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The fundamental process of light-light scattering is related to non-linear quantum electrodynamic effects /1/ that violate the classical Maxwell's electrodynamics. For the first time this process has been mentioned in the Vavilov's paper /2/. Detailed investigation of the elastic scattering of light by light has been carried out in works /3-5/. In the case considered the cross section of the process increases as the sixth power of energy, reaches the maximum ($\approx 10^{-31}$ cm^2) in the 1 MeV region and rapidly falls for larger energies. It is characteristic that in the region of possible hadron intermediate states this cross section becomes small.

Resonant scattering of light by light through strongly interacting intermediate particles (π°, η_0, X_0 and other) /6/ is large (10^{-26} - 10^{-27} cm^2), but only in a very narrow energy regions.

Therefore it is very interesting to investigate the contribution from the continuous spectrum of two pion intermediate state and to compare it with the resonant light-light scattering.

In the present paper making use of dispersion relations, the lowest s and d partial waves of the reaction $\gamma\gamma \to \gamma\gamma$ are calculated from the partial waves of the process $\gamma\gamma \to \pi\pi$ obtained in paper /7/.

Let us introduce the relativistic amplitudes (in the c.m.s.) $T_{\alpha\beta\gamma\delta}$ (t, $\cos\phi_t$) of the light-light scattering with given transversal polarizations:

$$<2\gamma'|s|2\gamma> = \frac{i}{(2\pi)^2}\frac{1}{4k_0^2}\,\delta^{(4)}(k+k'-q-q')\,T_{\alpha\beta\gamma\delta}(t,\cos\phi_t)\epsilon^{\alpha}(k)\epsilon^{\beta}(k')\epsilon^{\gamma}(q)\epsilon^{\delta}(q')$$

Here $k=(k_0,\vec{k})$, $k'=(k'_0,\vec{k}')$ and $q=(q_0,\vec{q})$, $q'=(q'_0,\vec{q}')$ are 4-momenta of the initial and the final photons;

$$t = 4k_0^2; \qquad k_0 = k'_0 = q_0 = q'_0 ;$$

ϕ_t is the scattering angle; α, β, γ, δ take two values x, y. We expand the amplitudes of the process in partial waves and write for s and d waves of the reaction $\gamma\gamma \to \gamma\gamma$ two-particle unitary condition with the two-pion intermediate state (in the $\gamma\gamma \to \pi\pi$ process only even values of relative orbital momentum l are present):

$$Jm\,T_{\alpha\beta\gamma\delta}(t)_l = \frac{1}{32\pi}\sqrt{1-\frac{4\mu_\pi}{t}}\sum_{T=0,2} T^{(T)*}_{\alpha\beta}(t)_l\, T^{(T)}_{\gamma\delta}(t)_l\,, \qquad (1)$$

where $T^{(T)}_{\alpha\beta}(t)_l$ are amplitudes of the reaction $\gamma\gamma\to\pi\pi$ with isospin T described in the works /7,8/.

Later amplitudes $T^{(T)}_{\alpha\beta}(t)_l$ were normalized according to Thompson's limit. Let us use these normalized partial waves to determine the imaginary part of the $\gamma\gamma \to \gamma\gamma$ amplitude. We demand the cross section of light by light scattering to tend to zero for $t \to 0$. Then the real part of the $\gamma\gamma \to \gamma\gamma$ amplitude can be calculated from the dispersion relation with one subtraction:

$$Re\, T_{\alpha\beta\gamma\delta}(t)_l = \frac{t}{\pi} P \int_{4\mu_\pi^2}^{\infty} \frac{Jm\, T_{\alpha\beta\gamma\delta}(t')_l}{t'(t'-t)}\, dt' . \qquad (2)$$

One can obtain the contribution of the two-pion intermediate state to the cross sections of s and d waves for reaction $\gamma\gamma \to \gamma\gamma$ confining to the relations (1) and (2) only and not taking account of the additive contributions from the one-particle intermediate states and the left-hand cuts.

The formula for the partial cross section has the form

$$\sigma_{\gamma\gamma\to\gamma\gamma}(t)_l = \frac{(2l+1)}{16\pi}\frac{1}{t} T^*_{\alpha\beta\gamma\delta}(t)_l\, T_{\alpha'\beta'\gamma'\delta'}(t)_l\, e^{\alpha\alpha'}(k) \times$$

$$\times\, e^{\beta\beta'}(k')\, e^{\gamma\gamma'}(q)\, e^{\delta\delta'}(q'),$$

where $e^{\alpha\alpha'}(k)$ are the photon polarization density matrices. The calculations were performed for white light i.e. for the case $e^{\alpha\alpha'} = \frac{1}{2}\delta^{\alpha\alpha'}$ and so on.

Earlier we got s and d waves of $\gamma\gamma \to \pi\pi$ process and presented two solutions for s wave corresponding to the known "down" and "down-up" experimental sets of δ_0^0 phase shift of the $\pi\pi$ -scattering /7/. These amplitudes were used as the basis of the calculations of s and d waves (see Fig. 1 and Fig. 2, respectively) of the light-light scattering (dotted curves correspond to the threshold variations of the δ_0^0 phase shift of the $\pi\pi$ -scattering in the way it was described in papers /7/). s wave cross section connected with the "down-up" s wave solution for $\gamma\gamma \to \pi\pi$ reaction exhibits the resonance behaviour in the σ -meson and the S^* -meson regions. For the "down" wave the σ -resonance transforms into broad distribution. Dotted variations in the threshold behaviour of the cross sections correspond to the δ_0^0 $\pi\pi$ -scattering phase shift variations (in the region of experimental values).

Cross section for d wave of $\gamma\gamma \to \gamma\gamma$ process is small at the threshold if compared with the s wave cross section, but in the region of the f -meson it grows rapidly and gives the contribution as large as s wave.

Comparison of these cross sections with the results of work /5/ shows that in the energy region $\approx 2\mu_\pi$, M_σ the contribution of the processes with two pion intermediate states to the cross section of the light-light scattering dominates.

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