Control and characterization of the optical nearfield by next generation nearfield optical microscopy

Scanning near-field optical microscopy (SNOM) is a powerful tool to studying optical characteristics of diffraction limited nanoparticles and molecules where the electromagnetic field is localized to the emitter’s near-field region. The principle and performance of such SNOM measurements strongly depend on the tip design and the tip’s apex size. With the aim to improve the performance of SNOM-based near-field detection and control we develop a new generation of high-performance plasmonic tips, which provide unprecedented performance parameters and at the same time are easy to apply to many applications in different environments. Thus, we are aiming to substantially improve the applicability and value of near-field optical microscopy. Generally, our tip concept relies on tapered and fully metal-coated fiber tips. These tips employ the radially polarized surface plasmon polariton mode and the plasmon superfocusing effect to improve the optical resolution, contrast, as well as signal to noise and background ratios. As the radially polarized plasmonic mode propagates toward the tip apex, the electromagnetic field is compressed longitudinally, due to the shrinking propagation constant, and transversally, due to the nature of the surface plasmons. Furthermore, the field amplitude increases enormously due to the in-phase field oscillation within the metal. These effects result in so-called plasmon superfocusing allowing us to achieve highly localized and strong electromagnetic fields at the tip’s apex.

In the scope of the PhD project, initially, new technologies have to be developed to increase the sharpness of the plasmonic tips. As a next step, their performance parameters are to be evaluated by exploring the tip’s interaction with different quantum systems, as e.g. single fluorescent molecules, quantum dots, lanthanide nanoparticles, and emission centers in atomically thin membranes of MoS$_2$. To explore the spectral and temporal characteristics of the quantum systems, the superfocusing SNOM setup will be combined with a time correlated single photon counting system and a single photon sensitive optical spectrometer. After establishing stable measurement methods and skills, we want to apply this tool to the in-depths investigation of the interaction of the nano-sized quantum systems with plasmonic and dielectric nano-antennas. Besides experimental characterization, analytical and computational modeling shall be carried out to further understand the complex behavior of the quantum emitters and their interaction with the tips.

Required qualification: Master or Diploma in physics, photonics, electrical engineering, or comparable

Applicant should also have good experimental experience and basic knowledge in programming skills. Experiences in electromagnetic simulation software and process control software (e.g. LabView) are helpful.

References

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