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Next generations VLTI instruments

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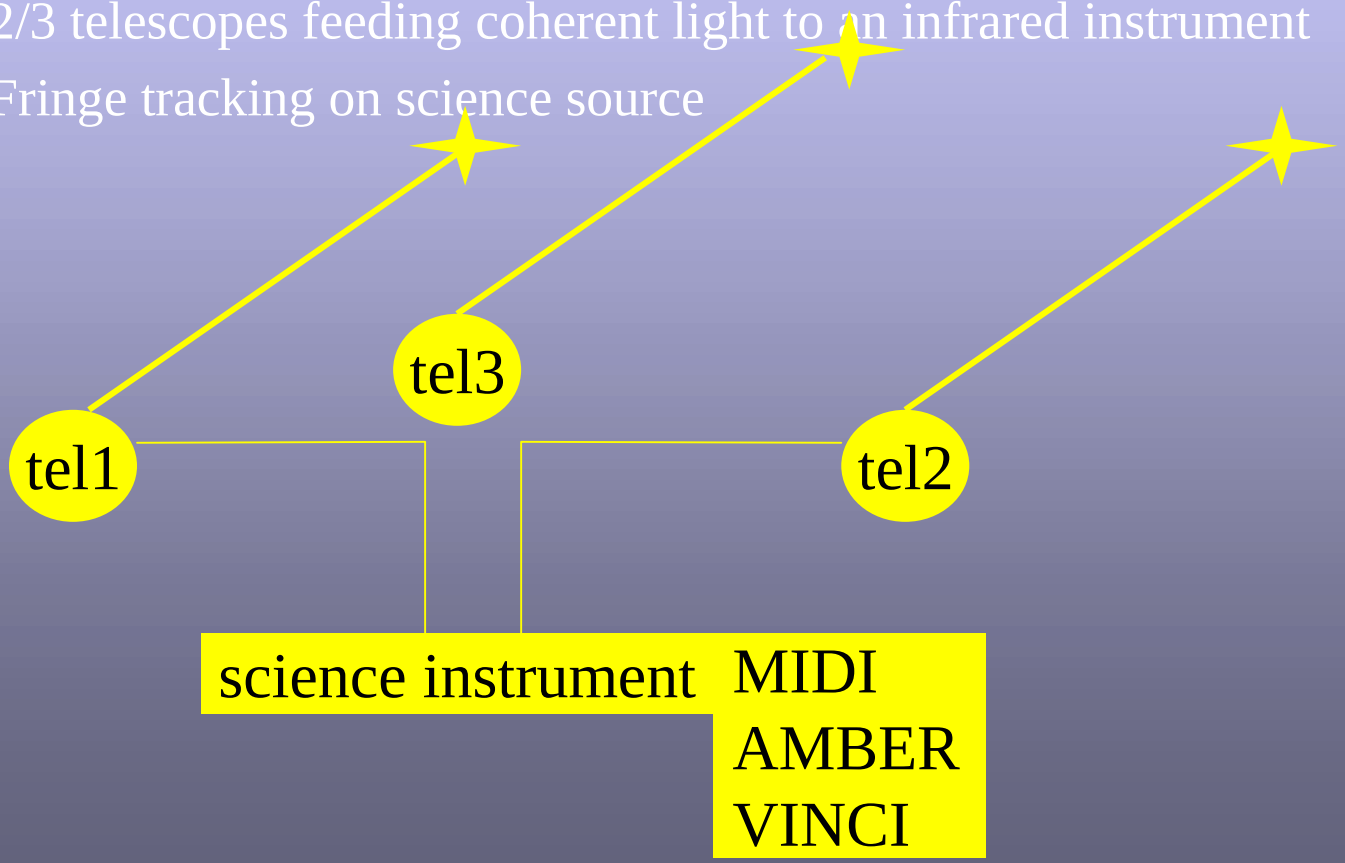
Leiden Observatory/NEVEC

Phase A: 2001-2005
2/3 way-beam combination

- 2/3 telescopes feeding coherent light to an infrared instrument
- Fringe tracking on science source



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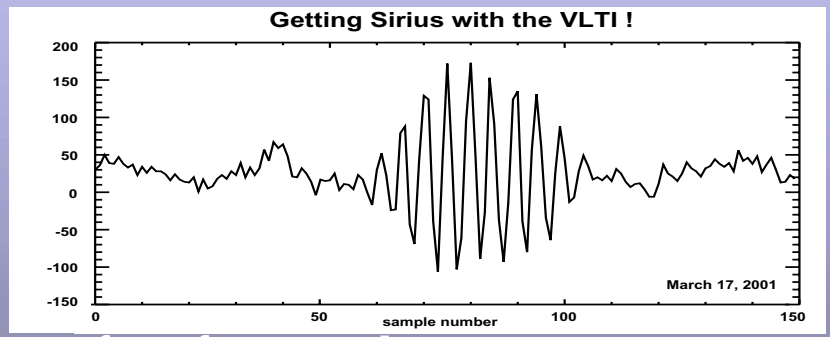
Phase A instruments/facilities

	commissioning
• **Delay lines 1&2**	2000 Q2
• **Siderostats**	2000 Q3
• **VINCI**	2001 Q1
• **Beamcompressors**	2001 Q4
• **Delay line 3**	2001 Q4
• **MIDI**	2002 Q3
• **AT1 and AT2**	2003 Q2
• **AO on UT 2&4**	2003 Q3
• **AMBER**	2003 Q3
• **AT3**	2003 Q4
• **AO on UT 1&4**	2004 Q3

VLTI/VINCI first fringe
17 March 2001



first fringe July 2002

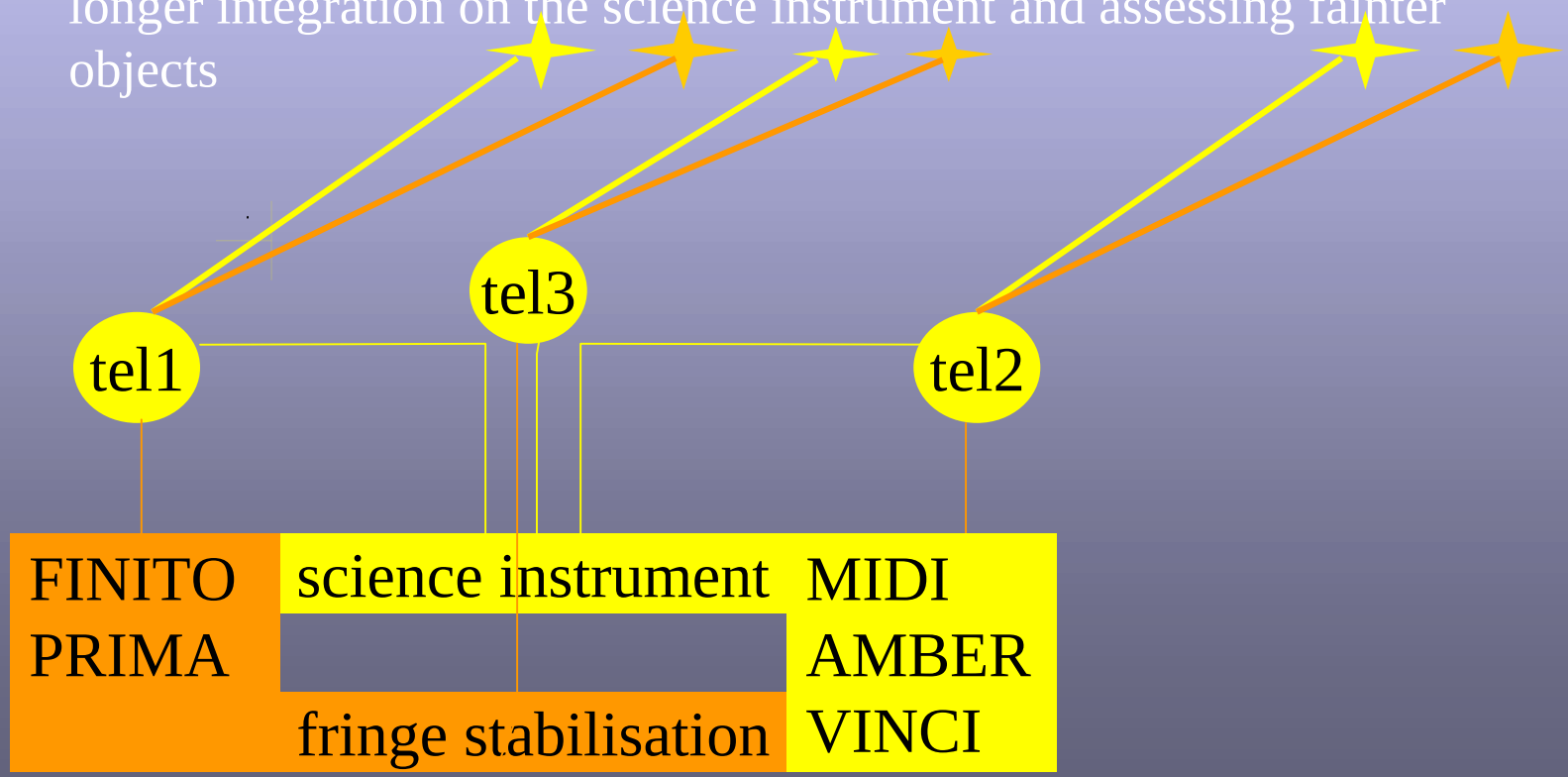
MACAO

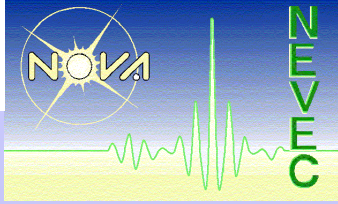
first fringe June 2003

Phase B: 2003-2010

2/3-way beam phase referencing

- A bright reference source can be used for phase referencing allowing longer integration on the science instrument and assessing fainter objects





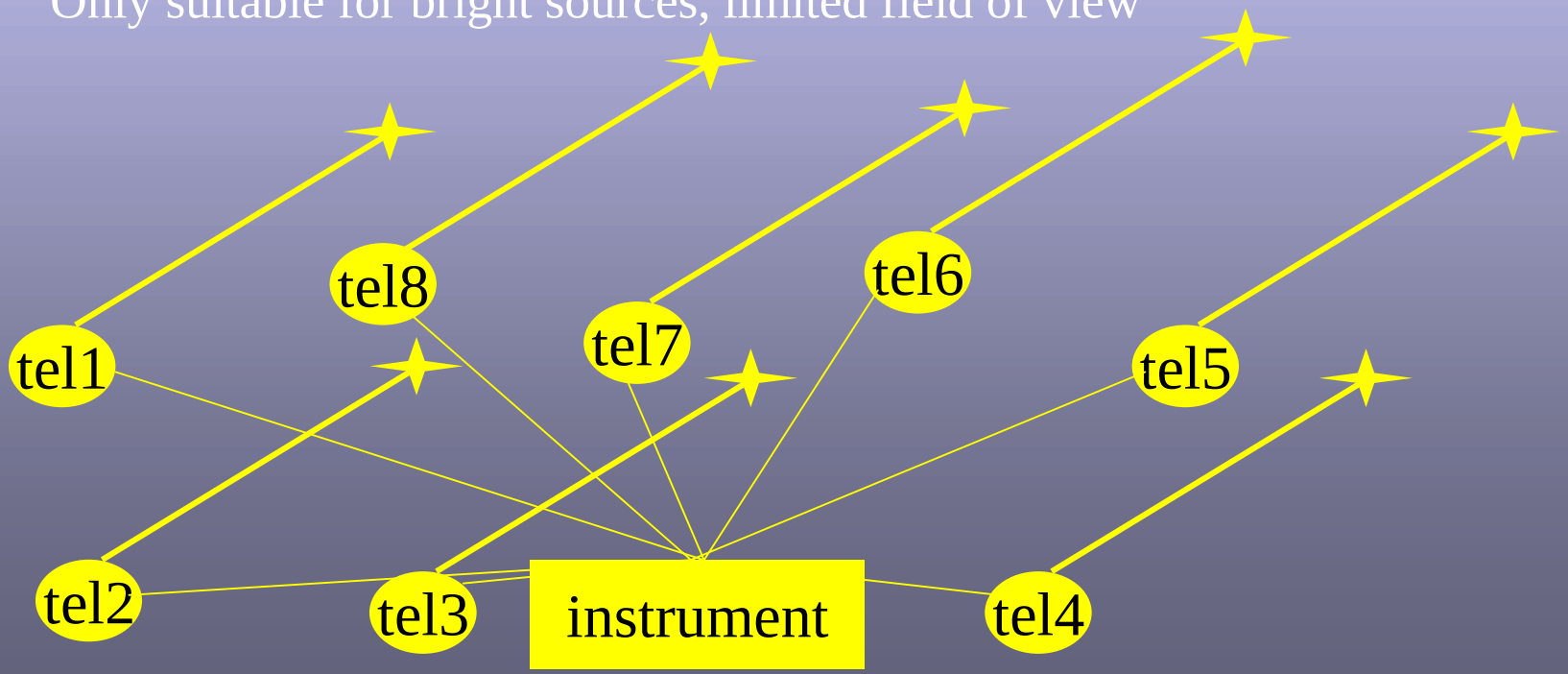
Phase B instruments/facilities

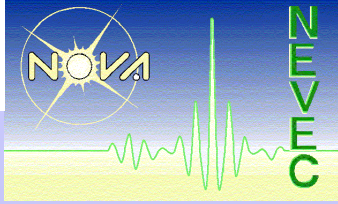
	commissioning	
• **FINITO**	2002 Q3	first fringe June 2002
• **Delay lines (N=4,5,6)**	2003 Q4	
• **PRIMA**	2005	limited performance
• **Dedicated Astrometry**	2005	Glindemann et al. [3]
• **GENIE**	2006	Fridlund et al. [4]
• **PRIMA**	2007	full performance
• MIDI II (20 micron) **new**	2005^{++}	Leinert et al. [3]
• MIDI B (3-beams) **new**	2005^{++}	Leinert et al. [3]
• AMBER VIS**new**	2005^{++}	Stee et al. [3]
• Differential Interferometer**new**	2005^{++}	Vannier et al. [3]
• Achromatic Coronograph**new**	2005^{++}	Rabbia et al. [3]
• Phase Mask Coronograph**new**	2005^{++}	Rouan et al. [3]

new: not yet planned

Phase C: 2006-2015 multi-beam closure phase

- Applying closure phase on up to 8-way beam combination to allow model independent image reconstruction
- Only suitable for bright sources, limited field of view





Phase C instruments/facilities

	commissioning	
• more Auxiliary Telescopes (N=4-8) new	2006^{++}	
• more Delay lines (N=7,8) new	2006^{++}	
• Integrated optics beam combiner (N=8) new	2006^{++}	Malbet et al. [3]
• 10X10 pixel imager, closure phase new	2006^{++}	Haniff et al. [3]
• Multi beam advanced PRIMA (N=8) new	2006^{++}	
• Integral field spectrograph new	2006^{++}	Petrov et al. [3]

new: not yet planned

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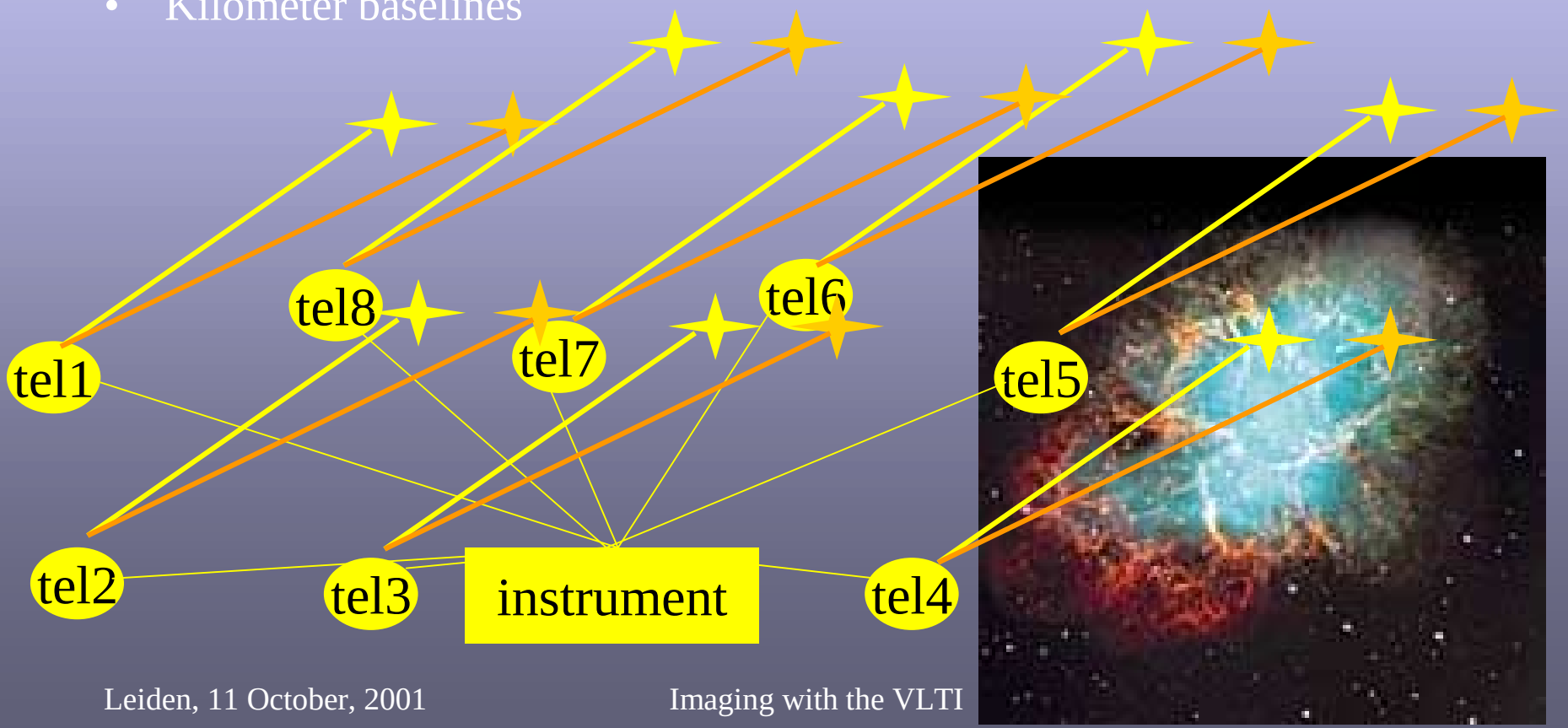
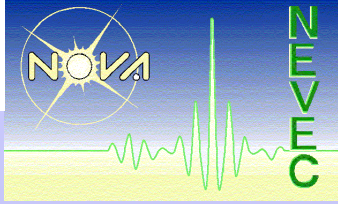
Phase D: 2010-2020 wide-field and km baselines

- Applying model independent imaging over a large field of view
- Kilometer baselines

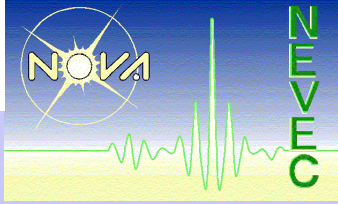




Phase D instruments/facilities

	commissioning	
• Wide field imager (homothetic mapper)[new]	2010[++]	Le Poole et al.
• km baseline[new]	2010[++]	Glindemann et al. [3]
• Laser guide stars (FOV~2 arcmin)[new]	2010[++]	Glindemann et al. [3]
• Overwhelmingly Large Array (OLA)[new]	2010[++]	Glindemann et al. [3]

new: not yet planned



VLTI roadmap

Phase A:	**2/3-way beam combination** K<14 at 2 μm, N<8 at 10 μm (UT)	2001 - 2005
Phase B:	**2-3-way phase referencing** K<20 at 2 μm, N<18 at 10 μm (UT)	2003 – 2010
Phase C:	**multi-baseline closure phases** 4- to 8-way beam combination expansion to visible with Adaptive Optics	2006 – 2015
Phase D:	**wide field imaging and km baselines** Homothetic mapping and kilometer arrays	2010 - 2020

Dates are estimates made by EJB, phase definition after Paresce 2001 [7], science drivers after Paresce 1996 [6], other details from Percheron et al.[1] and Léna and Quirrenbach [2]

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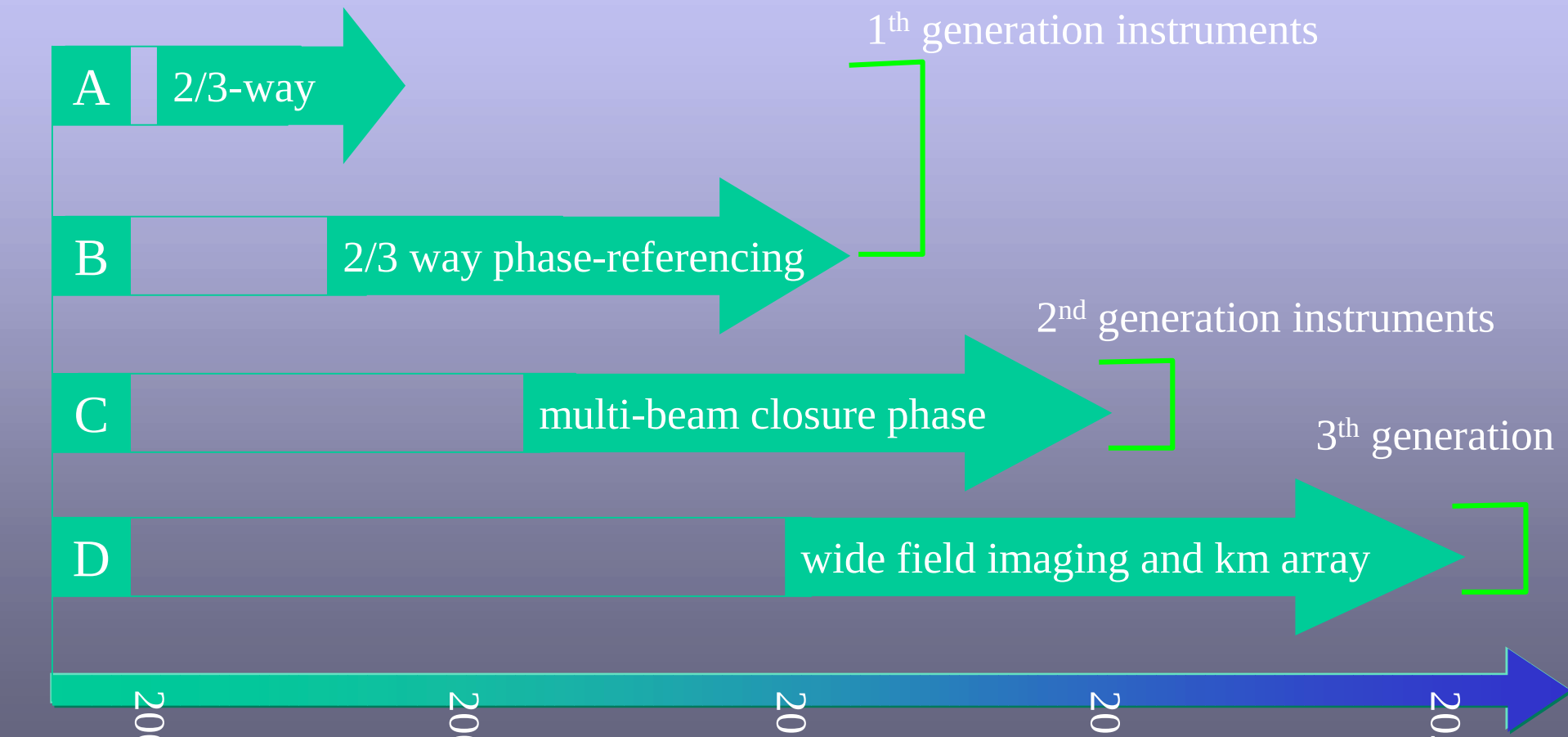
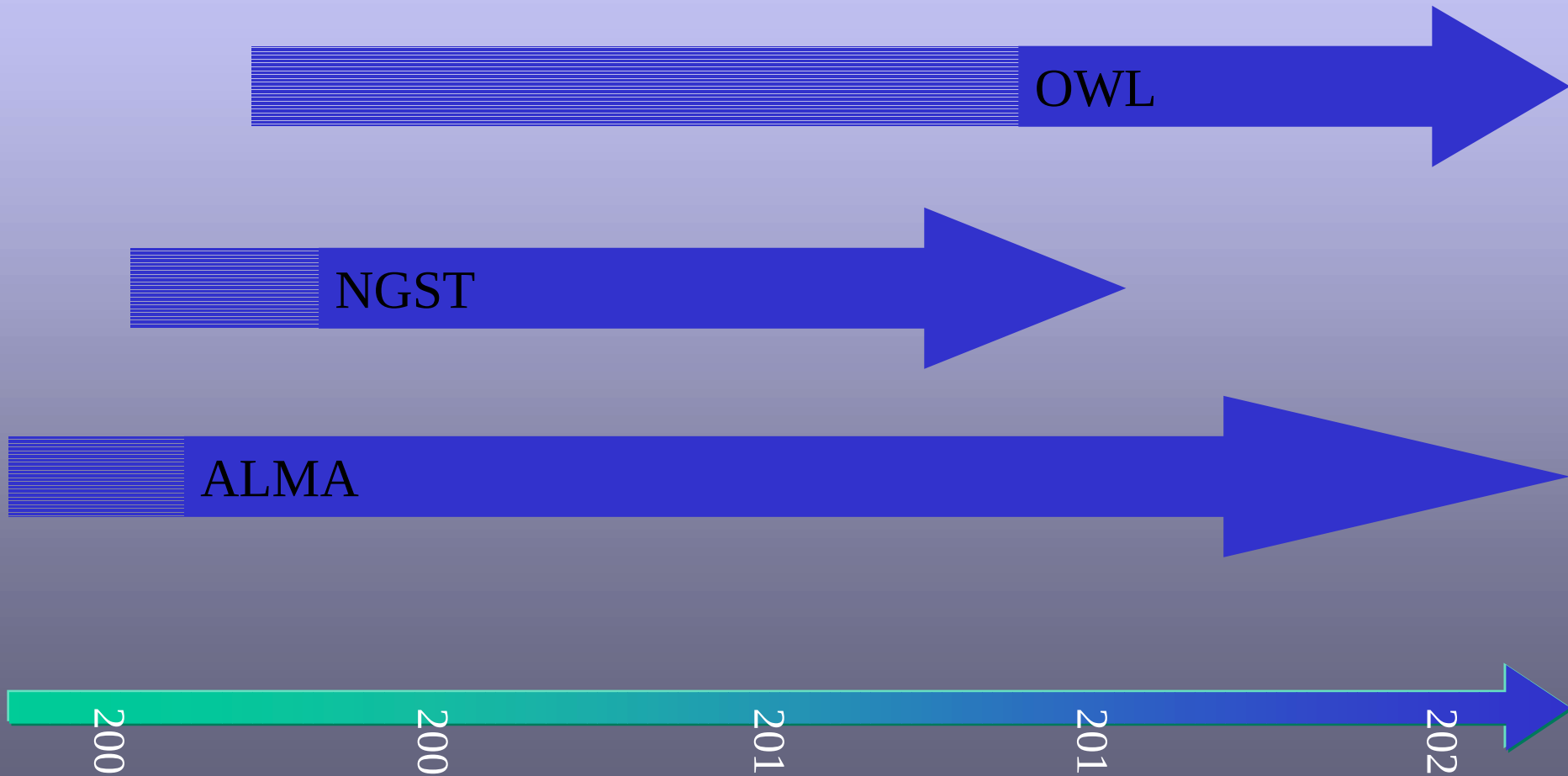
VLTI time line



Competitors



1th generation 1999++

1th generation VLTI instruments (Phase A & B)

- phase A&B instruments
- R&D phase 1996-1999
- Construction 1999++

All instruments currently planned and being or will be build

- VINCI
- MIDI
- FINITO
- AMBER
- GENIE
- PRIMA

2nd generation 2007++

2nd generation VLTI instruments (ESO long range plan [4])

- phase C instruments
- R&D phase 2003-2006
- Construction 2007++

Two instruments planned by ESO (design 2004 + design 2006)

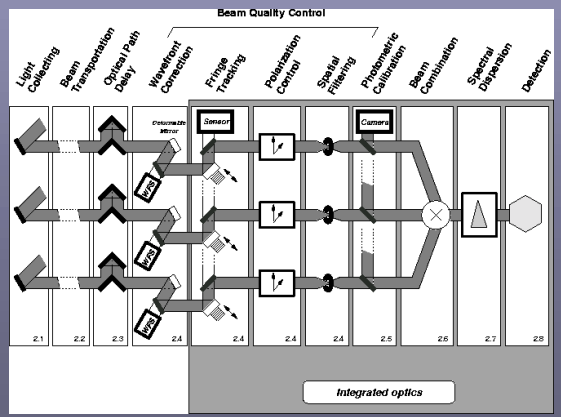
1. 6-8 way beam combiner (more DLs and more ATs)
2. dual-feed for all telescope (advanced PRIMA)

Other instruments anticipated (but not in ESO's long range plan)

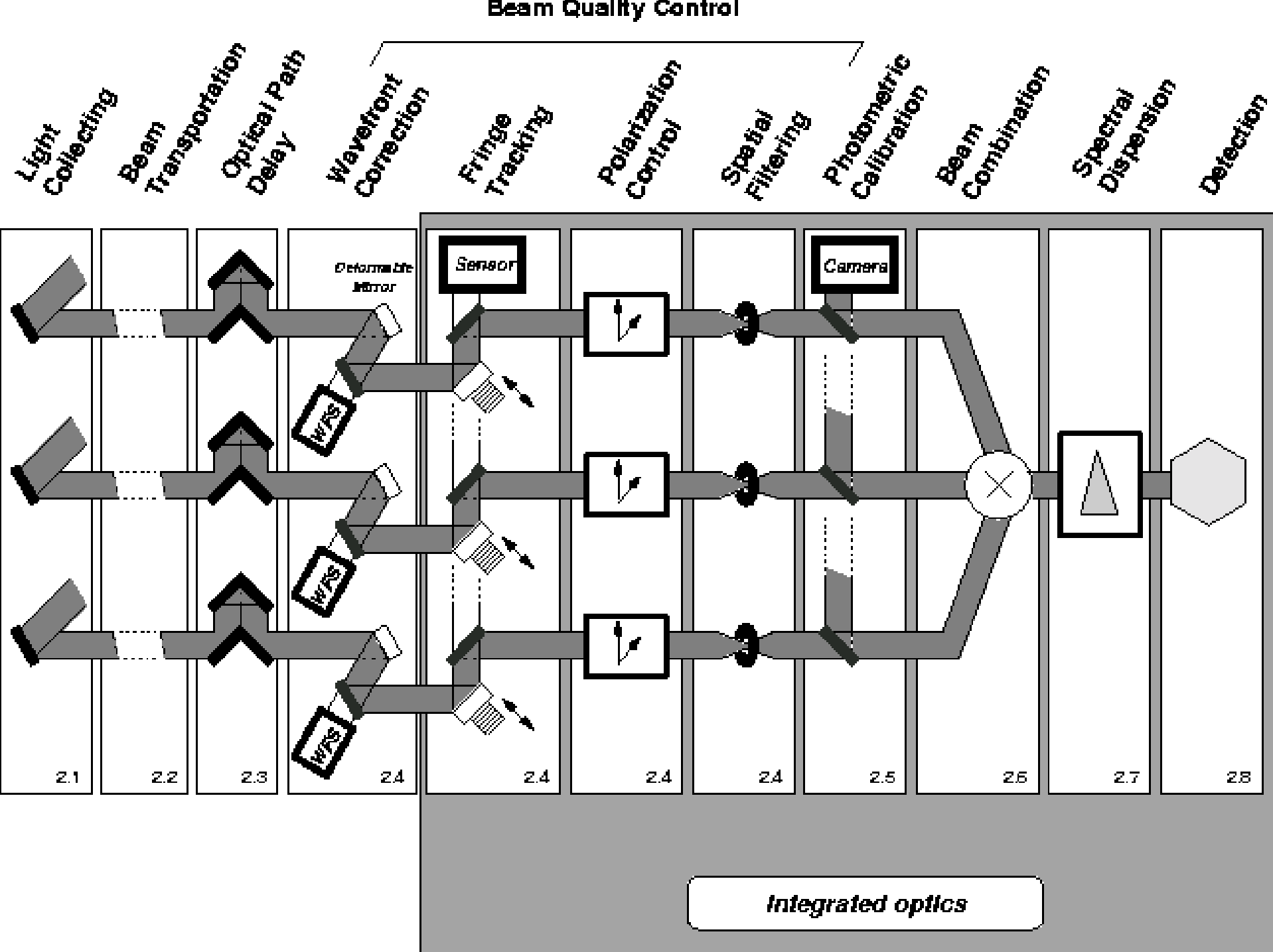
3. Super Tunnel Junction detector
4. Advanced MIDI (N>2, Q band)
5. Advanced AMBER (Visible)

1. 6-8-way beam combiner

- Integrated optics on planar substrate (Malbet et al, 1999 [5]), possible in combination with fibres
- Technology available from telecom industry
- Does not require bulk optics, but allows complex function on small substrate
- Fabrication through ion-exchange (Na+ ion), or etching layers



Single-mode interferometer

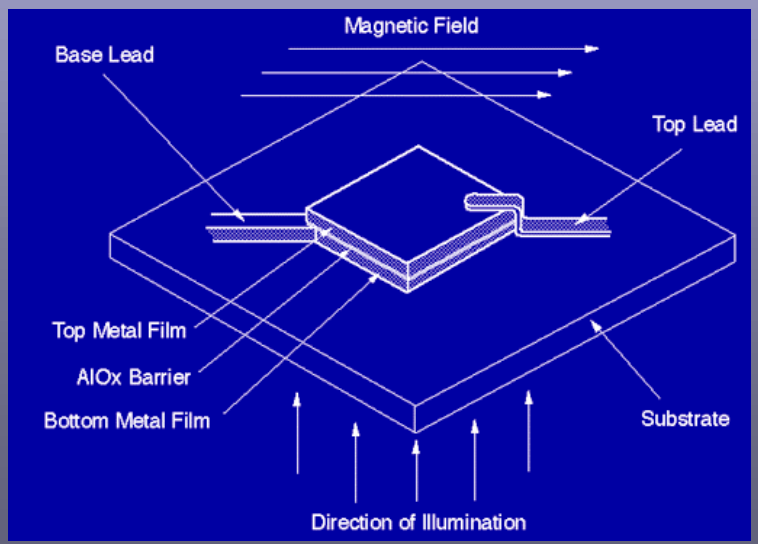

Beam Quality Control
Light Collecting
Beam Transportation
Optical Path Delay
Wavefront Correction
Fringe Tracking
Polarization Control
Spatial Filtering
Photometric Calibration
Beam Combination
Spectral Dispersion
Detection
Deformable Mirror
Sensor
Camera
WFS
WFS
WFS
Integrated optics
2.1
2.2
2.3
2.4
2.4
2.4
2.4
2.5
2.6
2.7
2.8

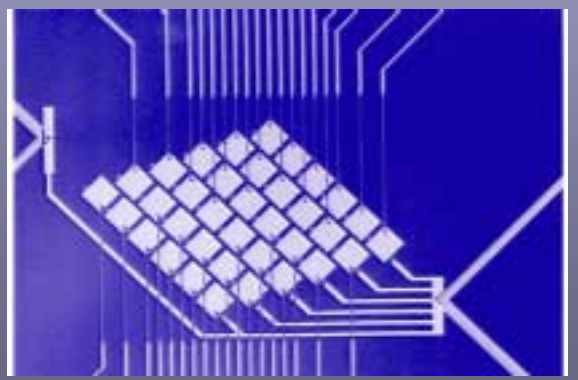
2. Advanced PRIMA

- Upgrade of current PRIMA design to pair-wise combination of light from up to eight telescope
- Four sub-systems:
  - Star separator (2” beams, separated 1’)
  - Metrology (15 nm over 30 minutes)
  - Differential Delay line (5 nm)
  - Fringe Sensor Unit
- K-band (2.0-2.4 μm), later H-band added (1.6-1.8 μm)
- 1th phase: 2002-2005: 50 mas astrometry on 2 ATs
- 2nd phase: 2004-2007: 10 mas astrometry on 2 ATs and 2 UTs
- 3th phase: 2006-2009: improved performance
- Advanced PRIMA 2007^{++}

3. STJ

- Super Tunnel Junction Detector (Rando et al. 2000 [8])
- Photon counting detector (115 nm < λ < 2 μm (thermal background))
- Energy resolution of 5-50 nm (R ~ 5)
- Can be used as Fringe Sensor Unit or be integrated in IO Beam combiner





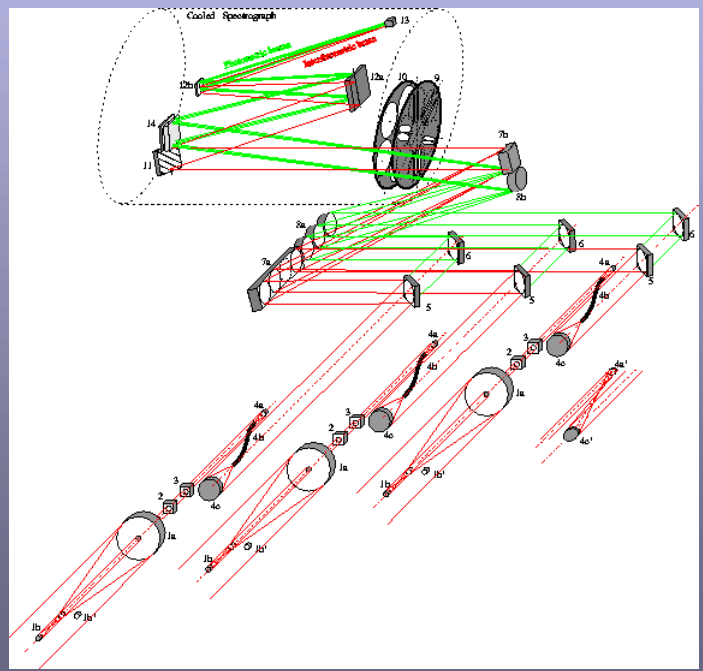
4. Advanced MIDI

- Q-band (20 μm) availability
- Multi-beam capabilities to measure closure phases

5. Advanced AMBER

- Near IR Instrument (1.0–2.5 μm)
- Limiting Magnitude K ~ 11–19 (UT), R ~ 10000
- Three beam combination
- Closure phase

Advanced AMBER: Operating in the visible



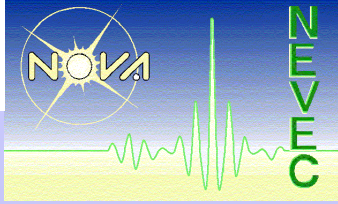
Optical layout AMBER

3th generation 2010++

3th generation VLTI instruments

- phase D instruments
- R&D phase 2005-2010
- Construction 2010++

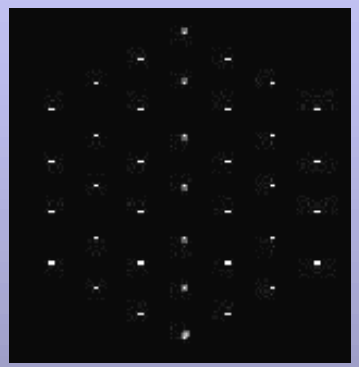
1. Enlarged field of view
2. Extend wavelength coverage
3. Laser guide stars
4. Kilometre baselines

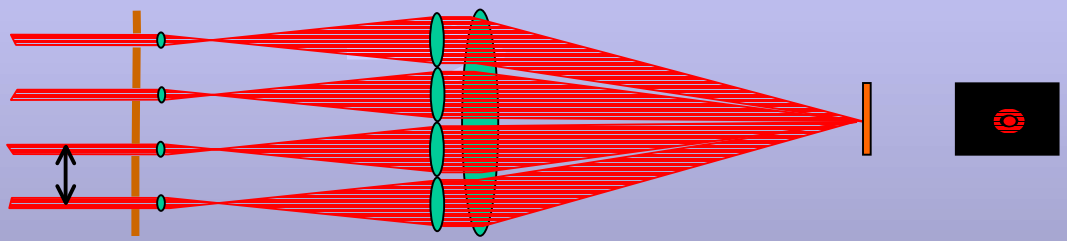


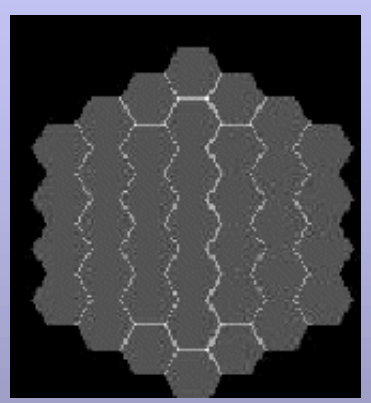
1. Wide-field imaging

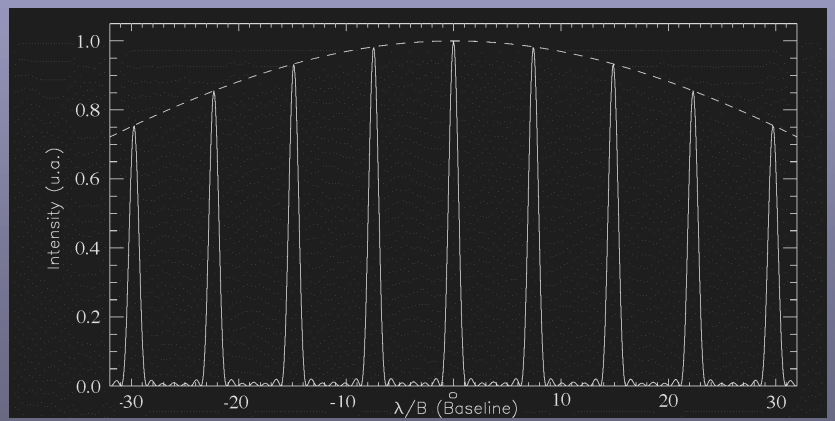
- Homothetic mapping of entrance pupil to exit pupil
- By maintaining the pupil configuration (in 3-D) the array of telescopes acts as a large monolithic telescopes with a small filling factor
- Would require advanced metrology, fast and accurate fringe tracking, and large detector arrays
  - Learn from the Dutch Testbed Interferometer (TNO/TPD)
- Among the alternatives are
  - mosaic procedure (WITT testbed, NASA Goddard)
  - step mirror (Montilla , Univ. Delft)

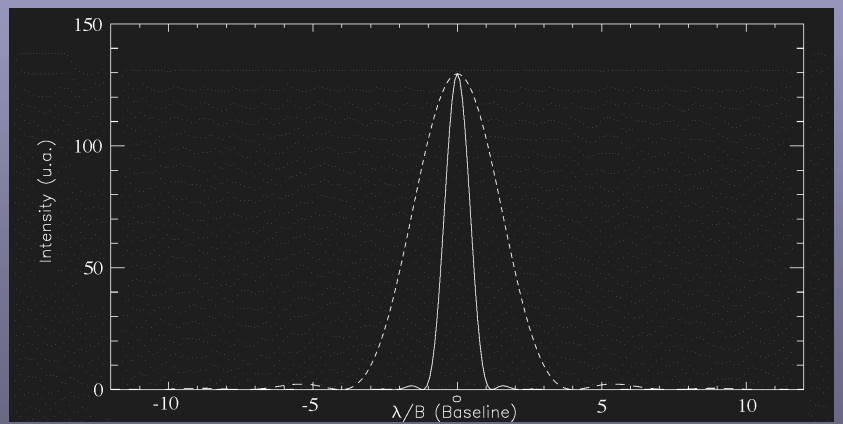
Wide-field imaging











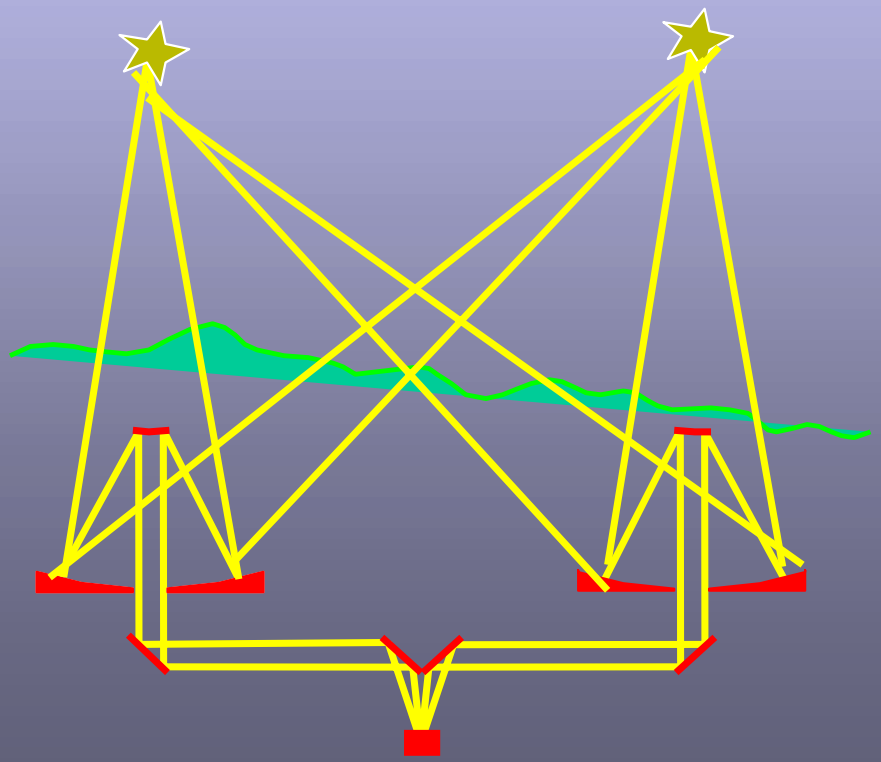
From Arnold, 2001 [9]

2. Extended wavelength coverage

- The Hα line (6563 Ångstrom) is an important diagnostic in astronomy
- Access to Hα allows to study disks, accretion, ejection processes for galactic and extra-galactic science
- Hα access would required adaptive optics to operate 600 nm (0.6 μm) on both the UTs and ATs
- It also would require the VLTI to be operating at this effective wavelength, instead of 2 μm< λ<10 μm

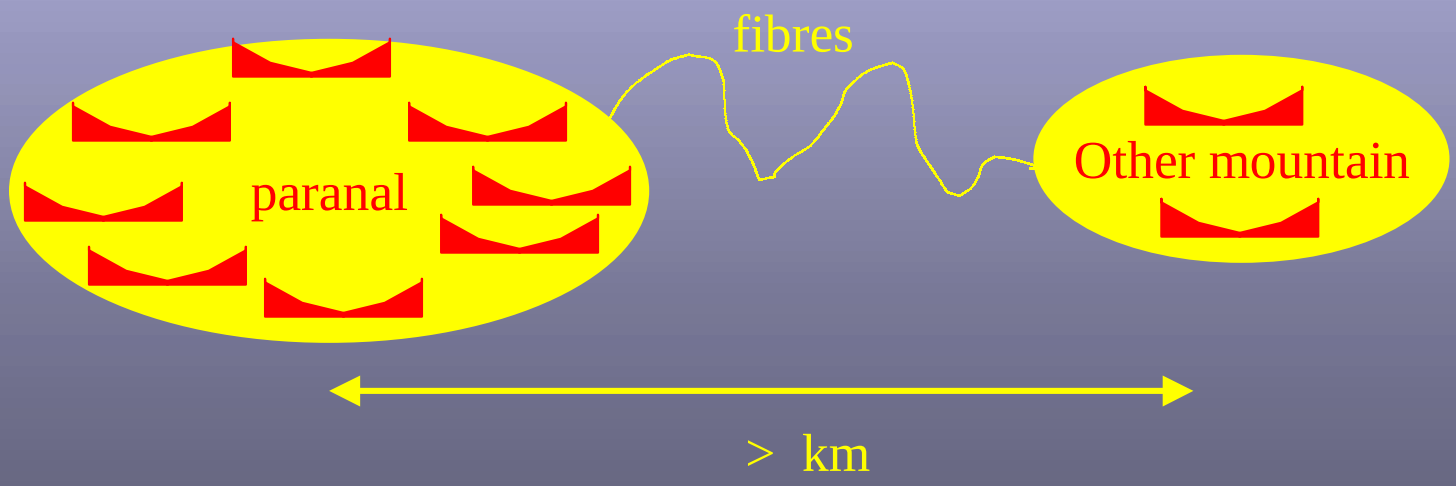
3. Laser guide star

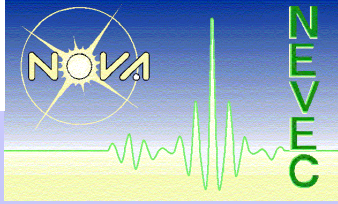
- Wide field diffraction limited imaging
- However there is a discussion among scientists whether this is feasible



4. Kilometre array

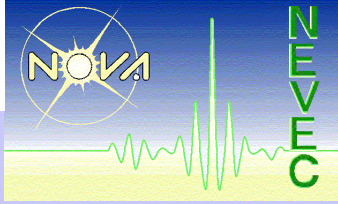
- Super resolution to compete with Over Welmingly Large Telescope (OWL)
- Transportation of light using optical fibres





Conclusions

- There are ample of opportunities to participate in the VLTI developments
- This is the time to start making preliminary designs of 2nd generation VLTI instruments such that if time comes alternative designs and systems can be assessed
- 2nd generation instruments will be designed in 2003-2006, and be build in 2007 and beyond
- 3th generation instruments will be designed in 2005-2010, and be build in 2010 and beyond
- Everybody is invited to participate in this process, strong need for
  - Model computations
  - Experiment on optical benches in laboratory
  - Careful study of alternative approaches proposed in other countries
- **Suggestions on how to proceed after this workshop ?**



References

[1] "Space and Ground Based Optical & Infrared Interferometry", 2000, Eds. I. Percheron, I. Montilla, L. D'Arcio

[2] "Interferometry in Optical Astronomy", 2000, SPIE Vol. 4006, Eds. P.J. Léna, A. Quirrenbach

[3] "Science drivers for ESO future VLT/VLTI instruments", 2001, Eds. G. Monnet

[4] ESO Long Range Plan 2001-2006, Issue 2.0

[5] Malbet et al, 1999, A&AS 138, 135

[6] Paresce, 1996, "Science with the VLT Interferometer"

[7] Paresce, 2001, messenger 104

[8] Rando et al., 2000, Review of Scientific Instruments, 71, 4582

[9] Arnold, 2001, "Science case for OWL", OPTICON workshop, Leiden