[1)]Practically the only decays of the neutral intermediate boson of the type in the model[2] are decays into hadron systems of the type $K^-\pi^+$ and others with $\Delta S = \pm 1$. As a crude estimate, for m_W = 2-3 GeV and $\Delta E \approx$ 1-10 MeV the mean resonance cross section is $\bar{\sigma}_R \sim 10^{-34} - 10^{-35}$ cm^2. Decays into symmetric lepton or hadron pairs are suppressed by a factor of $\sim 4 \times 10^{-6}$.

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98

NEGATIVE DISPERSION IN THE R_1 LINE OF RUBY

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It follows from the theory of dispersion that if the population of the upper level n_2 is greater than the population of the lower level n_1, the anomalous dispersion curve corresponding to a transition between these two levels should change sign. In this case the dispersion curve exhibits unusual behavior, corresponding to negative dispersion.

In a number of well known papers, Ladenburg[1] used the Rozhdestvenskiĭ hook method to study the effect of increasing the population of the upper level on the dispersion curve for lines in neon. However in his experiments the lower level population always remained larger than the upper level population.

We have studied the dispersion of light in ruby in the presence of population inversion[1)]. Under these conditions the investigated material has a very high luminescence brightness. The radiation source used to measure the index of refraction of the luminescent ruby must be still brighter. In other words, when using the photographic method the temperature of the test source must be considerably greater than the emission temperature of the luminescing ruby, which is approximately 20,000°K. A laser is the natural source to use to satisfy this condition, and for this reason a ruby laser was used as the source of test radiation.

The optical dispersion was measured with the polarizing interferometer first used in [6] and described in a paper by one of the authors [2], with a modification suggested by I. V. Obreimov: instead of using quartz to compensate for the anomalous dispersion we used a ruby crystal which was identical with the one being investigated but with its optic axis perpendicular to that of the sample.

The experimental set-up was the following (Fig. 1). Polarized light from the ruby laser RL was passed through the ruby sample P_1 whose optic axis was vertical, made an angle of 45° with the plane of the polarized light and made an angle of 90° with the direction of propagation of the test light. The beam then passed through the compensating ruby P_2 whose optic axis was perpendicular to the direction of the optic axis of ruby P_1; the light then went through a cemented quartz double wedge W, the optic axes of which were perpen-

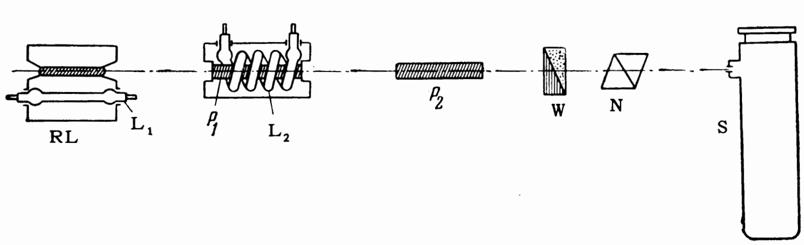

FIG. 1. Optical set-up for observation of dispersion.

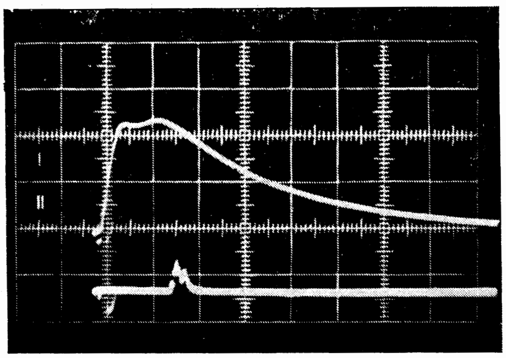

FIG. 2. Oscillogram of the pumping flash lamp for the crystal P_1 (upper beam) and the laser pulse (lower beam). The time scale is 0.5 millisec per large division.

dicular to each other and parallel and perpendicular to the axes of P_1 and P_2. It is simple to show that the path difference Δ between the vertical and horizontal components of the vector upon exit from the wedge W are

$$\Delta = \{[\mu_0^*(\lambda) - \mu_e^*(\lambda)] - [\mu_0(\lambda) - \mu_e(\lambda)]\} l + Cx, \quad (1)$$

where μ^* and μ are the refractive indices of the sample and the compensating rubies, the indices 0 and e refer to the ordinary and the extraordinary rays, l is the length of the rubies, x is the coordinate in the vertical plane, and C is a constant depending on the properties of the wedges W.

After passing through a Vlasov prism N, whose principal plane made angles of 45° with the axes of P_1 and P_2, both components are made to interfere. After dispersion in a grating spectrograph S of linear dispersion of 3.6 Å/mm in the focal plane, the following interference pattern was observed: at height x satisfying the condition

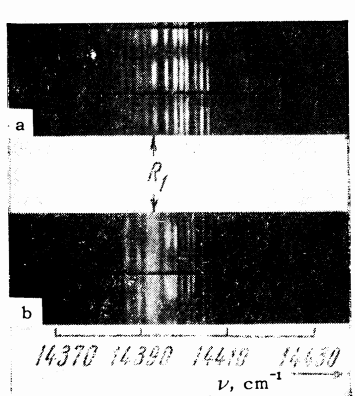

FIG. 3. Interferograms obtained on the set-up described: a) without pumping; b) with optical pumping of crystal P_1. In the figures each bright vertical band corresponds to a spike of the ruby laser.

$\Delta(x) = m\lambda$, a bright field occurs, and for $\Delta(x) = (m + 1/2)\lambda$ a dark field occurs (m is an integer). A single plate was used to photograph many interference patterns taken with many flashes of the laser at different wavelengths. The wavelength was varied from $\lambda = 6937$ Å to $\lambda = 6947$ Å by changing the temperature of the ruby laser from −100°C to +70°C [3]. As is clear from Eq. (1) the dark (or light) bands on the plate represent simply the dispersion curve of the quantities $(\mu_0^* - \mu_e^*) - (\mu_0 - \mu_e)$ to some scale. However the excursion of the dispersion curve μ_e should be twenty times smaller than the excursion of the dispersion curve of μ_0 (cf.[4]) and therefore the bands correspond approximately to the dispersion curve of $\mu_0^* - \mu_0$. The rubies P_1 and P_2 were polished cylinders with polished plane parallel ends, 72.3 mm long, 10.5 mm in diameter, and had a Cr_2O_3 concentration of 0.05% compared to Al_2O_3. Ruby P_1 was pumped with a model IFK-15000 spiral xenon flash lamp (L_2 in Fig. 1) with a pulse duration of about 3.5 millisec. The output power of the test laser was chosen so that the change in the population of the upper level n_2 of the test ruby P_1 due to stimulated emission caused by the test light was small and could be neglected. For all flashes the energy of the pumping laser was chosen so that its output, lasting about 200 μsec, always began at the same time, about 800 μsec after the start of the pumping lamp (Fig. 2). The energy of the flash lamp pumping the ruby P_1 was more than a factor of two above laser threshold measured with the same illumination and with dielectric mirrors.

Figure 3a shows an interferogram obtained with the above apparatus without pumping the sample. The optical path difference in crystals P_1 and P_2 has been compensated and in the region of the R_1 line one may see straight horizontal interference bands on the photograph. When the sample is pumped, the dispersion of the crystal P_1 changes and the previously compensated dispersion curves of the two crystals no longer cancel. The path of the interference bands reflects the difference in dispersion of crystals P_1 and P_2. In Fig. 3b we show an interferogram taken with crystal P_1 pumped. One clearly sees the characteristic wave-like shape of the negative dispersion curve in the region of the R_1 line. The anomalous dispersion of the crystal P_2 in the R_1 line was measured by putting in place of the crystal P_1 a plate of crystal quartz whose thickness was chosen so as to compensate the optical path length of crystal P_2 in the transparent region near the R_1 line. In Fig. 4 we show the data derived from the inter-

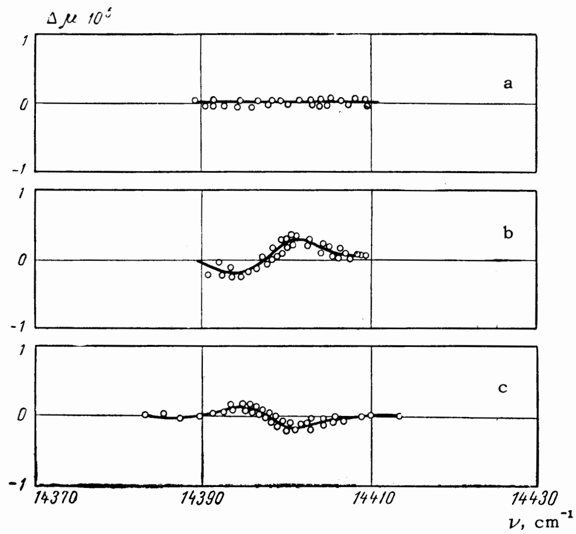

FIG. 4. Dispersion curves: a) without pumping; b) with optical pumping (negative dispersion in ruby P_1); c) dispersion curve of ruby P_2 without pumping and with a quartz plate in place of crystal P_1.

ferogram of Fig. 3 (the negative dispersion of the crystal P_1), and the curve of the anomalous dispersion of crystal P_2. The excursion of the dispersion curves, i.e., the separation between the maximum and the minimum ordinates of the dispersion curve under the conditions of pumping illumination are about 36% of the spread of the anomalous dispersion curve in the crystal P_2; this corresponds to a change of 3.7×10^{-6} in the index of refraction with respect to the unexcited ruby. The accuracy in measuring these dispersion curves was 86%. The population inversion, i.e., the quantity $(n_2 - n_1)/(n_2 + n_1)$, corresponds to the excursion of the measured negative dispersion curve and therefore to 36%. This is in agreement with the magnitude of the inversion measured in[5] for luminescence under approximately the same conditions. The measurements of negative dispersion give a method for direct determination of population inversion.

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99

ANNIHILATION OF ANTIBARYONS AND UNITARY SYMMETRY

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IN this letter we investigate relations among amplitudes for the production of baryon-antibaryon pairs (which belong to the irreducible representation of SU(3) of dimension 10) in the annihilation of $\bar{p}$ and $\bar{\Sigma}^+$ on protons. The processes have the form

$$\begin{array}{llll} f_1 & \bar{p}+p\to\bar{\Omega}^-+\Omega^-, & f_5 & \bar{\Sigma}^++p\to\bar{\Omega}^-+\Xi^{*-}, \\ f_2 & \bar{p}+p\to\bar{\Xi}^{*-}+\Xi^{*-}, & f_6 & \bar{\Sigma}^++p\to\Xi^{*-}+Y_1^{*-}, \\ f_3 & \bar{p}+p\to\bar{Y}_1^{*-}+Y_1^{*-}, & f_7 & \bar{\Sigma}^++p\to\bar{Y}_1^{*-}+N^{*-}. \\ f_4 & \bar{p}+p\to\bar{N}^{*-}+N^{*-}, & & \end{array} \quad (1)$$

The relations among these amplitudes resulting from unitary symmetry have already been discussed in detail [1]. However, in view of the success of the Okubo mass formula [2] it is interesting to try to derive these relations also with account of those symmetry-breaking interactions which preserve isotopic spin and hypercharge (medium strong interactions).