Abstract— The results of analytical, numerical, and experimental investigations of the resonantly coupled dynamics of the classical system (strip resonator, plasmonic nanoresonator) and quantum systems (Josephson Junction (JJ), quantum dots, dye molecules, etc.) are presented. The wide range of the physical phenomena appearing in these coupled system, is analysed in the frame of the unified approach.

Keywords— optical metamaterials, spaser, Schawlow-Townes theory, luminescent enhancement, Purcell effect.

Recent technological advancements allowing creation of nanoobjects/metamaterials in the optical domain has forced the revisiting of basics electrodynamic principles and assumptions. A large amount of new experimental and theoretical data has to be structured within the frame of a new unified approach, in order to distinguish the really fundamental knowledge from various applications and particular cases. A unified approach appears to be extremely important for educational courses in the area of nanophotonics/optical metamaterials. In particular it allows us to present a self-consistent physical picture, which in turn minimizes the amount of educational material to be memorized to the crucial physics.

The results of analytical, numerical, and experimental investigations of the resonantly coupled dynamics of the classical system (strip resonator, plasmonic nanoresonator) and quantum systems (Josephson Junction (JJ), quantum dots, dye molecules, etc.) are presented. The wide range of the physical phenomena appearing in these coupled system, is analysed in the frame of the unified approach. The following problems will be considered:

1. Regular and stochastic characteristics (radiation linewidth) of the nanolasers (such as the spaser).

2. It is shown that direct application of Schawlow-Townes expression overestimates the linewidth and has to be avoided at the description of the nanolaser. Analytical results are compared with ones obtained from the direct numerical simulation of the dynamics of the laser equations.

3. A model for anapole laser will be presented.

4. Propagation of the plane wave in a metamaterial with gain (metaatoms in form of spasers) is considered using the developed earlier multipole model and the results of the spaser dynamics. It is shown that the stable propagation is possible if ratio of the coupled and uncoupled active molecules is chosen carefully.

5. The problems of the luminescent enhancement and lifetime shortening are analysed in the frames of the developed approach and compared with the experimental data.