Zhao *et al.* Reply: We argue that chiral metamaterials can reduce substantially (by 90%) the attractive Casimir force. If the chirality is strong enough, one obtains a repulsive Casimir force, which might violate the passivity of the passive material in agreement with the previous Comment.

In our recent Letter [1], we have calculated the Casimir force by including chirality terms for the first time. We have shown that chirality, if strong enough, will give repulsive Casimir force. In our original Letter [1] we took explicit caution regarding the physicality of the parameters that give repulsive Casimir force. In our theoretical calculations [1] we push the strength of the chirality, Ω_κ, to above the critical value, Ω_κ^c, to obtain repulsive force.

For the particular parameter in Ref. [1], the strong chirality violates the passivity of the passive materials in agreement with the first point of the previous Comment [2].

We used the following formulas for the chiral metamaterials

$$\epsilon(\omega) = 1 - \frac{\Omega_\epsilon \omega_R^2}{D}, \qquad \mu(\omega) = 1 + \Omega_\mu - \frac{\Omega_\mu \omega^2}{D},$$
$$\kappa(\omega) = \frac{\Omega_\kappa \omega_R \omega}{D},$$

where $D = \omega^2 - \omega_R^2 + i\gamma\omega$. Chiral models, based on simple loops [3,4] and in our recent publications [5,6] produce a relation between Ω_ϵ, Ω_μ, and Ω_κ, which is

$$\Omega_\kappa^2 \leq \Omega_\epsilon \Omega_\mu. \tag{1}$$

This relation limits the possibility of obtaining strong chirality Ω_κ, equivalent to $\Delta > 0$ in Ref. [2], where

$$\Delta = \frac{1}{c^2}[\mathrm{Im}(\epsilon)\mathrm{Im}(\mu) - (\mathrm{Im}(\kappa))^2]. \tag{2}$$

In the parameters used in Ref. [1], Δ remains positive if Ω_κ is less than $0.032\omega_R$, while our relation, $\Omega_\kappa^2 \leq \Omega_\epsilon\Omega_\mu = (\omega_R)(0.001\omega_R) = 0.001\omega_R^2$, gives the same condition $\Omega_\kappa \leq 0.032\omega_R$. To satisfy conditions (1) and (2) beyond that limit, one needs to increase Ω_ϵ and Ω_μ, therefore, the chirality will increase. Thus, even if the chirality is limited by conditions (1) and (2) imposed by the passivity of the metamaterial, Ω_κ can still be large and reduce the attractive Casimir force. In Fig. 1, we plot the reduction of attractive Casimir force when the chirality increases and satisfies conditions (1) and (2). Therefore, it does not violate the passivity of the material. As seen in Fig. 1, one can reduce the attractive Casimir force by up to 90%. Another challenge for obtaining experimentally a repulsive Casimir force is to find new chiral designs that do not satisfy condition (1). Another option is to use gain materials to produce a strong chirality and break the condition (1) without violating the passivity of the materials.

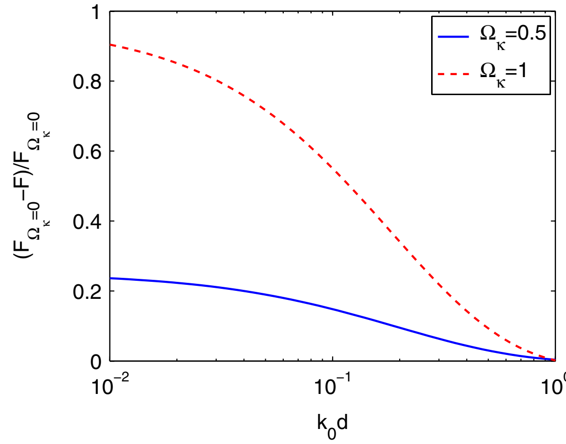

FIG. 1 (color online). Reduction of the attractive Casimir force for two different strengths of chirality. The reduction is 20% for $\Omega_\kappa = 0.5$ and 90% for $\Omega_\kappa = 1$. Here, $\Omega_\epsilon = \Omega_\mu = 1$ and $\gamma = 0.05\omega_R$.

R. Zhao,[1,2] J. Zhou,[1] Th. Koschny,[1,3] E. N. Economou,[3] and C. M. Soukoulis[1,3]

[1]Ames Laboratory and Department of Physics and Astronomy
Iowa State University
Ames, Iowa 50011, USA
[2]Applied Optics Beijing Area Major Laboratory
Department of Physics
Beijing Normal University
Beijing 100875, China
[3]Institute of Electronic Structure and Laser, FORTH and
Department of Materials Science and Technology
University of Crete
71110 Heraklion, Crete, Greece

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