Fourier phase grating for THz multi-beam local oscillators

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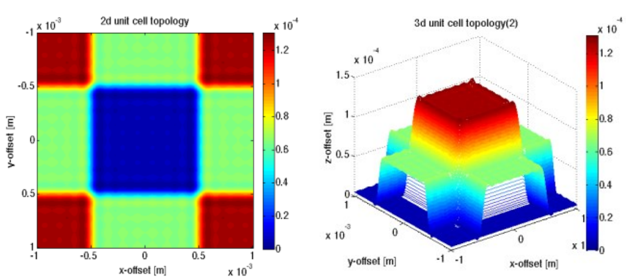
Abstract—**A Fourier phase grating mirror will be applied to split a single, coherent terahertz source beam into multi-beams, which are spatially distributed as required for the local oscillator in an array receiver. We report on the simulation, design and fabrication of a Fourier phase grating at 1.25 THz for generating 2×2 beams, and the measurements at 1.39 THz as a proof of concept study. We find that the characteristics of the measured diffraction beams are in good agreement with the model. In addition, we present the simulation and design of a grating for 4×4 beams as required for the GUSSTO's 4.7 THz local oscillator.**

I. INTRODUCTION

It is known that a Fourier phase grating is able to transform a single, coherent beam into multiple beams [1-3]. For a reflective grating, the smoothly defined surface structure, which is designed based on the Fourier series expansion theory, is used to manipulate the phase of the reflected terahertz waves in such a way that the multiple beams are formed on a detection plane in the far-field [4]. Such gratings have so far been demonstrated only up to 1.1 THz [5]. In this work, we report a grating for 2x2 beams measured at 1.39 THz. Our ultimate goal is to demonstrate a grating for 4x4 beams at 4.7 THz as a local oscillator for the GUSSTO (Galactic/Xgalactic Ultra long duration balloon Spectroscopic Stratospheric THz Observatory) array receiver to map [OI] line.

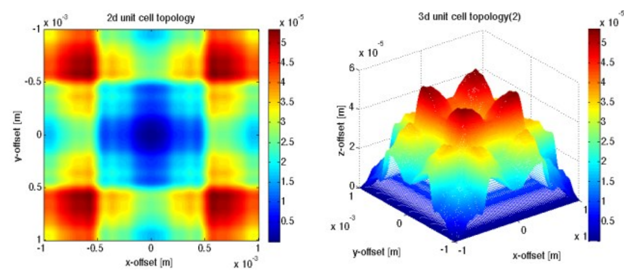


(a) (b)

Fig. 1 (a):Surface topology of one unit cell of a Fourier reflective grating for 2x2 beams at 1.25 THz. (b):3D profile of the same unit cell as in (a)

II. FOURIER PHASE GRATINGS

Fig. 1 shows a designed one unit cell of a Fourier reflective grating to produce 2x2 beams at 1.25 THz with a normal incident Gaussian beam.



(a) (b)

Fig. 2. (a): Surface topology of one unit cell of a Fourier reflective grating for 4x4 beams at 4.7 THz. (b):3D profile of the same unit cell as in (a).

Fig. 2 shows the design for one unit cell of a Fourier reflective grating for producing 4x4 beams with a normal incident beam at 4.7 THz.

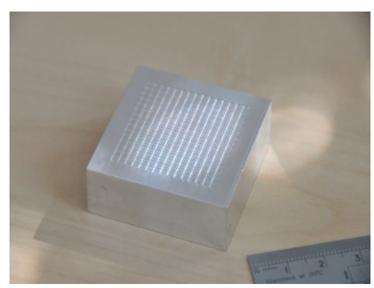


Fig. 3. Photo of the manufactured grating for producing 4 beams at 1.25 THz.

Fig. 3 shows a photo of the 1.25 THz grating that consists of 15×15 unit cells, in which the unit cell size is 2x2 mm. The grating was manufactured by a CNC micro mill.

III. EXPERIMENTAL RESULTS

Fig.4 shows the experimental setup to characterize the grating. We apply a FIR gas laser line at 1.39 THz as the incoming beam due to the lack of a suitable source at 1.25 THz. To measure the beams reflected from the grating, we apply a pyro-electric detector (detector 1 in Fig. 4) and record the radiation intensity by scanning the detector along the detection plane. The beams are measured by varying the distance between the grating and detection plane and incident angles. Fig. 5 shows the measured diffraction beams for three different distances. Fig. 6 shows the measured diffraction patterns in two different incident angles. The undesired beams (modes) can be seen when the angle is 32.5 degree, which is too large. For comparison, the simulated diffraction beams at different angles are given in Fig. 7.

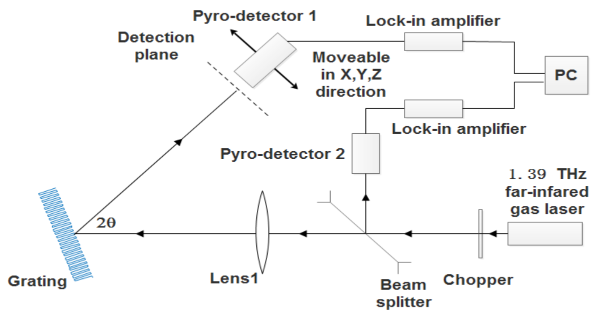


Fig. 4 Schematic setup for characterizing the grating.

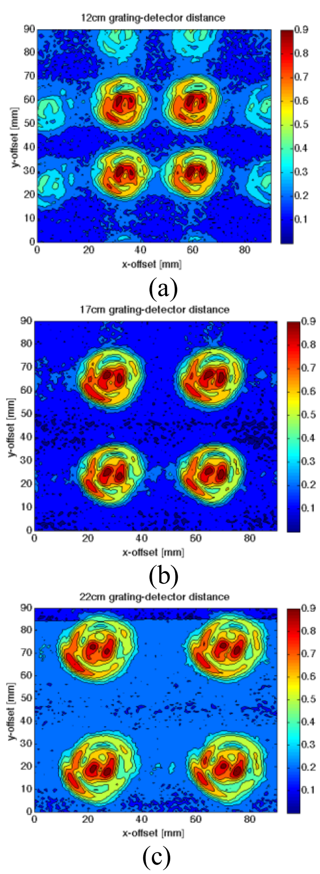


Fig. 5 Measured diffraction beam patterns at 1.39 THz for three different grating-detector distance: (a): 12cm (b):17cm (c): 22cm. All are with an incident angle of 25 degree.

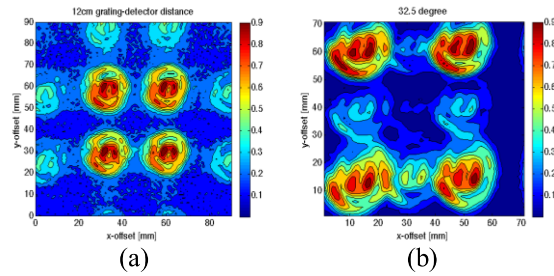


Fig. 6 Measured diffraction beam patterns at 1.39 THz for two different incident angles. (a) 25 degree, (b) 32.5 degree.

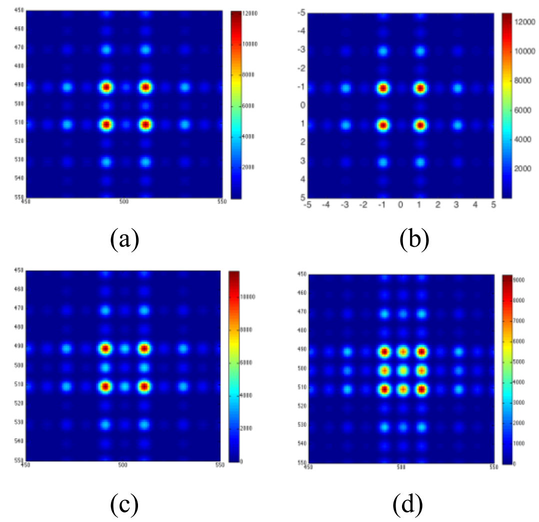


Fig. 7. Simulation results when different incident angles have been introduced, (a) normal incident (b) 25 degrees (c) 32 degrees (d) 41 degrees.

IV. Summary

We succeed in obtaining four diffraction beams at 1.39 THz as designed and we also find the measurement results agree well with the simulations when the incident angle is taken into account. We are currently manufacturing the 4.7 THz grating. Furthermore, the grating has been applied as the local oscillator for operating a 2x2 HEB array at 1.4 THz [6].

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