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Experimental observation of the far field diffraction patterns of functionalization single and multi-walled carbon nanotubes using nonlinear diffraction technique

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Abstract

Nonlinear diffraction pattern can be induced by focusing CW laser into a thin quartzes cuvette containing nanofluid. The number of revealed pattern rings indicates to the nonlinear behavior of fluid. Here, the nonlinear refractive index of each of functionalized single wall carbon nanotube (F-SWCNTs) suspention and multi wall carbon nanotube (F-MWCNTs) suspention have been investigated experimentally .Each of CNTs suspention was at volume fraction of 13×10^{-5} and 6×10^{-5}. Moreover the laser source at wavelength of 473 nm was used. The results show that SWCNTs suspention possesses higher nonlinearty than other at the same volume fraction.

Key words
Nonlinear, nano-fluids, nonlinear diffraction.

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دراسة الصفات اللاخطية للأنابيب النانوية الكاربونية مفردة ومتعددة الجدران بأستخدام تقنية الحيود غير الخطي

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الخلاصة

يمكن تحفيز نمط الحيود اللاخطي بحصر ليزر موجه مستمرة خلال حاويه كوارتز تحتوي على مائع نانوي. ان عدد حلقات النمط المكتشفه يشير الى السلوك اللاخطي للمائع. هنا تم التحري عمليا لايجاد معامل الانكسار اللاخطي لمعلق الكاربون احادي الجدار الانبوبي المعامل ولمعلق الكاربون متعدد الجدران الانبوبي المعامل. كان الحجم الكسري لكلا النوعيه من معلق الكاربون الثانوي الانبوبي 6×10^{-5} و 13×10^{-5} بالاضافه الى ان المصدر الليزري المستخدم كان بطول موجي 473 نانومتر. اظهرت النتائج ان مائع الكاربون احادي الجدار الانبوبي المعامل يمتلك خاصيه لاخطيه اعلى من الاخر ولنفس الحجم الكسري، و في هذا العمل تم التحري عمليا لايجاد الخاصيه اللاخطيه للموائع الثانويه المتكونه من كاربون احادي الجدار انبوبي المعامل وكاربون متعدد الجدران انبوبي المعامل ومعلق في قواعد مائع بحجمين كسرين.

Introduction

Nonlinear optics has been a section of optics that was studied the interactions between the media and electromagnetic radiations [1, 2]. The interaction means, this issue respond in a non-linear way incident radiation fields. The nonlinear optical effects take much attention in the last decade because of their useful application in science and industry such as frequency conversion phase modulation, and multi absorption [2]. Therefore, the nonlinear pattern concentric rings can be detected as far field diffraction [3] when a Gaussian laser beam irradiates a thin slice of nanofluid [4-6]. This phenomenon had been revealed in many nonlinear materials like organic substance [7-9] nanofluids [9, 10], dye [11], graphene and CNTs [12]. The most application of nonlinear diffraction effects as optical power limiting, optical switching, and beam modulation [13, 14].

Experimental work

The experimental set up Figs.1 and 2 consist of Diode laser [model MBL-FN- 473 nm-299.1 mW-15050466] operates at wavelength of 437 nm, attenuter, power meda [Edmund Industrial Optics Barrington, NJ. Polarizing 24 mm Japan] lens with focal length of 7 cm, quartz cuvette (5 mm) containing nanofluids, CCD camera [model Beamage- CCD12, genetic-EO, Canada] and PC with a certain software. Moreover, the nanofluids consist of either functionalized single wall carbon nano tube F-SWCNT's or multi wall carbon nano tube F-MWCNT's suspended in DI water, or functionalized multi wall carbon nano tube (F-MWCNT's) suspended in DI water, also. Each of those suspensions was at volume fraction 13×10^{-5} of and 6×10^{-5} .

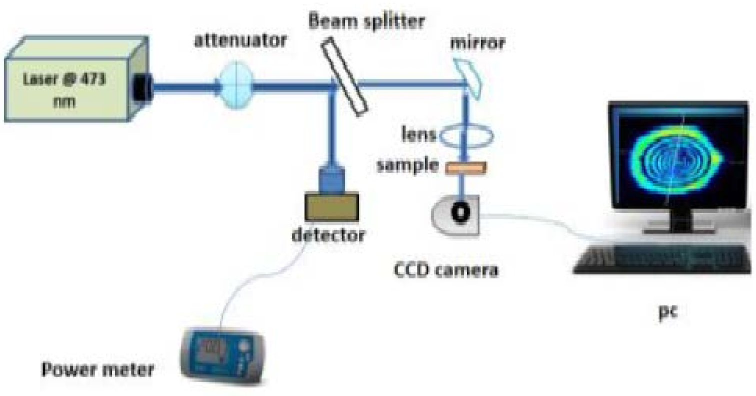

Fig.1: Graphical diagram of the experimental set-up.

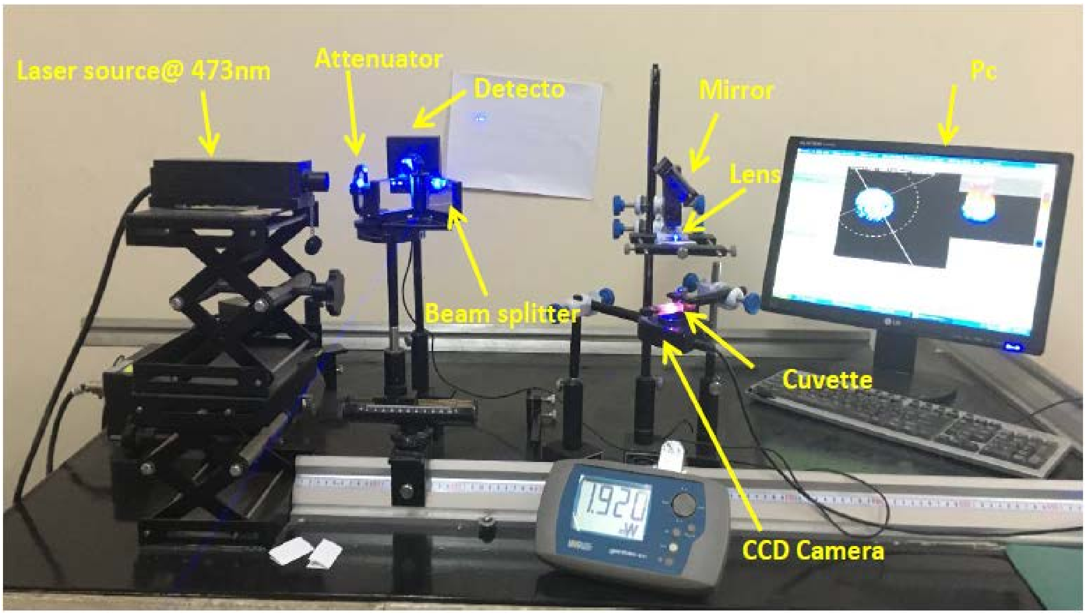

Fig.2: A photograph of the experimental setup.

Results and discusses

Absorption spectra of (F-SWCNTs) suspension at volume fraction $13x10^{-5}$ was about 405 nm checked by using UV–VIS spectrometer. The absorption peaks were detected at 415 nm as shows in Figs.3 and 4 show the absorption spectra to SWCNTs suspension at volume fraction ($6x10^{-5}$) was about 454 nm.

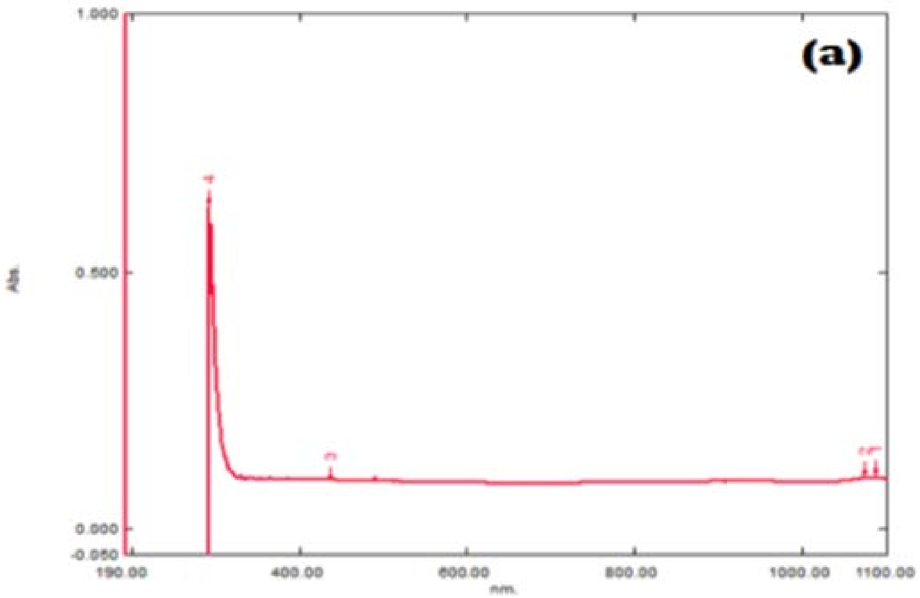

Fig.3: The UV–VIS absorption spectra of S-WCNTs DI water, suspension at volume fraction 13 x10^{-5}.

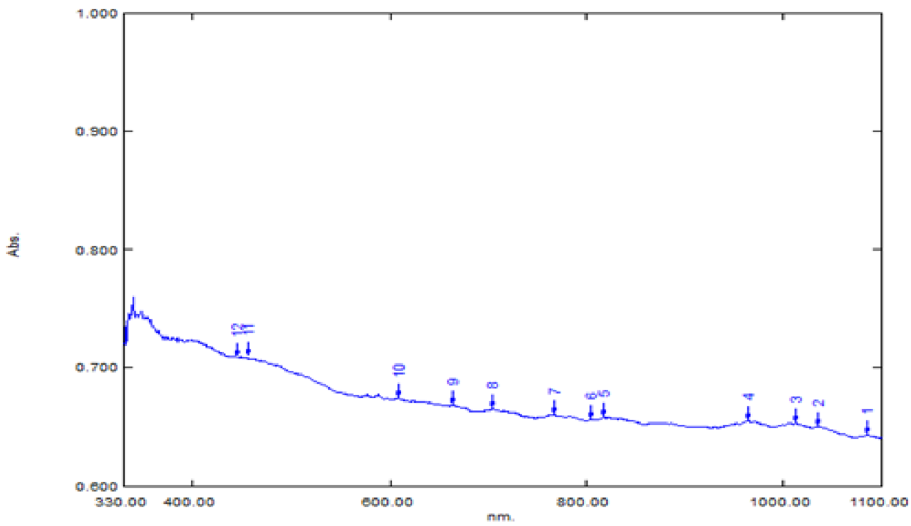

Fig.4: The UV–VIS absorption spectra of S-WCNTs DI water suspension at volume fraction 6x10^{-5}.

While Fig.5 shows that the peak of MWCNTs suspension at volume fraction $13x10^{-5}$ was about (405 nm). It can be concluded from all previous absorption spectrum of both of two suspensions that the laser source at 473 nm was suitable for all the process of this experiment, where the peak was around 485 at the volume fraction $6x10^{-5}$, as shows in Fig.6. For all the previous absorption peaks the laser source at wavelength 473 nm was suitable for the process.

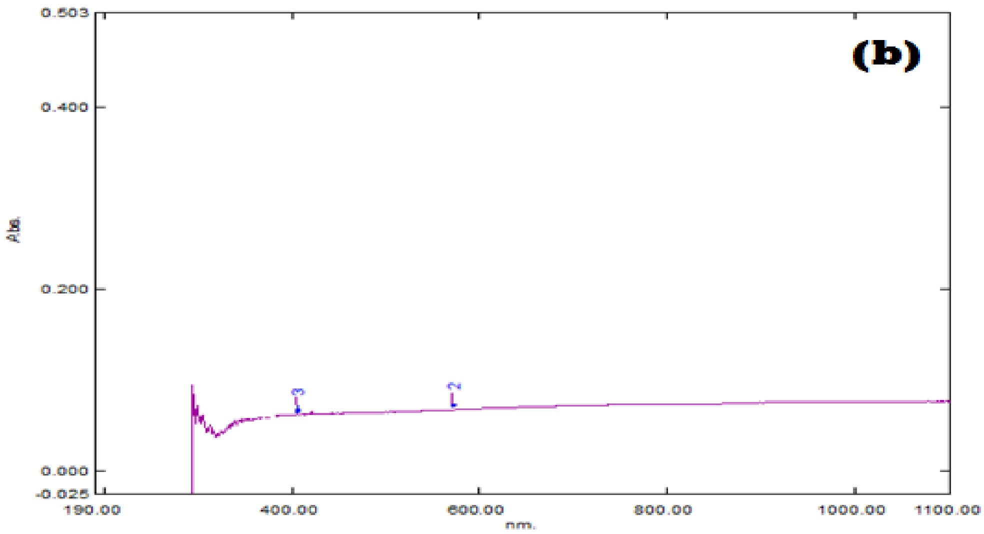

Fig.5: The UV–VIS absorption spectra of M-WCNTs DI water suspension at volume fraction 13 x10^{-5}.

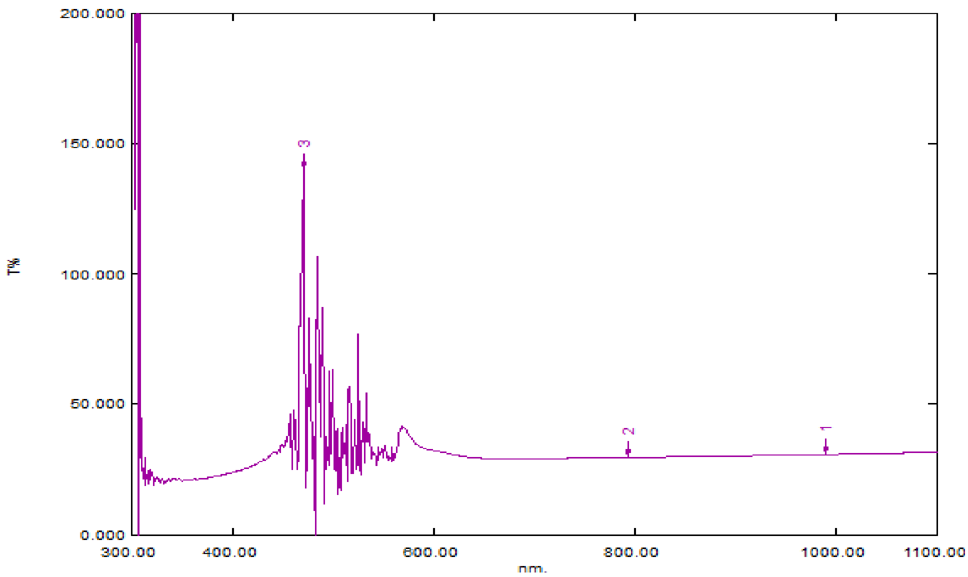

Fig.6: The UV–VIS absorption spectra of MWCNTs DI water Suspension at volume fraction 6 x10^{-5}.

Table 1 and 2 show that the nonlinear refractive index change Δn_{nl} has been increased for both F-SWCNT's and F-MWCNT's suspensions by increasing of their volume fraction using the same value of laser power density. This can be attributed to fact that increasing of suspension volume fraction means increasing its density and finally leads its nonlinear refractive index to be increased. Also it can be noticed that F-MWCNTs suspension possess higher nonlinear refractive index change then that of F-MWCNT's suspension at the same volume fraction (Table 1 and 2). The calculation of the maximum nonlinear refractive index change (Δn_{nl*max}) was from the following equation [15].

$$\Delta n_{nl,max} = \frac{\lambda_{beam}}{L_{material}} N_{rings} \quad \textbf{(1)}$$

where λ is the laser wavelength, λ and L $_{materials}$ are the cuvette thickness and N number of diffraction rings respectively, for each volume fraction value.

Figs. 7 and 8 show the relationship between the incident laser intensity and the maximum change the nonlinear refractive index of nanofluids in different volume fractions.

Table 1: The maximum change of nonlinear refractive index and their coinciding at two volume fraction in SWCNTs.

Laser intensity W/cm^2	***volume fraction* ×10^{-5}**	**Number of rings**	**Δnnl, max ×10^{-4}**
353.38	6	17	20.1
353.38	13	18	21.28

Table 2: The maximum change of nonlinear refractive index and their coinciding at two volume fraction in MWCNTs.

Laser intensity W/cm^2	***volume fraction* ×10^{-5}**	**Number of rings**	**Δnnl, max ×10^{-4}**
353.38	6	13	17.73
353.38	13	17	20.1

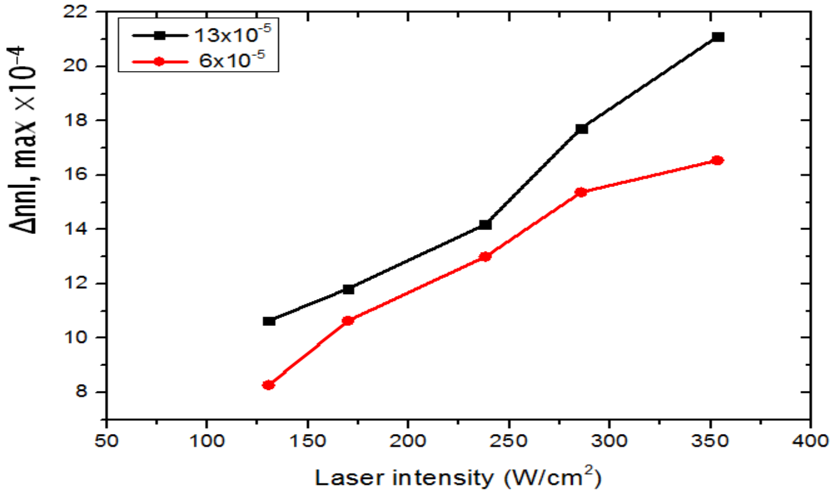

Fig.7: Maximum change of non-linear refractive index created using F-SWCNTs DI water by fraction different than (13 X10^{-5}), and (6 X10^{-5}) irradiated by laser intensity.

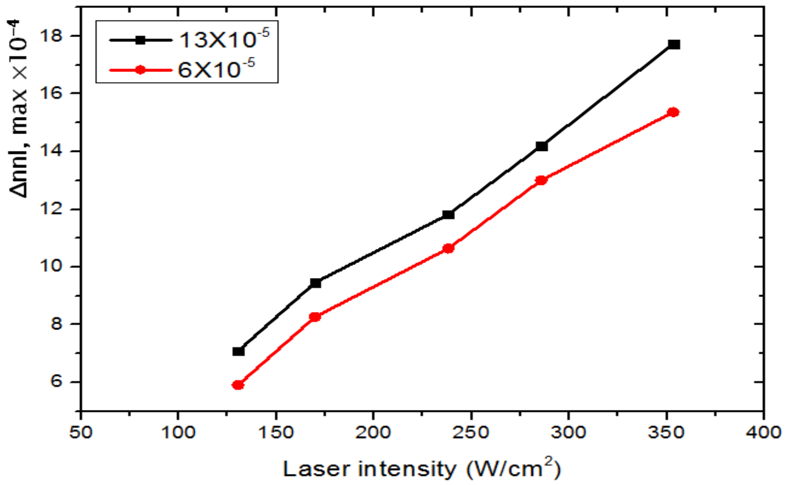

Fig.8: Maximum change of non-linear refractive index created using F- MWCNTs suspension in DI water of the volume fraction (13X10^{-5}), and (6 X10^{-5}) irradiated by laser intensity.

At high laser beam intensity and high volume fraction the maximum change of the nonlinear refractive index Δnnl, max will be increases as seen in previous table and figure.

Different density values were used to obtain different numbers of nonlinear pattern rings that lead to different values of nonlinear refractive indices and maximum change in previous Nano liquids, as shown in Figs. 9 and 10.

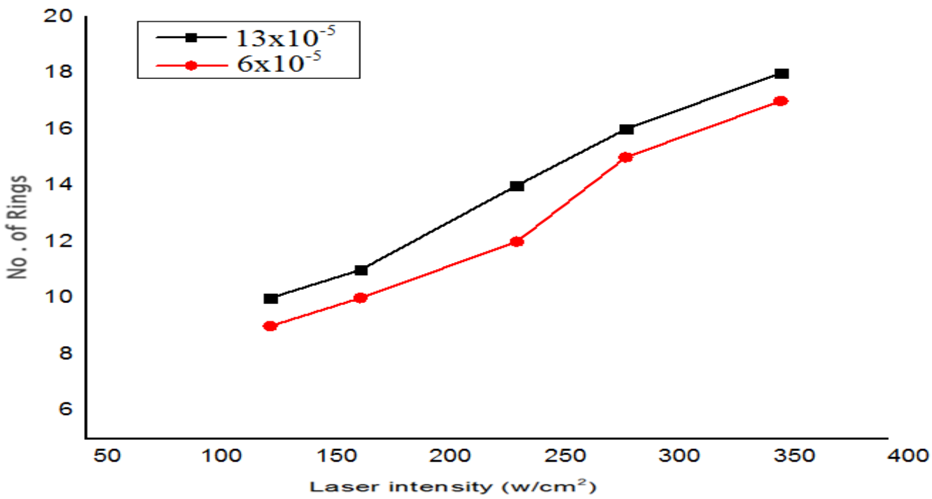

Fig.9: The diffraction rings from DI water (F-SWCNTs) suspension different laser densities at volume fraction13 × 10^{-5} and 6×10^{-5}.

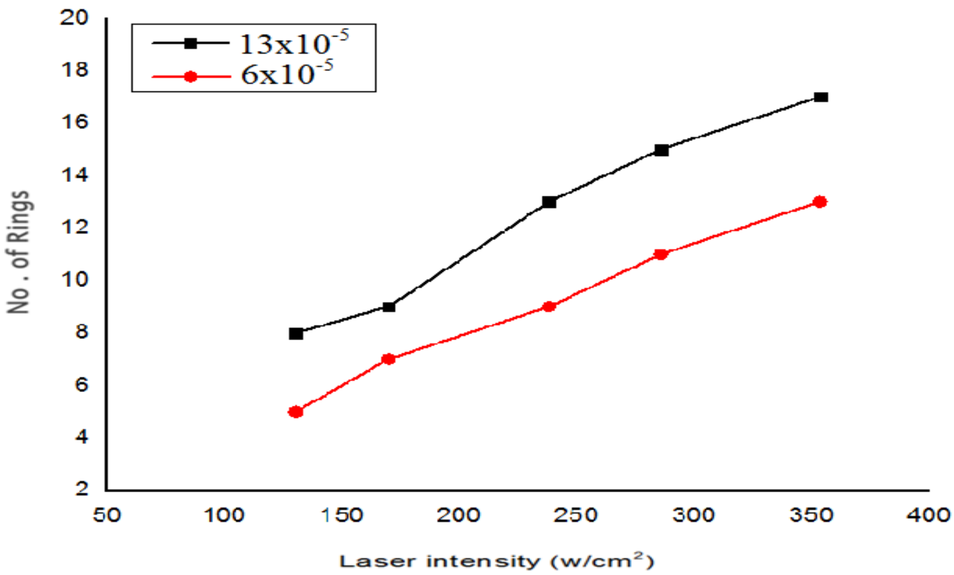

Fig.10: The diffraction rings of DI water (MWCNTs) suspension at different laser densities at volume fraction 13 × 10^{-5} and 6×10^{-5}.

The impact of nonlinear refractive index of the functionalization single and multi-wall Carbone nanotube at two volume fraction can be measured from the following equation [15]:

$$\Delta n = n2\ I \qquad (2)$$

It has been shown from the Figs.11 and 12 that the nonlinear refractive index increase with decreases lasers intensity according g to the Eq. (2), and increase with increased volume fraction

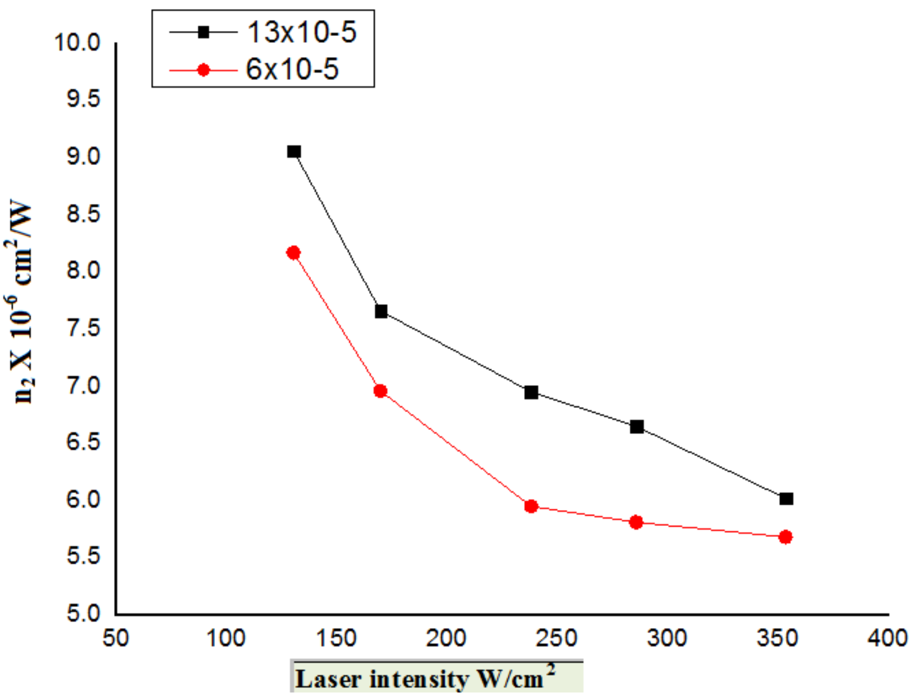

Fig.11: The non-linear refractive index produced at SWCNTs Nanoparticals DI water suspension at volume fractions of 13x10^{-5} and, 6x10^{-5} in different laser intensities.

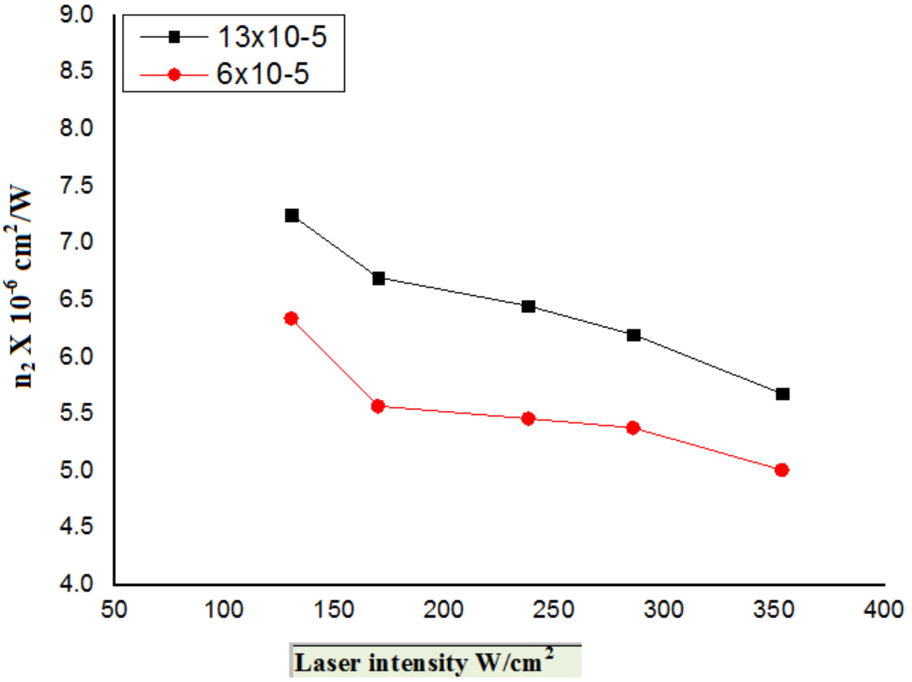

Fig.12: The non-linear refractive index of F-MWCNTs Nanoparticles DI water suspension at volume fraction of 13X10^{-5}, and 6X10^{-5} in different intensities.

Figs.13-16 show that the number of non–linear diffraction patterns detected by the CCD camera increases exponentially with increased fracture size and laser energy intensity according to the Eq. (1), the number of rings is proportional to the intensity of the laser.

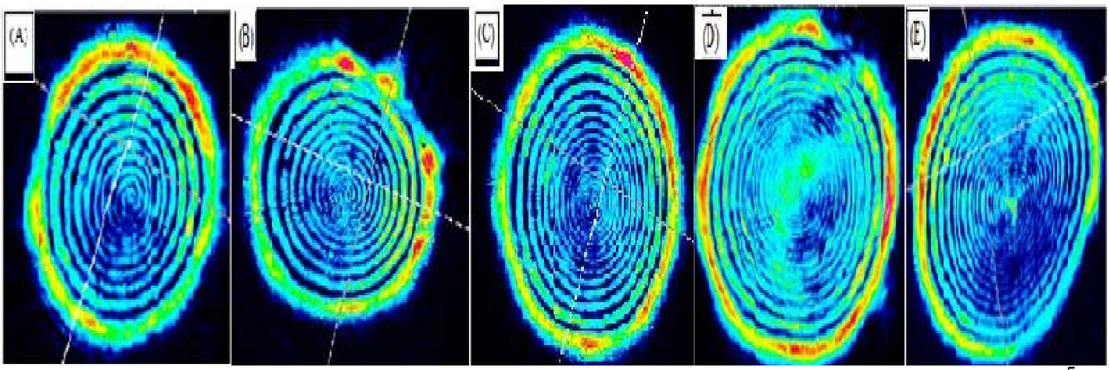

Fig.13: Non-linear diffraction pattern produced by SWCNTs at volume fraction 13x10^{-5} at laser intensity (A) 130.41, (B) 169.81, (C) 238.31, (D) 285.69, and (E) 353.38 W/cm^{2}.

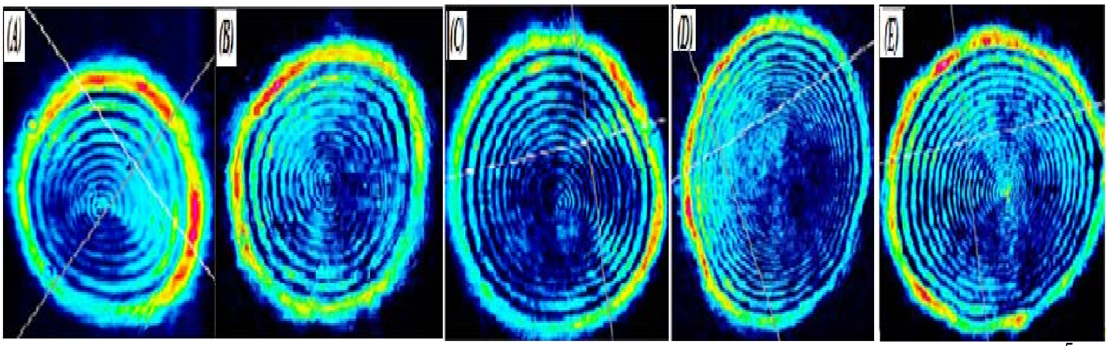

Fig.14: Non-linear diffraction pattern produced by SWCNTs at volume fraction 6x10^{-5} at laser intensity (A) 130.41, (B) 169.81, (C) 238.31, (D) 285.69, and (E) 353.38 W/cm^{2}.

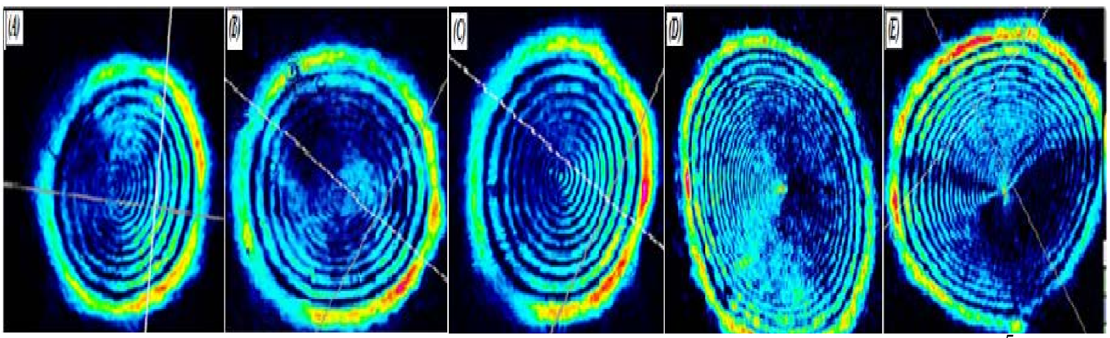

Fig.15: Non-linear diffraction produced by MWCNTs at volume fraction 13x10^{-5}at laser intensity: (A)130.41, (B) 169.81, (C) 238.31, (D) 285.69, and (E) 353.38 W/cm^{2}.

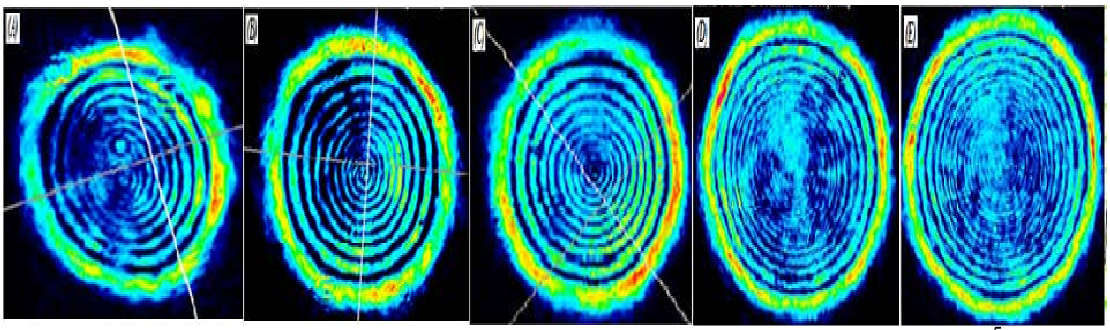

Fig.16: Non-linear diffraction produced by MWCNTs at volume fraction 6x10^{-5} at laser intensity: (A) 130.41, (B) 169.81, (C) 238.31, (D) 285.69, and (E) 353.38 W/cm^{2}.

Conclusions

From this experiment in short, were found that by increasing the intensities, the number of rings will be increased until they reach a specific number, after which they will remain constant even in increasing density. This leads to increasing the nonlinear refractive index change ($\Delta n_{nl,max}$) to both of (SWCNTs and MWCNTs) diffuse in DI water at two volume fraction. By determining the nonlinear parameters of the jaginocytes prepared in DI water. The results show that F-SWCNTs suspended fluid possess higher nonlinearity than other at each volume fraction. The material shows non-linear good grade III(third order non linearity), on the other hand the nonlinearity of the F-SWCNTs and F-MWCNTs at volume fraction $13x10^{-5}$ it was more efficiently than other and also it was noted that the minimum threshold of F-SWCNTs at all volume fraction was lower than F-MWCNTs.

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