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Nano Fluid Detection for HPHE System Using Different Lasers

Aysar A. Alamery **Hussein A. Jawad** and **Zainab F. Mahdi**

Institute of Laser for Postgraduate Studies, University of Baghdad, Baghdad, Iraq

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Abstract: Among the different passive techniques heat pipe heat exchanger (HPHE) seems to be the most effective one for energy saving in heating ventilation and air conditioning system (HVAC). The applications for nanofluids with high conductivity are favorable to increase the thermal performance in HPHE. Even though the nanofluid has the higher heat conduction coefficient that dispels more heat theoretically but the higher concentration will make clustering .Clustering is a problem that must be solved before nanofluids can be considered for long-term practical uses. Results showed that the maximum value of relative power is 0.13 mW at nanofluid compared with other concentrations due to the low density of nanofluid at this concentration. For higher concentration, the agglomeration can occur so the scattering of laser light was increased resulting in the decrement of output power. Laser with longer wavelength (650nm) at visible spectral region was more sensing compared with 532 nm laser for low concentration of Ag inside deionized water. The starting sensing powers of 532nm CW diode laser is 0.1W of these concentrations for this type of nanofluid while the ending detection power is 1W.

Introduction

Recent reports highlight the usage of HPHE for energy saving purposes [1]. Heat exchange devices undergo a serious limitation due to the relatively low thermal conductivity of conventional fluids [2]. Dispersion of highly conductive solid nanoparticles within the base fluid is a good way to enhance liquid thermal conductivity[3]. The idea of utilizing nanoparticles within the working fluid of a heat pipe has become a subject of interest in recent years. Using gold and silver nanofluid in a heat pipe increases thier thermal performance. Similar experiments were done using nanofluid in heat pipes and thermosyphons (Tsai et al.2004; Kang et al.2006; Naphon et al.2008, 2009; Noie et al. 2009; Kang et al. 2009)[4].Yu-Tang Chen 2010 investigated the effect of nanofluid on FHP thermal performance. Gabriela et al. 2011 [5] measured the temperature distribution and compared the heat transfer rate of the thermosyphon heat pipe with nanofluid and with deionized-water. S. ZeinaliHeriset al. 2012 investigated experimentally the efficiency of two-phase closed thermosyphon (TPCT) with nanofluid as working fluid under magnetic field effect. They found that thermal efficiency in the presence of magnetic field somewhat increases [6]. E. Firou far et al., 2012, studied attempts to use the methanol–silver nanofluid filled heatpipe heat exchanger and compare the effectiveness as well as the energy saving with pure methanol under steady-state conditions. Clustering is still a major problem in nanofluids even though the occurrence of agglomeration has decreased. To prevent the particles from clustering several methods are currently used, but in the long run, it is inevitable. Clustering is a problem that must be solved before nanofluids can be considered for long-term practical uses. Although the increase in thermal conductivity would increase the efficiency of the systems where nanofluids are used, the life of the system may be decreased over time if particles begin to form clusters [7]. To overcome this problem and elongate the life of the system, laser detection was used to determine the variation of concentration within the operation of the system so that the loss concentration could be compensated. Laser diode is used because of its benefits of low cost nondestructive test and it can be operated during the operation of the system.

Experimental set-up

HPHE was home built. The copper and aluminum were chosen as a raw materials of pipes and fins respectively in manufacturing HPHE as standard materials for this application [8]. To allow laser light to pass through working nanofluid from one side and is being received at the other side, pipe with two glass transparent windows were connected in the evaporator section where the evaporation process occurred. These windows are insoluble for water and acids. Fig (1: A, B) show the windows and their location with HPHE.

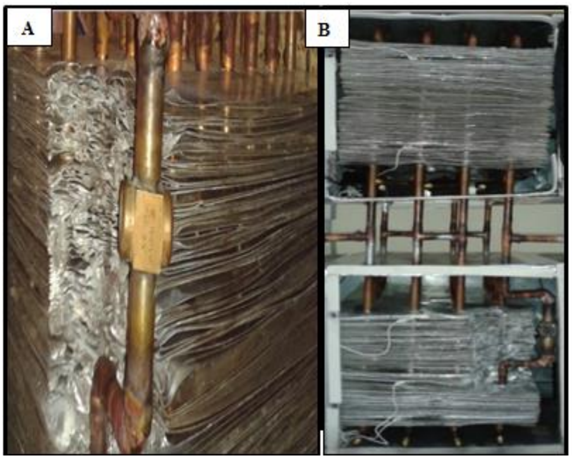

Fig (1: A, B): HPHE with windows.(A) Side view of connecting windows with HPHE, (B) HPHE contains windows in the evaporator section.

A Test rig was implemented. It consists of a removable 8-row HPHE, interconnecting duct work, and a fixed variable speed fan with a fixed CWC as shown in Fig (2).

Fig (2): complete test rig of thermosyphon heat pipe heat exchanger. 1. Heat pipe heat exchanger (HPHE)a. Evaporator section b. Adiabatic section, c. Condenser section,2. U Duct,3. Fixed variable speedFan,4. Rotated plate,5. Air filter,6. Air heater,7. Chilled water coil system(CWC),8.Digital anemometer,9.Terminator, 10.Thermometer, 11. Diode laser with wavelength 532nm, 3W power,12 .Diode laser with wavelength 650nm, 0.13W power, 13.Detector .

Working the nanofluid at 45% filling ratio was investigated with a concentration of (0.05, 0.2, 0.6 and 1) wt%.of silver nanoparticles. De-Ionic water and four wt.% of nanofluid were tested using UV-VIS spectrophotometer model (SP3000, Optima, Japan) for measuring the transmission with wavelength range(190-1100)nm. The nanofluid showed high transparency from 490nm to 1091nm wavelength range as shown in Fig (3).

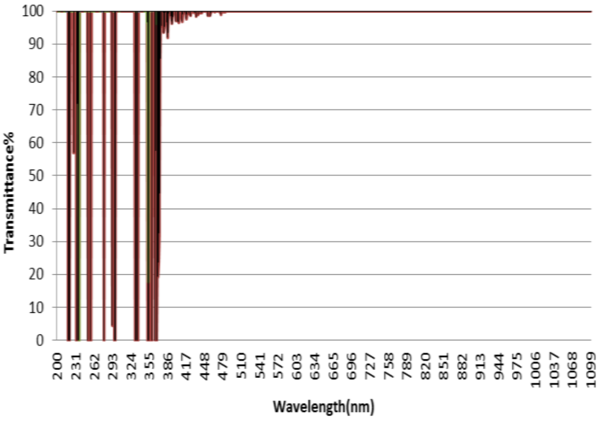

Fig (3): UV-VIS transmission spectrum of Ag/D.I. water nanofluid.

Testing and measuring devices

PHE was evacuated from air by using VALUE 1 stage vacuum pump model VE115N, free air displacement 2CFM, 230V, 50-60 Hz

,1/4HP and ultimate vacuum 150 micron with PM High- Low pressure gage. After the evacuation of the HPHE, 532nm diode Laser of 3W power and a detector with a broad band power/energy meter Melles Griot company and calibrated range of 400-2000 nm were used to measure the losses of windows cell. HPHE was charged from the opposite side of evacuation side with working fluid. After the steady-state condition of operation, (532,650) nm diode lasers at different powers were used.

Results and Discussion

The output relative power as a function of the input power at 0.05wt.% concentration of nanofluid for two diode lasers wavelengths (532,650)nm is shown in Fig(4). The scattering pattern will change with the change of particle size for wavelength (D/λ>1, D/λ <1 and D/λ =1) where D is the diameter of the particle and λ is the wavelength of the laser used .

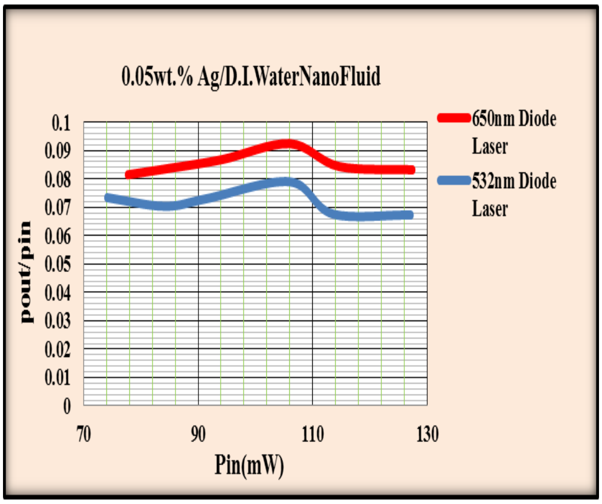

Fig (4): Relation between the relative power of (532,650)nm CW diode laser with input power.

The ratio of D/λ for 650nm diode laser is smaller than D/λ for 532nm diode lasers at the same diameter of the nanoparticle. This represents an additional reduction in the particle size. The behavior of the output power for two lasers is shown in Fig (4). Based on this result longer laser wavelength at visible spectral region was more sensing for low concentration of nanoparticle if the water is the base fluid. The output relative power for different concentrations as a function of input power for 532nm diode laser are detected in Fig (5: a, b, c,d).

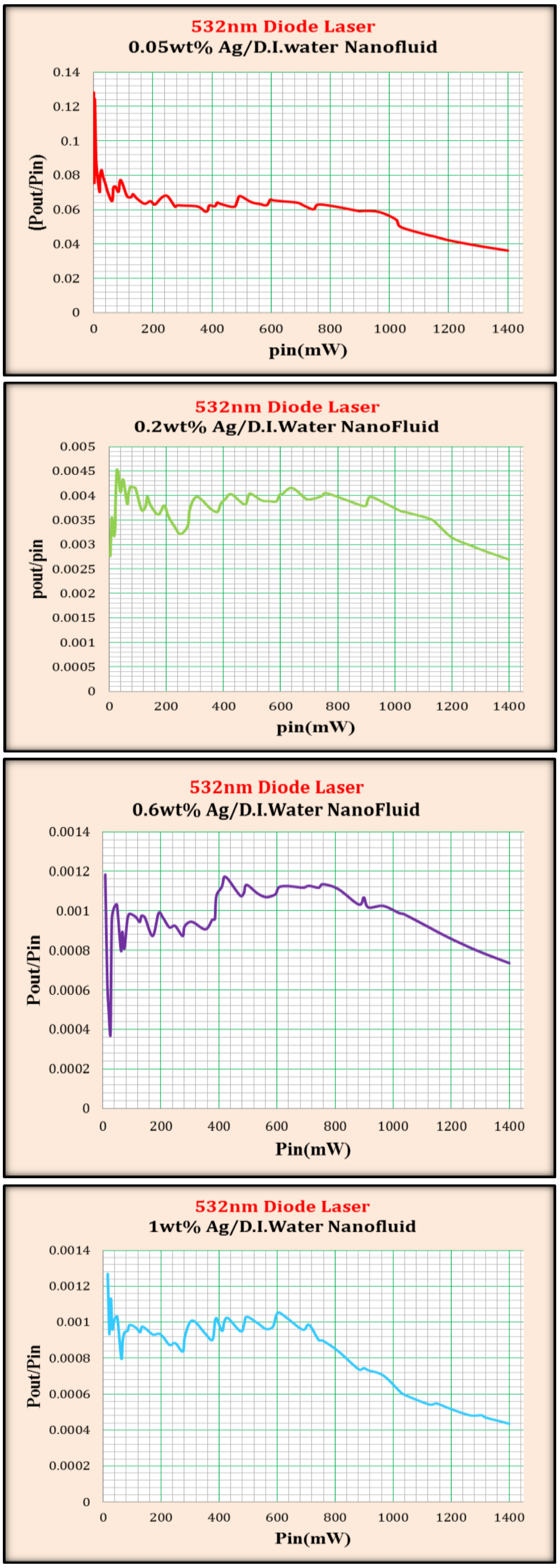

Fig (5:a,b,c,d): Relative powers of 532nm CW diode laser vs. input power with different Ag/D.I. water nanofluid concentrations. a-0.05wt.%silver water nanofluid,b- 0.2wt.% silver water nanofluid, c-0.6wt.%silver water nanofluid, d- 1wt.% silver water nanofluid.

These curves gave a clear indication that the laser is a good sensor for low concentrations of nanofluid when a relative output power of laser reduces from the path of these curves, the concentration of that nanofluid decreases so that the compensation of particles in nanofluid should be required. The relative power at different concentrations of Ag inside D.I water as a function of input power of 532nm CW diode laser is presented in Fig (6). The maximum value of relative power of 0.05wt.% nanofluid concentration is detected compared with the other concentrations due to the low density of nanofluid concentrations. For higher concentration, the agglomeration could be occurred so the scattering of laser light was increased resulting in a decrease of output power. If a particle is not small compared to the wavelength of laser (D/λ >1) when the agglomeration occurred with high concentrations, the light scattered from different parts of the particles cluster .Light scattering from different parts of these particles will not reach the detector due to the traveling in different paths [9].The difference in path lengths can lead to destructive interference that reduces the intensity of the scattered light.

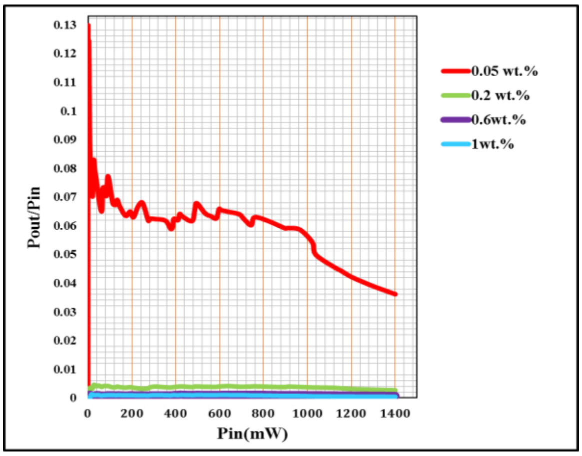

Fig. (6): Relationship between the relative output powers of 532nm CW diode laser with concentrations.

The amount of intensity reduction or the amount of destructive interference depends on the scattering angle (θ). At θ equals to zero, the path lengths will always be identical; accordingly, there will be no destructive interference. At non-zero angle destructive interference occur. Fig (7) shows the start sensing powers of 532nm CW diode laser with different Ag/D.I. water nanofluid concentrations.

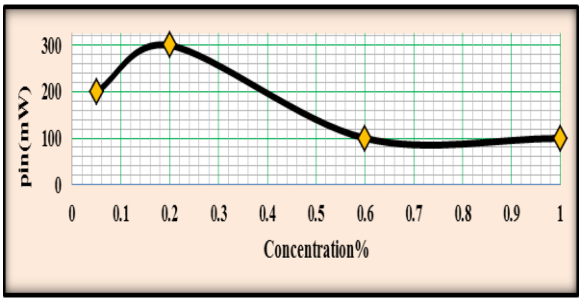

Fig (7): start sensing powers of 532nm CW diode laser with different Ag/D.I. water nanofluid concentrations.

The useful CW laser with minimum power is 0.1W for these concentrations for this type of nanofluid. Fig (8) shows the ending detection power of 532nm CW diode laser with different concentrations of Ag inside deionized-water. The useful CW laser with maximum power is 1W for these concentrations for this type of nanofluid.

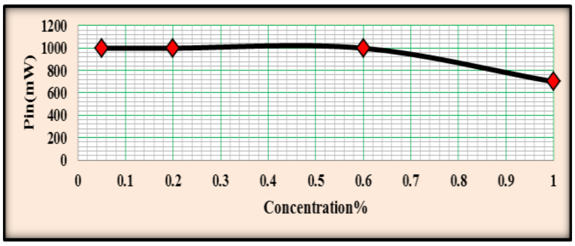

Fig (8): ending detection powers of 532nm CW diode laser with different Ag/D.I. water nanofluid concentrations.

Conclusion

The maximum value of relative powers of 0.05wt.% nanofluid concentration is detected compared with the other concentrations due to the low density of nanofluid concentrations. For higher concentration, the agglomeration will be occurred so the scattering of laser light is increased resulting in the decrement of output power.

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كشف المائع النانوي في منظومة المبادل الحراري ذي الأنبوب الحراري بأستخدام الليزر

أيسر عبد الرزاق حسين علي جواد زينب فاضل مهدي

معهد الليزر للدراسات العليا ، جامعة بغداد، بغداد ، العراق

الخلاصة: من بين مختلف التقنيات الخاملة، يعد المبادل الحراري ذو الأنبوب الحراري هو الأكثر فعالية لتوفير الطاقة في منظومات التدفئة والتهوية والتكييف. أن تطبيقات الموائع النانويه ذات التوصيلية الحرارية العالية مفضلة لزيادة الأداء الحراري للمبادل الحراري ذو الأنبوب الحراري.رغم امتلاك السائل النانوي لمعامل توصيل حراري عالي نظرياً لكن التراكيز العالية تسبب التكتلات العقديه.العقد هي مشكله يجب ان تحل للتمكن من الأستخدام البعيد الأمد للمائع النانوي. للتغلب عمليا"على هذه المشكلة تم أستخدام ليزري الدايود المستمر (532,650) nm كوحدة كشف لحساب التغير في تركيز السائل النانوي أثناء تشغيل المنظومه. لقد بينت النتائج ان اقصى قيمه للطاقة النسبيه هي 0.13mW عند تركيز 0.05wt.% فضة في الماء المتأين مقارنة ببقية التراكيز لنفس السائل النانوي بسبب الكثافة القليله للسائل النانوي عند هذا التركيز. في التراكيز العالية يحصل تكتل وينجم عنه زيادة في تشتت ضوء الليزر مسبباً النقصان في القدرة الخارجه.الليزر ذو الطول الموجي الطويل في المنطقة المرئيه من الطيف كان أكثر تحسساً للتركيز القليل من الذرات النانويه.كانت طاقة ليزر 532nm لبداية التحسس 0.1W لهذه التراكيز ولهذا النوع من السائل النانوي بينما طاقة نهاية الكشف هي 1W.