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# Analysis of Optical Spectrum for Hematite Nanofluid Longpass Tunable Filter

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***Abstract: -*** The appropriate liquid-filter material must meet several requirements, including exact refractive index and absorption coefficients, optical constants that determine a satisfactory spectral response, solubility and stability in cold and hot water, and environmental safety. Recent research indicates that nanofluids must be very carefully chosen to see improvement in the proposed application. This is especially true for the nanofluid optical properties in tunable filters. If the volume fraction of nanoparticles is very high, all the incoming light will be absorbed in a thin surface layer where the thermal energy is easily lost to the environment. On the other hand, if the volume fraction of nanoparticles is low, the nanofluid will not absorb all the incoming radiation. Therefore, the optical properties of the fluid must be controlled very precisely or a nanofluid could actually be detrimental for the application. This paper focuses on analyzing the transmittance spectrum of hematite nanofluid for varying levels of volume fraction, particle size (diameter) and thickness of liquid layer using simulation results based on an established mathematical model.

***Keywords:*** *- Nanofluid , transmittance, tunable filters.*

## I. INTRODUCTION AND METHODOLOGY

Nanofluid optical filters, which recently are the objects of research in the field of nano electronic devices, have a bright prospect in optical communications, sensing, lighting, photography, and energy harvesting[3]. They can meet the transient needs in a system because of the substantial amount of control that can be achieved by varying the particle size, volume fraction, thickness of the liquid layer and external factors like magnetic and electric fields. The transmittance and absorbance of the spectrum is highly affected by the choice of the base fluid alongside other factors like the extinction and scattering efficiency of the nanoparticles. An ideal optical limiter should be transparent to low energy laser pulses and opaque at high energies, so that it can protect human eyes and optical sensors from intense laser radiation[4]. The objective of this paper is to analyze the performance of hematite or iron(III) oxide ($Fe_2O_3$) nanofluid using simulation results to justify its usability as a longpass filter in various fields of operation. Fig. 1 shows a flow chart that describes how this proposed filter can be used as a tunable filter in communication.

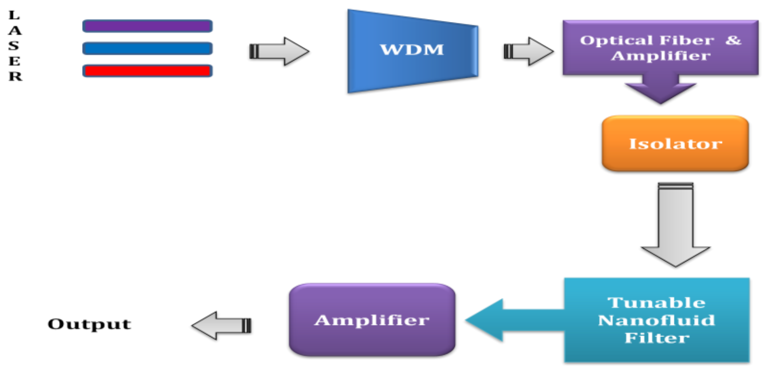


Fig 1: Block diagram of a tunable Nanofluid Filter application in a transmitter circuit.

Shinde et al [5] compared the transmittance of aluminium doped $Fe_2O_3$ with that of pure hematite thin films whereas Nair et al [4] reported having successfully implemented a ferrofluid optical limiter. The simulation results here show that there is a close match between transmittance of the hematite nanofluid filter and that of hematite thin films given in previously published work by Shinde et al [5]. The equations given in section III of this paper takes into account the effect of the base fluid (which is water here) , volume fraction, thickness of liquid layer and particle size or diameter of the nanoparticle to the transmittance of electromagnetic radiation through the hematite nanofluid filter.

## II. RESULTS AND ANALYSIS OF TRANSMITTANCE SPECTRUM

The variation of transmittance with thickness of the liquid layer at a constant volume fraction of 70% and particle diameter of 0.005µm is presented in Fig 2. There is significant transmittance for a nanofluid layer thickness of 1µm compared to the rest of the values considered as can be seen from the simulated data collected on Table 2. It is also noteworthy that such a high transmittance pattern has been obtained at a comparatively high concentration or volume fraction of the nanoparticle in the base fluid. Therefore, the results infer that the thinner the nanofluid layer at a high volume fraction the greater the similarity in performance of the hematite nanofluid to the conventional solid hematite thin film filter for a small particle size.

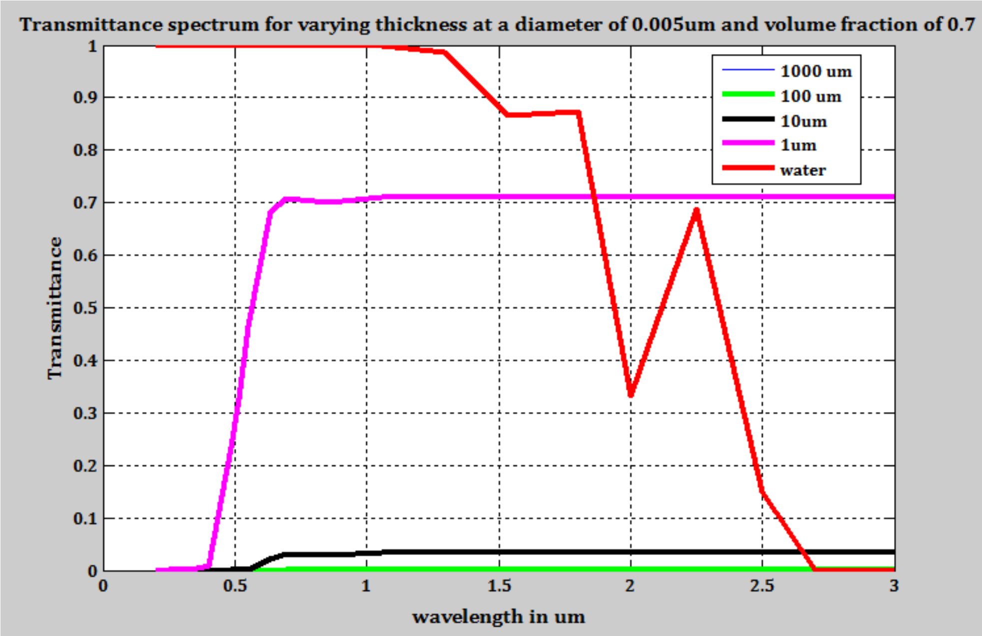


**Fig 2:** Transmittance spectrum of hematite nanofluid at different thicknesses of liquid layer. Basefluid transmittance (in red) is at l=1000µm.

**Table 2:** Showing transmittance for varying thicknesses of hematite nanofluid layer at a constant volume fraction and particle diameter.

| Volume fraction=70% and Diameter=5nm | | | | | | |
|---|---|---|---|---|---|---|
| Thickness (µm) | Color code | %Transmittance at Wavelengths in (µm) | | | | |
| | | 0.300 | 0.500 | 0.850 | 1.350 | 1.550 |
| 1 | Magenta | 0% | 25% | 70% | 71% | 71% |
| 10 | Black | 0% | 0% | 2% | 2% | 2% |
| 100 | Green | 0% | 0% | 0% | 0% | 0% |
| 1000 | Blue | 0% | 0% | 0% | 0% | 0% |

Fig: 3 shows the transmittance spectrum for varying particle sizes while the volume fraction and thickness is kept constant. From Table 3 it can be inferred that transmittance tends to improve at the mid and higher infrared wavelengths for a hematite nanofluid. The transmittance spectrum is also consistent over considerable wavelengths in the infrared region and has a significantly high level of transmittance there. From Fig: 3 it can be seen that the cutoff frequency can be regulated by varying the particle size at fixed values of volume fraction and thickness of the nanofluid layer. The results in Fig 3 were obtained by varying the volume fraction of the nanoparticle at a constant thickness of 0.1µm and a diameter of 0.005µm.

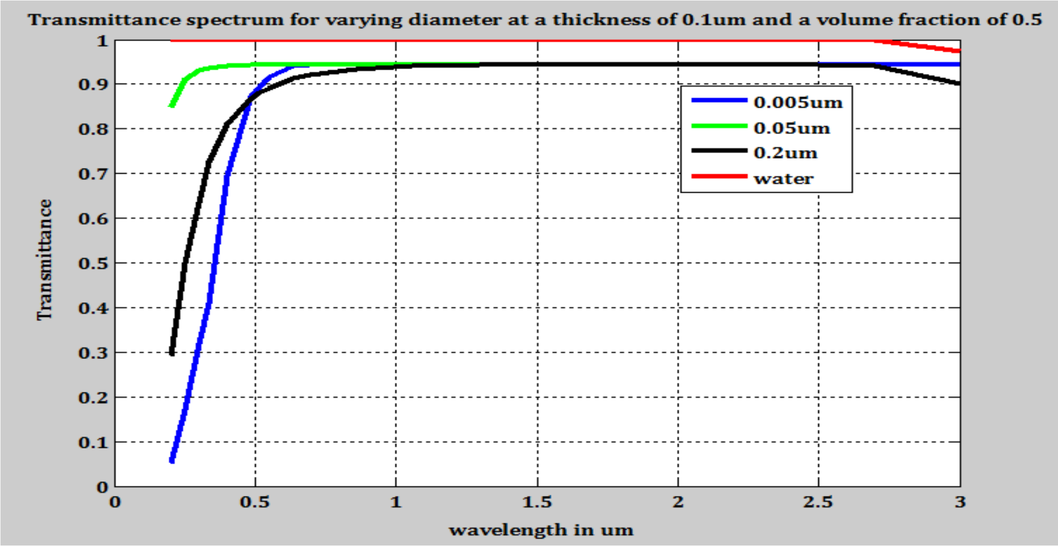


**Fig 3:** Transmittance spectrum of hematite nanofluid at different particle diameters.

**Table 3:** Showing transmittance for different sizes of hematite nanoparticles for fixed thickness and volume fraction.

| Volume fraction=50% and Thickness=0.1 μm | | | | | | |
|---|---|---|---|---|---|---|
| Diameter (μm) | Color code | %Transmittance at Wavelengths in (μm) | | | | |
| | | 0.300 | 0.500 | 0.850 | 1.350 | 1.550 |
| 0.005 | Blue | 32% | 87% | 94% | 94% | 94% |
| 0.05 | Black | 63% | 87% | 92% | 94% | 94% |
| 0.2 | Green | 93% | 94% | 94% | 94% | 94% |

Fig: 4 presents the effect of varying the volume fraction of hematite nanoparticles of diameter 0.005μm at a nanofluid layer thickness of 0.1μm or 100nm. As seen earlier the effect of a high concentration evidently plays an important role in transmittance of the fluid filter. With increasing volume fraction the level of transmittance increases and the cut off frequency tends to shift towards the right i.e deep into the infrared region.

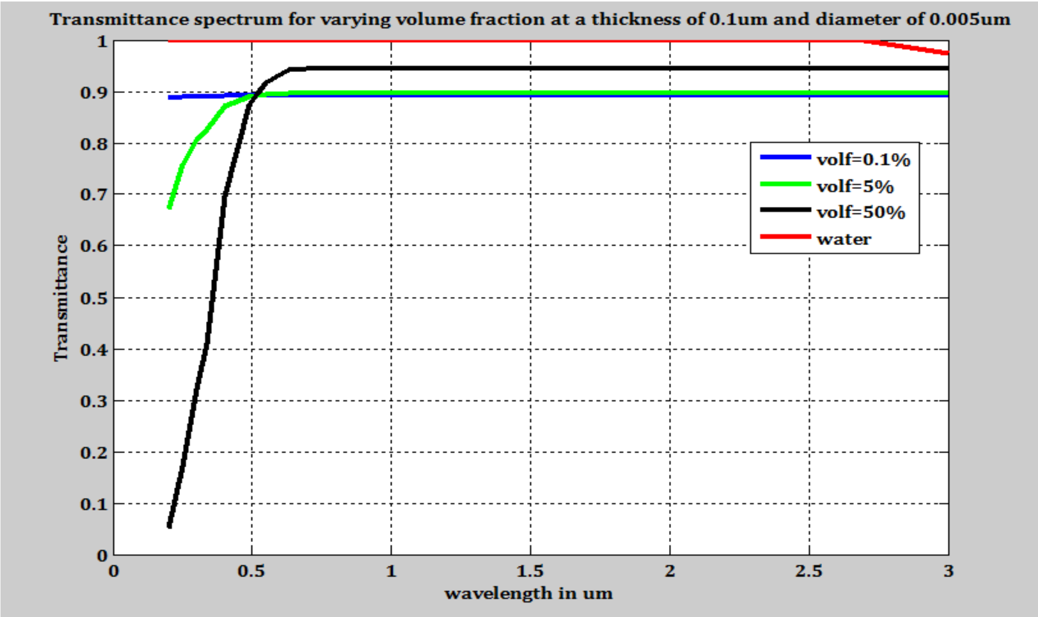


**Fig 4:** Transmittance spectrum for varying volume fraction of hematite nanofluid.

**Table 4:** Showing transmittance for different volume fractions of hematite at fixed thickness and particle diameter.

| Diameter=0.005µm and Thickness=0.1 µm | | | | | | |
|---|---|---|---|---|---|---|
| Volume Fraction (µm) | Color code | %Transmittance at Wavelengths in (µm) | | | | |
| | | 0.300 | 0.500 | 0.850 | 1.350 | 1.550 |
| 0.1% | Blue | 89% | 89% | 90% | 90% | 90% |
| 5% | Green | 80% | 89% | 90% | 90% | 90% |
| 50% | Black | 32% | 87% | 94% | 94% | 94% |

Considering the combined effect of the size parameter, volume fraction and thickness of liquid layer it can be concluded that the best results for transmittance of hematite nanofluid are obtained for higher concentration, lower thickness and smaller particle size.

## III. MATHEMATICAL MODEL

Mie theory was used to calculate the scattering and extinction efficiency[1] factors of a single homogeneous sphere particle. In this study the relative refractive index was applied because the nanoparticle was immersed in the base fluid. The relative refractive index is defined as:

$$m=\frac{n_p+ik_p}{n_m} \qquad \text{eq-1}$$

where $n_p$ and $\kappa_p$ are the real and imaginary parts of the complex refractive index of the nanoparticle, respectively, and $n_m$ is the refractive index of the dispersed medium. The size parameter is defined by equation (2) where **d** is the diameter of the nanoparticle and $\lambda$ is the wavelength in the medium.

$$\chi = \frac{\pi d}{\lambda} \qquad \text{eq-2}$$

The extinction efficiency factor of the nanoparticle can be calculated by

$$Q_{e,\lambda} = \frac{2}{\chi^2}\sum_{n=1}^{\infty}(2n+1)Re(\, a_n + b_n) \qquad \text{eq-3}$$

where $\mathbf{a_n}$ and $\mathbf{b_n}$ are Mie scattering coefficients, which can be found by solving Bessel functions. The determination of the extinction coefficient for a non-absorbing monodisperse particulate medium where $f_v$ is the volume fraction of nanoparticles is given by equation (4). If absorbing of the base fluid (water) is taken into account, the extinction coefficient for the water-based nanofluid is given by equation number (5) where $\kappa_{bf}$ is the extinction coefficient of the base fluid.

$$K_{e,\lambda} = \frac{1.5}{d} f_v Q_{e,\lambda} \qquad \text{eq-4}$$

$$K_{e,\lambda} = \frac{1.5}{d} f_v Q_{e,\lambda} + (1 - f_v)\ \frac{4\pi\kappa_{bf}}{\lambda} \qquad \text{eq-5}$$

$$T = \frac{I}{I_0} = e^{(-K_{e,\lambda}, l)} \qquad \text{eq-6}$$

The regular transmittance of a liquid layer with a thickness of l µm can be determined by Beer's law using equation (6).

## IV. CONCLUSION AND FUTURE WORK

It has been demonstrated through the simulation results that the hematite nanofluid can be employed to effectively control the transmittance of infrared radiation by varying the volume fraction, thickness and particle size. Further consideration of external factors like magnetic field and temperature change will have some added effect on the transmitted or absorbed spectrum but were not explored in this paper. In the experimental setup the liquid layer is generally enclosed in a quartz cell during the measurements of radiative properties. Therefore, reflection exits on the interface of air and glass and on the interface of glass and liquid. The multiple reflection can affect the transmitted thermal radiation. Hence, the quantity obtained from Eq. 6 needs to be corrected to address the multiple reflection[2] in order to attain results which are closer to the actual values obtained from realistic experiments . In general the main advantages of this type of optical filter are (a) a single filter can be used for a range of central wavelengths, where the desired central wavelength region can be tuned by external magnetic field[8] (b) it is suitable for selecting wavelengths in the ultraviolet, visible and infrared regions[8] (c) there is no need for changing the optical element for different wavelength regions[8] (d) tuning can be easily achieved by changing the field strength (e) the spectral distribution can be controlled by adjusting the polydispersity (objects that have an inconsistent size, shape and mass distribution) of the emulsion[8] (f) The intensity of the transmitted light can be controlled by changing the emulsion concentration[8] (g) it is simple to operate and less expensive compared to the existing filters[8]. For optical filters 'line' absorbers are highly preferred for selective light extinction and this can be achieved by the use of metallic shell/silica core particles that exhibit pronounced plasmon resonance[3]. The wavelength or natural resonant frequency at which this occurs is determined by parameters such as the particle's size, shape, shell thickness, and bulk optical properties of the materials involved [3,9]. Core/shell nanoparticles can then be tuned to achieve the desired optical properties by changing the above mentioned parameters.

## REFERENCES


[1] Qunzhi Zhu, Yun Cui, Lijuan Mu, Liqing Tang, *Characterization of Thermal Radiative Properties of Nanofluids for Selective Absorption of Solar Radiation*, *DOI 10.1007/s10765-012-1208-y*

[2] S.H. Wemple, J.A. Seman, Appl. Opt. 12, 2947 (1973)

[3] Robert A. Taylor et al, *Feasibility of nanofluid-based optical filters,* Applied Optics, Vol. 52, Issue 7, pp. 1413-1422 (2013)

[4] Swapna S. Nair,Jinto Thomas,C. S. Suchand Sandeep,M. R. Anantharaman,and Reji Philip,*An optical limiter based on ferrofluids***,** Applied Physics Letters 92, 171908 2008 , DOI: 10.1063/1.2919052.

[5] S.S.Shinde, R.A.Bansode, C.H.Bhosale, and K.Y.Rajpure,*Physical properties of hematite -Fe2O3 thin films: application to photoelectrochemical solar cells, DOI: 10.1088/1674-4926/32/1/013001.*

[6] Lei Zheng, Jarrod Vaillancourt, Craig Armiento, and Xuejun Lu Thermo-optically tunable fiber ring laser without any mechanical moving parts, Optical Engineering July 2006/Vol. 45(7) 070503-1

[7] E.D. Palik, Handbook of Optical Constants of Solids, vol. 3 (Academic Press, San Diego, 1998)

[8] http://www.igcar.ernet.in/igc2004/htdocs/technology/ferroseal_2009.pdf

[9] L. K. Kelly, E. Coronado, L. L. Zhao, and G. C. Schatz, "The optical properties of metal nanoparticles: the influence of size, shape, and dielectric environment," J. Phys. Chem.B 107, 668–677 (2003)