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# Investigation on Heat Transfer Properties of Nano-fluids Using Michelson Interferometry

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**Abstract**: Interferometry is an optical non-intrusive technique becoming increasingly popular in the flow and heat transfer visualisation and measurement. In the present study, experimental investigation on heat transfer properties of Zinc Oxide (ZnO) Nano fluids using Michelson Interferometry has been carried out. The temperature, at a reference point in the Nano fluid, is recorded by a thermocouple placed at a known distance from the heat source. Interference patterns are captured by a camera and analysed using an image processing tool in MATLAB software. From the observations, it is pellucid that the change of fluid temperature in one path of the coherent laser beam results in the deformation of the interference pattern. Comparison of initial and deformed fringe patterns using digital image processing technique, the temperature distribution near the heat source has been obtained. Recorded interferograms are to be quantitatively analysed to retrieve two dimensional temperature fields. Real time evolution of thermal boundary layers as a function of concentration of Nano fluids is to be recorded in order to understand the plausible role of Nano particle in the heat transfer enhancement.

**Keywords**: Nano fluids, heat transfer, interferometry, temperature.

## I. INTRODUCTION

Nano fluids are new class of solid/liquid mixtures engineered by dispersing nanometre size particles or any nanostructures in conventional base liquids. Enhanced thermal characteristics of Nano fluids have generated considerable interest among the researchers in recent times. The fact that the metals and their oxides have higher thermal conductivities compared to the common fluids like water, ethylene glycol etc., uniform dispersion of small concentration of these nanometer-sized metals (e.g. copper, zinc)/metal oxides (e.g. CuO, Zno ) into the base fluid significantly improves the heat transfer performance of the fluid. The improved thermal properties of Nano fluids has primarily been the reason for their wide applications in many industrial sectors including heating as well as cooling, air-conditioning, micro-electronics etc. Knowledge of the thermal characteristics of Nano fluids is found to be very critical in deciding there suitability for heat transfer application.

Interferometry is a non-intrusive technique used to determine the heat transfer properties of the fluid. It is a family of techniques in which waves, usually electromagnetic are superimposed in order to extract information about the waves. The principle of superposition to combine waves in a way that will cause the result of their combination to have some meaningful property that is diagnostic of the original state of the waves. When two or more propagating waves of same type are incident on the same point, the total displacement at that point is equal to the point wise sum of the displacements of the individual waves. The resultant waves are constructive interference or destructive interference depends on the point of contact.

A brief review of the recent work on Interfrometric study and Nano fluidsare presented here.Anooplal and Binoy Baby.[1] measured temperature distribution of a hot body by Michelson Interferometer. Binoy Baby and Sobhan C B[2] have made a study into the flow and heat transfer behaviour of fluids flowing through channels with small cross sectional dimensions with Mach- Zehnder interferometry was performed. Sajith and C.B Sobhan.[3] have introduced digital interferometric technique is used for heat transfer measurement in a liquid medium flowing through channels of small cross sectional diameters. S. Vajjha et al.[4] give an understanding of the density of nano fluids for different temperatures (0°C to 50°C) for different particle volume concentrations.

Honorine et al.[5] presented effective thermal conductivity measurements of alumina/water and copper oxide/water Nano fluids. Bhagat et al.[6] has described the preparation of ZnO based Nano fluids. Sang Hyun Kim et al.[7] made a study into the thermal conductivity of water and ethylene glycol based Nano fluids containing alumina, zinc oxide, and titanium-dioxide using the transient hot-wire method. Particle size and also volume fraction of Nano fluid was varied to study the effect. It also demonstrated that high power laser irradiation lead to substantial enhancement in the effective thermal conductivity.

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## II. EXPERIMENTAL STUDY

The basic concept of Michelson Interferometry is shown in the line diagram at Fig.1.The laser beam from the source is passing through the collimating lens and split into two coherent beams by beam splitter. Then, one of the beams (Test Beam) is passed through the test cell (with heating plate)to the mirror and reflected back to beam splitter, whereas the other beam (Reference Beam) goes through the test cell (without heating plate) to another mirror and is reflected back to beam splitter. The two reflected beams combine together in beam splitter and produce the fringe pattern on the screen, which is captured by the HD camera.

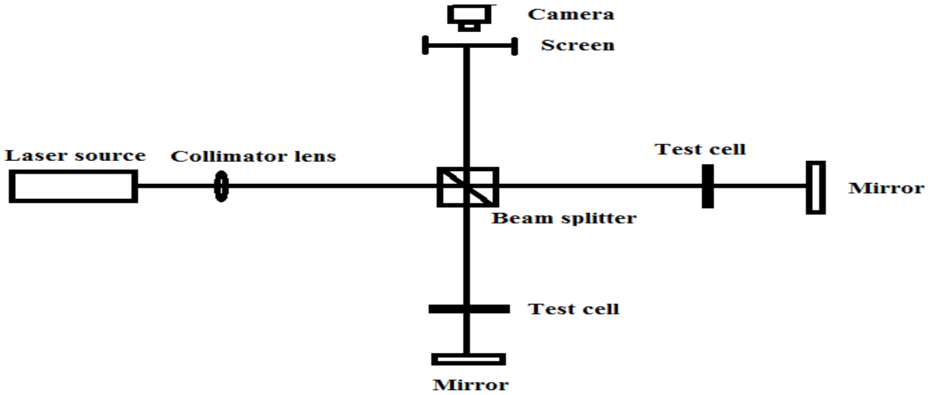


Fig. 1.Line diagram of Michelson-Interferometer

As the experimental set up shown in the Fig.2, carbon dioxide laser unit and an adapter were connected to the electric power socket. After switching on, the carbon dioxide laser beams were passed through a collimator lens which further increase the intensity of the beam and make it more precise. A beam splitter splits the beam into two parts namely transmitted beam and reflected beam. These beams hit the mirrors at the two extremes through lenses provided in between them. The returning beams are recombined and a converging lens is provided. A light filtering arrangement is provided for adjusting the brightness to make it easier for image to be captured on a camera at a better quality. A laptop was provided to operate the camera remotely since manual operation of the camera can lead to small miss-alignment of same pixels in consequent pictures taken. The fringes are obtained by adjusting the course screws. It takes a very high time for adjusting both these screws as even a minute disturbance could lead to the distortion of the fringe pattern. The fans were switched off in the room which was closed to prevent the disturbances that affect the medium in order to obtain a clear fringe.

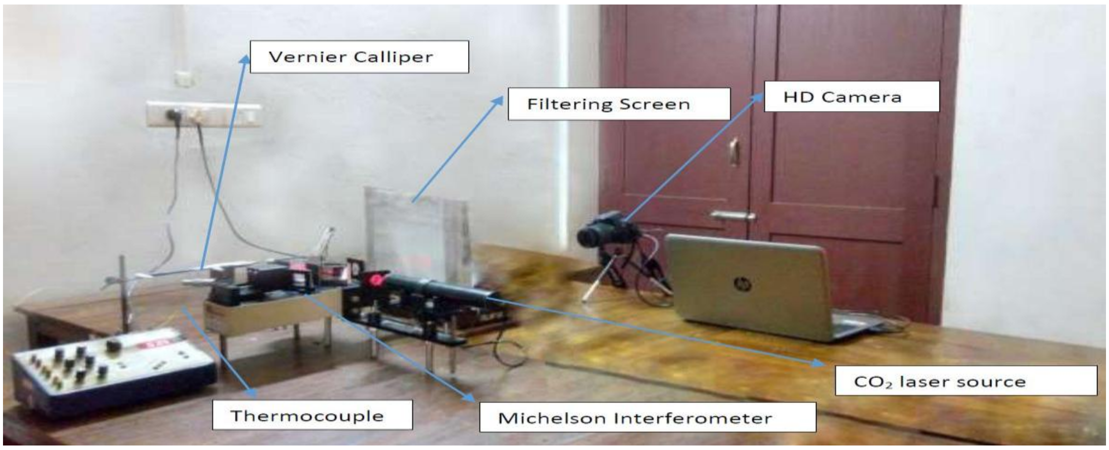


Fig.2. Experimental setup

The test cell is of rectangular cross section, with dimensions of 40mmx40mmx50mm with material used as glass. The heating plate is made using Nichrome wire of 9m length and 40gauge.Insulation is provided by giving mica coating. It is then covered using stainless steel. Maximum temperature of 300°C can be obtained at a power input of 100w and 220V. Heat dissipation into the fluid is provided by the use of a flat, uniform heating element attached to the wall of the test cell. The heating level is controlled using a variable transformer in the heater circuit. Zinc oxide is the Nano particle is used were mixed with base fluid water at 0.003% volume and were sonicated using ultrasonic mixer Sonix VCX 130 (20 kHz, 130 W) with amplitude of 123 µm for 32 minutes. This process was done in order to ensure uniform mixing of nanoparticles with water. Thus by this process ZnO nanoparticles were distributed whole throughout the water medium.

In this measurement method, it is required to find the temperature of a reference fringe in the fluid, in order to calculate the temperature distribution of the fluid. Thus, a K-type thermocouple is kept at a measured distance from the fin surface. Initial (without heating) and final (with heating) fringe patterns are captured by the camera and analyzed by digital image processing techniques. Intensity profile is obtained by processing the image using MATLAB software. The only phase lag introduced between the test and reference beams is due to the effect of heat dissipation from the test cell, and upon interference, the fringe patterns can be analyzed to obtain the temperature distribution of the fluid in the test cell. Initially for measuring the accuracy of experimental setup water is used as the working fluid. The obtained results such as heat flux, convective heat transfer coefficient and Nusselt number giving a fine agreement with actual values.

## III.RESULT AND DISCUSSION

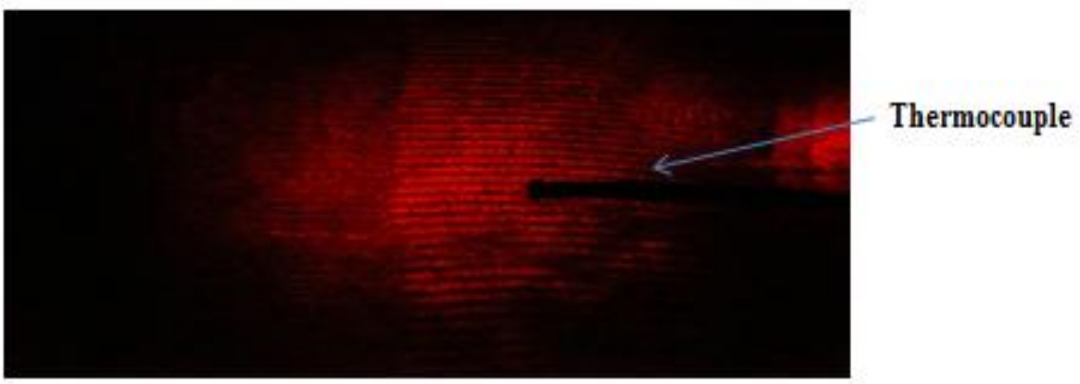


Fig.3. Initial fringe pattern of Nano fluid (without heat dissipation)

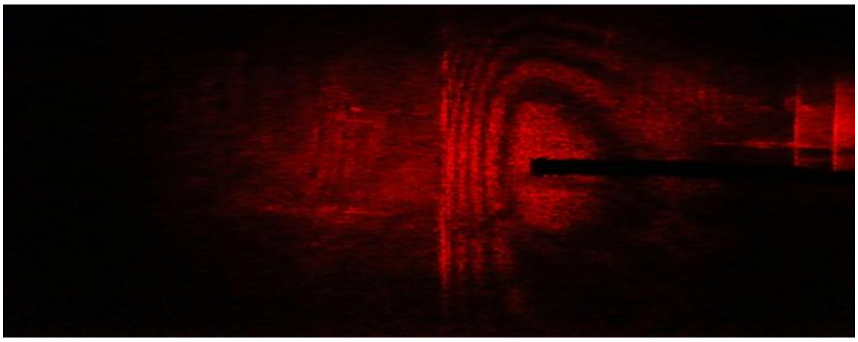

Fig.4. Deformed fringe pattern (with heat dissipation)

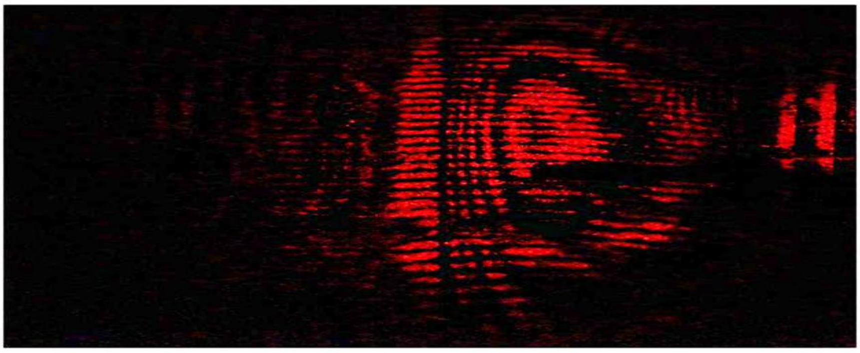

Fig.5. Digitally subtracted image

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When heat is dissipated from the heatingplate, the fringes near to it get dislocated. Fringe spacing changes due to the density variation of fluid. The refractive index of a medium depends on the density of the medium. Initial (without heat dissipation) and deformed fringes (with heat dissipation) are obtained. The initial and deformed fringe images captured with and without heat dissipation are shown in Fig.3 and Fig.4 respectively. Isotherms or Moire fringes are obtained by digitally subtracting the initial parallel fringe from the deformed fringe pattern. The narrow dark bands among them are called isotherms since they are constant temperature regions. The isotherms around the vertical fin and the position of the thermocouple are shown in the Fig.5. The intensity profile of the resultant image is measured over the distance between isothermal vertical fin surface and the thermocouple by digital image processing using MATLAB. The intensity profile plotted between surface of the fin and thermocouple is shown in Fig.6. By analysing this intensity plot neglecting its sharp fluctuations, it can be seen that the crests represent the high light intensities and the troughs the dark isotherms. Length of one pixel is determined by dividing the known distance between the fin and the thermocouple by the pixel count between the two.

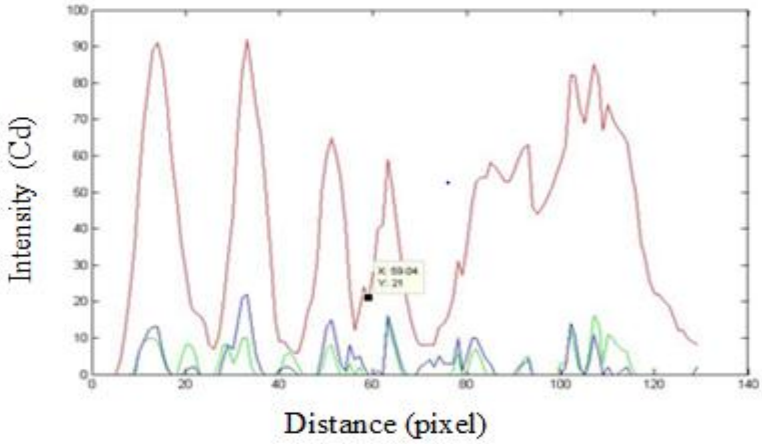


Fig.6. Intensity profile between thermocouple and heater plate

Density variation of Nano fluid with temperature is plotted and a polynomial is fitted as shown in Eq. (1). This polynomial is used to find the isotherm temperatures using Lorentz-Lorenz equation.

$$y = 0.0008x^2 - 0.6611x + 1121.9 \quad (1)$$

$$\frac{0.0008T_r^2 - 0.6611T_r + 1121.9}{0.0008T^2 - 0.6611T + 1121.9} = \frac{1}{1-as} \quad (2)$$

$$a = \left(\frac{n+1}{n^2+1}\right)\left(\frac{\lambda}{CL}\right)\left(\frac{1}{0.0008T_r^2 - 0.6611T_r + 1121.9}\right) \quad (3)$$

**Refractive index, n = 1.33, Wave length of laser, λ = 0.000000632 meter, Gladstone Dale constant, C= 0.00033,Length of test cell, L = 0.04 m, s = isotherm number**

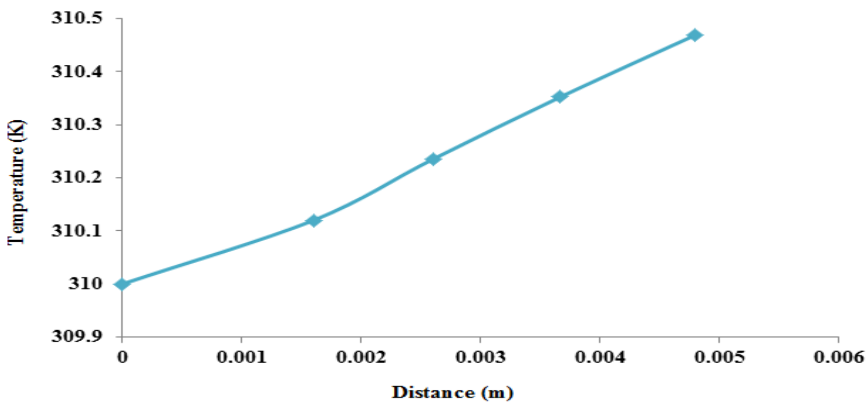


Fig.7. Temperature distribution along the distance from reference point to heater plate

By counting the number of pixels from the thermocouple to each isotherm its distance (in mm) from the thermocouple can be calculated using the length of a pixel determined earlier. The temperature of each isotherm from the heating plate is determined by the stepping process. Fig.7 shows the temperature distribution of Nano fluids. Temperature increases from the thermocouple position (Reference point) to the surface of the heater plate.

The heat flux, heat transfer coefficient and Nusselt number at different sections can be obtained as follows:

$$T_{avg} = \frac{\sum T\,dx}{\text{final pixel value}} \quad (4)$$

$$\Delta T = T_{\text{final isotherm}} - T_{avg} \quad (5)$$

$$q = k\left(\frac{dT}{dX}\right) \quad (6)$$

$$h = \frac{k\left(\frac{dT}{dX}\right)}{\Delta T} \quad (7)$$

## IV. CONCLUSION

A simple Michelson Interferometry has been aligned to study the heat transfer properties of 0.003% ZnO based Nano fluids. A single thermocouple for measurement of the temperature at a point far from the heat source is the only essential requirement. Thus, the non-intrusive temperature measurement is made possible without disturbing the medium. The deformed interference pattern containing the data regarding the heat distribution is captured as an image. This is analysed on MATLAB to obtain an intensity plot and a resultant image shows the positions of isotherms. Lorenz-Lorentz relation is used to determine the temperatures at these isotherms. Positions of the isotherms are determined using data cursor on MATLAB. From the temperature and position, temperature plots are drawn. The temperature of any point between reference and heat source can be determined using the temperature plot. These temperatures are used to find heat transfer properties. This measurement technique can be used to measure the heat dissipation of any heat exchanging device without the measuring instruments disturbing the surrounding medium.

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