MECHANICAL DESIGN OF A FRELON CCD CAMERA 16BIT

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Introduction :

Many beam lines in synchrotron facilities use CCD camera for detectors. At the ESRF, a FRELON camera has been developed to have **16 Bit and Fast Readout and Low Noise** numerical images.

At the start of the project, it was necessary to design the electronics and the thermal and mechanics in parallel. The exchange with J.C. Labiche's team was aimed at building up a common know-how and the first prototype was built in 1994.

In 1997 the first prototype of the FRELON was equipped with a CCD 1k (1024x1024 pixels) and series of 6 FRELON 1k (fig. 1), they are still in use. In 1998 a new version using a CCD 2k (2048x2048 pixels) was designed and two prototypes were made. A series of 4 FRELON 2k was built and they are still in use.
The new design for FRELON 2k started in 2003. Two prototypes have been manufactured and are now in the test phase.

Fig 1: FRELON 1k in 1997.

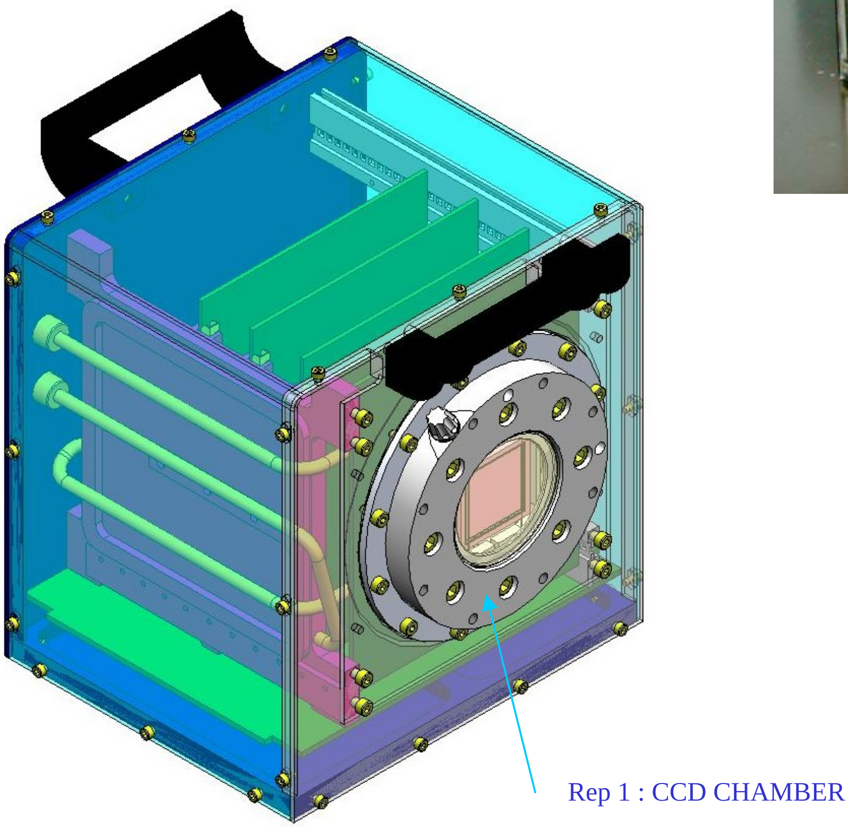

Fig 2: New FRELON 2K camera

Main constraints for mechanical designing of such a FRELON camera.

1/ The environment of the CCD has to be compatible with a temperature of -20°C and a dry atmosphere.

The CCD, to work at the lowest noise possible, has to be kept at a temperature of –20°C. A one-stage Peltier cell with 72 elements is used to reach and maintain the temperature. The required thermal power is 7W for an electric power of 18W(fig3).

Thermoelectric Parameters	Values
Geometry Factor (cm)	0,118
Number of Couples	71
(Tc) TEC Cold Temp (°C)	-20,00
(Th) TEC Hot Temp (°C)	18,51
(Qc) Heat Pumped at Cold Surface (W)	7,09
COP	0,39
Optimum COP	0,41
(Pin) Power Supply (W)	18,05
(Qh) Total Hot Side Heat Dissipated (W)	25,13
∆T Max (C°) (@Qc=0)	63,53
Qmax (W) ∆T=0	28,21

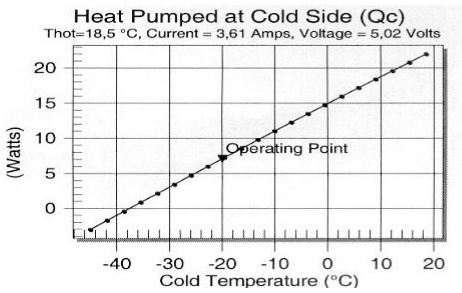

Fig 3: Thermal exchange between CCD and Peltier Cell

The internal atmosphere of the CCD chamber (fig2-rep1, previous page) must be absolutely dry. It is very important to protect the CCD and there out put connections against short circuits. Any small short circuits between two pins, can partially or totally damage the CCD. A dry atmosphere is also needed to prevent ice growing on the working surface of the CCD.

2/ The chamber which hosts the CCD must be vacuum compatible and enable electrical throughput of signals and inside sensors. It must be also allow for the cooling of the hot side of Peltier cell.

In the first prototype, static vacuum of the chamber at less than 1.10^{-1}mBar was foreseen. This solution is compatible with a dry atmosphere in the chamber but has a major disadvantage: it necessitates the pumping of the chamber from time to time as out gassing is produced by some of the inner components. At this stage, it was decided to fill the chamber with a dry neutral gas. With this case we have a neutral and dry stable atmosphere in the chamber. There for, no leaks can appear because of the very low pressure difference between the inside and outside of the chamber is mainly caused by atmospheric pressure variations.

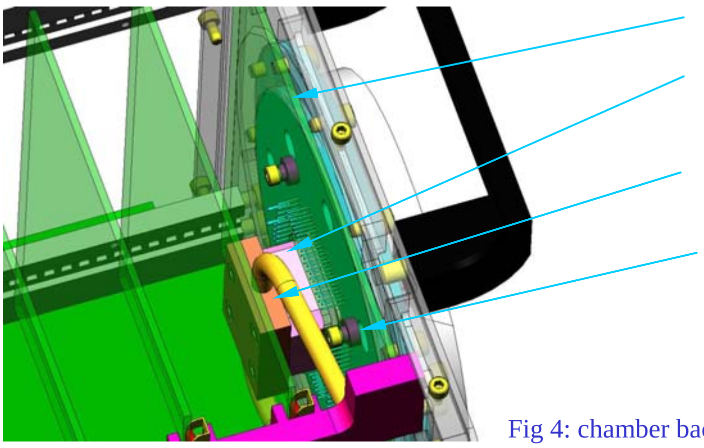

Fig 4: chamber back side

To be sure that there is good sealing of the chamber, electrical feed throughs are made by glass/metal welding. All the CCD pins are connected through the chamber to the driver board (fig4-rep1).
The thermal exchange with the Peltier cell hot side is achieved by a copper cooler welded on the back side of the chamber (fig4-rep2). This cooler is connected (fig4-rep3) to the inner water circuit of the camera.

3/ The temperature in the housing of the FRELON camera must be compatible with best operation of the electronics.

Heat is produced in the housing by the high integration electronic boards. Maintaining a stable temperature in the housing is very sensitive. The main source of cooling is the water cooled plate (fig5-rep1), some of power chips are directly fixed onto the cooling plate (fig5-rep2) to obtain the best exchange.

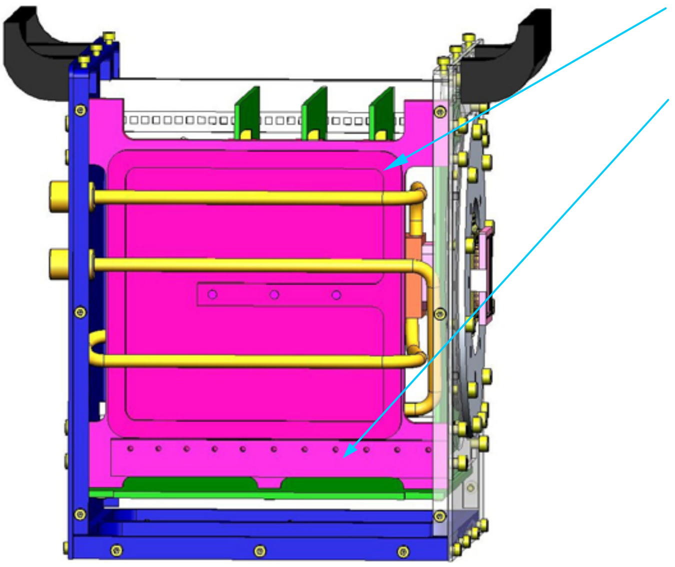

Fig 5: Water cooling plate, front side

All the electronic boards, except the driver board, are fixed to the cooling plate through the lok-tainner (fig6-rep1) host in grooves on the back side of the cooling plate. In some cases a thermal drain fixed to the board is added. One end of the thermal drain is blocked between the board and the groove of cooling plate where board is placed. This is to increase the cooling for some chips sitting on board.

An external cooling unit is close loop, produce cold water at 15^{o}C. Lower water temperature should cause water condensation on cold parts and will damage the electronic board.

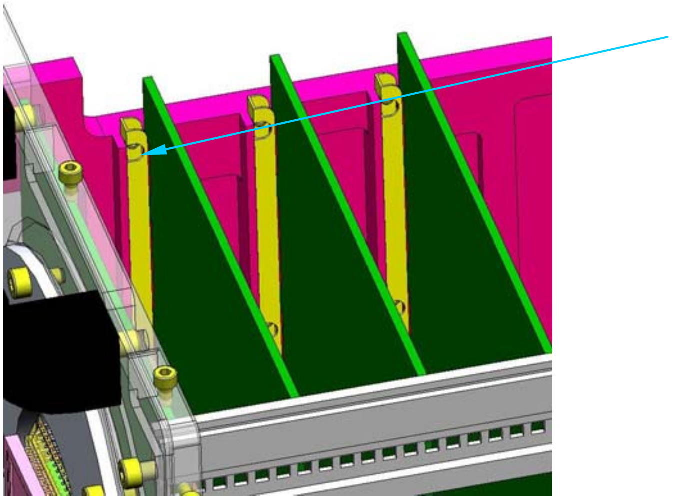

Fig 6: Water cooling plate, back side

4/ The housing should be compatible with the mounting of the electronic board, the CCD chamber and all the connectors (electronic, power and water).

All the connectors are located on the back side of the housing. Power supplies (fig7-rep1), input and output commands (fig7-rep2), data output (fig7-rep3) and water in and out flow (fig7-rep4).
The FRELON camera has to be protected from electro-magnetic field and radiation. Electro magnetic shielding and grounding continuity between mechanical parts and with connectors, has to be optimised to guarantee the best performances.

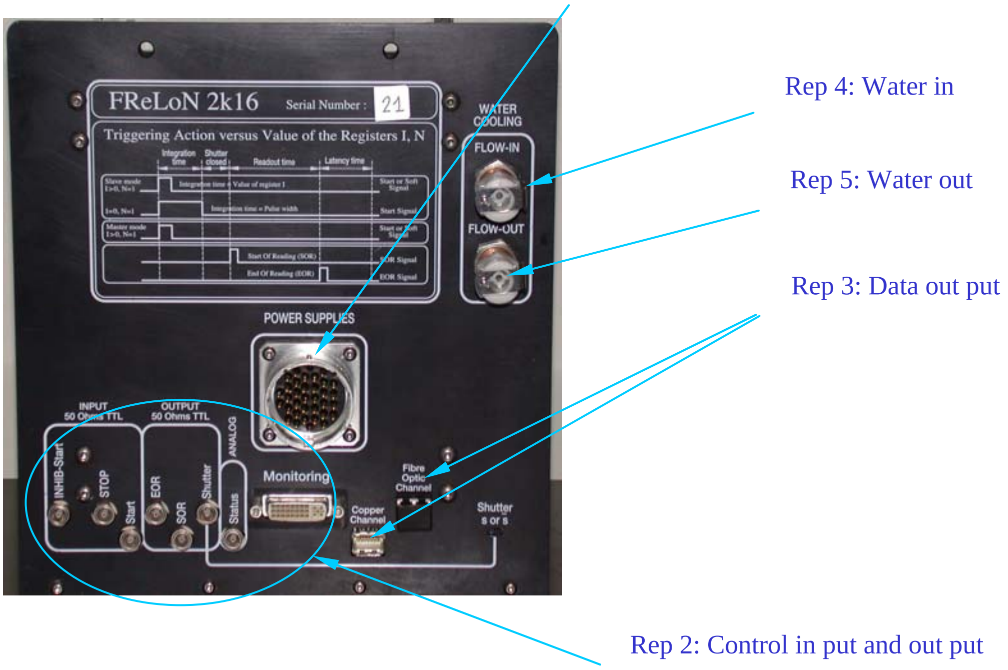

Fig 7: Back side of the housing

5/ Examples of use for the FRELON camera

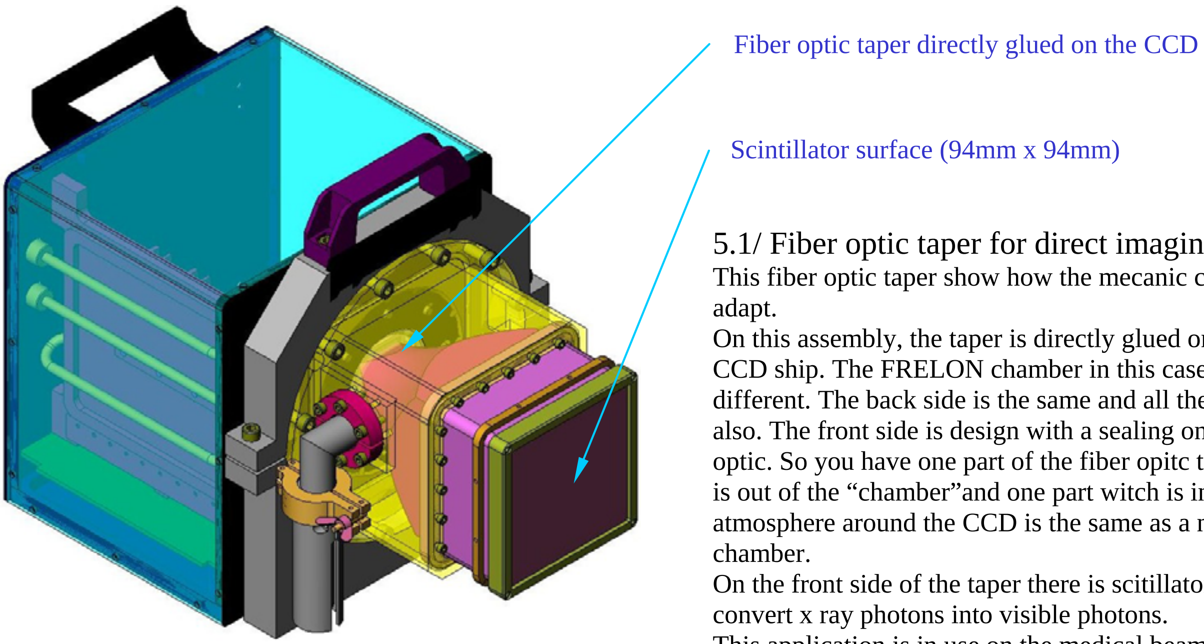

Fig 8: Fiber optic taper for direct imaging

5.1/ Fiber optic taper for direct imaging (Fig8) :

This fiber optic taper show how the mecanic can be adapt.
On this assembly, the taper is directly glued onto the CCD ship. The FRELON chamber in this case is different. The back side is the same and all the electronic also. The front side is design with a sealing on the fiber optic. So you have one part of the fiber opitc taper witch is out of the “chamber”and one part witch is in. The atmosphere around the CCD is the same as a normal chamber.
On the front side of the taper there is scitillator foil to convert x ray photons into visible photons.
This application is in use on the medical beam line ID17

5.2/ FRELON 2k prototype with tri-focus folded microscope optic for micro imaging (Fig 9) :

This assembly show a FRELON camera coupled with microscopy optics elements. For High Resolution imaging (between 5 and 1 microns) we ofen use microscope objectives to magnify the sample image.
On this design made by Optique Peter for ESRF, there is 3 ojectives witch can manualy selected. In front of the obljective we have scintillator to convert x ray photons into visible photons.
This application is in use on the ID22 beamline at ESRF and in SLS with another camera.

FRELON 2k prototype

Scintillator support and objective cover

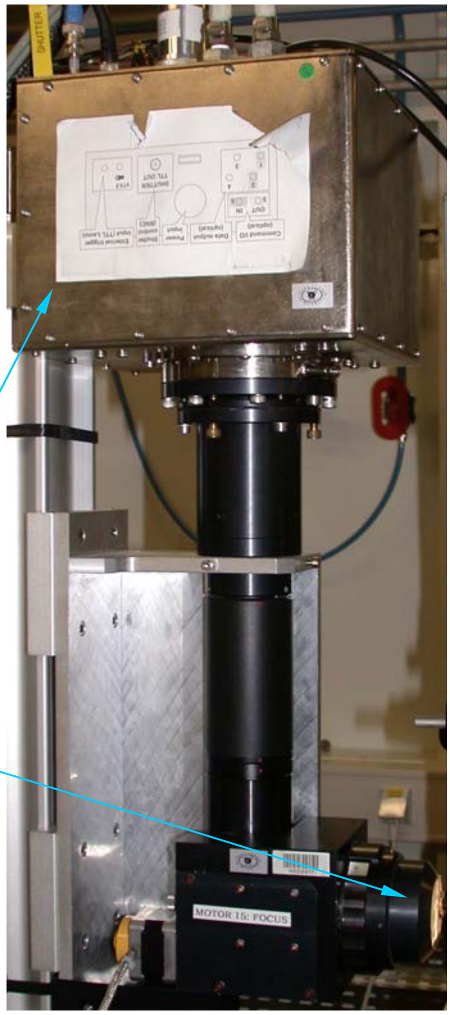

Fig 9: FRELON 2k prototype with tri-focus folded microscope optic for micro imaging

Brass shielding of the FRELON 2k or 1k

Reflective ojective equipped with beam stop

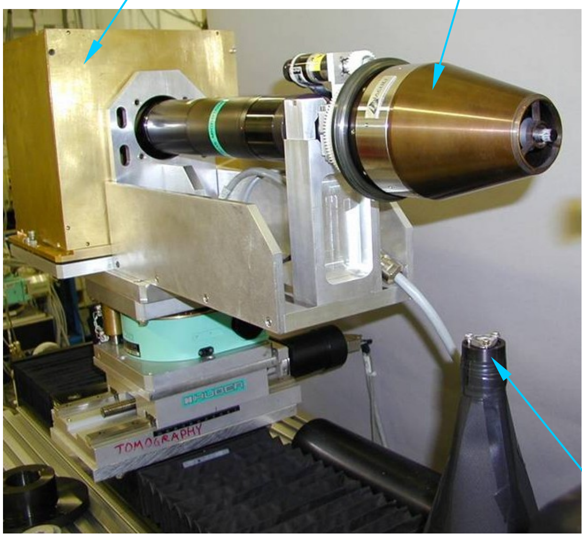

Fig 10: FRELON in brass shielding for high energy

Scintillator support and objective cover

5.3/ FRELON in brass shielding for high energy (Fig 10) :

This assembly show another type of application for High Energie beam line.
On this design, the objectif use is reflective one because standard objective have only few minutes of use and after that are dark.
To bloc hard Xray there is little beam stop of tungsten and the scintillator support witch is covering the objective is made with a very light material.
This application is in use on the ID15 beam line at ESRF for making tomography around 50Kev mainly.

CONCLUSION

Three generations after, the design bases for FRELON camera are the same as for the first prototype. Only few details has been modify to inprove manufacturing or the performances.
Interaction between electronique and mecanic design is still very important for finding the best solutions in new development. Specialy for thermal matters and athmosphere in the CCD chamber. It is also true for temperature control of electronics power ships and board.
Only a change in electronic technologie for having a smaller camera will cause very new design. Such change can have dramatic effect on thermal exchange in the housing or on connectors sizes. The chamber itself cannot be change because the size of it is mainly caused by the dimension of the CCD ship.