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The Crystal Counter Method for the Measurement of γ-Ray Energies

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The experiments described in the lecture by Prof. MILATZ[1]) have established under certain geometrical conditions exact proportionality between the energy of β-particles (< 1 MeV) entering an AgCl-crystal and the charge pulses induced in the crystal. For an electron source outside the crystal, the pulse amplitude measurement should therefore yield a good determination of electron energy. In the case of γ-ray counting, however, secondary electrons will be produced mainly inside the crystal and their energies will be spread over a wide range even for monochromatic γ-radiation. Only for energies higher than ~ 2 MeV does the fraction of secondaries emitted in forward direction become so preponderant that most of the pulses should involve either nearly the full quantum energy or (for pair production) 1 MeV less. On the other hand we must reduce the collecting field in order to provide favourable geometrical conditions for the energy measurement, because the secondaries are distributed at random between anode and cathode of the crystal. If most of the tertiary electrons are trapped in the crystal, then we may expect the same pulse amplitude-energy relationship to hold for nearly all secondary electrons; but also the pulse amplitudes will be at least one order of magnitude below the saturation values, so that amplifier noise becomes a serious limitation for this type of measurement. This is particularly true if we wish to make use of the short rise time offered by the crystal counter with conventional pulse shaping techniques; however, the influence of amplifier noise can be kept near the natural limit without sacrifice in time resolution by a new pulse measuring circuit which we shall describe below.

In connection with ionization chamber and crystal counter amplifiers, MILATZ and coworkers[2]) have introduced the concept of "natural precision": The behaviour of the amplifier input stage is described by two characteristic data $\overline{q_0^2}$ and τ_0[3]), with the meaning that the difference between the averaged output potentials before and after the pulse should be taken as a measure of the charge Q of the pulse, in order to find Q with the smallest possible uncertainty $\overline{q_0^2}$. The averaging process should be carried out with exponential

weight functions (time constants $\pm \tau_0$); any different pulse treatment will lead to an uncertainty $\overline{q^2} > \overline{q_0^2}$.

For the measurement of pulses at a finite counting rate, this definition of $\overline{q_0^2}$ should be modified because of the possibility of overlapping pulses. To define the natural precision ${}^{N}\overline{q_0^2}$ at a given counting rate N/sec, we extend the averaging procedure only over time intervals free from pulses, so that no other pulse can contribute to the measurement of the pulse under consideration. According to the formulae derived from this definition[4]), ${}^{N}\overline{q_0^2}$ increases with counting rate N much more slowly than the $\overline{q^2}$-value of the more conventional pulse measuring systems, which suffer from the superposition of pulses. In order to attain experimentally the natural precision at all counting rates, we need 2 time-dependent averaging circuits, the first one being switched on and off by the preceeding and the considered pulses respectively, and the second one by the considered and the following pulses, respectively. Such a device offers, as compared with conventional circuits, (1) the advantage of much higher permissible counting rates for a given uncertainty in charge measurement, and (2) the possibility of combining direct energy measurements with coincidence counting. The appropriate circuits are being incorporated in a fast pulse spectrograph in course of construction.

Our investigations on crystal counters have so far been carried out with a less refined apparatus. AgCl-crystals prepared by M. Sempert[5]) were exposed to the Th(B + C)- and Li(p, γ)-radiations. With the latter radiation the pulse amplitude distribution showed a pronounced peak at about 6 times the maximum amplitude of the 2.6 MeV-measurements. Apart from demonstrating the possibility of estimating unknown γ-ray energies, this result confirms the proportionality between electron energy and pulse amplitude over a wide energy range. The accuracy was limited by the relatively high noise level of the apparatus used for these preliminary experiments. The pulse amplitude analyser was the same as described in a note on proportional counter measurements[6]).

References.

[1]) Milatz, van der Velden and Veenstra, Remarks on the Crystal Counter (this report, p. 89).

[2]) Milatz and Keller, Physica **9**, 97 (1942); van Heerden, Dissertation, Utrecht (1945).

[3]) This case is covered in a more general discussion of the noise problem by den Hartog and Muller, Physica **13**, 571 (1947).

[4]) Maeder, Helv. Phys. Acta **21**, 174 (1948).

[5]) Sempert, Diplomarbeit ETH., Zürich 1948.

[6]) Maeder and Medicus, Measurement of Converted γ-Radiation by the Proportional Counter Technique (this report, p. 175).