Soft X-Ray Emission from a CO$_2$ Laser-Heated Z-Pinch Plasma

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We report results of soft X-ray measurements in which a high-power ($10^{10}-10^{11}$ W/cm$^2$) CO$_2$ laser was used to heat a near critical density ($<10^{19}$ cm$^{-3}$) helium Z-pinch plasma. Frequency-integrated X-ray data show that the unheated Z-pinch plasma is Maxwellian with a temperature of about 30 eV. During laser heating, the X-ray emissions were enhanced over the unheated emissions. Analysis of the experimental X-ray spectra indicate that the low-energy portion of the X-ray emission spectrum (up to 600 eV) is enhanced over the baseline 30 eV Maxwellian emissions. This result is consistent with an inverse bremsstrahlung-modified distribution which results when the plasma heating rate is more rapid than the collisional thermalization rate. These results suggest that it may be possible to enhance the soft X-ray yield of a plasma lithographic source with laser heating.

KEY WORDS: Laser-heated Z-pinch plasma; helium; soft X-rays; plasma lithography.

1. INTRODUCTION

Soft X-ray sources have a number of important applications ranging from semiconductor processing$^{(1)}$ to X-ray microscopy.$^{(2)}$ Laser-heated targets have provided one source of soft X-rays,$^{(3)}$ whereas the gas-puff Z-pinch is now available commercially for soft X-ray generation. For certain applications it may be desirable to use a laser to control the soft X-ray spectrum from a Z-pinch. While a high-energy tail can be achieved in CO$_2$ laser-solid target interactions,$^{(4)}$ the enhancement of a low-energy soft X-ray component is less straightforward.

In this article we present results of soft X-ray measurements on a CO$_2$ laser-heated helium Z-pinch plasma. Our results show that laser heating of plasmas close to critical densities results in an enhancement of X-ray production in the lower-energy portion of the spectrum. This result is

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consistent with existing models of inverse bremsstrahlung absorption of laser light.

2. EXPERIMENTAL

2.1. Configuration

This section describes the experimental configurations and diagnostics used to characterize the soft X-ray emission as a function of the electron temperature and density of the Z-pinch plasma, both with and without CO₂.

Fig. 1. Z-pinch configuration.