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Final Report
X-ray Spectroscopy of Xenon
FG03-92SF19202
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Final Report

X-Ray Spectroscopy of Xenon

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Uri Feldman, P.I.

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Abstract

A high-resolution x-ray spectrometer was constructed and fielded at the National Laser Users Facility at the Laboratory for Laser Energetics, University of Rochester. The spectrometer was attached to a streak camera, and time-resolved x-ray spectra were recorded. The targets were irradiated by the 24-beam Omega laser and consisted of CH microballoons filled with DD, argon, and xenon. The x-ray spectral lines from Ar and Xe were used to determine the plasma properties of the compressed core region.

The spectrometer was designed to cover the spectral lines of highly-charged argon (2.9-3.9 keV) and xenon (4.3-5.3 keV) with high spectral resolution. The spectrometer was also designed for attachment to a streak camera to provide time-resolution of the spectra. A sketch of the spectrometer is shown in Fig. 1. The spectrometer consisted of a crystal mount that accommodated two crystals for alternating coverage of two energy regions on successive laser shots, a support frame that attached to the streak camera, and a filter mount.

A variety of crystals provided coverage of all of the energy ranges of diagnostic interest. These included ADP, Ge, and quartz. A specially designed system of alignment pins and slots made it possible to easily change the crystal Bragg angle.

The targets consisted of CH microballoons filled with varying pressures of argon, xenon, and DD. Spectra were recorded on the shots listed in the following table.

Shot #	Gas Fill	Shell	Crystal
24498	Ar(20 atm)	CH(6 μ m)	ADP 101 (m=1)
24500	Ar(0.8 atm) DD(19.2 atm)	CH(6 μ m)	ADP 101 (m=1)
24501	Ar(0.1 atm) DD(19.9 atm)	CH(6 μ m)	ADP 101 (m=1)
24504	Ar(20 atm)	CH(6 μ m)	ADP 101 (m=1)
24545	Ar(0.1 atm) DD(19.9 atm)	CH(6 μ m)	ADP 101 (m=1)
24705	Xe(0.02 atm)		Quartz 1011 (m=1)
24707	Xe(0.5 atm)		Quartz 1011 (m=1)

The streaked spectra were recorded on photographic film and were digitized using a microdensitometer. Typical digitized argon spectral images are shown in Fig. 2, where the most intense lines are the K shell transitions of Ar XVII and Ar XVIII. Figure 2(a) is the spectrum from a target with high-pressure argon fill (shot 24504), and the Ar lines appear intense throughout the laser pulse. This emission primarily originates from argon dissolved in the CH shell. Figure 2(b) is the spectral image from a target with low-pressure argon and high-pressure DD fill (shot 24501). The argon emission is most intense from the compressed plasma core, and the spectral lines are Stark broadened. A lineout of the spectrum from the compressed plasma is shown in Fig. 3.

The Ar He β line ($1s^2\ ^1S_0 - 1s3p\ ^1P_1$) was prominent in the core spectrum of shot 24545, and the Stark broadening of this line was used to determine the electron density. The lineshape was calculated as a function of electron density, and the electron density at various times during the compression was determined by the best fit to the observed lineshape. As shown in Fig. 4, the determined electron density at peak compression was $1.2 \times 10^{24}\text{ cm}^{-3}$. The calculated lineshape depended weakly on electron temperature, which was assumed to be 600 eV.

The images of the xenon spectra are shown in Fig. 5. Shown in Fig. 5(a) is the spectrum from a high-pressure xenon fill (shot 24707), and emission is present throughout the laser pulse. As for the high-pressure argon shots, this xenon emission originates from xenon that is dissolved in the CH shell. The spectrum from the low-pressure xenon (shot 24705) is shown in Fig. 5(b), and the emission is more confined to the core plasma. A lineout of the xenon spectrum is shown in Fig. 6. The most intense spectral features are from the Ne I, Na I, and Mg I ionization stages. The analysis of the xenon spectra is in progress.

Streaked Crystal Spectrometer for Omega Laser

Fig. 3 Shot 24501

Fig. 4

Fig. 5(a) Shot 24707

Fig. 5(b) Shot 24705

Fig. 6 Shot 24707