Xiao Replies: Chaumet and Rahmani [1] seem to have the impression that my Letter [2] was intended to challenge the long existing theory by Johansson *et al.* for light emission in scanning tunneling microscopy (STM), in terms of accuracy of the calculations. However, as clearly demonstrated in the Letter [2], my challenge was rather to the concept of plasmon mediation. A new concept of coupling modes mediation was supported by a rough numerical estimation, and only a qualitative comparison to experiments was claimed [2].

A plasmon somehow residing in the tip-surface gap was believed to be responsible for the light emission. This plasmon mediation theory, largely promoted by Johansson and co-workers, has been well known for a long time. One sees two problems here. First, it is difficult to understand this particular plasmon, which actually stimulated the remarks I cited in the Letter [2], such as “fortuitous” [3] and “occasional” [4]. Second, the plasmon concept does not seem applicable to nonmetal materials. If there is no plasma, whence comes a plasmon?

Electromagnetic coupling between two objects may be resonant if the feedback is strong enough. The strength of the feedback depends on the distance between the objects and the local response of each object, the latter may be associated with local plasmon or not (for example, a semiconductor quantum dot contains strong response lines). The above coupling modes may be excited due to fluctuations in the tunneling current and thus cause light emission in STM, which is what my new concept is about, and which removes immediately the two difficulties one has with the old concept.

Self-consistent calculation is the key to solving resonant couplings. Electrostatic solutions from the Laplace equation, with or without the retardation factor attached, can never do the job because the feedback (or infinite reflections) is missing. For a dipole-surface system, an old way to take into account the self-consistent effect is to take an expanded field to be the feedback [5]. Nowadays, the problem is more often solved exactly as an eigenvalue problem for the dipole surface (see Ref. [6] for some references) and the group-dipole-surface problems (see, for example, Ref. [7]).

However, self-consistency is not the only important consideration; one also needs to describe the feedback rigorously, which means, for dipole-surface system, a reflection propagator. In Refs. [6] such a rigorous propagator was developed, which is divided into two parts, evanescent and propagating, and which takes an exact reflection coefficient for each plane wave in the plane wave expansion. In contrast to what Chaumet and Rahmani believed [1], this full spectrum and fully retarded propagator is not to be found in the present or old literature. Several curves calculated with my self-consistent formalism can be found in the first paper in Ref. [6], which are comparable to the curves presented in Refs. [5,7], but are in no way similar to the curve by Chaumet and Rahmani [1]. The difference is clearly that, if the self-consistent effects are included, the local field at the sphere (or the dipole in the simpler model) may be resonantly enhanced when the sphere approaches the surface; otherwise, one obtains uniform exponential curves like the one Chaumet and Rahmani obtained [1]. This difference is beyond the accuracy of calculations.

Chaumet and Rahmani [1] repeatedly emphasize the insignificance of the difference between nonretarded and retarded calculations in their approach. However, this difference is insignificant only in their solution to the Laplace equation, while in self-consistent solution the difference can be significant if the system reaches resonant coupling [6]. The reason is simply that resonant coupling implies infinite reflections between the dipole and the surface.

Finally, my understanding is that the agreements claimed by Chaumet and Rahmani are due to the use of dispersive dielectric functions of the objects. Since the plasmon enhancements are already included in the functions, electrostatic methods using these functions may show a combination of the enhancements. I stress that these local enhancements may contribute to the resonant coupling particularly in the case of metal samples. However, as demonstrated in my Letter [2], without the local plasmon enhancements the coupling modes exist and may still be excited. This means, for example, in semiconductor samples strong interband transmissions may create resonant tip-sample couplings which may be excited by the fluctuations in the tunneling current. In whatever cases, the photons stem from the excited coupling modes, not from vaguely defined intermediate plasmons.

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[1] P. Chaumet and A. Rahmani, preceding Comment, Phys. Rev. Lett. **84**, 3498 (2000).
[2] M. Xiao, Phys. Rev. Lett. **82**, 1875 (1999).
[3] K. Takeuchi *et al.*, J. Vac. Sci. Technol. B **9**, 557 (1991).
[4] I. I. Smolyaninov, Surf. Sci. **364**, 79 (1996).
[5] R. R. Chance, A. Prock, and R. Silbey, J. Chem. Phys. **60**, 2744 (1974).
[6] M. Xiao, Chem. Phys. Lett. **270**, 169 (1997); M. Xiao, Opt. Commun. **143**, 11 (1997).
[7] Ch. Girard, O. J. F. Martin, and A. Dereux, Phys. Rev. Lett. **75**, 3098 (1996).