Comment on “Quantum Theory of Secondary Emission in Optically Excited Semiconductor Quantum Wells”

In a recent Letter, Kira *et al.* [1] propose a fully quantum mechanical theory for the secondary emission (SE) of a quantum well (QW), assuming that the QW is free of disorder, and that SE originates from the interaction between excitons in the system. The authors ask if “disorder is necessary to explain coherent signatures in the SE.” They claim that their “microscopic theory reproduces many of the experimentally observed effects, showing that the SE exhibits *intrinsic coherent characteristics*” In this Comment we show that the SE calculated by Kira *et al.* is incoherent and nonlinear, and therefore inadequate for SE experiments performed under low-excitation conditions [2–8]. Such experiments are in agreement with an explanation in terms of disorder-induced resonant Rayleigh scattering (RRS) and have indeed given clear evidence for the following: (i) The temporal coherence of the SE at early times. (ii) A fully linear relation between emission intensity and excitation density over 3 orders of magnitude. (iii) The temporal profile depends only on statistical properties of the disordered potential.

On the other hand, the new theoretical formalism by Kira *et al.* combining semiconductor Bloch equations and field quantization is of largest importance for the dynamics of temporally incoherent resonant QW luminescence [3,9].

The term “temporal coherence” of SE has received very lately a clear definition that is experimentally verifiable. The *coherent* part of SE produces interferences with a replica of the exciting laser pulse [5,8] and present speckles [7]; because the quantum average of the electric field operator in the SE direction is nonzero, $\langle E_q \rangle \equiv \langle b_q + b_q^\dagger \rangle \neq 0$. Experiments show that this average electric field makes up 25% [5] or up to 50% [8] of the total intensity of the SE. Fluctuations of the electric field operator are much too weak to explain these experimental findings. The calculations by Kira *et al.* [1] use explicitly the fact that only in the specular directions is $\langle E_q \rangle \neq 0$. For the scattered directions only the correlation functions $\langle b_{q\perp, q_{\parallel}}^\dagger h_{-\mathbf{k}} e_{\mathbf{k}+q_{\parallel}} \rangle$ are nonzero. The calculated SE is therefore mainly incoherent as it does not carry a phase that could produce strong enough interferences, which would be quantitatively in agreement with the experiments [5,8].

Another important property of the coherent SE is the linear dependence on the excitation density, which has been explicitly reported [5,6,10]. The early SE calculated by Kira *et al.* shows a nonlinear dependence of the peak intensity and density-dependent rise time (see Fig. 1 in [1]).

Nonlinearity is also explicit in their two pulse calculations in which “the two pulse excitation for $\Phi = 0$ leads to an enhancement of the emission intensity by more than an order of magnitude” in comparison to the single-pulse excitation. Experiments on SE excited by two pulses show that the enhancement factor is never larger than 4 [4,10], as predicted by linear theories [11].

Finally, the physical origin of the “pulse replica” found at $t \approx 500$ fs needs to be clarified. If the pulse replica is due to exciton-exciton interaction, we would expect that the position of the peak depends on the exciton density, something that does not seem to happen in the work of Kira *et al.* [1] (Fig. 1 in [1]).

Our conclusions are as follows: (i) the interaction-induced SE [1] is incoherent and nonlinear. (ii) It is therefore incompatible with the experimentally observed coherent and linear SE. (iii) The SE calculated by Kira *et al.* is more appropriate and of highest value for the description of incoherent luminescence dynamics due to exciton-exciton interaction.

J. Fernández-Rossier,^{1,*} S. Haacke,² and B. Deveaud²

¹Departamento de Física Teórica de la Materia Condensada
Universidad Autónoma de Madrid
Cantoblanco, 28049 Madrid, Spain

²Physics Department, IMO
Swiss Federal Institute of Technology Lausanne
CH-105 Lausanne, EPFL, Switzerland

Received 14 July 1999

PACS numbers: 78.66.-w, 42.25.Kb, 42.50.Dv

*Present address: Physics Department, University of California San Diego, 9500 Gilman Drive, La Jolla, CA 92092.

- [1] M. Kira, F. Jahnke, and S. W. Koch, *Phys. Rev. Lett.* **82**, 3544 (1999).
- [2] M. Gurioli *et al.*, *Phys. Rev. Lett.* **78**, 3205 (1997).
- [3] S. Haacke *et al.*, *Phys. Rev. Lett.* **78**, 2228 (1997).
- [4] M. Woerner and J. Shah, *Phys. Rev. Lett.* **81**, 4208 (1998).
- [5] D. Birkedal and J. Shah, *Phys. Rev. Lett.* **81**, 2372 (1998).
- [6] S. Haacke, *et al.*, in *OSA Trends in Optics and Photonics*, edited by D. Citrin (Optical Society of America, Washington, DC, 1998), Vol. 18, p. 64.
- [7] W. Langbein, J. Hvam, and R. Zimmermann, *Phys. Rev. Lett.* **82**, 1040 (1999).
- [8] S. Haacke *et al.*, *Phys. Rev. B* **61**, 5109 (2000).
- [9] H. Wang *et al.*, *Phys. Rev. Lett.* **74**, 3065 (1995).
- [10] N. Garro (private communication); N. Garro *et al.*, *Phys. Rev. B* **60**, 4497 (1999).
- [11] J. Fernández-Rossier, C. Tejedor, and R. Merlin, *J. Phys. Condens. Matter* **11**, 6013 (1999).