Ultra-Fast IR Detector for Astronomy Transients

Alessandro Drago (a), Emanuele Pace (b), Simone Bini (c),
Mariangela Cestelli Guidi (c), Augusto Marcelli (c), Valerio Bocci (d)

(a) Università di Firenze & INFN/LNF, (b) Università di Firenze & OPC-Osservatorio Polifunzionale del Chianti, (c) INFN/LNF,
(d) INFN/RM1

NanoInnovation2022 Conference – Roma 19-23 September 2022

INTRODUCTION

After approximately half a century of development, HgCdTe infrared detectors have become the first choice for high performance infrared detectors, which are widely used in various industry sectors, including astronomy, military reconnaissance, infrared guidance, infrared warning, weather forecasting, and resource detection. The sensitive and fast response mid-IR photodetectors (MWIR) working at High Operating Temperature (HOT) are of increasing demand for numerous applications in the infrared technology [1]. But obtaining photodetectors of high detectivity and fast response at the same time stays in contradiction. An example is one of the first HOT detectors with narrow-band gap semiconductors used for uncooled room temperature (RT) detection of CO2 laser radiation [2]. Hetero-structural HgCdTe photodiodes, due to the inherent flexibility of design, are very promising for using in sensitive and broadband HOT detectors. Careful optimization of the devices architectures makes possible to achieve low noise , high gain at GHz frequency range. In this work, partially funded for the year 2022 by CSNV of INFN, we present a simple fast IR detector realized by using HgCdTe photoconductor made by Vigo System S.A (Poland) [3], see Fig.1 and 2, that, in principle, could be used in a wide area of applications. Nowadays, the research in the time domain astronomy is constantly expanding, achieving nanosecond scale detectors [4], in order to search fast transients in the infrared astronomy with the temporal scale of the GRB (Gamma Ray Burst) and the FRB (Fast Radio Burst) ones. An ultrafast IR longitudinal detector could be useful to be used with a ground based telescope.

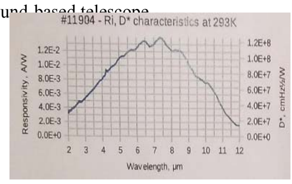

Fig.1 Responsivity (A/W) vs. wavelength (µm) of the HgCdTe detector.

Fig.2 The To39 package detector by Vigo System S.A.

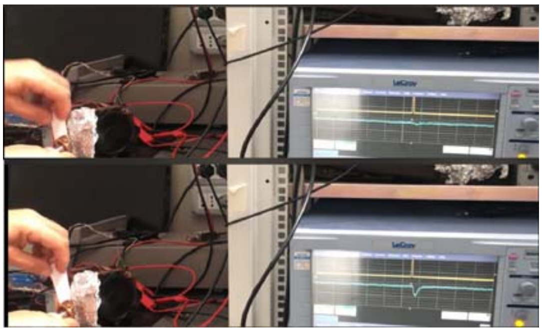

Fig.4 Shows detector under test. Signal (blu line) is clearly visible taking off the sheet of paper covering the detector.

AMPLIFIER DESIGN STUDY

In order to develop a fast (nanoseconds) and cheap detector in the infrared region [5] many simulations has been performed using LTspice software. The detector chosen is a photoconductor one, it must be polarized, so it means that it gives us a small current each time it detects radiation. For this reason, the configuration chosen for preamp is a classic transimpedance. Choosing the more appropriate electronic components, a small PCB has been realized and tested by using a commercial infrared emitter diode (see Fig. 3). The results are quite good and obviously cheaper compared to other commercial amplifiers available. Further experiments are foreseen at Sinbad, the DAFNE infrared beamline, giving us a complete characterization of the device.

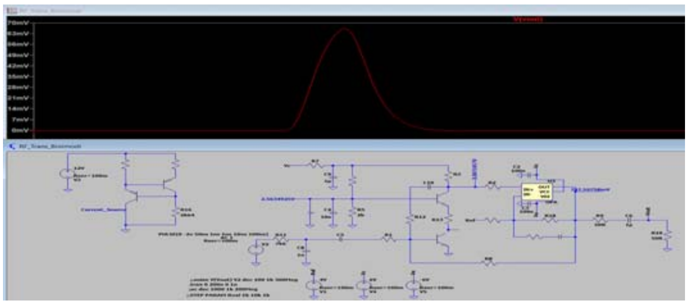

Fig.3 LTspice simulations of the low noise Cascode amplifier developed at INFN_LNF.

Contact Simone Bini Simone.Bini@lnf.infn.it

EXPERIMENTAL SET UP AND RESULTS

The detector has been assembled into a metallic case, cooled by two Peltier cells, as you can see in Fig. 7. There is a small hole so that radiation to reach HgCdTe crystal and it is a compact device simple to move and to use. Responsivity of the detector is shown in Fig 1, so in order to excite it a fast commercial IR diode as been chosen. Example of data acquisition is shown in Fig. 4. A small pulse, about 8 ns length, feeds the IR LED and excites the detector response, but shading the small hole with a little piece of paper the signal from the detector vanish.
The yellow trace peak corresponds to the signal as made by generator, the "light profile" of the diode, and even if, it has rise time and fall time of few nano seconds, it is surely broader than the original one, but, as you can evaluate from Fig. 5, the detectors has a high speed of operation (the rise time is no more than 10 ns), and good sensitivity, considering also that is not working at maximum of its responsivity.

Fig 5. Photodiode IR LED,
OSLON Black, 940nm 90deg 320mW/sr.

Fig.7. Final assembled detector cooled by Peltier cells ready to be tested.

In Fig. 6 it is plotted the amplifier 6x4cm pcb that is equipped with two LEMO connectors for output and test. The detector pcb will be loaded with the pixels (1 at the begin, then up to 10) on one side: inner pixels for the astronomical signal, outer pixels for the "dark" reference. The digital acquisition system should be done by an oscilloscope in the phase 1 and by ARDU-SIPM [6] compact data acquisition system in the phase 2.

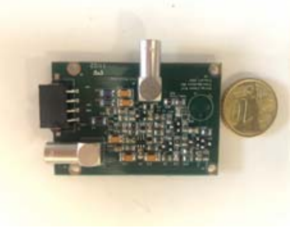

Fig.6 shows the final PCB

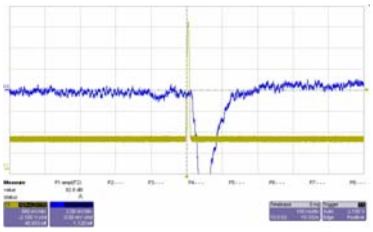

Fig.8 Screenshot taken from oscilloscope, vertical scale is 2mV/div, horizzontal scale 100ns/div.

CONCLUSIONS

The designed amplifier for HgCdTe detector silicon detectors has a high speed of operation (the rise time is no more than 5/7 ns), good sensitivity, low noise and excellent stability.In principle the detector is very reliable and durable, ready to be tested also on the new generation syncrothrone light sources. Further experiments are foreseen at Sinbad, the DAFNE infrared beamline, giving us a complete characterization of the device.

REFERENCES

[1] Piotrowski, J., Rogalski, A. (2007). High-Operating-Temperature Infrared Photodetectors. SPIE, Bellingham

[2] Piotrowski, J., Galus, M., Grudzien, M. (1991). Near room-temperature IR photo-detectors. Infrared Phys.,31(1), 1−48

[3] https://vigo.com.pl/en/home/

[4] https://iopscience.iop.org/article/10.3847/1538-3881/ab44d3

[5] A. Drago et al., "Ultra-Fast InfraRed Detector for Astronomy", Frontier Detector for Frontier Physics - 15th Pisa Meeting on Advanced Detectors, La Biodola, 22-28 May 2022

[6] V. Bocci, "Compact and Light All-in-One Detectors for space application", Frontier Detector for Frontier Physics - 15th Pisa Meeting on Advanced Detectors, La Biodola, 22-28 May 2022