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# TERAHERTZ COHERENT SCANNING PROBE MICROSCOPE

We present the terahertz (THz) scanning probe microscope which combines a THz coherent spectrometer and a scanning probe microscope. It detects forward-scattered radiation and employs harmonic signal demodulation to extract the signal of near-field contribution to scattering of THz electromagnetic waves.

*Keywords*: Terahertz, near-field, microscopy, scanning probe microscope.

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**ТЕРАГЕРЦЕВЫЙ КОГЕРЕНТНЫЙ СКАНИРУЮЩИЙ ЗОНДОВЫЙ МИКРОСКОП**

Мы представляем терагерцевый сканирующий зондовый микроскоп, объединяющий ТГц когерентный спектрометр и сканирующий зондовый микроскоп. Он детектирует пряморассеянное излучение и использует демодуляцию гармонического сигнала для выделения сигнала ближнепольного вклада в рассеяние ТГц электромагнитных волн.

*Ключевые слова*: терагерцевый, ближнепольный, микроскопия, сканирующий зондовый микроскоп.

## Introduction and background

The advent of the THz scanning probe microscope instrument can hardly be overestimated – it will add new powerful diagnostic instrumentation to the analytical arsenal of nanotechnology. The THz technology features accurate spectroscopic specificity over a very wide frequency band, together with other object recognition properties that are not present in the existing diagnostic instrument. It employs the THz radiation coherently generated and detected using ultrashort optical pulses and the tip-enhanced radiation scattering near a specimen under test [1-3]. Here we introduce a differential type of the THz near-field microscope and present recently obtained experimental results.

## Experimental details

Our THz microscope is a combination of a THz time-domain spectrometer with a scanning probe microscope (SPM) operating in the tapping mode. The forward scattered THz radiation is analyzed. The near-field signal and the

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spatial contrast are extracted by measuring the THz signal at the frequency of SPM tip excitations. We used a GaAs sample with Au stripes deposited on it as a test phantom. The geometric parameters of the test phantom were controlled independently using a scanning electron microscope and a scanning probe microscope. We obtained the dependencies of the differential THz signal induced by the scattering and absorption of radiation by a "probe-nanoobject" structure on the probe height when the probe was either under metal or semiconductor. Probes with different tip radii were used in the measurements.

**Results**

The experimental dependencies of specularly reflected THz electric field amplitude on the probe-phantom distance (height) were obtained in both the full reflected and differential signal registration modes. The fundamental and second harmonics of differential THz signal were measured. The real position of the probe above the sample was determined via synchronous registration of the "THz amplitude-tip height" dependences and the SPM approach curves. It was observed that the character of the approach curves (the typical distance at which a differential signal starts to increase) for differential THz signals varies depending on what material is underneath the probe and also on the tip radius. Fig. 1 shows an example of approach curve for a differential THz signal when a 150 nm probe was above an Au stripe.

It was experimentally shown that the growth of THz signal for approach curves depends on the object under the AFM probe. The growth rate of THz signal above a metal surface is considerably higher than that above a semiconductor surface. Enhancement of THz near-field depends on the properties of the material under the AFM tip which was used for scanning the test semiconductor sample with metal stripes deposited on it. Fig. 2 shows the surface topology of the test sample (a) and the corresponding distribution of THz signal (b).

Experimental THz waveforms and corresponding spectra were obtained for both full reflected THz radiation and radiation scattered

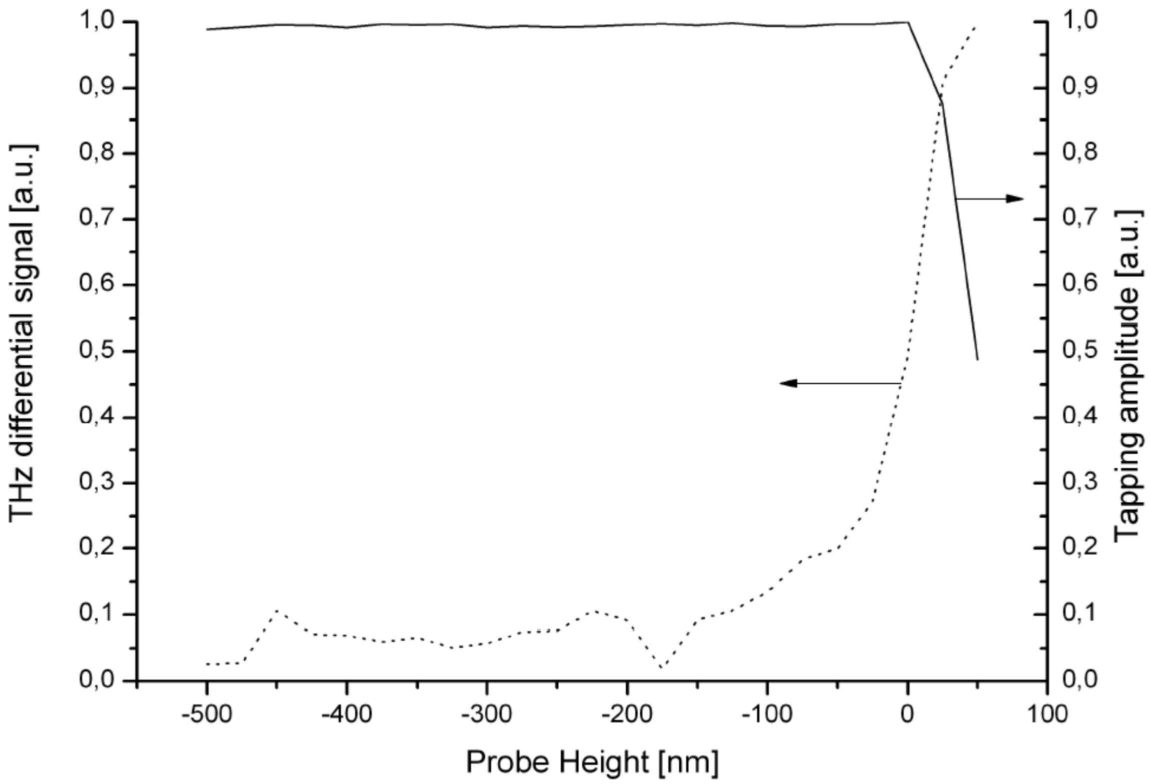
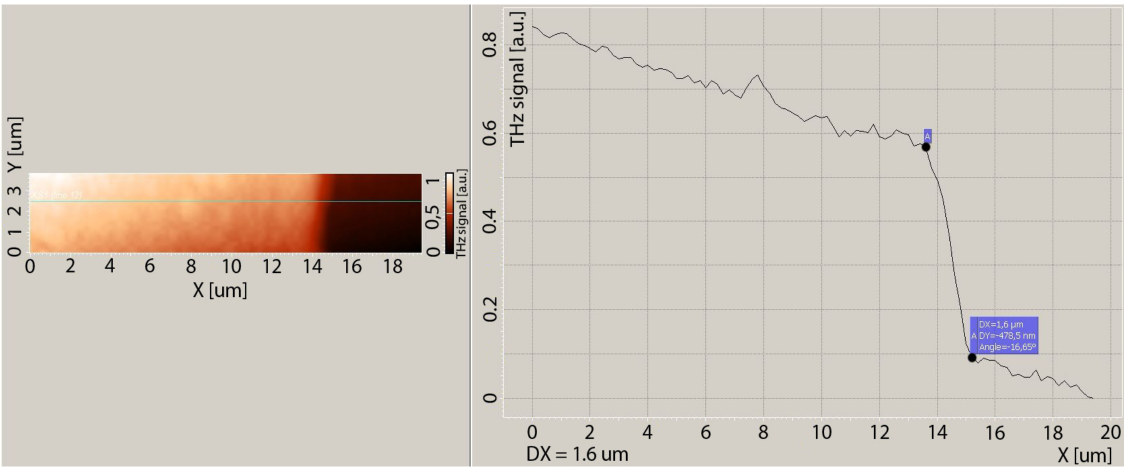
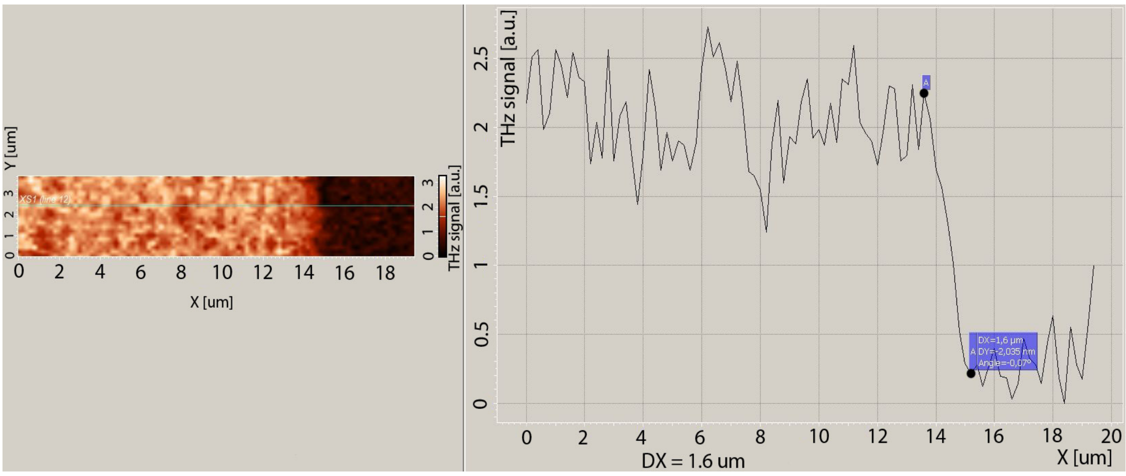



Fig. 1. The approach curve for differential THz signal and SPM tapping amplitude. A tip of 150 nm in radius was above the Au stripe




a




b

Fig. 2 Surface topology (a) and simultaneously obtained corresponding THz signal distribution (b)

by the "probe-nanoobject" system. The experimental THz field approach curves were analyzed on the basis of several models: the Mie theory and the simple antenna model [2]. The spatial resolution of the differential THz near-field microscope was determined through simultaneous THz-SPM analysis of several topographic samples. We have found that the THz spatial resolution is the same as that of the SPM and, in common case, is controlled by the tip radius.

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