IR and Visible Radiation from Laser Induced Silver Plasma

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Abstract

Plasma is a rich source of electromagnetic radiations like Infra Red (IR), Visible, Ultra Violet (UV) & X-rays. Emission of visible; green and violet and IR radiation are investigated from the Silver plasma produced by Nd:YAG laser (1064nm, 10mJ, 12ns). Green and violet radiation were detected using a photocell with combinations of color filters having peak responses at 546.1 nm (Green) and 435.8 nm(Violet), respectively. The IR radiation was detected by PIN photodiode (peak response at850 nm). The output voltage signals were displayed on a 500 MHz digital storage oscilloscope (DL-1740 YOKOGAWA). The results reveal that IR emission regime was dominant over visible regime (green and violet). As for as the visible spectrum itself is concerned, green regime was found more intense than violet. The emission spectrum is a promising tool for the spectroscopic studies of the material.

Keywords: Laser Induced Plasma; IR; Visible; UV Radiation; PIN Photodiode

1. Introduction

Plasma acts as a source of electromagnetic radiation which comprises of broadband including infrared, visible, ultraviolet and X-rays radiation. A laser pulse focused on an opaque surface can produce high heating rates and high temperatures. Optical emission spectra from laser produced plasma contain much useful information about the laser matter interaction, plasma formation and characteristics of the target material. When the laser beam is irradiated on a target, it ablates the material which is instantaneously superheated, generating a plume with high temperature. At this temperature the ablated material dissociates into excited ionic and atomic species forming plasma which is a rich source of a continuum radiation [1-4].

There are several diagnostic techniques for characterizing laser-induced plasma including optical emission spectroscopy [5], laser induced fluorescence [6] and laser interferometry [7]. Different techniques have been applied for the recording and analysis of emission spectra [8-10].

The work presented in this paper is to diagnose the optical emission spectrum (IR and visible radiation) from the laser produced silver plasma generated by a high power Nd: YAG laser. In order to analyze the emission spectrum, photodiodes and photocell in combination with color filters are used. A comparative analysis of visible and IR radiation signals has also been discussed.

2. Experimental Setup

The plasma was produced by irradiation of an Nd: YAG laser (9-14 ns, 1064 nm, 1.1 MW) on the silver target. The pressure in the vacuum chamber was pumped down to 10^{-3} torr with the help of rotary vane pump. The target holder containing the silver sample was placed at the centre of the chamber. An IR focusing lens of 10 cm focal length was fixed at the inner side of one port to focus the laser beam at the target. The target was exposed to the laser at 45° relative to the normal at the surface of the sample. The photocell and photodiode were placed at an optimum distance from the target in order to capture the visible and IR radiation, respectively.

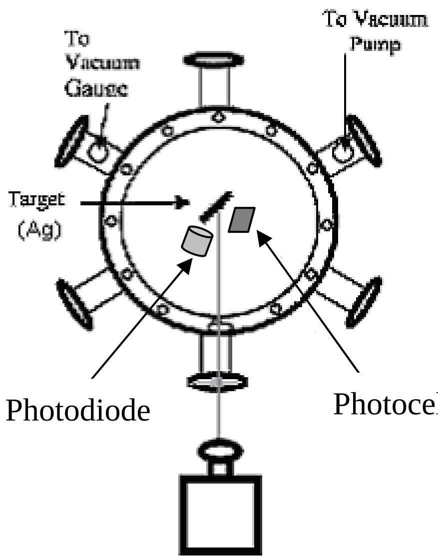

Figure 1: Schematic of the experimental setup

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Two narrowband filters, green with peak response at 546.1 nm and violet with peak response at 435.8 nm, were used for the detection of the respective signals. The signals were displayed on a 500 MHz digital storage oscilloscope. A schematic for the experimental arrangement is shown in Figure1.

3. Results and Discussion

The resultant signal profile of IR and Green region are displayed in Figure 2. And a comparison of IR and Violet is represented in Figure 3. The spectrum is analyzed on the basis of photocell and photodiode response to the incoming radiation. The pulse width (FWHM) of IR and Violet radiation recorded was 30 ns. The average photocurrent generated by IR radiation was 2 mA found by using the relation

$$I = V_p / R \qquad (1)$$

where V_p is the peak voltage and R is the load resistance.

The signals obtained also described the generation mechanism of optical radiations in laser induced silver plasma [11-12]. Referring to Figure 2, the signal 1 from photodiode for IR radiation was shown on channel 1 while the visible signal 2 of green filter is displayed on channel 2. Both signals have the same pulse width (FWHM). The IR signal initiates 10 ns earlier than green signal; this might be due to the reflection of incoming IR radiation from the surface of silver target as wavelength of incident laser lies in the infrared region of the electromagnetic spectrum. Initially when the laser energy is absorbed, the metal gets heated and breakdown occurs due to which low energy electrons are generated.

These electrons make collisions with the atoms and ions which are excited to the higher energy levels due to collision, as they decay to their initial levels their wavelength corresponds to the IR as well as visible radiation. But due to the further absorption of laser light, electrons get more energy via various phenomena such as resonance absorption, inverse bremsstrahlung and parametric scattering processes [13]. The emission spectrum lies in the IR and visible wavelength range if the plasma temperature corresponds to in the range of 1eV [14]. The laser used in this experiment is multimode. The green colour in the emission spectrum might be due to the second harmonic generation of Nd: YAG laser at 1064 nm. When the plasma frequency becomes equal to the incoming frequency, the resonance absorption takes place that leads towards the second harmonic generation which lies in the green wavelength range The time lag of green wavelength signal from IR appears because after 10 ns atoms absorb more energy

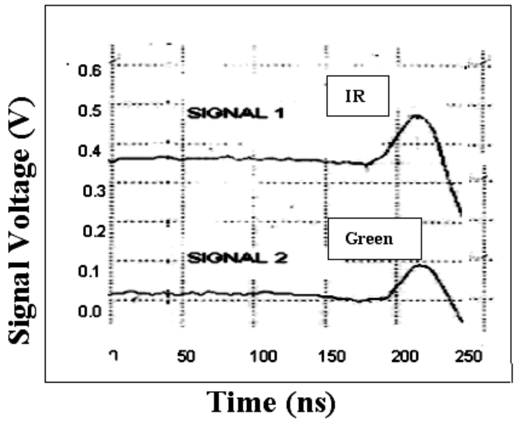

Figure 2: Optical output signals from photodiode and photocell

to correspond the green wavelength signal of 546.1 nm [13, 15]. The IR signal profile in Figure 2 shows that absorption of incoming photons increases with time. After 15 ns from start of the pulse the rate of absorption becomes maximum contributing the maximum current at the peak. At this stage the relative density of electrons seems to be greater than neutral species. Because intensity of the emitted radiations is always proportional to $n_e n_i$, where n_e and n_i are the electron and ion densities respectively. The IR signal was found to be more intense as compared to visible signal because intensity is always proportional to the density [16]. After15 ns the absorption begins to decrease, so there is a fall in voltage pulse. Usually these radiation are emitted through the under dense plasma region where electron density is less than the critical density [16].

In Figure 3 the IR (signal 3) and violet (signal 4) signals through photodiode and photocell were recorded. The pulse width of these signals is same as that of signals 1and 2 shown in Figure 2.

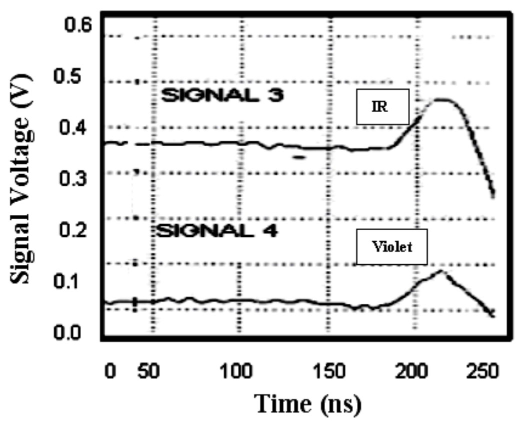

Figure 3: Optical output signals from Photodiode and photocell

But this time transmission of radiations is through violet filter of peak response at 435.8 nm. The voltage signal corresponding to this wavelength was recorded as 85 mV. The IR voltage output was 100 mV. Figure 3 clearly illustrates that IR signal generates more current than for the violet. But the pulse of violet shows some dip or edge that might be due to some instabilities in the under dense plasma region [17].

Figure 4 indicates that the emission of violet radiation keeps on increasing from 185 ns to 200 ns time which is indicative of time dependent increase in the absorption of incoming radiation.

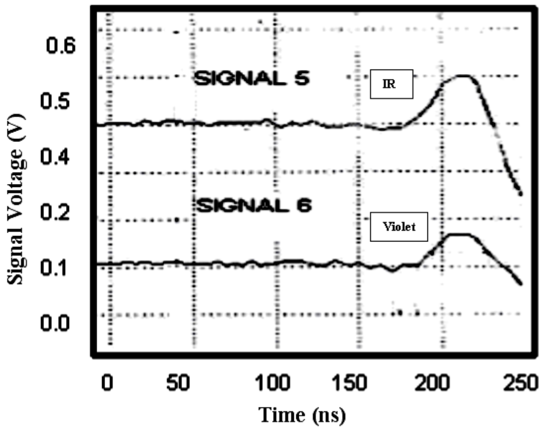

Figure 4: Optical output signals from photodiode and photocell

It shows that after 15 ns no more photons were absorbed as indicated in the flatness of pulse lasting for 15 ns. This indicates that absorption of photons by photocell becomes constant or saturated. These radiation are emitted from the under dense plasma region because the photons do not have enough energy to escape from the over dense plasma region. A plateau for violet signal in Figure 4 reveals an additional aspect of saturation of photocell that is absent in Figure 3 [18-19].

4. Conclusions

The study reveals that the IR radiation signals are more intense as compared to the signals produced by green and violet radiation. The comparison of green and violet signals shows that the amplitude of green signal is greater than that of violet. The emission duration of almost all the radiations under discussion is same.

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