Study the Effect the Pressure on the Plasma Emission Intensity

دراسة عن تأثير الضغط على شدة انبعاث البلازما

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Abstract

In the present work we study the effect of the pressure which surrounds the laser targets on the plasma emission intensity. The laser produced plasma has been carried out using Nd : Glass laser with energy (0.5) j for two different metal targets. A new detection system set up has been used for plasma emission intensity measurements.

الخلاصة

نقوم في الدراسة الحالية بدراسة تأثير الضغط الذي يحيط بالأهداف الليزرية على كثافة انبعاث البلازما تم توليد البلازما المنتجة من الليزر باستخدام Nd ليزر الزجاج بطاقة مقدارها(٠.٥) جول لكل هدفين معدنيين مختلفين. تم استخدام نظام كشف جديد لقياس كثافة انبعاث البلازما.

Introduction :

As a beam of laser light impinges on a material's surface, energy is partially reflected, partially absorbed, and partially transmitted depending on the material type and laser wavelength of the light energy impinging on the surface, the portion that is absorbed is of interest in material processing.[1,2] Light is absorbed in the form of electronic and vibration excitation of the atoms, and energy converts into heat, which dissipates to adjacent atoms. As more and more photons are absorbed, the material temperature increases, thereby increasing the fraction of light absorbed. The process sets off a chain reaction resulting in a rapid rise in temperature in a very short time—typically within a millisecond for welding applications. The rate of temperature rise depends on a balance between energy absorption and energy dissipated by the material.

The *optical absorption length* is the length over which photon energy is absorbed so that beam intensity drops to 1/e (37%) of its original value. The energy absorbed over this volume produces thermal energy that is diffused to a distance of[1] :

$$L = (4Dt)^{1/2} \qquad \ldots\ldots 1$$

where *L* equals diffusion length, *D* is the thermal diffusivity (heat flow), and *t* is the pulse width of the laser.

If the thermal diffusion length is much longer than the absorption length, temperature rise at the laser spot will be limited. By contrast, if the diffusion length is shorter than the absorption length, there will be a very rapid rise in temperature, the surface temperature reaches the melting temperature, and surface melting begins, the melting process of the material depends on the heat flow inside the material. The heat flow (D) in turn depends on the thermal conductivity K (in W/m.K), material density ρ in kg/m^3, and specific heat C=(J/kg.K) [2,3], where

$$D = K/\rho C \text{ ....} 2$$

To produce the desired result, whether for heating, soldering, welding, drilling, marking, and cutting, or micromachining, engineers must choose a suitable wavelength and pulse width. By equating the optical absorption length to thermal diffusion distance, a threshold value can be obtained and used as a guide to selection of pulse- width duration for particular frequency. At high laser power densities >10^6 W/cm^2, the dominant physical processes are vaporization and ionization. As a result of ionization plasma will be produced [4].

The plasma consisting of electrons and highly ionized atoms will expand rapidly and cool down due to the high temperature and non-equilibrium condition. However, during a short period before the expansion has gone too far the temperature of the ions and electrons in the plasma will be sufficiently high to emits a radiation with wavelength depending on the plasma temperature. For example, plasma with temperature of tens eV produces EUV radiation. To achieve this temperature the laser intensity should exceed 10^{11} W/cm^2. The plasma emission can be used for diagnostics i.e, to measure plasma properties like temperature and density. Photon emission from the laser-produced plasma is basically a result from three processes. First, non bound (free-free) bremsstrahlung radiation from free electrons interacting with highly charged ions producing continuum radiation. Next, recombination between free electrons and ions will also result in continuum radiation since it is a free-bound processes. Finally, the radiative emission from the bound-bound electron transitions within the exited ions will give line emission[5]

Experimental Details:

This section is concerned with the experimental arrangements used in this work Fig. (1) .

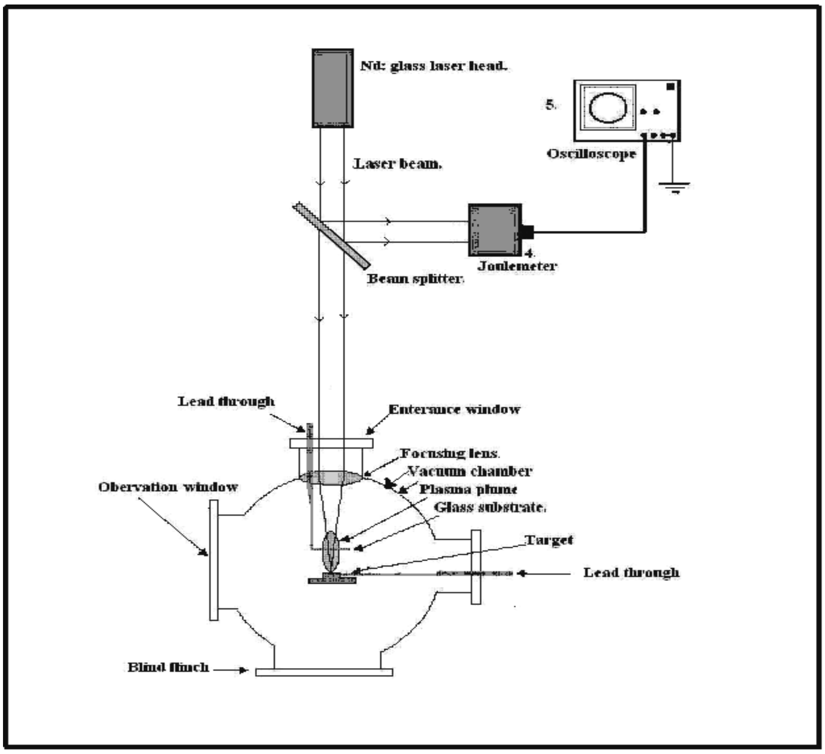

Figure 1:Represents the Experimental set up

Laser system is Nd:Glass laser was used to pump laser beam of 1.06 µm. The detector used to measure the laser output energy was a joule meter of type "Genetic" model ED-200" by using a beam splitter, a part of the laser beam was reflected to the joule meter, which was in turns connected to an "Meteix" oscilloscope to measure the amount of laser energy reached to the head of detector. A spherical chamber with two windows, glass window of 5 cm in diameter was mounted in front of of the laser beam as an entrance window, and a 10 cm diameter quartz window was mounted at aright angle with the laser beam. The chamber was of 50 cm in diameter. The detector used to detect the emission of Visible and UV photons produced from plasma was PMT photo multiplier tube, and the output signal from PMT was shaped, amplified and measured using the usual nuclear detection technique. Pure metal namely Cu, Al were used in the investigation of the UV emission from the plasma.

Results and Discussion:

In this work we used Nd:Glass laser beam was focused onto two metals Al, Cu were used in the investigation of the UV –VIS emission from the plasma.

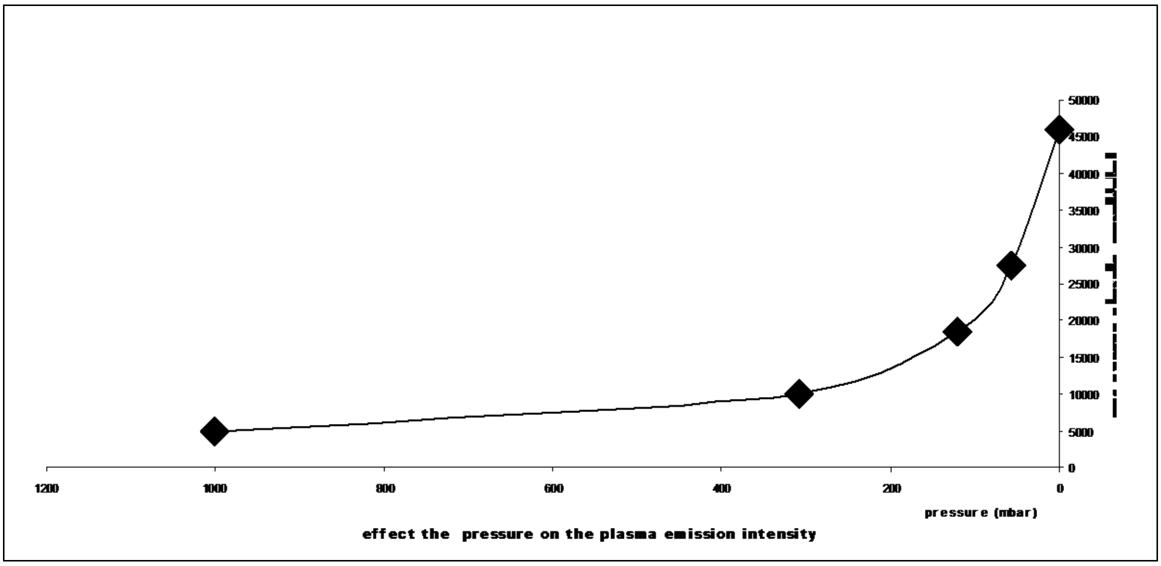

Fig. (2) The effect of the surrounding pressure inside the vacuum chamber of the Al target on the plasma emission intensity.

From the Fig.(2) and Fig.(3) Al target has a higher plasma emission intensity than Cu target where $K_{Al} = 237W/m.K$ and $K_{Cu} = 398W/mK$ [6]because of a significant dependence of the plasma emission intensity on the target thermal conductivity. One can notice that the intensity of the emitted plasma photons is decreased with increasing the target thermal conductivity.

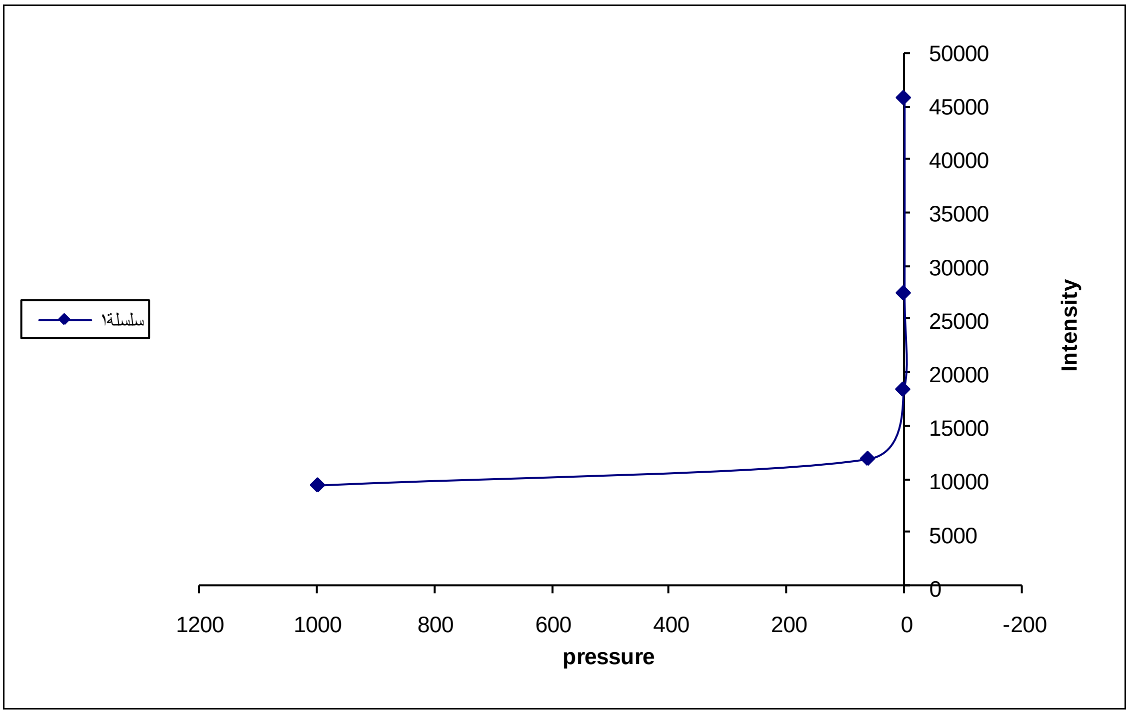

Fig (3) the effect of the surrounding pressure of the Cu target on the plasma emission intensity.

It can be noticed that decreasing the air pressure, causes a significant increase in the expansion of plasma plume. This might be inferred to the increase of the amount of ionized material, the air contains significant concentration of O_2 molecules at atmospheric pressure. This gas can react strongly with plasma electrons to produce a layer of O^- ions surrounding the plasma and are combination process in O^- ions takes place [7]. Therefore, the O_2 molecules make a quenching for the plasma, i.e. a decrease in the electron density leads to a decrease in the electron temperature.

Conclusion:

1- The laser produced plasma (LPP) provides high emission of soft UV photons from metal surface that it is attractive source of soft UV emission for spectroscopic studies.
2- The intensity of plasma emission is highly effected by the surrounding pressure inside the vacuum chamber, by decreasing surrounding pressure inside the vacuum chamber the plasma emission intensity increased .
3- The intensity of plasma emission is highly effected by the target thermal properties(Thermal conductivity), by choosing target with low thermal conductivity the intensity of plasma emission will increased.

References:

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