## Comment on "Physical Picture for Light Emission in Scanning Tunneling Microscopy"

In a recent Letter [1], Xiao presents a theoretical study of light emission induced by a scanning tunneling microscope (STM) based on the electromagnetic coupling of a *dipolar* tip and a flat surface. Xiao also emphasizes the importance of retardation.

We first wish to emphasize that when the theory of Johansson, Monreal, and Apell (JMA) [2] is used with the adequate optical constants and when retardation is accounted for—*although it may be important to do so only in some particular cases* [3,4]—it shows an excellent agreement with experiments [5], and this agreement is definitely not "fortuitous" as claimed by Xiao [1].

In his paper, Xiao conveys the idea that JMA resort to the Tersoff-Hamann theory for the current while this is not the case [2]. Besides, in the JMA model, the electromagnetic coupling between a spherical tip and a flat sample is determined rigorously in the static case as in the original JMA theory [2] and in the retarded regime as presented by Johansson [3]. Unlike Xiao, JMA do not model the tip as a single dipole; a hypothesis that is too crude given the rapid variation of the electric field inside the tip which makes the dipole approximation irrelevant [6]. Figure 1 represents the electric field inside a 15 nm radius Ir sphere located 0.5 nm away from an Ag plane. The field is computed as an exact solution to the Laplace equation as described in [7]. It is obvious that we are far from a dipolar regime (field uniform in the sphere). Opting for a dipole representation despite the strong field variation inside the tip can lead not only to a bad representation of the field outside the tip but also to an incorrect spectrum as higher order multipoles influence the spectral response of the tip [8].

Xiao then uses the formalism developed by Agarwal [9] to account for the electromagnetic coupling between the tip and the surface. Incidentally, more realistic studies based on this formalism, accounting for many-body interactions and not restricted to a dipolar tip, have already been conducted and shown to be consistent with JMA's theory and with experiments provided that adequate dielectric functions are used [4]. In the case investigated by Xiao, the tip-sample distance is of the order of 0.5 nm. Over such a small distance, retardation effects are certainly not an issue. At 600 nm, the two field propagators (in $\mathrm{nm}^{-3}$) for the $zz$ component are [10] $(2.3087 + 2.2079i \times 10^{-2})$ and $(2.3085 + 2.2073i \times 10^{-2})$ for the retarded and the static propagators, respectively. Hence, retardation is negligible. The need for a retarded description strongly depends on the model of the tip. Johansson demonstrated that retardation could be important, but he was using a more realistic model where the Ir tip consisted of an actual sphere whose size (diameter 60 nm) made the contribution of retardation become significant as different parts of the tip see different values of the field (Fig. 1). This essential feature is absent from the dipolar model of Xiao.

Besides, the definition of the variable $d$ in [1] as the tip-sample separation is inconsistent with its use in Eq. (9) as the separation between the tip center and the surface ($d \approx 0.5$ nm). For consistency, Eq. (9) in Ref. [1] should be solved for $z = d + R$, not for $z = d$, because the expression of the polarizability used by Xiao for the tip is that of a sphere with radius $R$. In the case treated by Xiao the tip is "buried" in the surface (the tip radius is 15 nm while $d$ is of the order of only 0.5 nm). To conclude, let us emphasize that a discussion of STM-induced light emission requires a realistic description of the electromagnetic coupling between the tip and the sample which implies to go beyond the dipole approximation for the tip [2–4,6].

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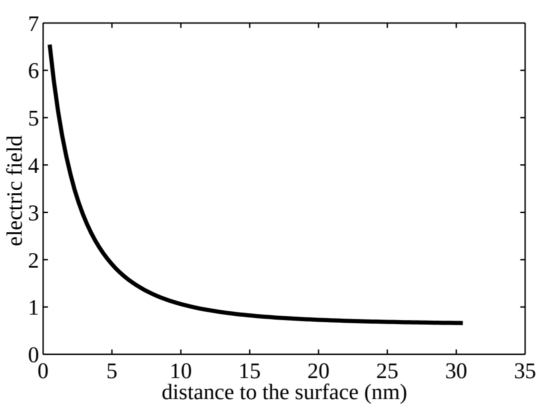


FIG. 1. Electric field (modulus) inside a 15 nm radius spherical Ir tip, located 0.5 nm away from an Ag plane. In accordance to the reciprocity theorem used by JMA, the calculation is done by using a normalized incident field (wavelength 600 nm, angle of incidence 45°; see also [4]).

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