The Global phase grating

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Abstract—**In heterodyne array receivers, phase gratings are useful to divide the local oscillator (LO) signal into several beams to pump the mixers of an array. We have developed a new iterative algorithm to generate phase gratings without any geometrical constraints. Two prototypes (a reflective one and a transmissive one) were fabricated at 610 GHz and their splitting efficiency validates the design, the simulation, and the manufacturing process of these phase gratings.**

Introduction

Early THz heterodyne systems concentrated on high spectral resolution and large bandwidth (with many spectral channels), but they usually only had one spatial pixel (i.e. HIFI instrument on Herschel satellite [1]). Recently, arrays of heterodyne receivers have been developed to simultaneously measure spectra at several positions in the sky. In heterodyne receivers, each pixel has a mixer. So, observing with several pixels involves pumping all these mixers with an LO. The most efficient way of doing it is to split the LO beam into several beams to specifically illuminate each mixer.

Phase gratings are the perfect tool for achieving this goal and they are already used in some heterodyne receivers such as CHAMP or upGREAT [2]. However, the existing phase gratings for THz frequencies, the stepped and Fourier gratings [3,4], have a constrained geometry and are limited in the beam patterns they can efficiently produce. For the next generation of THz heterodyne receivers we need a phase grating able to efficiently produce any kind of beam pattern above 1 THz.

Stepped gratings, such as Dammann gratings, have discrete steps able to shift the phase of the signal. Fourier gratings [5,6] use a spatial phase modulation given by Fourier series expansion. They are smoother than stepped gratings and can usually reach higher efficiency. Because these two kinds of phase gratings have geometrical constraints, the efficiency and the far-field pattern that can be generated is limited. To overcome this limitation, the algorithm presented hereafter has been developed to be able to design phase gratings without any geometrical constraints, and reach a good efficiency for any far-field distribution. To validate this method, we have designed, simulated and built two Global phase grating prototypes (one in transmission and the other in reflection) able to split the LO beam into four beams.

Design process

The design process of the phase grating is based on an iterative algorithm which calculate the shape of the grating. Then, this profile is simulated with an electromagnetic software in order to evaluate its efficiency and improve it if possible.

A. Phase profile design

The iterative algorithm is based on alternate projections using an inverse Fourier transform and a Fourier transform. It converges to an aperture distribution that matches both the desired radiated field pattern and the grating's physical constraints. This iterative algorithm has been used to generate the phase profile for two phase grating prototypes (a reflective one and a transmissive one) generating four beams of similar intensity at 610 GHz, making an angle of ±12.6° with respect to the specular reflection axis.

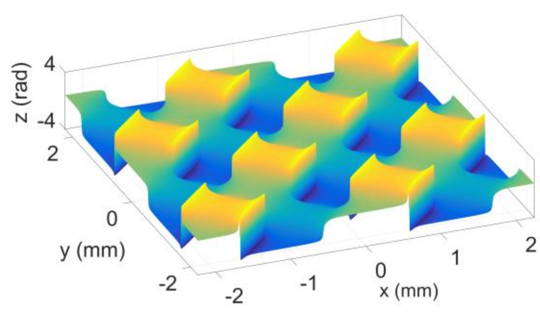

Fig. 1 Phase grating profile calculated by the iterative algorithm.

Both prototypes are based on the same phase profile (fig. 1), but are differently scaled. The transmissive grating is made of TPX® and is illuminated by an orthogonal incident beam, while the reflective phase grating is made of brass and is illuminated by an oblique incident beam making an angle of 25° with the normal of the grating.

B. Electromagnetic simulation

The transmissive and reflective grating prototypes have been simulated with a commercial electromagnetic simulation software Feko™, which is based on the Method of Moments (fig. 2). In both cases, only a part of the gratings has been simulated (because of limited computing power). So, the results of the simulation can only predict the diffracted beams' efficiency but not the beams' widths. Both simulations used the Multilevel Fast Multipole Method (MLFMM).

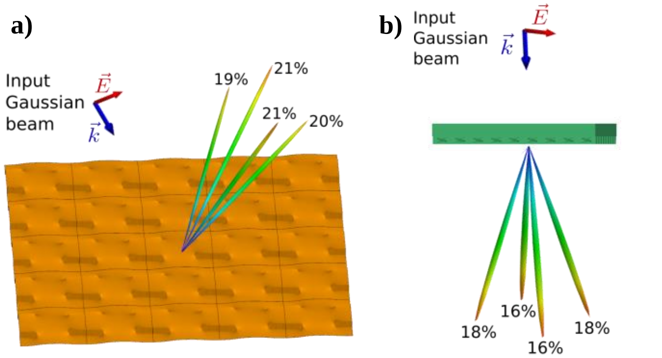

Fig. 2 Far-field beam patterns calculated by the electromagnetic simulations in reflection (a) and in transmission (b).

The efficiency predicted by the simulation is 81 % for the reflective grating and 68 % for the transmissive grating.

TEST OF THE GRATINGS

A. Mechanical test

The phase grating prototypes were milled by a 100 µm diameter end-mill with a surface accuracy of 6 µm (fig. 3). The size of the reflective grating is 44.8 mm x 49.4 mm and the transmissive grating is circular with a diameter of 44.8 mm. In both cases these dimensions were chosen to be large compared to the incoming Gaussian beam, whose beam waist is 10 mm.

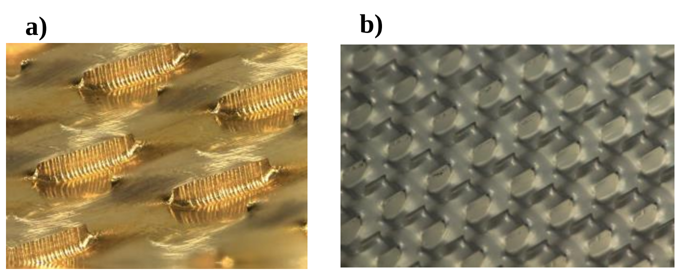

Fig. 3 Pictures of the manufactured (a) reflective and (b) transmissive gratings taken with a microscope.

B. Efficiency test

The prototypes were tested with a 610 GHz source and a Golay cell power meter to measure the intensity of the output beams. The source and the phase gratings were positioned on a rotating platform and the horizontal radiation pattern of the gratings was measured by rotating the platform. The distance between the Golay cell power meter and the LO was kept constant, so the measured beams had always the same radius and were comparable. The power measured by the power meter with and without the phase gratings was compared to the calculated relative intensity of each output beam, as well as to the total efficiency of the gratings (fig. 4). The measured efficiency of the prototypes is 78 ± 4 % for the reflective grating and 62 ± 4 % for the transmissive grating. These efficiency values are quite good and very close to the ones predicted by the electromagnetic simulations.

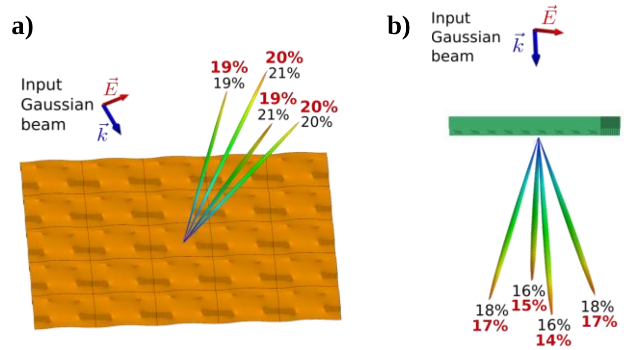

Fig. 4 Far-field beam intensities measured (in red) and compared to the simulation results, in reflection (a) and in transmission (b).

CONCLUSION

The two first Global phase grating prototypes are successful in dividing the LO beam into 4 similar intensity beams. Moreover, the experimental beam intensities are very close to the simulation predictions (within 2 %). These good results validate the design and fabrication processes of this new kind of grating. Therefore, Global gratings are ready to be used in the next generation of array receivers.

ACKNOWLEDGMENT

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