A low-noise HAWAII detector system and new cold optics for CLIMB

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A low-noise HAWAII detector system and new cold optics for CLIMB

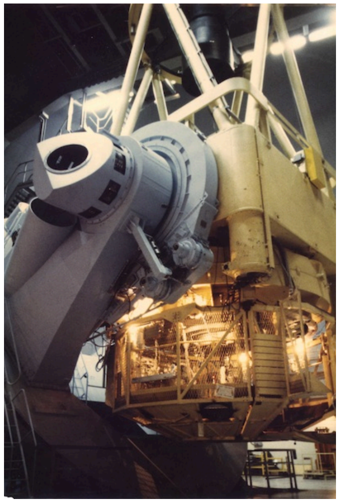
- As part of a new collaboration between CHARA and the MPI for Radio Astronomy, we are developing a new detector systems for the CLASSIC/CLIMB beam combiner.

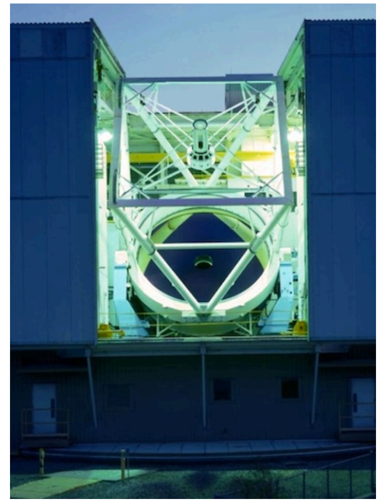
- Our detector system is based on the Rockwell HAWAII-1 HgCdTe focal plane array and has lower read out noise (e.g., 5 electrons) than the current PICNIC based system.

- The new cold optics have a geometric point spread function smaller than one 18.5 micron pixel over the whole J, H and K wavelength range.

Our IR camera system built at the MPI for Radio Astronomy

ESO 3.6 m & NTT, 6 m BTA, MMT, GI2T, IOTA, AMBER, LBT

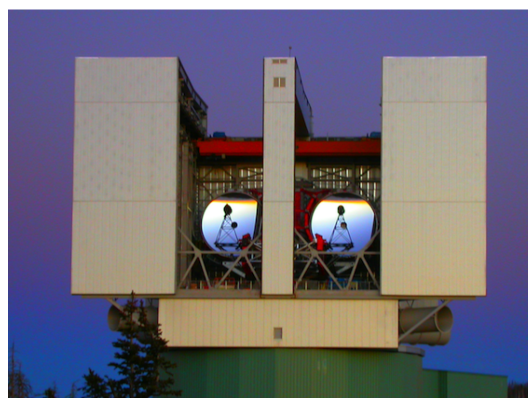




Camera for bispectrum speckle interferometry method

GI2T IR beam combiner instrument

IOTA JHK beam combiner



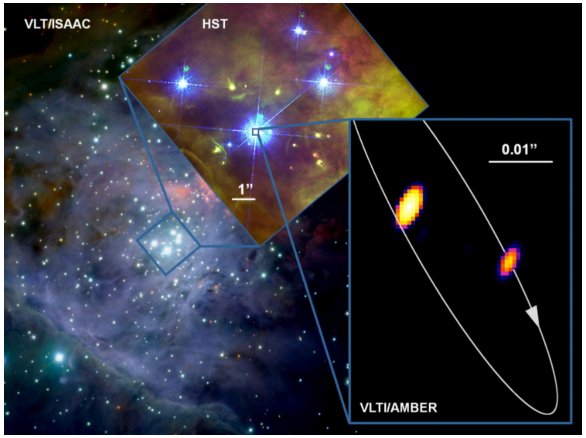
LBT/LINC fringe tracker detector

VLTI/AMBER detector

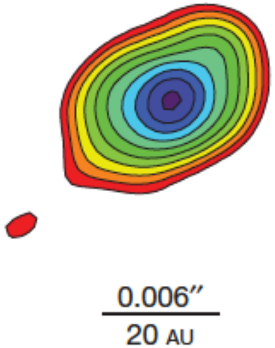
Science goals

- Dust tori of AGNs (K = 8-10)
- T Tau, Herbig Ae/Be stars, jet energy sources
- Image reconstruction: e.g., disks of YSOs
- Simultaneous H-and K-band observations
- Interpretation: radiative transfer modeling

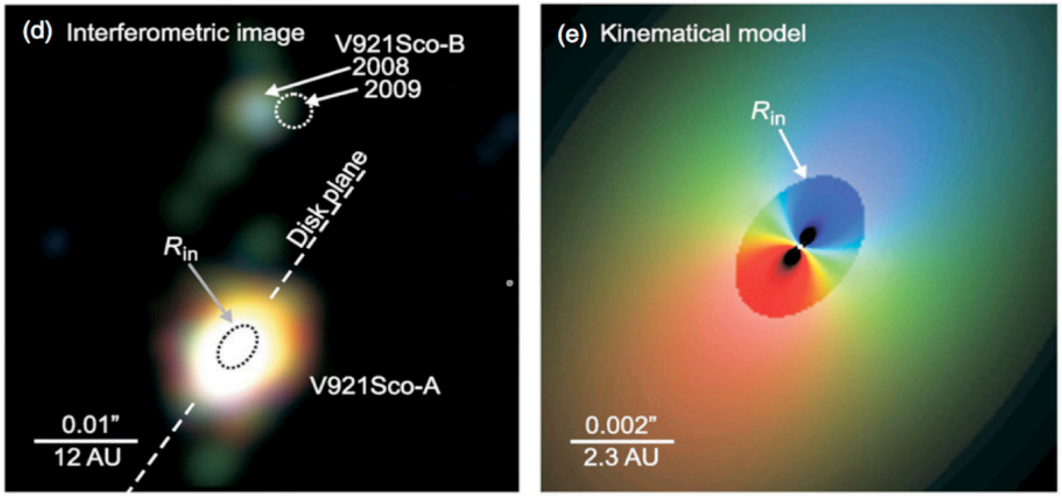
Science goal: image reconstruction



Theta 1 Ori C
Kraus et al. 2009



IRAS 13471
Kraus et al. 2010



V921 Sco
Kraus et al. 2013

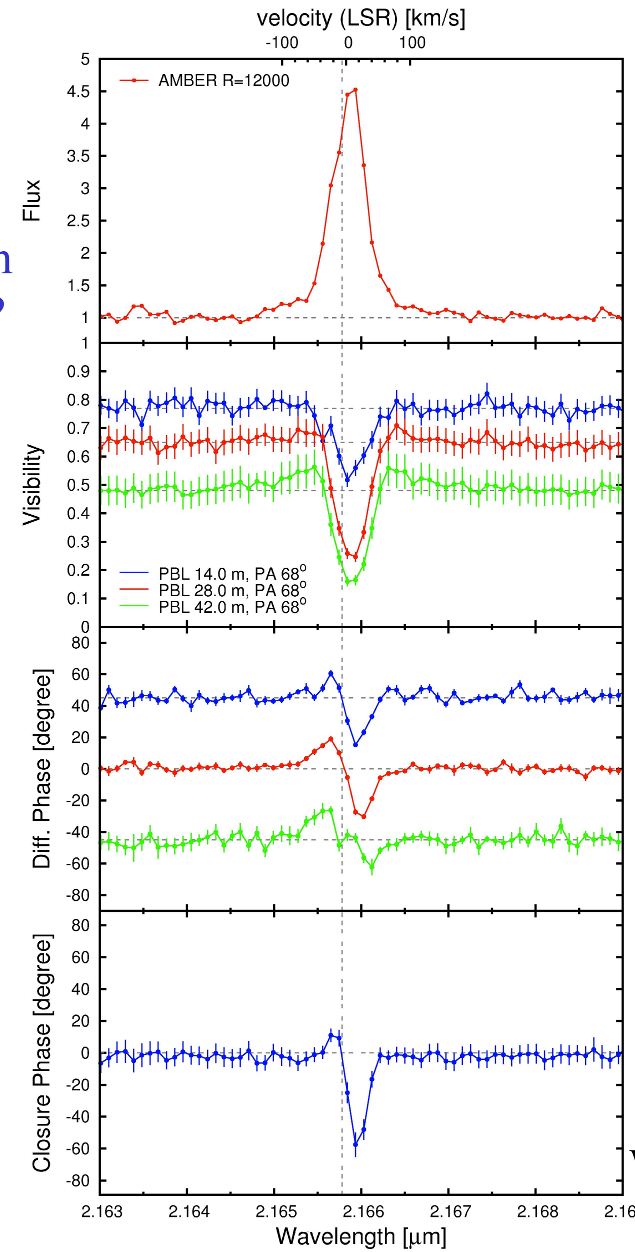
Science goals: T Tau, Herbig Ae/Be stars

Combination of CHARA HK observations with AMBER high spectral resolution observations?

CHARA data allow us to compute detailed continuum radiative transfer models (e.g., because of the long baselines).

AMBER data allow us to compute emission line radiative transfer models of the line emitting region (disk wind, disk, magnetosphere). These models have to reproduce the line profile, emission line visibilities and wavelength-differential phases (fringe shift between line and continuum).

However, the calculation of differential phase of the model requires a reliable continuum model intensity distribution. → If CHARA observations can improve the continuum model, they also improve the line modeling.



AMBER MWC 297

Spectrum/ Br Gamma

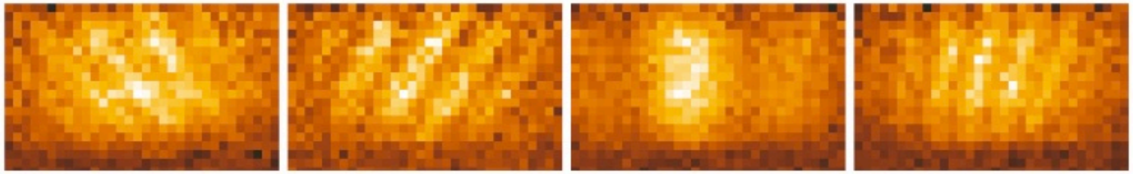
Visibilities

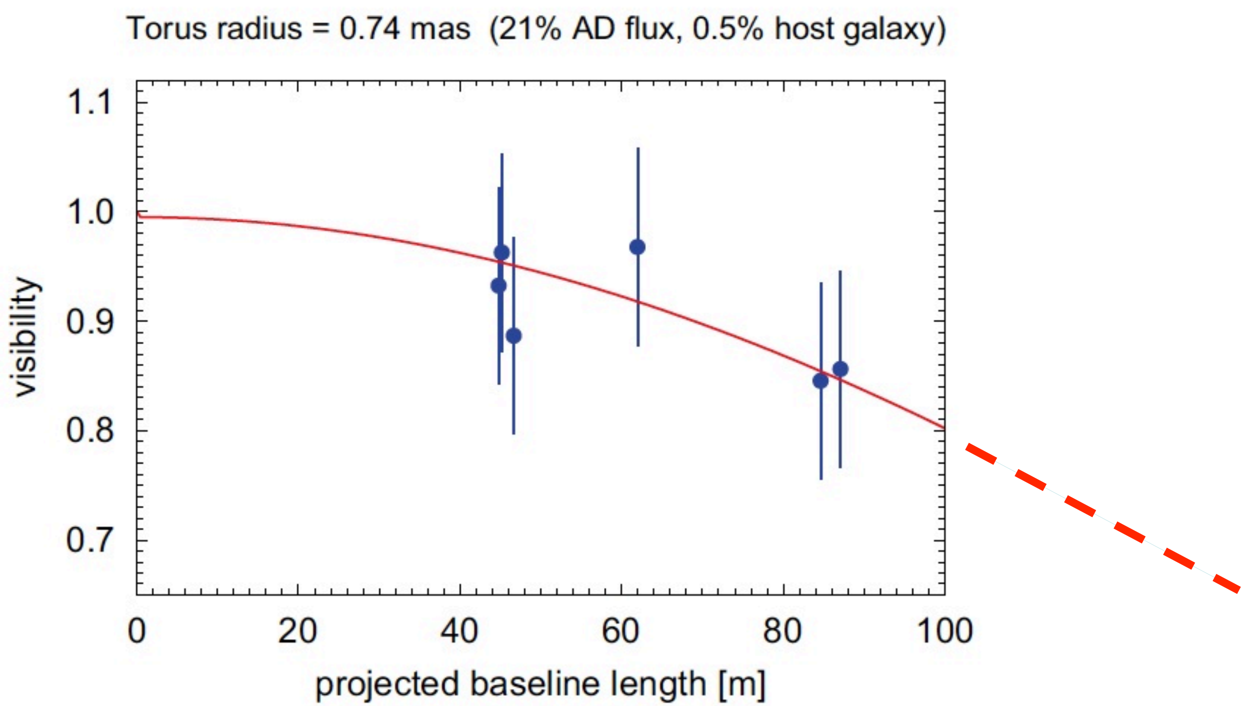
Wavelength-differential phases

Closure phase

Weigelt et al. 2011

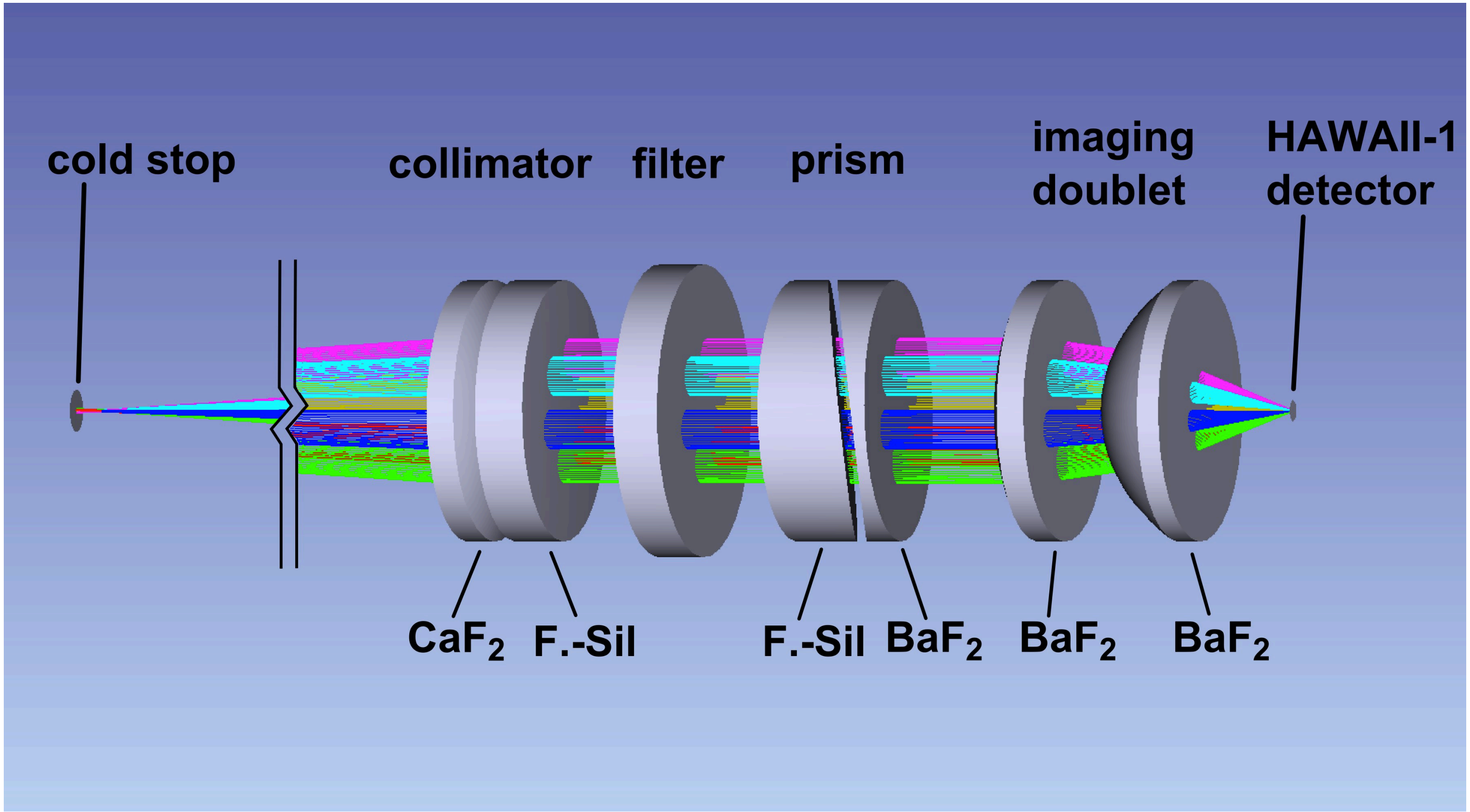
Science goals: Dust tori of AGNs: K = 9-10





VLTI/AMER observation of the AGN NGC 3783 (Weigelt et al. 2012)

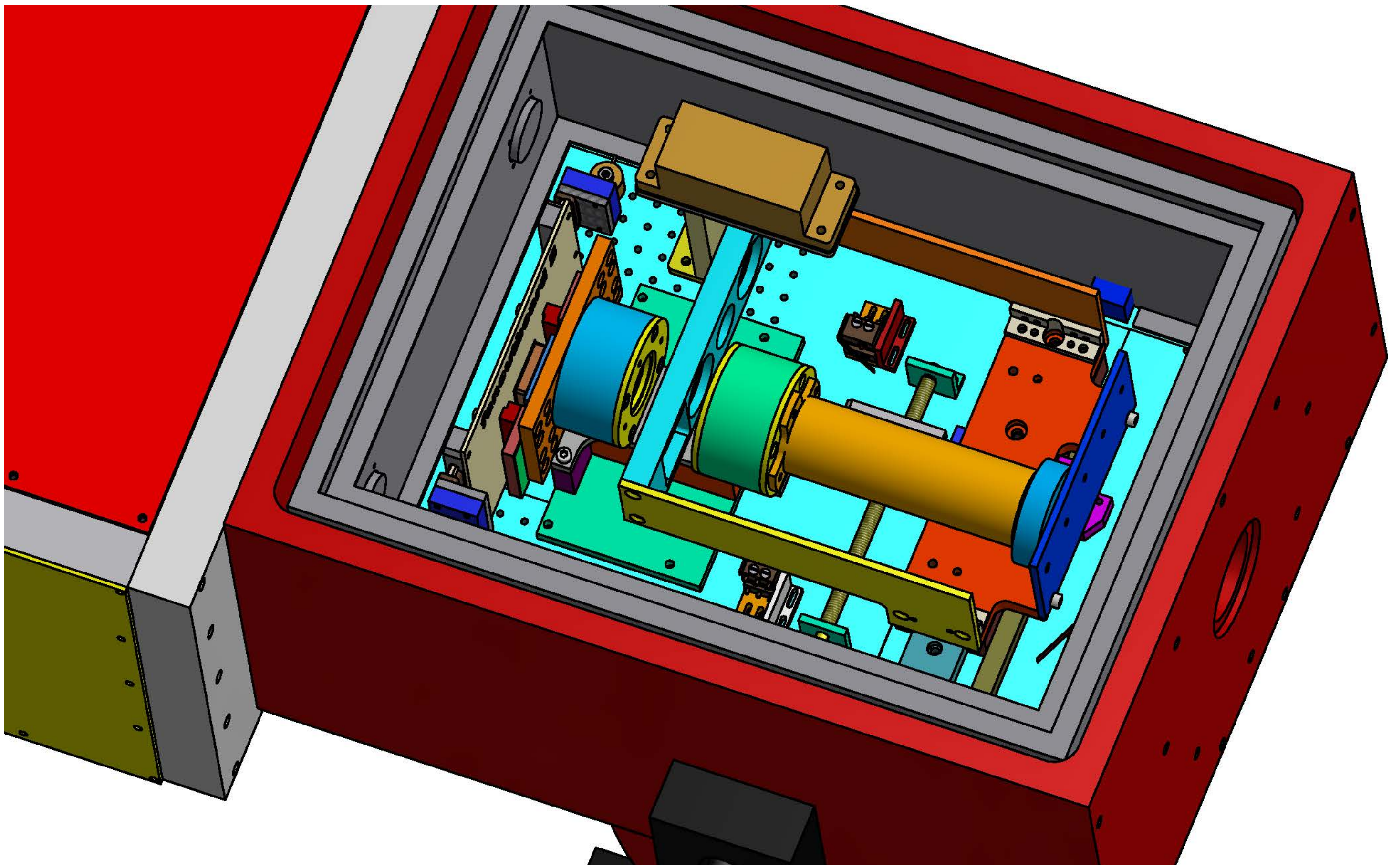
Cold optics in HAWAII-1 dewar



The rays represent the six beams of the CLASSIC/CLIMB beam combiner.

Optimax lenses

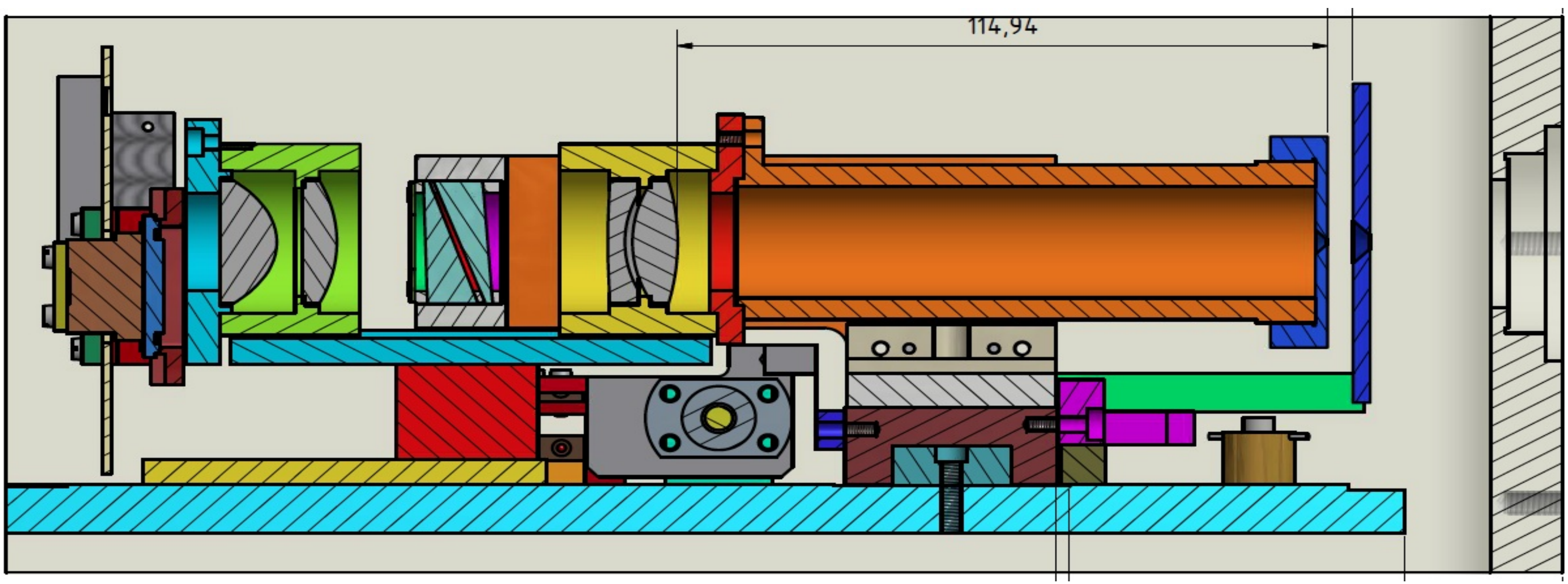
Cold optics & HAWAII detector in dewar



The detector read out electronics (left) are directly attached to the cryostat.

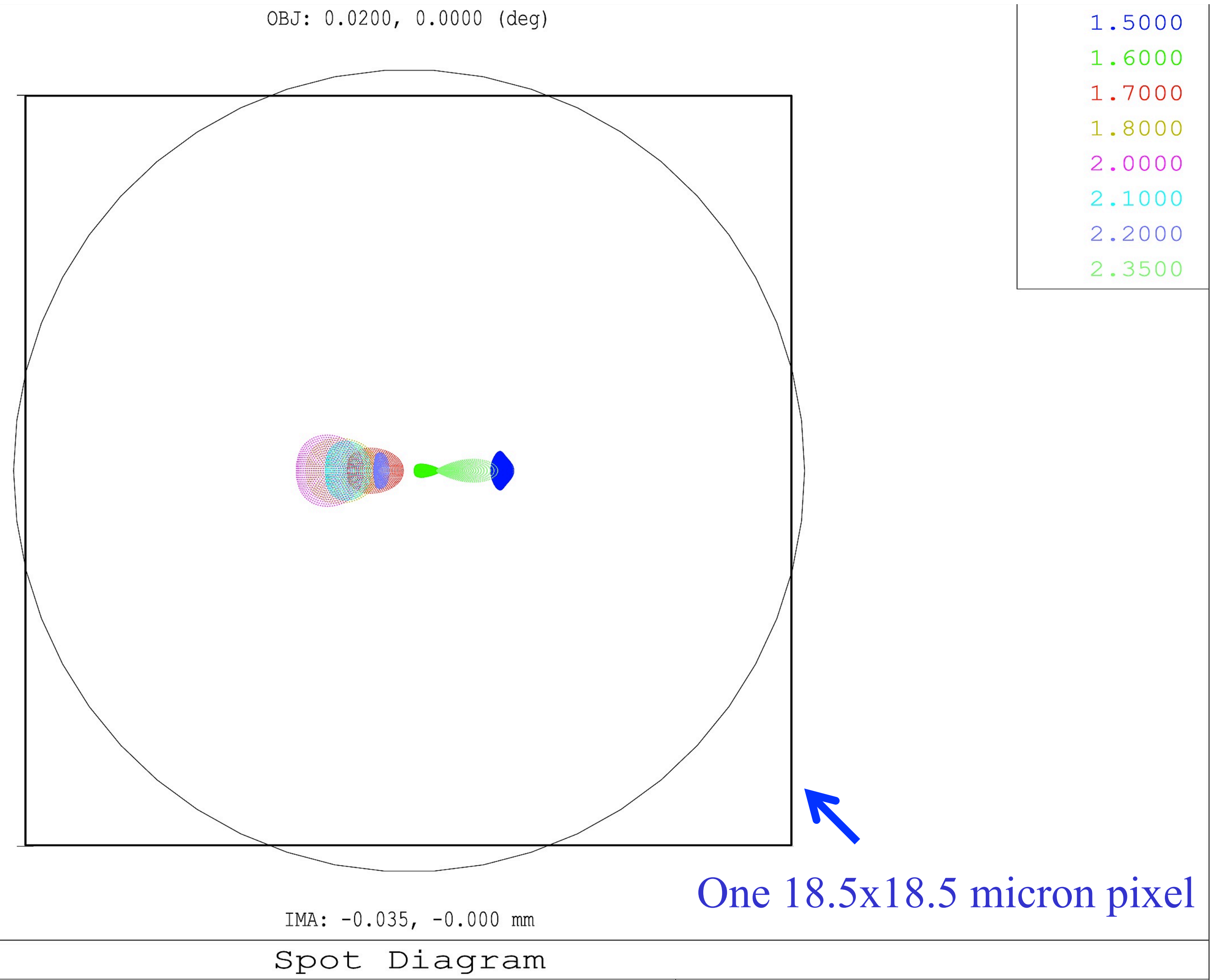
Hawaii detector & cold optics in dewar

J/H/K filters and non-deviating prism



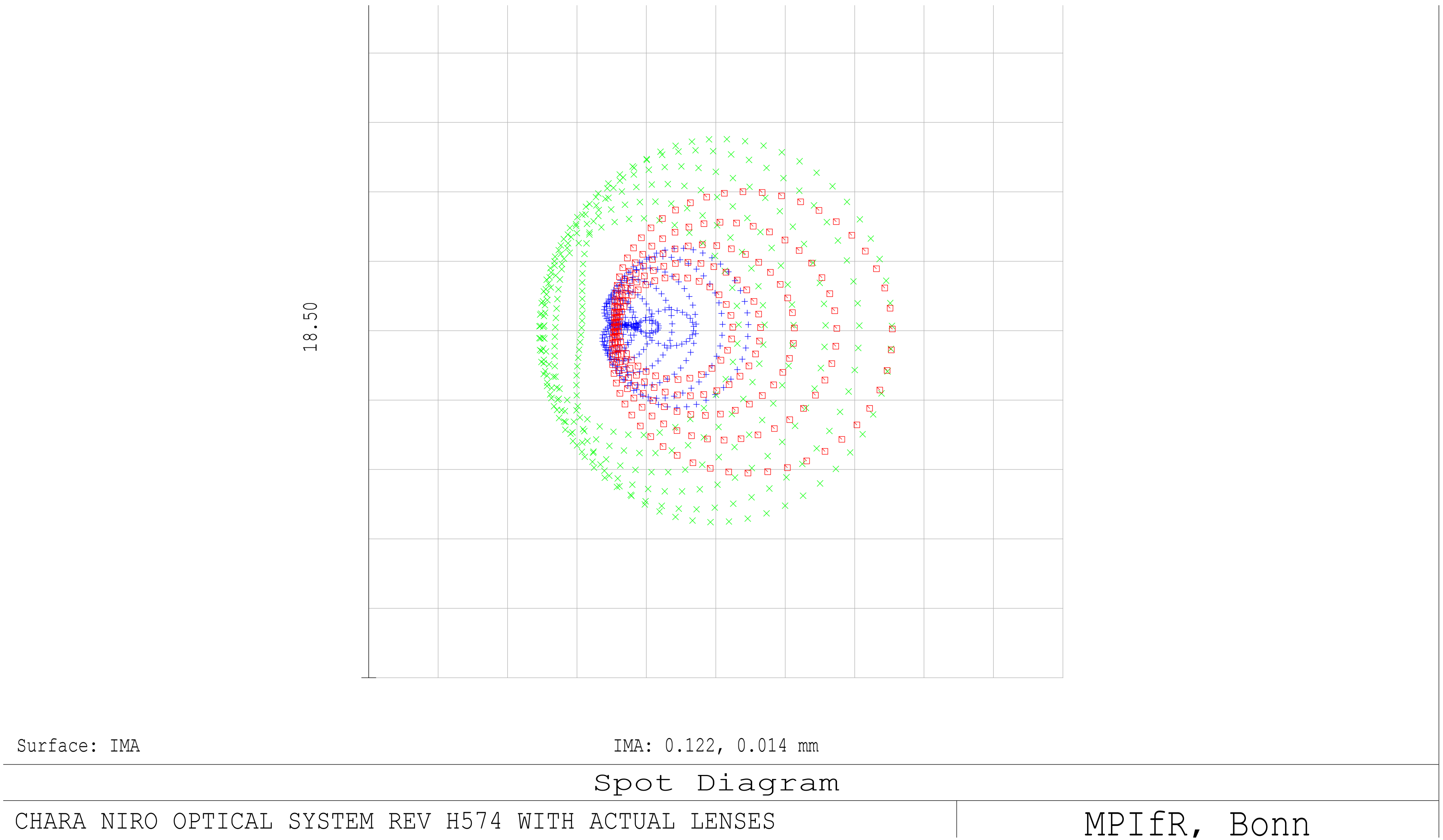
Detector lenses collimator

Spot diagram

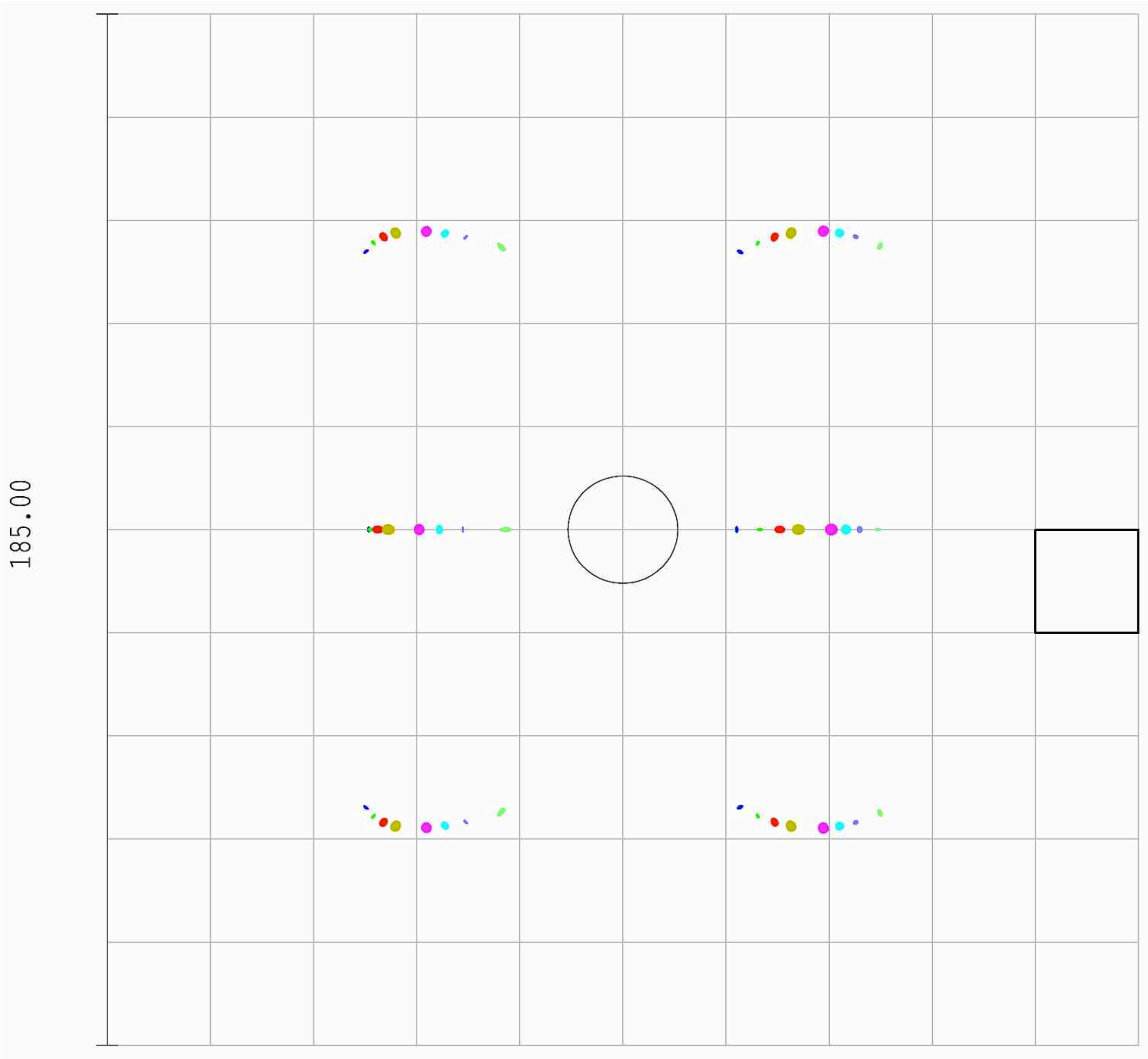


One 18.5x18.5 micron pixel

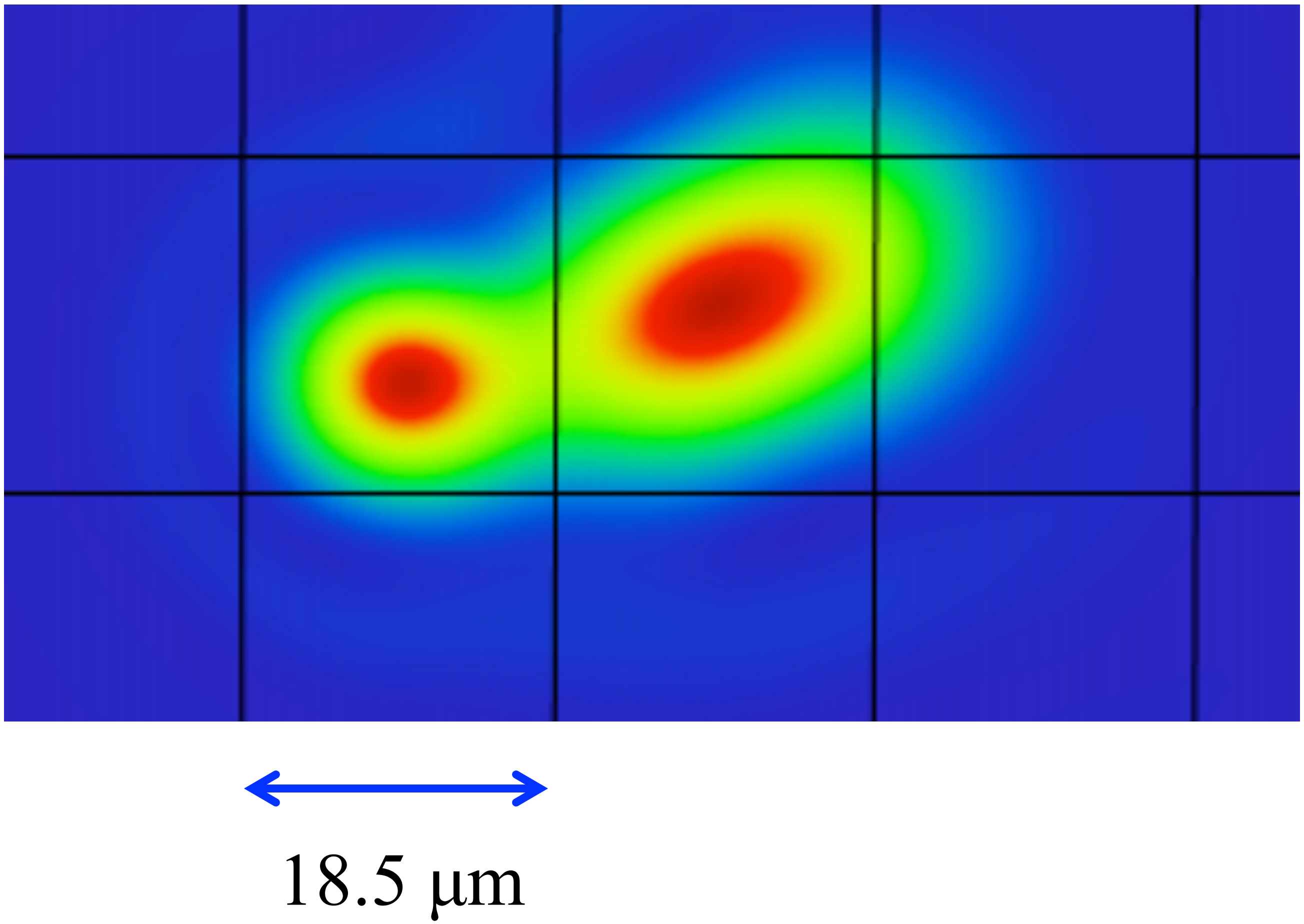
Spot diagram with simulated decentering errors



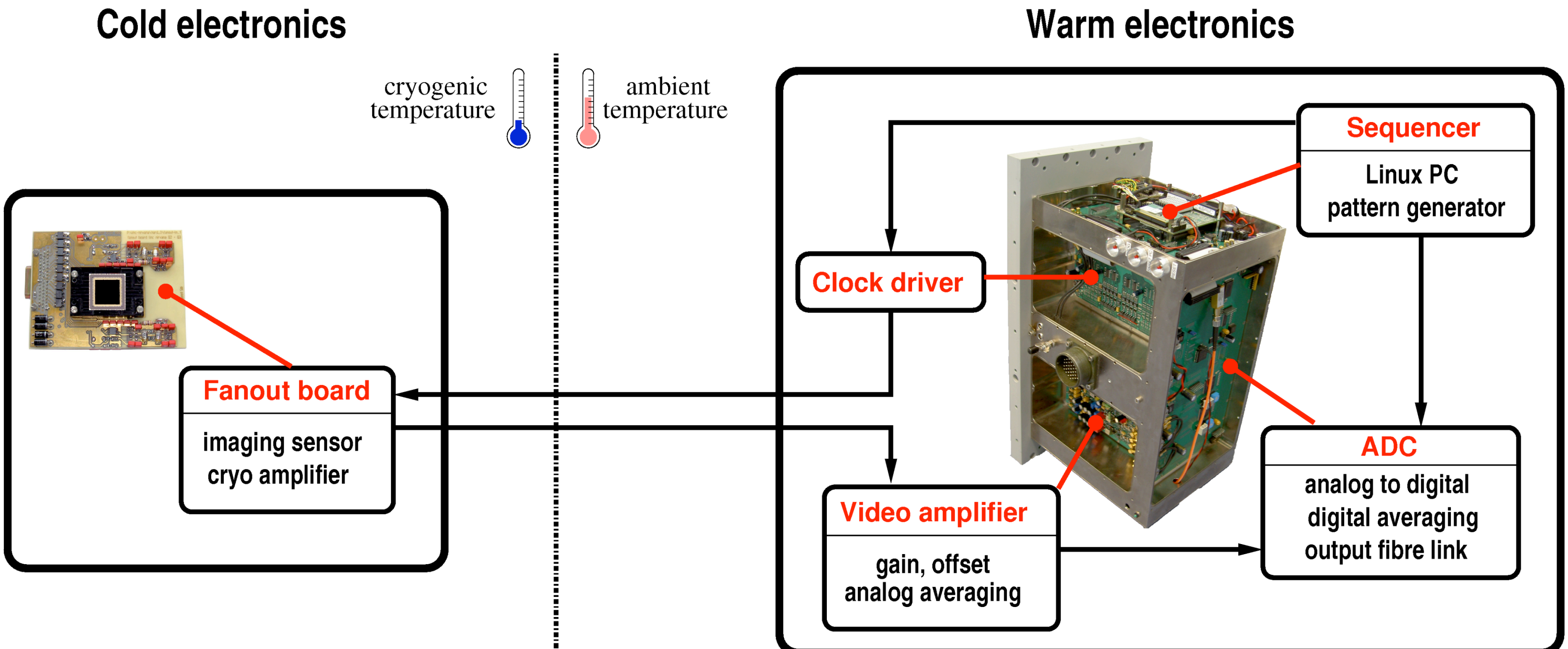
6 CLIMB beams with dispersion



Simultaneous recording of H & K data

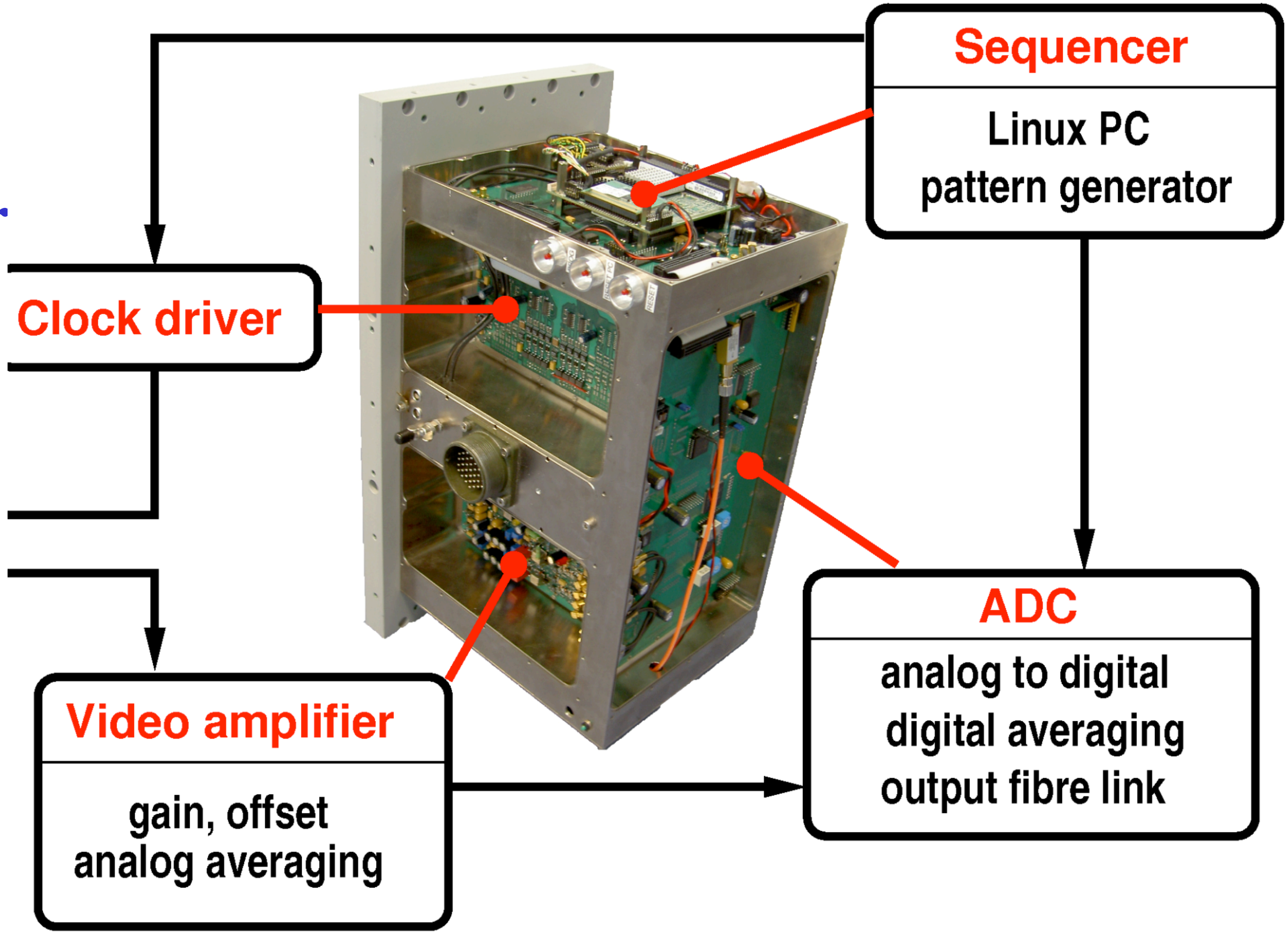


HAWAII controller



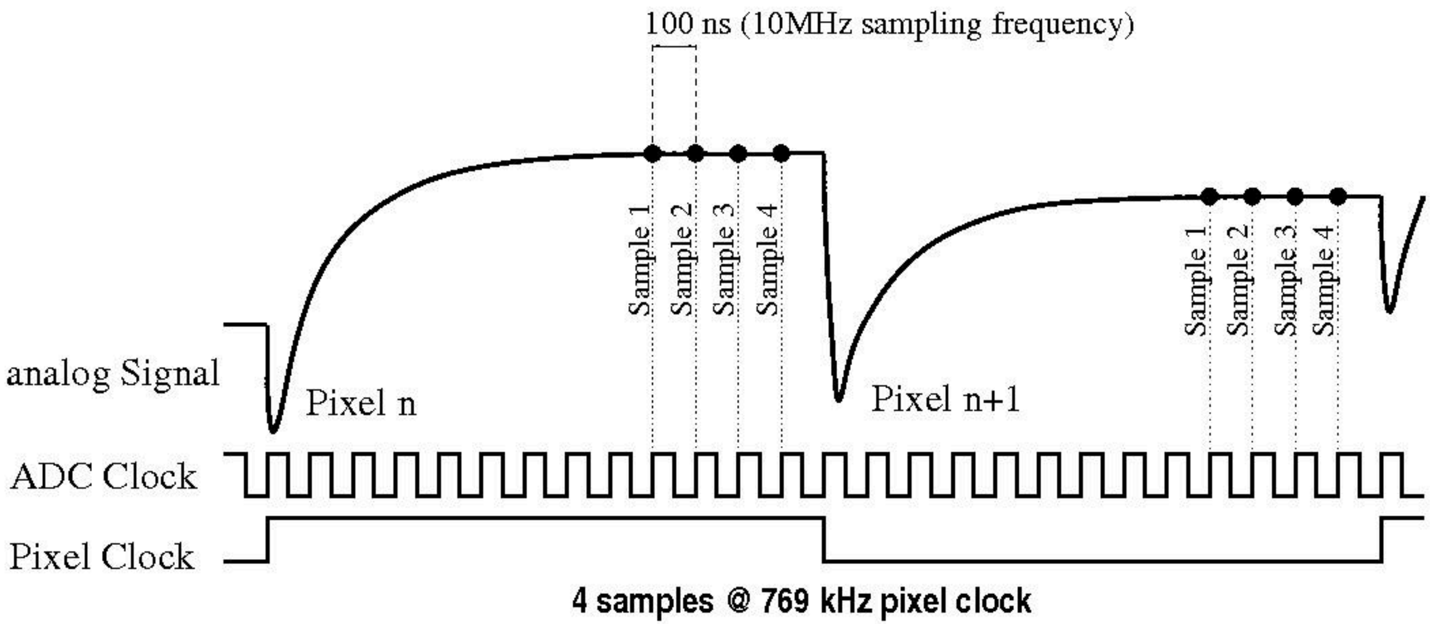
Detector front-end electronics with the HAWAII-1 FPA on its fan-out board inside the cryostat.

HAWAII controller



The detector control electronics are built at the MPI for Radio Astronomy. The goal was to achieve the lowest possible read out noise (RON) and electronic pick-up noise.

HAWAII controller: RON

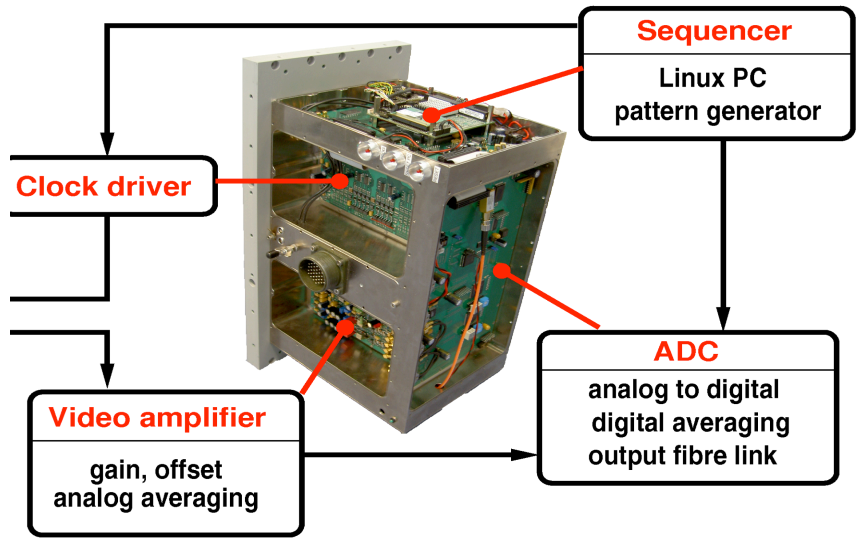


The detector read out noise can be significantly reduced by the following approach:

- The analog detector output signal is processed by a moving boxcar filter consisting of an analog approximation of a finite impulse response filter with a response time adapted to the 10 MHz sample rate of the analog-to-digital converter.
- A digital filter averages up to 1024 samples (above 4) for each addressed pixel.

This hybrid (analog+digital) filter approach allows us to obtain low RON.

Hawaii controller: Electric shielding of pickup noise

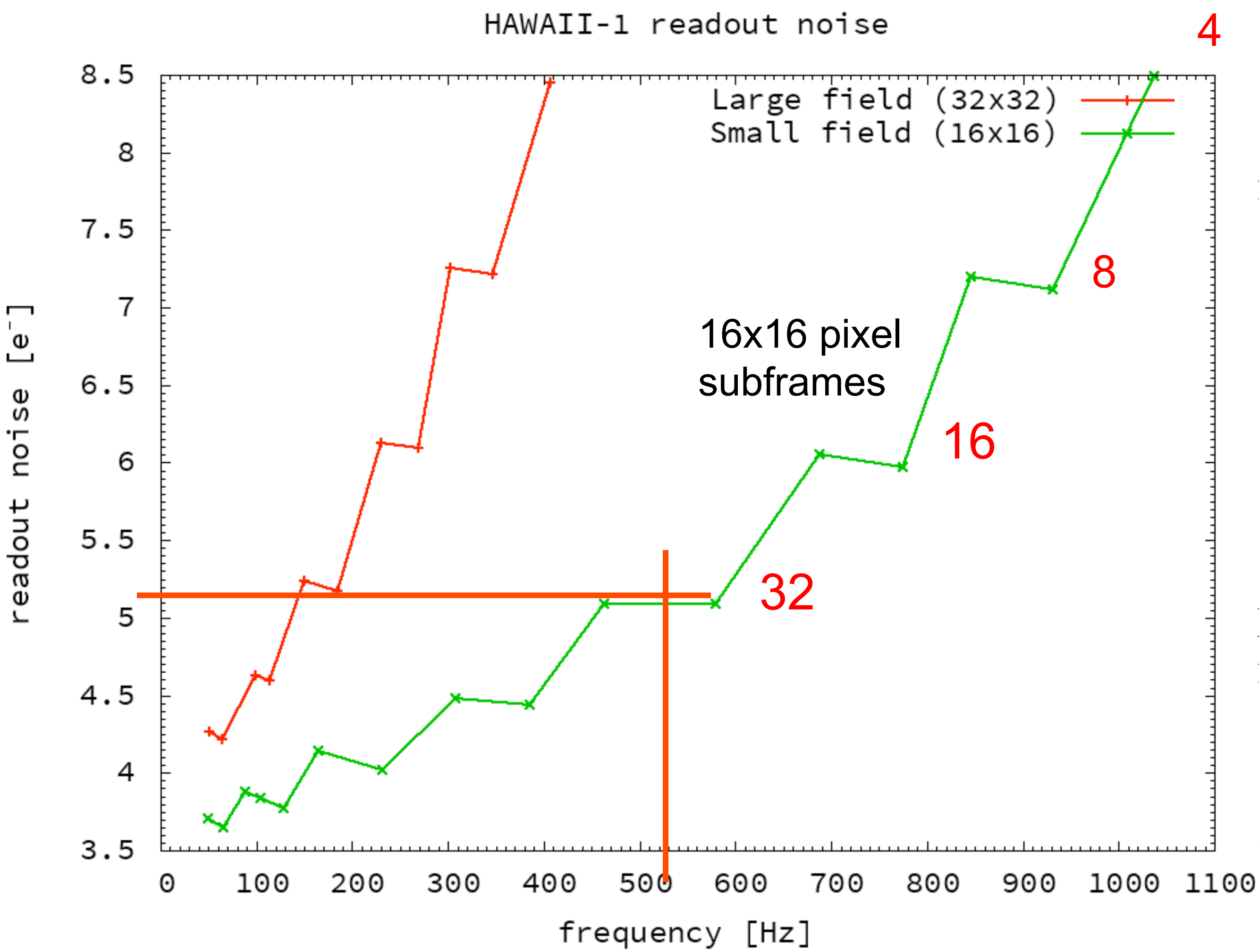


- Pickup noise: electronic interference signals from motor controllers, switching power supplies, machines, etc.

- The housing of the controller electronics is made from a single block of aluminum within which several chambers have been milled. The individual electronic boards are installed in these separated chambers.

- The pick-up noise is essentially zero — no pick-up noise peaks are visible in the average power spectrum even after averaging of thousands of frames.

Dependence of RON on frame rate and frame size (16x16 and 32x32 pixels): 5 electrons at 500 subframes per second



The steps in this diagram result from the numbers of ADC samples: 4, 8, ... 512 (the fastest read out rate in these plots corresponds to 4 ADC samples per pixel).

Green curve: 16x16 pixel subframes (we need only ~10x10)

(ten Brummelaar et al. 2013, JAI 2,1340004-1).