Indirect observation of the light emission in the tunnel junction with metal nanodisk

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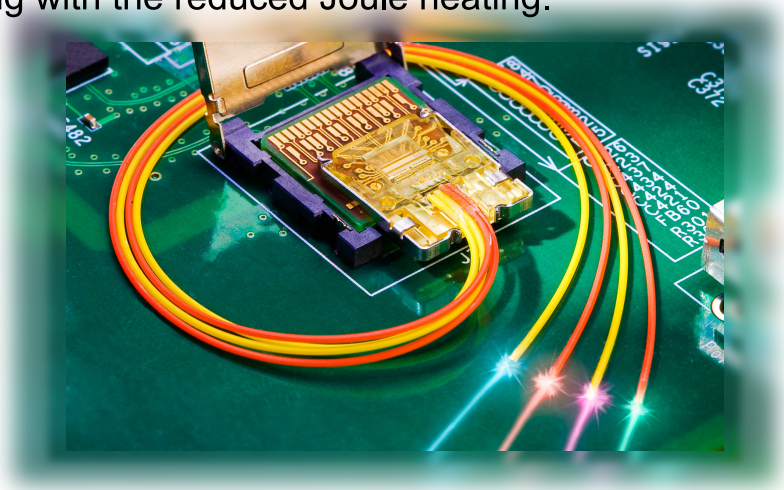
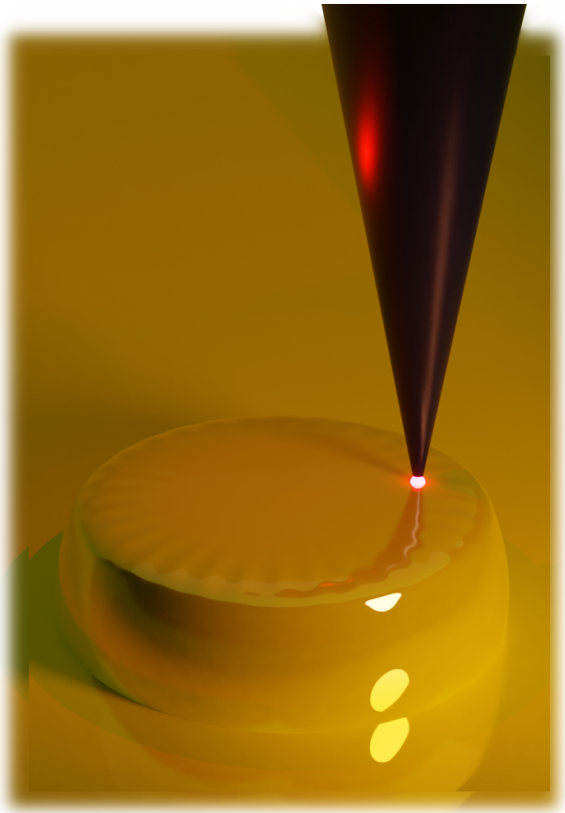
Introduction | Theory | Sample | Setup | Results | Conclusion

Modern computational devices are based on conventional integrated circuits, where data transfer is organized via electronic signals. Nowadays performance of these devices is close to their theoretical limit. One of the promising ways to overcome the current limitations is based on a transition to optical platform with a use of photonic integrated circuits, which may provide increase of operating frequencies along with the reduced Joule heating.



For real implementation of the integrated optoelectronic circuits, development of electrically driven localized photonic and plasmonic emitters is required. Tunnel electrical contact is one of the promising ways to develop sub-micron sized optical emitters.



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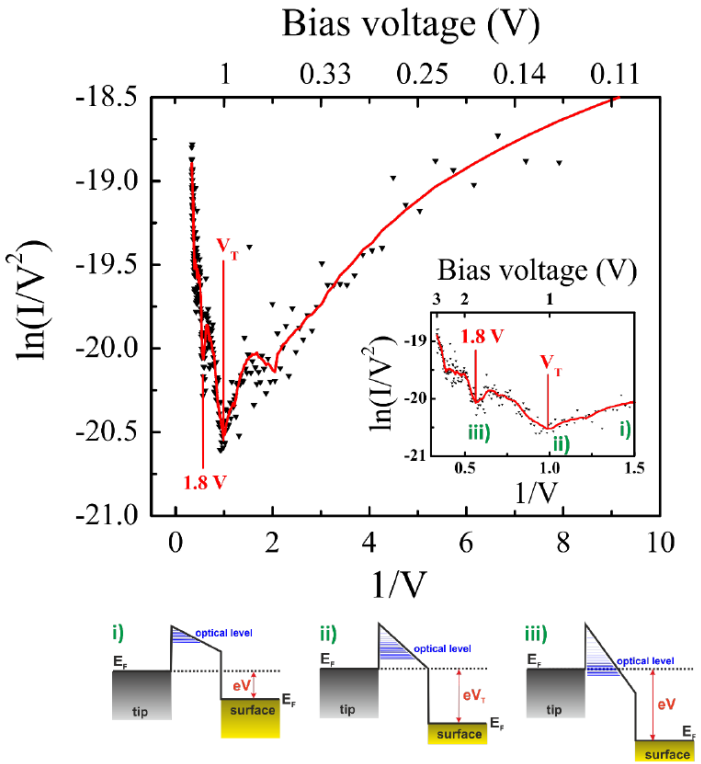
The study of inelastic electron tunneling and the processes of photons and plasmons generation opens up wide opportunities for understanding the processes of energy transformation. It should be noted, that the phenomenon of light emission from an MDM tunnel contact is promising for the development of electrically controlled nanoscale light sources. Previously, the emission from a tunnel junction has been studied in several experimental works through direct measurements of the emitted optical signal. However, recent studies have shown that in addition to the optical signal, the process of inelastic tunneling of electrons can also be analyzed via the I(V) characteristics. Thus, it makes possible to obtain information about the emission of photons and the excitation of plasmons from the tunnel junction by simultaneous acquisition of the optical signal and I(V) curves.



[Read more]: Lebedev, D. V., Mozharov, A. M., Bolshakov, A. D., Shkoldin, V. A., Permyakov, D. V., Golubok, A. O., ... & Mukhin, I. S. (2019). Indirect Detection of the Light Emission in the Local Tunnel Junction. physica status solidi (RRL)–Rapid Research Letters, 1900607.

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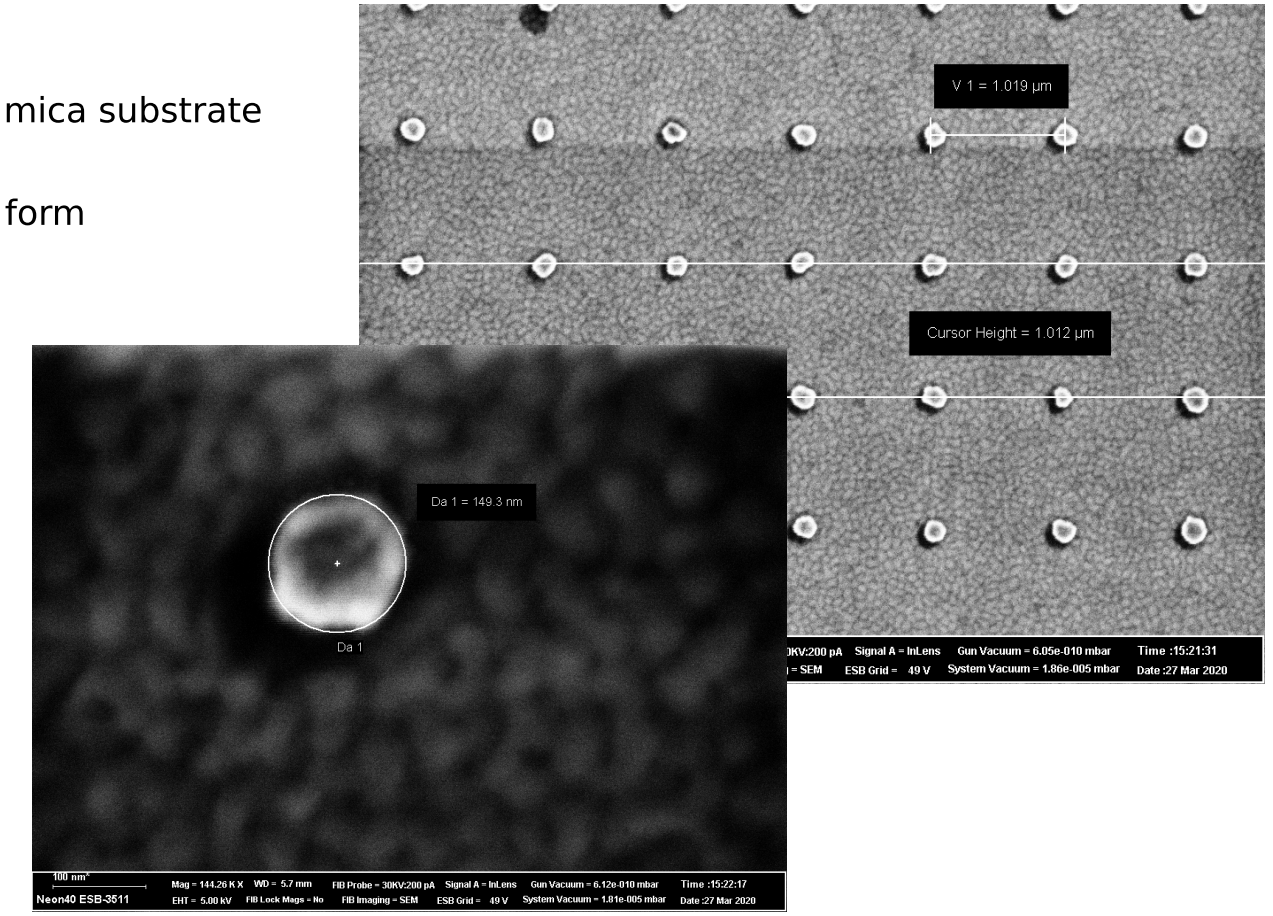
1) A thin gold film with thickness of 100 nm was evaporated on the mica substrate

2) The mica substate with the gold film was annealed in vacuum to form a single-crystal gold surface.

3) The disks were made by e-beam lithography

4) 1 nm of the chromium and 50 nm of the gold were deposited



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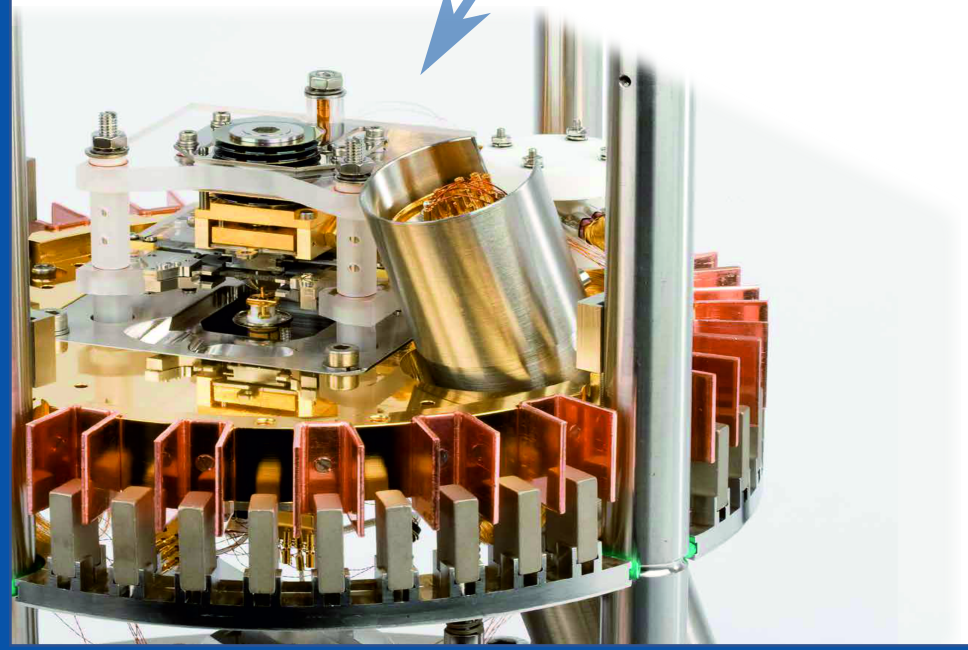
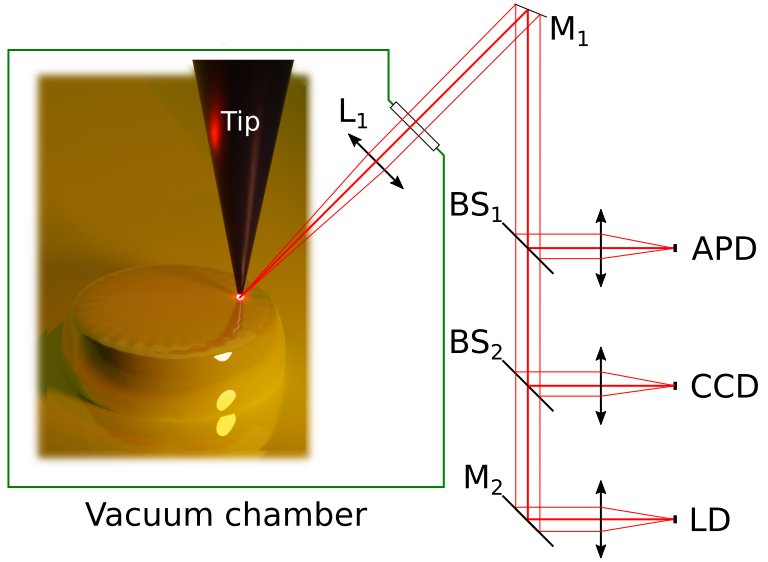
The experiment was carried out with the use of UHV Scanning Probe Microscope (SPM) Omicron VT650 (Germany) with a vacuum not worse than 8.1e-9 mBar. Before the measurements, the SPM chamber was baked out for 8 hours at 150 °C. In order to remove a thin layer of water from the surfaces the sample was additionally annealed for 3 minutes at 200 °C in the vacuum chamber.



Schematic of the experimental setup.



The light emitted from the STM contact is collected with a microlens (L1), installed inside the vacuum chamber of STM. Beam splitter (BS1) directs 90% of the light to the avalanche photodiode (APD). Laser diode (LD) and CCD camera are used to illuminate and observe the collection point, M1 and M2 – are mirror

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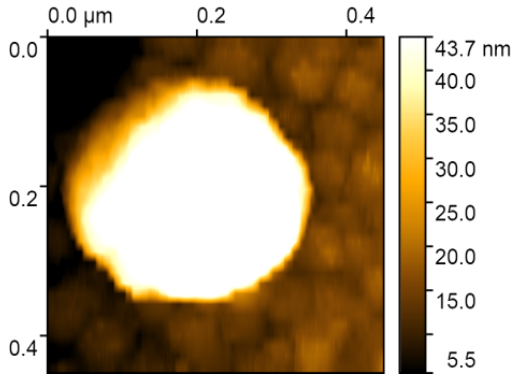
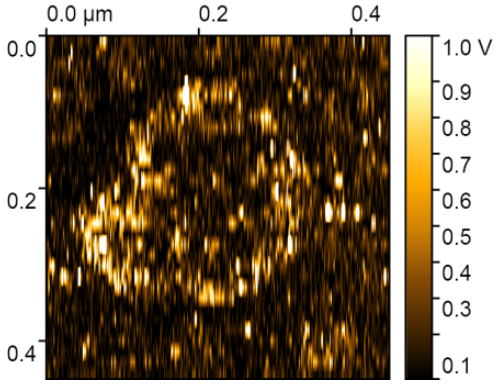
STM scan of gold disk

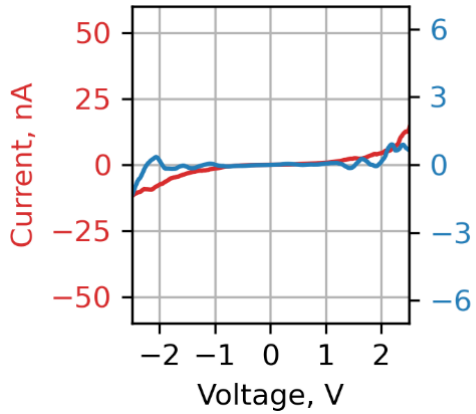


STM-induced luminescence map

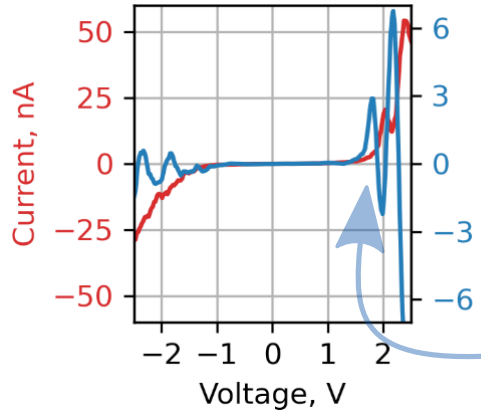


I(V) curves and corresponding d2I/dV2

obtained
at the center
of single nanodisk



obtained
at the edge
of single nanodisk



Both mesuarment clearly shows that the emission of photons at the edges of the disk is more efficient compared to the center.

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The technique based on the analyzing of I(V) dependences can be successfully used to study the optical properties of nanostructures. The results of the work open up new applications for the UHV STM to study the spatial distribution of the light emission driven by the tunneling current between the probe and the sample surface.This work was done with the financial support of the Russian Federation President Council for grants (grant MK-2428.2020.2) and Russian Foundation for Basic Research (project 19-32-90028).

Thank you!

Ready for your question!

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