Reply to “Comment on ‘Temperature dependence of the Casimir force for lossy bulk media’ ”

V. A. Yampol'skii, Sergey Savel'ev, Z. A. Maizelis, S. S. Apostolov, and Franco Nori

Phys. Rev. A **84**, 036502 — Published 13 September 2011

DOI: 10.1103/PhysRevA.84.036502

On the temperature dependence of the Casimir force for lossy bulk media

V. A. Yampol'skii,[1,2] Sergey Savel'ev,[1,3]
Z. A. Maizelis,[1,2] S. S. Apostolov,[1,2] and Franco Nori[1,4]

[1]*Advanced Science Institute, RIKEN, Saitama, 351-0198, Japan*
[2]*A.Ya. Usikov Institute for Radiophysics and Electronics, NASU, 61085 Kharkov, Ukraine*
[3]*Department of Physics, Loughborough University, Loughborough LE11 3TU, UK*
[4]*Department of Physics, University of Michigan, Ann Arbor, MI 48109, USA*

Abstract

Here we present an estimate of the characteristic wavelengths of the evanescent modes which define the main contribution to the thermal part of the Casimir force. This estimate is more precise than the one in the preceding Comment [1]. The wavelengths we derive are indeed smaller than the sizes of the interacting bodies. We also discuss the results of several experiments on the thermal effects in the Casimir force.

PACS numbers: 11.10.Wx, 73.61.At

The authors of the Comment [1] on our brief report [2] claim that the main contribution to the radiation term in the Casimir force comes from the TE evanescent waves if the material is described by the Drude model. They also claim that these waves provide about 99.7% of the thermal correction for the experimental separation of $l = 162$ nm, plasma frequency $\hbar\omega_p = 9$ eV, and relaxation frequency $\nu = 5.32 \times 10^{13}$ rad/s.

In our paper [2] we took into account exactly these waves and derived the difference ΔF_{rad} between the contributions to the Casimir force from thermal fluctuations in the cases of $\nu = 0$ and $\nu \to 0$ [see Eqs. (3)–(7) in Ref. 2]. It is important to note that our calculations are correct, and that the note [1] does not discredit them. Therefore, we do not understand why they write equivalent calculations [see Eqs. (1)–(8) in the Comment]. These formulas add nothing to ours.

The authors of the Comment [1] also pointed out that the main contribution to the integral in Eq. (7) in our paper comes from evanescent modes with wavelengths about or less than the separation l; that is, smaller than the size of the sample. We agree with this estimation only for the case of large separations, when $l \gg c/\omega_p$. For the opposite case, when $l \ll c/\omega_p$, a simple analysis of the integral in Eq. (7) in our paper shows that the main contribution to this integral comes from $x \sim l\omega_p/c$, which corresponds to wavelengths of the order of $c/\omega_p \gg l$. However, even for this case, the characteristic values of the wavelengths are much smaller than the size of the sample.

The conclusion of the Comment [1] claims that: "... the problem of the disagreement between the experimental data of several experiments and the theoretical prediction of the thermal effect in the Casimir force, obtained by using Lifshitz theory in combination with the Drude model, remains unsolved". In particular, in several previous papers, the authors of the comment interpreted the measurements made in Ref. 3 as being in contradiction with the Drude model and in agreement with the so-called plasma model. Unfortunately, these measurements were arbitrarily terminated at a maximum separation of 750 nm, which is the region where the $1/l$ force due to expected patch potential effect starts to become significant compared to the Casimir force. At such small separations, the relative difference between the predictions of the Drude and plasma models is very small, and it is hard to judge unambiguously the applicability of one of these models, based on those experimental results. In addition, the measurement technique relied on driving a mechanical oscillator, and the finite-amplitude motion caused a correction, which is impossible to assess based on the information in Ref. 3. So, the work made in Ref. 3 can be safely considered to be incomplete. Recently, Lamoreaux et al. [4] have corrected for observed systematic effects due to the $1/l$ patch potential and position fluctuations of the plates, both of which were measured. Contrary to Ref. 3, the newer and more systematic experiments [4] included measurements made at room temperature $T = 300$ K and for large separations $l \sim 3\,\mu$m, when the thermal force dominates over the force induced by quantum fluctuations. The results of the experiments [3] and [4] agree in the region where they overlap. The additional measurements made in Ref. 4 away from this common region, namely for large distances, are in excellent agreement with the Casimir force calculated using the Drude model. Therefore, we expect that the Decca et al. experiments, after a complete systematic study including measurements at larger distances, would also support the applicability of the Lifshitz theory in combination with the Drude model.

FN acknowledges partial support from the NSA, LPS, ARO, DARPA, AFOSR, NSF grant No. 0726909, JSPS-RFBR contract No. 09-02-92114, Kakenhi (S), MEXT, and the JSPS-FIRST program. SS acknowledges partial support from the EPSRC via No. EP/D072581/1, EP/F005482/1, and the ESF AQDJJ network programme.

[1] G. Bimonte, G. L. Klimchitskaya, V. M. Mostepanenko, arXiv:1010.0946.

[2] V. A. Yampolskii, S. Savelev, Z. A. Maizelis, S. S. Apostolov, and F. Nori, Phys. Rev. A **82**, 032511 (2010).

[3] R.S. Decca, D. Lopez, E. Fischbach, G.L. Klimchitskaya, D.E. Krause, and V.M. Mostepanenko, Phys. Rev. D **75**, 077101 (2007).

[4] A.O. Sushkov, W.J. Kim, D.A.R. Dalvit, and S.K. Lamoreaux, Nature Physics **7**, 230 (2011).