Exotic transfer of energy and angular momentum in pairs of rotating nanostructures

Juan R. Deop-Ruano[1], **Alejandro Manjavacas**[1,2]

1. Instituto de Óptica (IO-CSIC), Consejo Superior de Investigaciones Científicas, 28006 Madrid, Spain
2. Department of Physics and Astronomy, University of New Mexico, Albuquerque, New Mexico 87106, USA
E-mail: juan.deop@csic.es

The fluctuations of the electromagnetic field are at the origin of the radiative heat transfer between material structures. This phenomenon is especially interesting in the nanoscale, where the near-field components of the electromagnetic field and the strong resonances supported by nanostructures can significantly increase the transfer of energy [1, 2]. Another important phenomenon induced by the fluctuations of the electromagnetic field is the Casimir forces and torques between neutral nanostructures, which can be used as a tool to transfer linear and angular momentum in the nanoscale [3, 4]. Even though these phenomena share a common origin, radiative heat transfer and Casimir interactions are usually investigated separately. For the former, it is common to consider the nanostructures to be at rest, while, to study Casimir interactions, nanostructures are typically assumed to be thermalized. However, as we show here, Casimir interactions can notably modify the radiative heat transfer, and vice versa.

In this work [5], we study the simultaneous transfer of energy and angular momentum in a pair of nanostructures with different temperatures T_1 and T_2, that rotate around a common axis with rotation frequencies Ω_1 and Ω_2 (see Fig. 1(a)). We find that, due to the rotation of the nanostructures, the radiative heat transfer between them can be increased, decreased, or even reversed with respect to the transfer that occurs in absence of rotation, which is solely determined by the difference in the temperature of the nanostructures. This behavior is illustrated in Fig. 1(b), where we plot the power transferred between the nanostructures P_1, normalized to the power transferred in the absence of rotation Π_1, as a function of Ω_2, for $\Omega_1 = \pi k_B T_2/\hbar$ and $T_1 = 1.5T_2$. As shown in this figure, the normalized power transferred can take positive (red region) or negative values (blue region), that is, the heat flow can be revered and made go from the cold nanostructure to the hot one.

These results demonstrate that it is possible to completely control the radiative heat transfer between the nanostructures through their rotation. Our calculations are based on a combination of the fluctuational electrodynamics framework with the dipole approximation, which allow us to derive fully analytical expressions for the torque and the power transferred between the nanostructures. This work reveals the nontrivial phenomena arising from the interplay between Casimir interactions and radiative heat transfer and paves the way for the use of rotating nanostructures to control radiative heat transfer.

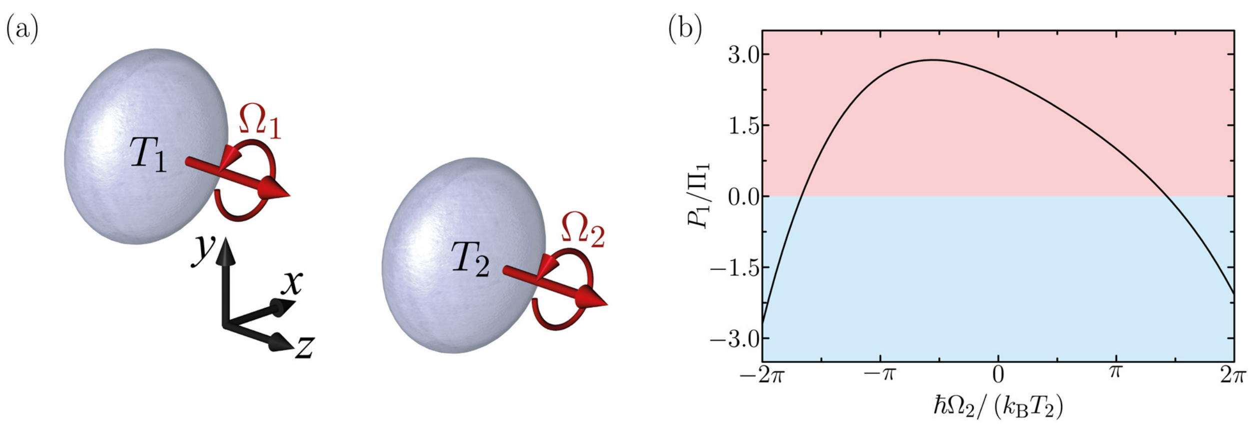

Fig. 1 (a) Schematics of the system under consideration. (b) Power transferred between the nanostructures P_1, normalized to the power transferred in the absence of rotation Π_1, as a function of Ω_2 for $T_1 = 1.5T_2$, $\Omega_1 = \pi k_B T_2/\hbar$. The red (blue) background indicates positive (negative) values of the normalized power transferred.

References

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