

The ESPRESSO Detector System (stability) and first results of the ultra-stable cryostat



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ABSTRACT

ESPRESSO, the Echelle Spectrograph for Rocky Exoplanets and Stable Spectroscopic Observations is designed to measure the radial velocity down to 10 cm/s precision. It will be installed on ESO's VLT in order to achieve a gain of two magnitudes with respect to its predecessor HARPS, and permits to combine the light of up to four 8.2m telescopes.

High precision Radial Velocity spectroscopy requires detector operation in an extremely stable mechanical and thermal environment; any tiny perturbation may affect the location of the detected spectral lines, affecting the instrument global performance. This paper describes the detector system stability considerations, from the detector selection, the CCD operating modes to the cryostat thermal/control design and the overall instrument system layout.

Ways to design and measure the performance of the detectors and the detector system without the spectrograph are illustrated in particular with regard to simulation and lab testing. We will report test results obtained so far with the ultra-stable cryostat testbench.

THE ESPRESSO DETECTOR SYSTEM

Detectors for red and blue arm

e2v CCD 290, 9k x 9k, 10 μm, 16 outputs in standard (blue) and high resistivity (red) version with improved Silicon Carbide (SiC) package and precise mounting.

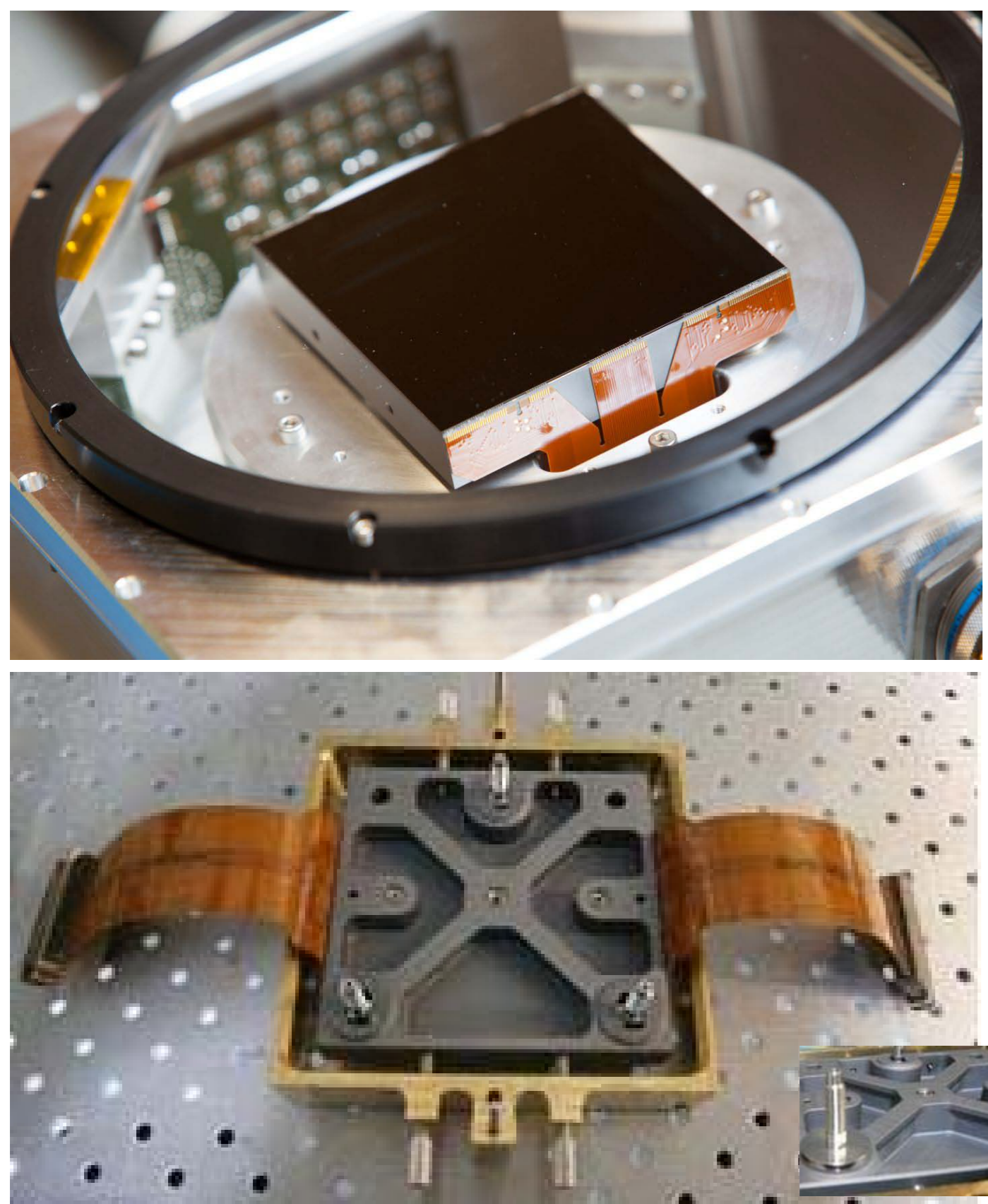


Figure 1: (Top) e2v CCD 290 mounted in ESO test set-up; (Bottom) SiC package backside view & Detail of stiffening ribs

The SiC package has been stiffened considerably (Fig. 1 bottom), also allowing to interface the centre of the detector to cooling connections. The central thread will be used to mount a pin to allow symmetrical expansion around the centre.

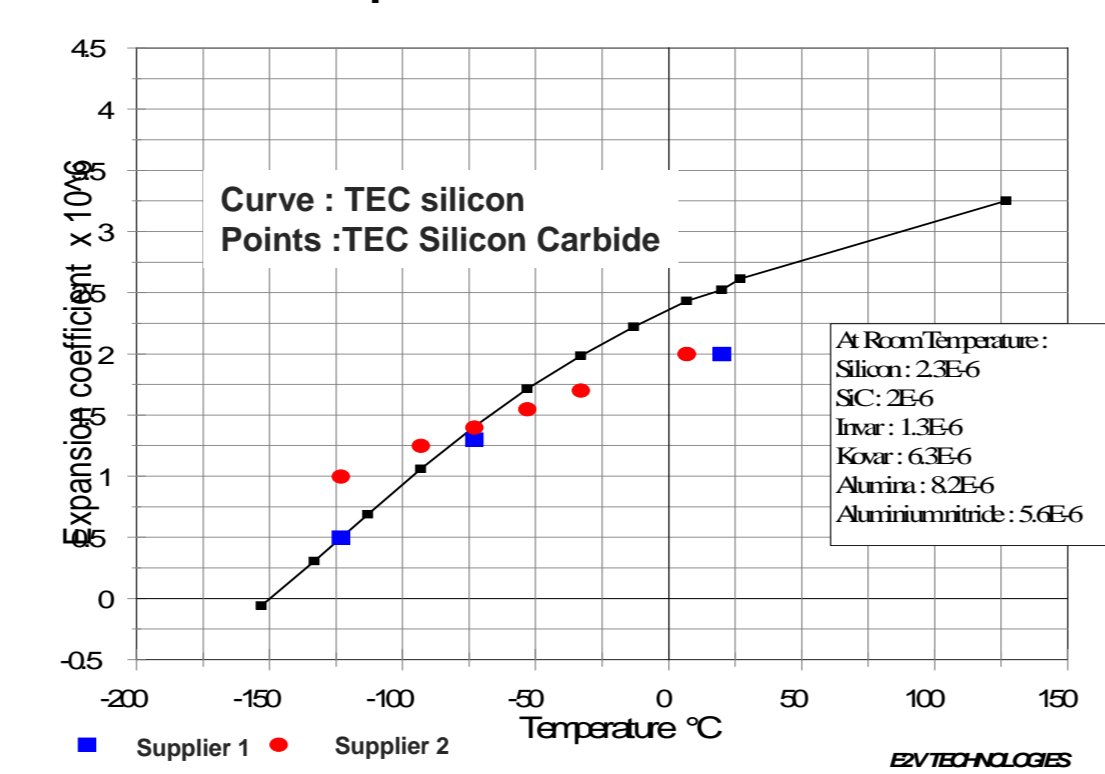


Figure 2: Thermal expansion coefficient of Silicon Carbide matched to Silicon

ESO CCD Controller NGC & CCD 290 early sample – warm first light

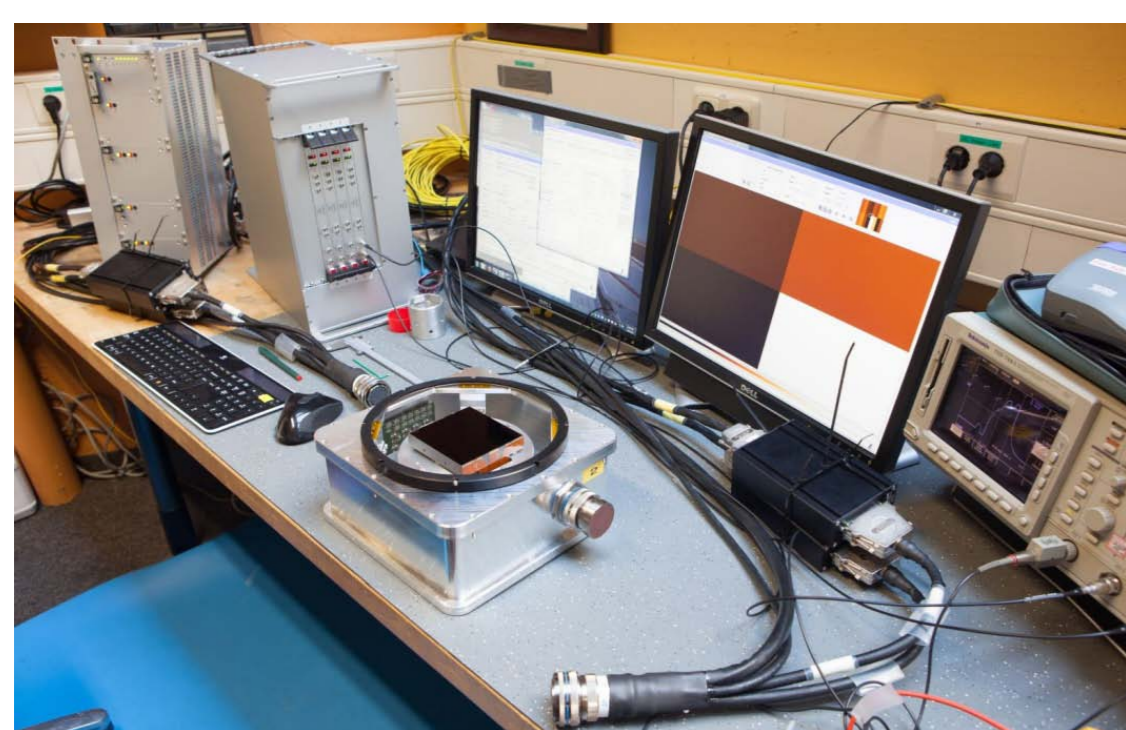


Figure 3: (Left) Lab Test set-up with NGC DFE & PS; (Right) Warm first light images showing projection on 8 channels each (top and bottom). Two outputs of this very early sample are non-functional.

Simulated Pixel Displacement during typical integration (worst case)

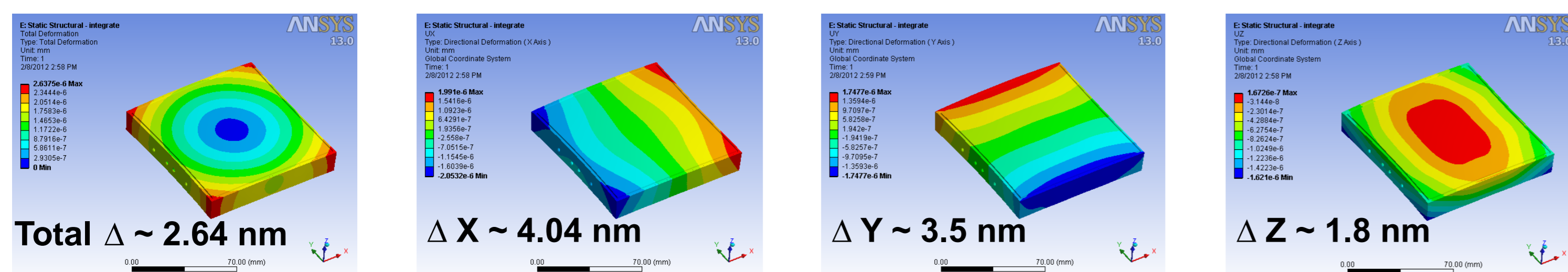


Figure 4: Simulation of CCD package deformation - assuming worst case power consumption and 600 sec. integration time, slew time of 500 sec.

2 nm RMS Centroid Stability required on CCD for 10cm/sec radial velocity instrument precision

Clock waveform measurement in-situ on CCD with NGC

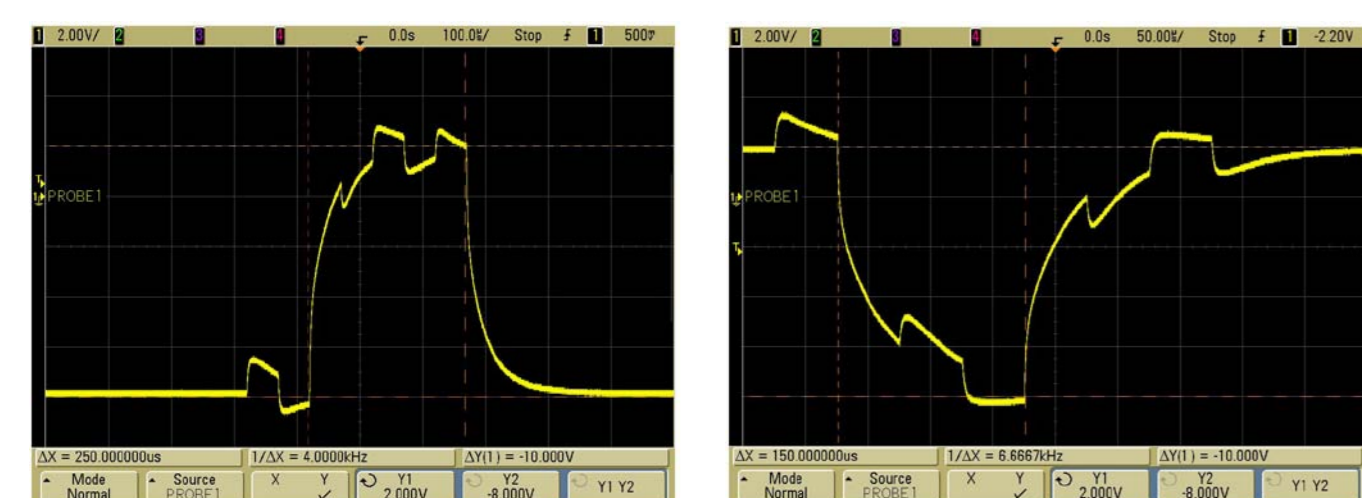
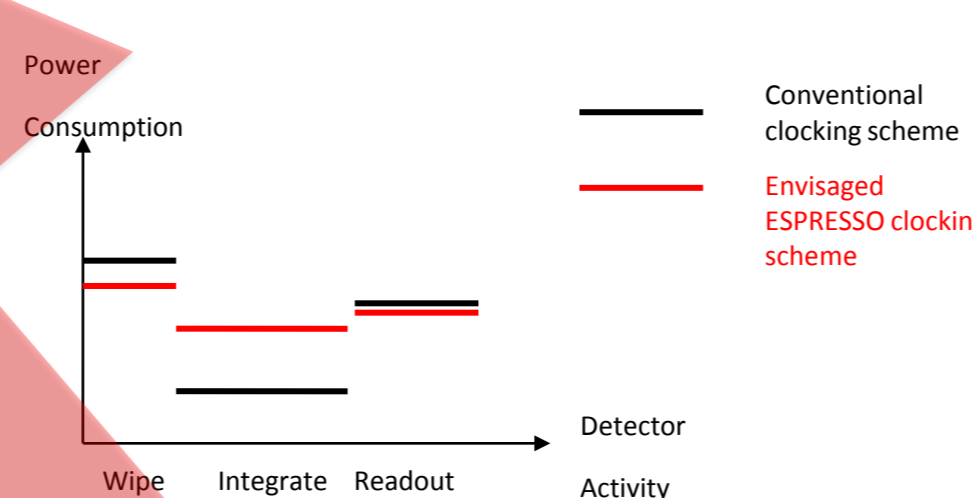


Figure 5: (Left) Parallel Clock Pulse shapes as a result of NGC and CCD; (Right) Envisaged 'dummy' clocking to result in more equalized power consumption

Special Clocking schemes



Cooling System with additional control loop

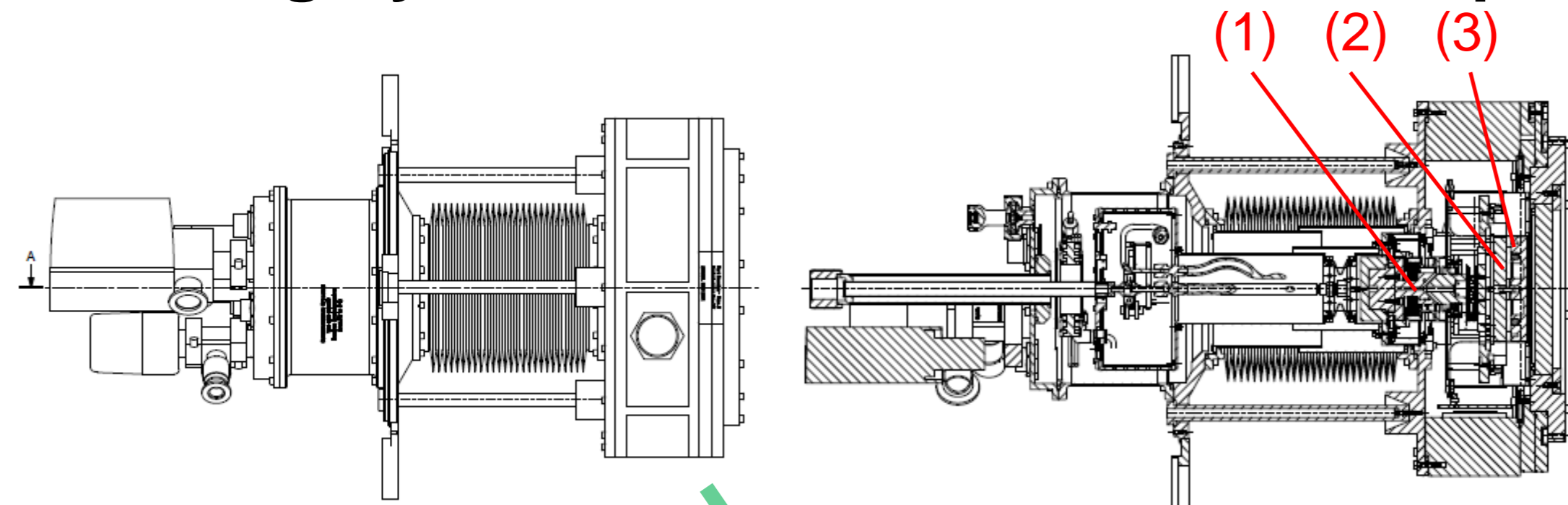
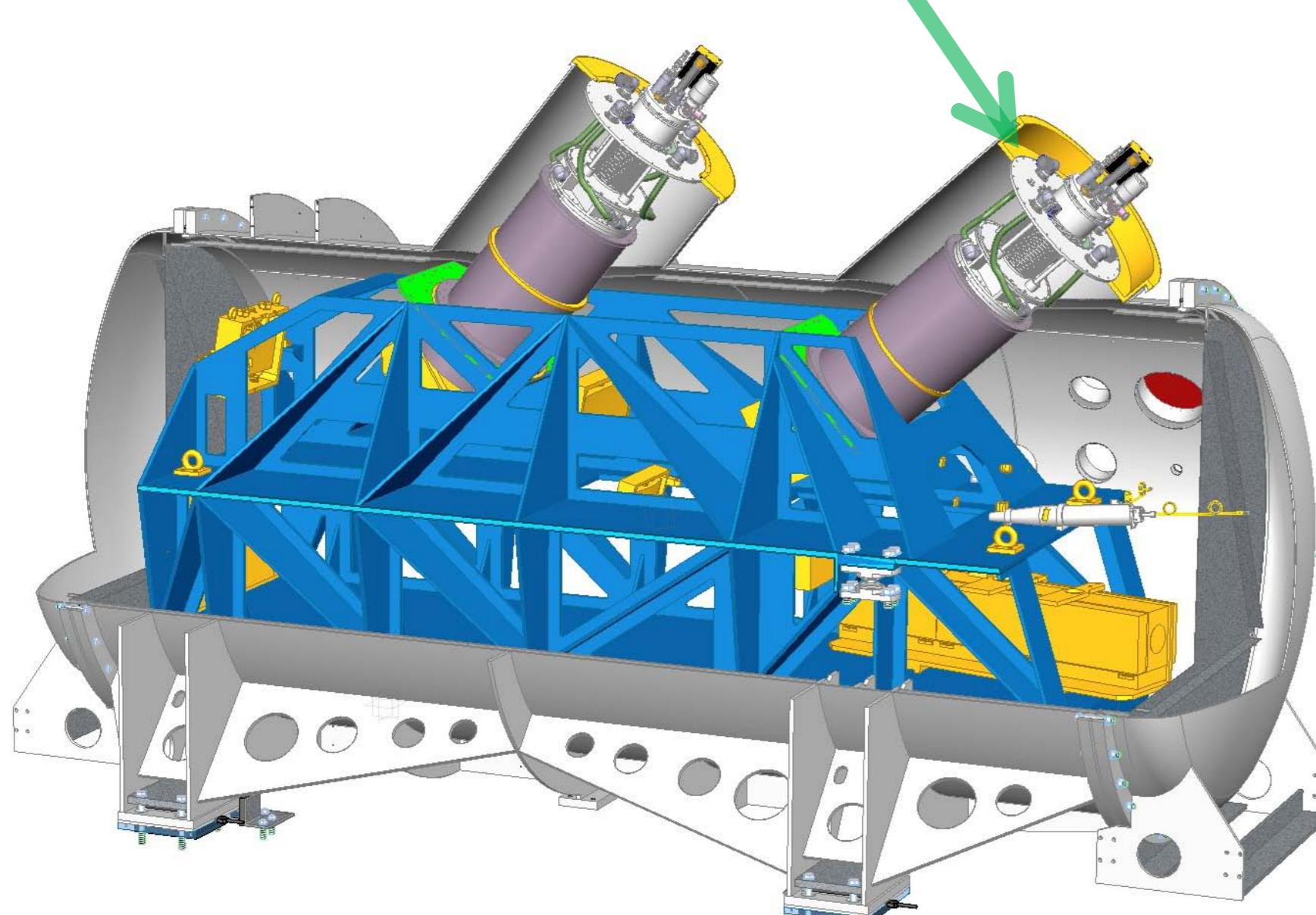


Figure 6: (Left) CCD Cryostat (Right) Cut view of CCD Cryostat

Three temperature control loops with increasing precision are used:
 (1) LN 2 flow +/- 1K
 (2) Larger thermal capacity with about +/- 0.1 K
 (3) CCD control loop Lakeshore +/- some mK

Instrument View



Thermal Enclosures

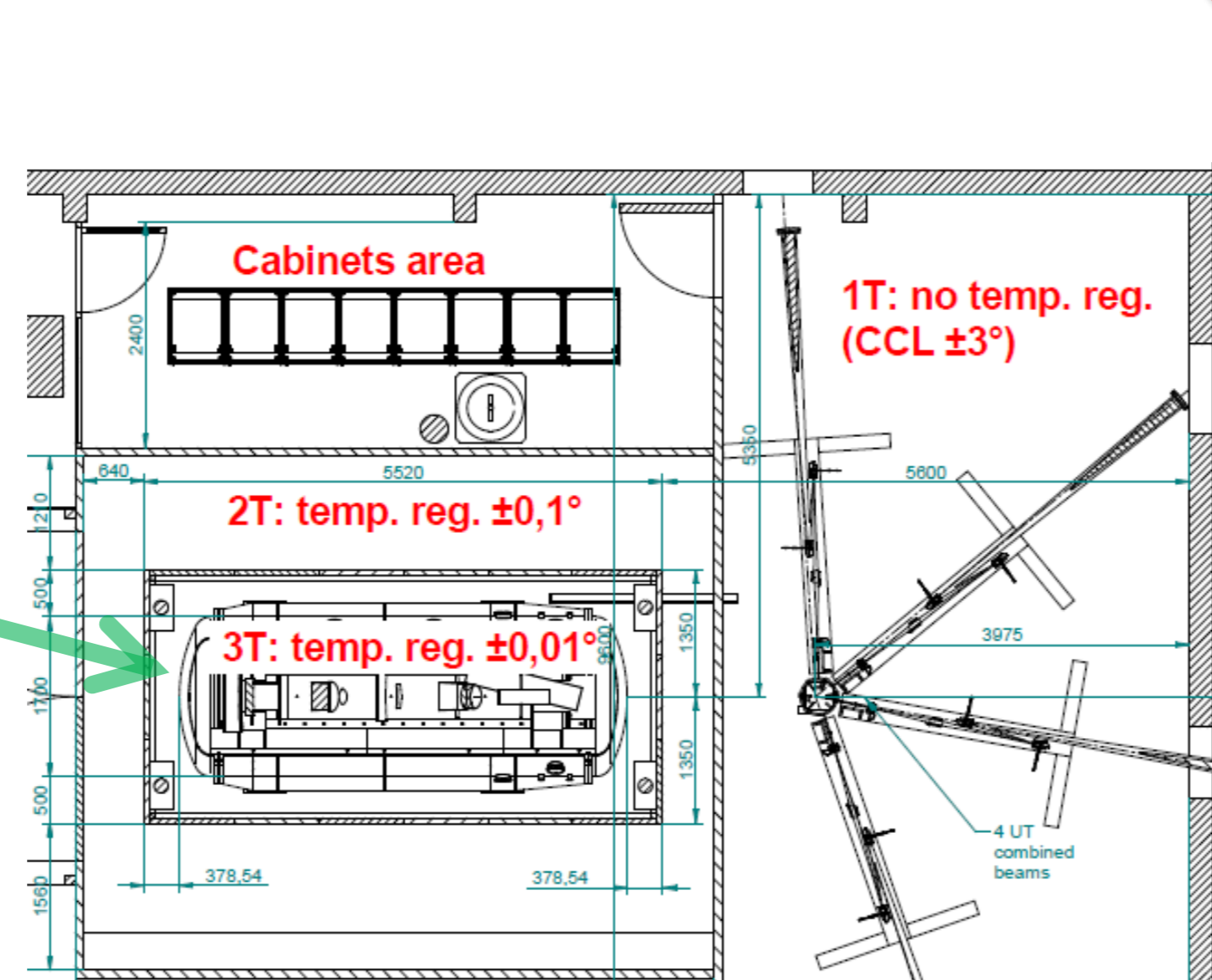


Figure 7: (Left) Instrument Vacuum vessel with opto-mechanical bench and red and blue CCD cryostats on top. (Right) Thermal Enclosures 1T ... 3T with different stabilization

TEST FACILITY ULTRA-STABLE CRYOSTAT

Measurement set-up

The ultra-stable cryostat enables optical centroiding stability tests of the detector system in the laboratory, independent of the actual spectrograph.

It is comprised of an outer vacuum vessel, accommodating the actual detector head, various temperature sensors, an active sorption pump, several fibre-fed multispot-projectors with LED illumination, Lakeshore detector temperature controllers and a data logging/analysis system continuously calculating the centroids of projected spots. This facility will in the long term be used with the ESPRESSO detector cryostat (left section) and is currently used with a copy of the HARPS detector mosaic (2 x e2v CCD 44-82).

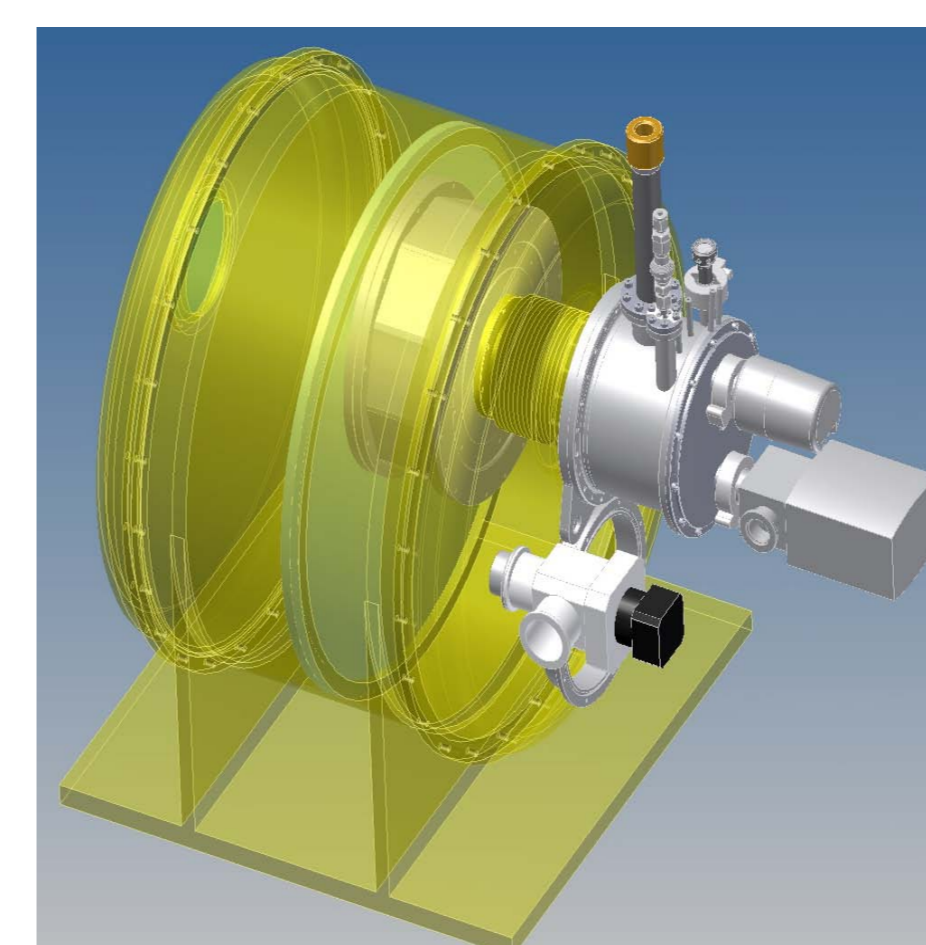
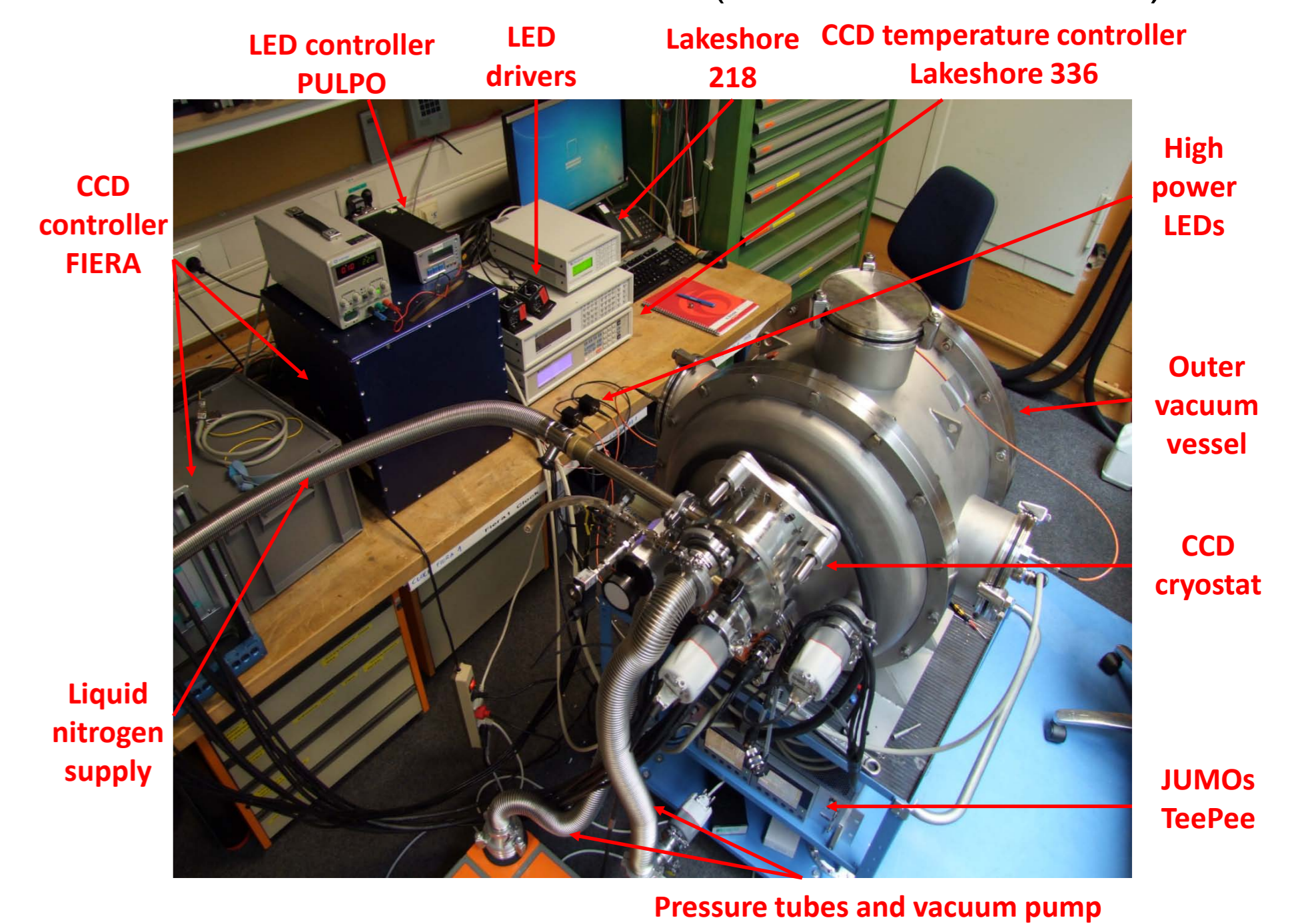


Figure 8: (Left) Detector head inside the ultra-stable set-up (concept); (Right) Complete set-up photograph



Each multi-spot projector consists of a pinhole mask producing an array of ~25000 spots on a 10 x 10 mm² field. Several projectors can be mounted close to the CCD surface across the field of one CCD.

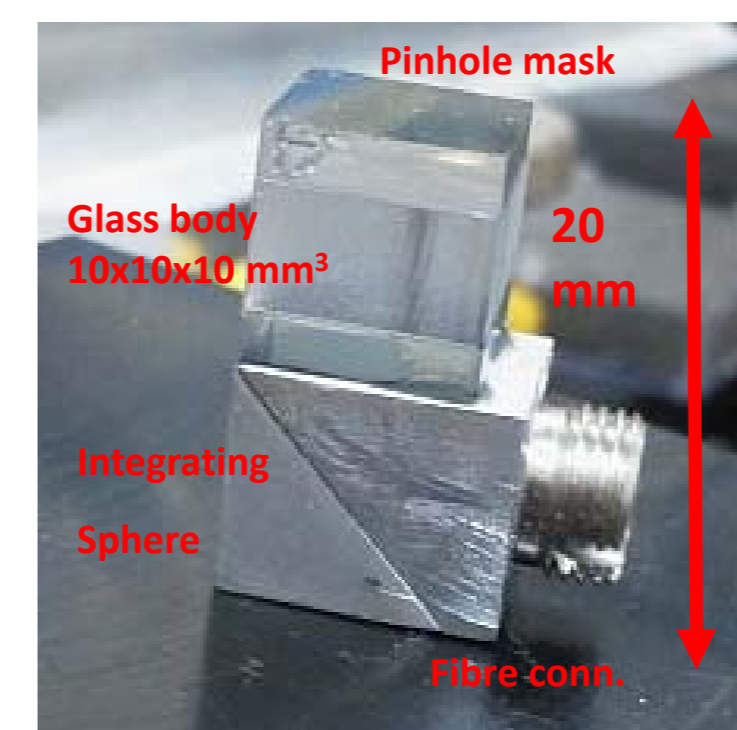


Figure 9: (Left) Multi-spot projector; (Right) Fibre set-up to feed four multi-spot projectors

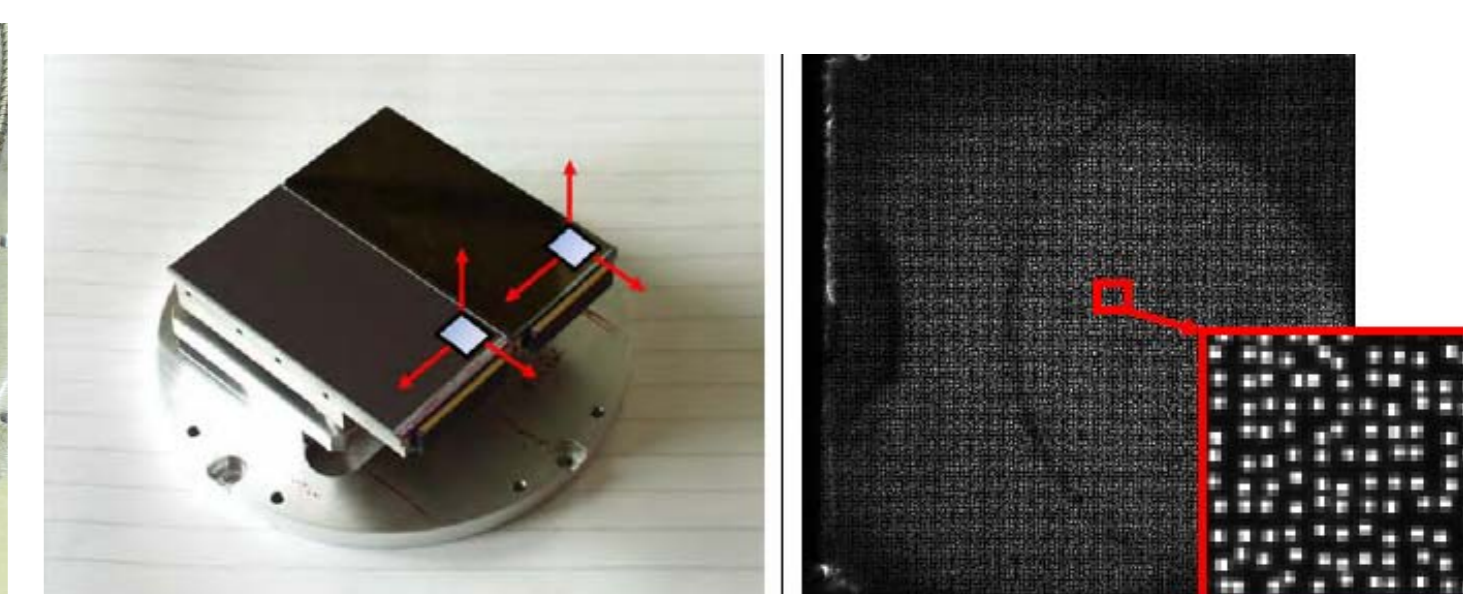
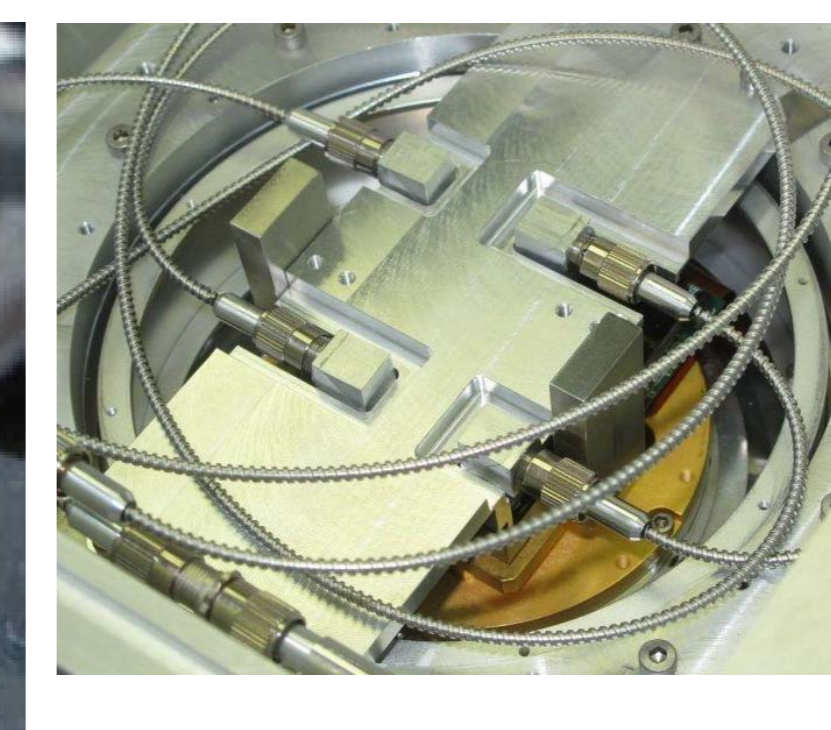


Figure 10: (Left) CCD mosaic and projector field; (Right) Resulting image and detail of spot pattern

Measuring the centroid positions in x,y,z of the generated spots on the CCDs and correlating the differential measurement graphs of individual temperature and pressure sensors inside the LabVIEW control program to centroid stability deviations, the sources for instabilities can be traced and studied (as shown below).

At sufficient environmental (~ < 0.5 K) and CCD stability (~ < 40 mK) the centroids can be measured as a function of specific set-up parameters to systematically study their effects onto the centroid stability, e.g., F [spot intensity / location, CCD Temp., pixel history etc.]

Measurement Results with a CCD mosaic of 2 x e2v CCD44-82 (HARPS-copy) inside the ultra-stable cryostat:

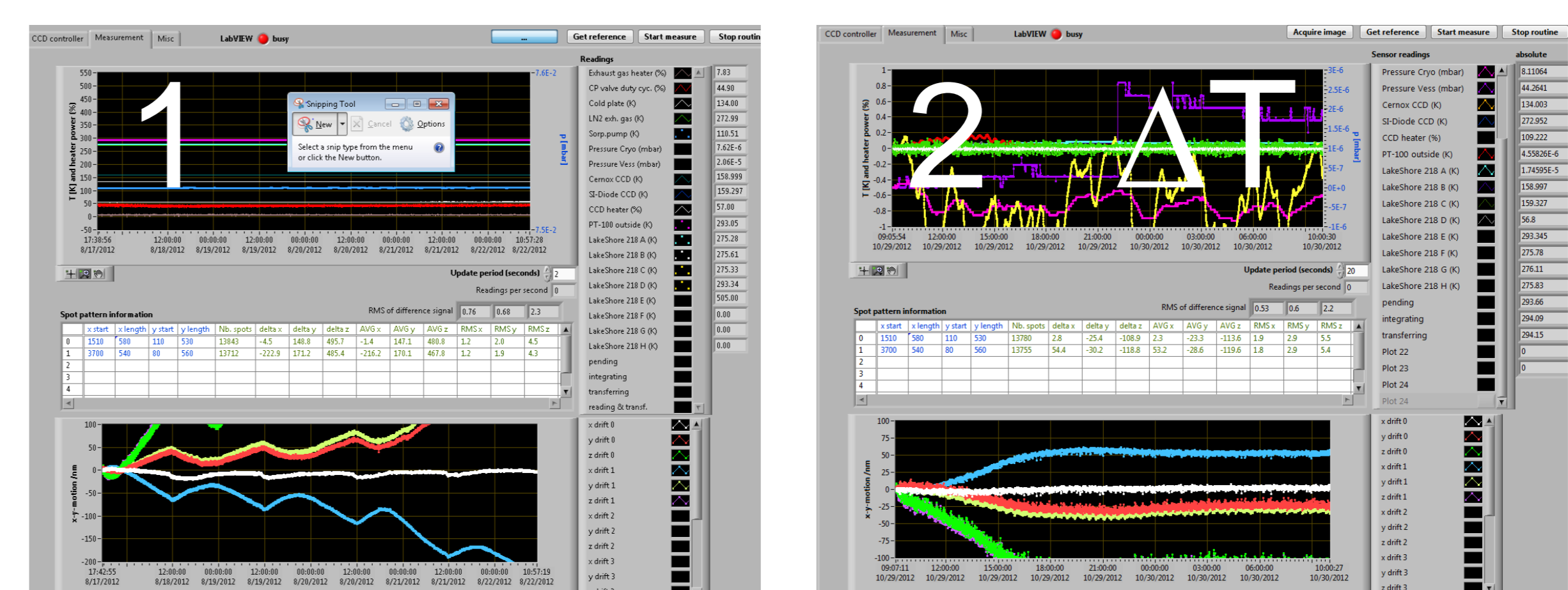


Figure 11: LabVIEW display (1) Early stage (2) More advanced (Top) Individual sensors, (Bottom) Centroid measurements, both over time

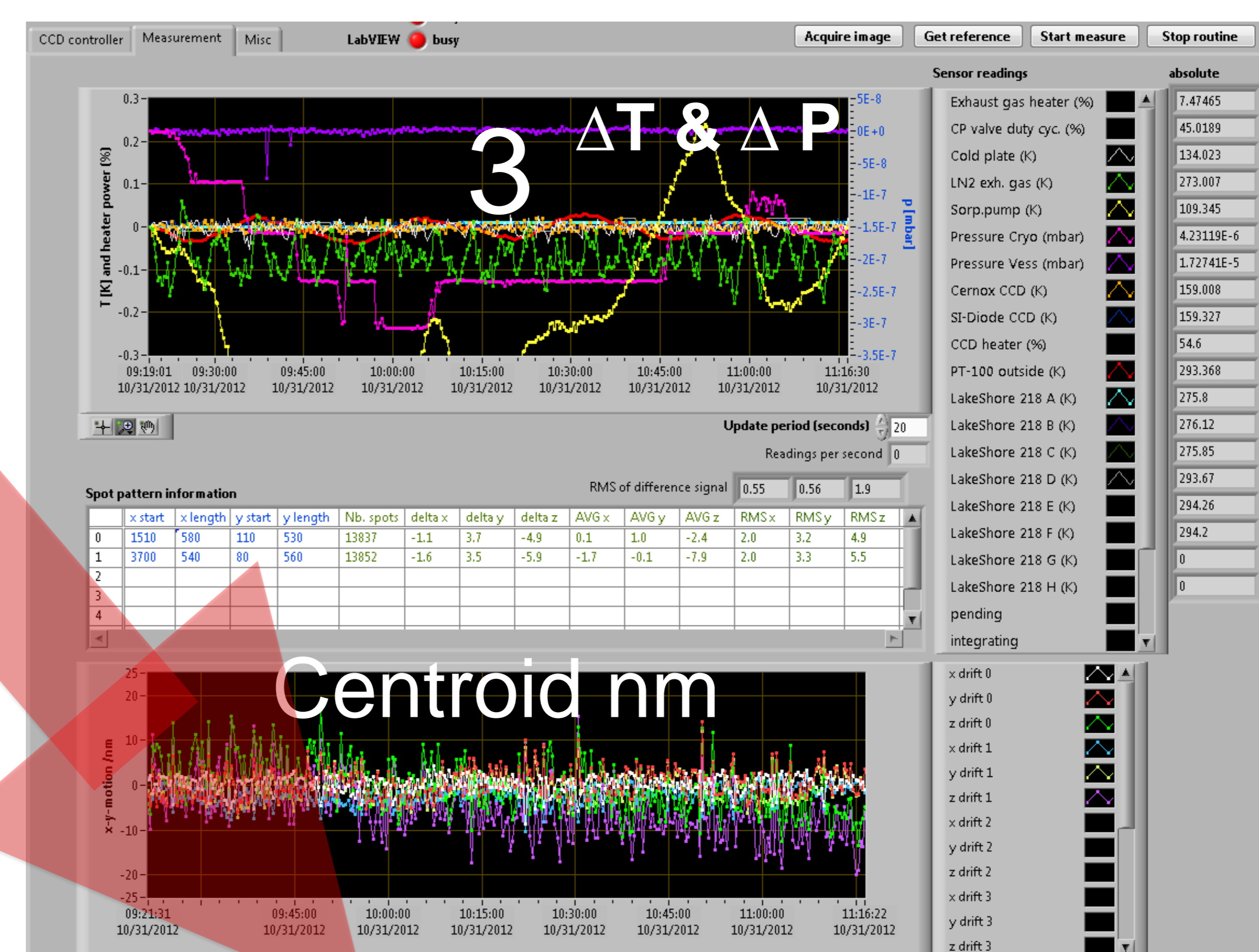


Figure 12: (3) Optimized system set-up & optimized ambient conditions:

(Top) Individual sensors in differential display;

(Bottom) Centroid measurements x, y, z of both detectors < 5 nm over time.

< 5 nm pv Centroid Stability measured

ACKNOWLEDGMENTS

E. Mueller developed the LabVIEW software for the ultrastable cryostat.