the peaks centered at 569.4 nm 573.8 nm (curve 1) consist of two and three closely spaced peaks, respectively (curves 3 and 4).

The spectra presented in Fig. 7 clearly show that in fact we have two processes working in parallel. First, the total PL of the spheres is enhanced by the Ag NPs, which can be seen by comparing the PL intensities in the WGM spectra (curves 1) with the WGM spectra of the sphere without Ag NPs. Secondly, the field enhancement provided by the Ag NPs reveals Raman lines of the J-aggregates (curve 1), which are not seen in spectrum 2. Obviously the increase of the Raman signal is stronger than the increase of the PL signals, which can be explained by the fact that the Raman intensity scales with the 4th power of the local field enhancement. Because of this well known effect [32], the Raman lines appear on the top of the enhanced PL spectrum (curve 1 in Fig. 7).

Figure 7 clearly demonstrates that the additional peaks in curve 1 of Fig. 7 (groups A and B) are Raman lines of J-aggregates adsorbed on Ag NPs. Moreover, the enhanced intensity of these Raman lines in spectrum 3 compared to the Raman lines measured on the glass slide (curve 4) indicates that the WGMs may provide an additional enhancement of the Raman signal. This assumption is supported by the fact that the peaks of group B in micro-PL spectrum (centered at 569.4 nm, 573.8 nm and 582.6 nm) perfectly match spectral positions of the TM_{103}^{1}, TM_{102}^{1} and TE_{101}^{1} WGMs, respectively, which follows from results of a mode identification using Eq. (2). This matching is of crucial importance for the enhancement of both the PL and Raman signal as a result of complimentary effects of locally enhanced electric fields due to the WGMs resonances and localized plasmons [34].

5. Conclusions

The results presented in this work demonstrate the feasibility of the development of a high-Q optical resonator consisting of a microsphere and fast-emitting composite shell possessing a large nonlinear optical susceptibility. Many interesting possibilities can be prompted by this work. Polarization sensitive mode damping observed in the spectral region of high J-aggregate absorption can be used for suppression of unwanted modes in high Q optical whispering gallery resonators. Coupling of the plasmonic fields supported by metal nanoparticles and excitonic states of J-aggregates to microcavity local fields might be employed to manipulate the density and quality of modes and to control spontaneous emission rate in coupled hybrid system. The next step in our research on the mechanism of surface enhancement effects will be to investigate in more details the cavity assisted luminescence enhancement and enhanced Raman scattering.

Acknowledgment

The authors thank Prof. A. O. Govorov for helpful discussions.