

## OPTICAL ARCHITECTURE FOR THE HET ON FIRST

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### The HET

The heterodyne instrument on FIRST will be a Double Side Band, Dual Polarisation receiver with continuous coverage in the frequency band 492GHz to 1113GHz, and will also have one narrow band channel at 1.8THz. Minimising the number of mechanical switches and tunable

components enhances the reliability of the instrument and for this reason, the present design has no side band rejection filters, and no diplexers for Local Oscillator injection. The instrument is built up in individual packages which can be separately assembled and tested, before finally coming together for integration in a complete HET box.

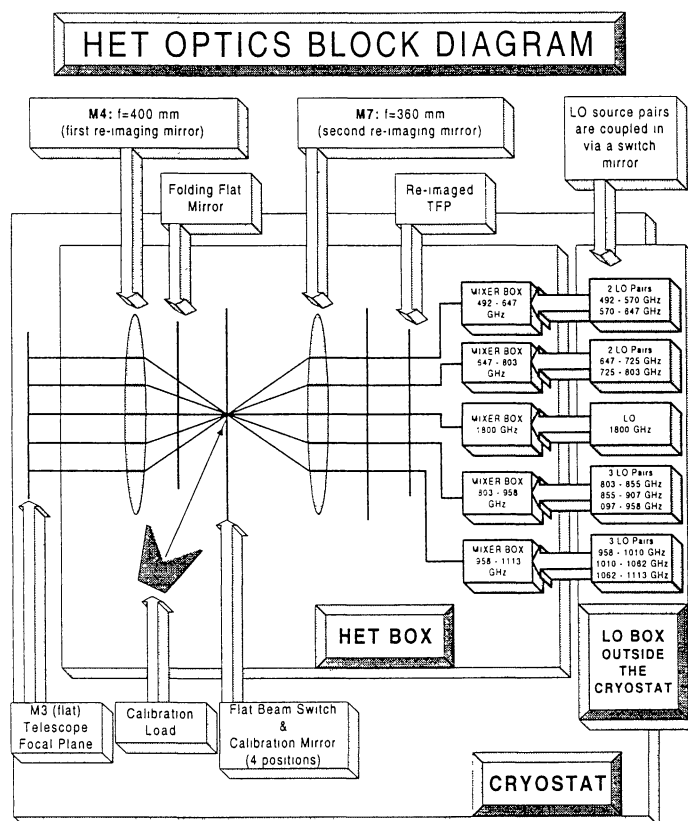


Figure 1: HET block diagram

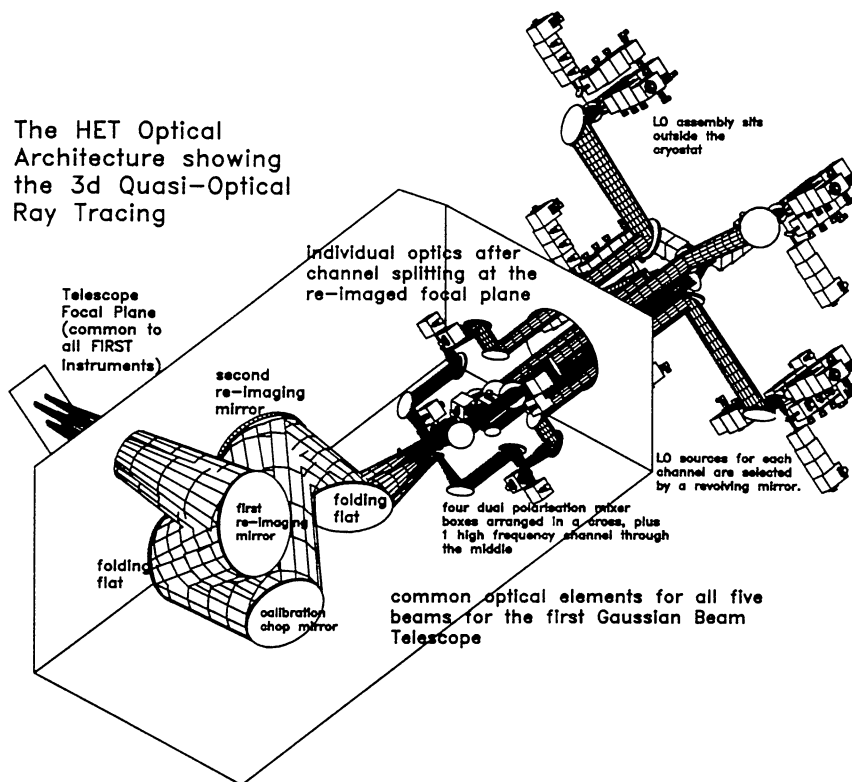


Figure 2: HET Optical Layout

## Mixer Units

In order to achieve full coverage across the band 492GHz to 1113GHz, only four mixers are required, and with the addition of a 1.8THz channel, this makes a total of five channels. While it is possible to have the five beams all coaligned on the sky, this can only be done with either switching mechanisms or dichroics. The former introduce the risk of mechanical failure, and the subsequent loss of part of the HET capability, while the dichroic is a lossy component which affects the performance of the receiver. Consequently, the HET is a multi-beam receiver sampling five adjacent positions on the sky in the different frequency bands.

The mixer technology will be based on Superconducting tunnel junctions, except at 1.8THz where the Hot Electron Bolometer mixers are showing promising results.

The HET is built up of individual mixer modules containing two mixers each. The beams of the

cross polar mixers pairs in each unit are coaligned through a polarising grid. Two mirrors forming a Gaussian Beam Telescope matches the beam to the image of the Telescope Focal Plane, and beam splitter for Local Oscillator injection completes the mixer module making it a independently testable receiver sub-unit which will ultimately be integrated into the HET.

## Local Oscillators

Local Oscillator power proves to be the crucial technology in the HET front end. The available technology to deliver Local Oscillator power does not match the wide bands possible in the mixers, nor the power levels necessary to pump the mixers, especially when beam splitters are used instead of diplexers. As a result, each mixer band is covered by more than one Local Oscillator source. It is most desirable to have tunerless sources and at the same time, we want to avoid the use of a diplexer inside the HET cold area and its associated tuning mechanism. By coupling the Local Oscillator power to the

mixer via a beam splitter, 80% to 90% of the LO power is thrown away. The only way to have the high power output necessary, and also be tunerless, is to have very narrow band LO's. The solution presented here uses a simple rotating

switch mirror to select from a number of LO sources to couple into each mixer. Thus each mixer frequency band is divided into two or three LO bands.

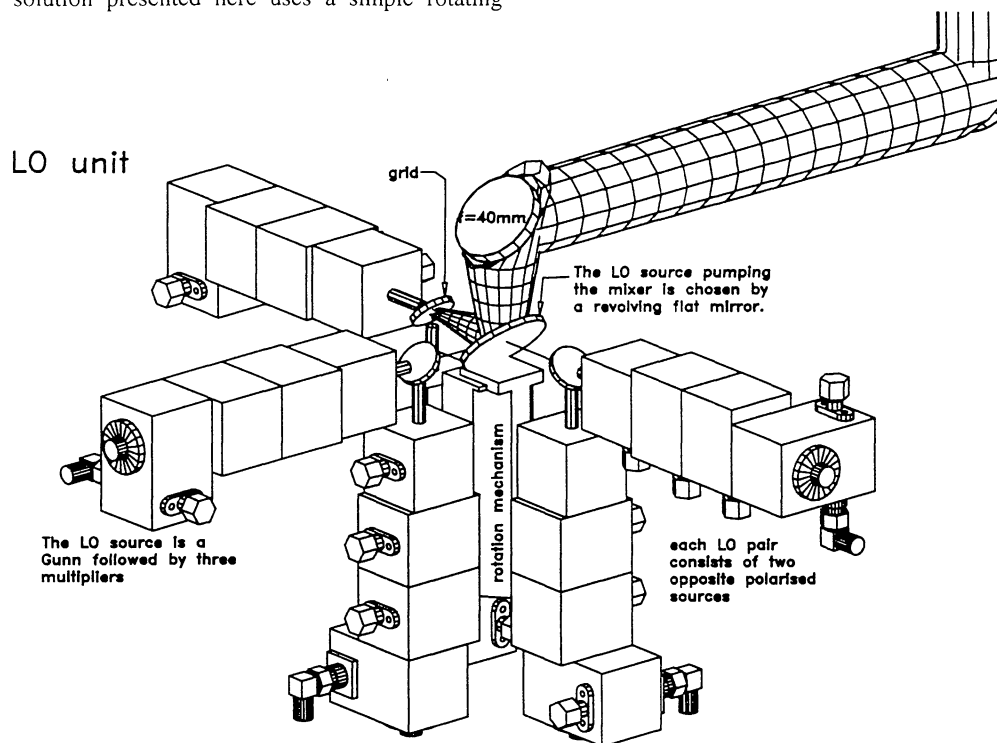


Figure 3: A rotating switch mirror selects between one of three pairs of cross polarised LO sources.

## Geometric Ray Tracing

A multi-beam system which uses common focusing elements for all the beams is subject to beam aberrations. For an on-axis beam, the aberrations can be eliminated using ellipsoidal mirrors (Murphy). A first order estimate of beam aberrations can be done using geometrical ray tracing and this was executed within the CAD drawings using software developed by the author. For the present HET design, the geometrical ray tracing was done for the off-axis pixel starting at the mixer position with rays emanating in a cone equivalent to the 10dB beam size. The result at the Telescope Focal Plane shows that the aberration is smaller than the diffraction spot size, but there is still room for improvement.

The advantage of having second Gaussian Beam Telescope within each mixer box is now

apparent. These optics can be used to individually correct the aberrations of each off-axis beam without affecting the other beams. Work is now continuing with the design of the mixer boxes that better compensate for the aberrations acquired in the common optics part of the HET.

## 3d Quasi-Optical Ray Tracing

The optics design was conceived and analysed using a 3-dimensional Quasi-Optical ray tracing program directly within the CAD drawings (Torchinsky). All the beams shown in the figures are accurately drawn to the 35dB edge taper of a Gaussian beam following definition of beam widths in Gaussian Beam Optics (see eg Goldsmith). This then gives a very clear picture of the aperture diameters required along the optical path for the various optical elements, and

the optical analysis then directly gives the physical design of the receiver.

### References

J.A. Murphy, *Int. J. Infrared and Millimeter Waves*, vol. 8, no. 9, 1987

Goldsmith, P.F., "Quasi-optical Techniques at Millimetre and Submillimetre Wavelengths,"

*Infrared and Millimetre Waves*, vol. 6, pp. 277-343, New York: Academic, 1982

S.A. Torchinsky, "3-dimensional Quasi-Optical Ray tracing in AutoCAD" Please see the Odin satellite radiometer homepage for more details on this software:

<http://www.oso.chalmers.se/~steve/odinradiometer.html>