Journal of Quantitative Spectroscopy & Radiative Transfer 99 (2006) 120–130

Journal of Quantitative Spectroscopy & Radiative Transfer

www.elsevier.com/locate/jqsrt

Line broadening analysis of implosion core conditions at Z using argon K-shell spectroscopy

T.J. Burris-Mog[a,*], R.C. Mancini[b,1], J.E. Bailey[b], G.A. Chandler[b], G. Rochau[b], G. Dunham[b], P.W. Lake[b], K. Peterson[b], S.A. Slutz[b], T.A. Mehlhorn[b], I.E. Golovkin[c], J.J. MacFarlane[c]

[a]*Department of Physics, University of Nevada, Reno, NV 89557, USA*
[b]*Sandia National Laboratories, Albuquerque, NM 87185, USA*
[c]*Prism Computational Sciences, Madison, WI 53703, USA*

Accepted 26 April 2005

Abstract

We report on spectral line broadening analysis of Ar K-shell lines from argon-doped implosion cores driven by a dynamic hohlraum z-pinch. The observed Ar spectra include emissions from the resonance series in H- and He-like Ar ions, i.e., Lyα, Lyβ and Lyγ, and Heα, Heβ, Heγ and Heδ lines, respectively. The analysis accounts for opacity and Stark broadening to determine electron density, N_e, and areal-density, $N\Delta R$, values for the ground state populations of H- and He-like Ar ions. Furthermore, these results are combined with the ratio of H- and He-like ground state populations to extract the electron temperature, T_e.
© 2005 Elsevier Ltd. All rights reserved.

Keywords: X-ray spectroscopy; Line broadening; Plasma diagnostics

1. Introduction

In experiments performed at the Z facility of Sandia National Laboratories (SNL) deuterium-filled, argon-doped plastic shells were driven by the radiation from z-pinch dynamic hohlraums

*Corresponding author.
E-mail address: burris@physics.unr.edu (T.J. Burris-Mog).
[1]On sabbatical leave from University of Nevada, Reno.

doi:10.1016/j.jqsrt.2005.05.009

[1–5]. Tracer amounts of argon were added to the gas fill for diagnostic purposes. At the collapse of the implosion, time- and space-resolved argon K-shell spectra were recorded. The observed argon spectra show emissions from the Lyα (1s ^{2}S–2p ^{2}P), Lyβ (1s ^{2}S–3p ^{2}P) and Lyγ (1s ^{2}S–4p ^{2}P), and Heα (1s^2 ^{1}S–1s2p ^{1}P), Heβ (1s^2 ^{1}S–1s3p ^{1}P), Heγ (1s^2 ^{1}S–1s4p ^{1}P) and Heδ (1s^2 ^{1}S–1s5p ^{1}P) line transitions in H- and He-like Ar ions, respectively, and their associated He- and Li-like satellite lines. We focus on line broadening analysis of the resonance lines and apply it to time-resolved, space-integrated data. This analysis is done within the scope of a uniform model approximation and thus the extracted plasma conditions represent spatial averages inside the core. The analysis relies on the fact that at the plasma conditions of these implosion cores broadening due to Stark, predominantly N_e dependent, and opacity, predominantly $N\Delta R$ dependent, dominate the line shape, so that the broadening can be modeled by combinations of Stark and opacity broadening. The correct combination can be determined by simultaneously working with several members of the same line series (i.e., same lower state, different upper states) since only a restricted set of plasma conditions can simultaneously fit the broadening of several members of the same series [6]. In contrast to previous applications of line broadening analysis [6–8], here, we work with the α, β and γ lines of *both* the Lyman and He-like line series of Ar, and use an opacity broadening function for the case of a uniform absorbing and emitting spherical plasma source based on an analytical integration of the intensity flux through the surface of a sphere.The analysis yields N_e values characteristic of the formation of Lyman and He-like series of lines, and $N\Delta R$ values for the ground state populations of H- and He-like Ar ions. From the $N\Delta R$ values, the optical depths of all lines used in the analysis can be computed. Furthermore, these results combined with ionization balance calculations can be used to extract the electron temperature, T_e, using the temperature sensitivity of the H-like Ar to He-like Ar ground state population ratio. For the range of densities relevant to these implosion cores the N_e dependence of this ratio is weak thus making it useful as a temperature diagnostic. This paper is organized as follows: in Section 2 we discuss the experiments, in Section 3 the analysis method is described, and in Section 4 we present our results and conclusions.

2. Experiments

The experiments were performed at the Z facility of SNL. Double-nested tungsten wire-arrays were driven with a pulsed 20 MA current to produce an imploding z-pinch plasma. A low density foam cylinder was placed co-axially within the wire-arrays. The impact of the z-pinch plasma on the foam cylinder launched a cylindrical shock in the foam whose radiation was trapped by the optically thick walls of the tungsten plasma. This shock is the main radiation source of the dynamic hohlraum cavity formed by the imploding z-pinch plasma [1,2]. Embedded at the center of the foam cylinder is the gas-filled plastic capsule. It undergoes implosion driven by the X-rays of the dynamic hohlraum. The capsules of these experiments absorbed up to 20 kJ of X-rays. At the collapse of the implosion, argon X-ray line emission and nuclear fusion reaction neutrons produced in the core were recorded [3,4].

X-ray line emission spectra from the core were recorded with a resolution power $\lambda/\Delta\lambda$ of 1000 using the TREX elliptical crystal spectrometer [5]. Fig. 1 shows the time-resolved (gated) space-integrated argon line spectrum recorded at Z during the time of brightest argon emission,