Mapping electrostatic and Casimir forces above metallic nanostructures using suspended nanowires

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We optically probe the vibrations of an ultrasensitive force sensor, a suspended silicon carbide nanowire to map the lateral electrostatic and proximity forces it experiences when its vibrating extremity is scanned above a metallic nanostructure.

To do so, we focus a laser beam on the nanowire and collect the back-reflected light on a dual photodetector to probe its lateral deformations. Exploiting its two quasi-degenerated fundamental modes which oscillate along both transverse directions above a sample of interest, the nanowire can be used as a lateral force sensor. As in an atomic force microscope, the force gradients are modifying the eigenmodes, causing both mechanical frequency shifts and a rotation of the eigenvectors, whose measurement allows extracting the four components of the lateral force field gradients [1,2] experienced by the nanowire.

We developed force and force field gradient sensing protocols of the 2D lateral force fields experienced by the nanowire, featuring a vectorial character with sensitivities in at the aN/Hz^0.5 level at room temperature (10 zN/Hz^0.5 at dilution temperatures [3]) operating at a quasi real-time measurement rate (10 Hz).

We then used the nanowire to investigate the electrostatic forces arising above nanostructured metallic surfaces and implemented protocols to simultaneously measure electrostatic forces and force gradients at each position above a 400 nm trench drilled in a gold layer where both sides can be separately voltage biased. This configuration allows to cancel both the horizontal and vertical components of the electrostatic field, including the parasitic stray fields produced by surface imperfections, paving the road towards the measurement of the lateral Casimir forces which persist at zero field. Our measurements demonstrate a laterally repulsive force structure above the trench, the nanowire being attracted towards the edges of the trench, as expected from the original theoretical predictions [4] and in agreement with our numerical simulations [5].

In this communication we will expose the measurement principles and protocols developed to image the electrostatic fields and vacuum forces above a single nanostructure.

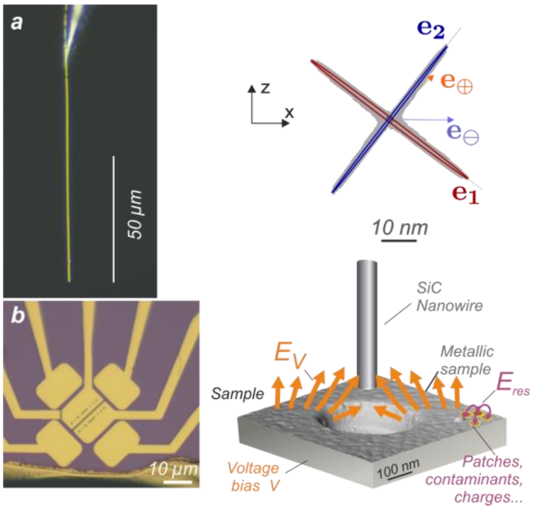

Fig.1 Optical images of nanowire and sample. Representation of nanowire's eigenvectors. Image of electrostatic field generated above a hole

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