Manipulating and visualising the local density of states at the nanoscale

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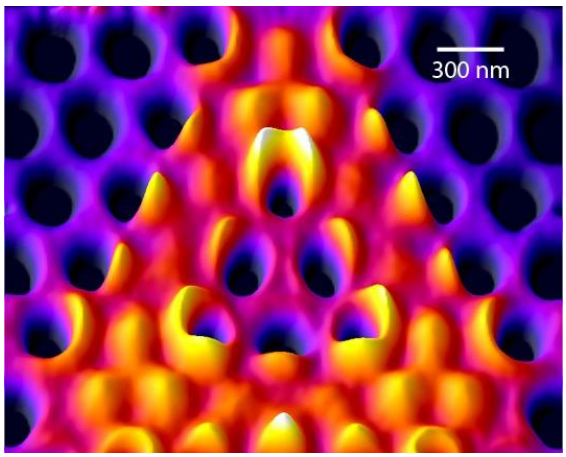
Numerous optical technologies and quantum optical devices rely on the controlled coupling of a local emitter to its photonic environment, which is governed by the local density of optical states (LDOS). Light spontaneous emission, absorption and scattering are all related to the LDOS that can be engineered in dielectric and metallic nano structures. I will present how a nano-sized light probe can illuminate complex materials and shed light on their optical properties and modes.

I will report nanoscale mapping of the local density of states by cathodo-luminescence microscopy, a combination of electron-beam scanning and optical spectroscopy [1]; it relies on scanning a transient dipolar emitter induced by electron beam bombardment with respect to its photonic environment while measuring the total emitted power. Each individual electron traversing the photonic structure generates a nanoscale transient dipole by the accelerated charge that we exploit as a local probe of the LDOS. With unprecedented resolution (∼10 nm) we image localized photonics crystal cavity modes in a nano-structured silicon nitride membrane, over the visible spectrum into the near-IR. We identify individual cavity modes that are spatially different and we map their LDOS. Also, our measurements reveal extended Bloch modes that are delocalized over the crystal and periodically modulated. Moreover, by momentum spectroscopy, we resolve the angular emission pattern of the radiation emitted, which exhibits complex diffraction patterns [1].

In addition, we image the LDOS for random gold films as their topology approaches percolation. Thanks to the high-resolution imaging we are able to observe single-particle resonances localized at the gold particle transforming into extended modes when the cluster merge into a network. We report a study of the rich spectral dynamics of the local hot-spot of the LDOS through all the visible range. We also observe a long-tailed distribution of the LDOS at percolation.



Experimental deep-subwavelength imaging of the optical local density of state in a nanostructured photonic membrane.

I will also discuss our recent studies of fluorescence from a nano-sized emitter embedded in complex photonic media, such as photonic crystals and random powders. By fluorescence dynamics we measure LDOS distributions in 3D disordered dielectric powders. We observe a surprisingly long-tailed distribution of the LDOS with Purcell factor up to ~10 [2]. I will discuss how our experimental results fed the ongoing discussion on the dependence of the C0 correlation function on macroscopic disorder parameters.

References

[1] R. Sapienza, et al. Deep-subwavelength imaging of the modal dispersion of light, Nature Materials 11, 781–787 (2012).
[2] R. Sapienza, et al. Long-Tail Statistics of the Purcell Factor in Disordered Media Driven by Near-Field Interactions, Phys. Rev. Lett. 106, 163902 (2011).