On the statistical aspect of electron interference phenomena

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percent activity increase

$$= \frac{\text{final activity} - \text{initial activity}}{\text{initial activity}} \times 100. \quad (2)$$

Two isotopes that are convenient for this demonstration, owing to their availability and relatively long half-lives, are ^{137}Cs ($t_{1/2} = 30$ yr, $E_\gamma = 0.66$ MeV, $E_\beta = 0.52$, 1.2 MeV) and ^{133}Ba ($t_{1/2} = 7.2$ yr, average $E_\gamma = 0.34$ MeV). These isotopes give about 50% and 140% activity increases, respectively. Any γ or β–γ emitter with γ energy between 0.1 and 1.0 MeV will show the effect.

The activity increase decreases with increasing γ-ray energy. After numerous correction factors were applied, the major one of which was the end-window factor for soft electrons, a relationship was obtained between scattered γ-ray energy and the activity increase. The details are beyond the scope of this note, but may be published elsewhere.

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On the statistical aspect of electron interference phenomena

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In a recent paper,[1] hereafter called I, two of the present authors have described how to perform—for instructional purposes—an experiment on electron interference by using a standard electron microscope.

In this short note we wish to show in a very impressive way that the complete interference pattern we registered on the photographic plate is really the sum of many independent events, each due to the interaction between a single electron and the interference apparatus. This was deduced in I with a simple and realistic calculation based on the main assumption that electrons were emitted at a constant rate from the gun filament. In the present case this result is shown not from a calculation but from direct observation. In fact, the experiment performed in I has been repeated on a Siemens Elmiskop 101 equipped with a TV image intensifier.[2,3]

With regard to the formerly described setup, the Möllenstedt and Düker electron biprism[4] has been now inserted at the level of the selector aperture plane. The objective lens acts in this case as third condenser lens, thus increasing the coherence and versatility of the illuminating system, whereas the fringes are magnified on the final screen by means of the two projector lenses (cf. Fig. 4 in I). If the coherence condition is satisfied, it is possible to register on a photographic plate an intereference fringe pattern with spacing above 300 μm as shown in Fig. 1(f). The exposure time of the photographic plate lies in a range between 10 and 100 sec. By the same electron optical conditions, however, the TV image intensifier allows the observation of the interference pattern directly on the monitor by means of the electrons stored in the SEC target of the TV tube[2,3] in a time of about 0.1 sec.

Figure 1(f), together with Figs. 1(a)–1(e), was filmed directly from the TV monitor. We note that the image on the screen was clearly visible, as in normal TV transmission, and that by varying the biprism potential we could follow, without difficulty, all the diffraction and interference phenomena described in I.

However, the most interesting performance that such a device offers is connected to the direct observation of the statistical process of fringe formation. It can easily be seen that, at low current density, the image is built up from the statistically distributed light flashes of individual electrons, as is shown in the sequence of Figs. 1(a)–(f) registered at different current densities on the final screen.

The same result can be reached in another way that didactically is more illuminating in concept. In fact, we

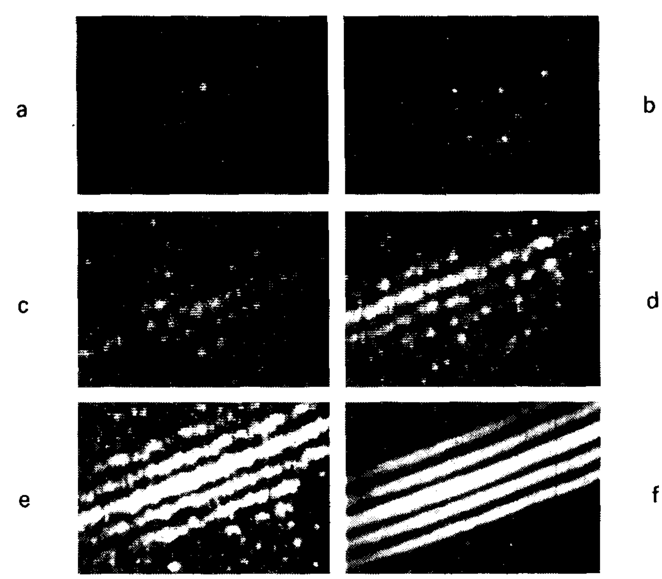

Fig. 1. (a–f) Electron interference fringe patterns filmed from a TV monitor at increasing current densities.

can operate with a very low electron current density which corresponds, on the average, to one or a few electrons arriving on the final screen in 0.04 sec [see Fig. 1(a)]. This is the lowest storage time available with the TV tube. While the electron optical conditions are kept constant, the storage time, which plays the same role as the exposure time of the photographic plate, can be increased step-by-step up to values of minutes. It can be verified that the image is gradually "filled" by the electrons until the shot noise vanishes completely.

We believe these results will be of great help to students by demonstrating to them, in an experimental form, the wave behavior of electrons and their statistical interpretation. Moreover, the whole apparatus is particularly valuable for student demonstrations in that the image can be directly seen by a large number of viewers and can possibly be recorded on video tape.

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