Surface-structure identification using THz radar techniques with spatial beam filtering and out-of-focus detection

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Abstract: We propose two terahertz reflectometry modalities, optimized to be sensitive to the curvature of surface features. A dark-field approach yields higher sensitivity whilst the out-of-focus technique allows one to distinguish between convex and concave shapes.

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A specific application of THz remote sensing may serve as an example to illustrate this point. For an inspection during metal production and processing, one searches for techniques which allow the online, i.e., fast identification of and distinction between protrusions and dents. These typically have a millimeter-scale width and a height (or depth) down to 5μm. Reliable detection is required to occur under production conditions which include such aspects as a visible surface roughness and a large working distance of more than 10 cm. This report deals with an optimization of THz line or areal scanning for such and related tasks.

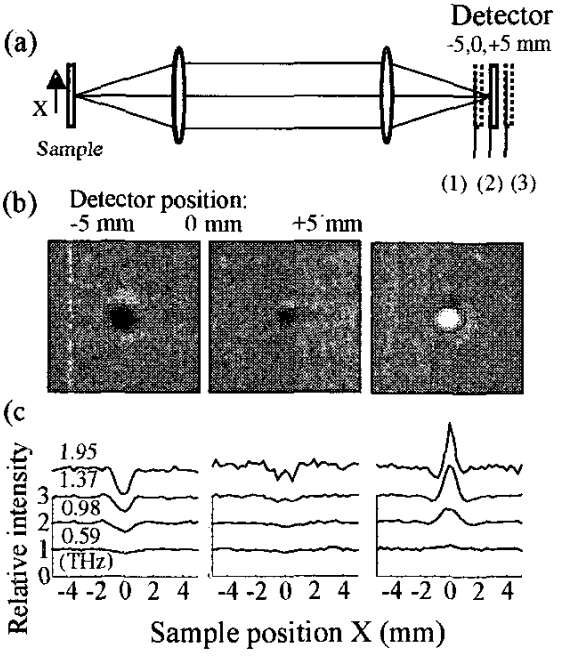

Fig. 1 (a) Schematic of out-of-focus detection. (b) Measured intensity profiles of sample with a dent, containing all Fourier components, and (c) frequency-resolved line-scan data extracted from these profiles.

The principle of out-of-focus detection is sketched in Fig. 1 (a). The key feature of this approach is that the detection occurs out of the focus of the second lens (the focus being marked as position (2)), either 5 mm in front of the focus (detector position (1)) or 5 mm behind it (detector position (3)). An example of measured results for a

sample containing a 2-mm-wide and 20-μm- deep dent is shown in Figs. 1 (b) and (c). Hardly any effect is observed at the central detector position (2) (see middle column). However, a shift of the detector position by ±5 mm yields large signals with different polarity. Measurements on a sample containing a protrusion reveal exactly the inverse signature (not shown). These findings, including the strong frequency dependence, are consistent with calculation results based on a paraxial Helmholtz theory.

At the conference, we also discuss a modified approach, dark-field detection, which brings an order(s)-of-magnitude signal enhancement at the cost of the loss of discrimination between protrusions and dents [1].

We reach the conclusion that the combination of these two techniques makes it possible to sensitively detect and discriminate small dents and protrusions, and more generally features of convex and concave shape.

[1] N. Hasegawa, T. Löffler, M. Thomson, and H. G. Roskos, "Remote Identification of protrusions and dents on surfaces by THz reflectometry with spatial beam filtering and out-of-focus detection," Appl. Phys. Lett., **83**, 3996-3998 (2003).