Materials doped with lanthanides ions, due to unique structure of the energy levels, exhibit unusual features, such as presence of multiple sharp absorption and emission lines, long lifetimes of excited states, high photostability and blinking free emission. This is the reason why nanomaterials of such type are considered as very promising alternative for other emitters, such as organic dyes or quantum nanodots, which are commonly used in nanosensorics, bioimaging and optical signals processing.

Recently, in lanthanides doped nanomaterials there has been reported successful demonstrations of one additional fascinating phenomenon – so-called photon avalanche emission. The characteristic feature of this effect is non-linear relation between the power of the laser beam used for sample excitation and the resulting emission intensity. Namely, after exceeding some critical power threshold, even minute further changes of the excitation power translates into significant (up to several hundredfold) change of the emission intensity. Such disproportion between these huge changes of emission intensity for tiny variation of the excitation power promotes application of this effect in e.g. super-resolution imaging of these nanoobjects, in means imaging with much better resolution than can be expected based on the diffraction limit. However, this approach has also one crucial limitation – in order to achieve required effects using of high power laser light sources is necessary (providing up to even MW per each cm^2 of the illuminated area), what results in much higher operating cost and may cause the damage of the imaged samples.

On the other hand, there are well-known and commonly applied metallic nanoparticles (in particular silver and gold), which, after proper illuminating, feature collective oscillations of the free electron gas (so-called local surface plasmon resonance). As one of the results of this effect, highly condensed electric field appears in the close vicinity of such metallic plasmonically active nanoparticles, which might lead to much more effective exciting of the emitters placed in such condensed field and thus to the more intense emission thereof. Nonetheless, results of this plasmon interaction critically depend on the distance between the metallic nanoparticle and the emitter, with the maximal emission enhancement appearing for the separation in the range of 5-15 nm.

The aim of this project is to combine these two types of nanomaterials – nanocrystals featuring photon avalanche emission and the plasmonically active metallic nanoparticles. Expected result of this is downshift of the photon avalanche threshold value of the nanocrystals, when placed in enhanced electric field induced close to the metallic nanoparticle. It would enable to obtain all the benefits of utilization of the avalanching nanocrystals in super-resolution imaging with considerably lower excitation power required for that.

It is planned to investigate this phenomenon in two ways. First, to mix these two types of nanomaterials, but using materials of various spectroscopic characteristics. Lack of the control on the relative distance between the nanoparticles of both types will bring the possibility to observe all possible results of the interactions taking place in such systems and would enable to define the most promising combinations of the materials to obtain significant photon avalanche threshold downshift. These selected combinations will then be used in the further studies, where, based on the chemical surface modification methods, some matching “hooks” will be produced on the nanoparticles surfaces to bond chemically in controlled way the metallic nanoparticles and avalanching nanocrystals. Obtaining of the structures with controlled separation will in turn enable to optimize these hybrid structures for the maximal photon avalanche power threshold downshift, making them an versatile platforms for applications in bioimaging and nanophotonics.