## 85

# Probing chirality of biomolecules with nano-structured laser light

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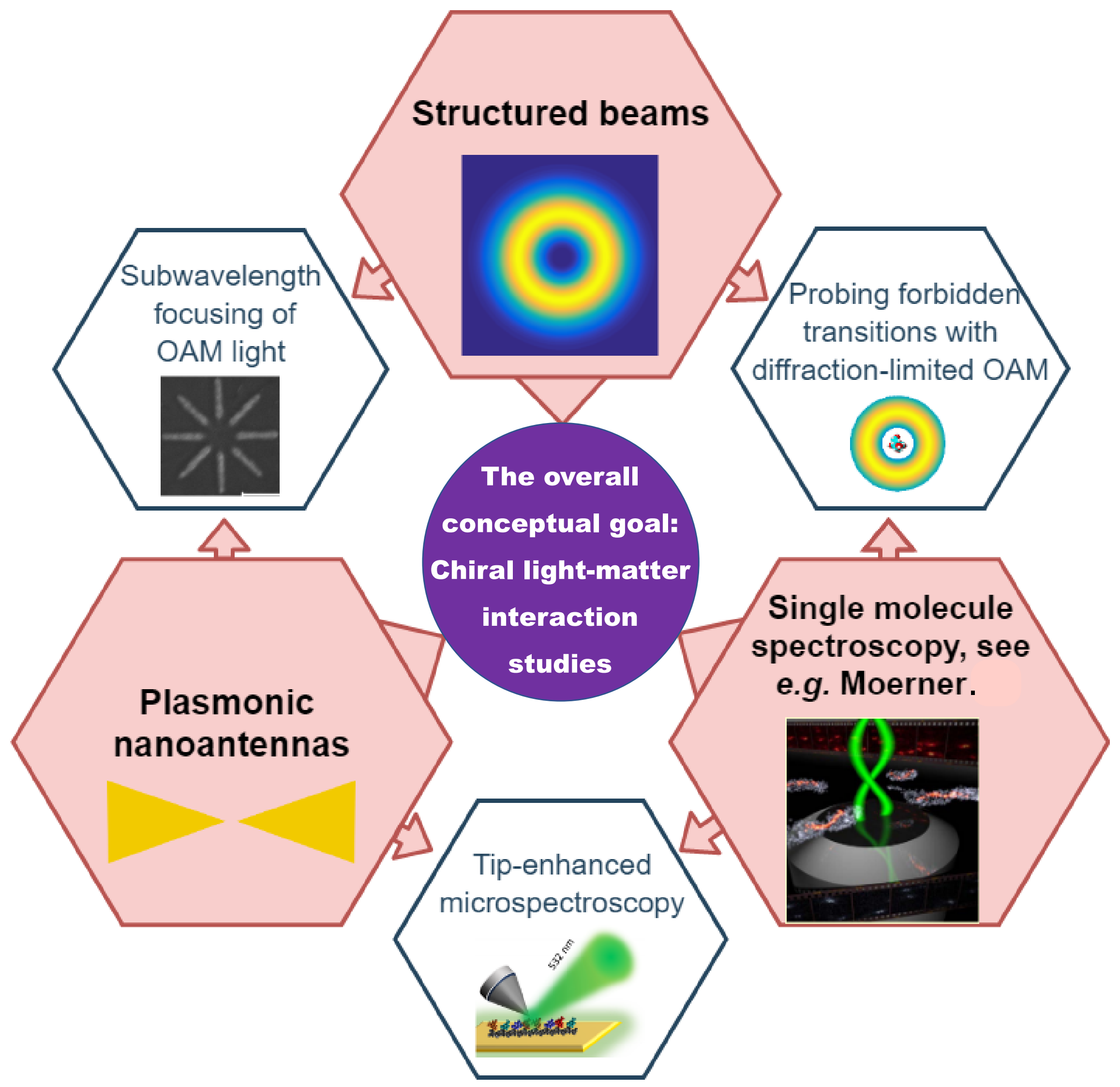
## MOTIVATION

The ability of plasmonic antennas to concentrate laser light into subwavelength volumes promoted the imaging of biological structures with super-resolution. However, the confinement of unstructured optical fields within a small volume is insufficient for studies of such phenomena as chirality in biomolecules. The confined field must also be structured to have specific properties.



Structured light carries orbital angular momentum (OAM), has corkscrew wavefront with the phase singularity at the center, where intensity equals zero. This light is left- or right handed in the same sense as some biological molecules. Left-/right-handed molecules are known as chiral. Modern research suggests possible interaction between "chiral" light and chiral molecules. To detect the impact of the structural "twist" on the chiral molecule, the twist feature size (the diameter of the dark spot at the center) needs to be comparable with the size of the molecule (~nm), Fig.1.[1,2]

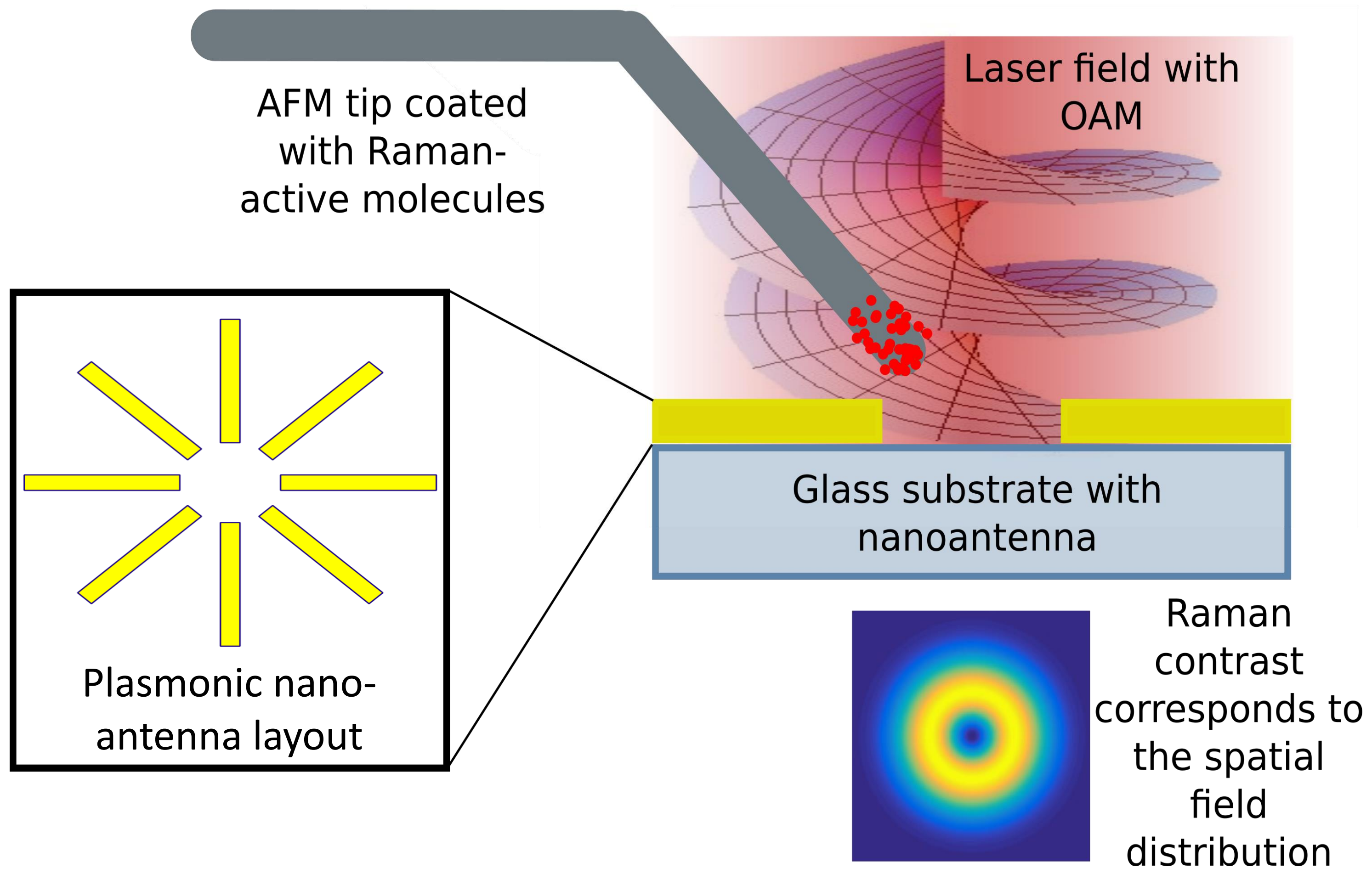


**Fig.1** Experimental concept for detecting structured electric field distribution on the nanoscale. Inset shows the antenna layout, where λ is wavelength of incident light. Coupling of an atom with the plasmonic nanostructure[2] allows for modification of its internal state or, in other words, induces dipole forbidden atomic transitions[3,4].

## SIMULATION

We optimize a nanolens for the experiment proposed for chirality studies. The optimization is performed for 532 nm wavelength, and is aimed to make the nanolens design easy to manufacture. We keep in mind both fabrication limitations and antenna efficiency, and search for a compromise between the two. We aim to create a universal plasmonic structure that efficiently focuses OAM beams with various TCs and handedness. Similar to the large scale antennas, the nanolens has several resonant wavelengths, that depend on the antenna's geometry. If light is in resonance with the nanolens, then the generation of the surface plasmons is more efficient, which causes larger electric field enhancement. The proposed nanolens preserves the spatial structure of the optical vortex - the ring of light and the phase singularity - for 532 nm laser wavelength, and focuses it to nanoscale as shown in Fig.2. The proposed nanolens is made of gold and consists of N rods (N can vary) aligned along radii pointing to the center.

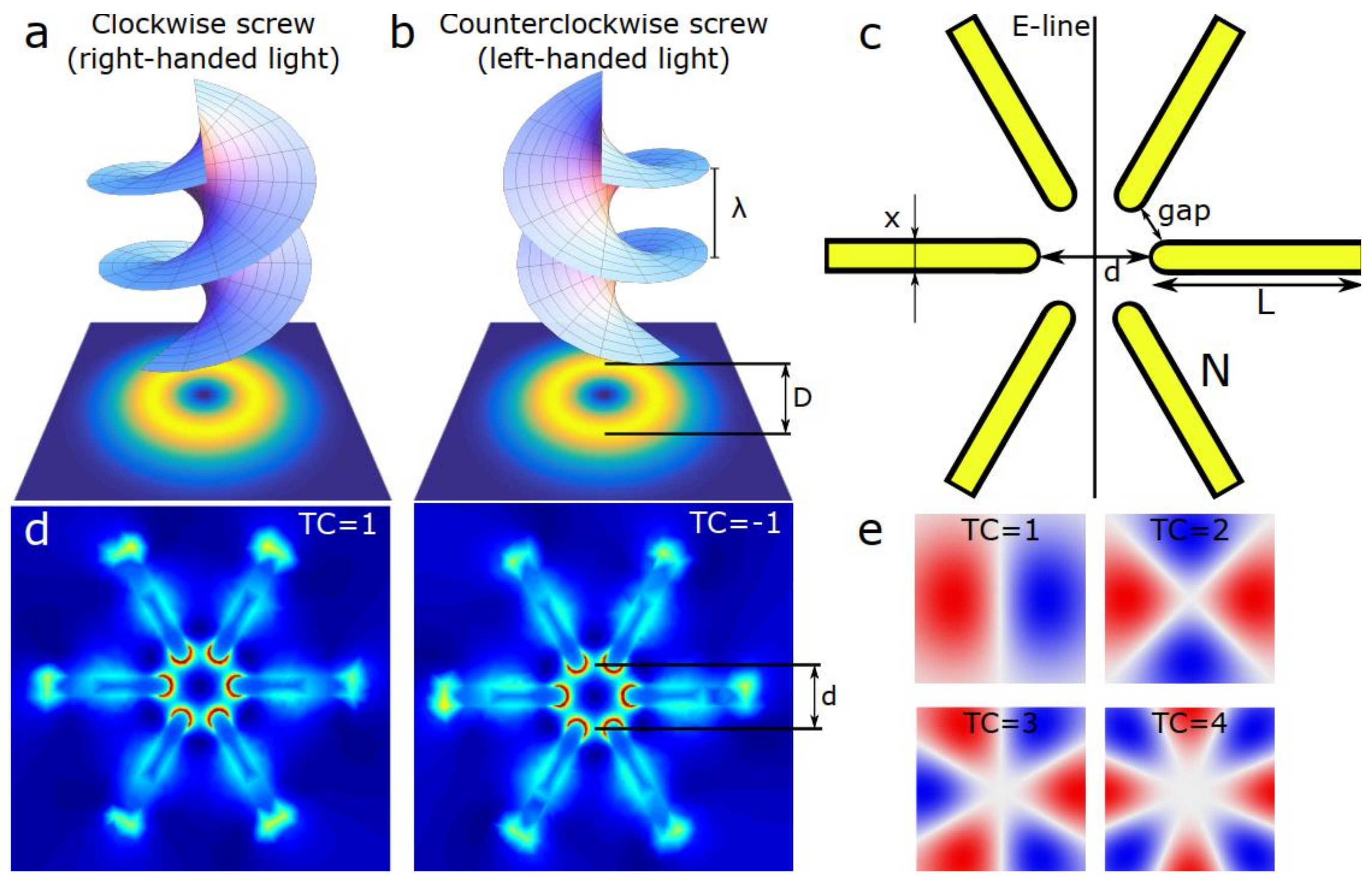


**Fig.2** a: Right-handed and b: left-handed light wavefront c: Geometrical layout of the nanolens d: An example of the field distribution, generated by the antenna c; e: 2Dphase of optical vortices with TC=1,2,3,4. Color gradient varies between -2π(blue) and 2π(red). White area in the center denotes the phase singularity point. The images are not drawn to scale.

## EXPERIMENT

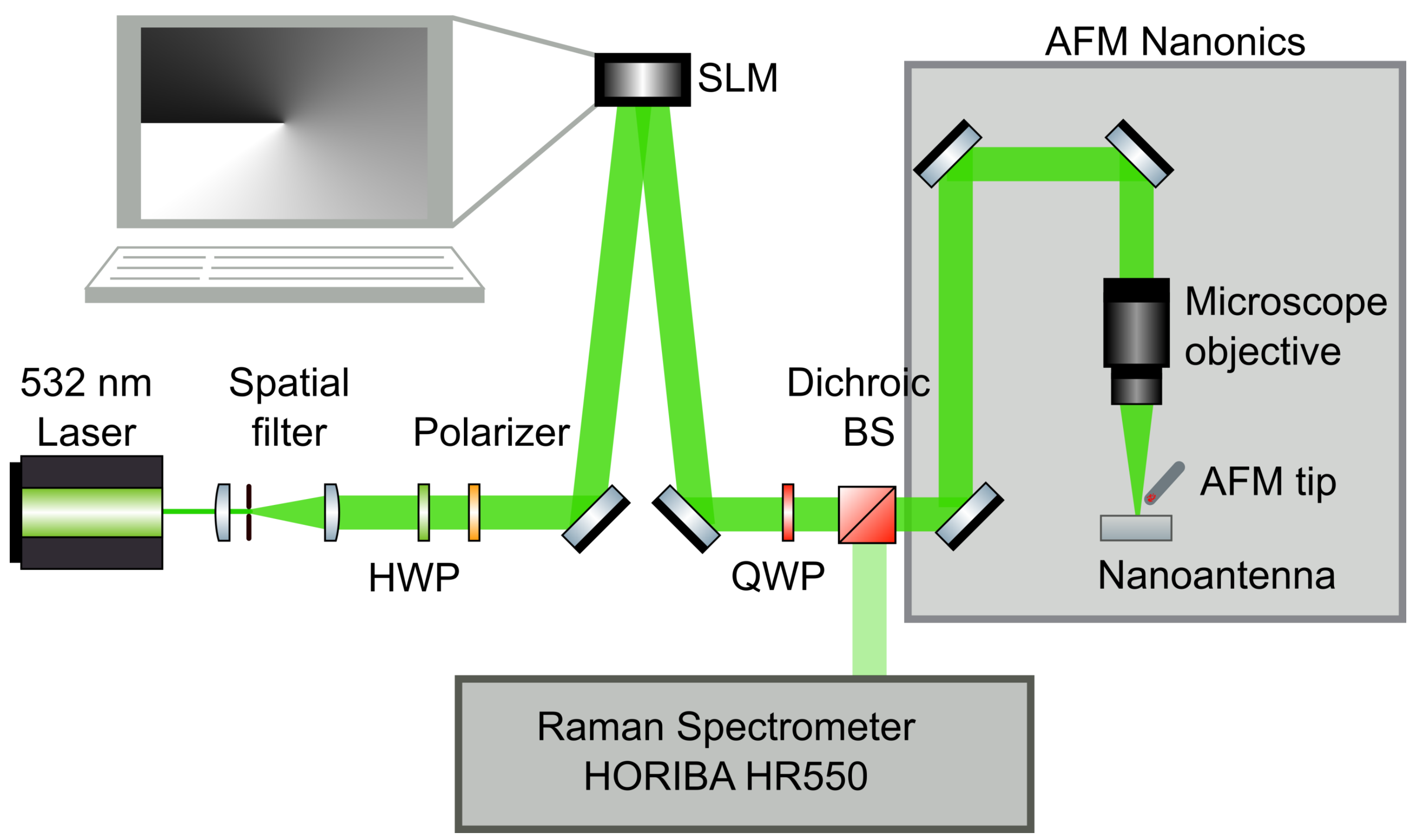


**Fig.3** Experimental setup with 532 nm continuous wave laser. HWP – half wave plate, QWP – quarter wave plate, Dichroic BS – dichroic beam splitter that sends Raman signal into spectrometer.

As known, an optical diffraction limit does not allow us to achieve laser light spot sizes below ~1μm, which is much larger than the size of the molecule. A plasmonic antenna confining the spatial structure of light inside the small volume can solve this problem. We propose to use a focused ion beam microscope to manufacture such a nano-antenna and build an experimental setup that is capable of detecting optical field structure on the nanoscale, Fig.3.

The experimental setup combines an atomic force microscope (AFM) with a Raman microscope and a spatial light modulator (SLM). Whole setup allows to do AFM (relief) + Raman (spectra) correlated maps of the sample. Moreover, in case when AFM tip is covered with Raman-active molecules, the tip can probe the spatial distribution of the laser optical field (OAM) with a few nanometer resolution[5,6].

The antenna geometry represents several dipole antennae oriented around one center. This system shows good ability to concentrate the incident OAM light inside the central area (~100nm in diameter), still achieving zero intensity (phase-singularity point) in the center. Each rod accepts only light polarized along its longest direction, so the antenna will properly transfer OAM to the nanoscale only if the incident light is circularly polarized.

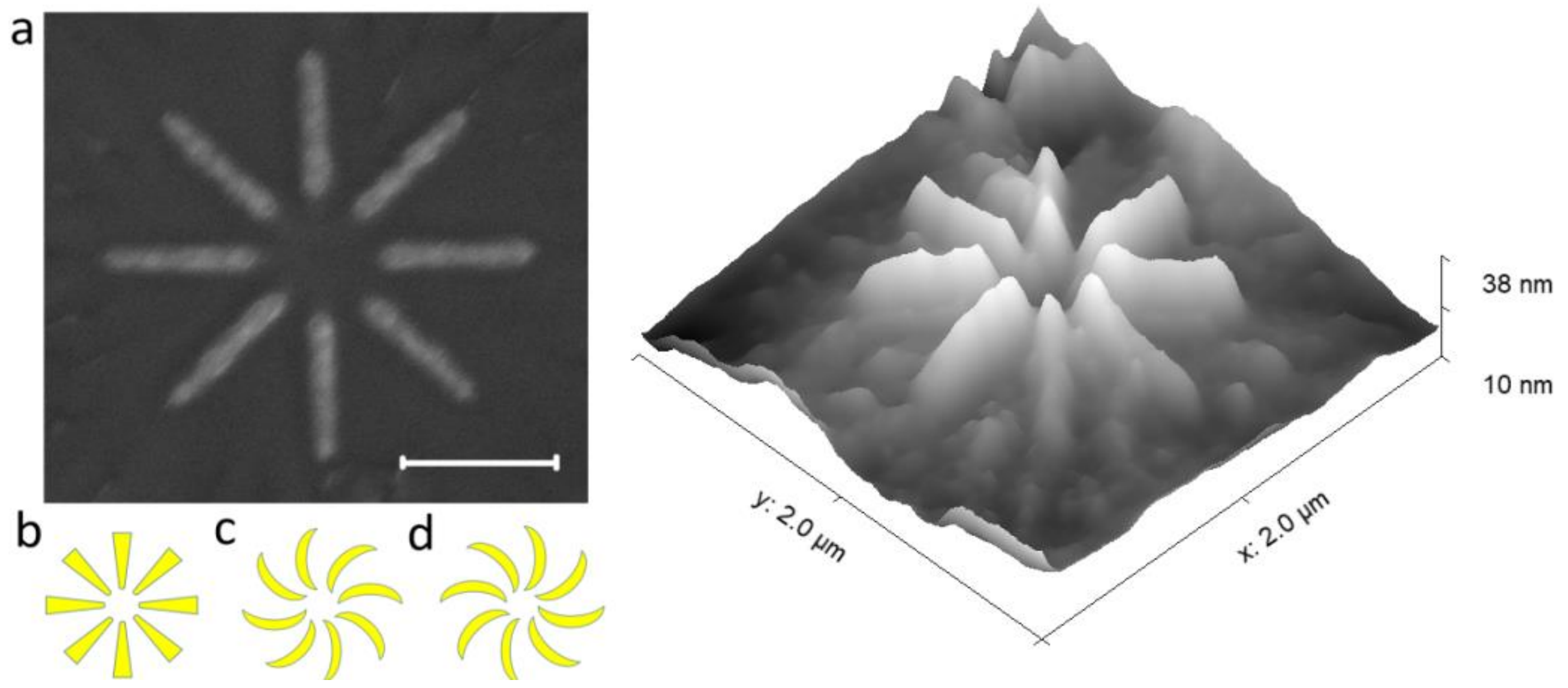


**Fig.4** Left: SEM image of the produced nanoantenna. Right: AFM image of the same nanoantenna[7]

## PROSPECTIVES

If successful, this work will help to answer the question: does the twisted, or so cold chiral light interact with chiral molecules in some special way? Then the transfer of OAM from light to the molecule may become possible. Our next step is to put chiral molecules, such as DNA, into the focus of the plasmonic nanolens, and see if the right vs. left chirality of incident light results in a difference in the molecular excitation. The ability to transfer the light structure to the nanosized volume can also bring the resolution of the imaging techniques to the atomic scale and help efficiently induce forbidden transitions in biomolecules. All this will lead to better understanding of the living organisms.

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