A fast AC mode measurement system for detector response and spatial uniformity characterization

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When high-accuracy radiometric measurements for photodetectors such as Si photodiodes are required, the prevailing practice is to perform DC measurements on the detector's response. For example, the signal from the detector is typically acquired and integrated over seconds if not longer for each input light configuration. The idea is that long integrating time helps in reducing noise related uncertainty. Here, we demonstrate an alternative to this paradigm with a radiometric measurement system that performs a versatile AC mode of operations. This system achieves not just fast but accurate measurements mainly by three components: a fast steering mirror that can position the probe beam rapidly, a fast data acquisition module that acquires responses from all detectors, and a computer algorithm for digital signal processing. This system enables fast data collection using a variety of measurement configurations. We illustrate the benefits of the system using two examples; measuring detector response using a chopped beam, and measuring detector spatial uniformity map with high density of pixels.

INTRODUCTION

In modern radiometry from UV to IR, the use of several types of solid-state photodetectors like Si and InGaAs photodiodes has been ubiquitous. Pyroelectric detectors are also gaining popularity. For photodiodes, while the frequency range of response typically extends from DC to several hundreds of kHz, it is a general tradition to perform radiometric measurements only at DC mode with a time constant of seconds. For example, a photodiode's response is integrated up to seconds with a fixed light configuration followed by the same measurement but with light blocked for background response. The difference of the two measurements is then the true response of the detector. Little was done to explore photodiode response using AC mode of measurement. As for the pyroelectric detectors, they can only be operated in AC mode at a frequency of tens of Hz. Consequently, the traditional measurement system for pyroelectric detectors often incorporates a chopper and a lock-in amplifier. Here, we introduce a measurement setup capable of AC measurements for both types of detectors without using conventional choppers and lock-in amplifiers. The versatile nature of the setup offers a variety of measurement modes that is very time-consuming to do using conventional systems.

MEASUREMENT SETUP

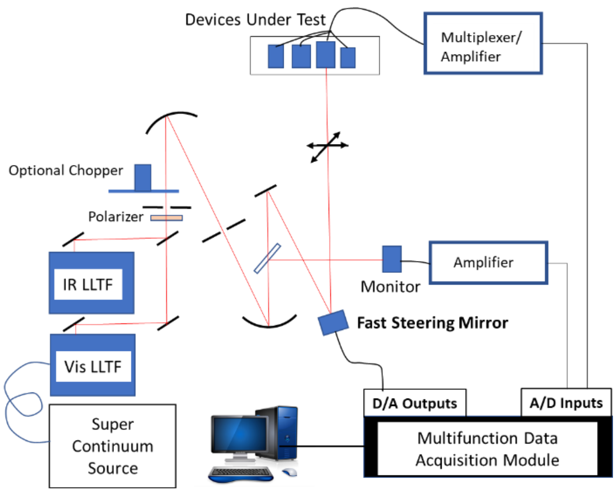

Figure 1. Setup for detector response measurement using AC/DC mode.

The setup is depicted in Fig. 1. The vis/IR light used by this setup is generated by a Super-Continuum (SC) source and filtered by a monochromator (labelled as LLTF in Fig.1). The light is directed to test detectors and steered by a Fast Steering Mirror (FSM). The FSM is capable of tilting along two perpendicular axis and the angles of the tilt are controlled by voltages from two D/A outputs of a Multifunction Data Acquisition (MDA) module. The response of the test detector is sent back to the A/D input of the MDA. The MDA is commanded by a computer and can perform synchronous A/D and D/A operation up to a sampling rate of 500 kHz.

DETECTOR RESPONSE MEASUREMENT USING CHOPPED BEAM

In the first example, we programmed the MDA such that the FSM steered the light beam and alternated between two positions, one inside the detector's active area and the other outside the detector's active area. At the same time, the detector's response was digitized synchronously with the steering operation. Fig. 2 shows the raw response data from a Si detector and a pyroelectric detector with a chopping frequency of 10 Hz and a sampling rate of 10k/s. The DC responses of the detectors were derived from the raw data using a Digital Signal Processing (DSP) algorithm which (1) eliminates data from the transient regions, (2) averages the flat response regions of the light-on and light-off periods, and (3) calculates the DC response from their difference. Using this method, we found excellent repeatability at the 10^{-4} level for the photodiode with 1 sec acquisition time. It is somewhat higher for the pyroelectric detector because of the intrinsic detector noise as evident from Fig. 2.

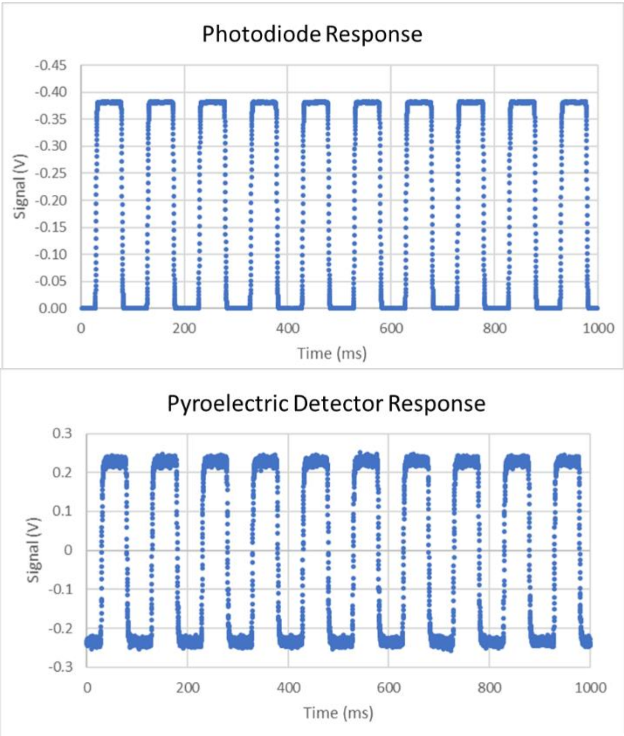

Figure 3. Data acquired by MDA from of a Si photodiode and a pyroelectric detector by chopped light using FSM.

DETECTOR SPATIAL UNIFORMITY SCAN

As a second example, the FSM was used to raster scan the light beam across a detector for uniformity mapping. The scanning sequence is controlled by the MDA which also collects data from the detector synchronously with the position of the light beam. Fig. 3 shows the contour plot at 0.1% contour level of a scan on a trap detector with a 4 mm aperture. The area of the scan is 8 mm x 8 mm with a 128 x 128 mesh with corresponds to more than 16,000 data points from the scan and the whole scan took about 3 minutes to complete. Notice the details exhibited in the plot especially the depressed hole near the bottom of the plot. It is believed to be caused by a speck of dust stuck on the detector surface.

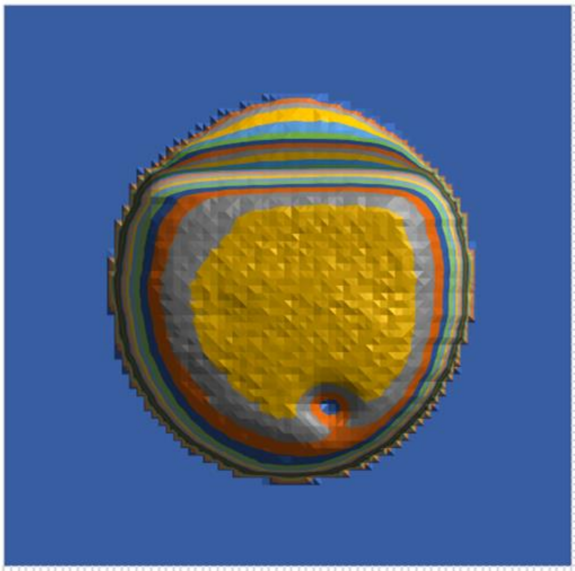

Figure 2. Uniformity contour plot of a trap detector. For clarity, only the contour lines of the top 2% are plotted and the adjacent contour lines represent 0.1% change in responsivity. This plot is generated using 128 x 128 data points.

SUMMARY

We have shown that a simple system with FSM, MDA, and DSP processing of data can extract DC response using AC measurement for detectors like photodiodes and pyroelectric detector. This technique is a variation of the conventional phase-sensitive lock-in measurement and is good at out-of-band noise reduction. This contrasts with the traditional DC measurements which is subject to possible slow drift from the system. In addition, we showed that this system can perform fast and high-density detector uniformity scan. Such scan can take many hours using a conventional DC system. This scanning technique can be a good diagnostic tool for evaluating a detector's general conditions.