Manned Spacecraft Safely Nondestructive Inspection with Terahertz

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***Abstract*— In this paper, we present a portable, video rate, low-cost and high imaging quality terahertz imager which is suitable for manned spacecraft on-orbit nondestructive examination and security inspection, the imager can hand-held by astronaut or space station's robot arm, and some components test results are given.**

I. INTRODUCTION

The spacecraft are exposed to potentially corrosive atmospheric elements while undergoing final closeout for missions at the launch pad and extreme conditions during ascent, orbit, and descent that may accelerate the corrosion process, and it is especially important for manned spacecraft to safety inspect when they work in complicated space environments. An on-orbit nondestructive inspection methodology is required. Of the nondestructive inspection methods, consideration should be given to X-ray inspection methods; however, this presents a health hazard, as there is a risk of exposure of personnel to radiation. Thus a safe, nondestructive inspection method which is suitable for hand-held by astronaut is need.

Terahertz (THz) radiation occupies an area of the electromagnetic spectrum between the infrared and microwave bands and terahertz technology has received a lot of attention because of its unique properties and capabilities that make it very attractive as a non-destructive evaluation tool in the past years.

THz nondestructive evaluation can offers a non-contact and high-resolution means of inspecting for corrosion effects that may be hidden under spacecraft surface.

A portable, video rate, low-cost and high imaging quality terahertz imager which is suitable for manned spacecraft on-orbit nondestructive security inspection are design, and experimental result of subsystem are presented.

II. DESCRIPTION OF THE SYSTEM

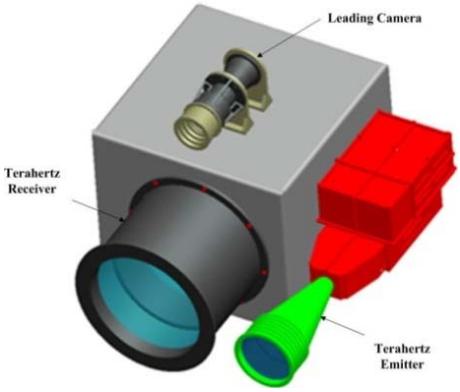

Fig.1 Schematic diagram of the system

The schematic diagram of the system is shown in Figure 1, which is mainly composed of terahertz transmitting system, terahertz receiving system and optical leading camera. The mainly features of the system are as follows:

- High sensitivity. Surface plasmon resonance optical antenna improve response of terahertz CMOS detector.
- High imaging quality. Improve the resolution of system utilizing the super-resolution reconstruction in image processing.
- High precision positioning. A leading camera help robot arm rapid positioning.

Tab.1 Specifications of the system

Items	Specification
Frequency range	Terahertz: 0.34THz Leading camera : 0.45μm ~0.76μm
Size	20cm×20cm×15cm
Frame rate	30fps
Resolution	≤3mm

III. SOME COMPONENTS TEST RESULTS

A Terahertz detector for imaging at room-temperature has been fully integrated in a 0.18μm CMOS bulk process technology. The gate length and width of the MOSFETs are 0.18 μm and 0.5μm, respectively, and the threshold voltage Vth is 0.5 V. The chip uses a novel reset and readout architecture with very low power consumption. Because THz frequencies are far below the plasma frequency of metal, the surface plasmon polariton waves cannot be supported along the metal/dielectric interface at THz frequencies, polysilicon optical antenna is adopted for increasing gain. Response comparison between FET only and FET with polysilicon optical antenna is shown in Fig.2, it's obvious that FET with polysilicon obtain higher gain than FET only.

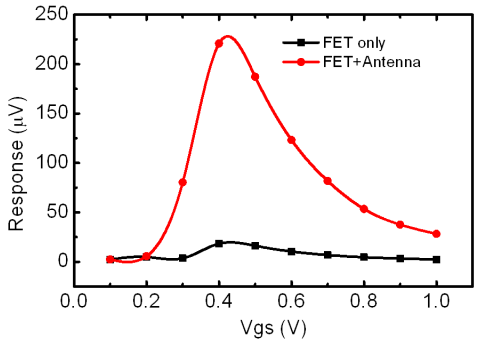

Fig. 2 Response comparison between FET only and FET with polysilicon optical antenna

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We improve the resolution of terahertz imaging system utilizing methodology of super-resolution reconstruction. We reconstruct a super-resolution reconstruction terahertz image from four subpixel-shifted low terahertz images acquired under the same condition.

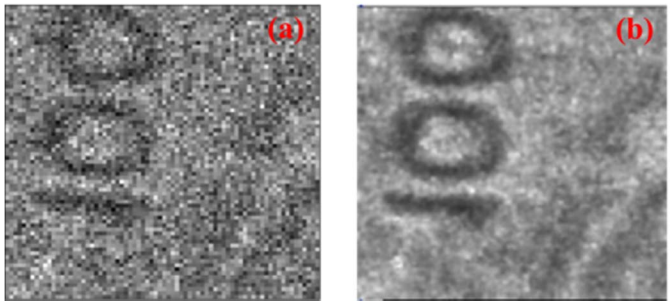

Fig. 3 Comparison between LR image and SR image(a).Linear interpolation of single low-resolution Thz image (b).The proposed method

Figure 3 illustrates the SR reconstruction results. The left image is one of four low resolution (LR) terahertz images with subpixel offset staggered, which is acquired under the same experimental condition. The right image is SR by the proposed algorithm. The sample is watermark of Chinese money, the result shows that the character"100" has more sharp edge and clear background after super resolution. The image is smooth as followed with sampling points increasing. From the table.2, we can see that the processed image by the proposed method has better value than LR image on the indexes, including SNR, contrast, entropy and power spectrum.

Table.2 Evaluation indexes of image quality

The comparison of the reconstructed methods	Linear interpolation of LR	The proposed method
SNR	7.27	13.76
Contrast	20.59	21.58
Entropy	6.86	7.24
Power spectrum	40.03	41.29

From the table.2, we can see that the processed image by the proposed method has better value than LR image on the indexes, including SNR, contrast, entropy and power spectrum. The SR has more useful information and high resolution than LR.

IV. SUMMARY

A portable, video rate, low-cost and high imaging quality terahertz imager which is suitable for manned spacecraft on-orbit nondestructive examination and security inspection are design, and experimental result of subsystem(detector and image processing) are presented. With the carrying out of the manned lunar landing project and deep space exploration project in China, this technology will play an important role.

ACKNOWLEDGMENTS

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