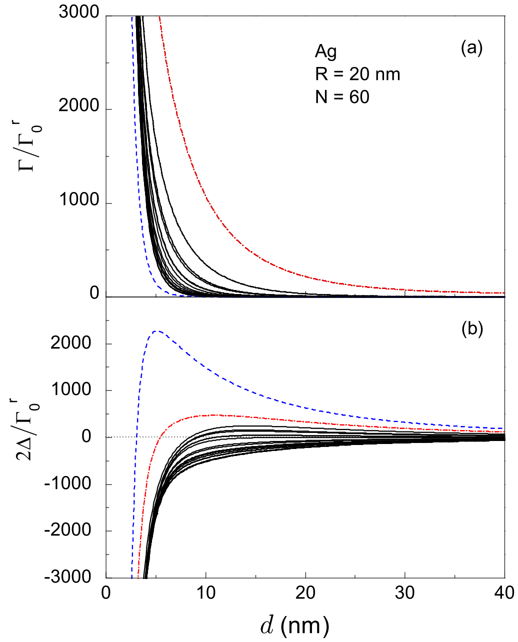

FIG. 7: (Color online) Same as in Fig. 6, but for 60 dipoles in C60 configuration.

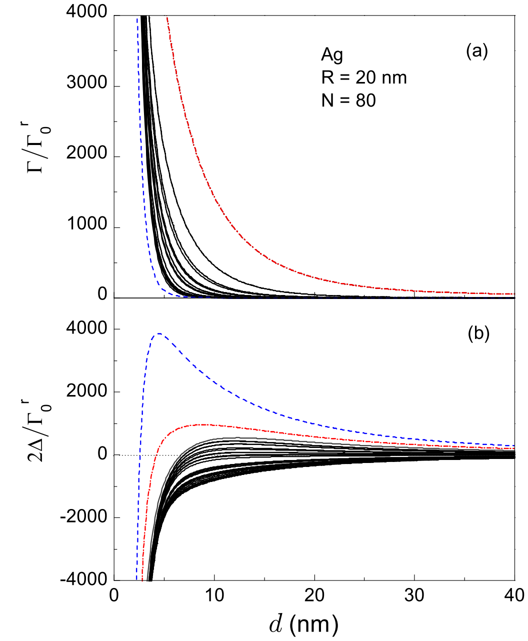

FIG. 8: (Color online) Same as in Fig. 6, but for 80 dipoles in C80 configuration.

when comparing the plots for Δ_J and Γ_J (curves for same eigenvalue sets have similar patterns). By their d dependence, the eigenvalues fall into three main groups. The superradiant states have the largest decay rate Γ_J for all d and relatively small mainly *positive* frequency shift for $d \gtrsim R/2$; these states are dominated by *plasmon-enhanced radiative coupling*. The non-degenerate state with large *positive* energy shift and smallest decay rate is dominated by direct nearest-neighbor dipoles interaction; this state is least affected by the presence of NP and does not participate in the emission. The third group of states with mostly *negative* Δ_J and small Γ_J is dominated by *nonradiative plasmon coupling*. Closer to NP surface, the coupling becomes dominant due to high-l plasmons and all states develop large decay rates and negative energy shifts. Note that down to $d \gtrsim R/4$, the admixture between superradiant and subradiant modes is still relatively weak; below $R/4$, the non-radiative coupling dominates the spectrum and the admixture is strong.

For larger ensembles, the eigenstates have similar structure, as illustrated in Figs. 7 and 8 which show calculated eigenvalues for dipoles in C60 and C80 configurations, respectively. Importantly, even with decreasing distance between the emitters in large ensembles, the dipole-dipole interactions still do not destroy cooperative emission. This can be understood from the following argument.[25] Mixing of superradiant and subradiant states takes place if the interactions between them are sufficiently strong. The latter requires that the electric field of a collective state is strongly inhomogeneous in space since, e.g., subradiant states couple only weakly to homogeneous field. On the other hand, such a field is comprised of individual fields of all the constituent dipoles so the resulting field's spatial fluctuations are weak if no two dipoles approach too close to each other, i.e., deviations of nearest-neighbor separations from their average, $\bar{s} = LN^{-1/3}$, L being characteristic system size, are small. However, if deviations from $\bar{s}$ are large, i.e., two dipoles can be separated by a much closer distance, $s \ll LN^{-1/3}$, causing a strong spatial field fluctuation, then the eigenstates are no longer superradiant and subradiant states and cooperative emission is destroyed. This argument was confirmed numerically here by finding system eigenstates for both cases – dipoles on a spherical lattice with some fluctuations (see Figs. 4 and 5), and a completely random angular distribution with *fixed* dipole-NP distance with no minimal separation between two dipoles (not shown). In the latter case, no superradiant states were formed and the reason was traced to configurations with extremely close dipoles. Note, however, that with both radial and angular distributions being random, these are rare events. In the case of repulsive interactions between individual dipoles, considered here, deviations from the average dipole-dipole separation $\bar{s}$ are exceedingly small and cooperative emission survives the interactions.

Another sharp contrast between plasmonic and photonic Dicke effects is the fate of subradiant states. In the latter, the energy trapped in subradiant states is eventually radiated, albeit with a much slower rate, resulting in sharp spectral features of emission spectrum.[2,3] Instead, in plasmonic systems, the trapped energy is dissipated in the NP and only a small fraction of total energy leaves the system via superradoant states. Thus, the net effect