Pure nanodiamonds for levitated optomechanics in vacuum

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Supplementary Information

Alternative thermodynamic calculation

Equation 4 in the main article models the temperature of a levitated nanoparticle as a function of pressure. A steady state temperature is achieved through a balance of heating and cooling rates, as the nanoparticle absorbs laser light and dissipates the heat predominantly through gas molecule collisions in low vacuum, and blackbody radiation in high vacuum.

Alternative calculations for the contribution of blackbody radiation have been used and predict different final temperatures [1]. The blackbody cooling term in equation 4 of the main article is replaced by

$$\frac{\delta q_{bb}}{\delta t} = -\frac{4}{\pi} k a^3 e^{-\frac{\hbar\nu}{k_B T}} \left(\mathrm{Im} \frac{\epsilon_{bb} - 1}{\epsilon_{bb} + 2} \right), \tag{S1}$$

where $\nu = 2\pi c/\lambda$. Figure 4 is reproduced in figure S1 using the new expression for blackbody heat dissipation.

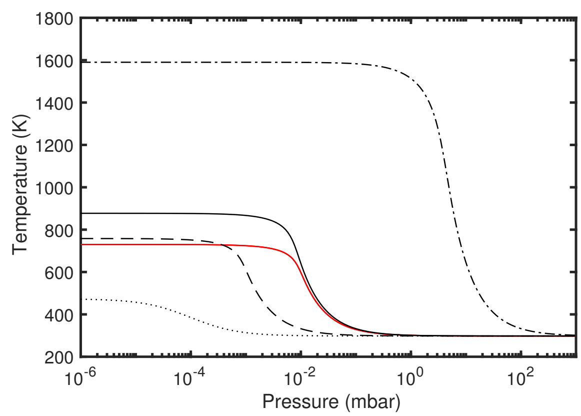

Figure S1. Modelled upper-bounds of temperature as a function of pressure, using the alternative calculation for the contribution of blackbody radiation. The absorption coefficient of the commercial nanodiamonds (— · —) has been set to 30 cm^{-1}. Standard grade (——) corresponds to the bulk diamond grade used to make the nanodiamonds used in this study, with an upper-bound absorption coefficient 0.03 cm^{-1}. Low absorption grade (- - - -) has 0.003 cm^{-1}. Electronic grade (······) has a predicted absorption coefficient of 4.5×10^{-5} cm^{-1}. The red line is a simulation of high purity silica with an absorption coefficient of 0.11 cm^{-1}.

Using equation S1, the approximate final temperatures are calculated to be 1600 K for commercial HPHT nanodiamonds, 900 K for the nanodiamonds discussed in this article, 750 K for low absorption grade diamond, 450 K for electronic grade diamond, and 750 K for silica. Whilst absorption coefficients for the diamonds used in this article are known, this data is not available for silica nanospheres synthesised using the Stöber process that survive high vacuum. Instead, one must assume these values based on the optical properties of silica [2] or ultra low loss optical fibres [3] - both of which are manufactured differently to silica nanospheres.

References

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