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PREPRINT

K-shell Emission from 140 Femtosecond Laser-Produced Plasmas created from Porous Aluminum Targets

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ABSTRACT

The K-shell emission from flat and porous aluminum targets is used to infer the efficiency of creating a high temperature (>100eV), thermal plasma with 800 nm, 140 fs laser light. The K-shell emission from flat aluminum targets is found to be significantly less than that of the porous targets, implying a lower temperature and less efficient coupling between the target and ultra-short pulse laser light.

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Introduction

The interaction of ultra-short pulse (≤ 1ps) lasers with solid matter is currently under investigation at numerous laboratories around the world [1-3]. The motivation for many of these studies is the production of near solid density, high temperature plasmas. The plasmas are produced by rapid absorption of the laser before hydrodynamic expansion. The enthusiasm for the production of high temperature, high density matter using this technique has been tempered by the difficulty of coupling high intensity laser light into solid surfaces. Numerous theoretical and experimental papers have addressed ultra-short pulse absorption, heating, and x-ray emission of flat solid targets at high intensities ($I \geq 10^{16}$ W/cm^2)[4-7]. Additionally work has been reported on the increased hard X-ray (> 1keV) yield in porous gold [8]. We report the first study of the K-shell emission of ultra-short pulse heated porous aluminum. The intensity dependent K-shell emission is used to determine the density and temperature of the plasma while the specular and non-specular reflected light are monitored to infer the absorption. A qualitative comparison of the K-shell emission indicates a much high temperature in the porous aluminum than that of the flat targets.

Experimental setup

The porous aluminum consists of clusters of aluminum particles (≈ 1 µm in diameter), with typically 200 Å between particles. The density is ≈ 1% solid density, with the voids assumed to remain unfilled during laser irradiation.

The laser used in this study consist of a 150 femtosecond (FWHM) Ti:Sapphire laser capable of producing 50 mJ focused to a 5 µm diameter spot at normal incidence. To minimize the effects of pre-pulse, we added an IR 140 saturable absorber after the last power amplifier in the system that transmits 70-75 % of the incident energy. The addition of the saturable absorber reduced the energy in the pre-pulse by a factor of 10, but limited our peak intensity to ≈ 10^{18} W/cm^2.

The aluminum K-shell data was collected with Von Hamos crystal spectrograph. The spectrograph uses a 7.62 x 1.9 cm potassium acid phthalate (KAP, 2d=26.623 Å) crystal cylindrically curved to 5 cm. The detector has an estimated resolving power of E/ΔE≈ 2000. The specular and non-specular reflected light was monitored using filtered silicon PIN diodes. The angularposition of the non-specular diodes could be varied between 20° and 80° in the plane of incidence of the laser beam. The non-specular 1 ω, 3/2 ω, and 2 ω light was monitored with a Czerny-Turner visible spectrometer viewing the plasma at 60° above the target normal.

Data and Analysis

The temperature was determined by minimizing the difference between the experimentally measured spectrum and a synthetically generated spectrum using the quasi-steady state equilibrium model [9]. A plot of the temperature as a function of laser intensity is displayed in figure 1. The temperature is noted as having a weak dependence on laser intensity. The electron density was inferred using Stark broadening of the $1s4p\text{-}1s^2$ line. By comparing the measured line width to the calculated line width [10], the density was estimated and plotted as a function of laser intensity. As a qualitative comparison of the relative thermal temperature achieved in the porous aluminum versus that of the flat aluminum indicated that under similar irradiance (4×10^{17} W/cm^2), the $1s2p\text{-}1s^2$ emission was a factor of four greater in the porous aluminum with a factor of ten fewer shots. Furthermore, no emission from Rydberg states higher than the $1s2p\text{-}1s^2$ was seen in the flat aluminum. Estimates of continuum lowering due to higher densities could not account for the lack of emission from the higher Rydberg states in the flat aluminum.

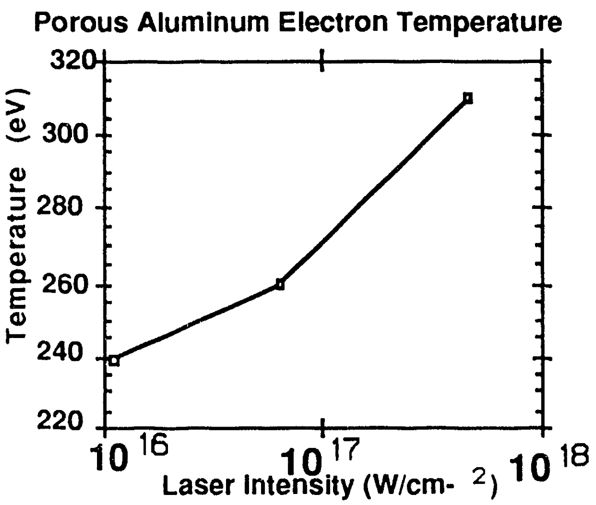

Figure 1

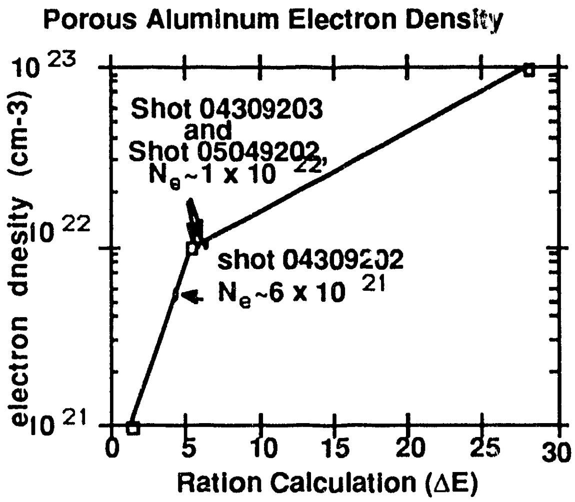

Figure 2

The data collected with the visible diodes indicated the relative amount of specular and non-specular reflected light was noticeably higher when shooting the flat targets. The visible spectrometer indicated 4-10 as much 2ω light was generated when the laser interacted with the flat targets as opposed to the porous targets. A small amount of 1ω was seen with flat target experiments as compared to no detectable amounts with the porous targets. The 3/2 ω observed from either target was negligible when the saturable absorber was used.

Conclusions

We have done the first measurement of the temperature and density of porous targets using spectroscopic. The data collected with the visible diodes indicated the relative amount of specular and non-specular reflected light was noticeably higher when shooting the flat targets. The visible spectrometer indicated 4-10 as much 2 ω light was generated when the laser interacted with the flat targets as opposed to the porous targets. A small amount techniques. The measurements indicate temperatures between 240 eV and 310 eV (depending on irradiance) and a density of $\approx 10^{22}$ e/cm^3. Work is currently being done to study the spectra in detail along increasing the density of the material.

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