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PLASMA PARAMETERS INDUCED BY LASER OF CADMIUM OXIDE

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Abstract: We have examined the optical emission spectra of the plasma created by cadmium oxide (CdO). Liquid (ethanol alcohol) by pulsed laser ablation in liquid media. PLA in the 200-600 nm range at the fundamental wavelength (1064 nm) Nd: YAG laser's wavelength. The Boltzmann diagram method and the extended Stark line coil, respectively, were used to extract plasma parameters such as electron temperature and electron number density. For temperature and selection, these lines at 313.316 nm, 326.363 nm, 340.365 nm, 346.62 nm, 361.050 nm, 467.814 nm, 470.991 nm, 508.582 nm, 588.582 nm, 609.914 nm are used to calculate the temperature, as well as choose the O.I. line 643.847 nm to calculate the electron density. Density number and electron temperature change were studied as a function of laser power.
The plasma frequency, Debye length, and Debye number were determined as the laser energy computed functions.

Keywords: Optical Emission Spectra, Plasma, Laser, Parameters

1. INTRODUCTION.

Laser plasmas, in particular, offer unique features not present in older types of plasma (e.g., densities characteristic of solids). An essential application of laser-plasma physics is inertial confinement fusion, also known as inertial confinement fusion. In this process, high-energy laser beams are concentrated on a small solid target and blasted at it until the densities and temperatures necessary for nuclear fusion are reached. Another use of laser-plasma physics is in particle accelerators, which accelerate particles by passing a high-intensity laser pulse through plasma., generating powerful electric fields. High-energy physicists use plasma acceleration techniques to reduce particle accelerators' size and expense [1]. Laser-induced plasmas (LIPs) have recently become quite helpful as spectroscopic sources. LIPs' optical emission spectroscopy (OES), also known as a powerful method for analyzing how laser beams interact with materials, is known as laser-induced breakdown spectroscopy (LIBS), sometimes known as laser-induced plasma spectroscopy. Inertial restricted fusion, pulsed laser deposition of thin films, and analytical spectroscopy are just a few disciplines where LIPs and laser ablation have been used [2]. The target material is affected by an intense laser pulse. This method (LIPs) resulted in plasma creation at 1064 nm due to high-intensity plume propagation. The inverse bremsstrahlung (I.B.) absorption re-heats the early section of the plasma. [3,4]

The target material's chemical composition and ambient factors such as pressure, space, and time all influence the character of the solid target material produced by the laser-induced plasma [5,6]. The elemental analysis of material using laser-induced plasma spectroscopy (LIPS), often referred to as laser-induced breakdown spectroscopy, is based on the optical emission spectra from a laser-induced plasma (LIP) (LIBS).[6,7] The ionization temperature manages the ionization equilibrium, and the excitation temperature governing the distribution of energy level excitation via the Boltzmann equation should be equal to the electronic temperature characterizing the Maxwellian distribution of electron velocities under local thermodynamic equilibrium (LTE) conditions. As a result, in LTE, the plasma is described by a single temperature (T), referred to as the plasma temperature [9].

In this work, we used Cadmium oxide, one of the transparent conductive oxides with atomic number (48). It is a powder that varies in color from brown to almost red depending on the surrounding conditions. It has a central cubic crystal structure in which each atom is surrounded by six other atoms of opposite electric charge, as shown in Figure (1). CdO is an n-type semiconductor, and its optical energy gap is rather large and reaches (2.28 eV) [12,13]

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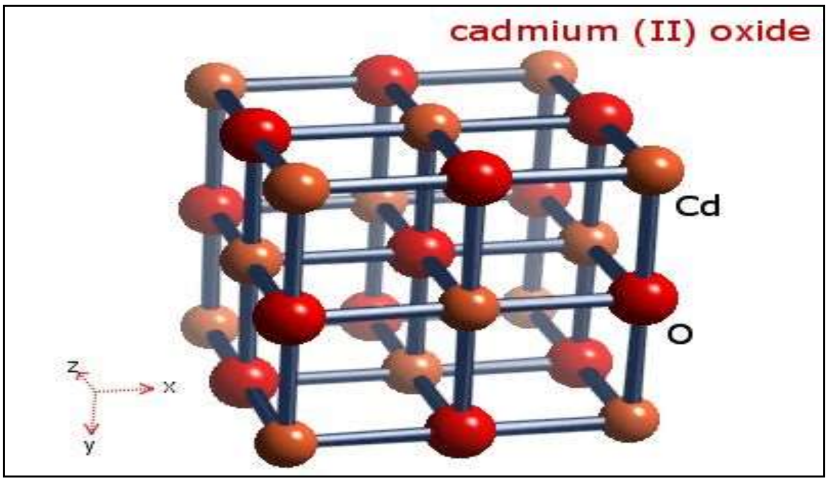

Figure (1) Crystal structure of cadmium oxide [13]

For LIP-based characterization, optical emission spectroscopy has recently received a lot of press. The most popular spectroscopic technique for calculating T is the Boltzmann plot method, which compares the integrated line intensities of two or more atomic lines. One of the diagnostic methods for determining plasma electron density in plasma spectroscopy is based on either the Saha-Boltzmann equation[10] or the Stark broadening of spectral lines. [10]
The elemental analysis and plasma properties, such as the electron number density and temperature, can be found in the emission spectra of the plume [9].

2. Experimental

In this experiment, the tablets were prepared from (pellets) of transparent conductive oxides, which are cadmium oxide (CdO), using equal molar quantities of high purity and pressed using a piston under a pressure of (5 ton) tons to produce targets in the form of high purity tablets 2.5 cm width 2.5 cm and thickness 1.2 cm. Figure (2) shows the plunger used in preparing the samples.

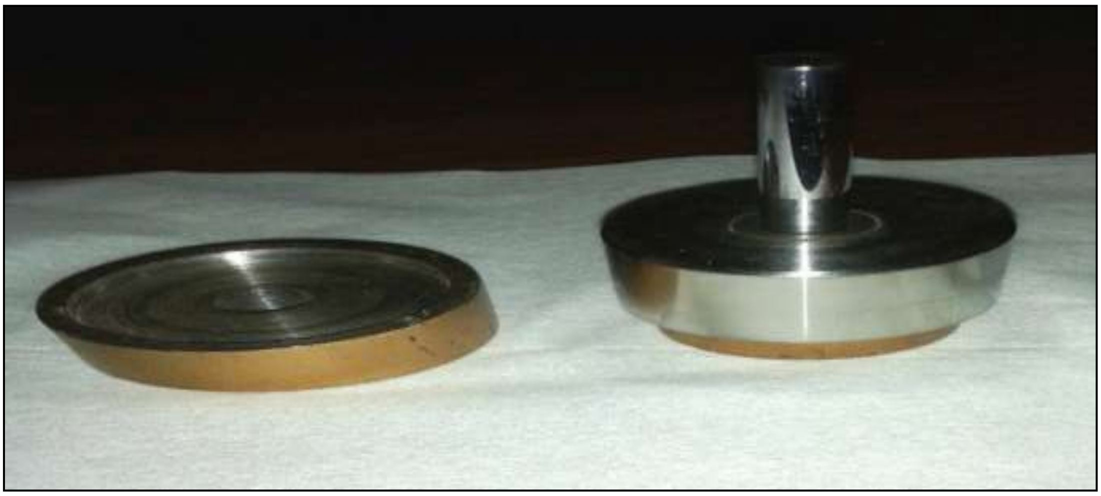

Figure (2) The plunger used to prepare the samples

And, In this experiment, we used Q-switching Nd: YAG laser Second Harmonic Generation (SHG) characterized by this specification: Laser wavelength (1064 -532 nm).Power density (J/cm2 1.8-0.8). and Frequency of repetition (6 Hz-1), Pulse time (10 ns)

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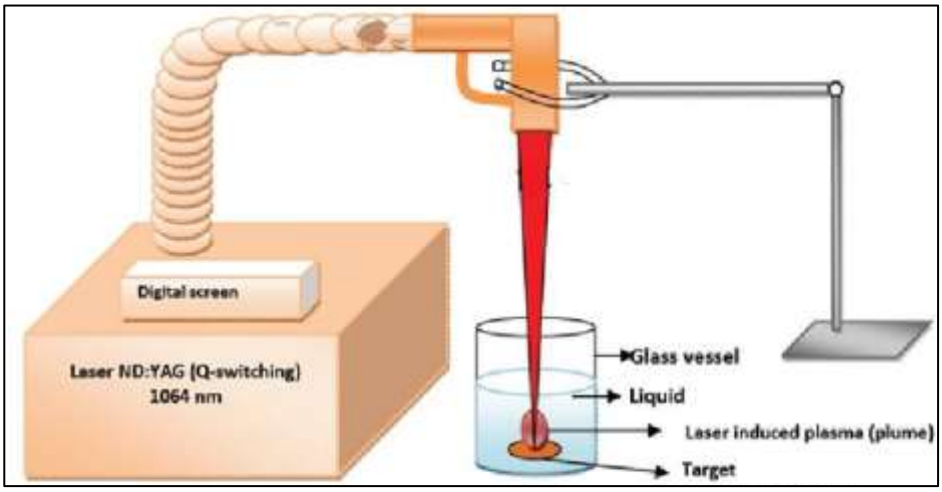

Figure (3) Experimental setup for pulsed laser ablation in liquid

In this experiment, a small glass flask was used as a cell. The solid target (cadmium oxide (CdO), was placed in a glass container filled with 3 ml of Ethanol (C_2H_5OH), where the depth of the solution on the sample was (3 ml) during laser ablation. A nano-solution of cadmium oxide was prepared using (PLAL) Pulsed laser ablation liquid) and the target (CdO) was immersed in a glass beaker containing alcohol Ethanol (C_2H_5OH). At a volume of liquid (3m) at room temperature, The laser beam A Q-switched Nd: YAG pulsed laser with pulse durations of 10 ns served as the source Whereas, nano solutions of the oxides used in this work are formed by focusing a laser pulse with a wavelength of 1064nm, several pulses of 1000, the energy of 200-400- 600mJ, and a beam diameter of 4 mm, on the oxide targets placed inside ethanol alcohol, thus producing nano-solutions. From those nano solutions of the oxides used to perform the plasma spectroscopy tests. Figure (4) shows pictures of the samples prepared by the laser.

(CdO)

Figure (4) Nano-solutions resulting from the laser ablation process of the materials used

At 1064 nm, Hertz energies range from 200 mJ to 600 mJ. The laser controller controlled the laser pulse power using a Q-switch delay of the flash bulb and measured by the power meter. The laser beam is focused at a 90-degree angle on the target, causing evaporation and ionization of the target substance, resulting in the development of a plasma column above the target's surface. The cadmium oxide sample is placed in a beaker containing ethanol alcohol. The

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optical emission spectroscopy (OES) technique is used to calculate electron temperatures and density, as well as the plasma frequency, using mathematics. The debye number's length and the debye in the space The OES of the plasma column created by a CdO target laser was recorded using a spectrophotometer to explore the ionic species present in plasma in greater detail (H.R. 4000CG-UV-NIR). To calculate OES, a Boltzmann and Stark-scaling plot was used

3. RESULTS AND DISCUSSION

Atoms and ions in various excited states, free electrons, and radiation make up the plasma generated by high-powered laser irradiation. The plasma temperature (Te) and free electron density measurement can be used to analyze this plasma (ne). The free electron density establishes the thermodynamic equilibrium state of the plasma, while the plasma temperature describes its condition. The plasma temperature and species density must be known to comprehend the atomic ionization and excitation processes inside the plasma.

1-Cadmium Oxide Target Plasma

Figure (5) illustrates the emission spectrum of ND: YAG laser-induced plasma formed at the surface of CdO at different laser energies of 200mJ, 400mJ, and 600mJ for a wavelength range of 740nm-320nm. The resulting peaks were compared with the theoretical values of the peaks of the atomic and ionic spectral lines taken from the source [11]. The research results show that when laser power increases, the strength of the ionic and nuclear spectrum peaks rises. And the intensity of the spectral peaks increases with increasing laser power. The reason is due to the increase in the number of spectral peaks in the emission spectrum with the increase in the laser power due to the increase in the ablation rate with the increase in the laser power, and it also shows the number of atomic spectral peaks of higher intensity compared to the ionic spectral peaks formed in the emission spectrum.

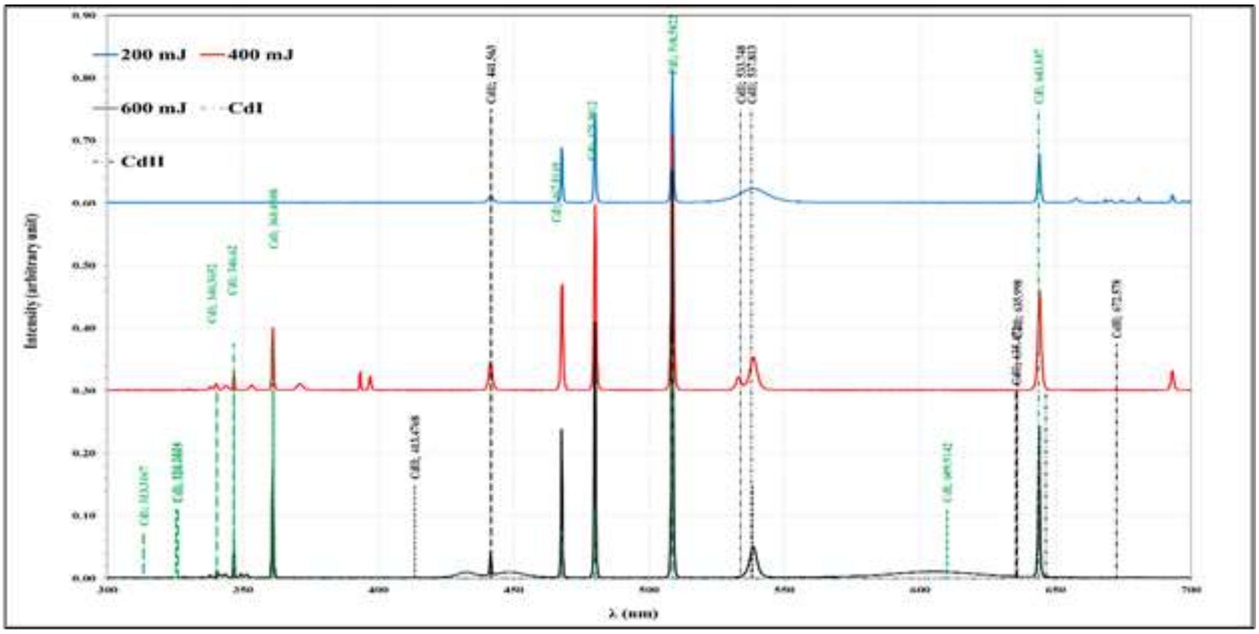

Figure (5) shows the spectrum of laser-induced plasma emissions on a CdO target at different laser energies (200, 400, and 600).

2-Electron temperature (Te)

The electron temperature (Te) values were obtained using the optical radiation spectroscopy technique, using the Boltzmann plot, and as shown in Figure (6) for the cadmium oxide sample at different laser energies (200,400,600) millijoules

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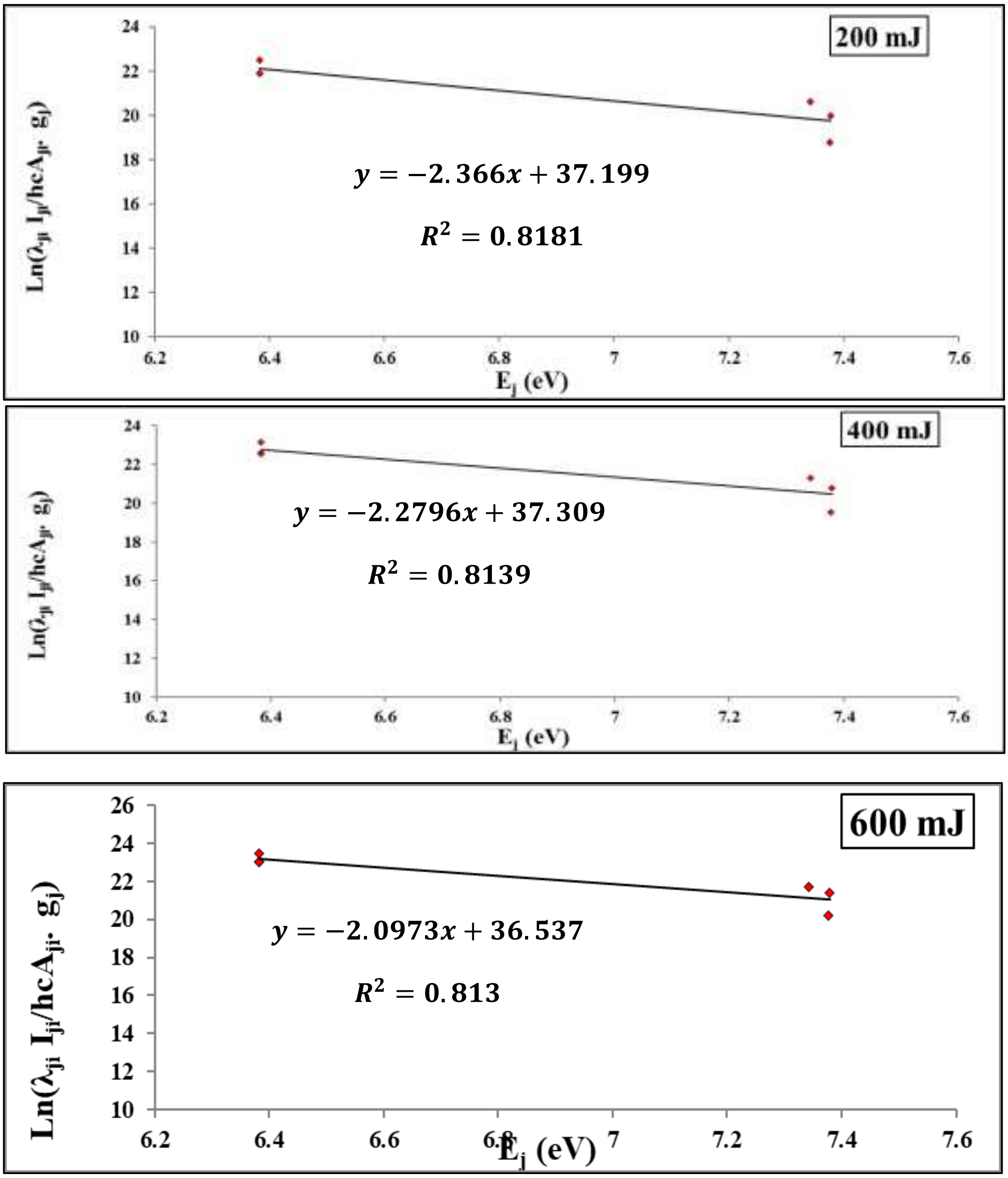

Figure (6): shows the Boltzmann distribution consisting of the analysis of six lines of cadmium monoxide at different laser energies (200, 400, 600) mJ

(CdI) was selected at wavelengths; (,347.354 644.79, 509.274, 480.469, 468.467, 361.757) nanometers. Te values were calculated from the inverse of the slope for the best linear value of the sum of the values. Fitting equations and mean R2 standard deviation values are displayed for all fitting lines as illustrated. The value of R2 ranges from 0.8181 to 0.813 of the ideal value 1. Table (1) shows the results of electron temperature using various laser intensities of cadmium oxide

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Table (1): Plasma parameters calculated from cadmium oxide spectral lines at different laser energies (200,400,600) mJ.

Laser energy	T_e (eV)	n_e*10^{17} (cm^{-3})	f_p (Hz) *10^{12}	λ_D *10^{-5}(cm)	N_d
200	0.423	29.71	15.478	0.280	274
400	0.439	72.97	24.257	0.181	183
600	0.477	114.66	30.408	0.151	165

We note from Table (1) that the calculated values for electron temperature (Te) from the Boltzmann diagram, electron density (ne) using Saha equation (1), Debye length (λD), plasma frequency (ωp) as well as the Debye number (N.D.) at various laser intensities. And that the plasma conditions satisfy all the estimated plasma parameters, including Debye length, Frequency, and number.

$$n_e = \frac{2(2\pi m_e k_B T_e)}{h^3}\frac{I^I_{mn}A_{ij}g^{II}_i}{I^{II}_{ij}A_{mn}g^I_m}e^{-\frac{E_{ion}+E^{II}_i+E^I_m}{k_B T_e}} \ldots\ldots(1)$$

3-Electron Density (Ne)

The electron density was calculated using Lorentzian curve fitting sing a suitable emission line's sharp expansion in the laser-plasma spectrum. The Lorentzian curve fitting at the line is depicted in Figures(7). (CdI) 441.52 nm and the change of the FWHM band using laser energy where the electron density was calculated using the relationship (2). Table (1) shows electron density results at different laser energies (200,400,600) mJ. Figure (8) shows the increase in both the electron density (ne) and the electron temperature (Te) when the laser pulse energy is increased.

$$n_e = \frac{2(2\pi m_e k_B T_e)}{h^3}\frac{I^I_{mn}A_{ij}g^{II}_i}{I^{II}_{ij}A_{mn}g^I_m}e^{-\frac{E_{ion}+E^{II}_i+E^I_m}{k_B T_e}} \ldots\ldots(2)$$

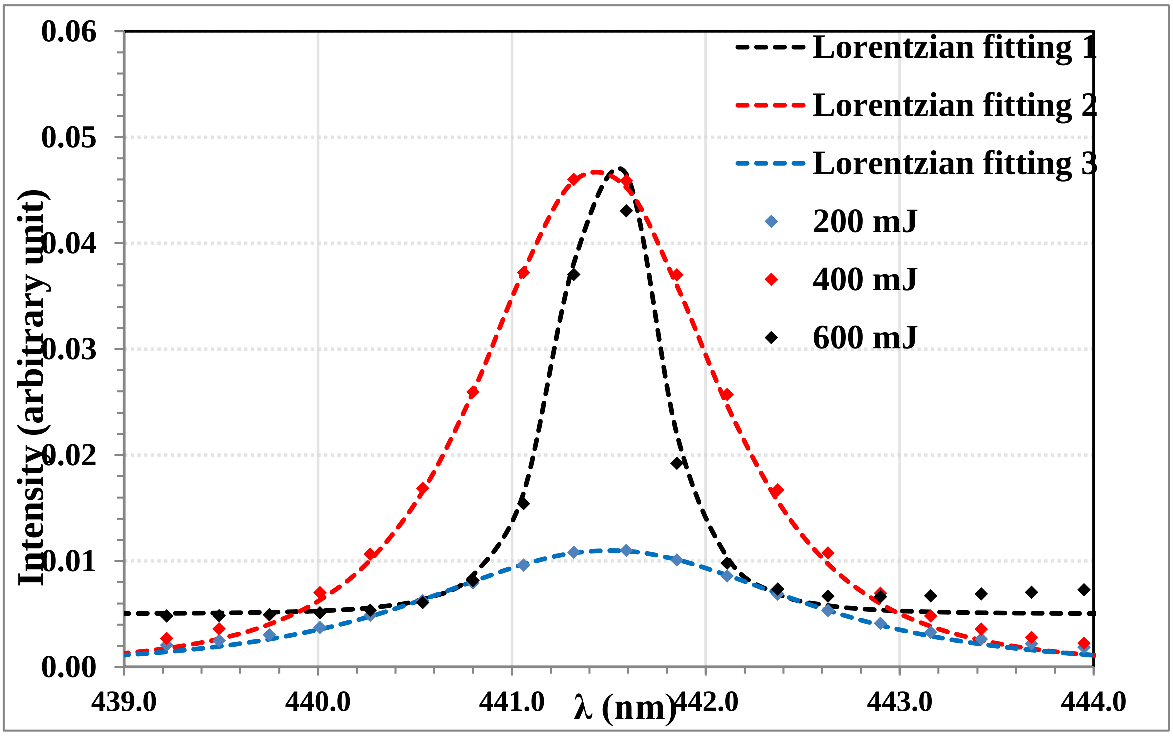

Figure (7): Composition of the Lorentzian curve at the line (CdI) 441.52 nm and its amplitude change with different laser energies (200,400,600) mJ

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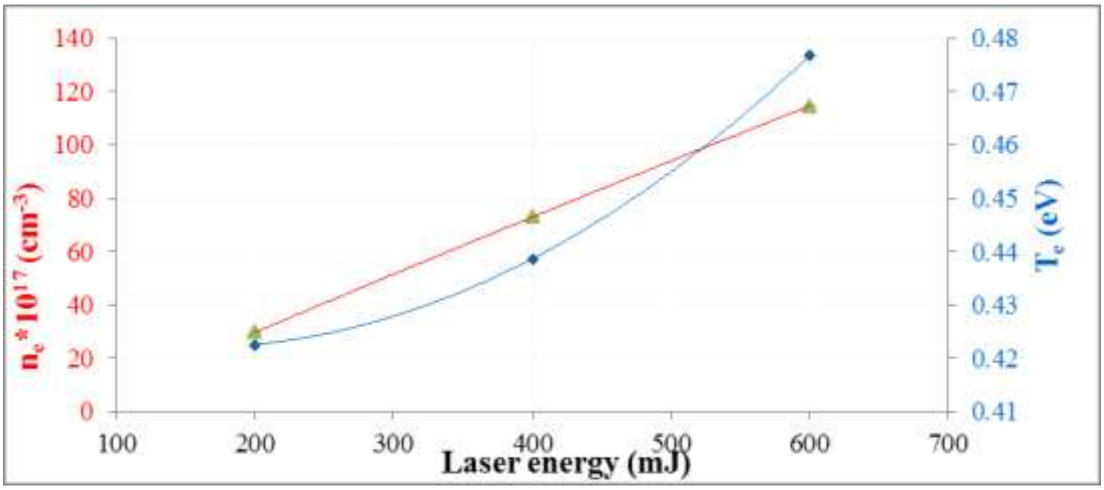

Figure (8): shows the variation of the electron es (200, 400, 600) mJ for cadmium oxide.

4-. Determine the plasma frequency (fp), the Debye wavelength (D), and the quantity of particles contained in a Debye (N.D.) sphere.

Equations (3), (4), and (5) were used to calculate the Debye number, Debye wavelength, and plasma frequency (N.D.), respectively, as these values were calculated at Different laser energies (200,400,600) mJ. The results shown in Table (1) showed that all the λD, fp, and N.D., computed plasma parameters, demonstrated that the plasma generated from CdO satisfies the conditions for plasma. Figures (9) and (10) The increase in plasma parameter values with increasing laser power

$f_p = \frac{\omega_p}{2\pi} = 9000\sqrt{n_e}$ Hz when (n_e in cm^{-3})..............................(3)

$$\lambda_D = \sqrt{\frac{\varepsilon_o \ k_B T_e}{n_e \ e^2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$N_D = n\left[\frac{4}{3}\pi\lambda^3 D\right] \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (5$$

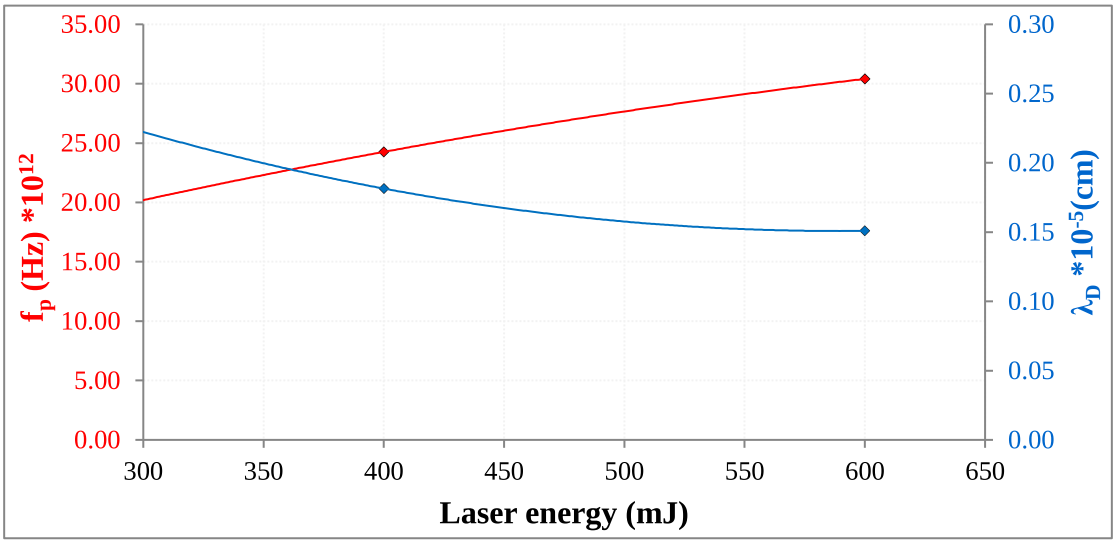

Figure (9): shows plasma frequency and Debye length variations with various laser intensities of cadmium oxide.

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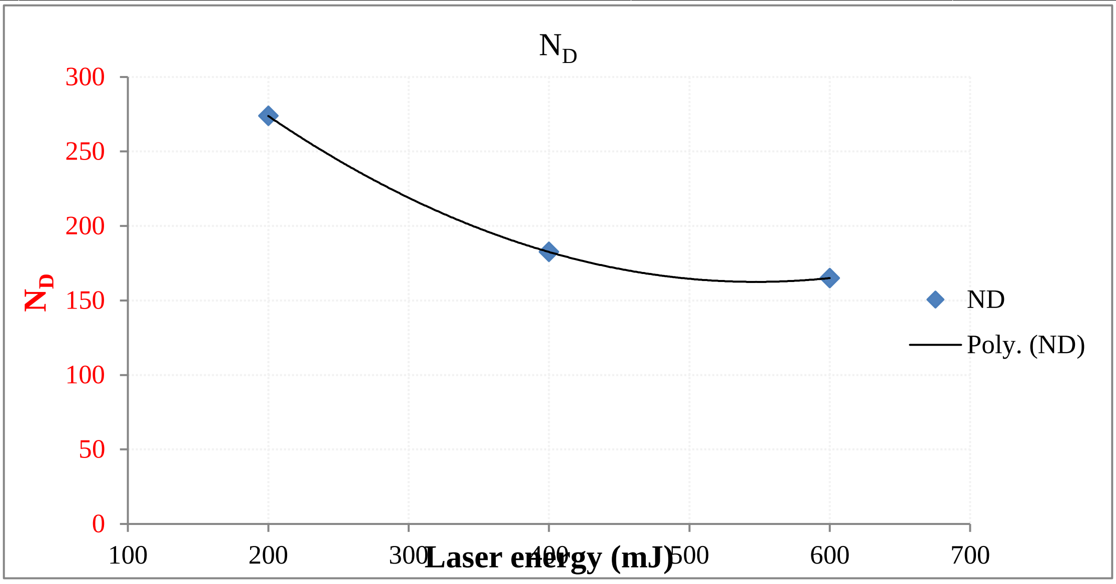

Figure (10): shows the change of Debye number with different laser energies of cadmium oxide.

CONCLUSIONS

The emitted spectra at laser energies (200,400,600) mJ were studied using an (Andy-Yak) laser with a wavelength of 1064 nm. A comparison was made between the resulting peaks and the theoretical values of ionic lines and commercial lines (standard ionic lines I, atomic lines II) from the Nist website. After the laser power increase, the increase in power increases. Using the optical emission spectroscopy technique to measure using the Saha-Boltzmann equation, it was discovered that the calculated values of electron heat (Te) corresponded to all plasma properties. The Debye wavelength (λD), the plasma frequency (fp), and the Debye number (N.D.) increase with increasing laser energies. And that all the calculated plasma parameters are satisfied with the plasma conditions.

REFERENCES

1. A. Keloth, "Laser-Induced Breakdown Spectroscopy (Libs) And Time-Resolved Studies of Copper Plasma Excited by Nanosecond and Femtosecond Laser Pulses", Cochin University of Science and Technolog, M.Sc. thesis,(2012)
2. A.W. Miziolek, V. Pallesschi and I. "Schecchter Laser-Induced Breakdown Spectroscopy", Cambridge University Press, Cambridge (2006).
3. C. Aragón J.A. Aguilera" Characterization of laser induced plasmas by optical emission spectroscopy" (2008)
4. D.A. Cremers and L.J. Radziemski, "Laser-Induced Breakdown Spectroscopy", John Wiley & Sons Ltd., West Sussex (2006).
5. E.D. Ali, H.A. Vural, B. Ortaç and T. Uyar, *Mater. Lett*., 65, 2941 (2011).
6. H.R. Griem, "Principles of Plasma Spectroscopy", Cambridge Uni. Press, Cambridge (1997).
7. J Jovović "Spectroscopic study of plasma during electrolytic oxidation of magnesium-aluminium alloy" University of Belgrade, Faculty of Physics, Students kitrg 12-16, 11001 Belgrade, Serbia(2014).
8. M. HANIF, M. SALIK, M. A. BAIG "Spectroscopic Studies of the Laser Produced Lead Plasma "Plasma Science and Technology, Vol.13, No.2, Apr. 2011.
9. M.A. Naeem ,M. Iqbal,N. Amin,M. Musadiq,Y. Jamil and F. Cecil" Measurement of Electron Density and Temperature of Laser-Induced Copper Plasma" Department of Physics, University of Agriculture(2013).
10. O. Gomez Daza, A. Arias-CarbajalReadigos, J. Campos, M.T.S. Nair, P.K. Nair,Mod. Phys. 02342.
11. W. Chase Jr and N.-J. T. Tables, "Data reported in NIST standard reference database 69, June 2005 release: NIST Chemistry WebBook," *J. Phys. Chem. Ref. Data, Monograph,* vol. 9, pp. 1-1951, 1998.
12. F. Koffyberg, "Thermoreflectance spectra of CdO: Band gaps and band-population effects," *Physical Review B,* vol. 13 ,p. 4470, 1976.
13. E. T. S. Al-Waisy, "Pulsed laser deposition of some TCO films for optoelectronic Application," *Ph. DthesisUniversity of Technology Department of Applied Science,* 2006.