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Polarization near the High-Frequency Limit of 500-kev Bremsstrahlung*

J. W. MOTZ AND R. C. PLACIOUS
National Bureau of Standards, Washington, D. C.
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The angular dependence of the linear polarization near the high-frequency limit of the bremsstrahlung spectrum for 500-kev electrons has been measured with a polarimeter that depends on the polarization sensitivity of the Compton process. The results confirm the polarization reversal predicted at large angles by the Gluckstern-Hull-Breit calculations, and are consistent with the reversal found in the photoelectric measurements of McMaster and Hereford.

THE bremsstrahlung process at the high-frequency limit is inverse to the photoelectric process within certain approximations involving the binding of the atomic electron.[1] Therefore, experimental information about either process is pertinent to the other.

In the course of our investigations of bremsstrahlung polarization, we have measured the angular dependence of the polarization near the high-frequency limit of the bremsstrahlung spectrum for 500-kev electrons. Our results can be applied to the photoelectric process, and are of particular interest because conflicting experimental results[2] have been obtained for the azimuthal distribution of photoelectrons ejected by linearly polarized photons.

The polarization behaviors for the bremsstrahlung and photoelectric processes are closely related as seen from a comparison of the corresponding differential cross-section calculations. The Gluckstern-Hull-Breit bremsstrahlung polarization formula[3] near the high-frequency limit has the same analytical form as the Sauter formula[4] for linearly polarized photons. At the high-frequency limit, the bremsstrahlung formula has the same dependence as the Sauter formula on the direction of emission, the polarization, and the primary energy, except for a normalization factor which has been discussed by Fano.[5] At 500 kev, the theory[3,4] for both processes predicts a reversal in which the emission plane and the photon polarization vector **E** tend to be parallel for small emission angles and perpendicular for large emission angles. (The theory predicts a reversal with increasing energy at constant angle as well as with increasing angle at constant energy.) In the photoelectric measurements, a reversal was found by McMaster and Hereford[2] but not by Brini *et al.*[2] In the present bremsstrahlung measurements, the results verify the reversal and support the general reliability of the approximate polarization calculations for each process.

A schematic diagram of the present experimental arrangement is shown in Fig. 1. (Figure 1 also shows the arrangement for the photoelectron measurements[2] in order to emphasize the similarity between the two experiments.) The experimental details and method of data analysis for the present measurements have been described previously.[6] The bremsstrahlung was produced with 500-kev electrons incident on a 4.3-mg/cm^2 beryllium target and on a 0.21-mg/cm^2 gold target. These targets were found[6] to be thin enough so that electron scattering effects could be neglected. The bremsstrahlung polarization was measured in terms of an azimuthal asymmetry ratio with a polarimeter[6] that depends on the polarization sensitivity of the Compton

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[1] Fano, Koch, and Motz, Phys. Rev. (to be published).

[2] W. H. McMaster and F. L. Hereford, Phys. Rev. **95**, 723 (1954); Brini, Peli, Rimondi, and Veronesi, Nuovo cimento **6**, 98 (1957). These measurements were made with a Compton-scattered photon beam from a Co^{60} source and with a fixed photoelectron emission angle of approximately 90°. The photoelectron azimuthal distribution at this emission angle was investigated as a function of photon energy (Compton-scattering angle) in the range from approximately 0.4 to 0.8 Mev.

[3] Gluckstern, Hull, and Breit, Phys. Rev. **90**, 1026 (1953), Eq. (15). The cross section integrated over the electron directions was calculated by R. L. Gluckstern and M. H. Hull, Phys. Rev. **90**, 1030 (1953).

[4] F. Sauter, Ann. Physik **11**, 454 (1931), Eq. (30).

[5] U. Fano (to be published).

[6] J. W. Motz, Phys. Rev. **104**, 557 (1956).

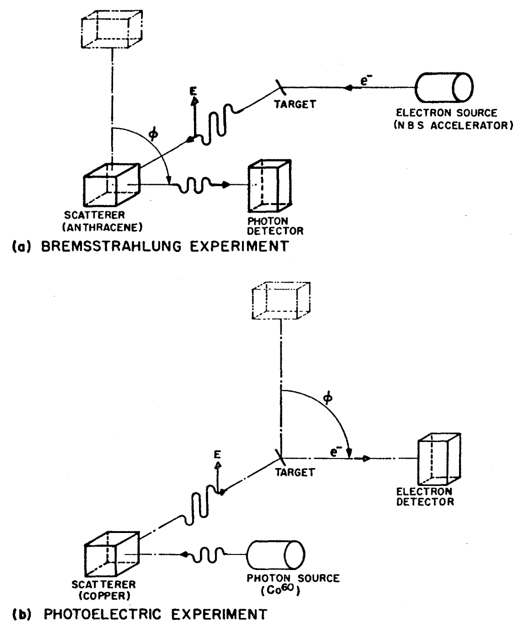

FIG. 1. Schematic experimental arrangements for (a) the present bremsstrahlung measurements, and (b) the photoelectron measurements.[2] The radiation flows in opposite directions in the two arrangements. Measurements are made with the detector in the two azimuthal positions ($\phi=0$, $\phi=\pi/2$). If the dominant mode of emission for each process occurs with the photon polarization vector, **E**, orthogonal to the emission plane as illustrated above, maximum counting rates in the detector are obtained when the three arms are coplanar ($\phi=\pi/2$).

process. The polarimeter was operated as a double-crystal Compton spectrometer in order to select photons near the high-frequency limit (420 to 500 kev) of the spectrum. Measurements were made for photon emission angles of 10, 20, 30, 50, 70, 90, 110, and 130 degrees.

The experimental results are plotted in Fig. 2. The solid line in Fig. 2 is predicted by the Gluckstern-Hull (Born-approximation) calculations[3] including their screening corrections for gold and aluminum (dashed line), and it shows the dependence of the polarization on the photon emission angle for 450-kev photons (median energy in the interval selected by the polarimeter). The polarization is defined by the difference to sum ratio of the cross sections, $d\sigma_{\parallel}$ and $d\sigma_{\perp}$, for radiation polarized parallel (negative values of polarization) and perpendicular (positive values of polarization), respectively, to the emission plane. The error limits for the polarization values include estimates of the systematic errors and of the statistical errors for the measured asymmetry ratios.

As shown in Fig. 2, our experimental results at large angles (greater than 50°) give approximately the same polarization values for *both* beryllium and gold, and show good agreement with the Gluckstern-Hull predictions.[3] The magnitude of the positive (perpendicular) values of the polarization that establish the reversal are observed to exceed three times the estimated error in four different cases (at two angles with two target materials). These measurements are consistent with the reversal found in the photoelectric measurements of McMaster and Hereford.[6] The measurements at small

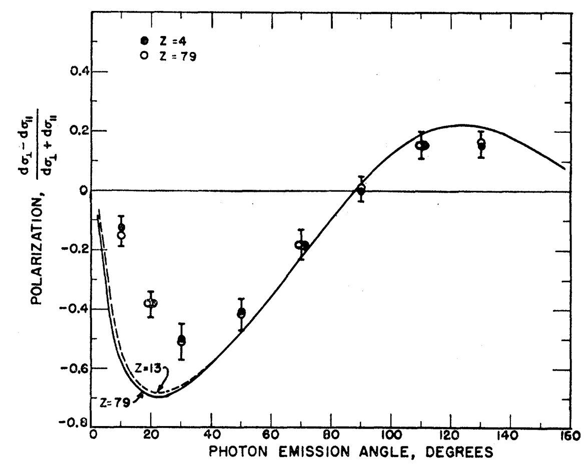

FIG. 2. Angular dependence of 500-kev bremsstrahlung polarization near the high-frequency limit. The experimental points for beryllium (closed circles) and gold (open circles) were obtained for an energy interval between approximately 420 and 500 kev. The solid line is the polarization for 450-kev photons predicted by the Gluckstern-Hull calculations,[3] including screening corrections for gold and aluminum (dashed line).

angles which agree only qualitatively with the theory, will be analyzed later in a complete report along with data for other energies.

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