Cryogenic Design of the EMCCD Cameras for the Brazilian Tunable Filter Imager

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Overview

We present the cryogenic design of the EMCCD (Electron Multiplication Charged Couple Device) cameras for the Brazilian Tunable Filter Imager instrument for the 4 meters SOAR telescope in Chile. The camera uses a e2v 1600 x 1600 pixels full-frame device, which is controlled by the new CCCP (CCD Controller for Counting Photons), an EMCCD controller developed by the University of Montreal. We present the design of the camera, its thermal analysis and cryogenic performance.

Camera Design

The camera operates the EMCCD detector at cryogenic temperatures. It consists of a vacuum chamber, a cryogenic cooler, a detector "fan-out" board and electrical wiring to connect the detector to the exterior. The camera body is made of Aluminum, with a 50 mm BK7 window. There are two hermetic connectors for detector signals and temperature.

Internally the camera is composed by a cryogenic cooler coupled through a copper-made cold finger to the detector mount. The detector sits on a FR4 fan-out board. A radiation shield coupled to the cold finger completes the internal mechanics. The figures below show the mechanical design and some pictures of the camera.

The cooling system

The cooling mechanism of the camera is a Cryotiger (or "PCC"), a type of closed-cycle refrigerator that incorporates a compressor and a cold-end, linked by pressurized gas lines, using a proprietary gas blend based on propane.

The thermal analysis goal is to show that, using the PCC cooling system with a PT-30 gas type, the camera is able to cool down the detector to the proper operating temperature for the EMCCD detector, which is about -100°C to -110°C. Under vacuum, the detector temperature will be defined by the thermal equilibrium due to heat transfer by radiation and conduction.

The equilibrium is reached when the following equation is satisfied:

$$PC_{finger} = PR_{window} + PR_{plate} + PR_{shield} + PC_{cables}$$

PC_{finger}: heat transfer by conduction between the mount and PCC;

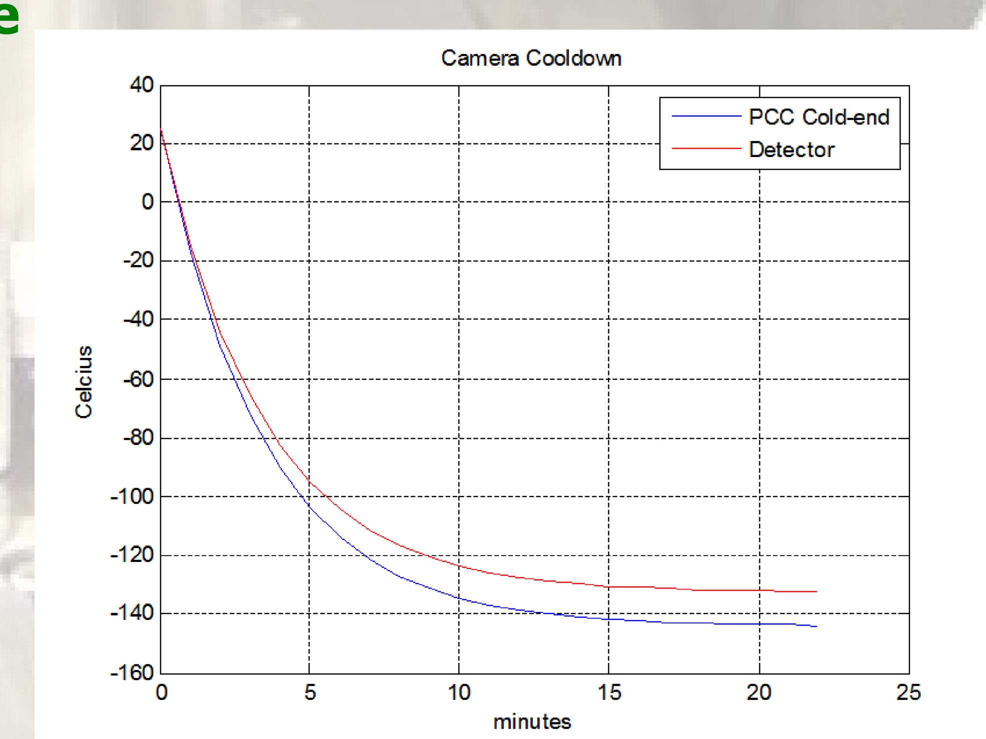
PR_{window}: heat transfer by radiation from the camera window;

PR_{plate}: heat transfer by radiation from the camera bottom plate (which does not have radiation shield);

PR_{shield}: heat transfer by radiation from the radiation shield;

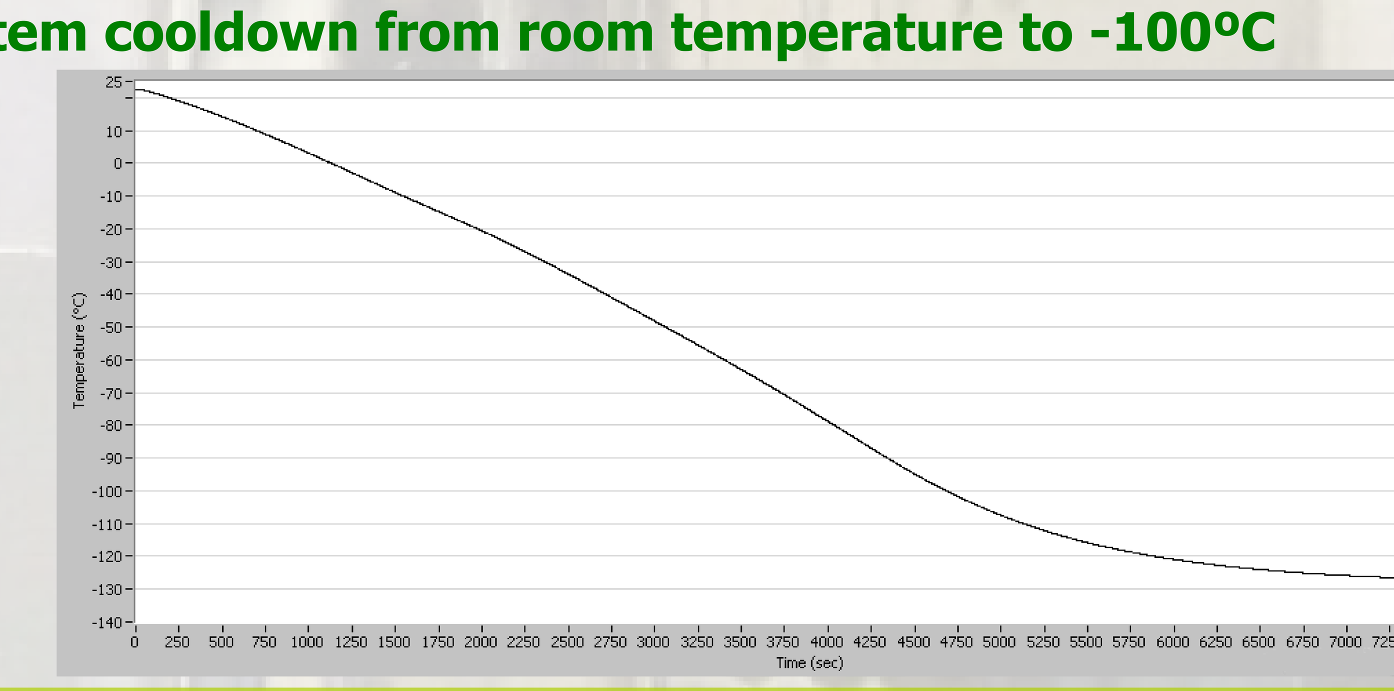
PC_{cables}: heat transfer by conduction between the hermetic connector and the detector, conducted by the cables and PCB copper traces;

Simulated cooldown, using a first-order exponential decay for the PCC temperature in time



Note that this dynamic simulation does not take into account the thermal inertia of the camera (a time constant), which is assumed to be zero for the simulation. It is only relevant to show the evolution of the two temperatures (PCC and detector) while cooling down.

Real system cooldown from room temperature to -100ºC



Conclusions

We have presented the thermal design, simulations and experimental results for the EMCCD cameras to be used with BTFI instrument. The camera accomplishes the requirements, regarding connections with the detector controller and free-running temperature .

The fan-out board, the connectors and cabling behaves adequately. During the laboratory tests we could measure that the signals are exactly the same if probed in the detector controller pins or in the detector socket. This means that the cabling is performing well and there is insignificant resistance and interference.

Cameras are currently undergoing intensive detector tests. We have one camera imaging in standard and EMCCD modes at 1 MHz, so we are concentrating in tuning CCCP for operation at 10MHz.

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