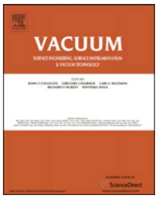
Vacuum 85 (2010) 312–316

Contents lists available at ScienceDirect

Vacuum

journal homepage: www.elsevier.com/locate/vacuum



Investigations on hard X-rays from laser induced plasmas

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A R T I C L E I N F O

Article history:
Received 6 March 2010
Accepted 1 July 2010

Keywords:
Nd: YAG Laser
Laser induced plasma
Hard X-rays

A B S T R A C T

Investigations are performed on significant parameters of Hard X-Rays emitted from metallic plasmas. Nd: YAG (1064 nm, 9–14 ns, 1.1 MW) laser is irradiated on three 4 N pure Lead (Pb), Platinum (Pt) and Copper (Cu) targets under vacuum $\sim 10^{-3}$ torr. The plasma plume images were captured by Charged Coupled Device (CCD). The Hard X-rays were detected by Photomultiplier tube. The signals thus produced were stored in digital storage oscilloscope. Variation takes place in the parameters of emitted x-rays with atomic numbers/mass of target. The intensity of emitted x-rays increases with the increase in atomic mass of the target materials used.

1. Introduction

Electromagnetic radiation may be produced from Laser induced plasma which acts as one of the best sources for x-rays [1,2]. Inverse bremstrahlung, recombination, electron-ion collisions and electron-neutral inverse bremstrahlung are main mechanisms of radiation emission from Laser Induced Plasma (LIP) [3].

When a laser beam, above ablation threshold, is irradiated plasma formation takes place [4]. The expansion of the high-pressure vapors drive a shock wave into the atmosphere and energy is transferred by a combination of thermal conduction, radiation and heating by the shock wave. The relative importance of these processes in determining the subsequent plasma evolution depends on irradiance, size of vapor plasma bubbles, target vapor composition, ambient gas composition and pressure, and laser wavelength. At low irradiance the conduction dominates and in surrounding gas the early stage of plasma is developed. The vapor plasma is too thin, spatially and optically, to transport energy efficiently by radiation. The shock heating dominates at high irradiance [5,6].

The atmosphere adjacent to the vapor plasma is heated. This enables the gases, which were initially transparent to the laser radiation, to start absorbing the laser light. As the ambient gas starts to absorb a significant part of the laser energy, a self-perpetuating absorption process starts. This results in plasma propagation into the surrounding atmosphere [3]. Various features of laser plasma interaction with ambient gas are shown in Fig. 1. When the plasma obtained thermal energy, radiations are emitted via free–free, free–bound and bound–bound processes. In 1st process, free electrons interact with the coulomb potential of the ions and radiate continuum electromagnetic spectrum. This process is called bremstrahlung radiation emission. 2nd process, known as recombination, consists of transition from initial free electron states to bound electron states, generates a continuum electromagnetic spectrum. Transitions between discrete levels of ionized atoms produces line spectrum in 3rd type of emission process [1–9].

Laser-produced plasmas are characterized by the large temperature and density gradients extending from the low density, high temperature corona region to the over dense ablation region. Temperatures and densities can vary over three orders of magnitude in regions extending only over tens of microns [10]. The precise nature of the plasma profile is governed by a complex balance between laser absorption and electron conduction for high *z* plasmas. X-ray spectra originate predominately from different regions of the plasma (see Fig. 2). The electromagnetic radiations including x-rays have been explored and investigated due to its versatile applications using different diagnostics [11–14].

The present paper is devoted to examine time integrated images of plasma plume and Hard X-ray (HXR) emission by different laser induced vvvmetallic plasmas under a vacuum $\sim 10^{-3}$ torr. The study is useful in material processing and surface modifications, medical science and security systems.

2. Experimental setup

Q switched Nd: YAG laser (1064 nm, 9–14 ns, 1.1 MW) was tightly focused on 4 N copper, platinum and Lead targets ($2 \times 2 \times 0.2$ cm^3) with the help of IR focusing lens. The focused laser spot size and the corresponding laser power density are 12 μm and

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doi:10.1016/j.vacuum.2010.07.002

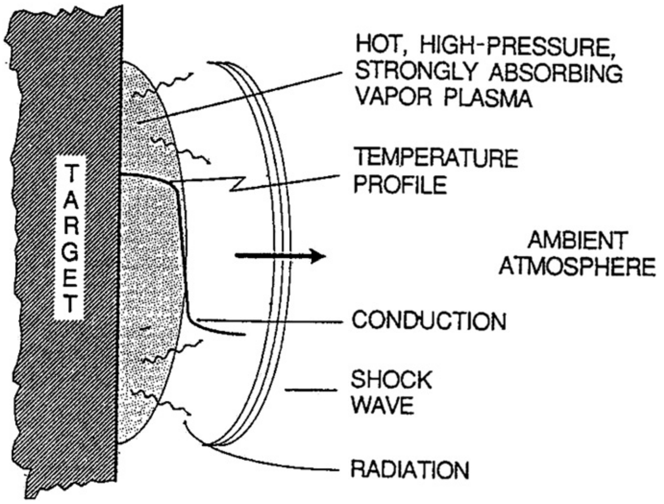

Fig. 1. Features of the interaction between the vapor plasma and the ambient gas [3].

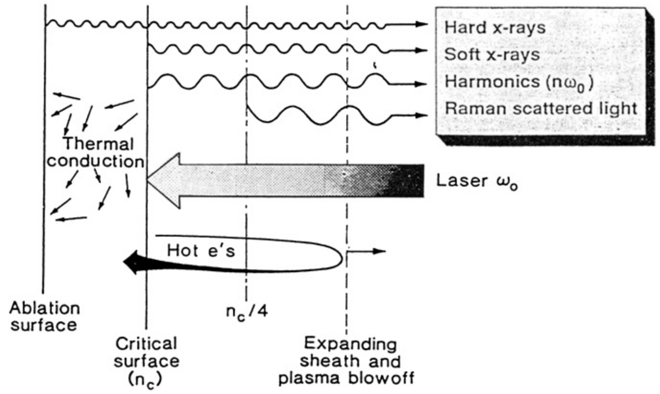

Fig. 2. X-rays emission from laser plasma [3].

3×10^{15} W/m^2 respectively. The experiments were performed in 8-port stainless steel chamber under vacuum $\sim 10^{-3}$ torr. The target motion was controlled by externally applied stepper motor.

Hard X-Rays emitted from laser plasma were detected by Photomultiplier tube (PMT) alongwith 50 μm thick Al scintillator. The signals of Hard X-Rays were stored on 200 MHz UNI-T (UTT220) digital storage oscilloscope. The CCD (Bosch Dinion^{XF} LTC 0510) based grabbing system was employed to capture plasma plume image. To avoid saturation neutral density filter were employed. Experimental setup is shown in Fig. 3.

3. Results and discussions

Repeated single shot ablation events were recorded by CCD camera. Data collected from each diagnostic was analyzed.

Fig. 4a–c represent the plasma plume images of Pb, Pt and Cu respectively. Plasma image of lead is fine as compared to others because Pb is soft metal as compared to platinum. Three dimensional plasma plume images for different targets are graphically

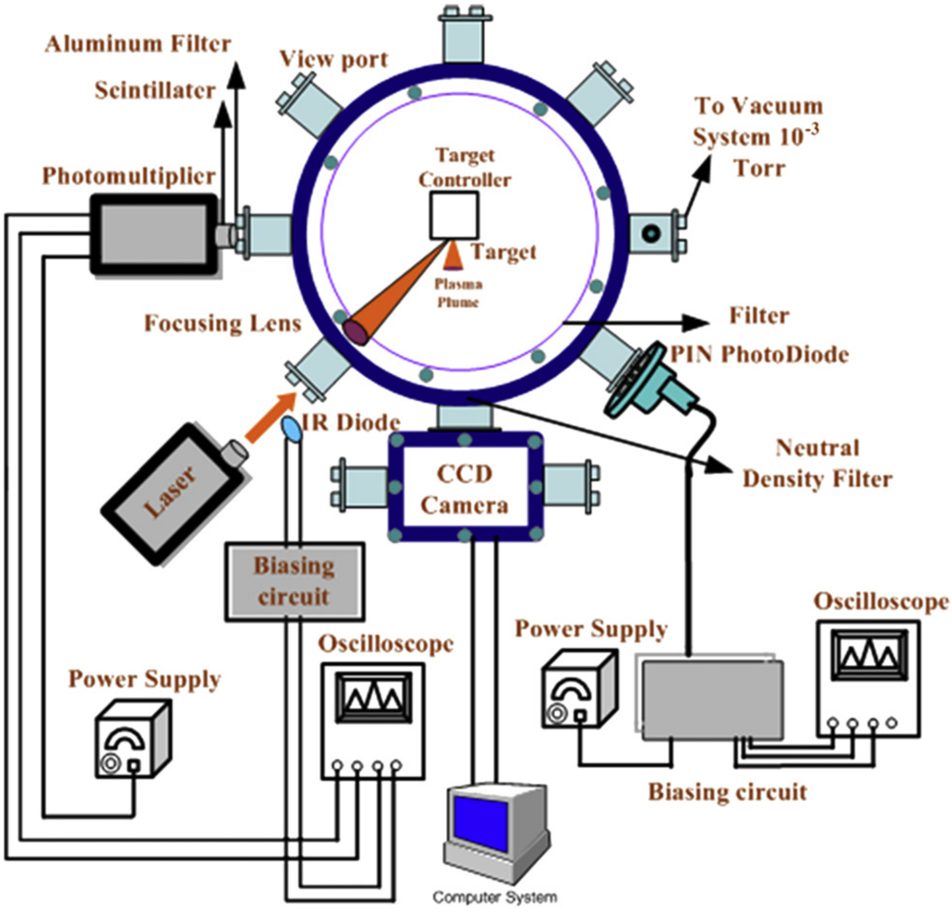

Fig. 3. Schematic design of experimental setup.