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Authors
Pehl, Richard H.
Goulding, Fred S.

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Richard H. Pehl and Fred S. Goulding

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LAWRENCE RADIATION LABORATORY
UNIVERSITY of CALIFORNIA BERKELEY

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RECENT OBSERVATIONS ON THE FANO FACTOR IN GERMANIUM*

Richard H. Pehl and Fred S. Goulding

Lawrence Radiation Laboratory
University of California
Berkeley, California

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ABSTRACT

Results demonstrating that the Fano factor for germanium is less than 0.08 are presented.

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The Fano factor has been something of a "phantom factor"[1] to many workers in the field of semiconductor detectors. However, the extensive work of Bilger[2] appeared to clarify the situation in germanium, and put an end to the era of plunging experimental values as summarized by Klein[3].

The objective of this brief note is to conclusively demonstrate that the intrinsic Fano factor for germanium is appreciably less than the 0.129 value obtained by Bilger[2]. For several years we occasionally have observed detectors, invariably having relatively small dimensions, whose resolution was significantly better than could be accounted for unless the Fano factor was less than 0.10. However, lack of time prevented us from studying these detectors extensively enough to warrant reporting these results. With the advent of our high-resolution optoelectronic feedback preamplifier[4], the opportunity to make a relatively simple assessment of the Fano factor became available. Early results using this technique are described in the following paragraphs.

Measurements were carried out using several small, thin window, lithium-drifted germanium detectors (intrinsic area of 4 mm x 4 mm, and a drift depth of 4 mm) that exhibited a leakage current of about 5×10^{-13}A at a bias of 1000 volts. It is quite possible that the energy resolution at high energies is degraded by charge collection problems but our purpose here is only to obtain an upper limit for

the Fano factor, and our result may therefore be considered conservative. The detectors were made from a germanium ingot grown by W. Hansen.

The electronic resolution of the complete system, measured with a Gaussian shaper peaking at 8 μsec, was 140 eV. Both pulser and RMS noise-meter measurements gave essentially the same value.

From 8 keV to 1333 keV, our results establish a maximum value of 0.08 for the Fano factor. We emphasize that this is a maximum value as it is easy for extraneous problems to broaden peaks but the reverse is an unlikely possibility. At energies higher than 122 keV the pulser peak is spread over so few analyzer channels that an accurate determination of the pulser resolution could not be made. However, this presents no serious problem since the electronic (pulser) resolution becomes an almost negligible component of the observed gamma peak width at higher energies. Consequently the safe assumption was made that the pulser resolution remained at the value determined at lower energies. Table I summarizes our results.

We plan to extend these measurements over a larger energy range, and to survey a number of detectors made from different germanium ingots. Present indications are that the measured peak widths in

earlier experiments are not representative of the intrinsic statistical processes in germanium, and are affected in some manner by properties of the particular piece of germanium. Since the results given here conclusively show that the presently accepted value of the Fano factor is in error, we have decided to present them at this early stage.

Recently an effective Fano factor of less than 0.11 has been measured using a collimated beam of gamma rays to irradiate selected areas between the n^+ and p contacts[5]; such a measurement is consistent with our observation that the effective Fano factor decreases as the detector size decreases.

TABLE I. Resolution of the germanium detector system at various energies. A pulser resolution of 140 eV was used throughout for the calculation of the Fano factor.

Source	Energy	Resolution	Fano factor
^{60}Co	1333 keV	1.30 keV	0.076
^{60}Co	1173 keV	1.23 keV	0.077
^{137}Cs	662 keV	924 eV	0.077
^{57}Co	122 keV	420 eV	0.078
^{241}Am	59.54 keV	310 eV	0.078
Br K_{β_1} X ray	13.3 keV	195 eV	0.084
As K_{α} X ray	10.53 keV	183 eV	0.080
Cu K_{α} X ray	8.04 keV	175 eV	0.083

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We wish to acknowledge the help of R. Cordi and E. Rivet for detector fabrication, D. Malone for mechanical design, and J. Walton for preamplifier testing.

FOOTNOTE AND REFERENCES

*This work was carried out as part of the program of the Nuclear Chemistry Division of LRL, Berkeley and was funded by the United States Atomic Energy Commission under contract W-7405-eng-48.

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TECHNICAL INFORMATION DIVISION
LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720