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# General computational spectroscopic framework applied to Z-pinch dynamic hohlraum K-shell argon spectra

M.L. Adams[a,*], D.B. Sinars[b], H.A. Scott[a]

[a]Lawrence Livermore National Laboratory, University of California, L-018, 7000 East Avenue, Livermore, CA 94550, USA

[b]Sandia National Laboratories, Albuquerque, NM 87185, USA

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**Abstract**

We describe a general computational spectroscopic framework for interpreting observed spectra. The framework compares synthetic spectra with measured spectra, then optimizes the agreement using the DAKOTA toolkit to minimize a merit function that incorporates established spectroscopic techniques. We generate synthetic spectra using the self-consistent nonlocal thermodynamic equilibrium atomic kinetics and radiative transfer code CRETIN, relativistic atomic structure and cross-section data from HULLAC, and detailed spectral line shapes from TOTALB. We test the capabilities of both our synthetic spectra model and general spectroscopic framework by analyzing a K-shell argon spectrum from a Z-pinch dynamic hohlraum inertial confinement fusion capsule implosion experiment. The framework obtains close agreement between an experimental spectrum measured by a time integrated focusing spectrometer and the optimal synthetic spectrum. The synthetic spectra show that considering the spatial extent of the capsule and including the effects of optically thick resonance lines significantly affects the interpretation of measured spectra.


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*Corresponding author.
*E-mail address:* mladams@llnl.gov (M.L. Adams).

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## 1. Introduction

Plasma spectroscopy is the science of determining plasma properties through the observation and interpretation of emergent radiation. In this paper, we develop a general computational framework to facilitate the interpretation of spectra. We then use this framework to analyze K-shell argon spectra from a Z-pinch dynamic hohlraum experiment done on the Z-Machine at Sandia National Laboratories [1].

Two approaches are commonly taken to interpret spectra. In the first approach, a spectral signature from a dominant physical process is used to identify system properties. Most approaches of this type determine a single property, e.g., chemical composition from the quantum fingerprints of atoms and molecules in the system or electron density from the full-width at half-maximum (FWHM) of a spectral line shape. While this approach requires several assumptions regarding the plasma, e.g., homogeneity or small optical depth, it often produces results that are within experimental diagnostic uncertainties. However, the underlying assumptions are frequently not justified and the interpretation of the results may be suspect. A second approach involves the generation of synthetic spectra. The reliability of this approach depends on the applicability or capabilities of the model used to generate the synthetic spectra, as well as the method used to determine and obtain agreement between synthetic and measured spectra. In what follows, we develop a general spectroscopic framework that combines both approaches.

Background radiation and debris make plasma spectroscopy on Z-pinch dynamic hohlraum experiments challenging, compared to laser driven inertial confinement fusion (ICF) experiments. Recent advances in radiation sources, resulting from improved wire array performance [2], and developments in diagnostic capabilities [3], have made Z-pinch experiments a more benign spectroscopic source. Thus, to test the capabilities of our synthetic spectra model and general spectroscopic framework, we analyze K-shell argon spectra from a Z-pinch dynamic hohlraum ICF capsule implosion experiment.

The remainder of this paper conforms to the following outline. Section 2 establishes the general spectroscopic framework. Section 3 covers the generation of synthetic spectra pertaining to Z-pinch dynamic hohlraum ICF capsule implosions. Section 4 applies the spectroscopic framework to Z-pinch dynamic hohlraum time-integrated K-shell argon spectra measured using a focusing spectrometer with spatial resolution. Finally, Section 5 summarizes the paper and discusses possible directions for future research.

## 2. General spectroscopic framework

Interpreting plasma spectra often requires either large amounts of time or the development of tailored algorithms for each application. To both automate the interpretation of plasma spectra and allow for simple adaptability, we have constructed a general computational framework for performing plasma spectroscopy based on the DAKOTA toolkit [4].

Designed as an engineering tool for finding extremum solutions, the DAKOTA toolkit includes several optimization algorithms and a noninvasive interface to outside computational models. The interface works by passing design variables to a computational model and returning evaluations of user-specified merit functions, or objective functions, to the DAKOTA toolkit. Using