Eqs. (22) and (23) of Ref. 8, thus establishing the relationship with the results obtained in Refs. 8-10. We note in conclusion that when inelastic collisions are taken into consideration, Eqs. (1) and (2) are replaced by

$$\sigma_r = \frac{\pi}{k^2} \sum (2l+1) \{1 - e^{2(\beta_l' + \beta_l'')} \cos 2(\eta_l' - \eta_l'')\}, \quad (6)$$

$$\sigma_i = \frac{\pi}{k^2} \sum (2l+1) e^{2(\beta_l' + \beta_l'')} \sin 2(\eta_l' - \eta_l''). \quad (7)$$

Here $\eta_l + i\beta_l$ are complex scattering phases.

[1] A. Kantrowitz, Phys. Rev. 90, 368 (1953).

[2] Petschek, Rose, Glick, Kaul and Kantrowitz, J. Appl. Phys. 26, 83 (1955).

[3] H. Baranger, Phys. Rev. 91, 436 (1953).

[4] H. Olsen and W. Huxford, Phys. Rev. 87, 922 (1952).

[5] C. Jurgens, Z. Physik 184, 21 (1952).

[6] A. Unsold, Symposium, *Modern Problems of Astrophysics and Solar Physics*, IIL, 1954, p. 7 (Russian translation).

[7] I. I. Sobel'man, Usp. Fiz. Nauk SSSR 54, 551 (1954).

[8] Kivel, Bloom and Margenau, Phys. Rev. 98, 495 (1955).

[9] B. Kivel, Phys. Rev. 98, 1055 (1955).

[10] H. Margenau and B. Kivel, Phys. Rev. 98, 1822 (1955).

[11] L. Landau and E. Lifshitz, *Quantum Mechanics*, Moscow, 1948.

Translated by I. Emin
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Obtaining Polarized Electron Beams

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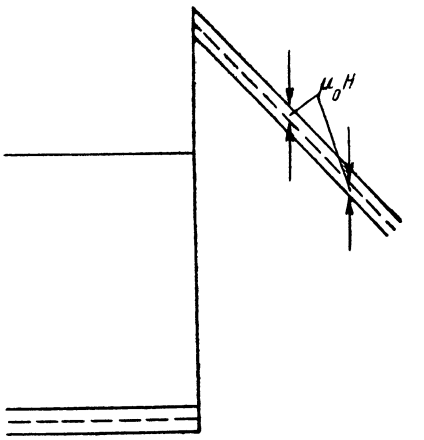
IF one can arrange for a sufficiently intense beam of polarized electrons it is possible to carry out a series of experiments with electrons as well as with circularly polarized bremsstrahlung[1]. Some methods of obtaining polarized electrons are well known (scattering of electrons by heavy nuclei[2], the photoelectric effect on aligned atoms[3], etc.). However, the values of the polarization and intensity obtained therewith are small; these methods are particularly ineffective in the high-energy region. Below is shown the principle of operation of a source of polarized electrons, which apparently has not previously been described in the literature.

We consider field emission from a cathode, to whose surface (along the normal) is applied a strong electric field E and a magnetic field H. The behavior of the potential near the surface of the metal (see Figure), owing to the presence of the



The dotted line shows the behavior of the potential with the magnetic field absent.

magnetic field, is shifted by the value $\pm\mu_0 H$ for each of the two electron groups with opposite spin orientations. But in the equilibrium state, the Fermi energies of both groups are equal, and consequently, the penetrability of the barrier differs for conduction electrons with different spin orientations. An elementary value for the ratio n_-/n_+ for the emitted electrons is given by (see, for example Ref. 4)

$$n_-/n_+ \sim \exp\left(2\sqrt{2\varphi/mc^2}H/E\right),$$

where φ is the work function. For $\varphi \sim 1$ ev (coated cathode) one needs an electric field strength of the order of $E \sim 10^6$ v/cm, and an observable polarization $\zeta = (n_+ - n_-)/(n_+ + n_-)$ is obtained, if the magnetic field is hundreds of kilogauss. Obviously, our derivation refers to the case $kT \lesssim \mu_0 H$, i.e., the cathode must be at the temperature of liquid hydrogen.

In this manner we are able to create a source of polarized electrons depending essentially on the

presence of the cathode, which gives an appreciable current in cold emission for an electric field strength $\sim 10^6$ v/cm and a temperature of $\sim 20°$ K. As for the strength of the magnetic field, we refer to what recently has been published in Ref. 5, whose authors write of producing an intensity $H = 6.5 \times 10^5$ G with a pulse lasting from 1 to 10 milliseconds, still far from the value of the threshold needed with existing technology. In spite of the fact that the time interval between such pulses far exceeds the normal interval between operating pulses of contemporary accelerators, the gain in the average current of polarized electrons of high-energy and the value of the polarization may prove to be much greater in comparison with other methods.

Depolarization of the electrons in the acceleration process may be examined for each concrete case with the aid of the formula, derived in Ref. 6.

The difference in the penetrability of the potential barrier, represented in the Figure, for electrons with different spin orientations may also be used for measuring the polarization of the electron beam* incident on the surface of the metal. In this case, the small work function and low temperature are not necessary; the potential of the measuring electrode must be chosen so that the usual classical "turning point" for electrons is somewhat lower than the peak of the barrier.

To summarize, it is possible to say that a practical realization of the source proposed here is not easy to carry out. The practicality is determined mainly by the magnitude of the circular polarization of bremsstrahlung from polarized electrons. This question is being studied in detail at the present time.

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* This possibility has been shown by K. D. Sinel'nikov.

[1] Ia. B. Zel'dovich, Dokl. Akad. Nauk SSSR 83, 63 (1952).

[2] N. F. Mott, Proc. Roy. Soc. (London) 124A, 425 (1929)

[3] A. Castler, Proc. Phys. Soc. (London) 67A, 853 (1954).

[4] R. Peierls, *Electron Theory of Metals*, 1947.

[5] H. P. Furth and R. W. Waniek, Nuovo Cimento 2, 1350 (1955).

[6] H. A. Tolhoek and S. R. de Groot, Physica 17, 17 (1951).

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Spectral Representation of Green's Function in the Nonrelativistic Many-Body Problem

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IT was previously shown[1,2] that the quantum Green's function gives very extensive information about the properties of systems of interacting particles. In this connection there is interest in investigating the general properties of Green's functions which are independent of any method of approximation. In work in the quantum theory of fields[3,4] the fruitfulness of the spectral approach to this problem was shown. In nonrelativistic theory there are certain complications, connected with the absence of Lorentz invariance; however, as will be shown below, there also exist analogous spectral theorems. For concreteness we will speak about a system of many electrons; the transition to a system of Bose particles will not present any difficulties.

We denote by $\Psi^*(x)$ and $\Psi(x)$ creation and destruction operators for electrons (in the Heisenberg representation); the symbol $\langle .. \rangle_0$ will mean the average over the ground state of the system of interacting particles, Φ_0 is the wave function of the ground state, $\Phi_{\nu,E}$ are the wave functions for the excited states, with characteristic energy E and (possibly) some other quantum number ν (the energy of the ground state is assumed to be zero). By definition

$$G_+(x, y) = i\langle \Psi(x)\,\Psi^*(y)\rangle_0;\quad x = \{\mathbf{x}, x_0\},\ x_0 = t, \tag{1}$$

$$G_c(x, y) = i\langle T\{\Psi(x)\,\Psi^*(y)\}\rangle_0 \tag{2}$$
$$= \theta(x_0 - y_0)\,G_+(x, y) + \theta(-x_0 + y_0)\,G_+(y, x).$$

If we assume

$$G_+(x, y) = i(\Phi_0, \Psi(x)\,\Phi_0)(\Phi_0, \Psi^*(y)\,\Phi_0) \tag{3}$$
$$+ i\sum_\nu \int dE\,(\Phi_0, \Psi(x)\,\Phi_{\nu,E})(\Phi_{\nu,E}\,\Psi^*(y)\,\Phi_0)$$