3) Physics Institute, Bulgarian Academy of Sciences, Sofia.
4) Institute of Physics and Chemistry, Mongolian Academy of Sciences, Ulan Bator.

BROKEN UNITARY SYMMETRY AND POSSIBLE $\Omega^-(1875)$ RESONANCE

V. M. Shekhter
A. F. Ioffe Physico-technical Institute, USSR Academy of Sciences
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It is reported in [1] that resonance with mass 1710 MeV has been observed in the $p\pi^+\pi^0$ system. Although its width is small ($\leq$50 MeV), it can be assumed that its presence is the very cause of the irregularity on the total π^+p scattering cross section curve in the ~1650 MeV region [2]. The resonance has in this case an isospin T = 3/2, and will be therefore henceforth denoted $\Delta(1710)$.

The three resonances $\Delta(1710)$, $\Sigma(1765)$ [3], and $\Xi(1820)$ [4-7] are equidistant. This suggests that, like the known isobars with quantum numbers $3/2^+$, they are members of a unitary decuplet. Their spin and parity are then most likely $5/2^-$. This is connected with the fact that both in π^-p and in K^-p scattering in the region of the resonances N(1688) and $\Lambda(1815)$ there are present waves both with $J^P = 5/2^+$ and $J^P = 5/2^-$. The presence of the latter can be attributed to the near-lying $\Delta(1710)$ and $\Sigma(1765)$. The same decuplet should contain also a resonance with strangeness -3, namely $\Omega^-(1875)$. It can be observed as a resonance in reactions of the type

$$K^- + p \to \Xi^- + \bar{K}^0 + K^0 + K^+$$
$$\Xi^0 + K^- + K^0 + K^+$$

The mass of $\Omega(1875)$ is determined by the equidistance condition. The error in its determination is apparently the same as in the other terms of the decuplet, and is of the order of ±10 MeV. We now present an estimate of the width of this resonance.

It is noted in [8] that the unitary relations for the partial widths of the members of the possible decuplet with $J^P = 5/2^-$ do not agree with the experimental data. We shall therefore use henceforth relations that are valid when account is taken (in first order) of the interaction that breaks unitary symmetry (the latter is assumed to be the eighth component of an octet) [9]. If we separate the kinematic factors, and set the width of the $I \to B + \pi$ decay equal to

$$\Gamma(I \to B + \pi) = \frac{m_B}{m_I} K^5[I \to B\pi]^2, \quad (1)$$

where k is the momentum of relative motion of B and π, and assume that the parameters [ ] depend little on the masses of the hadrons that participate in the reaction, then

$$[\Omega^-(1875) \to \Xi^0 K^-] = [\Delta^{++}(1710) \to p\pi^+] - \sqrt{3}[\Sigma^+(1765) \to p\bar{K}^0] + \sqrt{6}[\Xi^-(1820) \to \Xi^-\pi^0]. \quad (2)$$

By virtue of T-invariance, all the constants [ ] which enter in (2) are real, but their relative sign is unknown. To obtain information about this sign, we consider the relation

$$\sqrt{2/3}\ [\Delta^{++}(1710) \to p\pi^+] - 2\sqrt{2}\ [\Sigma(1765) \to p\bar{K}^0] + 2[\Xi^-(1820) \to \Xi^-\pi^0]$$

$$+\sqrt{3}\ [\Xi^-(1820) \to \Lambda K^-] - [\Xi^-(1820) \to \Sigma^0 K^-] = 0 \qquad (3)$$

and substitute in it the absolute values of the constants [ ]. According to [3], $\Gamma(\Sigma^+(1765) \to p\bar{K}^0) \approx 36$ MeV. This number corresponds to the total width of $\Sigma(1765)$, which is approximately equal to 60 MeV, and to the relative probability of the decay $\Sigma(1765) \to N\bar{K}$, which amounts to approximately 60%. For $\Xi^-(1820)$ the partial widths of the decay to $\Xi^-\pi^0$, ΛK^-, and $\Sigma^0 K^-$ are assumed to be respectively 10, 30, and 2 MeV. These values correspond to a total width of 70 MeV for $\Xi(1820)$, and to relative probabilities of 41% [7], 43% [7], and $\leq$10% [6] for the $\Xi\pi$, $\Lambda\bar{K}$, and $\Sigma\bar{K}$ channels, respectively, and also to isotopic ratios $\Xi^-\pi^0 : \Xi^0\pi^- = \Sigma^0 K^- : \Sigma^-\bar{K}^0 = 1:2$. Finally, according to [1], the total width for $\Delta(1720)$ is smaller than 50 MeV. Assuming that the relative probability of its decay to $N + \pi$ does not exceed ~30%, we find that $\Gamma(\Delta^{++}(1710) \to p\pi^+) \leq 15$ MeV. Although this quantity is not very accurately determined, it will be shown later that this is of little importance for the obtained results.

Knowing the partial widths, we obtain (absolute magnitudes in BeV^{-2})

$$\begin{aligned} [\Delta^{++}(1710) &\to p\pi^+] \leq 0.63, \\ [\Sigma^+(1765) &\to p\bar{K}^0] = 0.82, \\ [\Xi^-(1820) &\to \Xi^-\pi^0] = 1.11, \\ [\Xi^-(1820) &\to \Lambda K^-] = 2.30, \\ [\Xi^-(1820) &\to \Sigma^0 K^-] \leq 0.98. \end{aligned} \qquad (4)$$

We see now that in formula (3) the first and last terms are relatively small and that these equalities can hold only in the case when $[\Sigma^+(1765) \to p\bar{K}^0]$ and $[\Xi^-(1820) \to \Lambda K^-]$ have the same sign, which is the opposite of the sign of $[\Xi^-(1820) \to \Xi^-\pi^0]$. Then the last two terms in (2) add up in absolute magnitude and

$$[\Omega^-(1875) \to \Xi^0 K^-] = \pm 0.63 + 4.15. \qquad (5)$$

The sign of $[\Delta^{++}(1710) \to p\pi^+]$, meaning also the sign of the first term in (5), is unknown, but its value itself is small and lies essentially within the accuracy limits of the estimates. Neglecting this term when substituting (5) in (1), and recognizing that for the decays of $\Omega^-(1875)$ to $\Xi^0 K^-$ and $\Xi^-\bar{K}^0$ the constants [ ] differ only in sign, we obtain ultimately

$$\Gamma_{\Omega^-(1875)} \approx 13 \text{ MeV}. \qquad (6)$$

The result (6) calls for several remarks. First, the experimental values of the partial widths and the accuracy of the approximation (1) are not good enough to be able to regard (6) as anything but an order-of-magnitude estimate of $\Gamma_{\Omega(1875)}$. Second, the energy released in the decay $\Omega^-(1875) \to \Xi + \bar{K}$ is quite small. It would be perfectly natural for the width of this resonance to be of the order of 1 MeV, which is less than the value obtained in (6). The large value of (6) is connected with the fact that the parameter (5) is large compared with the typical numbers in (4). Thus, the use of broken unitary symmetry leads here to non-trivial results. This is all the more interesting, since the experimental confirmation of relations of this kind for the widths and the cross sections could hitherto be simply attributed to the presence in them of a large number of terms, the signs of which are unknown and are arbitrarily fitted to the experimental data.

In conclusion we note that if the assumed existence of the decuplet $\Delta(1710)$, $\Sigma(1765)$, $\Xi(1820)$, and $\Omega(1875)$ is verified, then other relations of broken unitary symmetry can likewise be verified experimentally, in particular

$$[\Sigma^+(1765) \to \Lambda\pi^+] = -[\Delta^{++}(1710) \to p\pi^+]/\sqrt{2} + [\Sigma^+(1765) \to p\bar{K}^0]\sqrt{3/2} - [\Xi^-(1820) \to \Lambda K^-],$$

$$[\Sigma^+(1765) \to \Sigma^0\pi^+] = [\Delta^{++}(1710) \to p\pi^+]/\sqrt{6} - [\Sigma^+(1765) \to p\bar{K}^0]3/\sqrt{2} \qquad (7)$$

$$+ [\Xi^-(1820) \to \Lambda K^-]\sqrt{3} + [\Xi^-(1820) \to \Xi^-\pi^0]2.$$

Using (4) and the sign rule derived above, we obtain in (7)

$$[\Sigma^+(1765) \to \Lambda\pi^+] = \pm 0.45 + 1.30,$$

$$[\Sigma^+(1765) \to \Sigma^0\pi^+] = \pm 0.26 + 0. \qquad (8)$$

From the second relation in (8) it follows that $[\Sigma^+(1765) \to \Sigma^0\pi^+] \leq 0.3$, whence

$$\Gamma(\Sigma(1765) \to \Sigma\pi) \leq 2.5 \text{ MeV}. \qquad (9)$$

The first relation in (8) can be reconciled with experiment if both terms in it have opposite signs. Then

$$\Gamma(\Sigma(1765) \to \Lambda\pi) \approx 20 \text{ MeV}. \qquad (10)$$

The experimental value of this partial width [3] does not exceed ~25 MeV. It must be borne in mind, however, that even a slight change in the experimental parameters can greatly influence the values of (8) - (10).

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POSSIBLE REALIZATION OF NEGATIVE CONDUCTIVITY WITH NONEQUILIBRIUM CARRIERS IN SEMICONDUCTORS

V. F. Elesin and E. A. Manykin
Moscow Engineering Physics Institute
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1. The energy distribution of nonequilibrium carriers (holes) usually differs little from the quasiequilibrium distribution, which is characterized by an effective temperature [1]. However, if the lifetime of the electron $\tau_e(\epsilon_{\vec{p}})$ in the conduction band is smaller than either the electron-electron interaction time or the time of relaxation on the acoustic phonons, then the electron distribution differs greatly from quasiequilibrium. The presence of such a nonequilibrium state can lead to several qualitatively new phenomena, in particular to negative conductivity, i.e., to the appearance of an electric current in a direction opposite to that of the external field $\vec{E}$. The effect of negative conductivity, which will be considered below, turns out to be connected with the threshold character of the interaction between the electrons and the optical phonons.

2. Let us consider a semiconductor at low temperatures ($kT \ll \hbar\omega_0$, ω_0 = frequency of the optical phonon) [1)]. Let the concentration of the equilibrium electrons be small compared with the concentration of the electrons produced in the conduction band under the influence of an external monochromatic source of intensity J with distribution $g(\Omega)$ (Fig. 1). The behavior of the electrons in the presence of an external field $\vec{E}$ is described by the usual kinetic equation:

$$-e\vec{E}\,\vec{\nabla}_{\vec{p}}\, f(\vec{p}) = \left(\frac{\partial f}{\partial t} \right)_{im} + \left(\frac{\partial f}{\partial t} \right)_{op} - \frac{f(\vec{p})}{\tau_e(\epsilon_{\vec{p}})} + Ig(\epsilon_{\vec{p}} - \omega), \quad (1)$$

where $(\partial f/\partial t)_{im}$ = integral of elastic collisions with impurities, $(\partial f/\partial t)_{op}$ = integral of collisions with phonons. The term $f(\vec{p})/\tau_e(\epsilon_{\vec{p}})$ describes the recombination of the electrons, while $Ig(\epsilon_{\vec{p}} - \omega)$ describes the creation of electrons, I being connected with the intensity of the source J and with the absorption coefficient $k(\omega)$ of the semiconductor by the relation $I = Jk(\omega)\pi^2/(2\omega)^{1/2}m^{3/2}$.

In weak electric fields the solution of (1) is sought in the form

$$f(\vec{p}) = f_0(\epsilon_{\vec{p}}) + \frac{e\,\vec{E}\cdot\vec{p}}{m}\,\tau(\epsilon_{\vec{p}})\,\frac{\partial f_0(\epsilon_{\vec{p}})}{\partial t}, \quad (2)$$

where