# Dimer and trimer nanoantennas from a transformation optics perspective

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**Abstract-**Understanding and controlling the light-matter interaction is of fundamental importance for science and technology. Scenarios involving nanoemitters and nanoantennas are nowadays routinely measured in the lab. However, interpretation of the observations is not always straightforward. We will show here how conformal transformation can be used to provide an analytical description of the commonly used bowtie nanoantenna and its trimer counterpart.

Most recent effort in nanophotonics and nanoplasmonics has been directed toward fabrication advancements. Very complex structures have been realized experimentally and their properties are routinely measured [1]. In combination with simulations the community has gained significant insight on the physics at the nanoscale [2],[3]. However, further insight could be gained if analytical descriptions of practical scenarios are laid down. In addition, an analytical frame would speed up the design procedure.

Transformation optics attracted the attention of the research community when it was used as a design tool for invisibility cloaking [4]. More recently, this technique has shown great promise to understand plasmonic nanoantennas [5], bridging the void of analytical tools at the nanoscale. Motivated by this, we looked at conformal transformation to provide an analytical description of two-dimensional bowtie nanoantennas [6]. Here, we extend this work on bowtie nanoantennas and investigate the underlying physics in trimers. We restrict ourselves to two-dimensional nanoantennas operating in quasi-statics to keep the analytical character of the results.

The bowtie nanoantenna and its trimer counterpart are complex geometries to handle analytically. However, by applying the conformal transformation $z = \ln(z')$, where $z$ and $z'$ are the spatial coordinates in the transformed and original frame respectively, the nanoantennas are mapped into an infinite array of metal slabs. If the nanoantennas are excited by a single nanoemitter modelled as a line dipole, such line dipole is transformed into an array of line dipoles; for the bowtie, the unit cell with periodicity $2\pi$ in the transformed space will be comprised of two metal slabs, whereas for the trimer, it will include three metal slabs. By virtue of the conformal transformation and the quasi-static treatment, the power dissipated in the original and transformed frames are identical. The latter can be computed by simply evaluating the electric field at the dipole position:

$$P_{nr} = P_{abs}^{(x',y')} = P_{abs}^{(x,y)} = -\frac{1}{2}\omega \mathrm{Im}\{p_x E_{1x} + p_y E_{1y}\} \quad (1)$$

where $P_{nr}$ is the nonradiative power emission by the dipole, ω is the angular frequency, $p_x$ and $p_y$ are the components of the emitter dipole moment along $x$ and $y$ directions, and $E_{1x}$ and $E_{1y}$ are the components of the electric field along $x$ and $y$ in the region of the $z$ plane where the line dipole is located.

Figure 1 shows the nonradiative Purcell enhancement ($P_{nr}$ normalized to the 2D dipole radiation $P_0 = 1/16\omega^3\mu_0|p|^2$; $\mu_0$ is the free-space permeability and |p| the magnitude of the dipole moment) for an aluminum bowtie and its trimer counterpart as a function of the nanoemitter orientation. The extra arm of the trimer yields a significant increase of the nonradiative Purcell enhancement and makes the nanoantenna more robust to the dipole orientation [7].

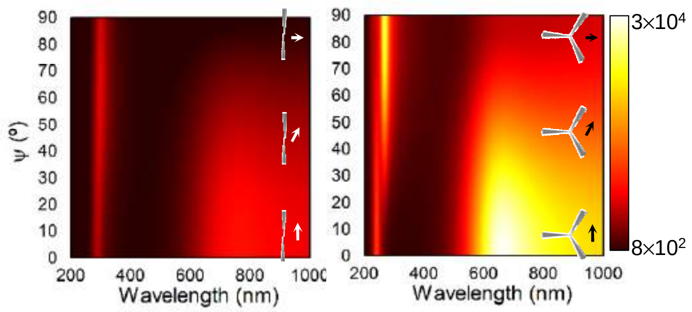


Figure1. Nonradiative Purcell enhancement spectra for an 8nm-arm aluminum dimer (left) and trimer (right) under different emitter orientation excitation.

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