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Abstract

In order to better understand laser plasma interactions an effort is being made to obtain quantitative temporally and spectrally resolved measurements in the low energy x-ray region using a soft x-ray streak camera. X-ray mirrors and absorption filters are employed to perform broad band spectroscopy measurements. The components of these systems have now been calibrated and the results of these measurements will be reported. The calibration of the x-ray streak camera, needed to made absolute flux measurements, cannot be measured using the usual x-ray sources because backgrounds interfere with the operation in the D.C. mode. Repetition rates and duty cycles are too low to complete calibration on a D.C. source in a reasonable time using the camera in a pulsed mode. As an alternative the calibrations are being done using a

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Nd(YAG) laser producing pulses of ~1 joule having pulse widths of ~150 ps. The x-ray flux is being monitored by three x-ray diodes having Al photocathodes. Absorption filters having the same thicknesses as those used with the streak camera provide x-ray energy responses of the diodes which approximate the channel responses of the streak camera. By comparing the charge from the diode with the integral response of the streak camera, the camera response can be measured. Preliminary results will be discussed.

Figure Captions

Figure 1. Schematic of the calibration of the soft x ray streak camera (SXRSC)1. The monojoule laser facility at LLL is used to provide a pulsed x ray source by irradiating slab targets of various Z materials. The 1.06 μm light pulses are incident normal to the target and have energies of ~ 1 joule and pulse widths of ~50 ps. The x ray fluence is measured using three calibrated x ray diodes (XRD) mounted on a port whose angle is 45° from the target normal. Three energy channels are defined using thin x ray filters. The x ray streak camera is located at 45° from the target normal to the XRD system. Three x ray energy channels similar to the three XRD channels are defined using the same absorber foil materials and x ray mirrors which descriminate against x rays about the filter absorption edge. These channels are similar to those used on the SXRSC system fielded on the Argus laser system.[2] The calibration is done by comparing the signals from similar channels in the XRD and SXRSC system.

Figure 2. Calibration of the absorber foils. The x ray transmission of the absorber foils are measured using characteristic K- and L-x ray lines produced by proton excitation. The curves are a best fit to the data using the mass absorption coefficients of the various elements as given by Henke and Schattenburg.[3]

Figure 3. A calibration curve for an Al XRD. The data shown are taken using proton-induced (LLL) and electron-induced (EG&G) line sources. The solid curve is a fit to the data assuming the response is proportional to E μ(E) where μ(E) is the x ray absorption coefficient for Al_2O_3.[4] The data are fit above and below the oxygen absorption edge independently. The functional form has been shown to be a fair approximation to photo-electron energy dependence[5] especially over a limited energy range and provides reasonable agreement to this data.

Figure 4. Measured reflectivities of the x ray mirrors. The data below 1 keV are taken using proton-induced characteristic line emission, above 1 keV a continuous x ray spectrum. The curves are calculated using a semiclassical calculation[6] adjusted to fit the data.

Figure 5. Comparison of the measured channel response for corresponding channels of the XRD system and SXRSC system. The responses have been normalized to unity at their peak. The 2500 Å carbon filter in the three XRD channels are used to approximate that part of the response of the SXRSC system due to transmission through the carbon substrate of the transmission photocathode.

Figure 6. Measured x ray fluence from various targets. The fluences are obtained from the XRD output using the response of the XRD channels averaged over the energy bands shown assuming a flat distribution. It is seen that the fluence levels above 280 eV are greatly affected by line emission in the various channels. For the vanadium channel from 280 eV - 510 eV the average fluence decreases by an order of magnitude or greater by changing the Z of the target by one from Z = 22 (Ti) to Z = 23 (V). The change shifts the L-emission band of the stripped V ions above the L-III absorption edge of cold V. Spectra of laser excited Ti and Fe have shown similar effects.

Figure 7. Example of the streak record from a Ti target. The film record is shown on the left. On the right a two-dimensional digital contour plot of the film record. The vertical lines show the approximate position of the three channels on the streak record. The data are integrated along these bands and background is subtracted to obtain the integrated signal from the SXRSC.

Figure 8. Equations used to reduce the x-ray data to determine the average response of the x-ray streak camera.

Figure 9. Preliminary values for the average response of the channels from various targets for a 300 Å Au transmission photocathode on a 2500 Å carbon substrate. The exposure units are arbitrary. The errors indicate shot to shot variation only. The preliminary values show that the calibration factor may depend upon the laser target. The spectrum varies from target to target which may cause some of the scatter in the calibration. More detailed analysis which includes measuring the relative intensity of the line spectra could reduce the variation in the calibration factors. Questions concerning cathode to cathode variations of the sensitivity, photocathode stability, and dependence on photocathode material need to be investigated.

Figure 10. Streak records from a Ti target using the calibration factors given in Fig. 9.

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SCHEMATIC OF THE SOFT X–RAY STREAK CAMERA CALIBRATION

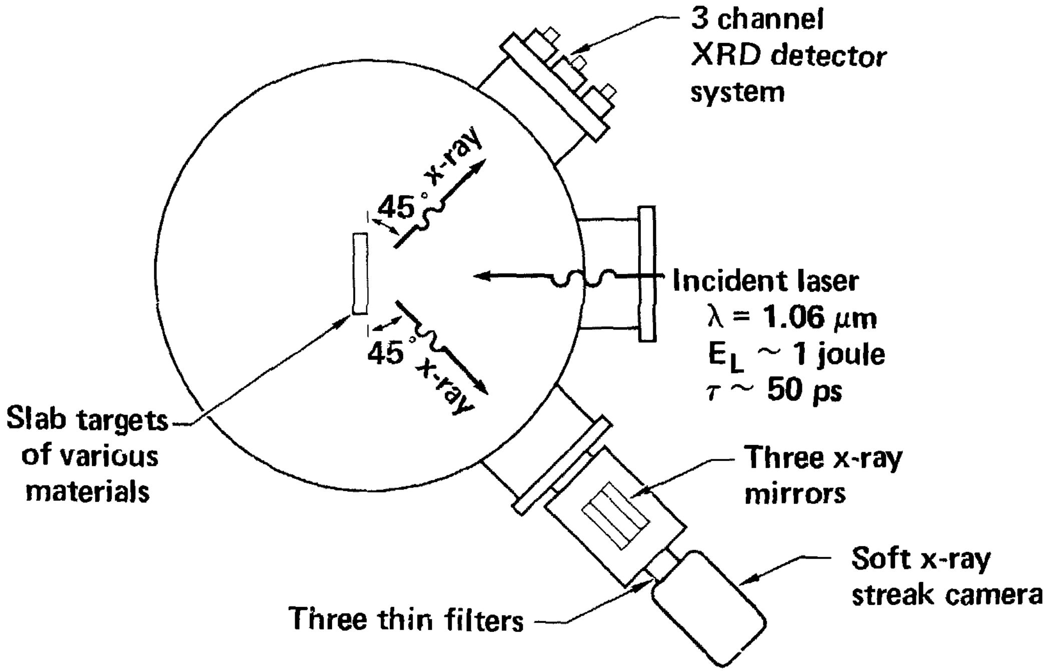

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Fig. 1

MEASURED FILTER TRANSMISSION

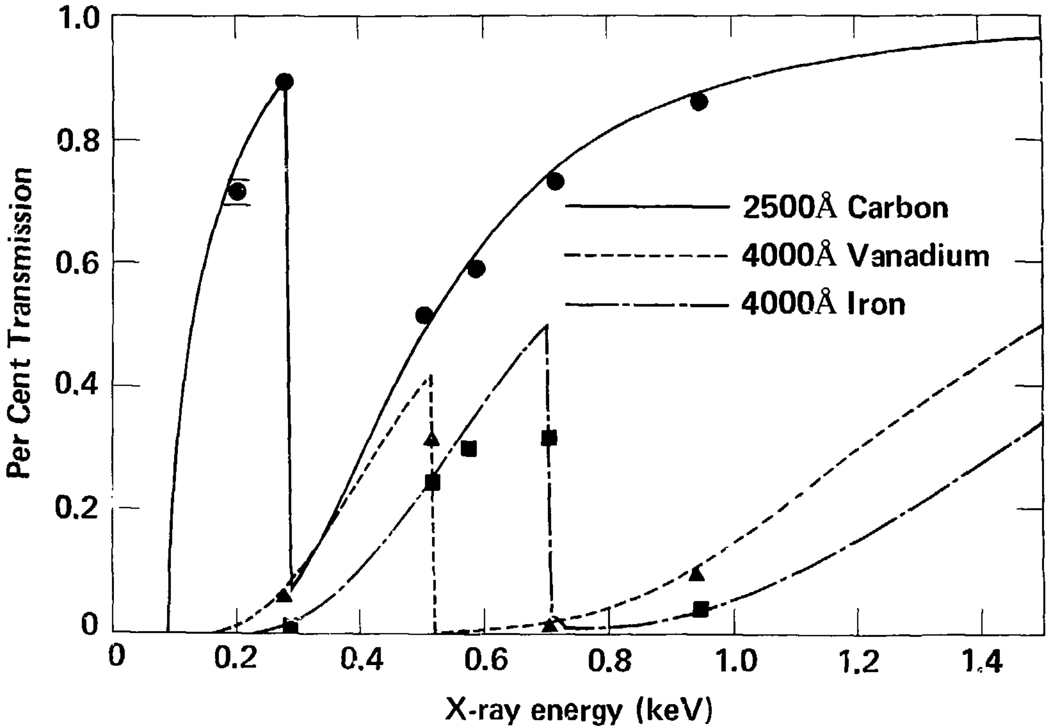

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Fig. 2

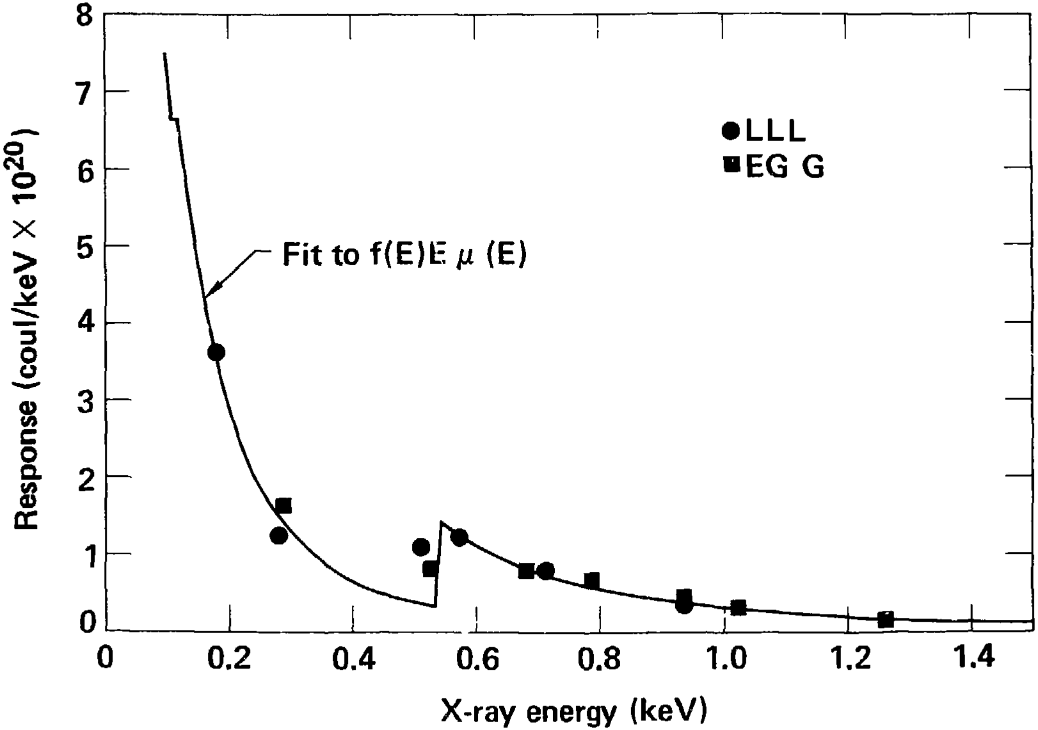

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Fig. 3

CALIBRATION OF THE X-RAY MIRRORS FOR THE SXRSC CHANNEL

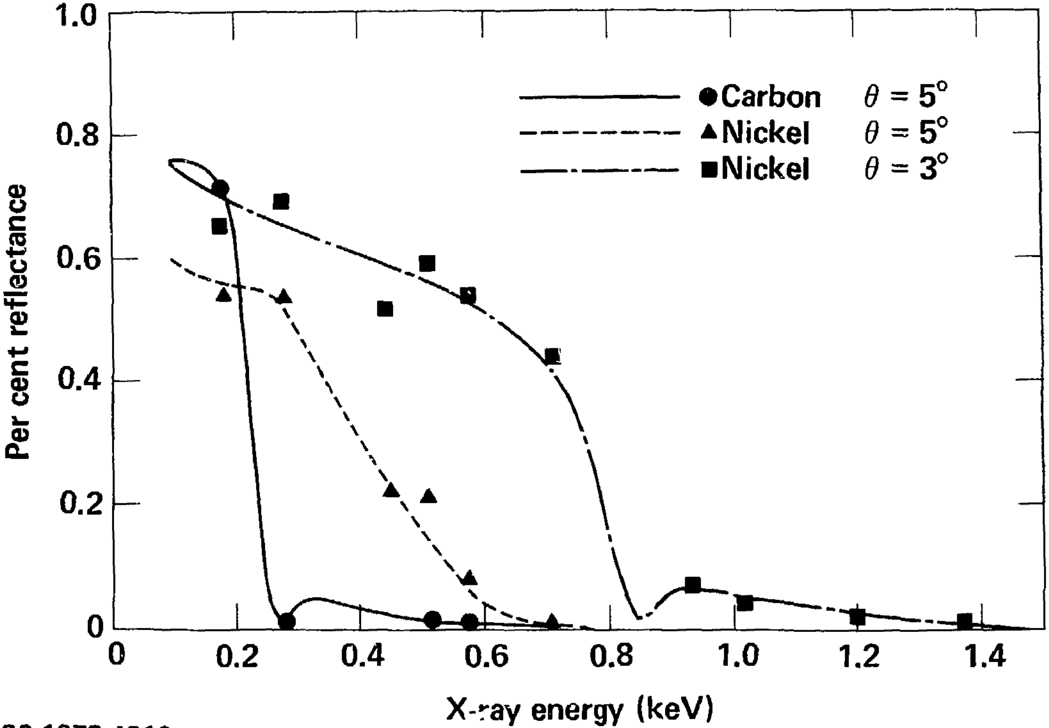

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Fig. 4

COMPARISON OF CHANNEL RESPONSE

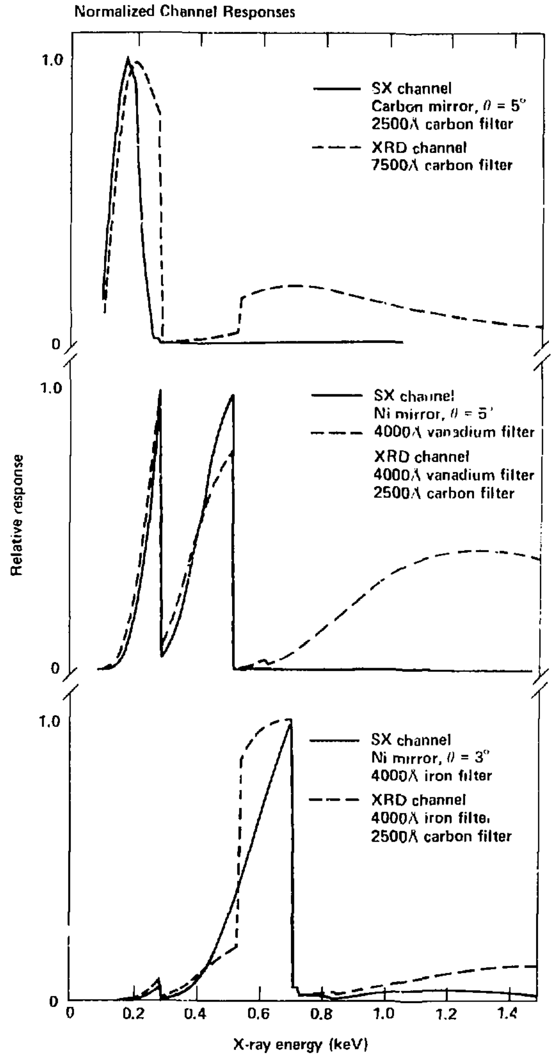

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Fig. 5

MEASURED X-RAY SPECTRA FROM VARIOUS SLAB TARGETS ON THE MONOJOULE

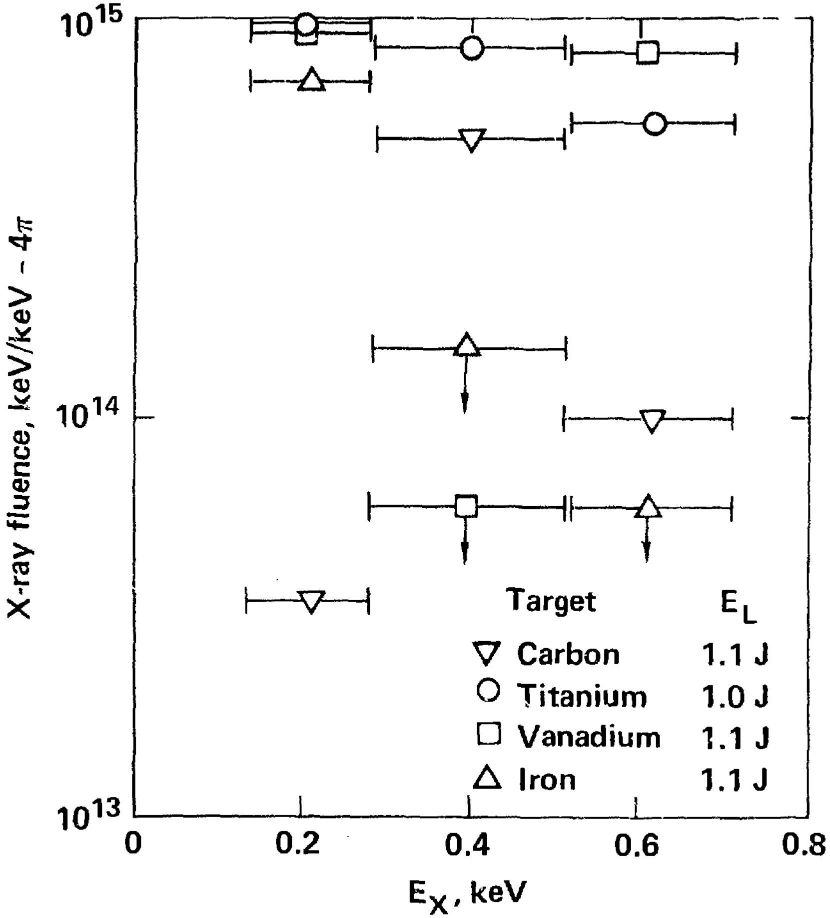

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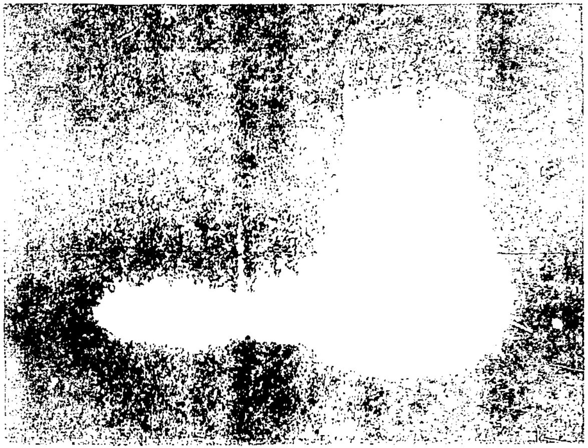
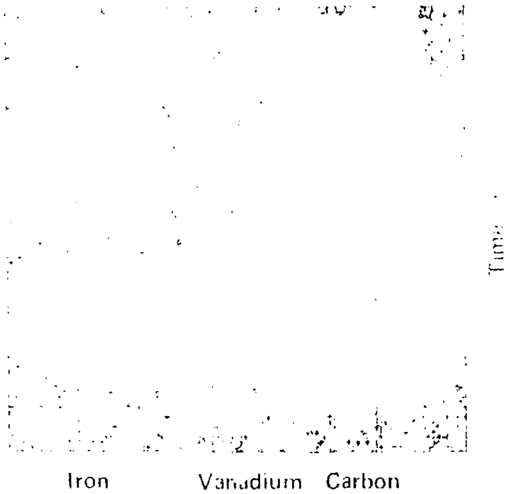
Fig. 6

SXRSC DATA FROM A Ti SLAB TARGET

Film image of
soft x-ray streak data



Digitized contours of
film record



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Calculation of the Calibration Factors

The signal from an x ray detector is given by

$$S = \int_0^\infty dE\ R(E)\ F(E) = \sum_i R_i\ F_i\ \Delta E_i \qquad (1)$$

where

R(E) = the energy dependent detector response.

F(E) = the x ray fluence into the detector.

If the signal results from a small energy region ΔE, the signal from two different detection systems viewing the same x ray spectrum are related by

$$\frac{S_1}{S_2} = \frac{\Omega_1 R_1\ \Delta E_1}{\Omega_2 R_2\ \Delta E_2} \qquad (2)$$

where the subscripts denote the two detectors. Ω is the correction for differences in solid angle for the two detectors. If one of the detector responses is known, other detector response can be computed using eq. (2). For the SXRSC, the response is given by

$$R_{SX} = \frac{S_{SX}}{S_{XRD}}\ \frac{\Omega_{XRD}\ \Delta E_{XRD}}{\Omega_{SX}\ \Delta E_{SX}}\ R_{XRD} \qquad (3)$$

where the signals for similar channels in the SX system and XRD system are compared.

To correct the response for signal from energies other than the channel of interest eq. (1) can be used if i = no. of x ray channels. (3 in this experiment). The signal from the jth detector is

$$S_j = \sum_i \overline{R}_{ji}\ F_i\ \Delta E_i \qquad (4)$$

or in matrix form

$$S = RF$$

$\overline{R}_{ji}$ is the average response in detector j for the energy bin ΔE_i. The average x ray fluence can be calculated by multiyplying both sides of R^{-1} so that

$$F = R^{-1}\ S \qquad (5)$$

Fig. 8

Using these average fluences eq. (4) can be solved for $\overline{R}_{jj}$ giving

$$\overline{R}_{jj} = \frac{S_j}{\alpha \, F_j \, \Delta E_j} \qquad (6)$$

where

$$\alpha = 1 + \sum_{i \neq j} \frac{\overline{R}_{ji} \, F_i \, \Delta E_i}{\overline{R}_{jj} \, F_j \, \Delta E_j}$$

α is a factor which measures the percentage of the response not originating from the primary energy bin. For most of the values quoted below the contributions are less than 15%. The sensitivities calculated by eq. (3) and eq. (6) agree within 25%.

Preliminary Response Calibrations

Channel Response (exposure/kev/cm^2/psec)	Target Titanium	Vanadium	Iron	Carbon	Avg.
R_{carbon} ($\times 10^{-3}$)	6.3 ±1.8	6.2 ±1.9	9.0 ±1.7	6.6 ±1.0	7.0 ±1.0
$R_{vanadium}$ ($\times 10^{-4}$)	1.9 ±0.6	-	-	0.6 ±0.1	1.4 ±0.8
R_{iron} ($\times 10^{-4}$)	5.3 ±3.1	5.0 ±2.9	-	3.6 ±0.3	4.8 ±2.6

Fig. 9

MEASURED X RAY FLUX FROM Ti

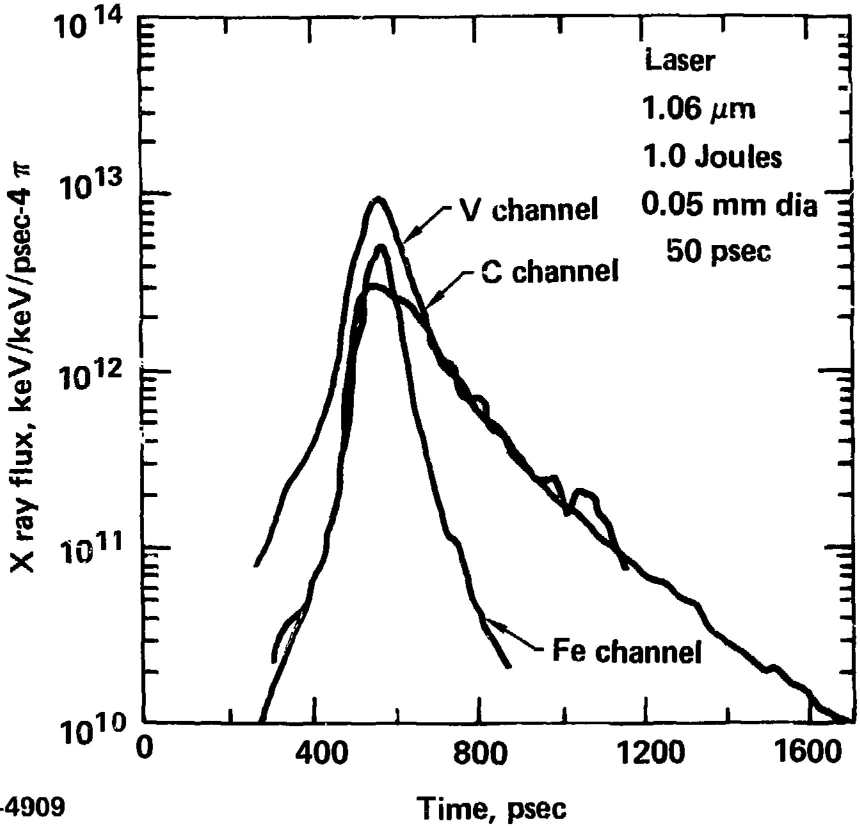

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Fig. 10