Terahertz s-SNOM with > λ/1000 resolution based on self-mixing in quantum cascade lasers

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Near-field imaging techniques have great potential in many applications, ranging from the investigation of the optical properties of solid state and 2D materials to the excitation and direct retrieval of plasmonic resonant modes, to the mapping of carrier concentrations in semiconductor devices for inspection. Further to this, the capability of performing imaging with the non-ionizing terahertz radiation on a subwavelength scale is of fundamental importance in biological applications and healthcare. The implementation in apertureless scanning near field optical microscope (s-SNOM) of stable, compact solid state sources such as the quantum cascade lasers (QCLs) instead of bulkier gas lasers has been already reported with a resolution ≥ 1 μm [1] based on metallic tips. Here we report on the realization of s-SNOM, based on tuning fork sensors [2], to maintain a constant sample/tip distance in tapping mode, and quantum cascade lasers emitting around 3 THz as both source and detector in a self-mixing scheme [3]. The implementation of a fast and efficient feedback mechanism allowed the achievement of a spatial resolution lower than 100 nm, as shown in Fig. 1, thus achieving the record resolution with a QCL > λ/1000. The self-mixing approach allows an extremely sensitive and fast detection scheme, which overcomes the slow response of traditional terahertz detectors, by monitoring the scattered signal fed back into the QC laser cavity modulating the power or the bias. In order to enhance the sensitivity of the whole apparatus and the collection of the scattered light, silicon lenses have been attached to the QCLs with an antireflection Parylene coating thick enough to strongly reduce the laser emission, but still allowing enough power for alignment. Figure 1 reports the topography a) and the THz voltage signal on the QCL b) of SiO_2/Si square features over a metallic substrate (top-left square corner), exhibiting a reduced scattering.

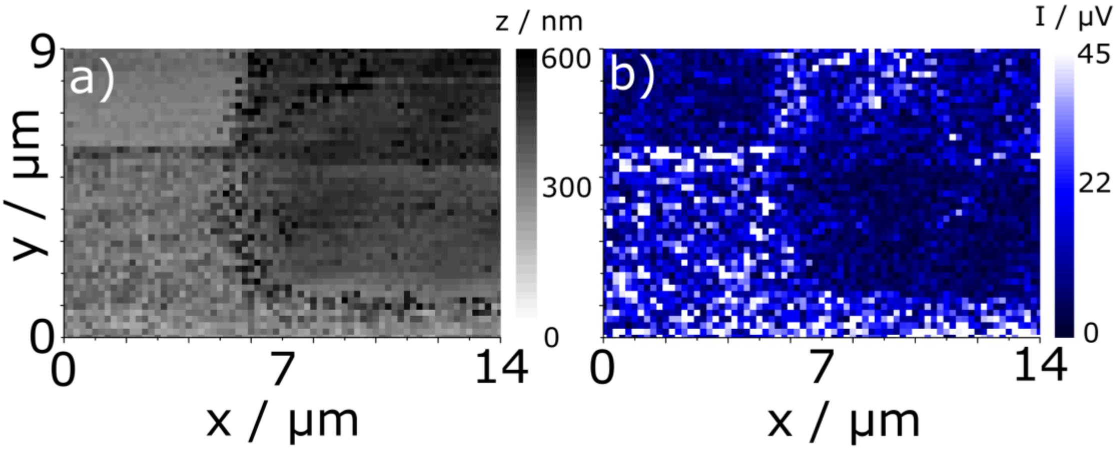

Fig. 1 a) Topography of metallic features onto SiO_2/Si substrate. b) Corresponding THz signal retrieved by using the self-mixing technique.

The home-made s-SNOM system has the advantage over standard atomic force microscopes modified for these purposes of being compact and versatile, thus opening the way to its possible exploitation in cryogenic operations. By further reducing all sources of noise and atmospheric perturbations, and placing the whole apparatus in a nitrogen environment we expect to push the resolution to ~ 30 nm, corresponding to ~ λ/10000.

References

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