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HYPER FILTER-FLUORESCER SPECTROMETER

FOR X-RAYS ABOVE 120 keV

By: Ching L. Wang, USA
2517 Regent Road
Livermore, Calif. 94550

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HYPER-FILTER-FLUORESCER SPECTROMETER
FOR X-RAYS ABOVE 120 keV

Background of the Invention

5 The invention relates generally to filter-
fluorescer combinations for measuring short bursts of
high-fluence x-rays, and more particularly, it relates to
measuring such bursts in energies above 120 keV, where no
practical material absorption edges exist for conventional
filter-fluorescer techniques. It is a result of Contract
10 No. W-7405-ENG-48 between the United States Department of
Energy and the University of California for the operation
of the Lawrence Livermore National Laboratory.

To determine the fluence in different energy bands
below 120 keV emitted by a high-fluence x-ray source, the
15 prior art uses a pre-filter, a fluorescer, and a
post-filter, all with properly selected absorption edges.
The responses of this combination are shown in graphs a-d
of Figure 1. With the pre-filter absorption edge E_{PRF}
determining the upperbound of the energy band of interest,
20 and the fluorescer E_F and post-filter E_{POF} absorption
edges coinciding with the lower bound of the energy band,
the result is a joint response function with a sharply
defined high transmission in the energy band $E_F < E <$
 E_{PRF} , a sharp transmission fall-off for energies $E < E_F$

and markedly attenuated transmission for energies $E > E_{PRF}$. As used herein, an absorption edge is the energy corresponding to an absorption discontinuity in the intensity of an x-ray absorption spectrum, which gives the appearance of a sharp edge in such a spectrum. Also, an energy band is a zone between two different energies in the x-ray spectrum. Combinations to achieve a sharply defined type of high transmission are described in the papers "Filter Fluorescer Experiment on the Argus Laser" (preprint UCRL-81471) published October 10, 1978, by H. N. Kornblum et al; and "A Ten Channel Filter-Fluorescer Spectrometer" (preprint UCRL-81477) published October 31, 1978, by B. L. Pruett et al.

In a paper entitled "Filtered Detector Arrays for Single Pulsed Photon Measurements Above 100 keV" (preprint UCRL-80314) published November 9, 1977, by K. G. Tirsell and H. C. Catron, the authors show that the spectrometer range may be extended to x-ray energies around 250 keV by replacing the filter-fluorescer combination with a simple filter-detector combination; i.e., a combination including only filters and detectors. The reason for this replacement in prior art is that above 120 keV there are no practical absorption edges available for conventional filter-fluorescer techniques. As shown in Figure 2, the result with the simple filter-detector combination is a response function having an energy transmission band of ~~2000~~²⁰⁰ to 5000 keV width. This bandwidth, however, is too broad for energy discrimination purposes. Furthermore, one or more undesirable windows (such as W1 and W2 of Figure 2) appear at lower bands corresponding to lower absorption edges of the filter material. These windows introduce a large error in the detector signal when the spectrum being measured is a rapidly decreasing function of the x-ray energy. This limitation is particularly troublesome when

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measuring x-rays from a gold source, since the windows occur in the region where the gold K-lines are present.

5 These problems related to the filter-fluorescer technique, establish the need for a well-defined response function when measuring high-fluence x-ray energies above 120 keV..

10 It is, accordingly, a general object of the invention to measure high-fluence x-rays above 120 keV energy, where there are no practical absorption edges available, for conventional filter-fluorescer techniques.

Another object of the invention is to improve the channel response function in measuring high-fluence x-rays above 120 keV by narrowing the energy transmission band to a width suitable for energy discrimination purposes.

15 Another object is to eliminate undesirable response windows in measuring high-fluence x-rays above 120 keV and to ensure that these windows vanish in the region where the gold K-lines appear..

20 Other objects, advantages, and novel features of the invention will be apparent to those of ordinary skill in the art upon examination of the following detailed description of a preferred embodiment of the invention and the accompanying drawings.

Summary of the Invention

25 In brief, the invention relates to a method and apparatus in which a new filter-fluorescer combination to measure short bursts of high fluence x-rays above 120 keV is utilized. By predetermining the associated absorption

edges of this combination so that the absorption edge of the fluorescer is equal to the post-filter absorption edge and more than the pre-filter absorption edge, the joint response function in the band range $E_{PRF} < E < E_F$ is
5 virtually 0 and the response for bands greater than E_F is found to be well defined and enhanced.

One important difference between the prior art and the present invention is that the absorption edges in the prior art are preselected so that $E_{PRF} > E_F = E_{POF}$
10 while in the invention $E_{PRF} < E_F = E_{POF}$.

Brief Description of the Drawings

Figure 1 is a graph showing the pre-filter and post-filter transmissions, the fluorescer cross-section (cross section is a quantity which is proportional to the probability of x-ray interaction in the fluorescer and is
15 measured as an area), and the joint response of a conventional filter-fluorescer spectrometer;

Figure 2 is a graph showing the response function of a simple filter-detector spectrometer channel;

20 Figure 3 is a schematic diagram of a filter-fluorescer spectrometer;

Figure 4 is a graph showing the pre-filter and post-filter transmissions, the fluorescer cross-section and the joint response of a hyper filter-fluorescer
25 spectrometer;

Figures 5 and 6 are additional graphs showing the response function of two hyper filter-fluorescer spectrometer channels; and

Figure 7 is a graph showing the response function of four hyper filter-fluorescer spectrometer channels with different peak positions at 150, 200, 250 and 300 keV.

Description of the Preferred Embodiment

5 Turning now to the drawings, Figure 1 shows the response of a conventional spectrometer with a filter-fluorescer combination having an absorption edge E_{POF} less than absorption edge E_{PRF} and equal to absorption edge E_F . This conventional combination
10 results in a sharply defined high transmission in the energy band $E_F < E < E_{PRF}$ below 120 keV. Figure 2 shows a conventional single-filter spectrometer channel where the high transmission occurs above 120 keV, in an energy band of ~~2,000~~²⁰⁰ to 5,000 keV, which is too broad for
15 *CLW*
6/19/81 energy discrimination purposes. This is a prior art attempt to measure short bursts of high-fluence x-rays above 120 keV.

Reference will now be made in detail to the present preferred embodiment of the invention. Referring
20 to Figure 3, a filter-fluorescer spectrometer combination is used for measuring high-fluence x-rays above 120 keV. Still referring to Figure 3, the filter-fluorescer spectrometer 8 consists of a pre-filter 10 having a predetermined absorption edge E_{PRF} , a post-filter 30
25 having a predetermined absorption edge E_{POF} which is more than E_{PRF} , a slab of fluorescer material 20 having a predetermined absorption edge E_F which is equal to E_{POF} , a detector 60 and two collimators, 40 and 50. The pre-filter 10, post-filter 30 and fluorescer 20 are made of
30 selected materials in order to obtain the required absorption edges. The pre-filter 10 transmits the high x-ray flux emitted from an x-ray source toward the

fluorescer 20. The collimator 50 receives this x-ray flux from the pre-filter 10 directing it as a parallel beam toward the fluorescer 20. The fluorescer 20 is oriented so as to receive the x-ray flux coming from the collimator 50 and re-emit it as K-fluorescence lines toward the post-filter 30. The post-filter 30 will improve the signal-to-noise ratio by transmitting preferentially the K-fluorescence lines E_K of the x-ray flux while absorbing unwanted x-rays such as higher shell fluorescence or background x-rays. The collimator 40 will direct the emerging x-ray flux, as a parallel beam, from the post-filter 30 toward the detector 60.

By selecting the thickness and material of the pre-filter 10, post-filter 30 and fluorescer 20, the band range $E_{PRF} < E < E_F$ can be adjusted to ensure that the response function vanishes in the region where the gold K-lines appear when measuring x-rays from a gold x-ray source. This is accomplished by imposing $E_{PRF} < \text{gold K-lines} < E_F$ to assure that no gold K-lines between E_{PRF} and E_F energies will be detected by the x-ray detector 60, thereby avoiding a large error in the detector signal. Only the K-fluorescence lines E_K will appear in the band range $E_{PRF} < E < E_F$, as shown in Figure 4(d).

Figure 4(a,b,c) illustrates the pre-filter, fluorescer and post-filter responses of the above embodiment with absorption edges chosen as $E_{PRF} < E_F = E_{POF}$. This combination results in the joint response function shown in Figure 4(d), where the response in the energy band $E_{PRF} < E < E_F$ is virtually 0, because there is a joint maximum absorption of that combination in this band. Also no undesirable windows, such as in Figure 2, will appear in this energy band. In energies greater than E_F , the response function is sharper and the energy transmission band is narrower than the response function in Figure 2.

An example of the above-explained embodiment is shown in Figure 5, which illustrates a channel response function of the filter-fluorescer spectrometer 8 shown in Figure 3 using a 48-microns thickness pre-filter of dysprosium, 29-microns thickness fluorescer of gold and a 9-microns thickness post-filter of gold. This response function rises from almost 0 at 80 keV to a maximum at 150 keV, and falls to 0 again near 1000 keV.

Another example of the same embodiment is shown in Figure 6, which illustrates a channel response function of the filter-fluorescer spectrometer 8 shown in Figure 3 using a 53-microns thickness pre-filter of hafnium, 10-microns thickness fluorescer of lead, and a 21-microns thickness post-filter of ytterbium. This response function rises from 0 at 90 keV to a maximum at 250 keV and falls to 0 again at an energy somewhat greater than 1000 keV.

The foregoing description of a preferred embodiment of the invention and examples have been presented for purposes of illustration and description. Further embodiments or combinations of those described herein will be apparent to those skilled in the art; and many modifications and variations are possible in the light of the above teaching. For example, by properly choosing the pre-filter, fluorescer, post-filter material and thickness, the peak position of the response function may be adjusted for any channel.

This modification is illustrated in the following table of physical parameters for four spectrometer channels with different peak positions at 150, 200, 250 and 300 keV:

ELEMENTS PARAMETERS
OF FOUR HYPER FILTER-FLUORESCER SPECTROMETER CHANNELS

M = Material

T = Thickness

5	Spectro- meter	Pre-Filter	Fluorescer	Post-Filter	Detector
	Energy (keV)	M T (mm)	M T (mm)	M T (mm)	NaI (TI) (mm)
	150	Dy 1.27	Au .0762	Au .254	3
10	200	Hf 1.37	Pb .27	Pb .381	3
	250	Hf 1.27	Pb .254	Yb .559	3
	300	Au 2.03	Pb .0508	Pb .508	3

Figure 7 illustrates the resulting response functions for those four spectrometer channels.

15 It is intended that the scope of the invention be defined by the claims appended hereto.

Abstract

An apparatus utilizing filter-fluorescer combinations is provided to measure short bursts of high fluence x-rays above 120 keV energy, where there are no practical absorption edges available for conventional filter-fluorescer techniques. The absorption edge of the prefilter is chosen to be less than that of the fluorescer, i.e., $E_{PRF} < E_F$, contrary to the prior art technique $E_{PRF} > E_F$. In this way, the response function is virtually zero between E_{PRF} and E_F and well defined and enhanced in an energy band of less than 1000 keV above the 120 keV energy.

RELATIVE
UNIT (RU)

Fig. 1a

(RU)

Fig. 1b

(PRIOR ART)

(RU)

Fig. 1c

(RU)

Fig. 1d

Fig. 2 (PRIOR ART)

Fig. 3

RELATIVE
UNIT (RU)

Fig. 4a

(RU)

Fig. 4b

(RU)

Fig. 4c

(RU)

Fig. 4d

Fig. 5

Fig. 6

Fig. 7