MODULATION TRANSFER FUNCTION MEASUREMENT OF INFRARED FOCAL PLANE ARRAYS WITH SMALL FILL FACTORS (SESSION 5, PAPER N°5-3)

F. de la Barrière[1], S. Derelle[1], G. Druart[1], N. Guérineau [1], S. Rommeluère[1], L. Mugnier[1], N. Baier[2], B. Cloix[2], O. Gravrand[2], N. Lhermet[2] and G. Destefanis[2]

[1]*ONERA - Chemin de la Hunière - 91761 Palaiseau Cedex - France*

[2]*CEA LETI MINATEC - 17 rue des Martyrs - 38054 Grenoble Cedex 9 - France*

INTRODUCTION

Today, both military and civilian applications require miniaturized optical systems. Associating a multichannel optical system with a focal plane array (FPA) of small fill factor is an interesting design strategy to obtain a very compact system which provides a high resolution image after post-processing[1]. We are currently designing a compact infrared camera which will be integrated at a wafer level on a detector with a small fill factor. We have tested various technological parameters to determine which parameter is best suited for the camera, provided its expected optical performance. We have made a specific cooled (77K) HgCdTe photodiode array. This infrared FPA is composed of nine areas: the pixel pitch is the same for all areas (30 µm), the only difference being the fill factor which differs from one zone to another (cf. Fig. 1). The small fill factors have been obtained by introducing a ion implantation circular confinement ring surrounding the tested diode. An important feature which has a direct impact on the optical performance of the camera is the modulation transfer function (MTF) of the detector. That is why we have developed an original method to measure the modulation transfer function (MTF) of the pixels for all areas.

MODULATION TRANSFER FUNCTION MEASUREMENT

This original method is based on the use of a Continuously Self Imaging Grating (CSIG)[2], which produces a non-diffracting spot array on the detector (cf. Fig. 2). This pattern excites 289 spatial frequencies widespread in the Fourier domain (cf. Fig. 3), which leads to the extraction of the two-dimensional MTF of the pixels for each zone. Assuming that the

MTF is radial, because the diodes have been implanted on circles (except from the central zone 5, where the pixels are square), we plot the amplitude of each bright spot (which corresponds to an excited spatial frequency) as a function of radial spatial frequencies μ which are defined as $\mu = \sqrt{\sigma_x^{\ 2} + \sigma_y^{\ 2}}$, where σ_x and σ_y are the spatial frequencies in two directions. We have also proposed a numerical model to assess experimental data. Filtering effects in the Fourier domain are modelled with a function of the form: $2\frac{J_1\left(\Pi\Phi_{diode}\mu^2\right)}{\Pi\Phi_{diode}\mu^2}$, where J_1 is the first order Bessel function and Φ_{diode} is the diode diameter for the area under study. Radial MTF experimental curves compared to the model are presented in Fig. 4. The values of the parameter Φ_{diode} are 14.7 µm, 12.6 µm, 11.2 µm, 20.6 µm, 21.0 µm, 14.1 µm, 12.3 µm and 11.3 µm for areas 1, 2, 3, 4, 6, 7, 8 and 9 respectively. We are currently working on comparing our experimental results with some physical features of the diodes.

CONCLUSION

Fig. 4 shows a good fit between the model and experimental data. Within future work, we are going to measure the MTF at higher spatial frequencies to provide a more physical filtering model which would include diffusion effects. Based on these results, we discuss the best suited kind of pixels for our compact on-chip camera.

Author: Florence de la Barrière (PhD Student) – Student paper – Advisor: N. Guérineau
ONERA, Chemin de la Hunière, 91761 Palaiseau Cedex France
Phone: +33 1 80 38 64 19 Fax: +33 1 80 38 63 45 Email: florence.de_la_barriere@onera.fr

FIGURES

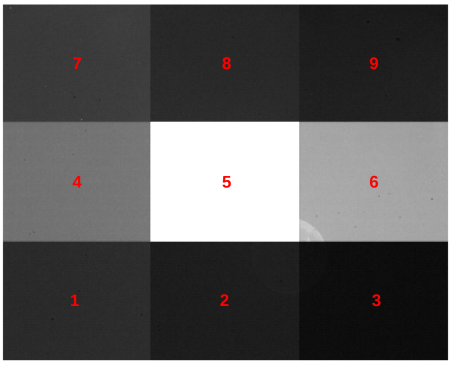

Fig. 1. Response of the HgCdTe detector to a black body at 25°C (the number of each zone is indicated). The different current levels are due to different fill factors.

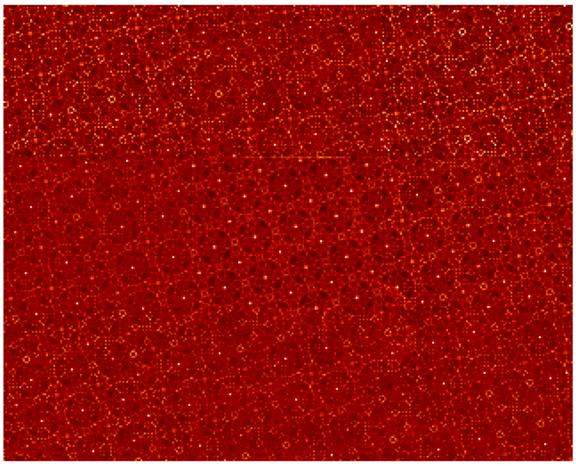

Fig. 2. CSIG pattern acquired by the detector (the integration time has been adapted for each area, so that the mean value for each area has been kept almost constant).

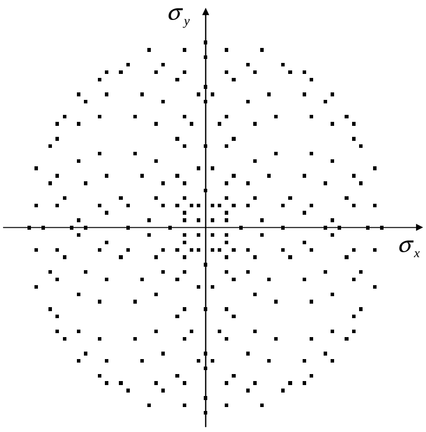

Fig. 3. Theoretical MTF of a CSIG. Each spot corresponds to an excited spatial frequency. For each radial frequency, we plot the amplitude of all the bright spots which are on a circle of radius $\mu = \sqrt{\sigma_x{}^2 + \sigma_y{}^2}$ centered on the origin as a function of the corresponding spatial frequency μ.

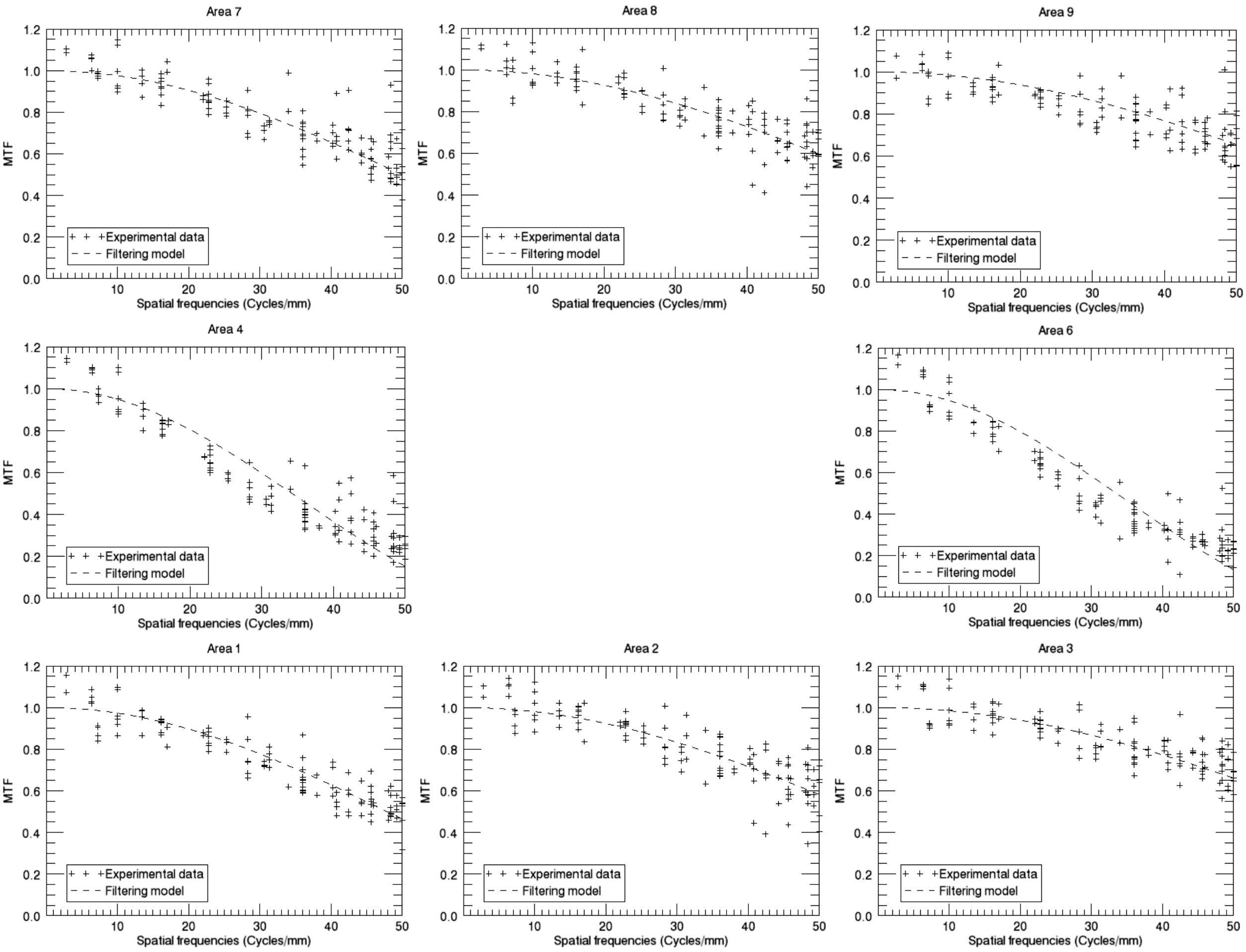

Fig. 4. Experimental data compared to the filtering model for small diodes zones.

REFERENCES

[1] F. de la Barrière, G. Druart, N. Guérineau and J. Taboury, "Design strategies to simplify and miniaturize imaging systems", Applied Optics, **50**, 943-951 (2011).

[2] S. Derelle S. Bernhardt, R. Haïdar, J. Deschamps, J. Primot, J. Rothman, S. Rommeluère and N. Guérineau, "Experimental performance and Monte Carlo modeling of LWIR MCT avalanche photodiode", J. Electron. Mat. **38**, 1628-1636 (2009).