FRINGE SENSOR UNITS FOR VLTI AND LBTI

Istituto Nazionale di AstroFisica – Osservatorio Astronomico di Torino

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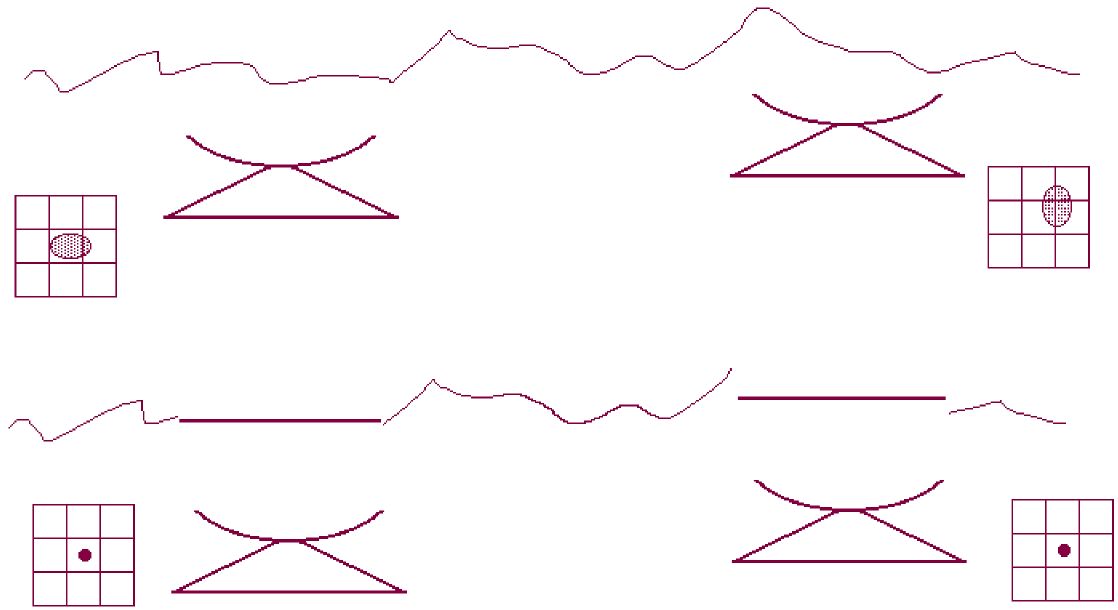
ABSTRACT

The Istituto Nazionale di Astrofisica - Osservatorio Astronomico di Torino (INAF-OATo) is developing the FINITO Fringe Sensor Unit (FSU) for VLTI, in collaboration with ESO. Also, INAF-OATo is part of the contract, led by Alenia Spazio, issued by ESO for construction of the PRIMA FSU.

The requirements for interferometric observation at VLTI and LBTI are reviewed, describing the function of an FSU and its interaction with the instrument complement, with reference to the current experience.

The main features related to VLTI FSUs and their application to a possible LBT implementations are discussed.

Atmospheric turbulence effects on visible / IR interferometry

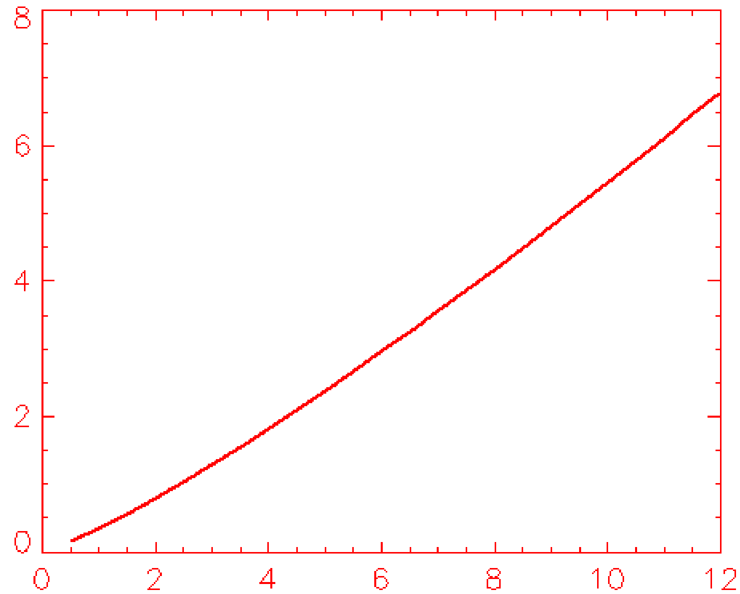


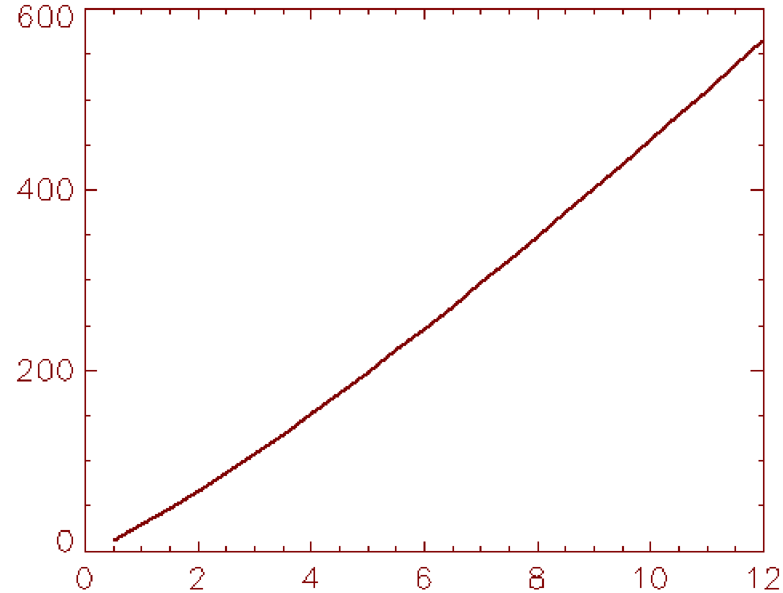
At the single telescope level, **active** and **adaptive** optics aim at generation of a focal plane image close to the diffraction limit

One-dimensional external delay = observing direction, controlled against atmospheric piston by a linear actuator: the Delay Line in VLTI

Interferometric performance limited by AO performance AND residual piston

Coherence length and time vs. wavelength





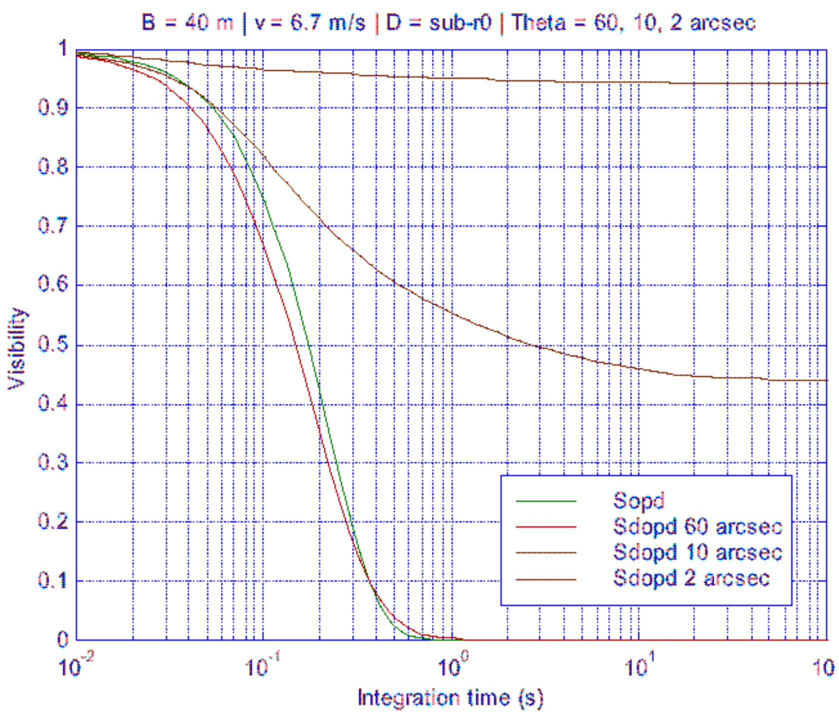
Coherence length [m] vs. wavelength [μm]   Coherence time [ms] vs. wavelength [μm]

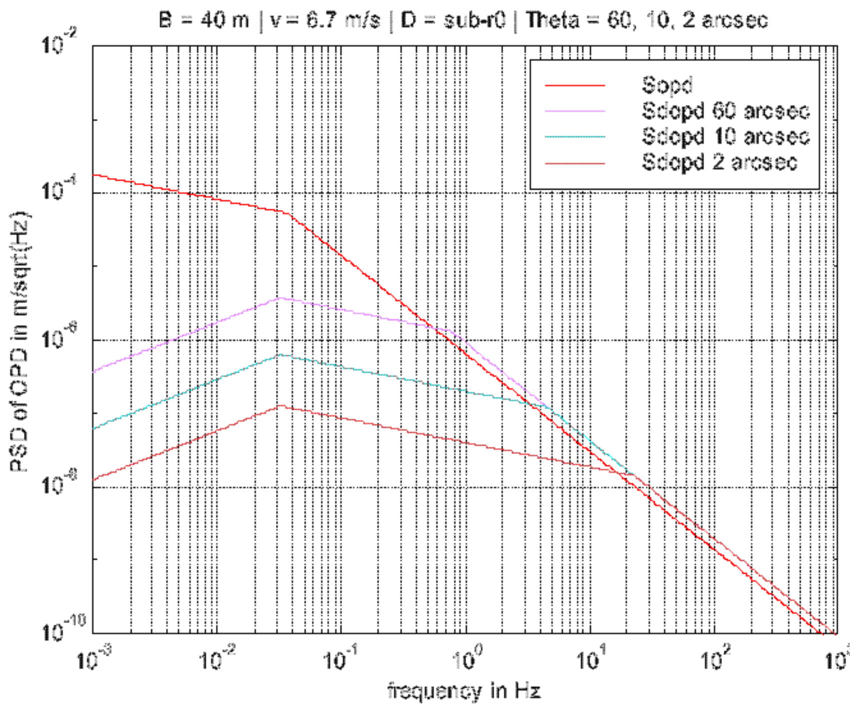
Conditions: $r_0=0.15$ m at $\lambda=500$ nm   wind speed: $V = 12$ m/s

Remark: requirements relaxed at increasing wavelength $r_0 \sim \lambda$ ^ $6/5$

For long exposures, fringe tracking is required whenever the telescope separation is significantly larger than the coherence length, i.e. few metres even for thermal IR!

Atmospheric piston noise and correlation vs. angular separation (VLTI simulation)





Limiting visibility, K band, vs. angular separation from the reference source

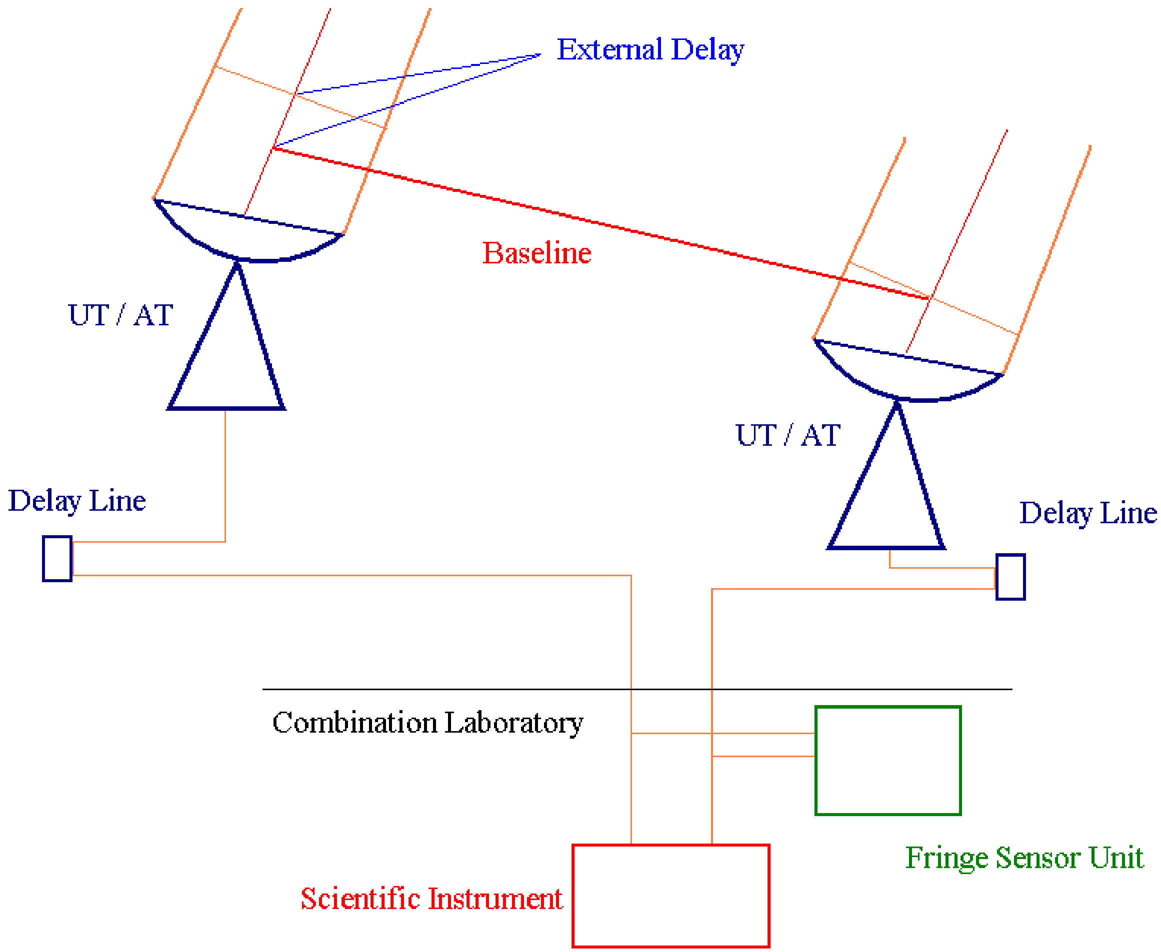
Power spectral density S_{OPD} of piston noise, and differential piston S_{dOPD} vs. field

Piston error correlation reduced at increasing distance

Potential sky coverage larger at longer wavelength

Low frequency PSD suppressed by fringe tracking loop

Fringe tracking loop: measurement and correction



Principle:

(a) locate fringes with a Fringe Sensor Unit (FSU) on short exposures of bright reference target (magnitude ~ AO case)

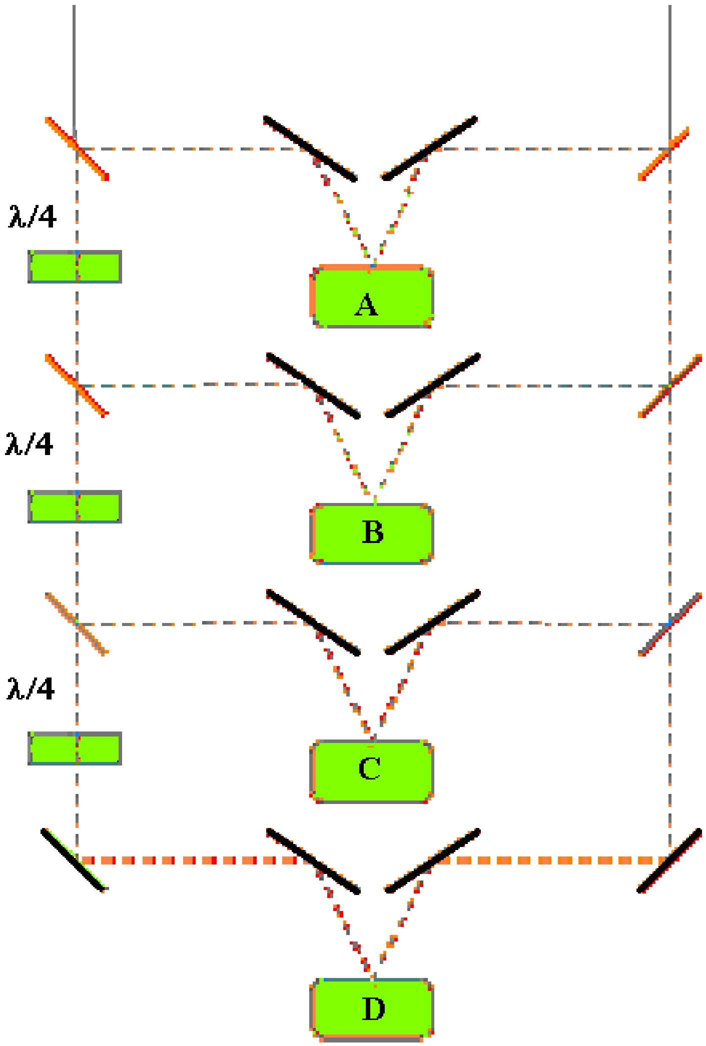
(b) feedback on Delay Lines (actuator) to stabilise the optical path

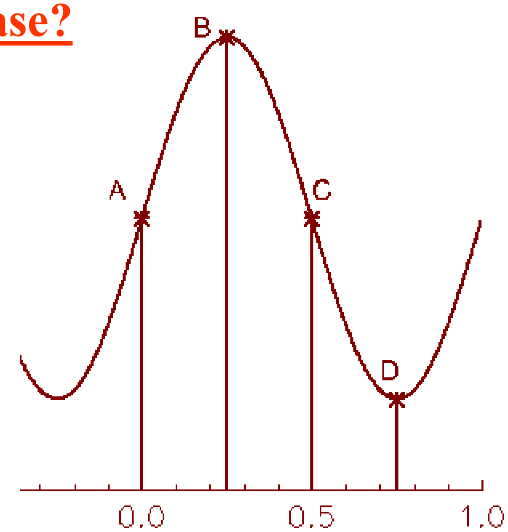
Options:

- spatial / temporal fringe modulation

- FSU wavelength vs. scientific instrument

How to measure the fringe phase?





The "ABCD" concept:

measurement of combined intensity at known phase difference and demodulation

<= A possible implementation with "spatial modulation"

Dynamic range: 1 λ

OPD performance: $\sim\lambda / SNR$

The Very Large Telescope Interferometer Array

4 Unit Telescopes (UT)

- 8.2 m Ø, fixed,

- Adaptive Optics

3-5 Auxiliary Telescopes (AT)

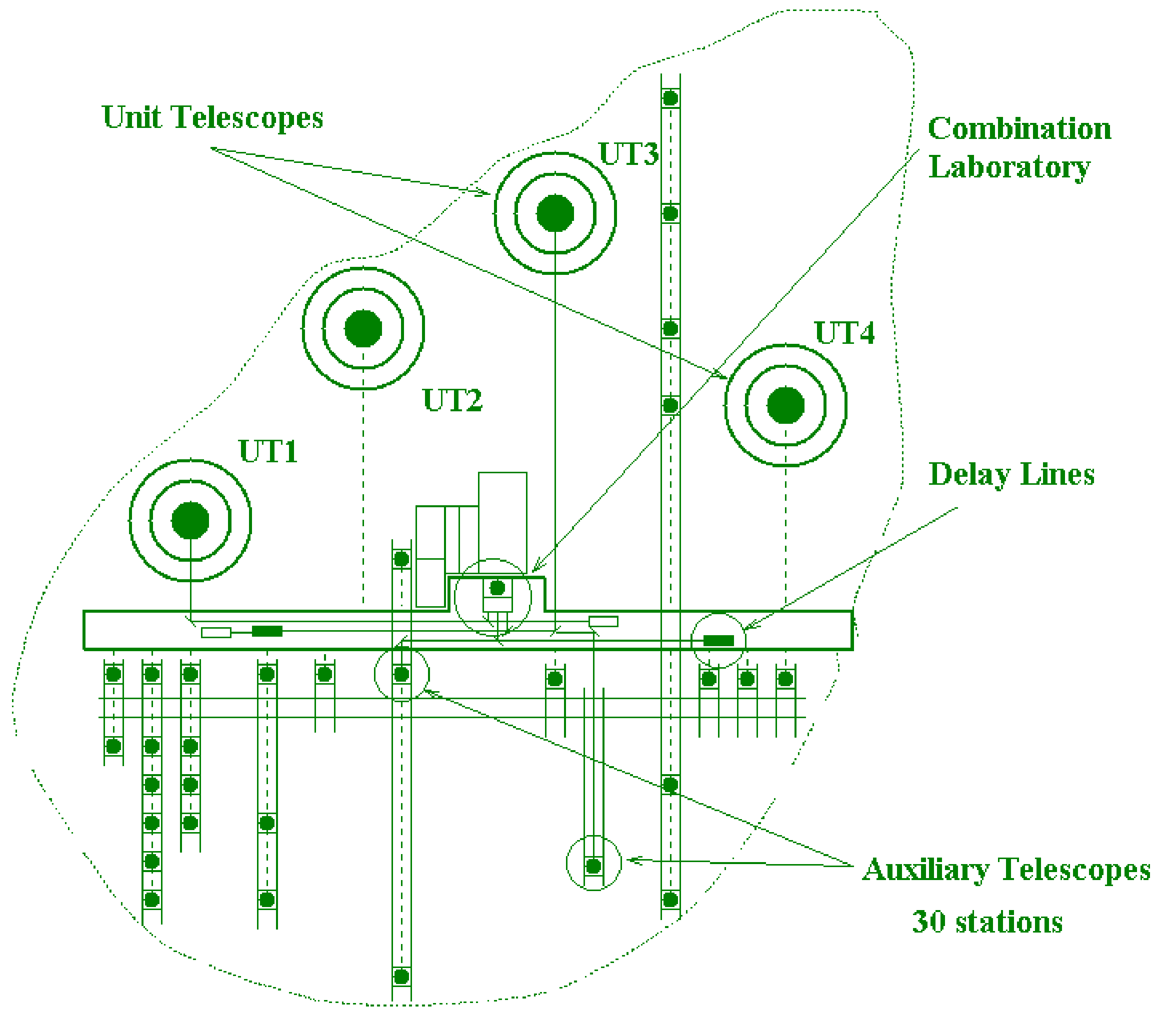
- 1.8 m Ø, movable in daytime

- Tip-tilt correction

30 AT stations

4 Delay Lines (8)

Baseline B = 8–200 m



VLTI Instruments

VINCI: VLT INterferometer Commissionning Instrument

AMBER: Near Infrared/Red VLTI focal instrument (OA Arcetri)

MIDI: Mid-Infrared interferometric instrument for the VLTI

PRIMA: Phase-Referenced Imaging and Microarcsecond Astrometry facility (OATo)

FINITO: Fringe-tracking Instrument of NIce and TOrino (OATo)

ESO Press Release 06/01 (18-III-2001): "First Fringes" on siderostats + VINCI

Next milestones:

2003: commissioning of AMBER, MIDI, FINITO; AO on UT1; AT1, AT2

2004: AO on UT3; AT3

2005: AO on UT2, UT4; AT4; commissioning of PRIMA

FSU wavelength: FINITO: H band PRIMA FSU: K band

FINITO: Fringe-tracking Instrument of NIce and TOrino

Collaboration between **ESO** and **INAF-OATo**

for implementation of a 2 – 3 beam Fringe Sensor Unit

Full upgrade of a lab prototype from Observatoire de la Côte d'Azur – Nice

FINITO Basic Concepts:

Operation in H band ($\lambda\lambda$=1.48-1.75 μm)

Amplitude combination of two / three beams

Compensation of atmospheric differential refraction

Temporal modulation of OPD for cophasing / coherencing

Spatial filtering to reduce random phase terms (wavefront errors)

Off-axis fringe tracking, over a field of about 1" radius on UT (~9" on AT)

Status:

Component procurement in progress

Integration and setup: end 2002

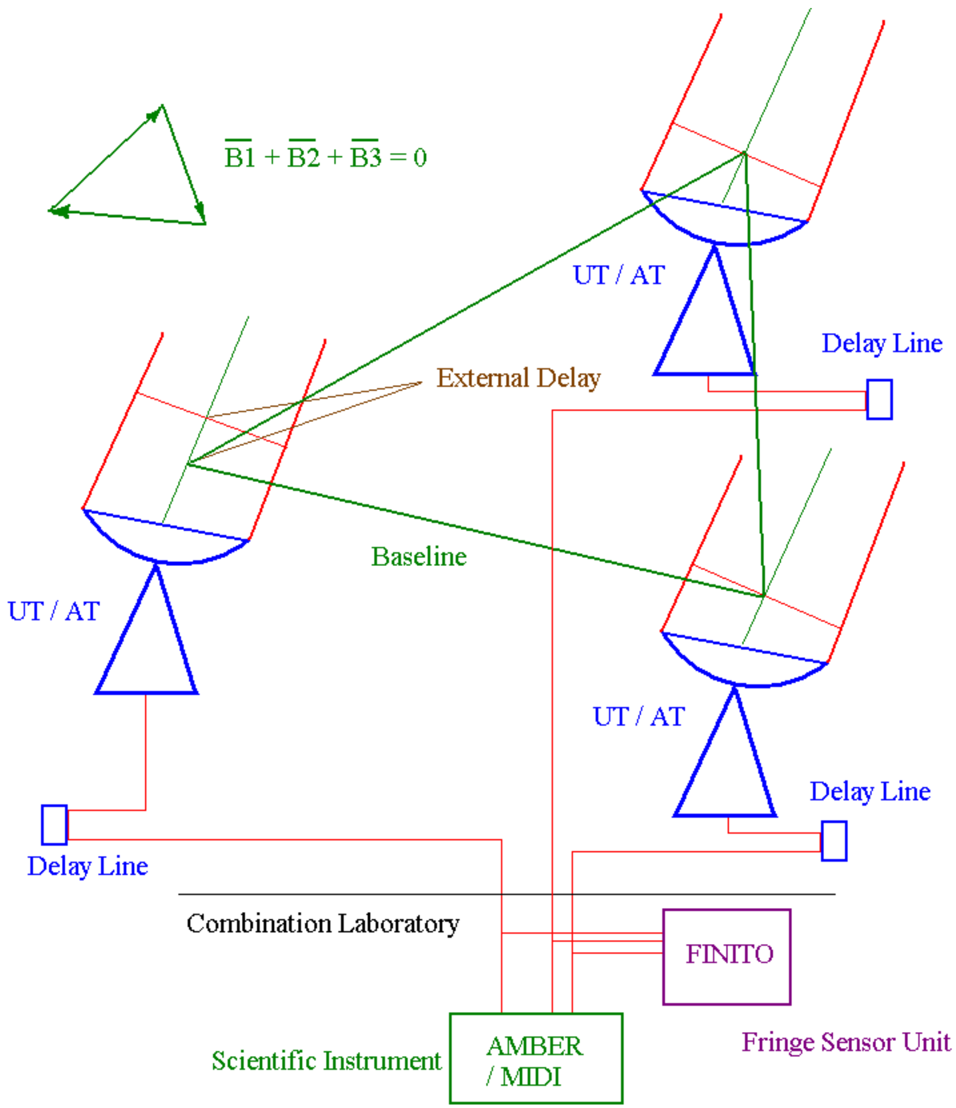
Delivery at Paranal: I Q. 2003

Supporting institutions:

OATo: opto-mechanical assembly, integration

ESO: detector system, project management

CNAA: upgrade from two to three beams



Scientific Rationale for FINITO:

accurate visibility maps around bright sources; closure phase: baseline bootstrapping

Closure phase measurement

Measurement over baselines 12, 13 and 23 simultaneously:

target complex visibility -

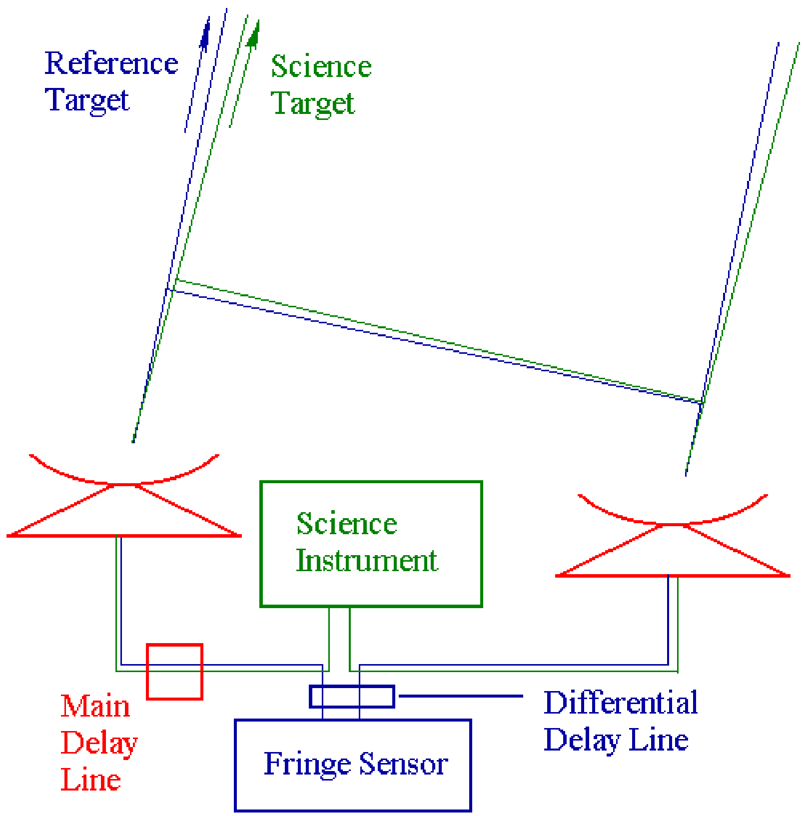
imaging of structured sources

Baseline bootstrap

Scientific exposure close to minimum of visibility: highest structure signature

Fringe tracking with high visibility on shorter baseline

PRIMA: Phase-Referenced Imaging and Microarcsecond Astrometry Facility



PRIMA Sub-systems:

- Star Separator (at each telescope focal plane)
- Fringe Sensor Unit A / B
- Metrology system
- Differential Delay Line

Integration of faint targets close to reference stars:

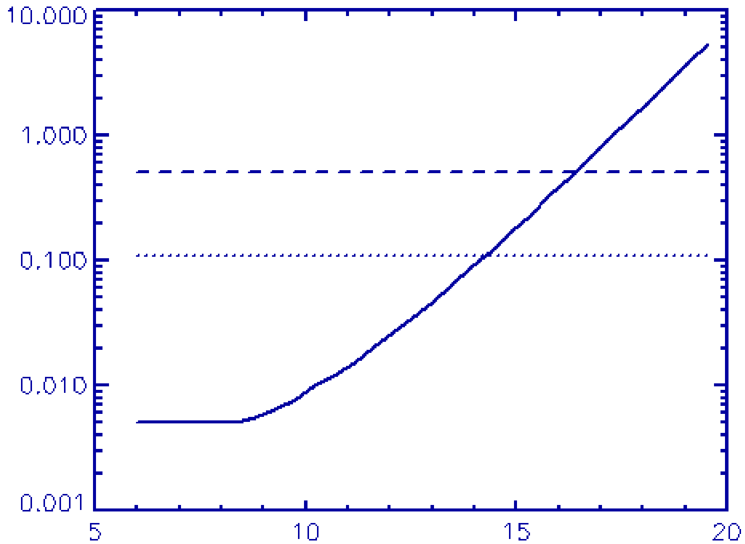
FOV ~ 20” (K) – 1’ (N)

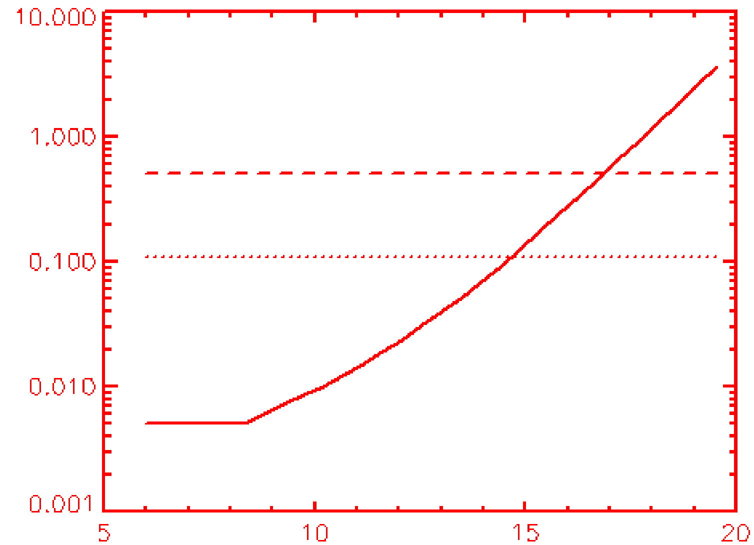
OATo + ALS: contract from ESO for PRIMA FSU manufacturing

Scientific Rationale for PRIMA:

phase referenced imaging - µas-level astrometry

Performance of FINITO and PRIMA FSU





FINITO (H band)

Limiting magnitude on UT:

H ~ 14 mag (imaging in K band)

H ~ 16 mag (imaging in N band)

PRIMA (K band)

Limiting magnitude on UT:

K ~ 15 mag (imaging in K band)

K ~ 17 mag (imaging in N band)

Assumption: exposure time adjusted with magnitude from 0.5 ms to 5-10 ms

Fringe tracking on the Large Binocular Telescope

Main features of LBTI vs. VLTI:

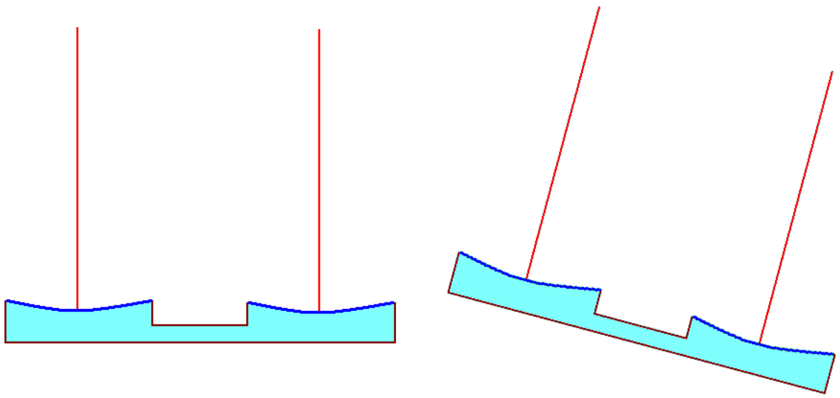
Multi-conjugate AO: large corrected field

High order AO: high instrumental visibility

Multiplex: simultaneous full-field interferometry

Comparable X-Y resolution: easier reconstruction with few baselines

Preferable e.g. for complex morphology sources at medium resolution



Advantage vs. VLTI: no Delay Line!

Common alt-az mount:

optical paths balanced by design

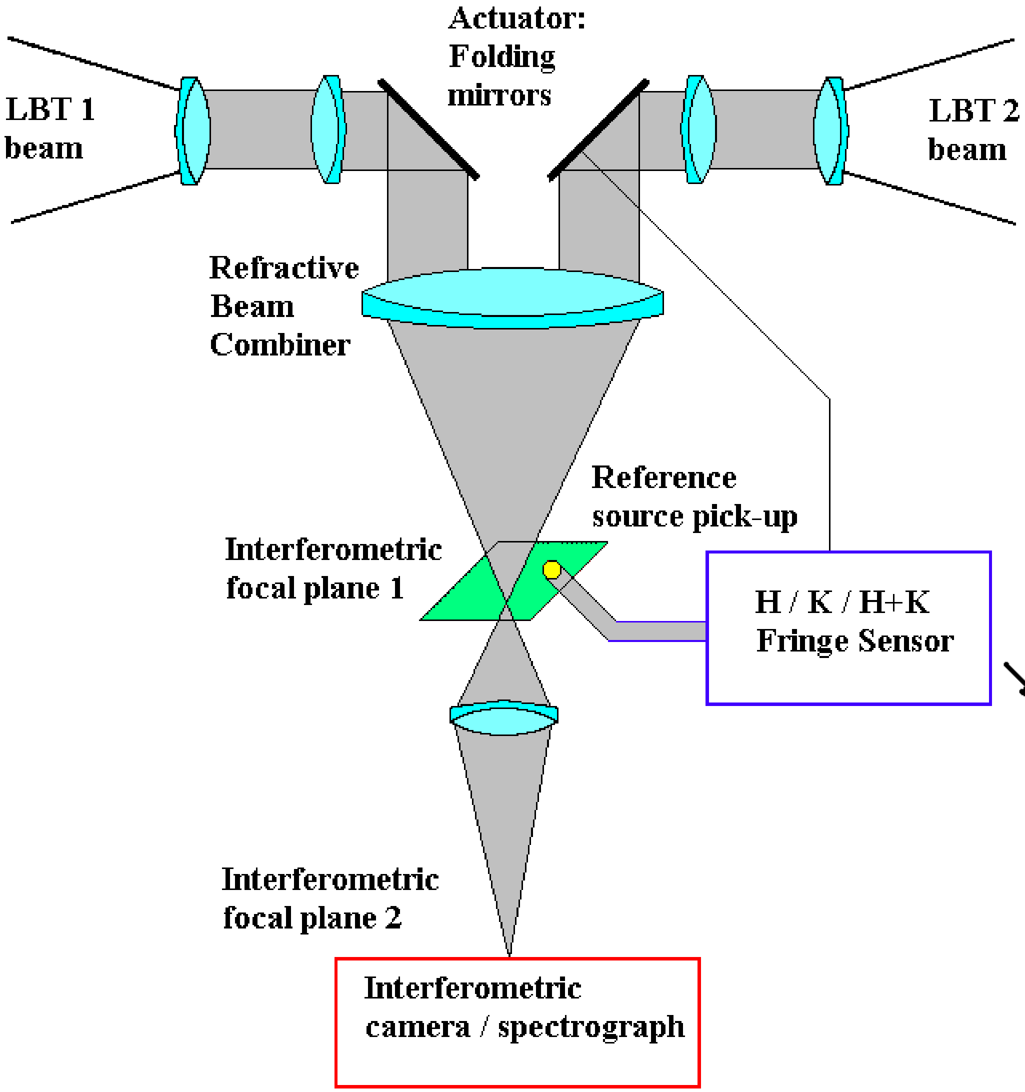
Also, no Differential Delay Line!

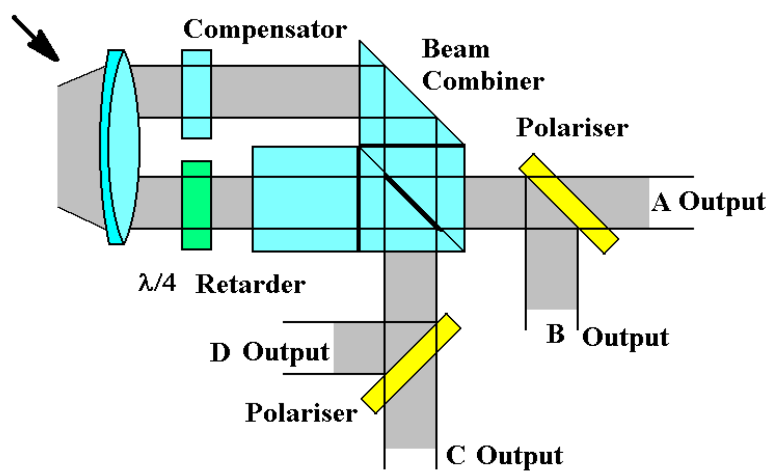
Metrology probably not needed in first implementation

Required only a one-dimensional actuator and a Fringe Sensor

Reference source pick-up on a combined focal plane for the FSU

Possible implementation scheme





Issues:

Allocation of actuator

(e.g. folding mirrors on collimated beams)

Focal plane trade-off: reference source pick-up vs. scientific instrument field

Spectral band: H, K?

Conclusions

Very high resolution in visible – IR accessible by interferometry

Fringe tracking required to achieve long exposures on faint sources

VLTI fringe tracking experience applicable to LBTI

Trade-off required on:

- operating spectral band: H, K, H + K?
- actuation range: residual instrument alignment?
- sensitivity / precision: residual OPD noise vs. source magnitude
- performance / cost / complexity

Possible focal station allocation for best match with foreseen instrumentation:

- requirements on focal plane compatibility: on-source / off-axis reference?
- thermal infrared instruments constraints: common focal plane accessible?
- volume allocation vs. optical layout