New scanning probe microscopy near-field imaging method for laser radiation intensity mapping

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Abstract— Novel scanning probe microscopy method of near field imaging of laser radiation is proposed. The method providing a submicron spatial resolution is based on detection of a shift of the probe resonance related to its heating by absorbed radiation. The method has been realized with a conventional silicon probe and has been employed for visualization of infrared emission from a half-disk semiconductor whispering gallery mode laser.

Keywords— scanning probe microscopy; near field; laser radiation

I. INTRODUCTION

It was found by the authors of this work [1] that the scanning probe microscopy (SPM)-probe resonant frequency shift (Δω) is linearly related to the intensity of the incident light flux (ΔI=I). It was also shown that the SPM-probe resonant frequency decreases when illuminated (Δω<0). On the basis of the observed effect it is proposed a new method for measuring of photosensitive probe frequency shifts for near-field mapping of the intensity distribution I(x, y) of the radiation emerging from the surface of the semiconductor laser structures. The advantage of the method is that its implementation does not require the use of special optical fibers and photodetectors. Also the method allows measurements over a wide spectral range.

II. EXPERIMENTAL RESULTS

By this method there were carried out near-field I(x,y) measurements on cleavages of infrared whispering-gallery mode (WGM) lasers (GaSb/GaAs/GaInSbAs). It was shown that at currents below the threshold value (I<It) the intensity of weak spontaneous emission is described by a shallow function with maxima near the edges of the cleaved WGM-disc. With increasing the current above the threshold (I>It) it appears near the edges of the WGM-disc the complex series (Fig. 1a, b) of laser emission spots. The presence of several laser emission spots presumably is due to the fact that the radial distribution of light intensity in the WGM-laser is described by the squared Bessel functions of higher order J_m(r). It is known that this function may have several maxima near the edge of the WGM-disc.

For laser emission spots near surface it was observed an exponential decrease of intensity I=exp(-z/d) with increasing of probe-surface z-distance (Fig. 1 c). The measured characteristic value of the decay length (d) was d = 0.1-0.2 μm. These features also can be observed in the far field at a distance of a few microns with slower decrease of intensity with increasing of probe-surface z-distance.

For experimental evaluation of lateral resolution there were measured sizes of minimal detectable laser emission spots. The detailed measurement showed that the lateral resolution (L) of the method is better than 150 nm. It is worth noticing that conventional silicon probe consists of cantilever and sharp pyramid with edge size about 10 microns. Due to the exponential decrease of light absorption with tip-surface distance only the small part of the pyramid interacts with the radiation, that leads to the subwavelength resolution.

REFERENCES