## Comment on "Plasmons in Coupled Bilayer Structures"

In a recent contribution, Das Sarma and Hwang (DSH) analyzed the collective charge density excitation spectra (plasmons) in bilayer semiconductor heterostructures, including effects of interlayer tunneling [1]. The main result that they obtained is that the acoustic plasmon $\omega_-(q)$ develops a long wavelength gap $\Delta$, with $\Delta$ being proportional to the square root (linear power) of the tunneling in the weak (strong) tunneling limit. However, and on the basis of results obtained from a realistic model, *where tunneling is treated exactly,* we prove here that the square-root dependence on the tunneling-induced gap is never realized, being replaced instead by a logarithmic correction to the linear term. Our model consists of a typical $GaAs/Al_xGa_{1-x}As$ double quantum well (DQW) system, with well size $d_w$, barrier width $d_b$, bare barrier height $V_0$, doped with a total electronic density $N_S$. Many-body effects are included by performing our calculations within the framework of the density functional theory, in its local density approximation. The elementary excitation spectra is obtained using the time dependent local density approximation (TDLDA) [2]. To analyze these results, it is useful to recall that in the long wavelength limit the following expression can be derived for this plasmon [2]:

$$\hbar\omega_-(0) \equiv \Delta = \Delta_{\rm SAS}\left(1 + \frac{2\gamma\Delta n}{\Delta_{\rm SAS}}\right)^{1/2}. \tag{1}$$

Here, $\Delta_{\rm SAS} \equiv E_2 - E_1$ corresponds to the tunneling-induced gap between the first-excited (antisymmetric) and ground-state (symmetric) DQW subbands; $\Delta n = n_1 - n_2 > 0$ is the difference of occupancy (density) between the ground-state and first-excited subbands, and $\gamma$ has two many-body contributions: one generally positive, $\gamma_H$, which corresponds to the Hartree mean-field term, and a second negative contribution, $\gamma_{\rm XC}$, which comes from the exchange-correlation effects. *It is important to realize that $\Delta_{\rm SAS}$, $\gamma$, and $\Delta n$ are all self-consistently calculated, starting from the sample parameters.* In the strong-tunneling one-subband regime of large $\Delta_{\rm SAS}$, $\Delta n = n_1$ and Eq. (1) can be safely approximated by $\Delta_S/\Delta_{\rm SAS} \simeq 1 + \gamma n_1/\Delta_{\rm SAS}$. The question is now: What happens when one moves from the strong- to the weak-tunneling regime of $\Delta_{\rm SAS} \to 0$? The authors of Ref. [1], elaborating from Eq. (1) by assuming that the one-subband regime extends down to arbitrarily small values of $\Delta_{\rm SAS}$, arrive at the conclusion that $\Delta_{\rm DSH}/\Delta_{\rm SAS} \simeq (2\gamma n_1/\Delta_{\rm SAS})^{1/2}$. The weak point of this line of reasoning is that for $\Delta_{\rm SAS} \to 0$, the system *always* enters in the two-subband regime. Besides, as soon as the second subband becomes occupied, $\Delta_{\rm SAS}$ and $\Delta n$ become linked by $\Delta_{\rm SAS} = \pi\hbar^2\Delta n/m^*$, and the dependence of $\hbar\omega_-(0)/\Delta_{\rm SAS}$ on $\Delta_{\rm SAS}$ changes dramatically. In the weak-tunneling regime $\Delta_{\rm SAS} \simeq \Delta_{\rm SAS}(0)\exp(-q_\perp d_b)$, and Eq. (1) reduces to

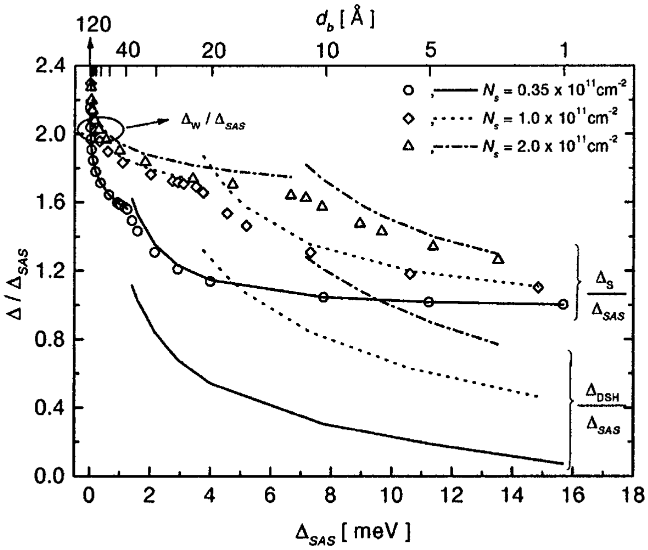


FIG. 1. Long wavelength limit of the intersubband plasmon ($\Delta$) versus tunneling strength $\Delta_{\rm SAS}$ (or $d_b$). Points are the results from a *full* TDLDA calculation; kinks at $\Delta_{\rm SAS} \simeq 1.25$, 3.57, and 7.14 meV correspond to the one subband → two subband transition. Lines correspond to different scalings explained in the text.

$$\frac{\Delta_W}{\Delta_{\rm SAS}} \sim \left\{\frac{2m^*}{\pi\hbar^2}\left[\frac{\pi e^2}{\varepsilon}\left(d_w - \frac{1}{q_\perp}\ln\frac{\Delta_{\rm SAS}}{\Delta_{\rm SAS}(0)}\right) + \gamma_{\rm XC}\right]\right\}^{1/2}. \tag{2}$$

Here, $\Delta_{\rm SAS}(0)$ is the $d_b = 0$ tunneling gap, $\varepsilon$ and $m^*$ are the GaAs dielectric constant and effective mass, respectively, and $\hbar^2 q_\perp^2/2m^* \simeq V_0 - (E_1 + E_2)/2$. From the comparison in Fig. 1 between our rigorous TDLDA results with the three different proposed scalings for $\Delta/\Delta_{\rm SAS}$, we conclude that the $\Delta_{\rm DSH}/\Delta_{\rm SAS}$ scaling of the weak tunneling regime of Ref. [1] is not applicable. Instead, it should be replaced by the scaling proposed by Eq. (2), with a logarithmic correction to the linear term.

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[1] S. Das Sarma and E. H. Hwang, Phys. Rev. Lett. **81**, 4216 (1998).
[2] T. Ando, A. B. Fowler, and F. Stern, Rev. Mod. Phys. **54**, 437 (1982).