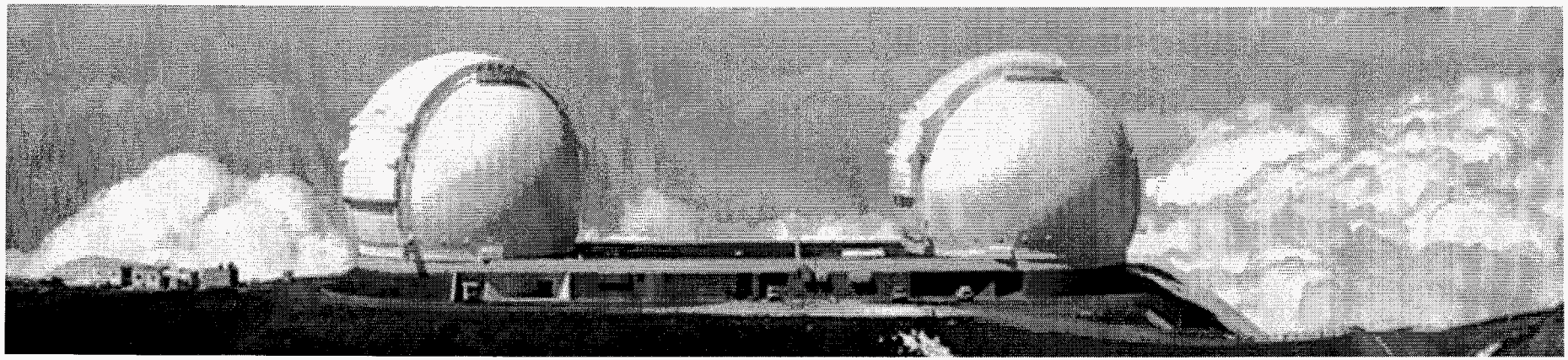
Long Baseline Nulling Interferometry with the Keck Telescopes: a Progress Report



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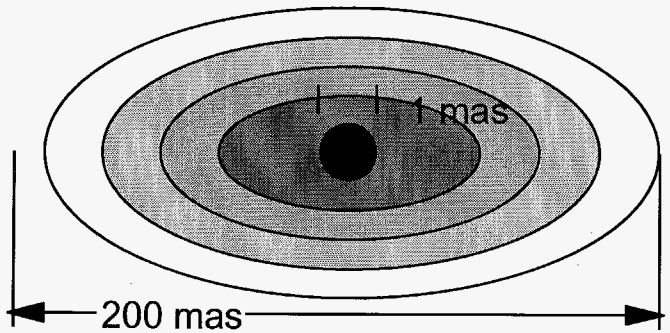
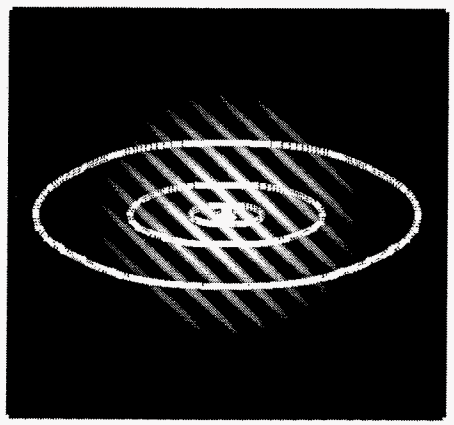
IAU Meeting, Nice 2005

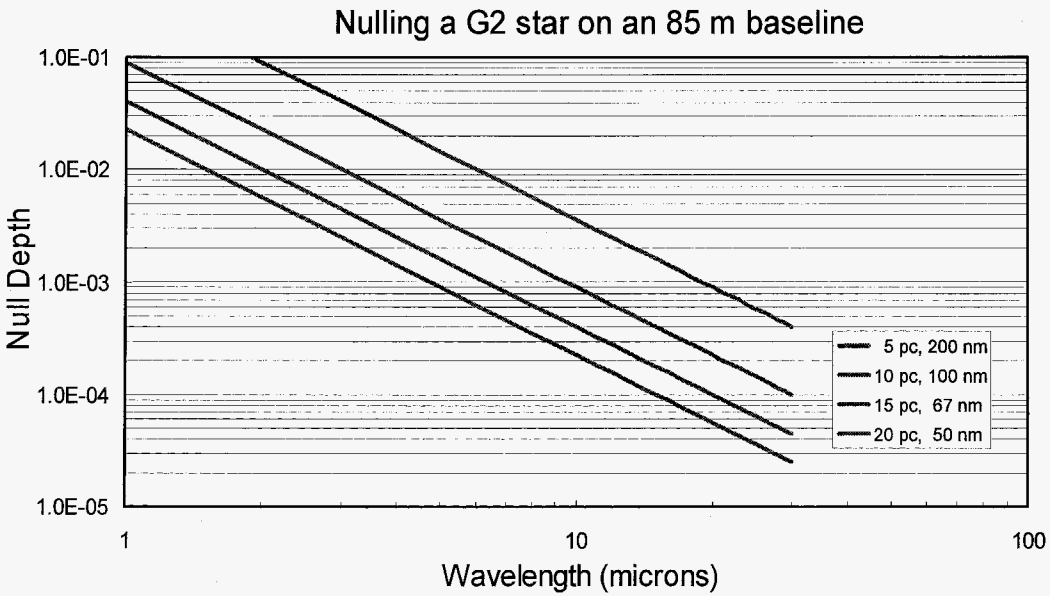
Keck Nuller Main Science Objective: Detection of Exozodiacal Dust

- Baseline = 30 zodis
- 10 solar system zodis corresponds to 10^{-3} of star
- For G2 star @ 10 pc, λ =10 μm, b = 85 m, diam-limited null = 10^{-3}



1AU radius disk at 10 pc



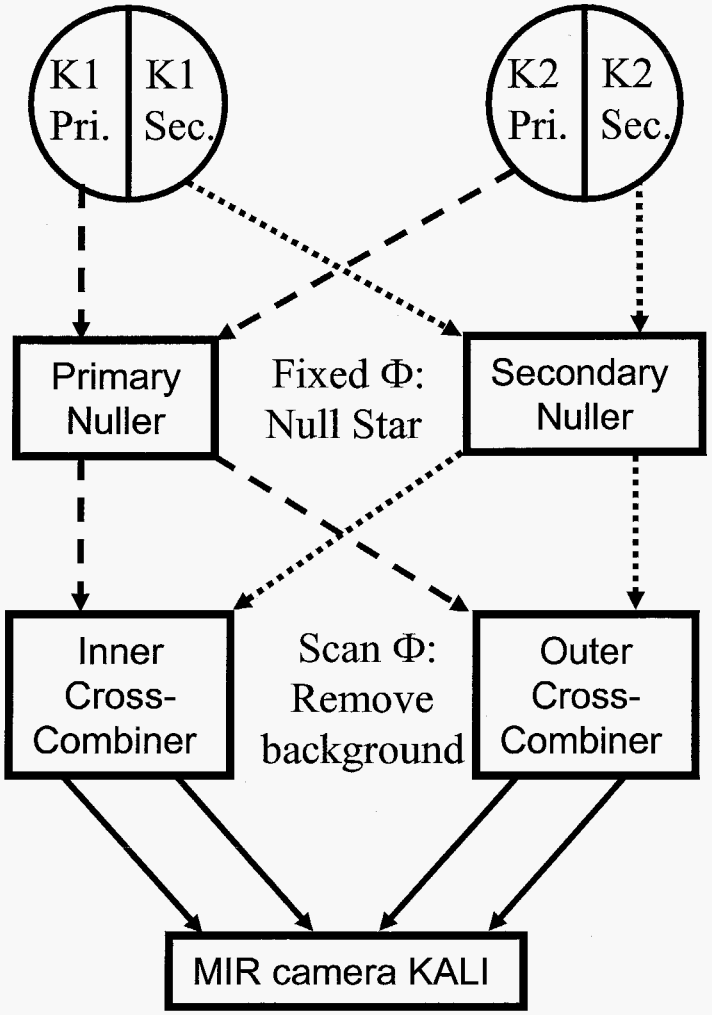


Configuration: dual nuller, dual cross-combiner

- Two extraneous signals:
  - Strong light from central star
  - Strong 10-μm background
- Need to remove both

  ⇒ two-step removal

4 Sub-aperture beams
4 beams to MIR beamcombiner
4 beams to MIR camera

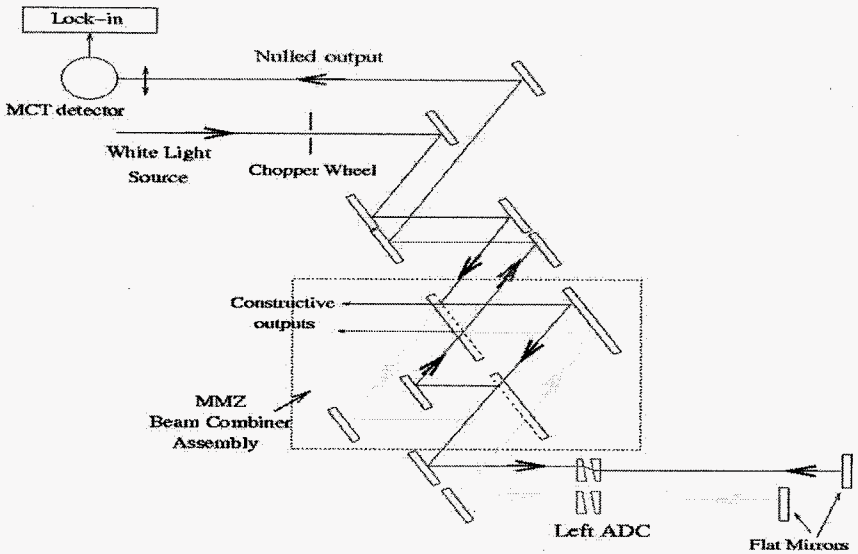


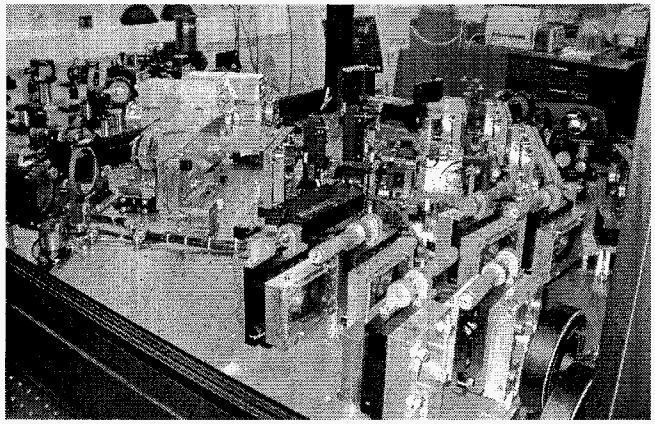
Step by step …

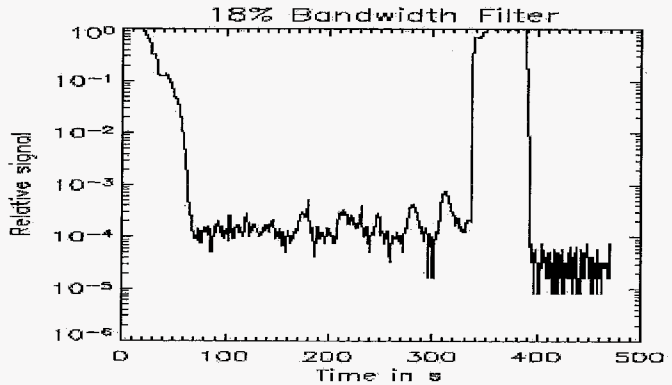
- Beam combiner testing (completed 09/03)
- Full lab set-up I&T (completed 05/04)
- Summit install (> 06/04)
- First 10 micron fringes (08/04)
- Primary, secondary and cross fringes (10/04)
- N band stable nulls using K band feed forward, metrology and dispersion correction (>05/05)
- Performance optimization (>05/05)

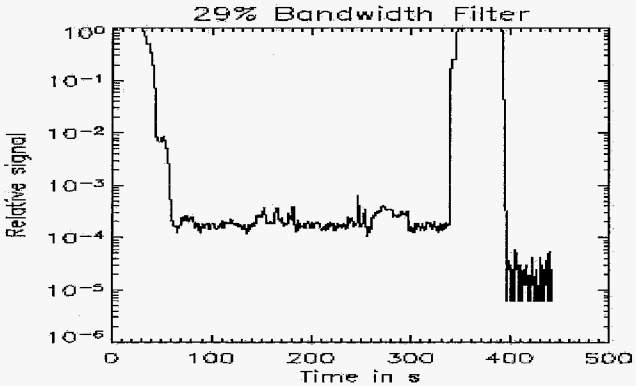
Initial lab tests

09/2003: Nulling Mach Zender beam combiner + Static Dispersion Correction testing 10^4 :1 broad band MIR nulls achieved



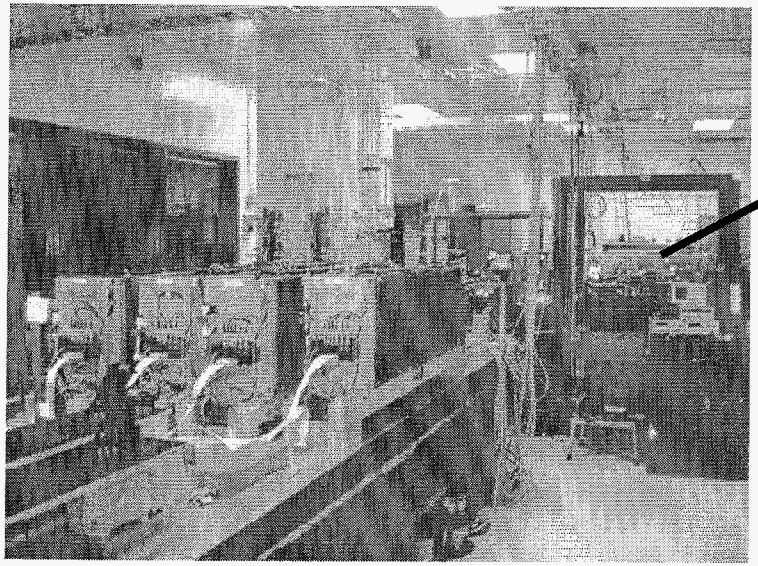


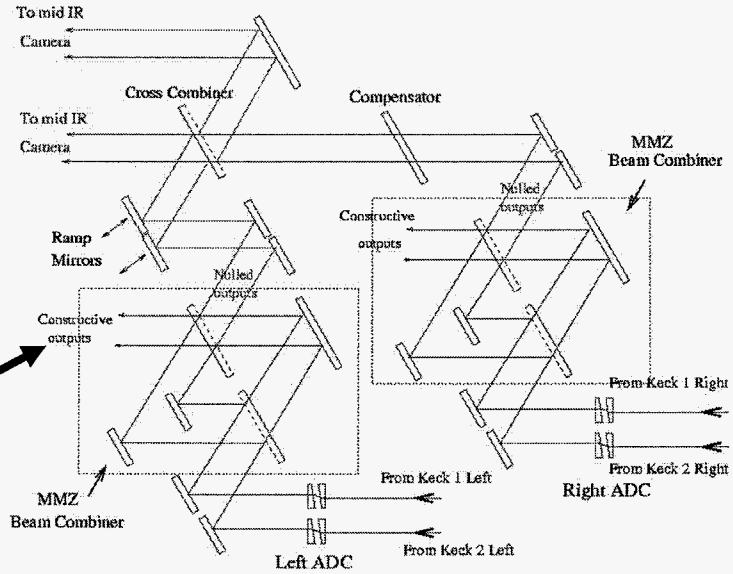


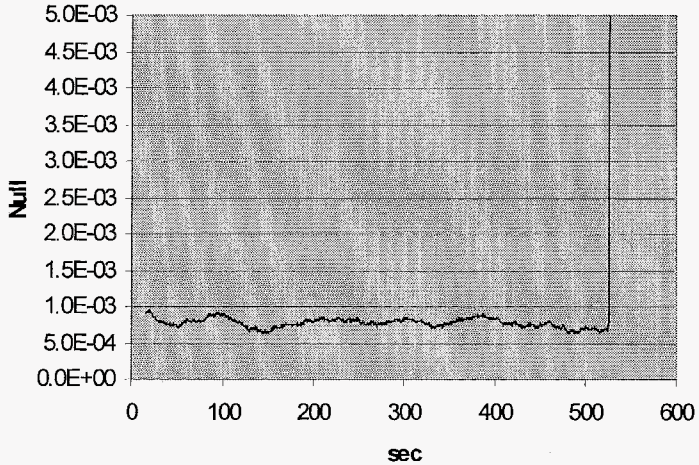


Full laboratory I&T

05/2004: Full basement system with 4 fast DL, 4 passive DL, LASER metrology, MIR He Cooled Camera

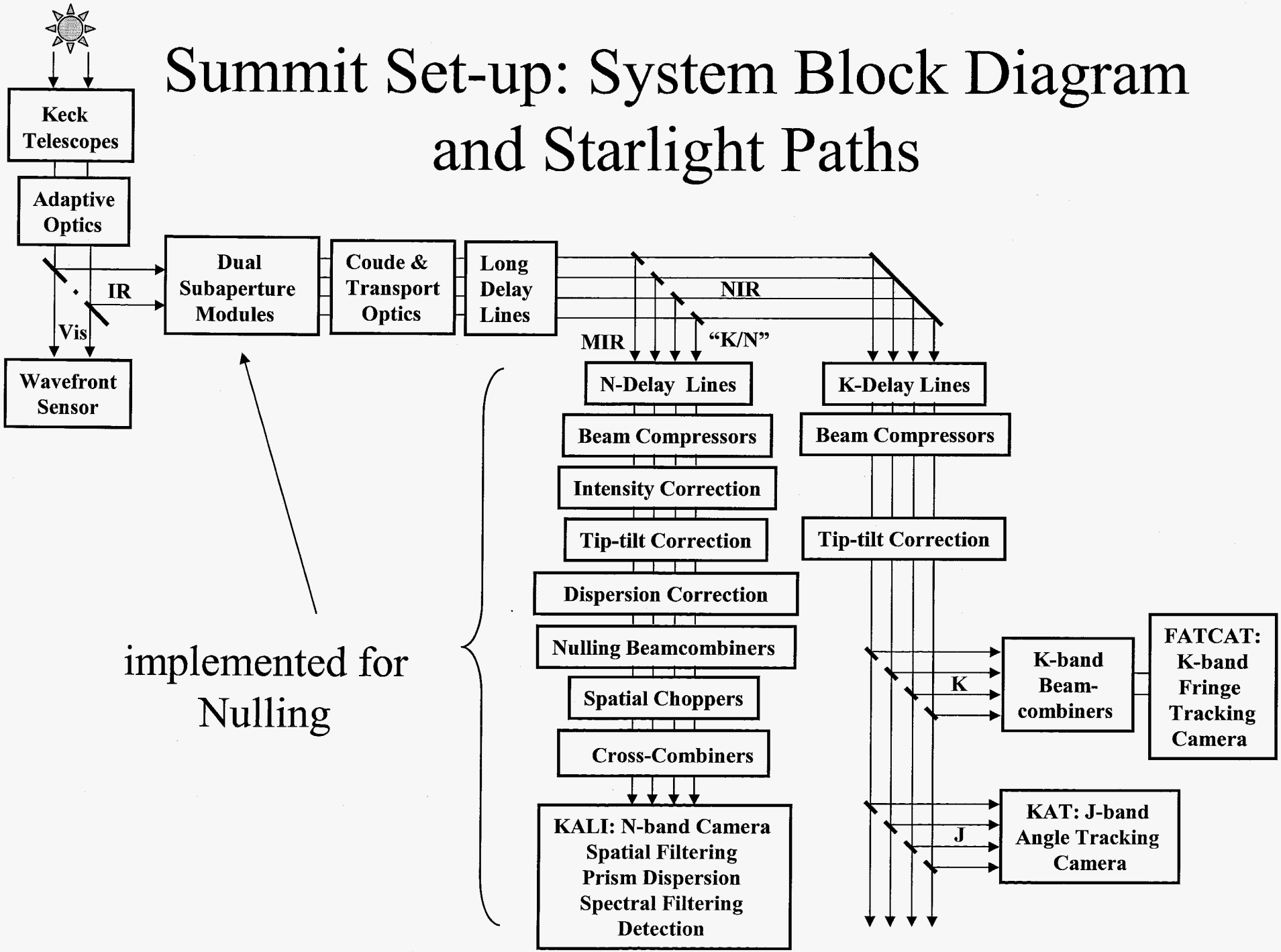




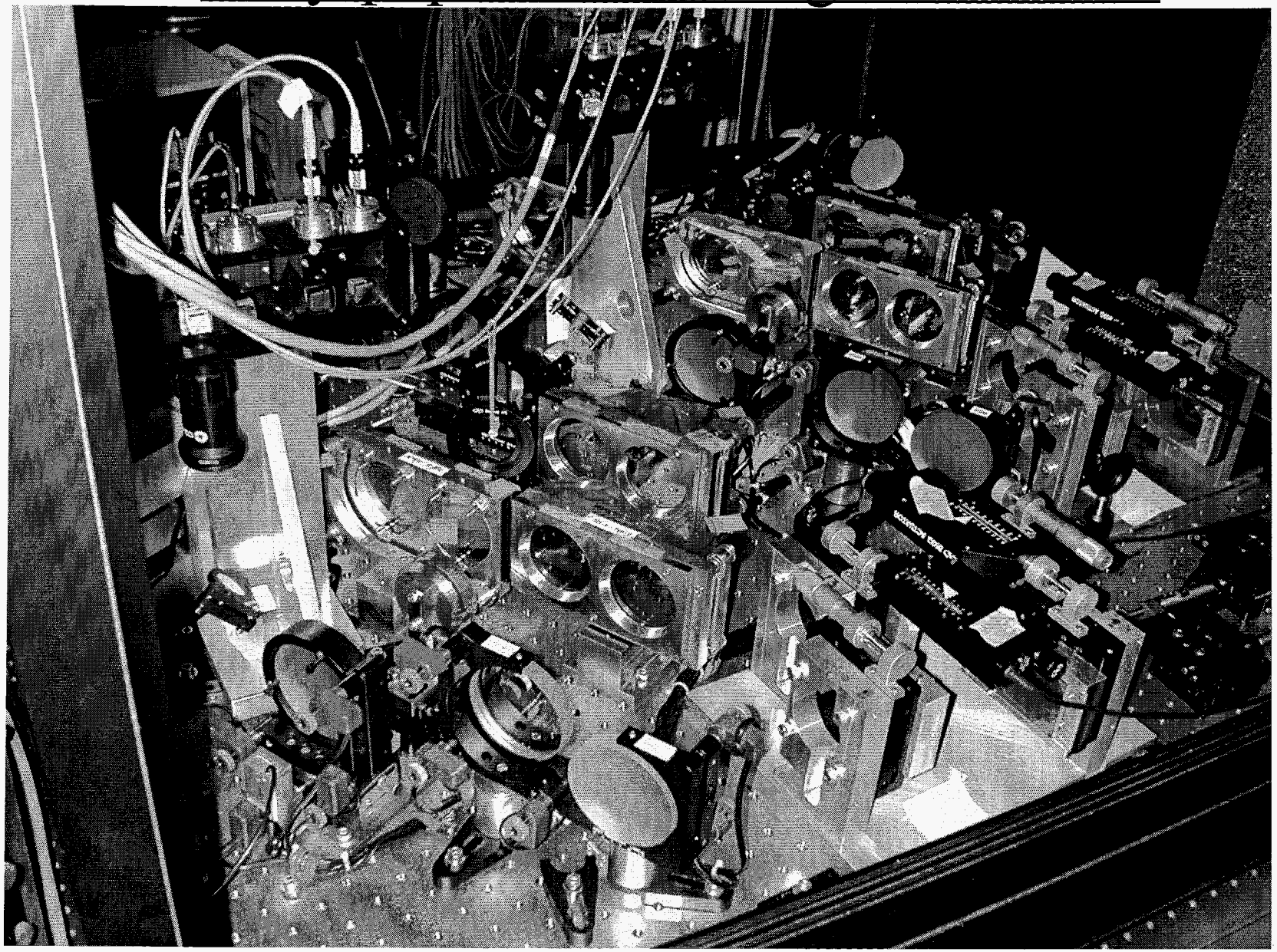


> 1000:1 stable null, repeatability over 48 hrs

Summit Set-up: System Block Diagram and Starlight Paths



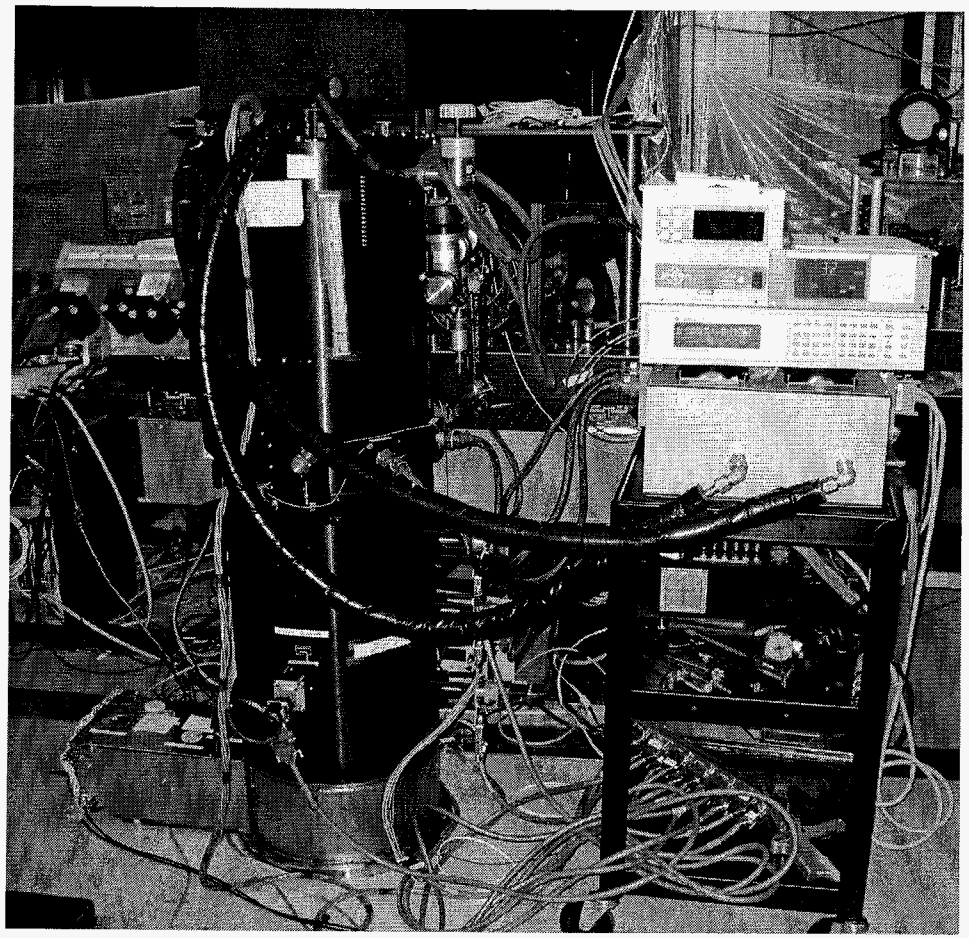
Fully-populated Nulling Breadboard

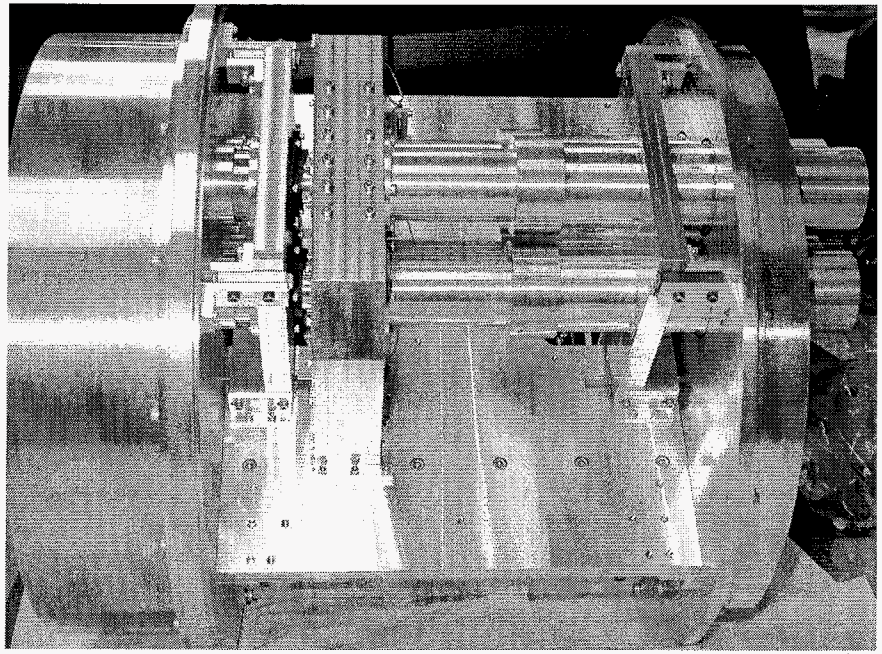


Measured one-way MIR transmission of nulling breadboard = 80%

MIR KALI Camera I

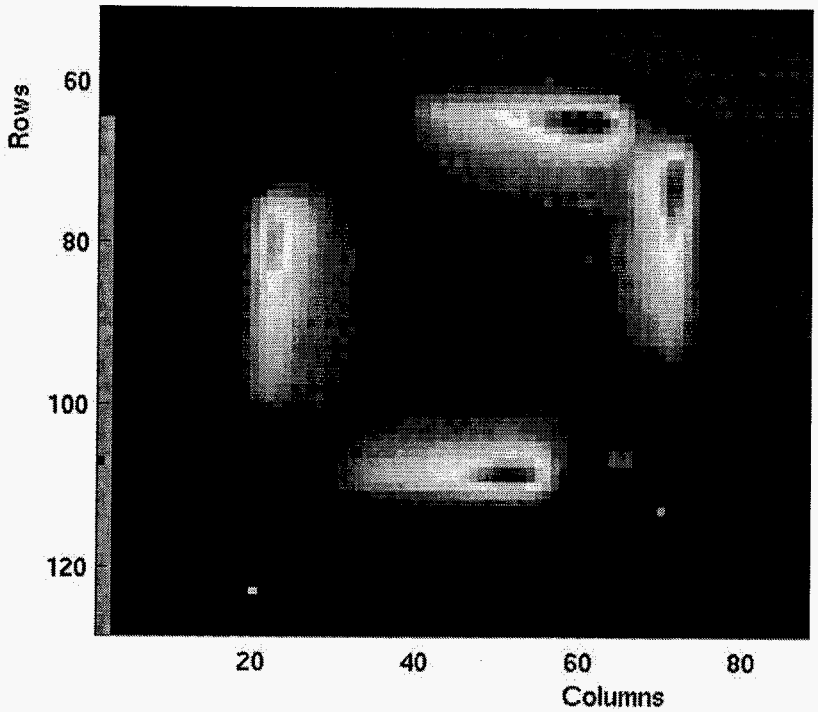
- Four input beams
- Pupil stops
- Focus stages (2)
- Pinholes
- Filters
- Direct view prisms
- 128x128 det. array

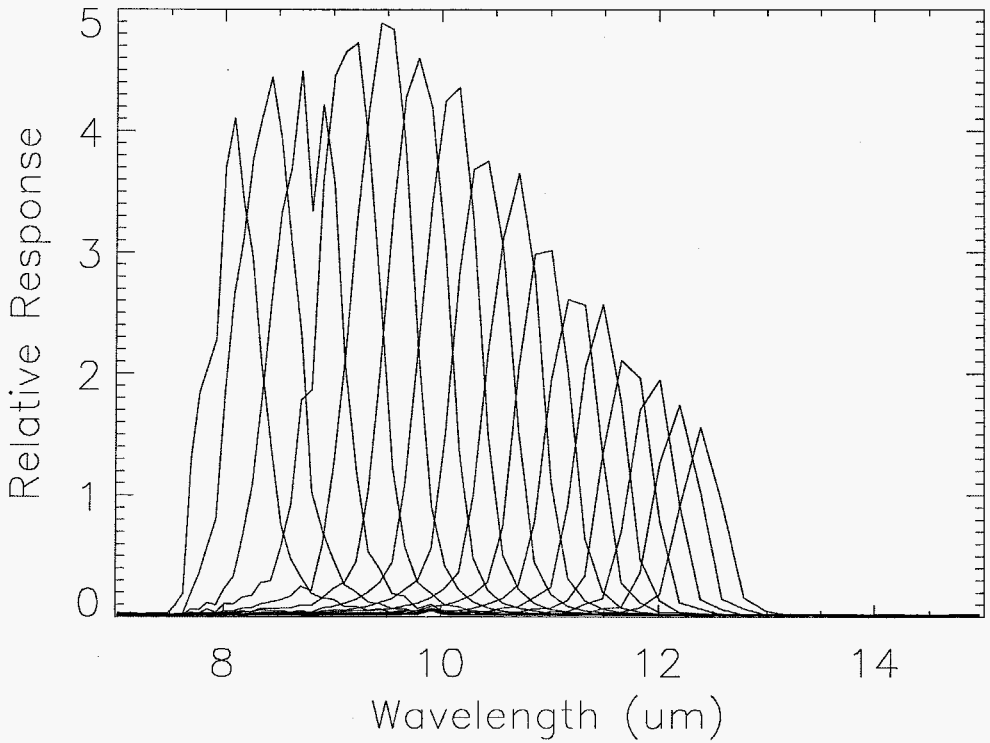




MIR KALI Camera II

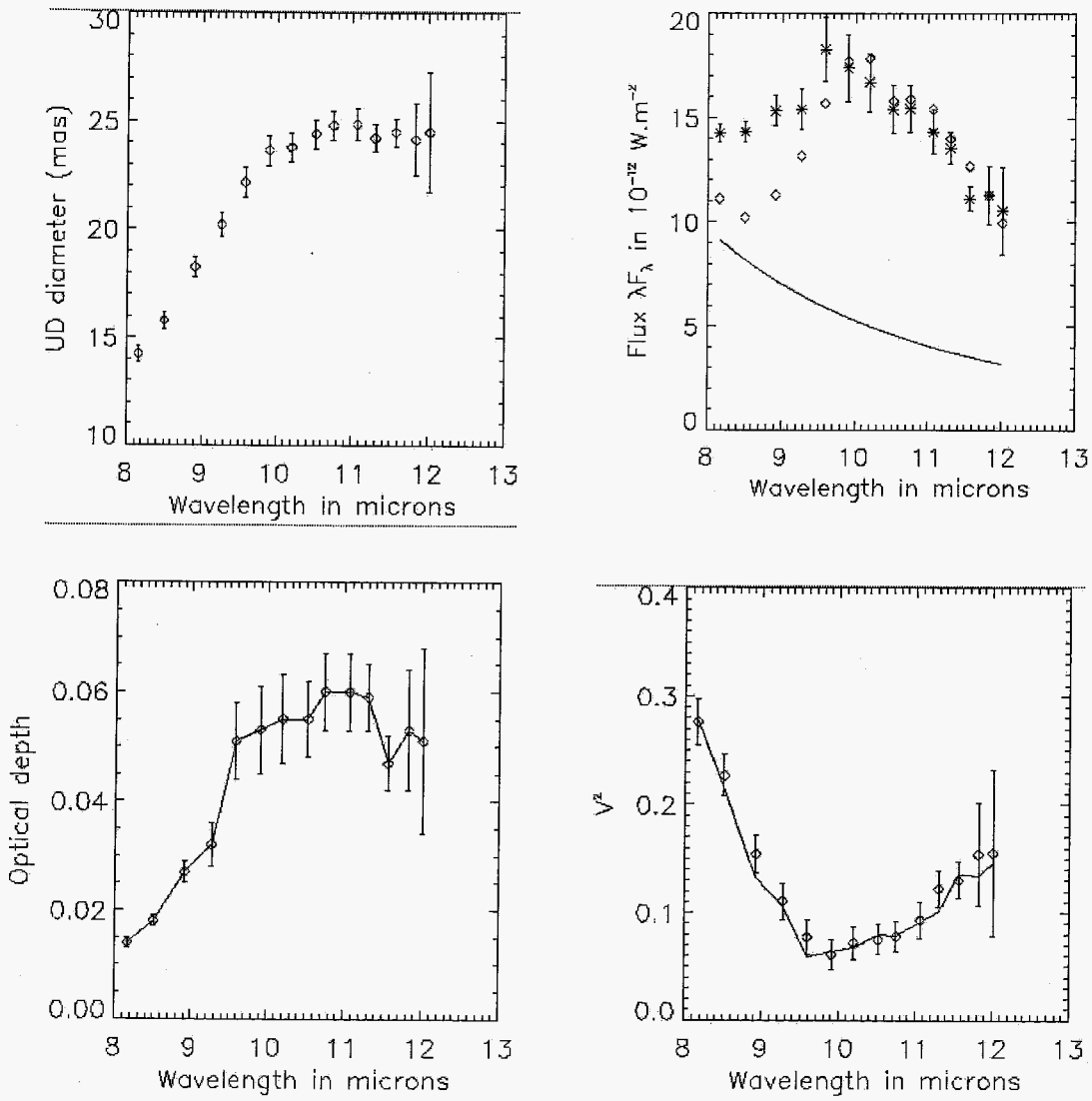
Camera aligned & focused; background-limited
All four beams co-optimized





First fringes (Aug 04)

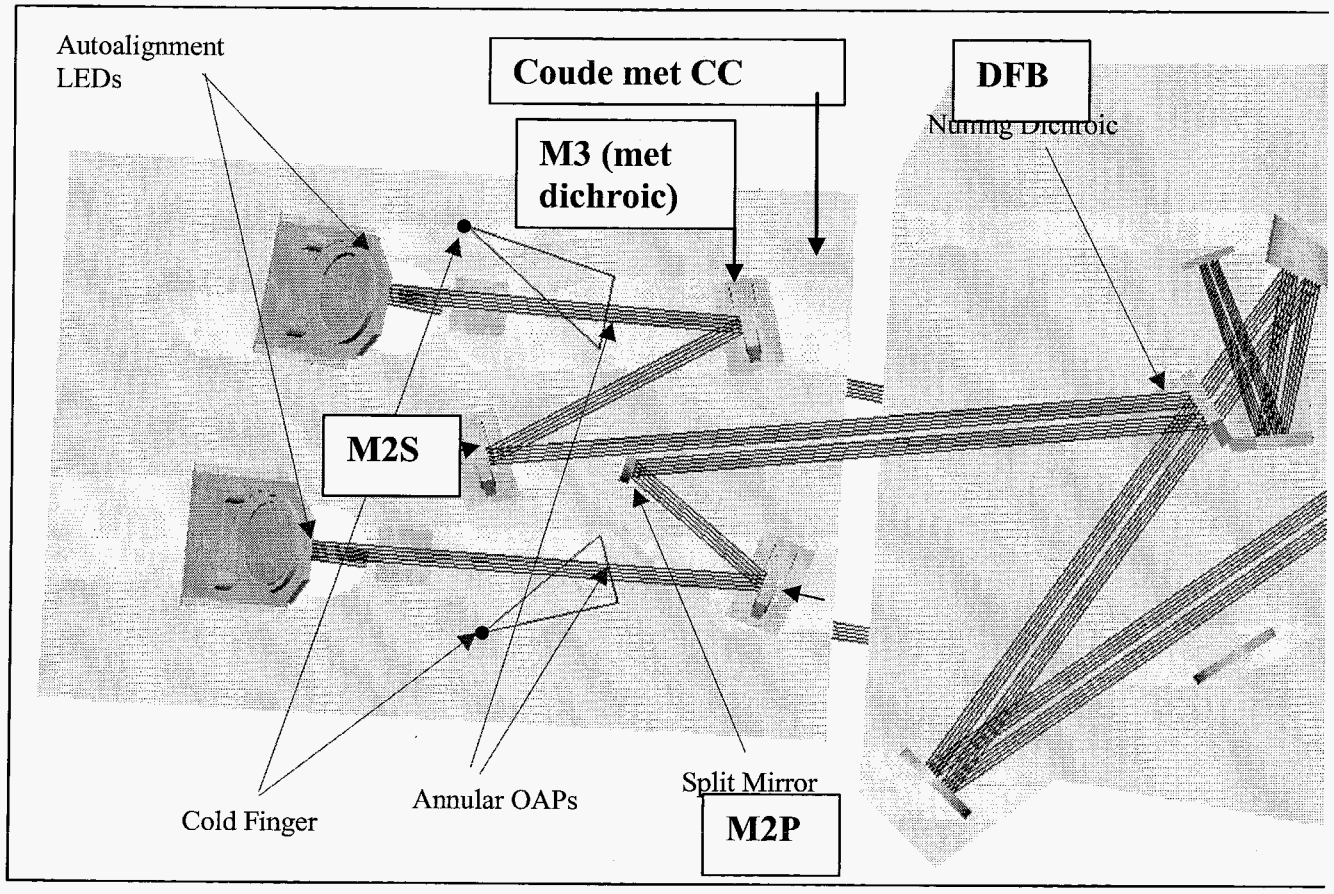
full telescopes - slow N band fringe tracking only



Observations of the dusty AGB star RS CrB
(Mennesson et al. 2005, ApJ Letters, in press)

Best fit model (star+ thin dust layer):
T*=3100 K, Tshell=1160 K
R*=1.9 mas, Rshell=13.8 mas
$\tau_{max} = \tau_{11\mu m} \sim 0.06$

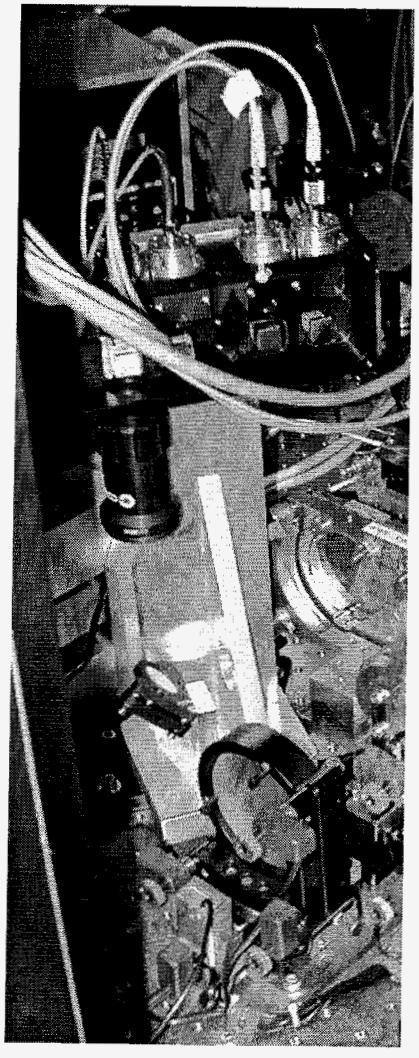
Operation in split pupil mode

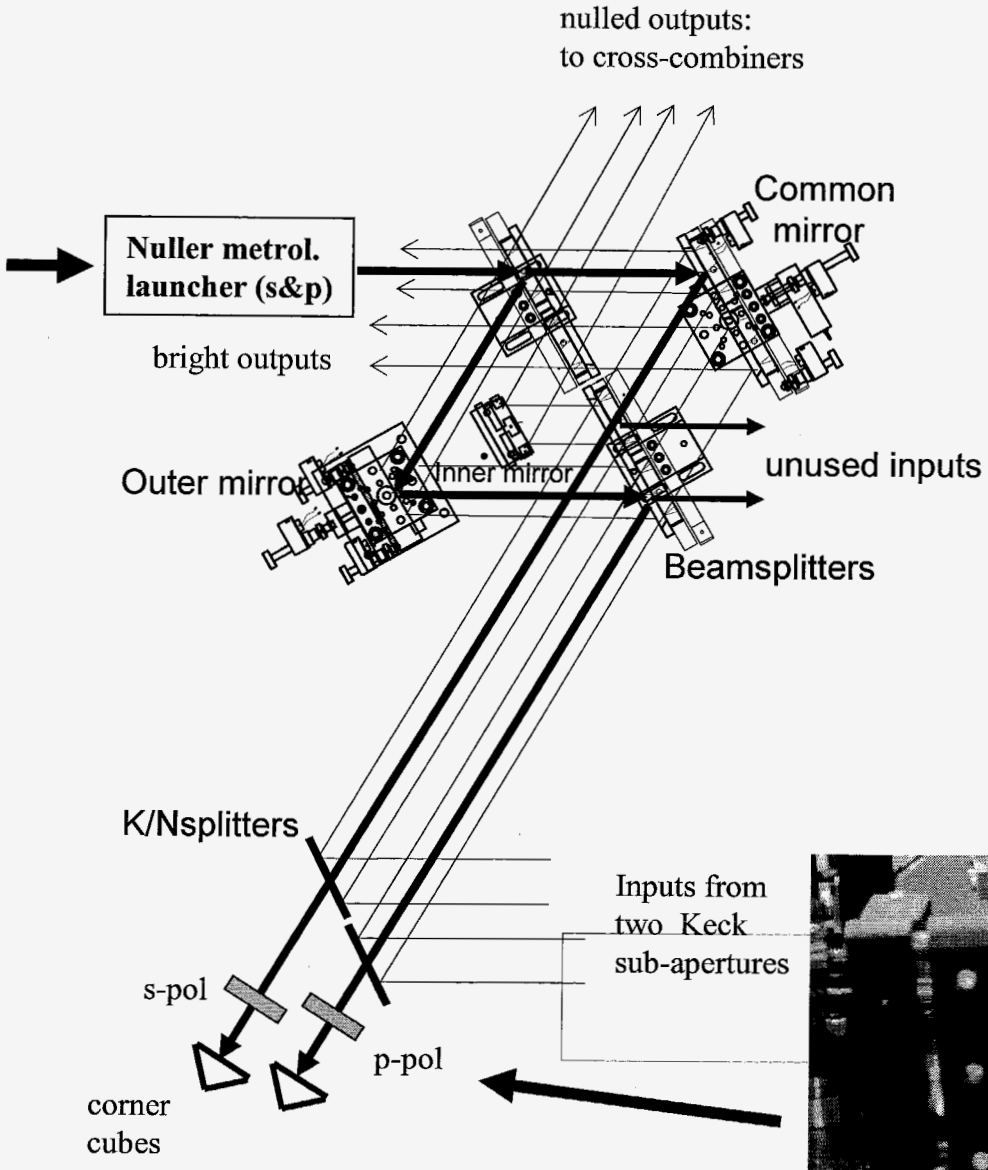


- Half Mirrors and additional Coude metrology installed
- Primary and secondary fringes obtained (09/04)
- Cross fringes (10/04)

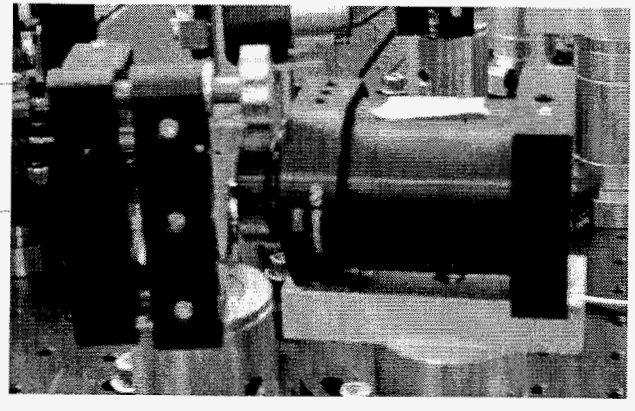
Nuller Metrology Configuration

Launcher

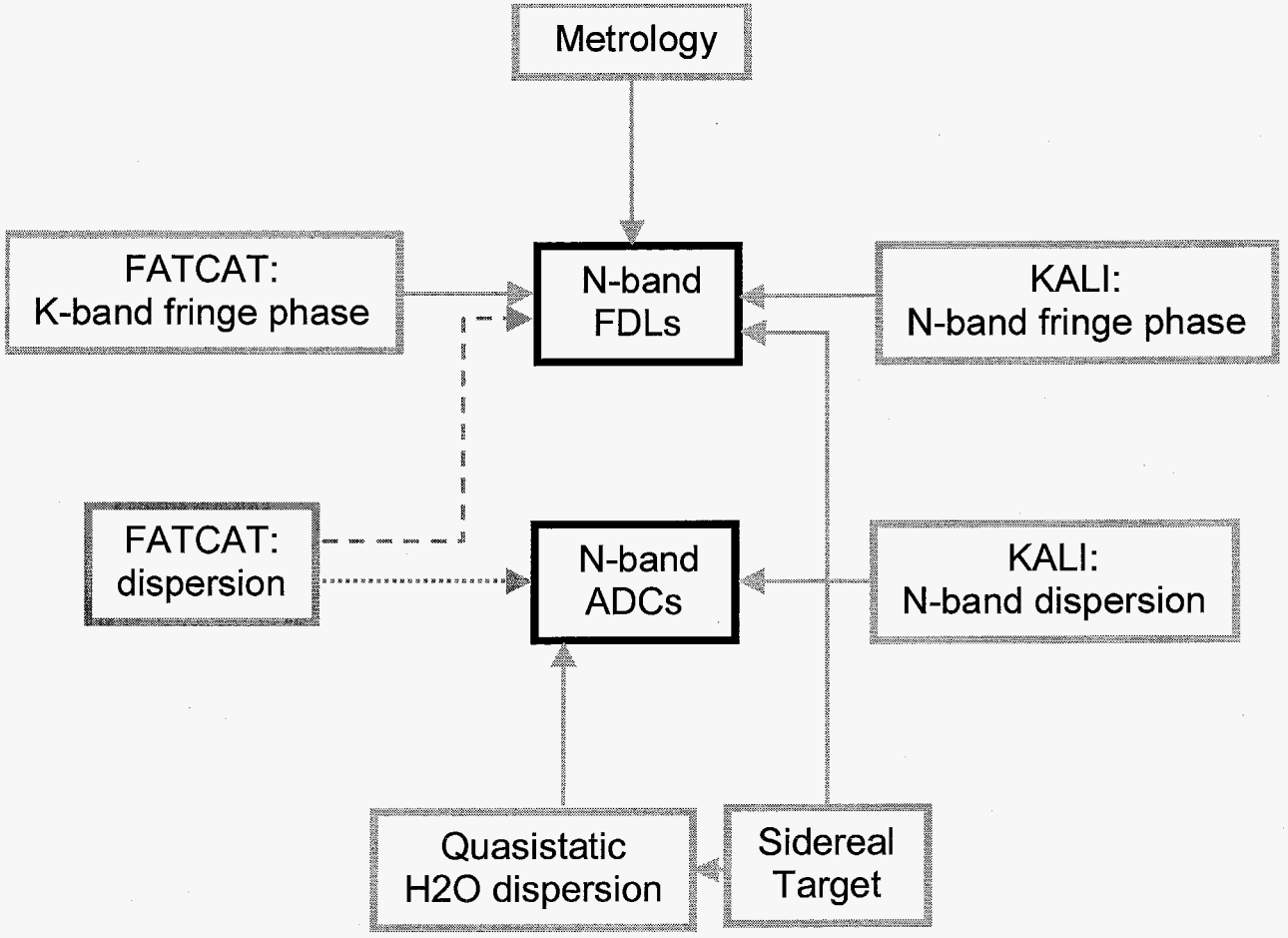




Retro-reflector

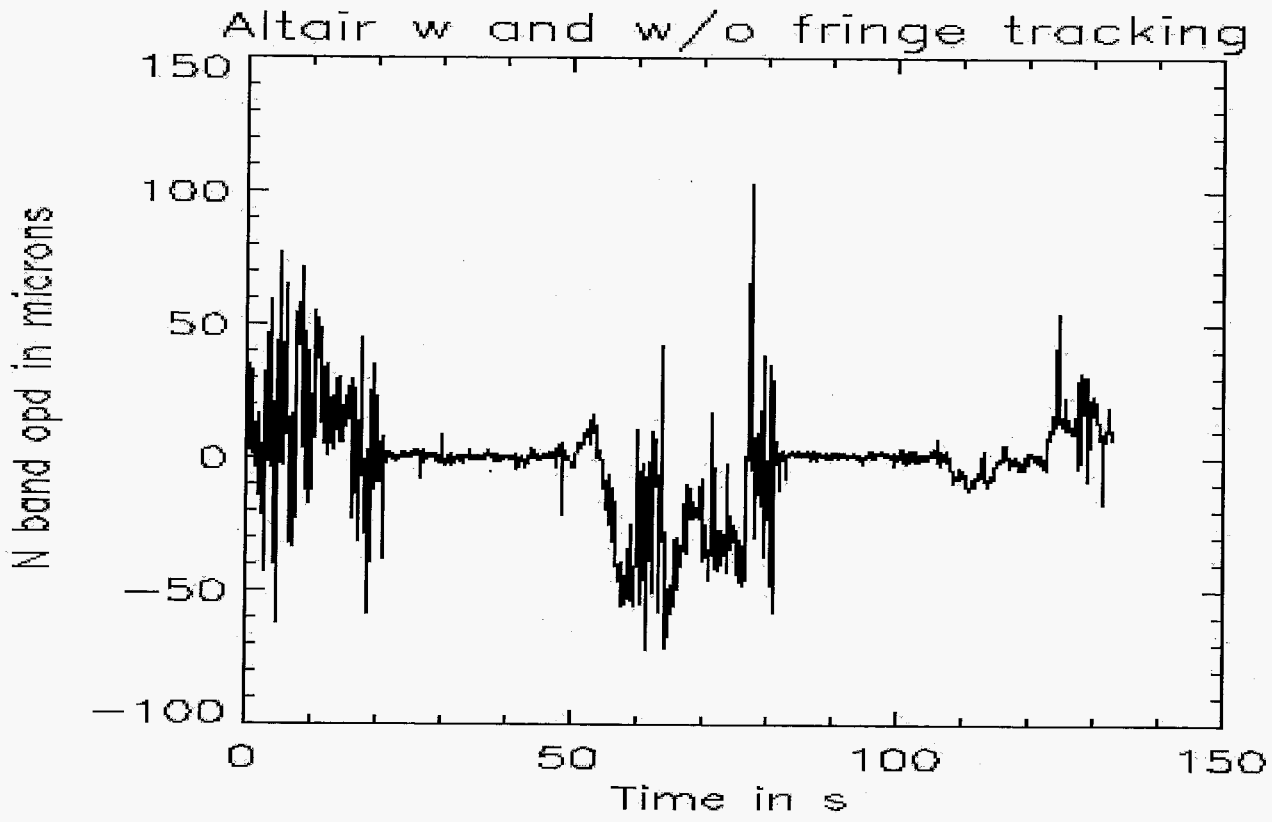


Overall Control Configuration



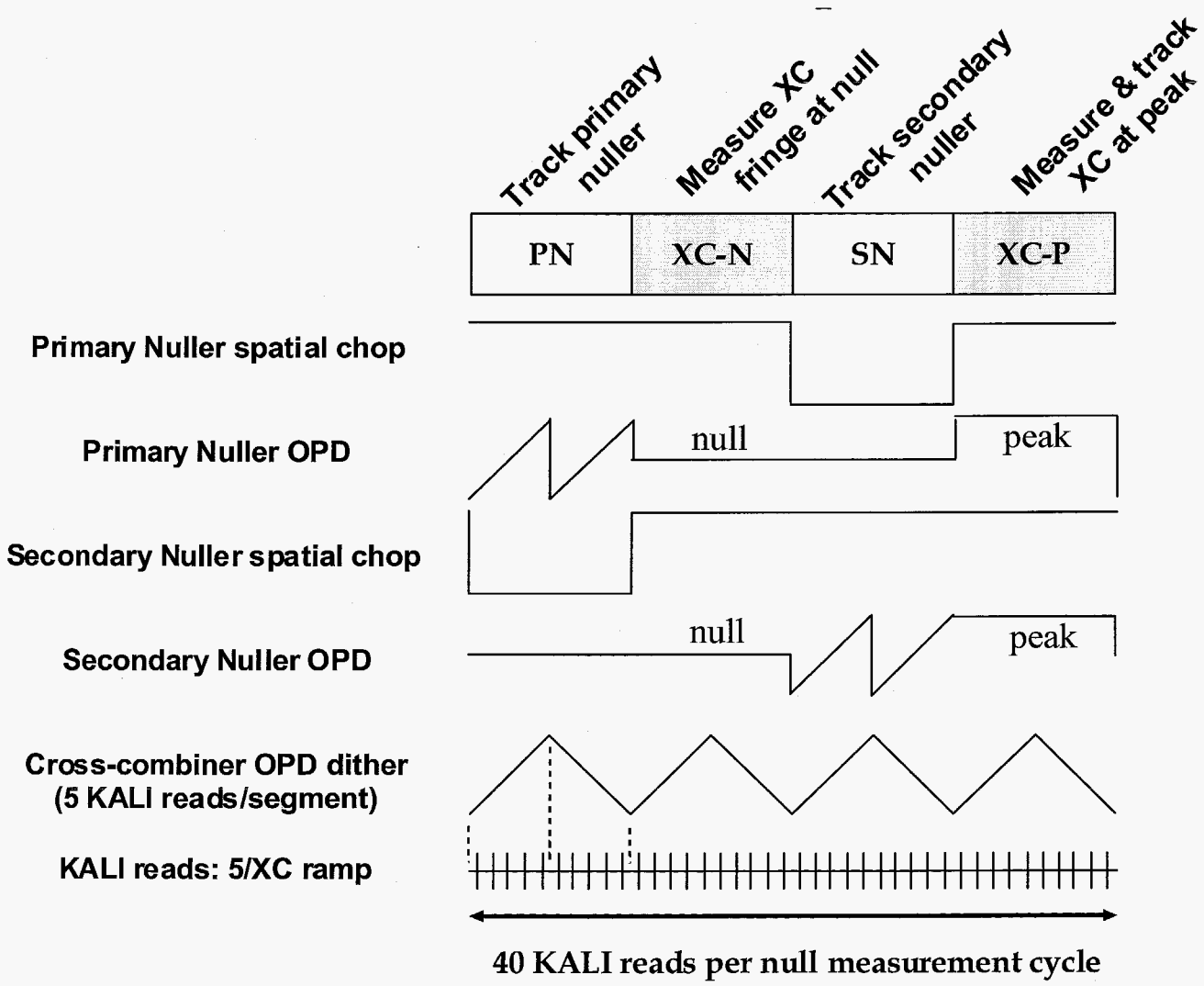
- Sources not bright enough at N-band for high-speed fringe tracking
- ⇨ Use K-band light and metrology to "feed-forward" stabilized paths

Feed-Forward Test on Altair



- May 2005
- K band Feed-forward loop, no LASER metrology
- Gain of MIR loop set to zero

Null Measurement Sequence

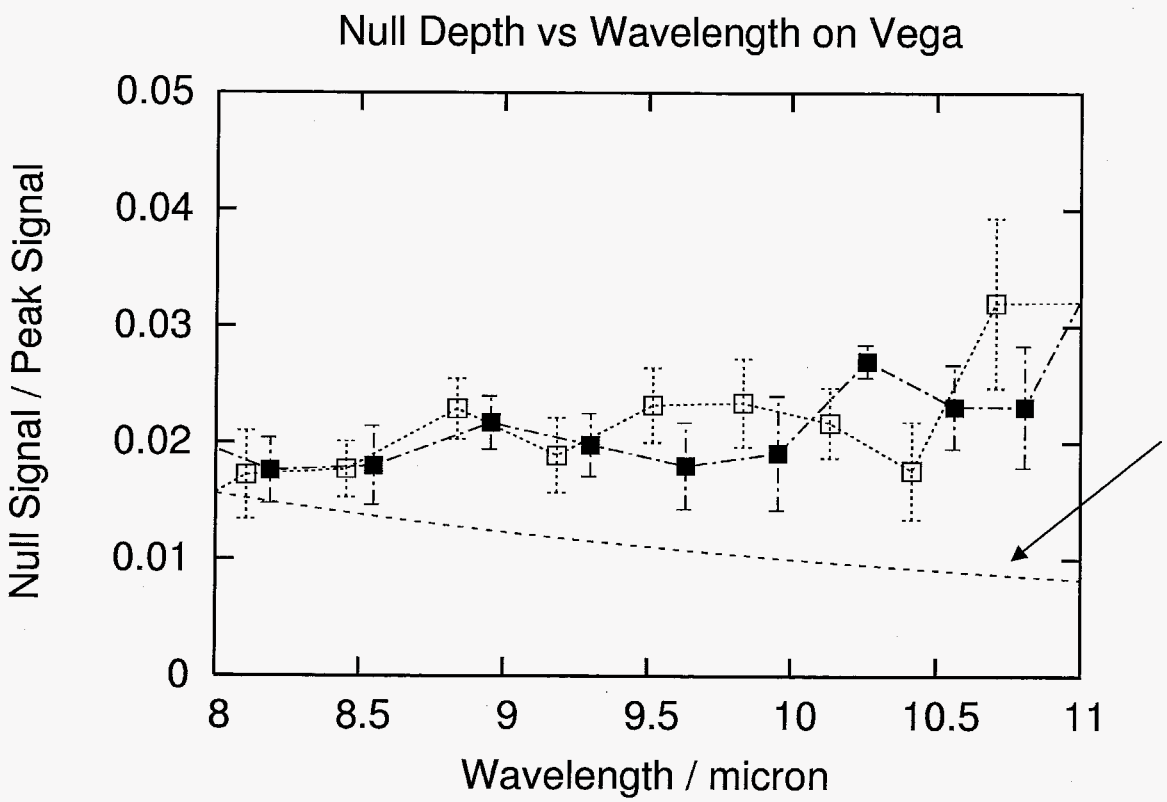


Null = destructive/ constructive XC fringe amplitude

25 ms/ramp

5 ms/read (200 Hz)

Null Depth Measurement on Vega (Aug 2005)



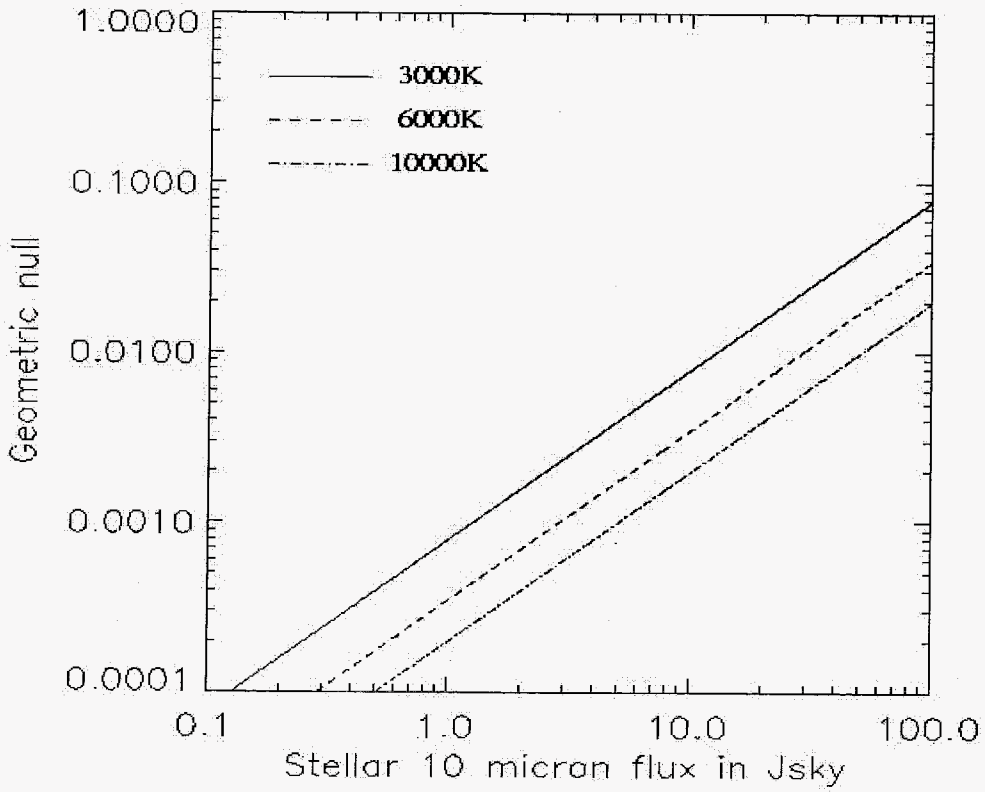
Expected geometric null for 3.24 mas uniform disk

- Coherent demodulation
- Stellar contribution >0.01 ==> Instrumental null of <0.01

Status

- ✓ First Keck MIR interferometry astronomy paper in press
- ✓ Components and functionalities necessary for null measurements are in place at Keck
- ✓ Initial result: actively controlled 10^{-2} stellar null achieved

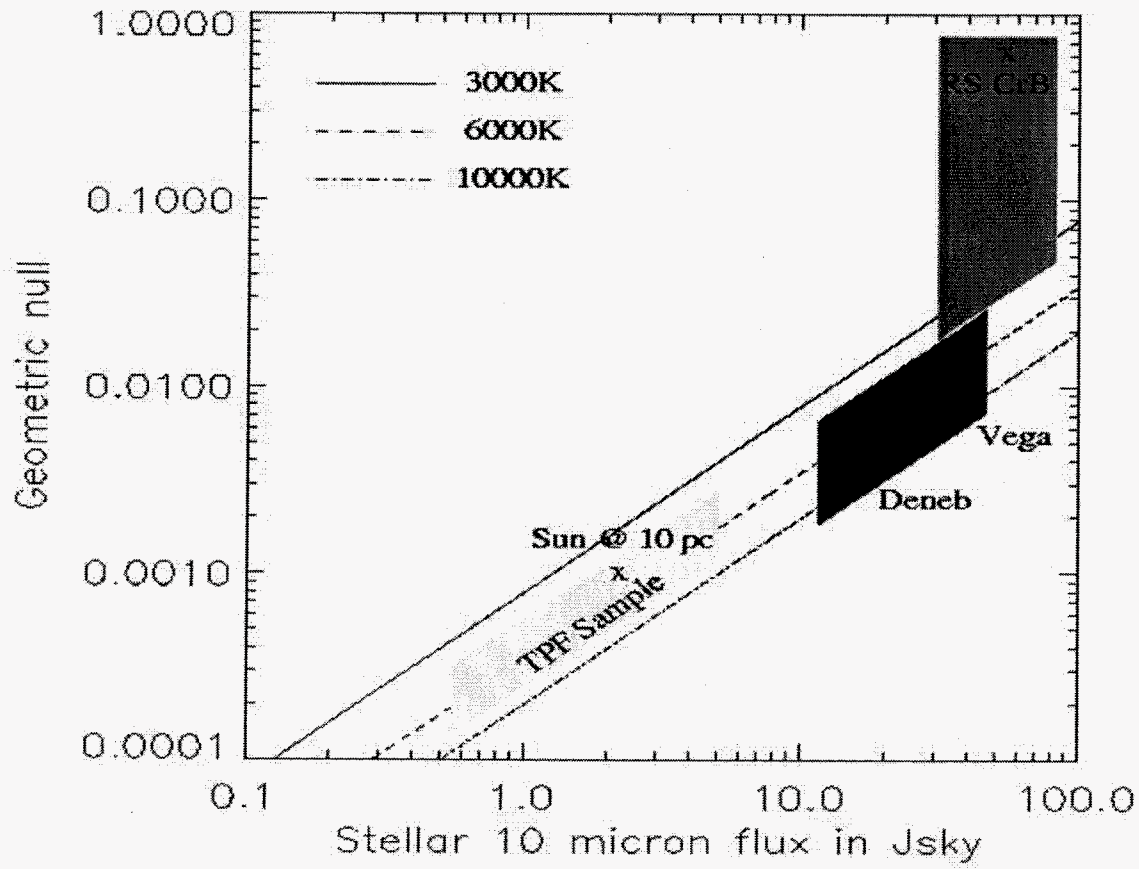
Performance Summary



NB: for a naked star seen as BB with temperature T > 4500K, flux density F_ν in J, interferometric baseline b=80m, λ=10 μm:

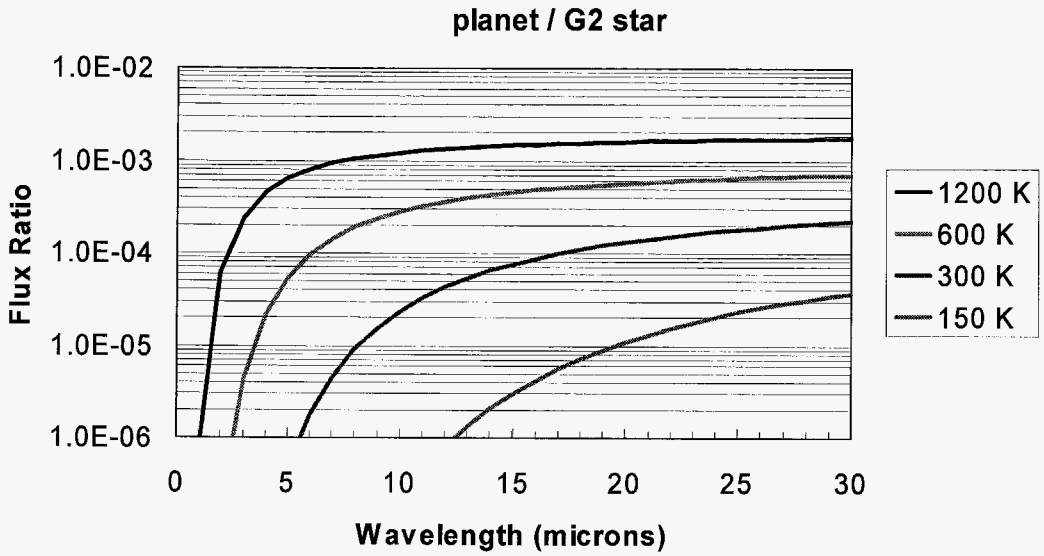
$$\mathbf{N \sim 2.F_\nu/T}$$

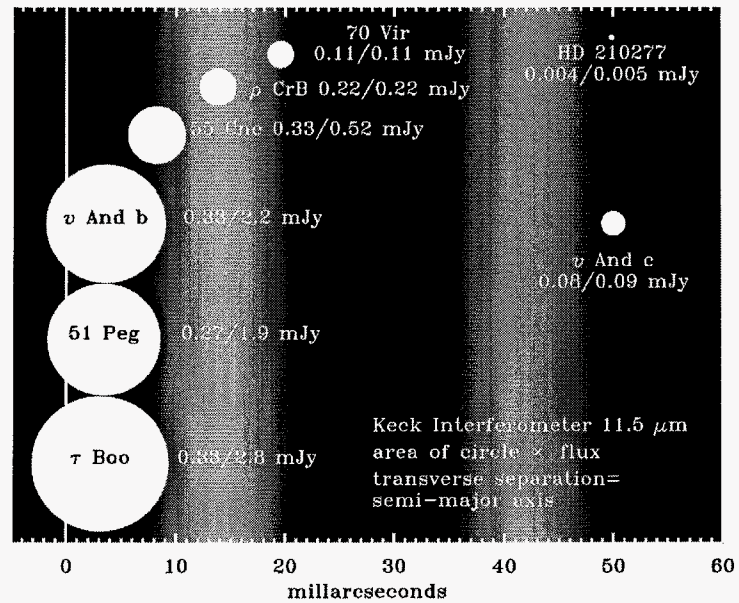
Performance Summary



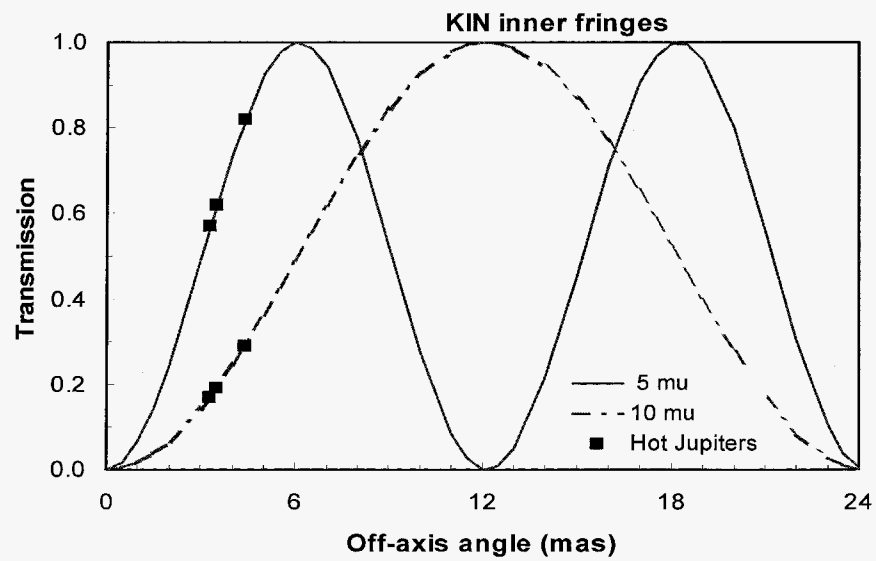
Back-up Slides

Hot Jupiters with ground-based nulling?

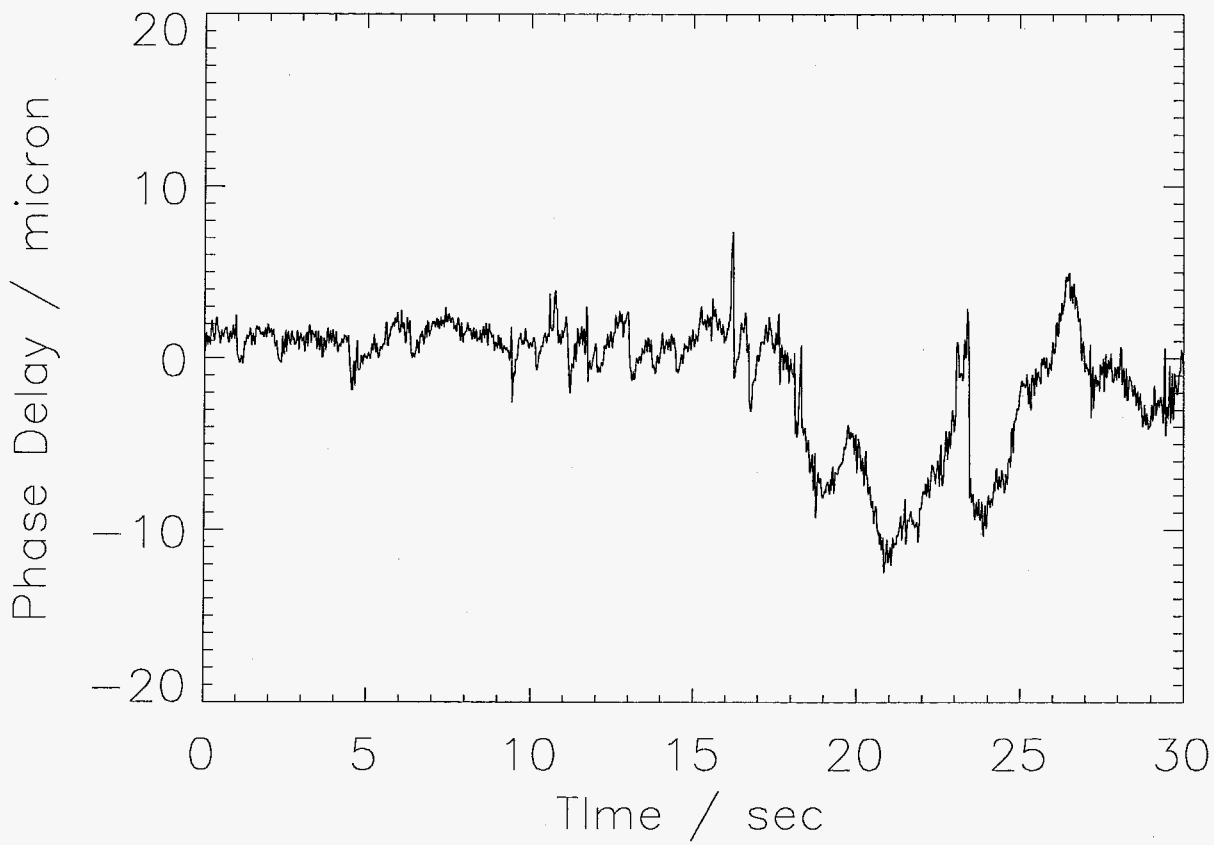




- First fringe maximum: $\theta_{max} = \lambda/2b$
- Equilibrium temp. there: $T \approx 300\ (b_{10}/d_{10}\lambda_{10})^{1/2}$
- Orbital Period: $P \propto b^{-1.5}$
- Short periods and wavelengths will help!

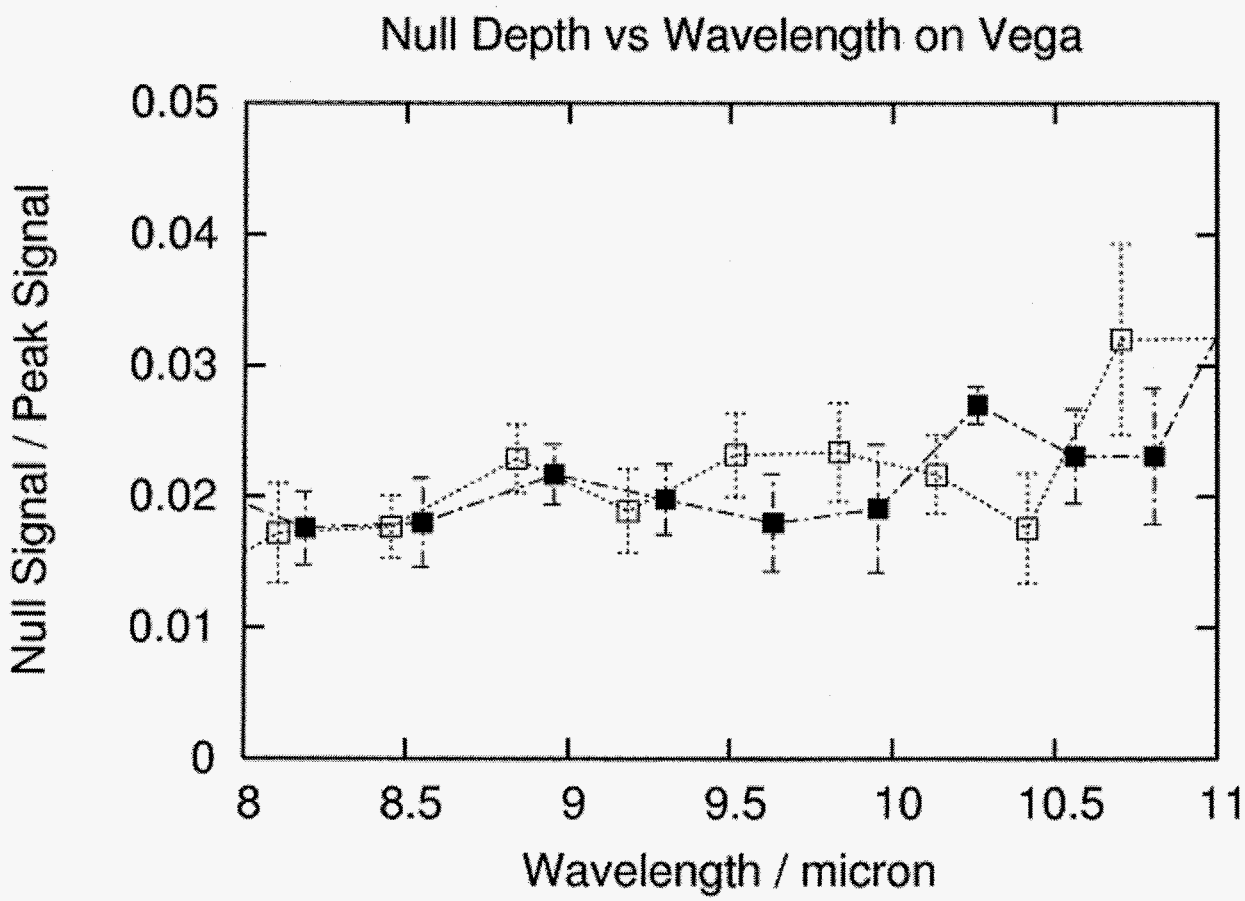


Feed-Forward Test on Altair



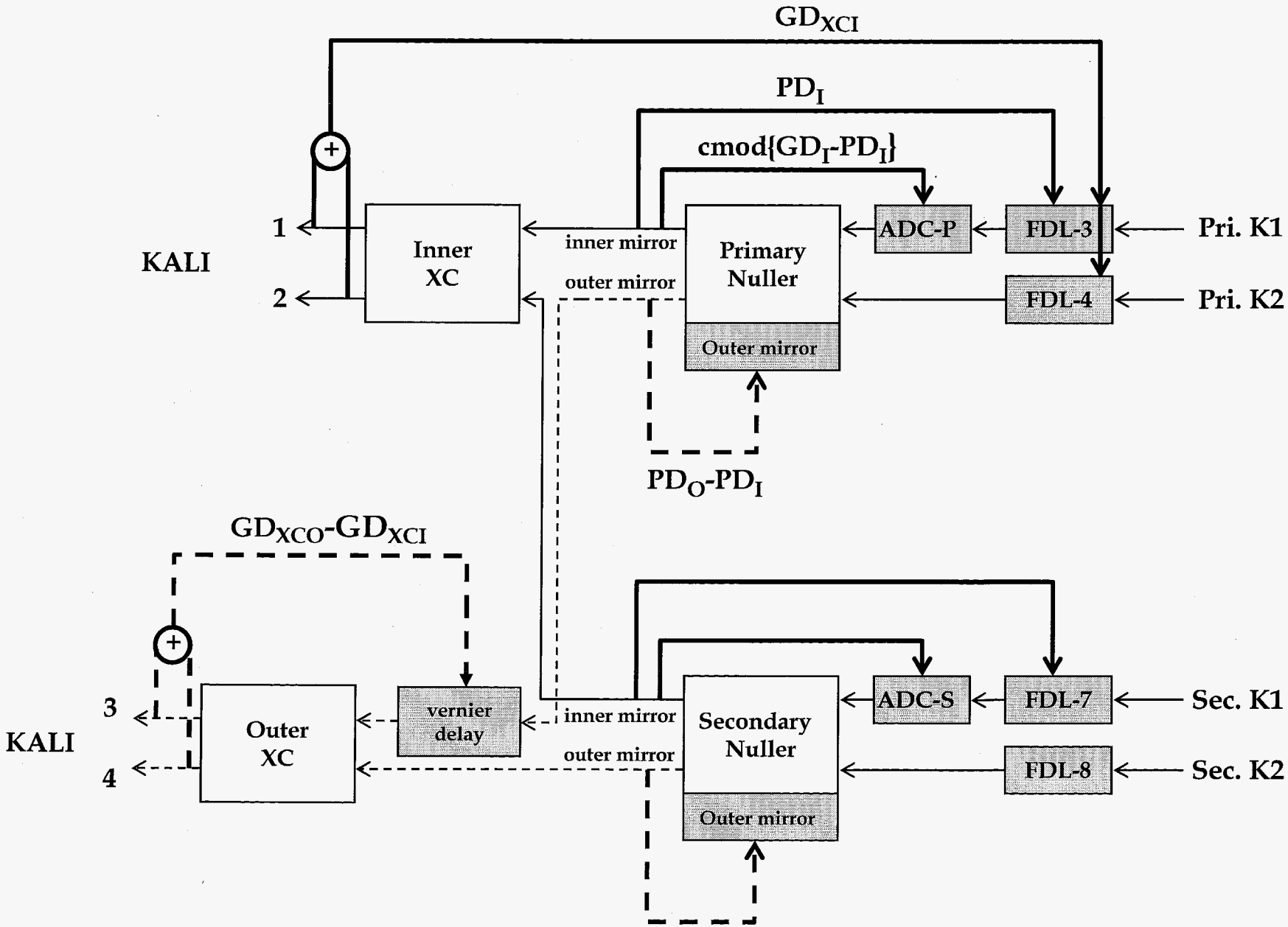
- May 2005
- Feed-forward loop turned off at about t = 15 sec
- Gain of MIR loop set to zero

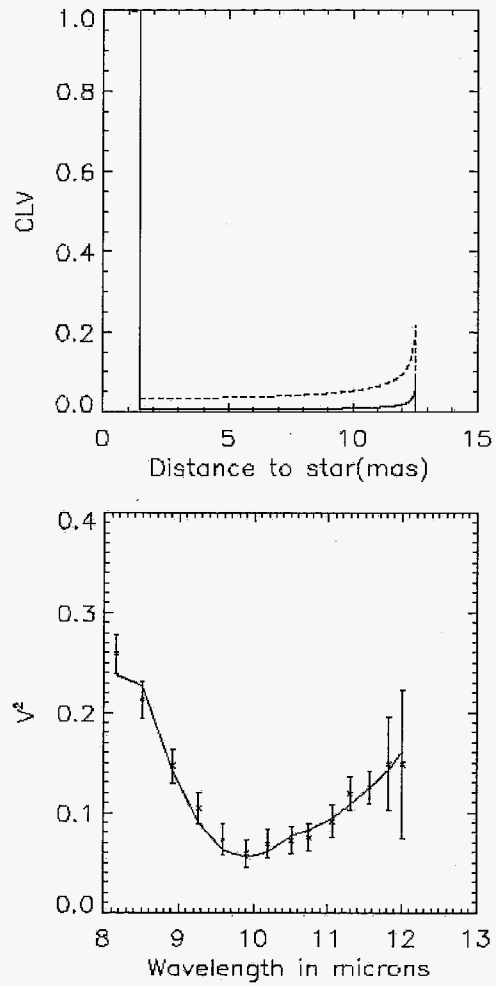
Null Depth Measurement on Vega (Aug 2005)



- Coherent demodulation
- Stellar contribution 0.01 ==> Instrumental null of 0.01

MIR Control Configuration and Status




1.0
0.8
0.6
0.4
0.2
0.0
CLV
0
5
10
15
Distance to star(mas)
0.4
0.3
0.2
0.1
0.0
V²
8
9
10
11
12
13
Wavelength in microns