Title
HIGH-RESOLUTION X-RAY AND ELECTRON SPECTROMETER

Authors
Elad, Emanuel
Nakamura, Michiyukl.

Publication Date
1965-12-10

UCRL-16515

University of California

Ernest O. Lawrence Radiation Laboratory

HIGH-RESOLUTION X-RAY AND ELECTRON SPECTROMETER

Berkeley, California

DISCLAIMER

Letter to the Editor -
Nuclear Instruments and Methods

UCRL-16515

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

HIGH-RESOLUTION X-RAY AND ELECTRON SPECTROMETER

Emanuel Elad and Michiyuki Nakamura

December 10, 1965

HIGH-RESOLUTION X-RAY AND ELECTRON SPECTROMETER*

Emanuel Elad and Michiyuki Nakamura

Lawrence Radiation Laboratory
University of California
Berkeley, California

December 10, 1965

Solid-state detectors are increasingly used nowadays for nuclear spectroscopy. Surface-barrier[1, 2] and lithium-drifted[3] silicon detectors are commonly used for beta-ray measurements. This letter describes briefly a high-resolution spectrometer with which resolution of 0.97 keV (fwhm) was obtained for ^{57}Co X rays and 1.5 keV for ^{237}U electrons. The influence of the electron source on the energy resolution is discussed.

The spectrometer consists of a cooled lithium-drifted silicon detector, a novel low-noise preamplifier,[4] and a main amplifier. The detector is mounted in a vacuumtight housing and is cooled by a liquid nitrogen cooling system. Measurements were made to establish the optimum operating conditions for the semiconductor detector, i.e., temperature and bias voltage. Figure 1 shows the results of these measurements on one particular detector (3 mm thick and 5 mm in diameter).[5] The optimum temperature was found to be -140°C, and the bias voltage corresponding to this temperature was 300 V. The optimum temperature for different detectors was in the range -150°C to -130°C, and in all cases the resolution was a slowly varying function of temperature in the range -170°C to -110°C. The optimum bias voltage range extends from 200 V to 500 V, and is a function of detector thickness and fabrication process.

The optimum temperature was achieved in the described spectrometer by the arrangement shown in Fig. 2. The lithium-drifted silicon detector is attached to a small circular aluminum plate by means of a thin Mylar strip. Two cylindrical ceramic rods are used to mount the plate on the cold surface and to provide the necessary heat leak. The required temperature of the detector was set by the diameter and length of the ceramic rods. The input stage of the preamplifier mounted on the cold surface is also shown in Fig. 2.

The ceramic rods, which are good electrical insulators, allow one to connect the detector in an isolated-from-ground configuration. This feature simplifies the input stage of the preamplifier, causing significant reduction of the input stray capacitance. The low-noise preamplifier[4] uses a field-effect transistor in its input stage, and its design is based on optimization of the signal-to-noise ratio. The pulse-generator resolution obtained for zero external capacitance was 0.5 keV, and it increases by 0.05 keV per picofarad. The choice of the main amplifier and its shaping time constants had little influence on the resolution of the system.

The performance of the spectrometer described was tested with ^{237}U electrons and ^{57}Co X rays. The spectrum of ^{237}U, electrons and γ rays, is given in Fig. 3. The γ-ray spectrum of this source was separated by means of a Teflon absorber, and is shown in the lower part of Fig. 3. The resolution for electrons measured from the energy lines of 89.4 and 42 keV is 1.5 keV (fwhm). The uranium source was a film-layer source, less than 7 $\mu g/cm^2$ thick.

In order to show the influence of the source thickness on resolution in electron spectroscopy, we compare the results for the K and L^{III}

lines of ^{237}U with the K line of ^{109}Cd (62 keV), which is not unlike in energy. The spectrum of ^{109}Cd is given in Fig. 4; the resolution measured from the K line is 2.5 keV. The thickness of this source was 250 $\mu g/cm^2$.

The resolution of the spectrometer for low-energy X rays is 0.97 keV (fwhm), and it is demonstrated by the spectrum of ^{57}Co, given in Fig. 5. In addition to the line of 14.37 keV, from which the resolution was measured, the X-rays of iron (K_α = 6.4 keV, K_β = 7.06 keV) are clearly resolved from the background. Thus, the spectrum also exhibits the very low noise of the system. The noise limit of the spectrometer was at approximately 3 keV.

Comparing the resolution values obtained for electrons and X rays, we can conclude that the energy-loss spread in electron-silicon interactions is larger than for X-ray interactions. The results obtained for electron spectra show that in high-resolution analyzing systems, the source thickness is an important factor in determining the resolution of the measurement. Furthermore, comparing the resolution values for electrons and X rays with the pulse-generator resolution of the preamplifier reveals that the noise associated with the electronics is not the limiting factor in the spectrometer described.

The described high-resolution spectrometer was used successfully by several experimenters in our Laboratory. A novel technique for chemical analysis of material samples was developed,[6] and angular correlation experiments involving subshell conversion electrons have been made.[7]

The authors would like to acknowledge the contribution to and interest in this work of Toshimitsu Yamazaki, Harry R. Bowman, Stanley G. Thompson, George W. Kilian, A. Judd Haverfield, and Rand L. Watson. Many thanks are due Roger A. Gembala, Richard C. Jared. and Donald F. Malone for their technical assistance.

Footnote and References

*This work was done under the auspices of the U. S. Atomic Energy Commission.

1. C. J. Borkowski and R. J. Fox, I. R. E. NS-9 No. 3 (1962), 213.
2. H. Bosch, F. Krmpotic, and A. Plastino, Nucl. Instr. and Meth. 23 (1963), 79.
3. J. L. Blankenship and C. J. Borkowski, I. R. E. NS-9 No. 3 (1962), 181.
4. Emanuel Elad, Nucl. Instr. and Meth., (to be published), (Lawrence Radiation Laboratory Report UCRL-16390, Sept. 1965).
5. F. S. Goulding and R. P. Lothrop (Lawrence Radiation Laboratory), private communication, 1965.
6. H. R. Bowman, E. K. Hyde, and S. G. Thompson, Report UCRL-16485. Nov. 1965.
7. T. Yamazaki, R. Stone, and J. M. Hollander (Lawrence Radiation Laboratory), private communication, 1965.

Figure Captions

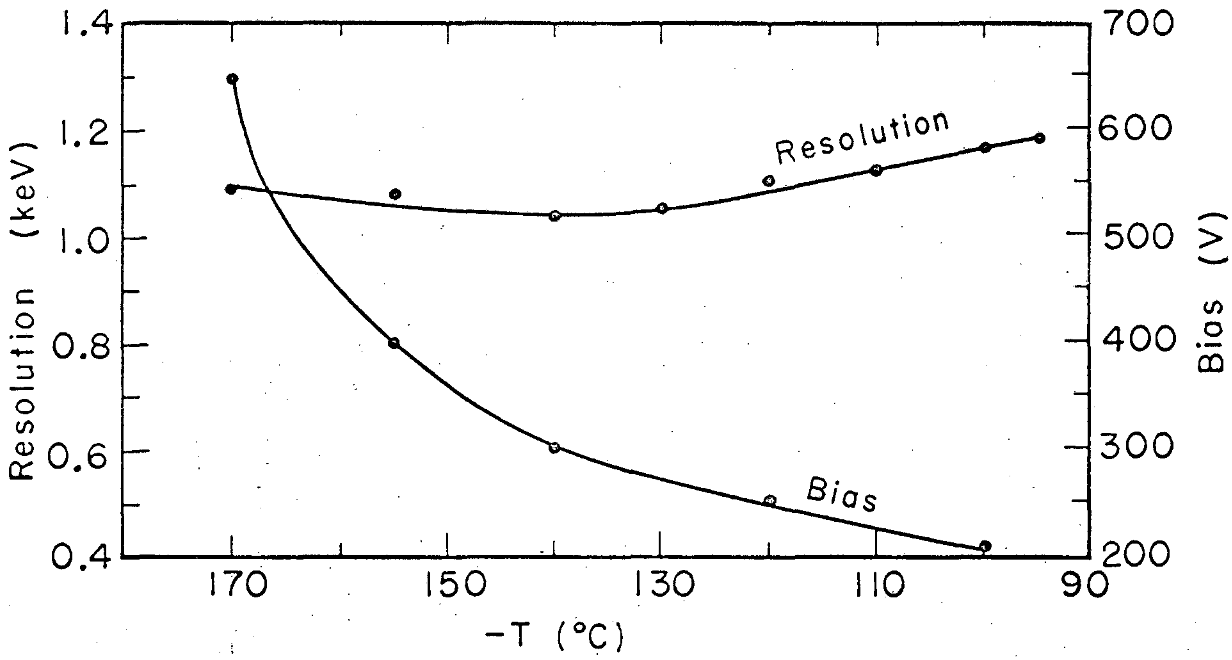
Fig. 1. Spectrometer resolution versus detector temperature and bias.

Fig. 2. Detector mounting.

Fig. 3. Electron and γ-ray spectrum of ^{237}U.

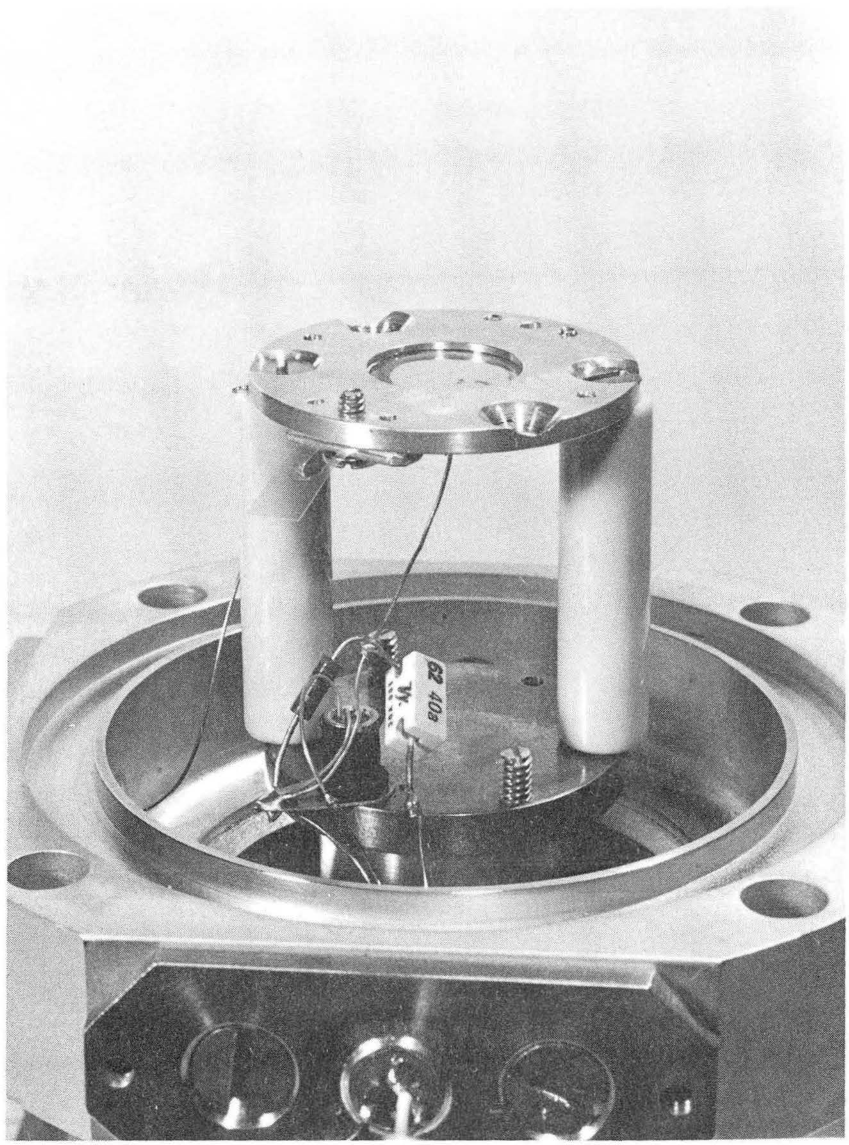
Fig. 4. Electron and γ-ray spectrum of ^{109}Cd.

Fig. 5. X-Ray spectrum of ^{57}Co.



MUB-9052

Fig. 1



ZN-5311

Fig. 2

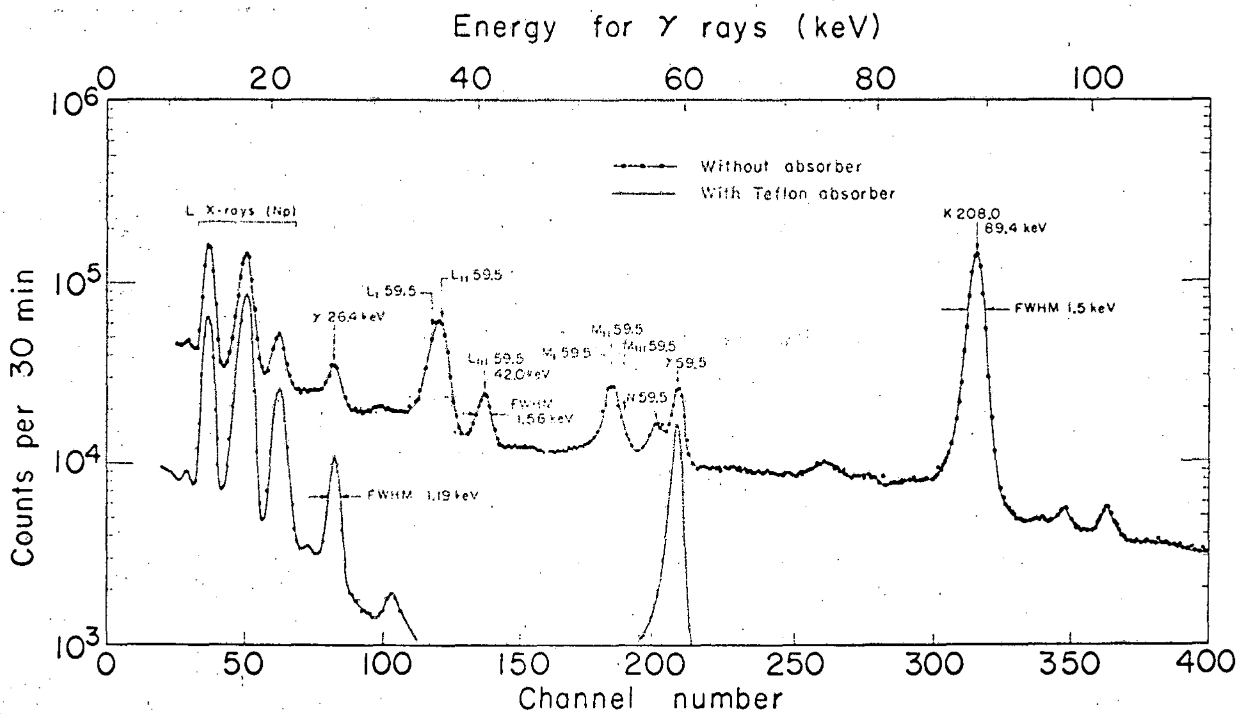
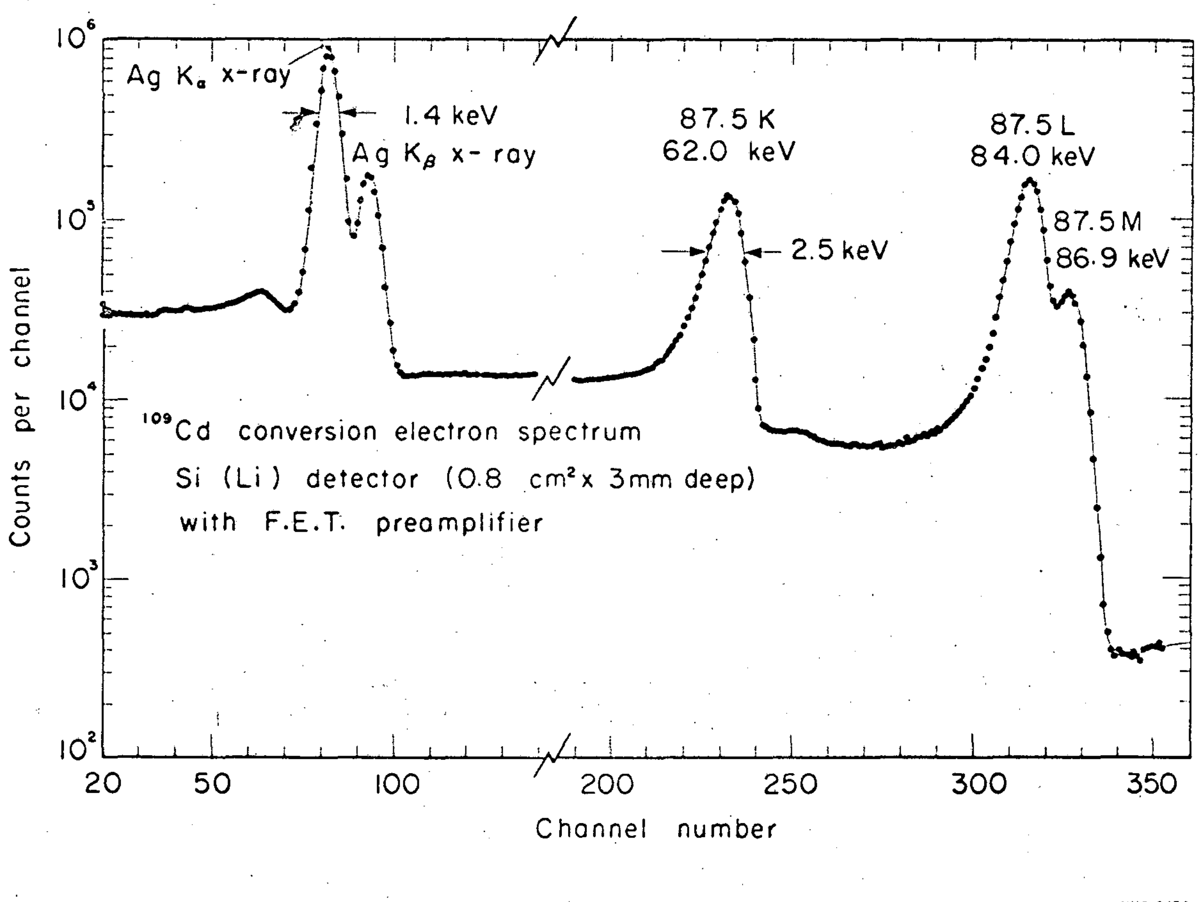


Fig. 3

MUB-5053



Ag Kα x-ray
1.4 keV
Ag Kβ x-ray
87.5 K
62.0 keV
2.5 keV
87.5 L
84.0 keV
87.5 M
86.9 keV
109Cd conversion electron spectrum
Si (Li) detector (0.8 cm² x 3mm deep)
with F.E.T. preamplifier
Counts per channel
Channel number
10⁶
10⁵
10⁴
10³
10²
20
50
100
200
250
300
350
MUB-8459

Fig. 4

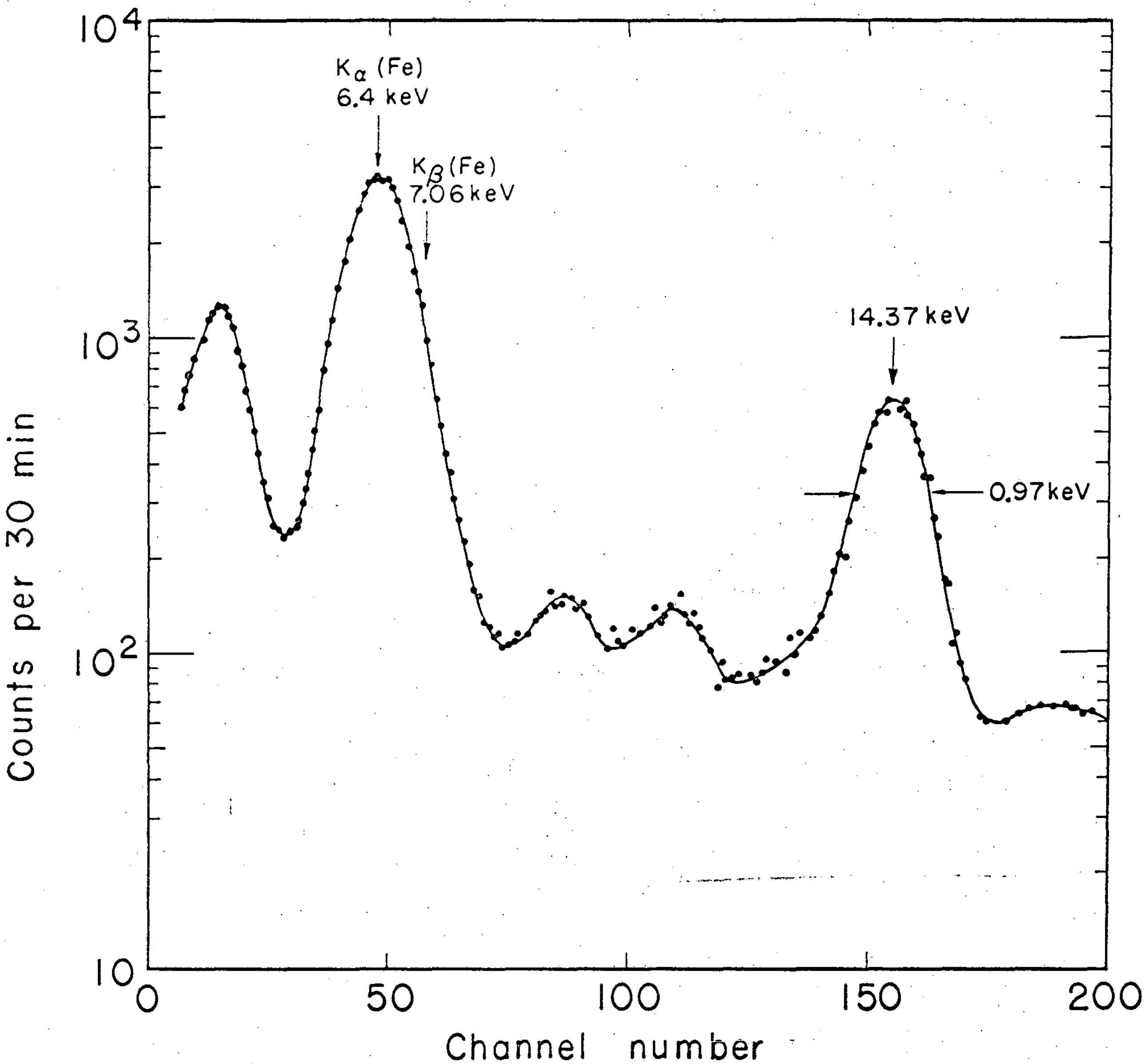


Fig. 5

MUB-9054