Owing to very good photo-stability, relatively small size, narrowband absorption and multicolour emission, long luminescence lifetimes and excitation bands in NIR spectral region, Ln^{3+} doped nanoparticles are considered as interesting alternatives to conventional organic dyes and quantum dots (QD) labels. Moreover, the capability to form core-(multi)shell nanoparticle structures and combine advantageous properties, to actually intentionally design the spectroscopic behaviour of such labels is of great interest for many bio-medical applications. Interestingly, lanthanides may also, apart from well-known, efficient, anti-Stokes energy transfer up-conversion (ETU), uniquely exhibit fascinating phenomenon i.e. **photon avalanche (PA). At the threshold of PA, luminescence intensity rises rapidly by 2-4 orders of magnitude in response to minute changes in excitation intensity.** PA so far has been observed in bulk crystals, but reports on PA in nanomaterials are almost inexistent. For this reason the project shall fundamentally contribute to understanding of this exceptional process in colloidal nanoparticles. Important differences between bulk and nano-materials have been already predicted and will also be studied here. This in turn shall enable to optimize and exploit new materials and optical setups for super-resolution imaging and enhanced bio-detection. Although some super-resolution imaging methods or FRET based biodetection methods with lanthanide doped nanoparticles are known but these studies are often singular, in their infancy and often suffer from technical complexity, single colour emission or insufficient sensitivity. The project will thus focus on alternative materials, dopants, optical setup, solutions and configurations, which, according to theoretical modelling are feasible, but were not studied extensively or experimentally verified yet.

Therefore, the project aims to (**GOAL 1**) theoretically predict, design and (**GOAL 2**) synthesize new functional lanthanide doped colloidal nanoparticles in order to theoretically and experimentally verify the possibility to obtain photon avalanche (PA) phenomenon in nano- (diameter ~ 8-25nm) and sub-micron (length 200-400nm) sized crystals. To make it happen, theoretical analysis, synthesis, optimization of dopants and chemical composition of the novel materials will be performed. Moreover (**GOAL 3**) a dedicated optical and data-acquisition instrumentation as well as unconventional characterisation methodology (i.e. photon avalanche excitation intensity dependent time resolved luminescence) will be developed. These materials, instrumentation and methods shall enable to advance (**GOAL 4**) optical imaging below diffraction limit (i.e. PA super-resolution imaging) and enhance optical bio-detection (i.e. Förster Resonant Energy Transfer).

Some of the proposed cutting edge materials, methods and techniques (e.g. PA based PASSI and eFRET) have never been demonstrated or studied and should significantly move forward both the fundamental understanding of photon avalanche in colloidal nano- and sub-nano sized particles as well as should advance bio-related detection/imaging beyond current state-of-the-art, towards unprecedented technological solutions and novel sensitive diagnostic tools.