Response to ''Comment on 'Sonoluminescence light emission' '' [Phys. Fluids 12, 472 (1999)]

Sascha Hilgenfeldt
Division of Engineering and Applied Sciences, Harvard University, 29 Oxford St., Cambridge, Massachusetts 02138

Siegfried Grossmann
Fachbereich Physik der Universität Marburg, Renthof 6, D-35032 Marburg, Germany

Detlef Lohse
Department of Physics, University of Twente, Postbus 217, 7500 AE Enschede, The Netherlands

(Received 20 October 1999; accepted 22 October 1999)

[S1070-6631(00)01402-1]

In their Comment, Hammer and Frommhold[1] check the validity of the results in the original publication[2] by comparing the approximate calculations found therein to their *ab initio*, quantum mechanical formalism. Overall, both computational methods yield similar results, which validates the assumptions about the principal physical processes involved in SBSL light emission (electron–ion and electron–neutral bremsstrahlung, radiative recombination) made in Ref. 2. When employing the quantum mechanical absorption coefficients, Hammer and Frommhold obtain spectra that are stronger in the UV than the approximate results, and are dominated by electron–neutral bremsstrahlung throughout the range of observable wavelengths. This leads to a change in the spectral shape, and, in particular, removes the spectral maximum obtained in the approximate calculations for argon.

It should be pointed out here that the approximate formalism can produce this change in spectral shape as well, upon even slight changes of the external parameters (driving pressure amplitude, ambient bubble radius). In particular, for a xenon bubble we predict (see Fig. 1) that increasing P_a by a very small amount (~ 0.01 atm) produces a noticeable shift in the spectral maximum to smaller wavelengths (closer to where it is observed in experiment); if P_a is increased further, the maximum gets indeed shifted out of the observable wavelength regime. Note that the curve for $P_a = 1.30$ atm in Fig. 1 corrects an oversight in the original paper, where for this example the corresponding spectrum was accidentally given for a calculation without water vapor; the spectrum as given here is more intense. This in part accounts for initial discrepancies between our results and approximate calculations by Hammer and Frommhold. A slight difference in modeling of the dynamics of the bubble also contributed to these deviations, which are now resolved.

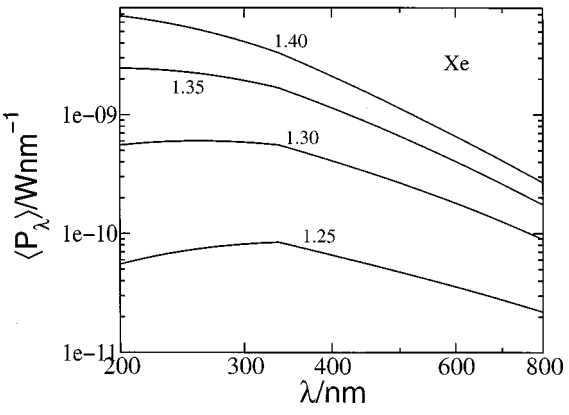

FIG. 1. SBSL spectra for xenon bubbles of ambient radius $R_0 = 5.0$ μm for different driving amplitudes $P_a = 1.25$, 1.3, 1.35, and 1.4 atm, indicated at the curves. The spectral maximum shifts to shorter λ as P_a increases and is eventually removed from the detectable wavelength range 200 nm $\leqslant \lambda \leqslant$ 800 nm.

In the calculations of Fig. 1, $R_0 = 5.0$ μm is kept fixed, and the bubbles driven at the higher P_a values are not necessarily shape stable.[2,3] However, if single-bubble sonoluminescence can be *upscaled*,[4] such an increase in the driving and consequently in the violence of the bubble collapse should be achieved quite easily (e.g., by lowering the driving frequency). This is a new prediction from the model, which was brought to our attention through the Comment by Hammer and Frommhold. We also thank Dominik Hammer for pointing out to us a typographical error in Ref. 2: the specific molar volume v_m in Eq. (4) should be in the denominator, rather than in the numerator.

Summarizing, we stress that our model uses extensive approximations to describe SBSL light emission, and is aimed at representing the main physical mechanisms correctly. The Comment supports the validity of our approach, and adds valuable first-principle calculations that improve the quantitative modeling of the light emission characteristics. We finally point out that an experimental observation of the difference between the two approaches is likely to be difficult, because of the importance of other effects that were neglected in the modeling. In particular, the presence of water vapor will reduce the temperature in the collapsed bubble by changing its effective adiabatic exponent and by the endothermal dissociation of water molecules,[5,6] and will thus be of some consequence to the emitted intensity.

[1]D. Hammer and L. Frommhold, ''Comment on 'Sonoluminescence light emission,' '' Phys. Fluids **12**, 472 (1999).
[2]S. Hilgenfeldt, S. Grossmann, and D. Lohse, ''Sonoluminescence light emission,'' Phys. Fluids **11**, 1318 (1999).
[3]S. Hilgenfeldt, D. Lohse, and M. P. Brenner, ''Phase diagrams for sonoluminescing bubbles,'' Phys. Fluids **8**, 2808 (1996).
[4]S. Hilgenfeldt and D. Lohse, ''Predictions for upscaling sonoluminescence,'' Phys. Rev. Lett. **82**, 1036 (1999).
[5]B. D. Storey and A. J. Szeri, ''Water vapour, sonoluminescence and sonochemistry,'' preprint (1999).
[6]R. Tögel, S. Hilgenfeldt, and D. Lohse, ''Squeezing alcohols into sonoluminescing bubbles: The universal role of surfactants,'' preprint (1999).