Comment on "Dephasing times in quantum dots due to elastic LO phonon-carrier collisions" - Uskov et al. reply

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Uskov *et al.* Reply: In our Letter [1] we analyzed the effect of a second-order elastic electron-phonon interaction on the broadening of the zero-phonon line in quantum dots (QD). If the energy of the dispersionless optical phonons does not match the energy differences of the QD levels, only virtual transitions are possible. These virtual transitions give rise to phase fluctuations of the QD electronic state, which in turn may lead to a broadening of the corresponding spectral lines. This physical picture has earlier been applied successfully to optical dephasing in doped crystals; see Ref. [2]. It is also well known that a fluctuating classical field leads to a Gaussian line shape; see, e.g., Ref. [3].

In order to accommodate quantum effects due to phonon statistics, we considered the phonon average of the time-evolution operator $A(t) = \langle \hat{U}(t) \rangle \propto \langle T \exp[-i \int_0^t dt_1 \times H^{(2)}(t_1)] \rangle$, where $H^{(2)}$ is the quadratic electron-phonon interaction derived in our Letter, Eq. (8). Our calculation was carried out with the cumulant technique, retaining the second-order cumulant, and in the limit $\sigma \gg \gamma_{\mathrm{LO}}$ we found a Gaussian line shape—in complete analogue with the case of classical fluctuations (here σ is a number characterizing the QD [Eq. (14) in [1]], and γ_{LO} is the inverse lifetime of the optical phonons).

In their Comment [4] Muljarov and Zimmermann (MZ) point out that the second-order cumulant is not exact for the present problem (as implied in our Letter). This observation is indeed correct: the quadratic electron-phonon interaction, unlike the linear electron-phonon interaction for which the second-order cumulant is exact, generates higher order linked clusters, which need to be considered. In their previous work [5] MZ have developed an elegant method, which allows a (numerically) exact evaluation of the higher cumulants *and* their explicit summation. When applied to the present case, their method gives rise to important qualitative differences as compared to our second-order results. Referring to the inset of the figure in the Comment, we note that the signal has an initial short-time Gaussian decay, in accordance with our results, which, however, at larger times becomes an oscillatory function of time, never decaying to zero. While the calculation of MZ was done in the limit of infinite phonon lifetime, and therefore is not immediately relevant to experiments where other interactions do lead to a decay, the principal conclusion is important (and with which we agree): in the limit $\sigma \gg \gamma_{\mathrm{LO}}$ the second-order interaction of electrons and dispersionless optical phonons alone does not lead to a decaying signal in time domain, and thereby to a finite spectral linewidth. Thus the conclusions of our Letter concerning this limit must be modified accordingly. We find it both intriguing and interesting that the classical and quantal fluctuations differ so much in this particular case.

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[3] See, for example, Sect. 6.5.3 in G. P. Agrawal and N. K. Dutta, *Semiconductor Lasers* (Van Nostrand Reinhold, New York, 1993), 2nd ed.
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