the refractive indices computation, let us focus on the

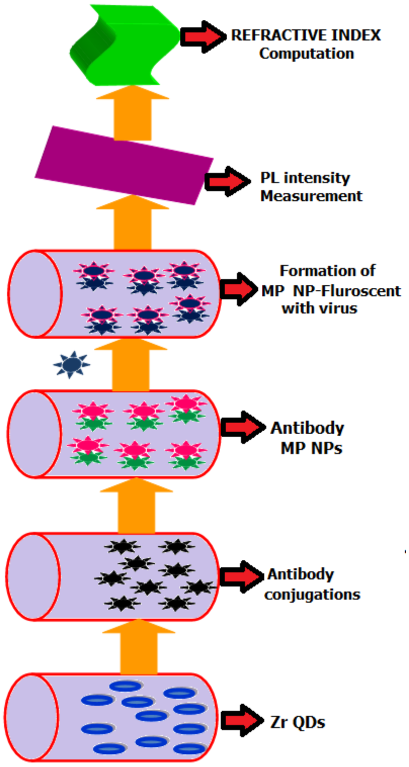
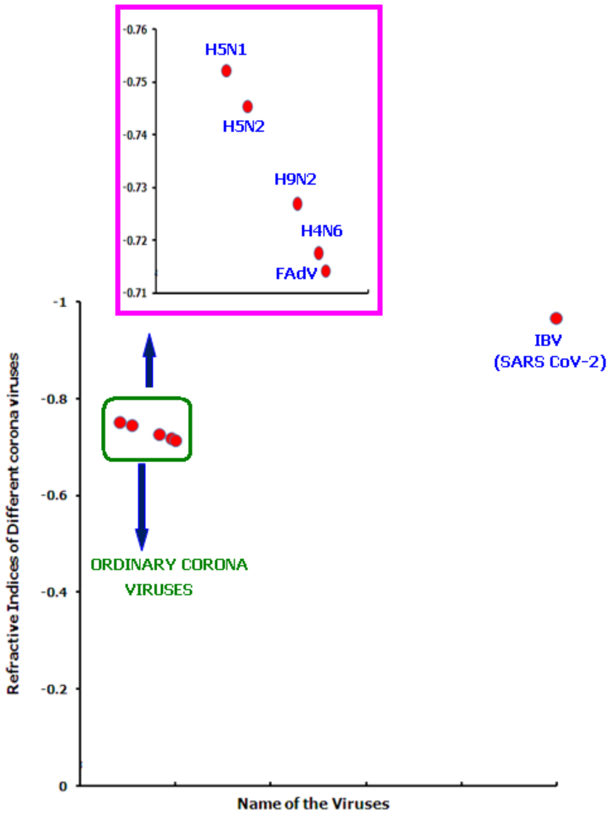



FIG. 1. Schematic representation of preparation of virus solution and computation of refractive indices.

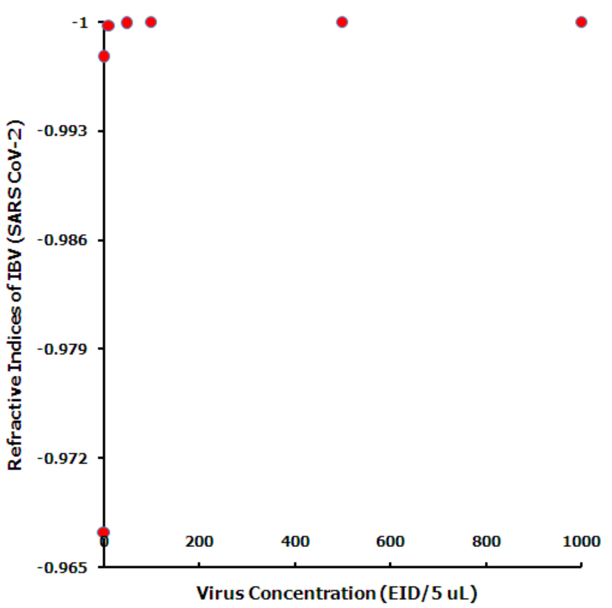
notion of the different viruses (H5N1, H5N2, H9N2, H4N6, FAdV and IBV) in brief as follows.

The H5N1 [14] of influenza virus causes a high infection, which is called bird flu. This type of influenza occurs occasionally but it is difficult to transmit from human to human. Similarly H5N2 [15] of influenza causes an infection in avians. It causes the outbreak in avians and can also be isolated from asymptomatic avians. This kind of bird flu is a contra virus for human beings. Further the influenza, H9N2 [16] is the virus which causes human influenza and birds flu. This influenza causes illness in children up to five years. H9N2 viruses are found worldwide in wild birds and it is endemic in poultry in many areas. Again, H4N6 [17] influenza viruses originated from pigs with high pneumonia. It was found in October 1999 in Canada. It is identified by Hemagglutination inhabitant's assays and microbiome minds inhabitants. This virus affects the human body, if anyone is closely in contact with infected pigs. Moreover the Flow Adenovirus (FAdV) [18] is a poultry disease with the inclusion of body hepatitis and hyper-cardium syndrome (HPS). Basically this type of disease affects the liver and kidney part of the animal. These are found in the humans who are closely associated with the affected poultry animals. In the case of human beings, it is called human adenovirus fiber 2, which are transmitted to the end of the virus genome. Finally, the corona virus of infectious bronchitis virus (IBV) [3, 5] resembles the current coronal virus (COVID-19). It produces both upper respiratory tract and reproductive tract infections. The COVID-19 (SARS COVID-2) also produces renal problems in severely ill patients. A new corona virus in humans produces severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS), which belongs to the IBV family as both are akin to each other. So COVID-19 is a derivative of IBV. So keeping the importance of the same, we in this paper compute the optical parameter (refractive index) of the various viruses including IBV using reverse calculation.

The above calculation leads to the computation of refractive indices from reflectance, where refractive index is function of reflectance. Basically direct calculation leads to the computation of reflectance through refractive indices, where reflectance is a function of refractive index e.g. Fresnel's reflection. From Eq. (1), it is revealed that the refractive indices of viruses rely on the reflectance as well as extinction coefficient which can be determined through the analysis of both absorbance and transmittance. The same could be investigated using Eqs. (2-4). Further transmittance of the signal depends on photoluminescence intensity (PL) which is experimentally investigated at the signal of 412 nm and that is indicated in reference [3]. The present numerical treatments concentrate on the computation of refractive indices of different corona viruses and refractive indices of IBV with respect to the different concentration (EID) of virus. Concentrating on the reference [3] and after analyzing the PL intensity, it is found that 50, 60, 63, 53, 64 and 160 are the PL of the H5N1, H5N2, H9N2, H4N6, FAdV and IBV, respectively at the signal of 412 nm. Basically photoluminescence (PL) is the emission of light from solutions under excitation of the signal, 412 nm. In this case, excitation energy and intensity are chosen to investigate the characterization of the internal properties of the specimen (different viruses). As far as the intrinsic mechanism is concerned, when an input signal of adequate energy is incident on a virus based solution, photons are getting absorbed and electronic excitations take place. Further these excitations get relaxed and the electrons return to the ground state after the time 10 ns (approximately). Here the radiative relaxation takes place which leads to the emission of light. This is called photoluminescence. These photoluminescence phenomena or photo luminescence intensity (PL intensity) provides information about the virus properties. Primarily, PL relies on the nature of the photonic excitation which depends on the strength of the input signals. The transmittance of the signal through a virus solution is defined as the ratio of transmitted intensities to the incident intensity. The transmittance of a sample can be computed through the normalised PL intensities. The normalised intensities can be determined by dividing the whole spectrum by the intensity of a selected peak. So the transmittance corresponding to each normalised intensity is computed. The result for transmittance are 0.3125, 0.375, 0.39375, 0.33125, 0.4 and 1 for H5N1, H5N2, H9N2, H4N6, FAdV and IBV respectively. Similarly the absorbance of the different viruses are found from the reference [3] at the signal of 412 nm and the numerical values are 0.03050, 0.03051, 0.03049, 0.03052, 0.03053, 0.03054 and 0.03058




(a)




(b)

FIG. 2 Refractive indices of corona viruses: (a) refractive indices of the different viruses (b) variation of refractive indices with virus concentration (EID) for IBV corona virus.

corresponding the virus, H5N1, H5N2, H9N2, H4N6, FAdV and IBV, respectively. Knowing the transmittance, and absorbance of the signals, the reflectance is determined using Eq. (4). Similarly, the extinction coefficient is calculated through Eqs. (2, 3). Finally putting the values of reflectances and extinction coefficients in Eq. (1), refractive indices of different viruses can be computed. The same result is disclosed through graphical representation, which is shown in Fig. 2(a).

In Fig. 2(a); the values of the refractive indices are taken along the vertical axis. Also the types of viruses have been indicated. From Fig. 2(a), an interesting result is found, for example the refractive indexes of all viruses are negative and the values of ordinary viruses are close to each other. The same is inset in this figure. The values of such refractive indices are -0.752147, -0.726881, -0.717555, -0.74535, -0.714207 and -0.967251, corresponding to the H5N1, H5N2, H9N2, H4N6, FAdV and IBV, respectively. Apart from this, the minute observation indicates that the refractive index is around -0.73 for all viruses except IBV which is found around -0.96. These values are the maximum refractive indices of the corona viruses. Since the nature of the refractive indices of the IBV is differed from other viruses and it belongs to the family of COVID-19, one can realize the status of corona viruses (whether affected by novel corona or not) by knowing the refractive indices. Since the refractive indices of the IBV are unlike as compared to common corona viruses, we want to disclose the nature of the refractive indices pertaining to the different EID concentration. The result corresponding to the same is disclosed in Fig. 2(b).

In this figure, the Electronic infusion device (EID) is a rate of infusion which is regulated by an electronic pump to deliver the fluids at the correct rate and volume in ml/hr. It is used for many types of patients, medications and solutions. Basically, it is a therapeutic effectiveness of IV fluids where a constant flow is necessary to prevent complications from too much or too little fluid. A physician must order a rate of infusion for IV fluids or for medications.

From Fig. 2(b), it is observed that refractive indices of viruses decrease with respect to the concentration of the virus. For example; it varies from -0.96725 to -.999998 for concentration 0.01 to 1000 (EID/5 μL). These variations lies within -0.96 to -1, which are completely away from other corona viruses. Similarly, though computation is made for other viruses, we have placed the ranges of refractive indices in tabular form (Table 1).

In Table 1, the type of corona virus, concentration of virus of 0.01 and 1000 are represented in the column 1, 2 and 3 respectively. It is clearly indicated that the refractive indices of the viruses (H5N1, H5N2, H9N2, H4N6, FAdV) vary from -0.71 to -0.783, however the refractive indices of IBV, which is family of novel corona virus fluctuates from -0.967 to -1. So Table 1 claims that the refractive indices of novel corona virus lies within -0.96 to -1 which is quite different from common corona viruses.

TABLE 1. Refractive indices of the corona viruses

| Type of viruses | Refractive index | |
|---|---|---|
| | 0.01 (EID concentration) | 1000 (EID concentration) |
| H5N1 | -0.752147 | -0.78266 |
| H5N2 | -0.726881 | -0.75739 |
| H9N2 | -0.717555 | -0.74807 |
| H4N6 | -0.74535 | -0.77586 |
| FAdV | -0.714207 | -0.74472 |
| IBV (Family of COVID-19) | -0.967251 | -0.999998 |

## IV. CONCLUSION

The investigation of the refractive indices of the different corona viruses is made in this paper through the analysis of the photo luminescence intensity. The numerical result indicates that the refractive indices of the corona viruses are negative in nature. The refractive indices of IBV (which is a family of COVID-19) has different with respect to the other corona viruses. After all, the natures of variation of refractive indices of IBV are studied with respect to the EID concentration and subsequently the ranges of the refractive indices of all corona viruses have been divulged.

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