X-Ray System Characterization

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We are implementing a forward model for x-ray system response that will enable us to predict the capability of our systems and allow us to choose optimal system parameters. The system model will include four components of the x-ray systems: source, transport, x-ray scattering, and detector. The components will be used in conjunction with the LLNL HADES program to model the x-ray system.

Project Goals

The overall project goal is to model the four components of the micro-XCT Xradia system. For FY2006, we focused on modeling the 150-kV Hamamatsu microfocus x-ray source. In FY2007, we will work on models for transport, scatter, and detection.

Relevance to LLNL Mission

A forward model for system response will enable us to better perform experiments for DNT, NIF and NHI.

FY2006 Accomplishments and Results

Our approach included coding of spectral algorithms and comparison of the algorithms with known empirical results. The first task was to validate a National Bureau of Standards x-ray source code called "Tubdet." Tubdet was originally implemented at LLNL on a VAX and ported to the Macintosh II in Absoft FORTRAN®. The latter version was used to evaluate Tubdet's performance on selected spectra. Comparing Tubdet to experimental spectra showed an overemphasis of the low-energy continuum and characteristic lines in the

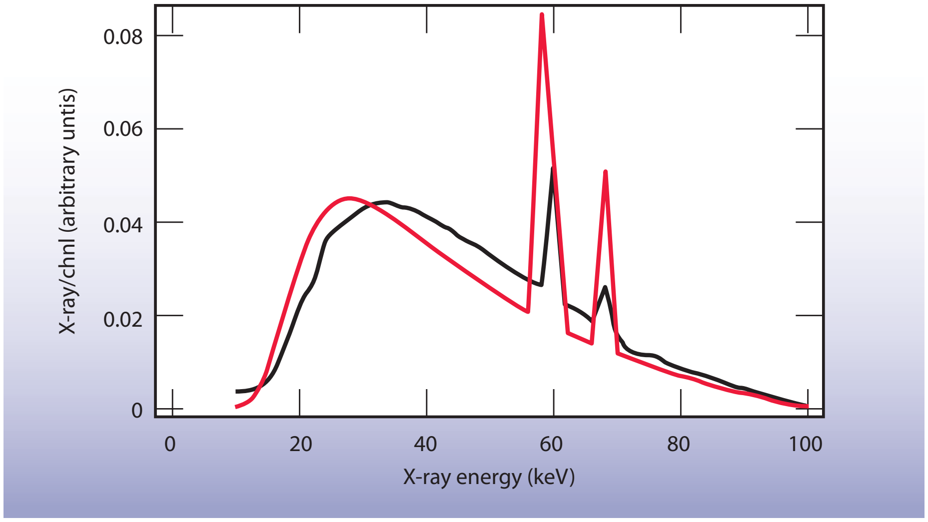

Figure 1. A Tubdet model spectrum (red) compared to an experimental spectrum. The overemphasis of low-energy continuum and very strong characteristic lines are typical of the Tubdet performance.

Tubdet-generated spectra. Figure 1 is a comparison of a Tubdet model spectrum and an experimental spectrum taken from a Toshiba x-ray tube head with 1.2-mm Al inherent filtration. Because of the poor match between the Tubdet model and the experimental data, Tubdet was determined not to be a good choice for modeling tube spectra.

We then changed our focus to two other models, Ebel and Finkelshtein. The names of the models refer to the first authors of the papers. Both models include separate descriptions of the generation of Brehmsstrahlung and characteristic lines within the material and the attenuation of the x-radiation on transport to the surface. We implemented the Brehmsstrahlung models of Ebel and Finkelshtein in Mathematica. Figures 2 and 3 show a comparison of the continuum models with the experimental data from a Machlett x-ray source. The model data has been filtered to match the attenuation of the 2.7-mm Al filtration of the Machlett tube. Both models appear to provide excellent spectral shapes for the continuum up to 120 kV.

Next, we focused our efforts on modeling the continuum with the characteristic lines of the spectra. Here we implemented the Ebel and Finkelshtein characteristic-line algorithms to generate the spectra. We compared the models with a selection of experimental data with differing characteristics lines (K and L), and anodes (Cu, Mo, W, and Au). Neither of the models consistently matched absolute intensity measurements. Model to experimental intensity ratios varied from 10% to 300% too high and the ratio of characteristics lines to the continuum varied by a factor of two.

Related References

1. Tao, G. Y., P. A. Pella, R. M. Rousseau, "NBSGSC—A FORTRAN Program for Quantitative X-Ray Fluorescence Analysis," NBS Technical Note 1213, April 1985.
2. Bhat, M., and J. Pattison, *et al.*, "Diagnostic X-Ray Spectra: A Comparison of Spectra Generated by Different Computational Methods with a Measured Spectrum," *Med. Phys.*, **25**, January 1998.
3. Ebel, H., "X-Ray Tube Spectra," *X-Ray Spectrometry*, **28**, pp. 255–266, 1999.
4. Finkelshtein, A. L., and T. O. Pavlova, "Calculation of X-Ray Tube Spectral Distributions," *X-Ray Spectrometry*, **28**, pp. 27–32, 1999.
5. Fewell, T. R., R. E. Shuping, and K. R. Hawkins, Handbook of Computed Tomography X-ray Spectra, Bureau of Radiological Health, U.S. Dept. of Health and Human Services, Rockville, Maryland, April 1981.

FY2007 Proposed Work

In FY2007, we will continue our work of modeling the source and begin work on a methodology to model the detector. The detector consists of a CsI scintillator mounted to a microscope objective. The scintillator/objective is optically coupled to a scientific grade charged-couple device. Each component of the detector will need to be modeled for an overall detector model. We will also include existing transport codes and x-ray scatter models to complete the model methodology for the four components. We will use HADES to generate an overall model of the system.

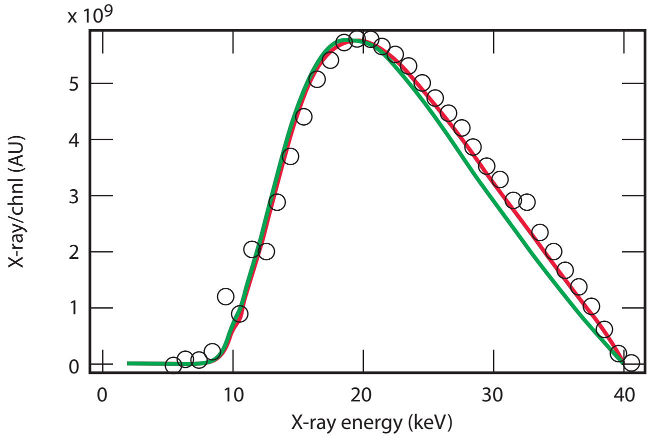

Figure 2. Measured spectra data (circles) compared to Ebel (red) and Finkelshtein (green) models at 40 kV. Measured data from Fewell handbook.

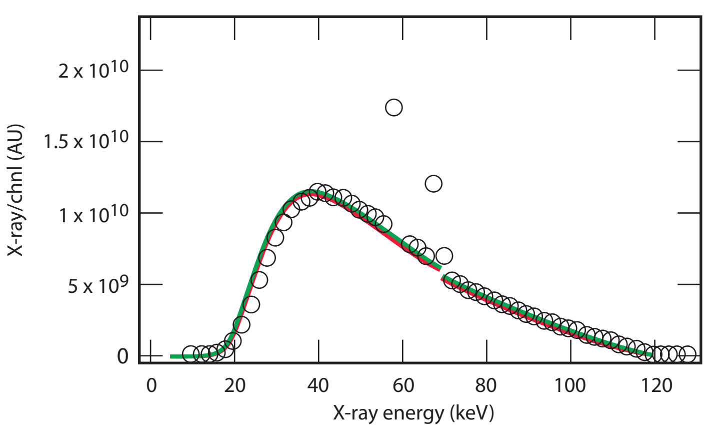

Figure 3. Measured spectra data (circles) compared to Ebel (red) and Finkelshtein (green) models at 120 kV. Measured data from Fewell handbook.