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Quasi-optical 2D system for non-contact non-destructive testing of defects in natural and artificial crystals

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ABSTRACT

The results of development the automated system of two-dimensional diagnostics of defects of crystalline materials are presented. Used technology imaging. The structural scheme of the system is given, its main blocks are indicated, the approbation process is described, the software of the system is described

Key words: quasi-optical system, terahertz, imaging, non-destructive testing, two-dimensional positioning, defects of crystalline materials

1. INTRODUCTION

The results of the interaction of microwave with natural and artificial materials give unique information that is inaccessible to other methods. Terahertz range, having a number of advantages over the optical range and X-ray, is used in a number of applications in medicine [1-3], biology, security systems [4, 5], Research of carbon nanomaterials [6-10]. The carrier of information in the study of objects by electromagnetic methods is the frequency dependence of the amplitudes and phases of the electromagnetic signals reflected and transmitted through the sample. Often specialists without special physical education are involved in the use of terahertz research methods. For these specialists it is necessary to present information in another convenient form for analysis. The problem is solved by using terahertz communications (THz imaging) [11-18]. Such systems significantly speed up the process of information processing, converting a terahertz signal into a visible image. The development of hardware, techniques for their use and software is an urgent task in connection with the expansion of the field of application of terahertz radiation At present, two-dimensional and three-dimensional terahertz [19] imaging systems are being developed. Scientists and engineers from all industrially developed countries are invited to work. The range of issues related to the use of terahertz radiation is broadening and the creation of information visualization systems is increasing with the need to make it easier for consumers to use it for their own purposes. In this paper, we consider the possibility of using terahertz imaging to determine defects in crystal structures using an automated system for two-dimensional diagnostics of crystalline materials.

2. 2D POSITIONING SYSTEM

The sample of the inhomogeneous material is fixed in the module of two-dimensional positioning of the measuring path of the spectrometer (Fig. 1).

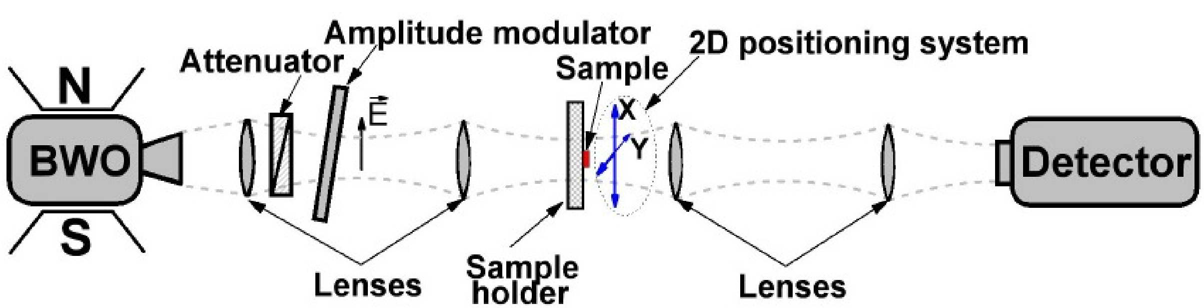

Figure 1 – Scheme of the quasi-optical path of the system of non-contact of material heterogeneity control

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The software was implemented in the National Instruments LabVIEW programming environment. The analog-to-digital converter (ADC) channel and the digital lines of the E-154 of firm L-card were used. The structural diagram of the system for diagnosing material i is shown in Fig. 2.

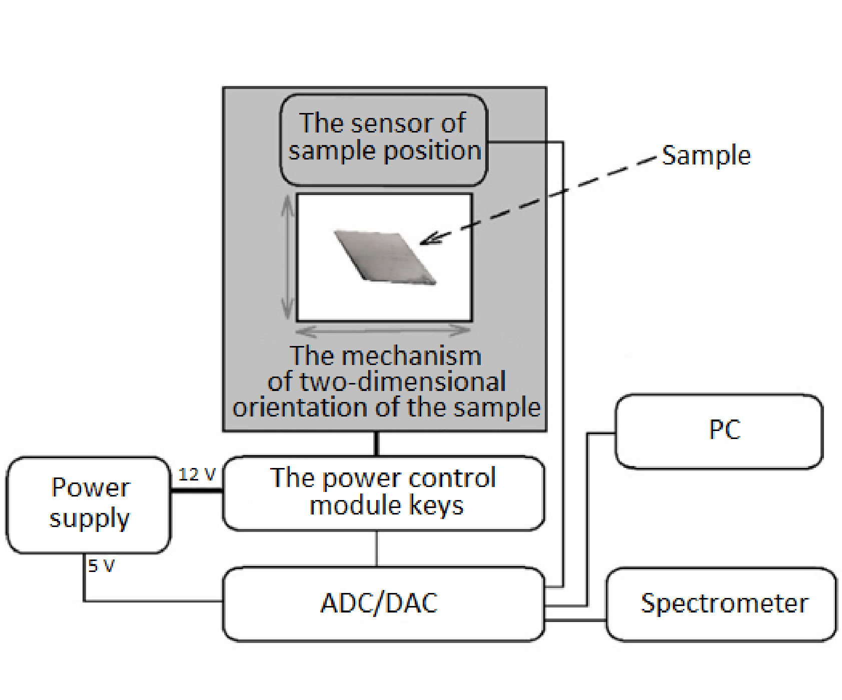


Figure 2 - Scheme of the quasi-optical path of the system of non-contact of material heterogeneity control

Figure 3 – The front panel of the scan system management program.

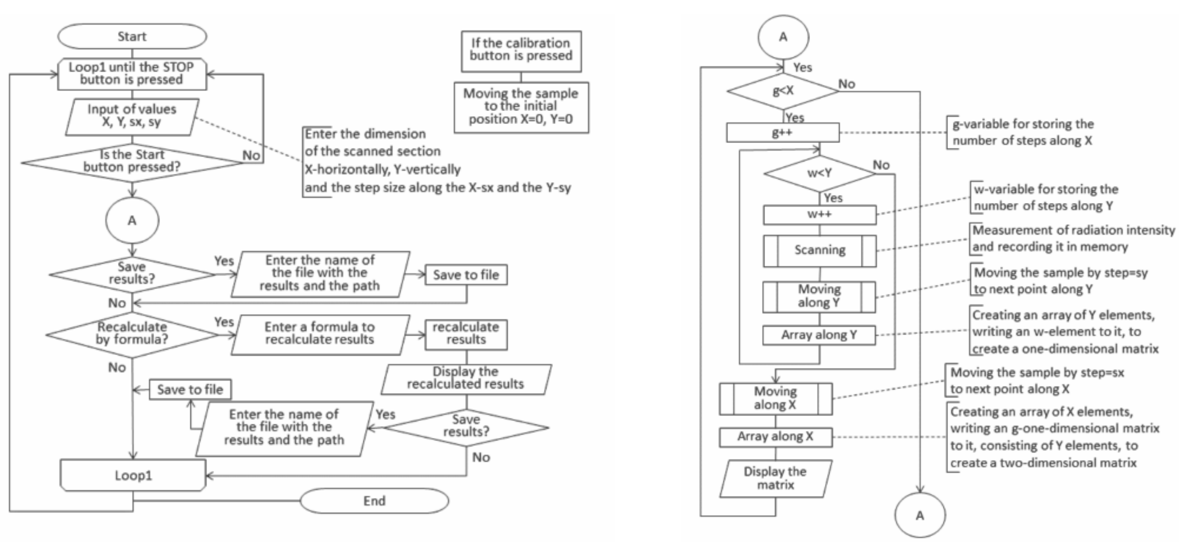


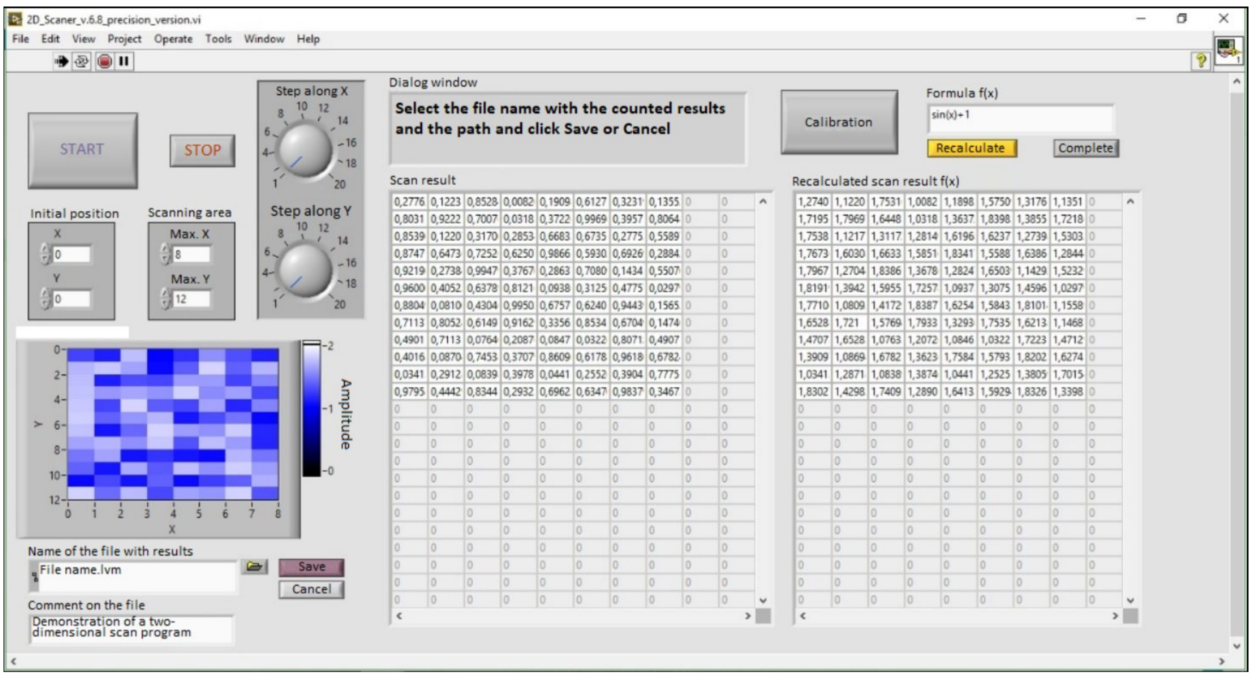
Figure 4 – Block diagram of the control program for the non-contact non-destructive testing of defects in crystalline materials

The algorithm of the control program for the non-contact non-destructive EHF and HFG system for controlling material inhomogeneities is shown in Fig. 4.

The sample is positioned by means of a two-dimensional orientation mechanism with respect to the beam of incident electromagnetic radiation. Bipolar stepper motors d were used as actuators of the positioning mechanism, Motor windings are switched using a power key management module made in accordance with the scheme of H-bridges with galvanic decoupling by optocouplers. The initial position is initialized by mechanical end sensors. The DC 12 V source is used to power the p The information is collected from the detector and the system is controlled by a 12-bit analog-to-digital converter that is part of the L-card E-154 of firm L-card. The analog input of the module is used as a communication line with the spectrometer detector. The detector is designed to record the intensity value transmitted through a sample of terahertz wave. The I / O module was controlled by a personal computer with installed software written in the programming language LabVIEW. In Fig. 3 shows the front panel of the program.

3. RESULTS AND DISCUSSION

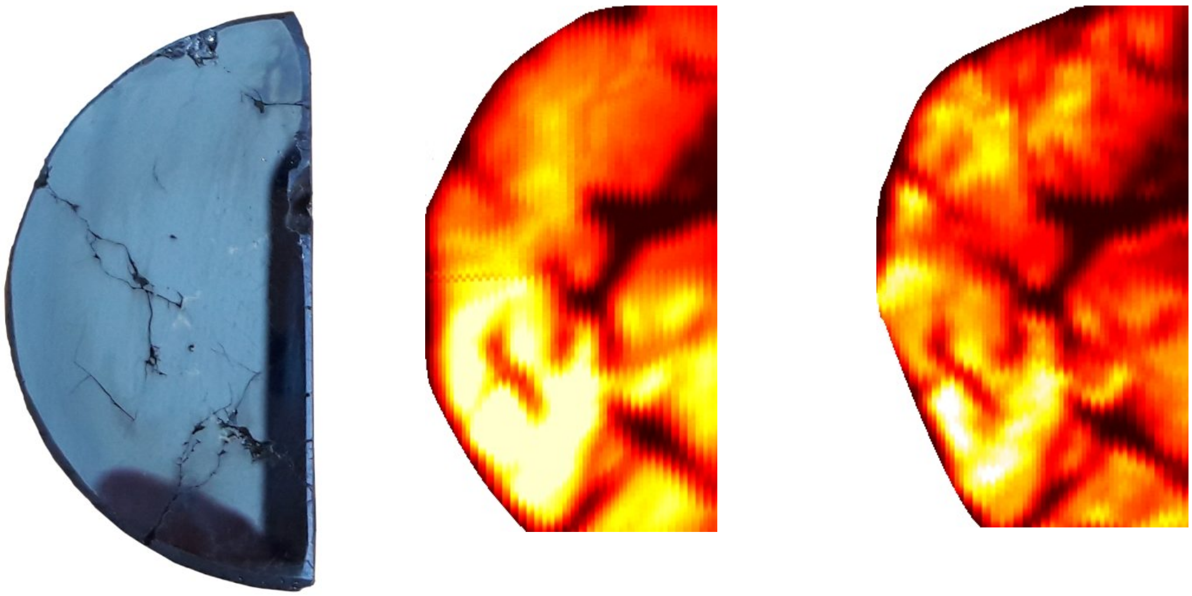
increase the accuracy in this case, it is necessary to introduce an additional taxonomic feature – the size of the planktonic particle (the sizes of Rotifera species in this sample did not exceed 250 µm, the species size of other taxes is more than 250 µm), then the classification accuracy is increased to 83.69%. The time taken to process this training sample was 3.5 seconds.



The following features are provided in the control program: input coordinates of the initial scan position (X0, Y0); Specify the size of the scanning area vertically and horizontally; Setting the magnitude of steps along the X and Y axes. Automatic saving of the results to a file with the addition of technical information about the system parameters occurs when the scanning process is forcibly stopped. The function of conversion of results into the program of the received matrix of intensity is built in by an arbitrary algorithm, set by the operator. The result is displayed on the screen as a two-dimensional graph of the intensity of the transmitted radiation during the scanning of the material. Operator prompts and status messages are displayed in a dialog box. The main control of the program is carried out by pressing the «Start», «Stop» and «Calibration» keys. When the calibration function is selected, the sample holder moves to the initial position.

4. RESULTS AND DISCUSSION

The system developed was used to study the defects of a plane-parallel sample of a ZnGeP2 crystal. Two reverse-wave tubes (QS-700 No. 18 and QS-350 No. 39-5) were used as tunable sources of a terachograph monochromatic signal. Detection of the transmitted radiation was carried out by an acousto-optical transducer (Golay cell). In Fig. 5 shows the intensity of radiation at 386 GHz and 861 GHz, obtained with a resolution of 30 points per mm 2.



а) б) в)

Figure 5 – The optical image (a) and the intensity of the transmitted terahertz for the sample ZnGeP2 at the frequencies 386 GHz (b) and 861 GHz (c)

A detailed comparison of the results gives grounds to conclude that using a higher frequency increases the detail of the drawing of the sample. However, it should be borne in mind that with increasing frequency, the coefficient of passage through most materials is noticeably weakened, so when choosing scan parameters, one should proceed from compromise considerations. The selected regions coincide with the regions characterized by increased conductivity, which were formed due to a violation of crystal growth technology. In this case, regions with an increased content of metallic zinc were isolated.

5. CONCLUSION

The developed quasi-optical system can be used in modern industries, for researching materials that are a cultural heritage, as well as for ensuring the safety of people.The developed quasi-optical system for diagnosing defects in crystalline materials was successfully introduced into the center for collective use "Center for Radiophysical Measurements, Diagnostics and Research of Parameters of Natural and Artificial Materials".

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