Ultrafast quantum nanophotonics: From nanoplasmonic strong coupling to quantum chaos in semiconductor lasers

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Enabled by progress in nanoscience and nanomaterials technology, nanoplasmonics and metamaterials have in the last 15 years inspired scientists to think about waves beyond traditional constraints imposed by materials in which they propagate to conceive functionalities. Concurrently, photonic quantum science is, particularly through a link with nano-plasmonics, progressing from its predominantly lab-based science base involving simple systems into the practical world, vividly evident through breakthroughs such as the recent demonstration of nanoplasmonic and near-field strong coupling at room temperature [1,2] and nanoscale ultraslow light [3]. Using the optical near-field with active quantum materials opens up new domains for science, materials physics and engineering, providing the foundation for novel photonic quantum technologies while linking up with the engineering, communication, security, energy and health care sciences and technologies. The talk will highlight some of the compelling new opportunites: (1) Ultrafast nanoplasmonic near-field photonics. Strong coupling of single quantum emitters (active molecules, quantum dots, etc) with light is of key importance for all photonic quantum technologies and may lead to new types of quantum sensors. Nanoplasmonics offers an innovative route route to realistic photonic quantum technologies, particularly strong coupling quantum technologies [1,2], quantum spectroscopy and ultrafast nano-chemistry. (2) Topological quantum metamaterials: Designing photonic and electronic metamaterials with topological near-field protection against disorder and materials-level functionalities provides the blue-print for symmetry protected near-zero-index materials and technologies [4]. (3) Chaotic near-field laser-dynamics: Combining concepts from the fields of (semiconductor) laser chaos and near-field wave-dynamical chaos providing a pathway to fight (chaotic) semiconductor laser instabilities by near-field optical chaos. We will show that this whole new research direction which will impact many fields dealing with complex spatio-temporal dynamics [5].

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