4-level scheme with mirrors having reflection coefficients R_1 and $R_2 = 1$, is

$$n \geq \left(2 - \frac{\Delta\lambda_3 \, \lambda_4^4 \, \eta_4}{\Delta\lambda_4 \, \lambda_3^4 \, \eta_3}\right)^{-1} N_0/k_0 , \qquad (1)$$

where N_0 is the activator concentration, k_0 the threshold inversion for 4-level lasing at R_1 or $R_2 = 1$, $\Delta\lambda_3$ and $\Delta\lambda_4$ the line widths, λ_3 and λ_4 the wavelengths, and η_3 and η_4 the luminescence quantum yields for the 3- and 4-level schemes, respectively.

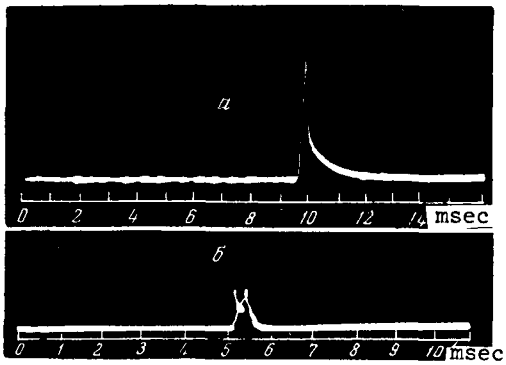

Fig. 2.

In the case of monopulse generation, appreciable inversion can be attained; for this reason, and allowing for the peculiarities of Q-switching by a rotating prism, we could expect the lasing in this mode to be in accordance with the 3-level scheme. An oscillogram of monopulse lasing with $\lambda_3 = 2.22$ μ is shown in Fig. 2a. The lasing pulse duration, measured on the oscillogram, is determined by the inertia of the apparatus and amounts to 2×10^{-7} sec. The laser radiation energy was 0.1×10^{-3} J. Assuming, in analogy with a ruby laser having the same resonator parameters (transmission loss 0.5 and resonator length 3 mm) and the same excess over threshold (~4-fold), that the true pulse duration is not more than 5×10^{-8} sec, we find that the pulse power is $\sim 4 \times 10^3$ W. In several crystals we obtained monopulse 4-level generation ($\lambda_4 = 2.51$ μ), apparently, because of the high concentration of the activator in these crystals [see expression (1)]. The shape of the pulse was the same as in Fig. 2a.

The maximum laser energy in the nonpulse was 10^{-3} J in this case, which yields, making the same assumptions concerning the laser pulse duration, a power of $\sim 5 \times 10^4$ W. At smaller prism speeds, several laser pulses were obtained rather than one. One such oscillogram is shown in Fig. 2b.

[1] Ermakov, Lukin, and Mak, Optika i spektroskopiya 18, 353 (1965).

[2] Anan'ev, Egorova, Mak, Prilezhaev, and Sedov, JETP 44, 1884 (1963), Soviet Phys. JETP 17, 1268 (1963).

EFFECT OF MASS SPLITTING WITHIN THE BARYON OCTET ON BB SCATTERING

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1. The consequences resulting from unitary symmetry for baryon-baryon scattering at low energies were considered in several papers [1]. One important result is the prediction that several reactions in which strange particles participate, connected in the limit of unitary symmetry with nucleon-nucleon scattering, are of resonant character. On the other hand, the

amount of experimental information on hyperon-nucleon interactions is increasing. In particular, there are weighty indications pointing to the existence of a virtual level in the Λp system, with a coupling parameter ϵ of the order of several MeV [2].

However, in comparing the experimental data with the predictions of SU(3) symmetry, the question always arises of the influence of the broken unitary symmetry. It was noted [1], for example, that the differences in the masses of the pseudoscalar mesons can strongly violate the unitary-symmetry character of baryon-baryon interaction. In this note we show that even if we forego such symmetry breaking, an account of the baryon mass difference can qualitatively change the scattering picture.

2. We consider by way of example the two-channel Λp scattering reaction with zero spin:

$$\Lambda p \to \Lambda p; \quad \Lambda p \to (\Sigma N)_{T=1/2} \tag{1}$$

where

$$(\Sigma N)_{T=1/2} = \sqrt{1/3}\,\Sigma_p^0 - \sqrt{2/3}\,\Sigma_n^+$$

and the mass difference inside the isotopic multiplets is neglected throughout for simplicity. Reactions (1) are described by two unitary amplitudes (a_{27} and a_8), and if in the limit of unitary symmetry the interaction is larger only in the {27} representation to which the virtual deuteron level belongs, then the relations between the elastic-scattering amplitudes are

$$a_{\Lambda p} = (9/10)a_{np}, \tag{2}$$

$$a_{\Sigma^+ p} = a_{np}. \tag{3}$$

In the real case, when the transformation of Λp into $(\Sigma N)_{T=1/2}$ is forbidden by energy conservation, the amplitudes of the pn, Σ^+p, or Λp elastic scattering have by virtue of unitarity the form

$$\frac{1}{1/a - ik}$$

and Eq. (2), unlike (3), can at best be realized for only one value of the momentum k. Unlike in the usual procedure [1], unitary relations for arbitrary but small momenta can therefore not be used.

One can hope that the unitary relations can nevertheless be compared with the experimental data at $k = 0$ in a manner similar to the comparison of the meson-baryon resonances with the widths of the allowed decays.

3. To clarify this question, let us consider a simple model of an interaction having unitary symmetry and zero force radius [3]. The model in which the elements of the R matrix are equal to their limiting values was used in many papers (see [3,4]) to analyze the consequences of broken symmetry in the particle masses. The BB scattering differs from these cases in that the binding energy is much smaller than the baryon mass difference Δm.

Let us return to Λp scattering. If the R matrix is of the form

$$R \sim \begin{pmatrix} a_{27} & 0 \\ 0 & 0 \end{pmatrix},$$

corresponding to resonant scattering only for one value of the unitary spin, then we can easily trace the motion of the pole of the S matrix and verify that when $(m_B \Delta m)^{1/2} \gg 1/a_{27}$ there should exist no levels, virtual or real, near the thresholds. An explicit form of the S-matrix elements is given in [3].

This result has a simple physical meaning. In the limit of SU(3) symmetry there is only one common level in the systems Λp and $(\Sigma N)_{T=1/2}$. If these systems are analyzed in the same manner even after account is taken of the mass difference, there are no grounds for expecting the level to be located at one of the thresholds, or the appearance of two levels [in Λp and $(\Sigma N)_{T=1/2}$ scattering].

4. Let us assume now that the R matrix is of the form

$$R \sim \begin{pmatrix} a_{27} & 0 \\ 0 & a_8 \end{pmatrix},$$

i.e., that the scattering lengths in states with different unitary spins are comparable. Then, when $(m_B \Delta m)^{1/2} \gg 1/a$, a level exists near $m_\Lambda + m_p$, but the Λp scattering length is connected with a_8 and a_{27} in a nonlinear manner,

$$a_{\Lambda p}^{-1} = (9/10)\ a_{27}^{-1} + (1/10)\ a_8^{-1}\ , \tag{4}$$

and not by the relation that follows from unbroken symmetry,

$$a_{\Lambda p} = (9/10)\ a_{27} + (1/10)\ a_8\ . \tag{5}$$

Thus, the existence of a virtual Λp level in the model in question can be explained only by the fact that the interaction is resonant in some irreducible representations of SU(3). We note that such a character of the interaction is natural if there exists some higher symmetry of interaction, for example SU(6) or SU(8) [5], where the different SU(3) representations are unified in a single supermultiplet.

5. It is clear that inclusion, for example, of terms corresponding to the effective scattering radius, which are small in the real case, could greatly change the derivations. However, we see even from the foregoing example that the breaking of unitary symmetry in the baryon masses can qualitatively change the BB-scattering picture obtained in the SU(3)-symmetry approximation.

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[1] De Souza, Snow, and Meshkov, Phys. Rev. 135B, 565 (1964); S. Iwao, Nuovo Cimento 34, 1167 (1964); I. S. Gerstein, ibid. 32, 1707 (1964).

[2] Melissinos, Redy, Reed, Yamanuchi, Sacharidis, Lindenbaum, Ozaki, and Yuan, Phys. Rev. Lett. 14, 604 (1965); Alexander, Karshon, Shapira, Yekutieli, Engelman, Filthuth, Fridman, and Minguzzi-Ranzi, Phys. Rev. Lett. 13, 484 (1964).

[3] R. H. Dalitz and S. F. Tuan, Ann. Phys. 8, 100 (1959); 10, 307 (1964).

[4] R. H. Dalitz and G. Rajasekaran, Phys. Lett. 7, 173 (1963).

[5] Y. Tomozawa, Phys. Rev. 138B, 1558 (1965).