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Study of photoluminescence in plasmonic nanoparticles

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Currently, plasmonic nanofibers doped with semiconductor quantum dots, organic dye quantum emitters (QEs), and metallic nanoparticles (MNPs) have attracted much attention due to their wide range of applications including waveguides, light-sources, and optical sensors. These nanofibers doped with QEs and MNPs have been fabricated using a variety of metals and emitters. For example, Hu et al. [1] have studied the fabrication of a plasmonic random fiber from gold MNPs and pyrromethene dye molecules (QEs) embedded in the liquid core optical fiber. They found that a narrower and sharper photoluminescence (PL) spectrum can be more easily obtained when there is greater overlap between the plasmonic resonance of the gold-MNP and the dye molecules. Here we have developed a theory of photoluminescence for plasmonic nanofibers [2]. When probe light propagates inside the nanofiber, it induces surface plasmon polariton (SPPs) and electric dipoles in metallic nanoparticles. These dipoles interact with each other via the dipole-dipole interaction (DDI) [3]. The energy of photonic bound states in the presence of the SPP and DDI fields is then calculated. We have demonstrated that the number of bound states can be controlled by changing the strength of the SPP and DDI couplings. The expression of photoluminescence has been calculated using the density matrix method in the presence of the DDI coupling. We found that the intensity of the PL spectrum depends on the quality called quantum efficiency, which depends on the radiative and non-radiative decay rates. We have found that the quantum efficiency is enhanced when the exciton energy is in resonance with the bound photon energy. Further, we predicted that the PL intensity is also enhanced due to the DDI coupling. The enhancement of the PL spectrum can be used to fabricate plasmonic nanosensors.

[1] Hu, Z et al., Gold nanoparticle-based plasmonic random fiber laser. J. Opt. 2015, 17, 35001.

[2] Singh, M. R.; Brassem, G.; Yastrebov, S. G. Optical quantum yield in plasmonic
Nanowaveguide. Annalen der Physik in press, 2021.

[3] Singh, M. R. The effect of the dipole–dipole interaction in electromagnetically induced transparency in polaritonic band gap materials. Journal of Modern Optics 2007, 54, 1739.

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