Relative Characterization of Low-Energy X-Ray Response of Kodak BioMax®-MS (BMS) Photographic Film

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Abstract

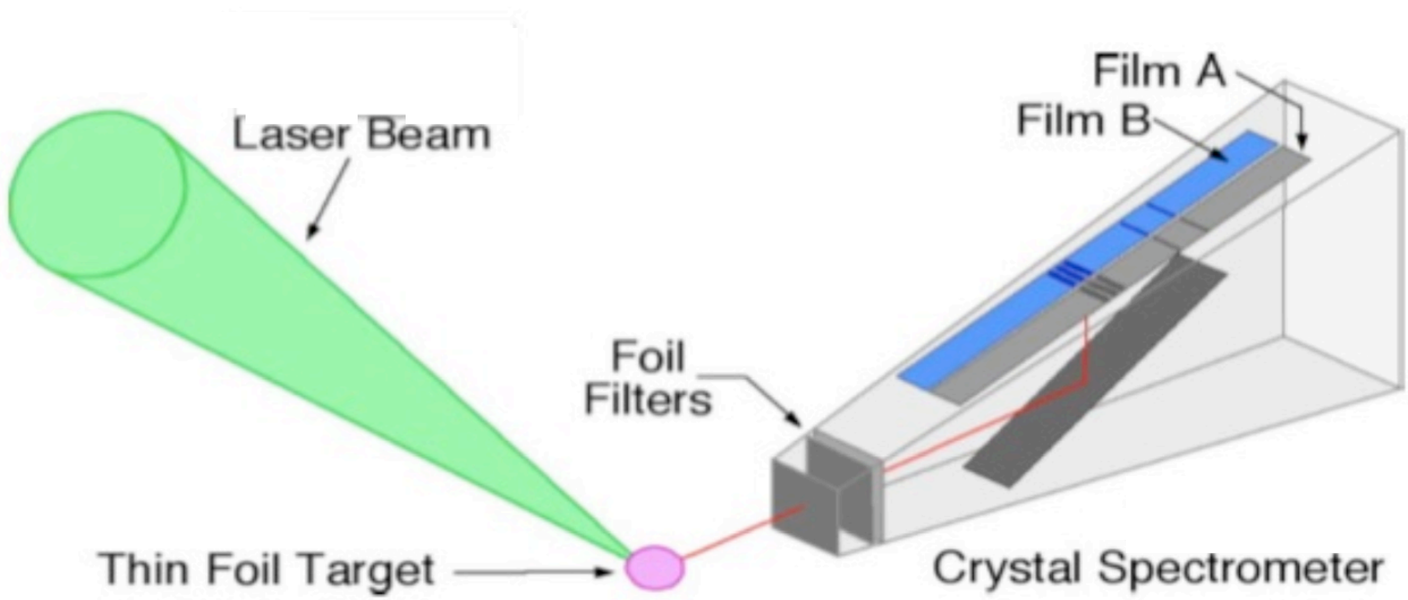
For the past few decades, the preferred film used for radiography of high energy density physics (HEDP) experiments has been the high-sensitivity, double emulsion, Kodak Direct Exposure Film® (DEF). This film has been well studied and characterized.[1] However, Kodak has ceased production of the film, resulting in a limited and aging film supply. This has led the inertial confinement fusion (ICF) and HEDP communities to search for a viable alternative. Current collaborative efforts are being aimed into providing an absolute characterization of BMS film. Presented here is a characterization of the response curve of BMS at low energies, using DEF as a standard.

[1] B. L. Henke, J. Y. Uejio, G. F. Stone, C. H. Dittmore, and F. G. Fujiwara, "High-energy x-ray response of photographic films: models and measurement," J. Opt. Soc. Am. B 3, 1540-1550 (1986)

Objectives

- Acquire data for film response at Fluorine and Magnesium x-ray emission energies
- Ultimately provide relationship between optical density (OD) and photons per square micron to complete BMS film model

Experimental Setup

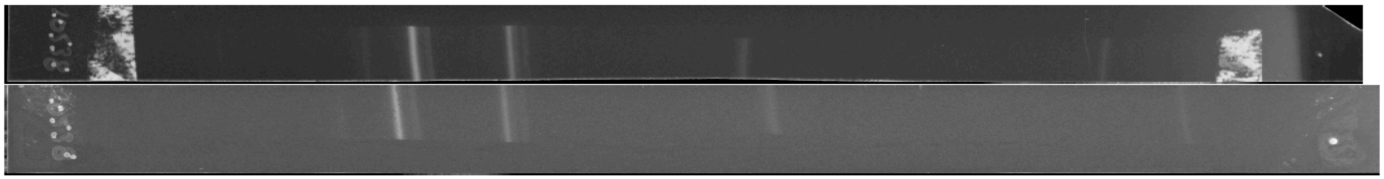


Shot Information

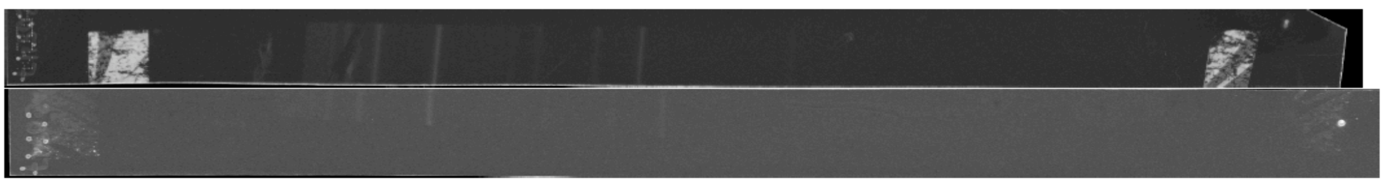
Shot	IR (J)	Green (J)	Target Material	Filter	Filter Thickness
20538	121	57	Mg	Be	$12\mu m$
20547	129	66	C_2F_4	None	N/A
20548	70	27	C_2F_4	None	N/A

- Be filter was used to reduce noise in the Mg plasma emission
- Filter was removed to prevent large attenuation of the low energy x-rays from Teflon
- The lack of a filter accounts for the higher noise levels in the C_2F_4 spectrums

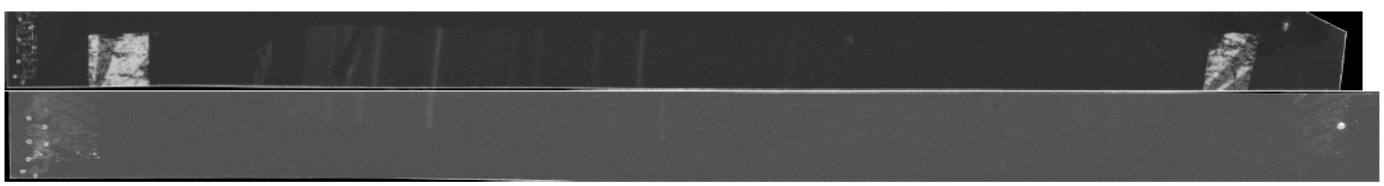
Shot Data



Shot: 20538, top: BMS, bottom: DEF



Shot: 20547, top: BMS, bottom: DEF



Shot: 20548, top: BMS, bottom: DEF

Optical Density Measurements

- The optical density of x-ray film is defined as

$$OD = log_{10}(\frac{I}{I_0})$$

- I/I_0 is given by the pixel value (PV) of the scanned film minus any base-plus-fog (BF) contribution
- The optical density for the microdensitometer employed is given by

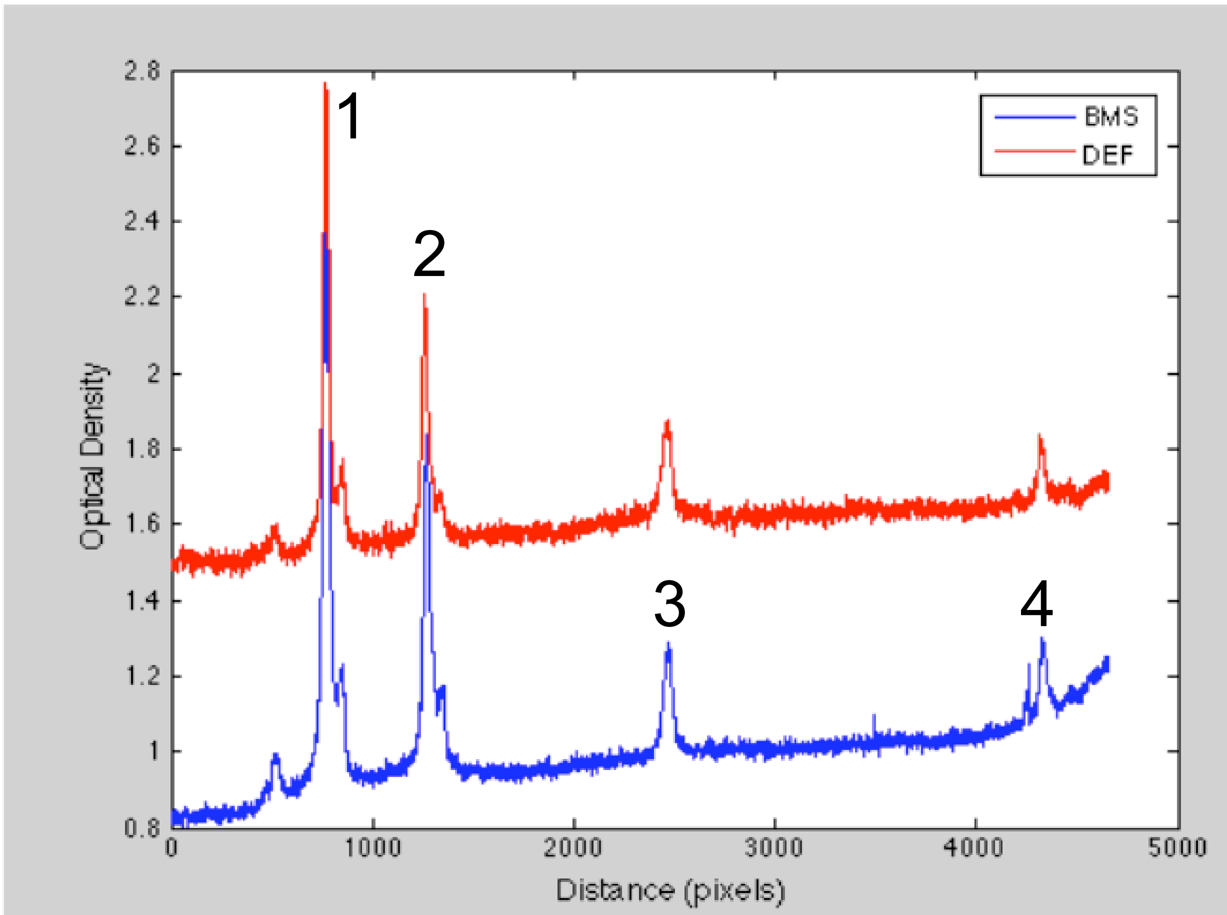
$$OD = \frac{PV - BF}{800}$$

- PVs were measured from averaged line-out profiles of each spectrum

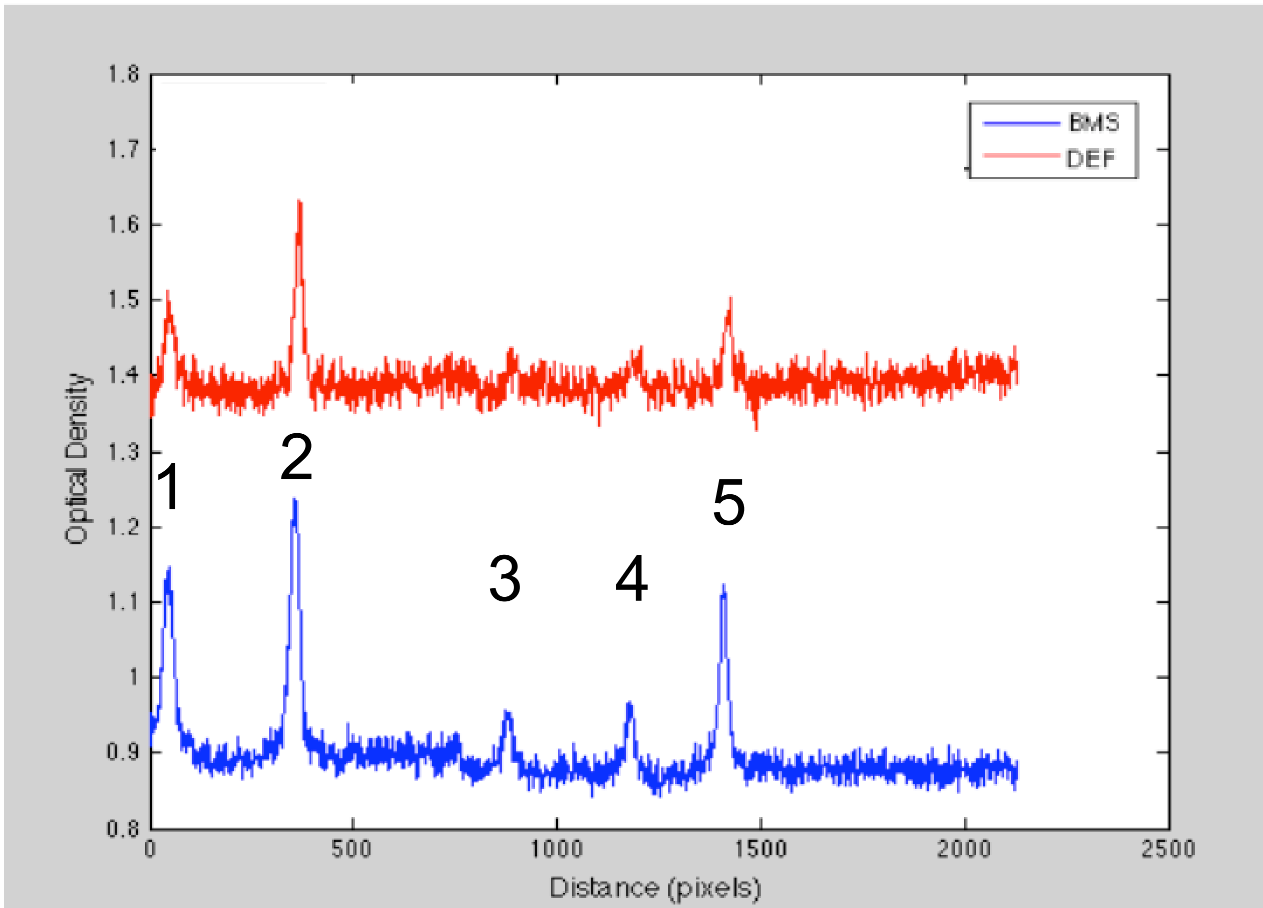
Spectrum Profiles

- Profiles were averaged for uniformity
- Number of line profiles varies between shots due to variations in film orientation between shots
  - Mg (shot 20538): 250 line-out profiles acquired
  - Teflon (shots 20547 and 20548): 200 line-out profiles acquired
- BF contributions measured from 100 line-out profiles taken in unexposed locations of each film

Magnesium Spectrum



Fluorine Spectrum (SN20547)



Methodology

- Identification of peak energy is essential to provide parameters necessary for film model from response curve data
- Expected dispersion of spectral lines can be obtained given geometry of setup and Bragg's law

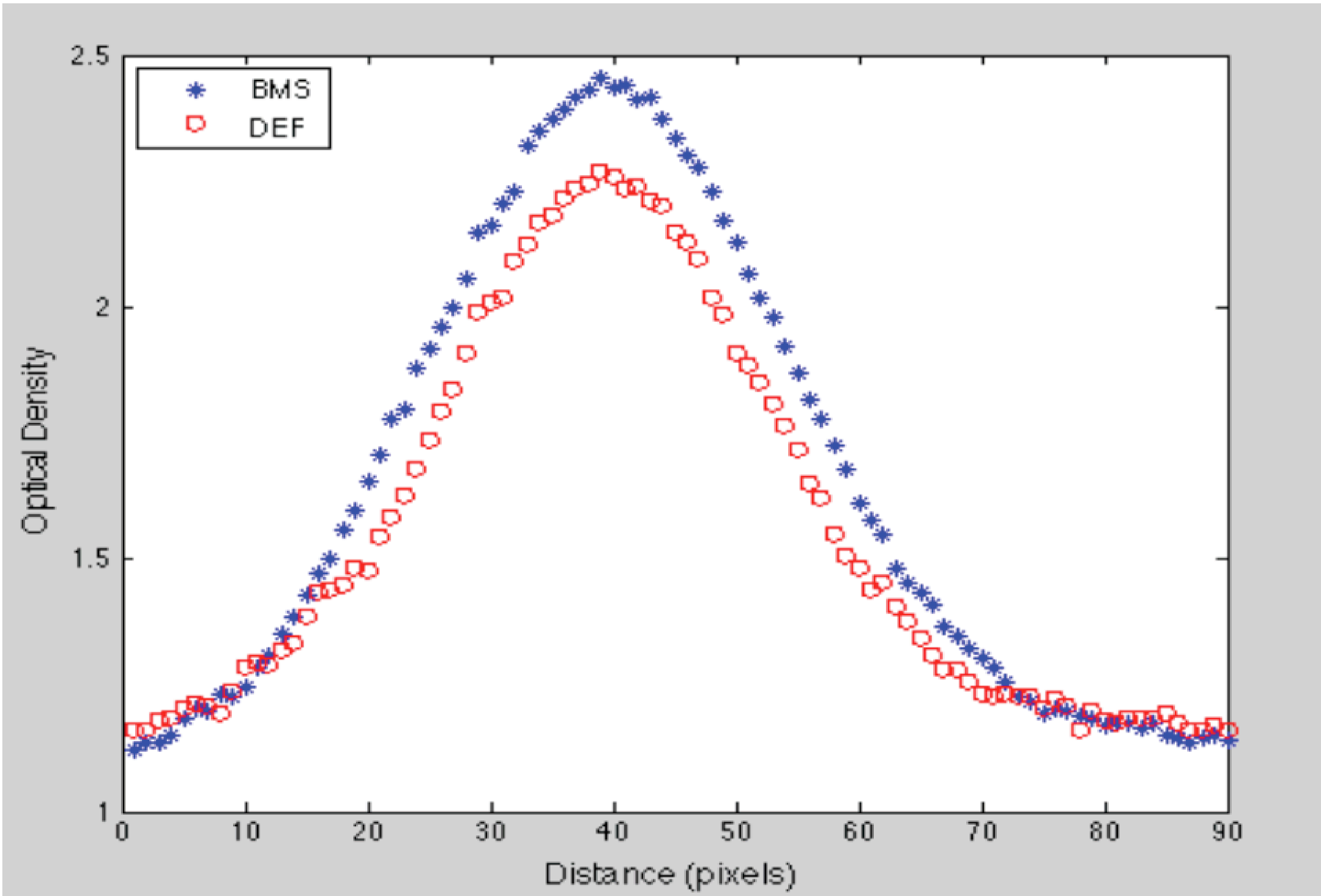
$$n\lambda = 2d\sin(\theta)$$

- Crystal used for spectrometer, Tiap (100), has 2d = 25.9 μm
- Second order spectral dispersion can also be obtained and used to help identify peak energies
- Expected spectral dispersions can then be compared to averaged line-out spectrum of Magnesium and Fluorine to determine specific peak energies

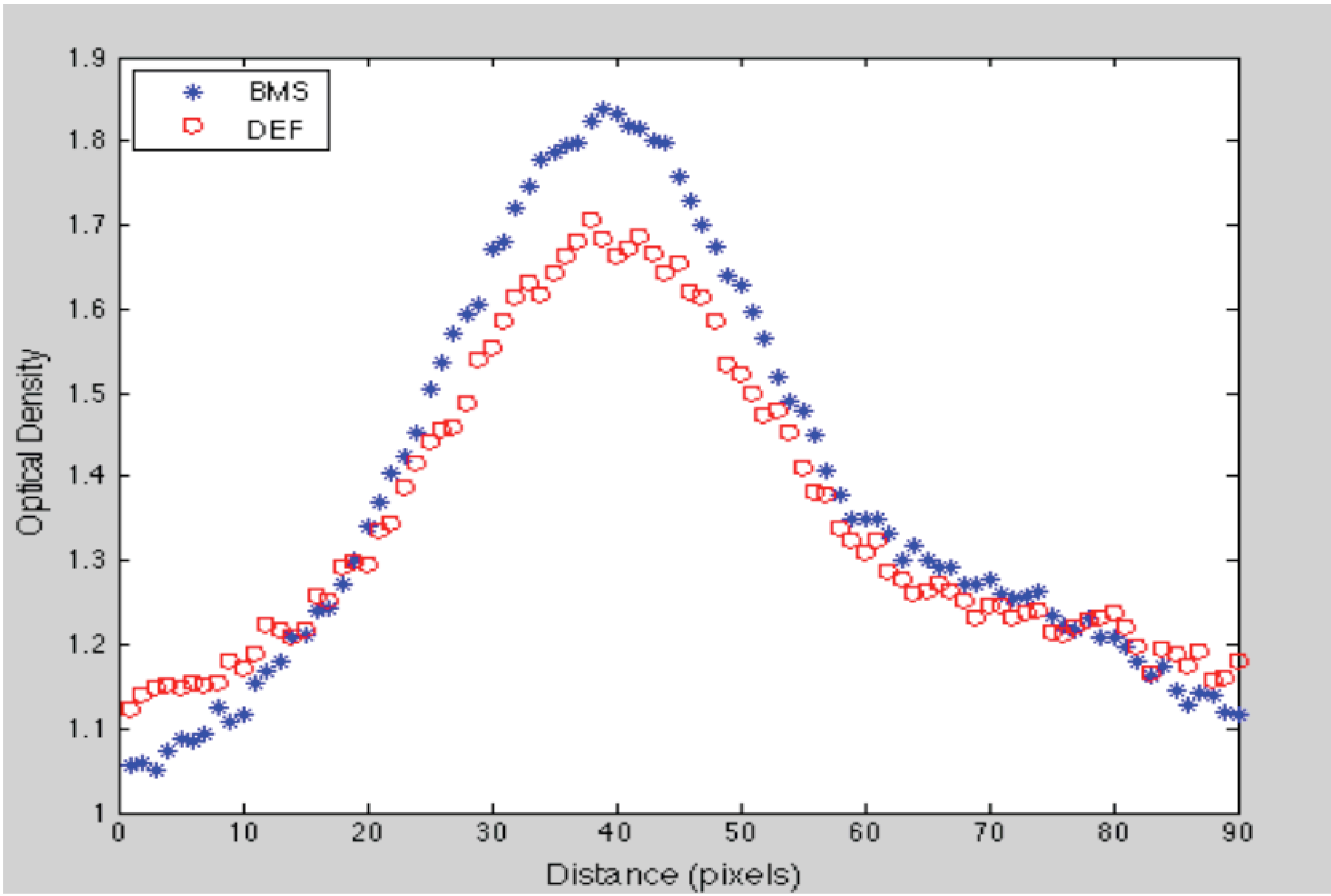
Response Curves

- Assumed that the individual spectral line on film is created by photons of the same energy
- Compared spatially cropped peaks from BMS and DEF for each shot
- Size of each crop was kept equal for specific peaks on both films to achieve a one-to-one correspondence between values

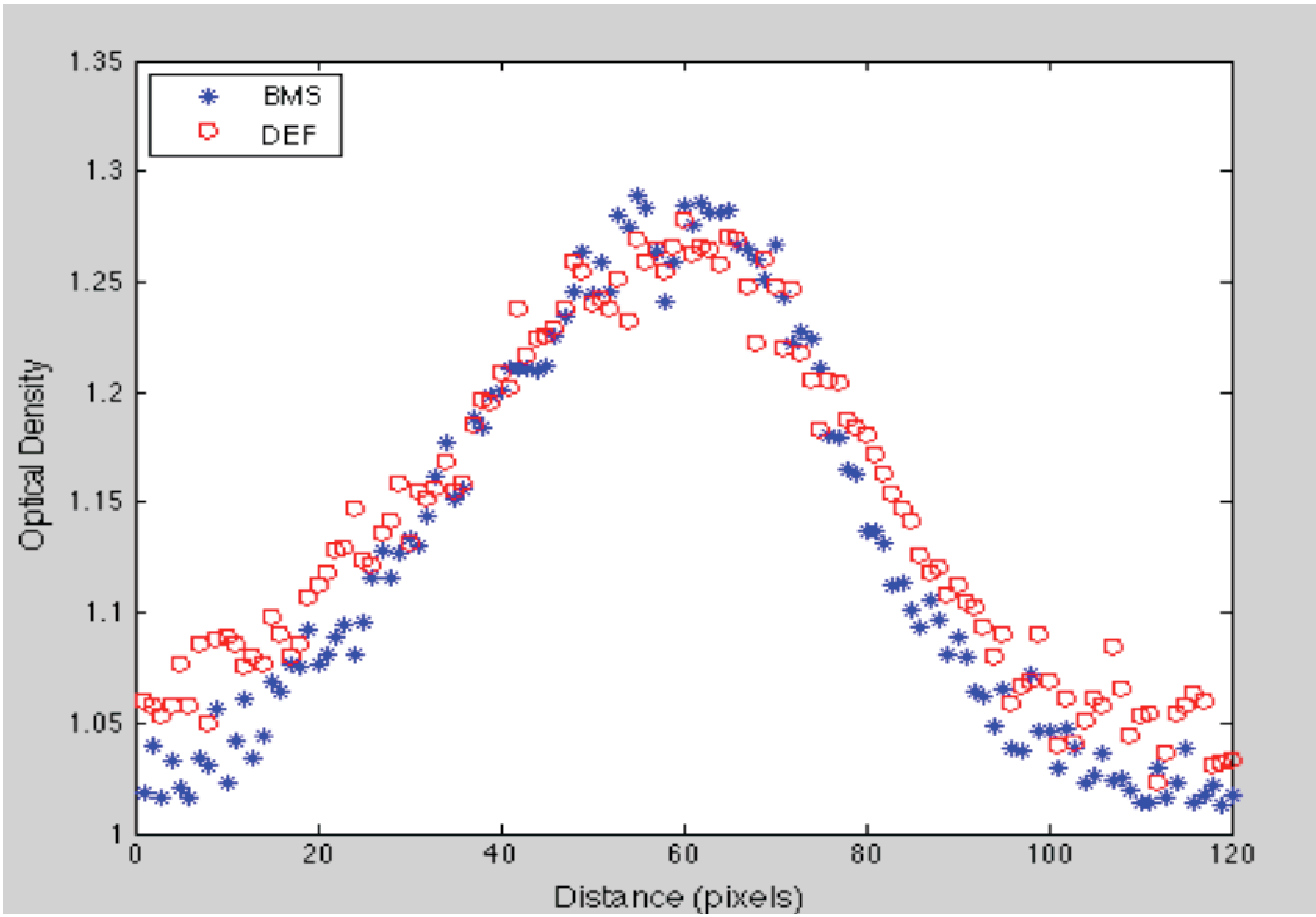
Magnesium Peak 1



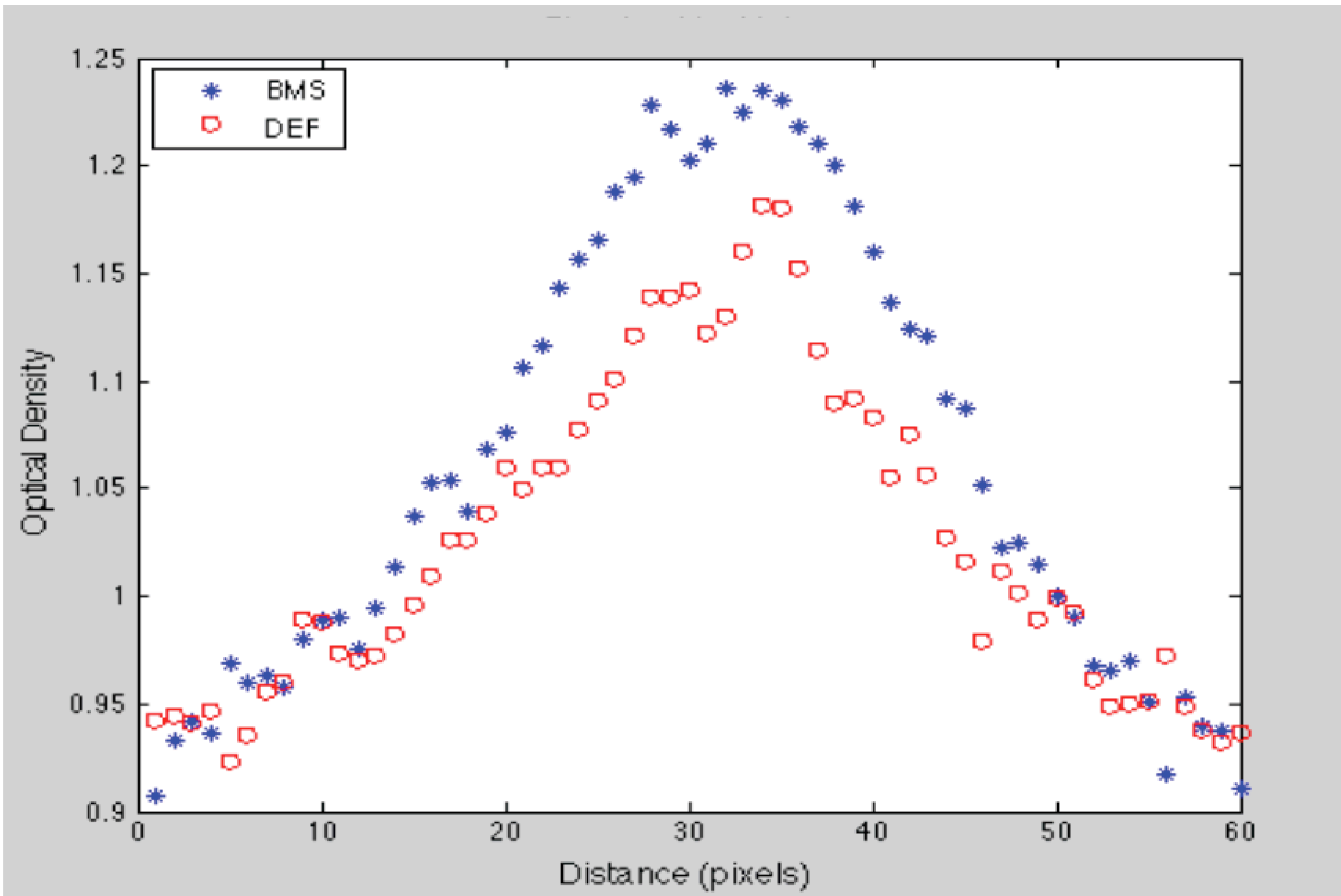
Magnesium Peak 2



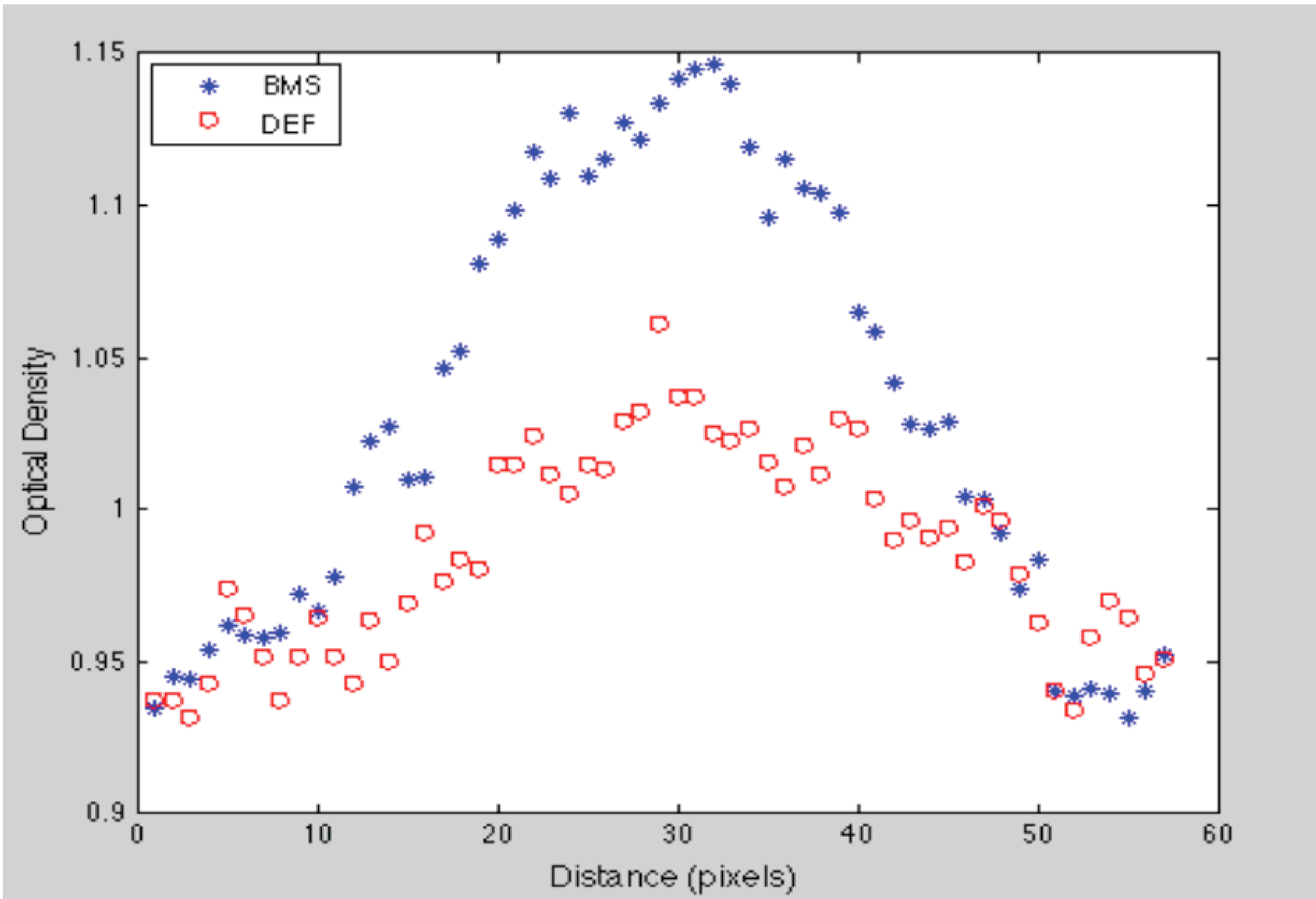
Magnesium Peak 3



Fluorine Peak 2



Fluorine Peak 5



Conclusions and Future Directions

- Spectral peak energy needs to be identified precisely for each peak
- Relative calibration of BMS film response with respect to DEF film response may not be applicable at the low x-ray energies used for this study due to breakdown of DEF model in the low energy regime