Terahertz imaging with a 160x120 pixel microbolometer 90-fps camera

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***Abstract*— An uncooled micromolometer matrix camera has been developed for IR and THz high-speed imaging. The 120x160 matrix consists of resistive vanadium oxide elements on a silicon nitride bridge. The element size is 46x46 micron at the array period of 51 micron. We describe device fabrication process and matrix operational characteristics. Application of the camera in quasi-optical systems with Novosibirsk terahertz free electron laser as a radiation source is described. Recording rate up to 90 frames per second has been achieved.**

***Index Terms*—Free electron laser, microbolometer matrix, terahertz imaging.**

I. Introduction

TERAHERTZ imaging is critically important for many applications. Appearance of high power terahertz sources, such as free electron lasers, enables using "parallel" recording techniques rather than recording images point-by-point with scanner. The last technique is routinely used in the time domain spectroscopy (TDS) systems, where recording an image takes minutes and hours.

Recently commissioned Novosibirsk terahertz free electron laser generates terahertz radiation at the fundamental mode in a range of 120 – 240 μm with the average power 100 – 200 W at the repetition rate 5.6 MHz and second and third harmonics with the average power of about several Watts. A number of imaging techniques employing the thermal effect of terahertz radiation were developed during past two years for recording images on the user stations [1 – 2]. These imaging techniques have many advantages, but each of them has at the same time certain drawbacks. One of them has a good spatial resolution, but pure sensitivity. Other being sensitive has no good spatial resolution. In this paper we describe the application of a microbolometer matrix to the recording of images in the terahertz spectral region.

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II. Matrix description

The expansion of application sphere of thermal imager and others infrared (IR) devices along with increase of its sensitivity demands of decrease of cost, power consumption and weight, more convenience to use and high reliability. All these requirements are satisfied by uncooled focal plane array (FPA) actively developed last two decades. Microbolometer FPAs, based on thermoresistance effect have got the greatest expansion. Vanadium oxides (VO_x) and amorphous silicon are mainly used as thermoresistance material. In the latter case process of microbolometer fabrication is carried out completely within the framework of usual silicon technology.

The high performance of uncooled FPA mentioned above is achieved the mainly due to development of technologies of thermosensitive layers preparation and microbridge structure fabrication. Since uncooled FPA are fabricated in integrated-circuit form the basic requirement to the technologies mentioned above is their compatibility with fabrication technology of the silicon readout integrated circuit (ROIC). The traditional methods of thermosensitive vanadium oxides layers preparation - reactive magnetron and ion-beam sputtering - are enough complicated and require the complex expensive equipment. For preparation of thermosensitive amorphous silicon layers the technology of plasma enhanced chemical vapor deposition (PECVD) from monosilane with addition phosphine is used that creates additional difficulties.

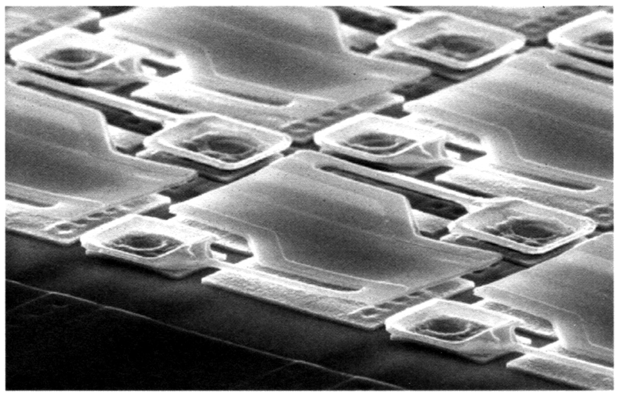

Fig. 1. Scanning electronic microscope photograph of 160x120 microbolometer FPA fabricated on silicon readout circuit.

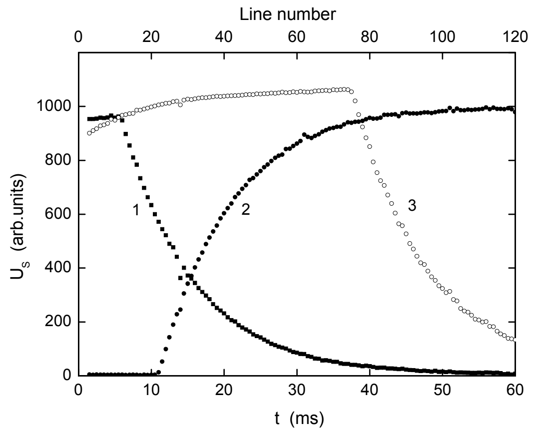

Fig. 2. Time dependence of 160x120 microbolometer FPA output signal normalized on sensitivity at pulse illumination. (1) the decay of FPA output signal after illumination: (2) the increasing of the signal during illumination, (3) is an intermediate situation.

Vanadium oxide 160×120 pixel matrix was designed for the operation in the middle infrared spectral region (8 – 14 μm). The fabrication technology and operational characteristics of the matrix in this spectral region are described in paper [3]. In this paper we describe the application of this matrix for the recording of the monochromatic radiation in the spectral range 130 – 150 μm.

III. Terahertz Imaging with VO_X Matrix

Though the matrix was not optimal for terahertz radiation, it approves itself as a very perspective tool for terahertz imaging. It appears to be more sensitive than previously developed technique. It has a spatial resolution close to the wavelength limit. We have demonstrated the recording of a moving object image with a rate up to 90 frames per second.

The microbolometer matrix was applied for study of focusing terahertz radiation with a reflective kinoform (Fresnel) lens [4]. It was used for imaging radioscopy of rat bones that is necessary for study of osteoporosis development [5].

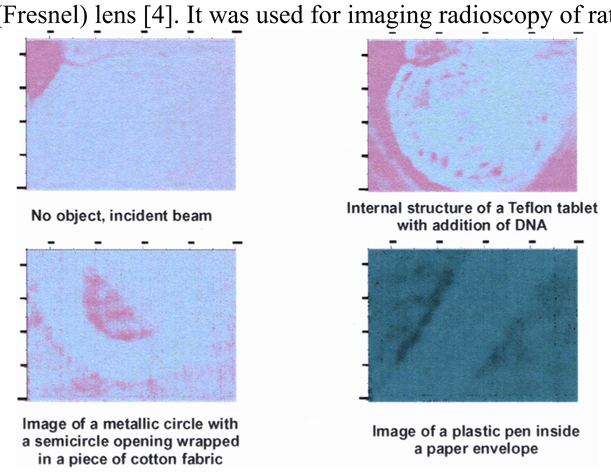

Fig. 3. Imaging terahertz radioscopy, λ = 130 mm. Imager: microbolometer matrix. Matrix size: 160x120 pixels, 16 bit, 8,2x6,2 mm, Recording rate: up to 90 frames per second.

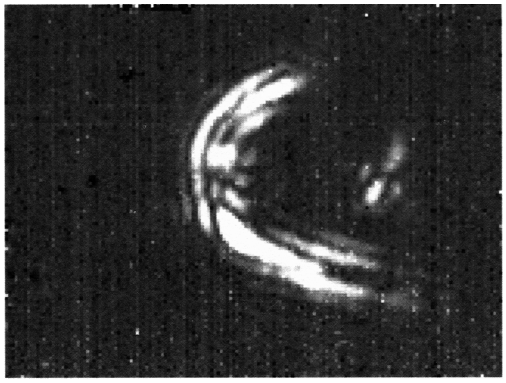

Fig. 4. Image of a wire spring with diameter of 2 mm.

The matrix was used as a recorder in a number of quasi-optical systems developed at Novosibirsk free electron laser. In the right upper corner in Fig. 3 the internal structure of a tablet pressed from Teflon powder with addition of DNA is shown. The image was recorded by means of the radioscopy of the tablet with FEL as a source (see schematic in Fig. 2, ref. [5]).

Other application of the matrix was the radioscopy of wrapped objects and substances. Two pictures in the lower row in Fig. 3 demonstrates the capability of the matrix for the examination of partially transparent to terahertz radiation substances for the inspection of illegal objects and for the control of the box and container contents in industry and stores by means of the radioscopy. Fig. 4 demonstrates a capability of the matrix for imaging of the objects illuminated by terahertz radiation (reflection/scattering mode).

IV. Conclusion

A microbolometer matrix approves itself as a powerful tool for terahertz imaging both in transmission and reflection modes. Further development of the technique will be directed on the increasing matrix elements and optimizing matrix design for the terahertz region.

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