Tuning of far-field and near-field via fs-laser in various hybrid oligomers

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Abstract. Oligomers have attracted intense attention due to the mode interference. We have simulated the tuning effect of far- and near-field properties of four different compositions of hybrid metal/dielectric oligomers before and after the gold components modified by femtosecond laser. The achieved results could be applied in optical sensing, field-enhanced nonlinear process as well as biophotonic applications.

1. Introduction
All dielectric or plasmonic oligomers are well theoretically and experimentally studied for Fano resonance, Mie resonance, near-field mapping with various compositions of oligomers [1–3]. Few works related with hybrid oligomers are focused on hexamer surrounded a relative smaller element, which could take advantage of the mode interaction provided by the central nanoparticle (NP) and the peripheral NPs [4,5]. Therefore, it’s highly important to research into the tuning effect with different configuration of hybrid metal/dielectric oligomers.

In this paper, we have calculated the scattering and near-field distribution in different types of hybrid metal/dielectric oligomers before and after reshaping by femtosecond (fs) laser.

2. Results and discussion
Here we have studied four different types of hybrid oligomers. Each hybrid element is formed up by a gold disk situated on the top of a truncated silicon cone. After fs-laser modification, the disks turn into spheres maintaining the identical volume. Fig.1 a-d depict the studied hybrid oligomers: trimer, tetramer, pentamer and hexamer. Trimer is composed of three identical hybrid element A, D_conebottom = 2 * D_conetop = D_disk = 190 nm, H_cone = 200 nm, H_disk = 20 nm, arranged in an equilateral triangle at a distance of 140 nm. Tetramer adds a hybrid element B in the central of the trimer, which reduces the diameter of the disk and bottom cone to 150 nm. The central-to-peripheral distance is 30 nm. Pentamer and hexamer utilize the same composition and distance for a square and regular pentagons distribution, respectively.

CST Microwave Studio is applied to simulate the scattering cross section as well as the electric field (E-field) distribution. All the hybrid systems are normally illuminated by an electromagnetic wave along the negative z-axis. Fig.1 e shows the scattering cross section before and after reshaping for the proposed hybrid oligomers. Each set spectra corresponds to the schematic view on the left side. As can be seen from the figure, the hexamer is more complicated and presents stronger interference between the central element B and the peripheral element A.
Figure 1. (a-d) Schematic view of different hybrid oligomers before and after modification; (e) simulated scattering cross section of the corresponding hybrid oligomers before and after modification.

Besides, we can observe the moderately modified resonance between 550-600 nm. Moreover, this resonance, as well as another predominant resonance around 645 nm exhibit a blue shift.

Since the resonances around 645 nm in various oligomers have minor and different shifts after the modification, we model the E-field distribution and show them in Fig.2. Obviously, the hot spots achieved in the hybrid oligomers are all enhanced upon fs-laser reshaping. However, it should be noted that the tetramer and hexamer even appear extra hotpots in the central and side, respectively. Especially the tetramer, the new-born hot spot has transformed from an extremely cold spot. This effect can be widely applied to surface enhanced spectroscopy, sensing, and so on.

Figure 2. (a-d) E-field distribution in four types of hybrid oligomers before reshaping; (e-h) E-field distribution of the corresponding hybrid oligomers after reshaping.
3. Conclusion
In conclusion, we research into the optical tuning of far- and near-field properties in the hybrid trimer, tetramer, pentamer and hexamer by modifying the shape of gold nanoparticles. For far-field, all the oligomers exhibit a slight blue shift in the same region. As for near-field, field enhancement has been observed in all oligomers as well as the new hot spots in tetramer and hexamer.

4. Acknowledge
This work was supported by the Russian Science Foundation (Project 19-19-00691).

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