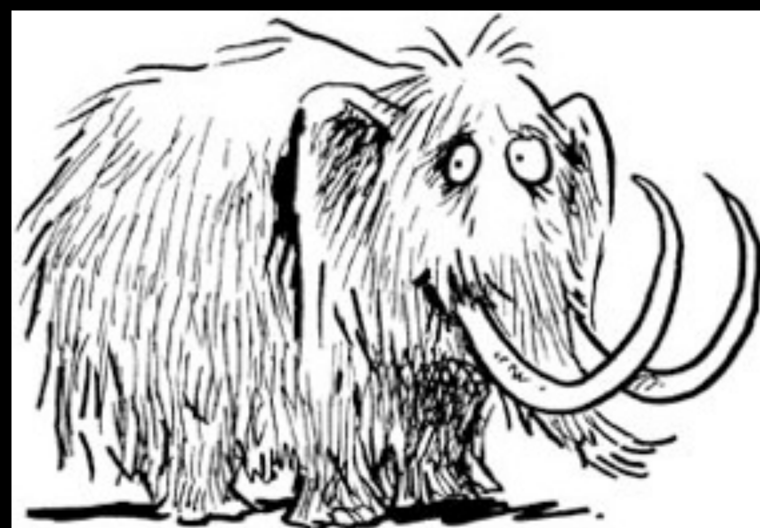
MAMMUT for ESO VLT UT's and VLTI

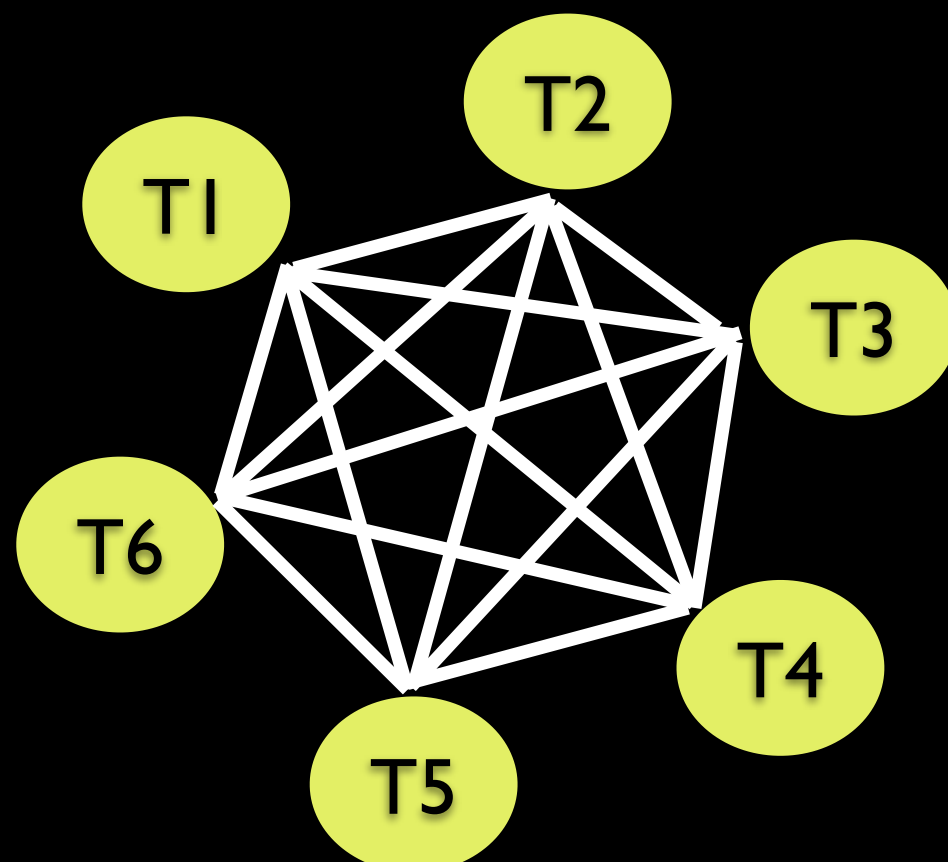


Dr. Stefano Minardi

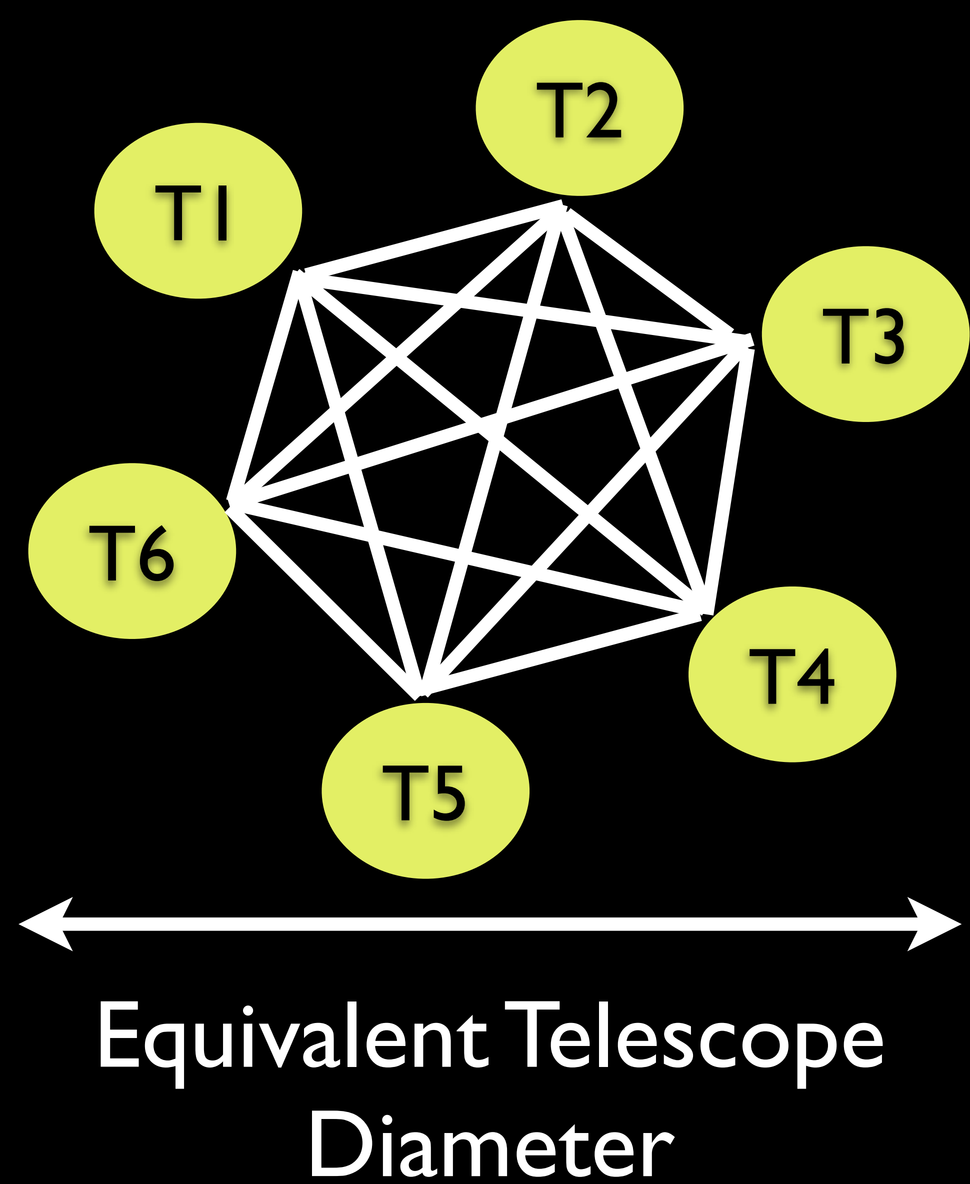
Friedrich Schiller University, Jena

Aperture synthesis via interferometry

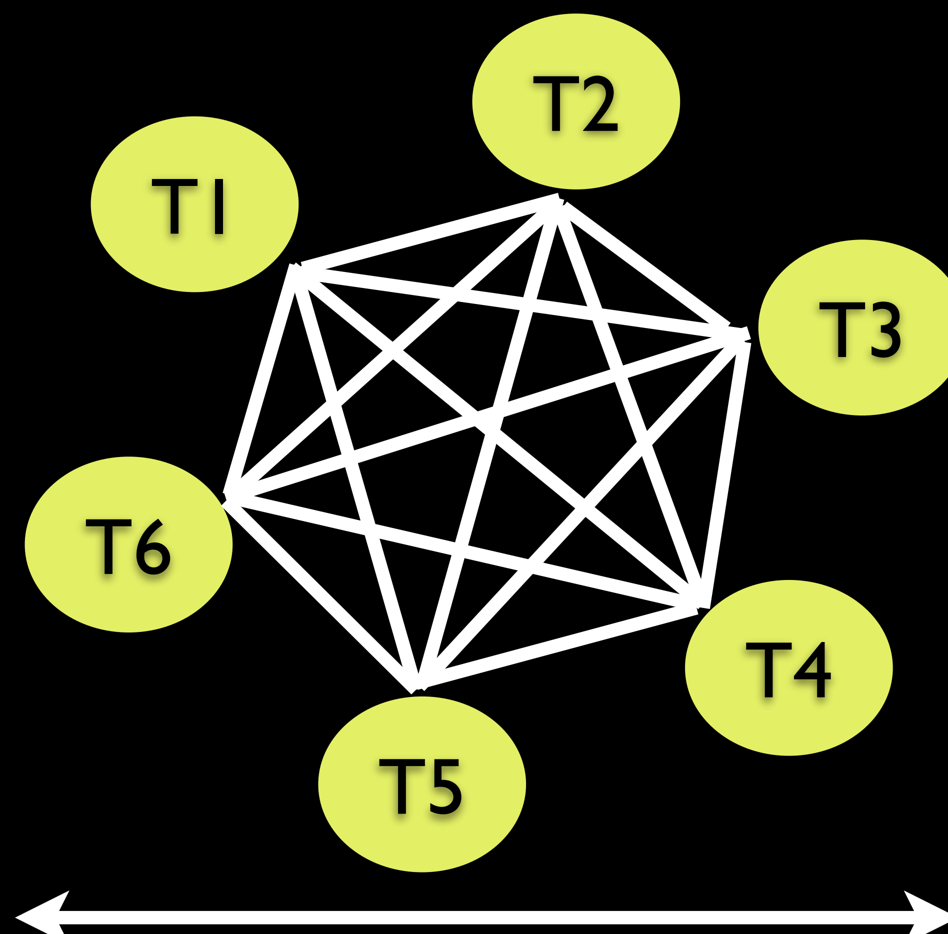
Aperture synthesis via interferometry



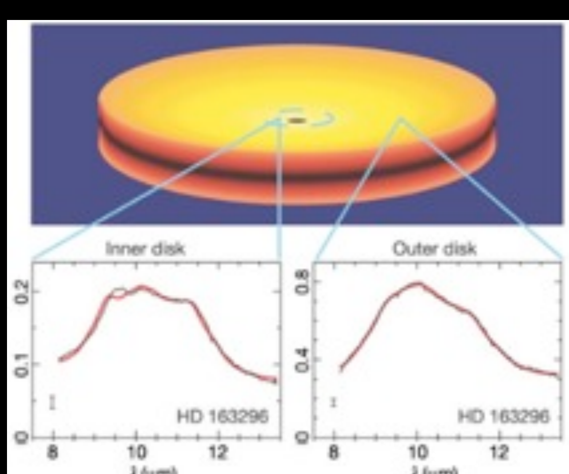
Aperture synthesis via interferometry



Aperture synthesis via interferometry

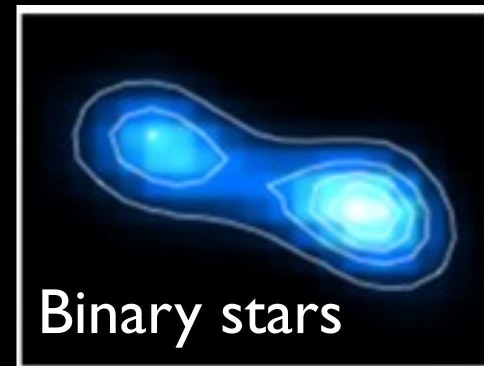


Equivalent Telescope Diameter

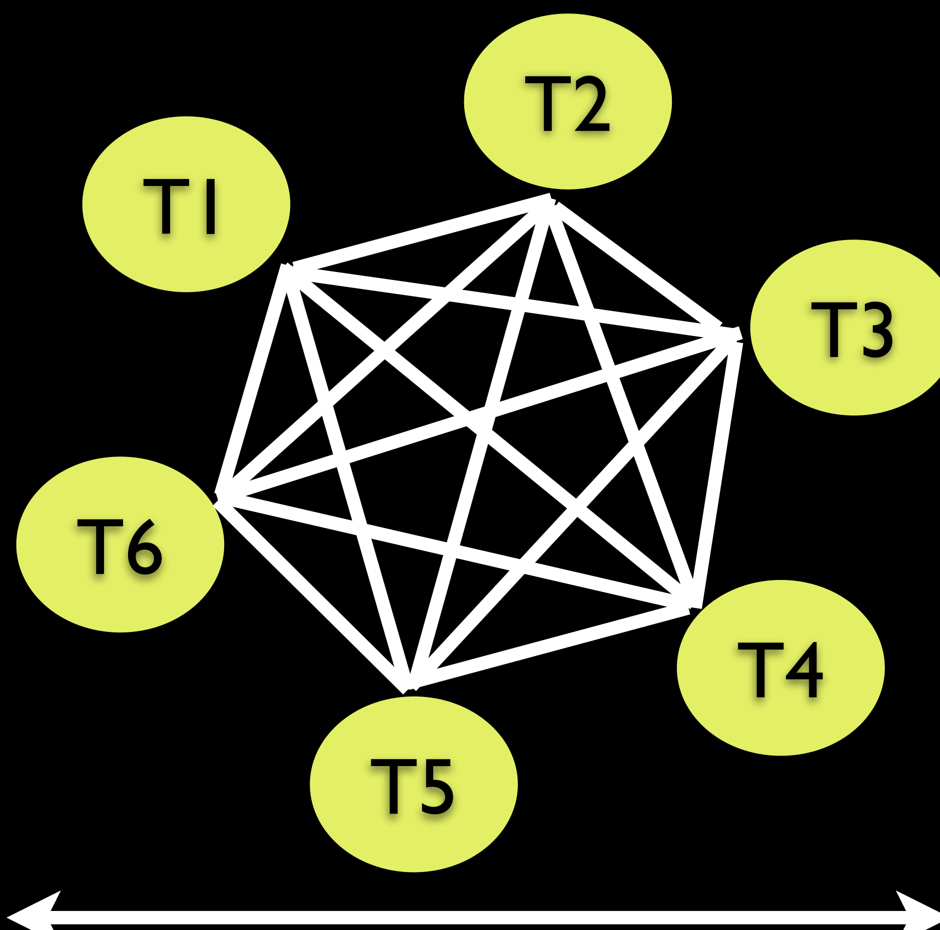


Protoplanetary disks

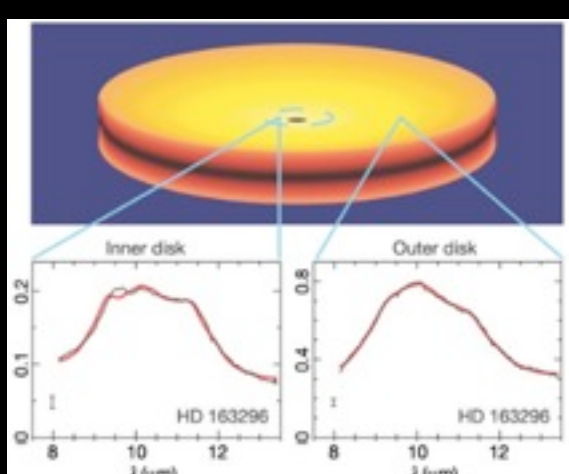
Aperture synthesis via interferometry



Binary stars

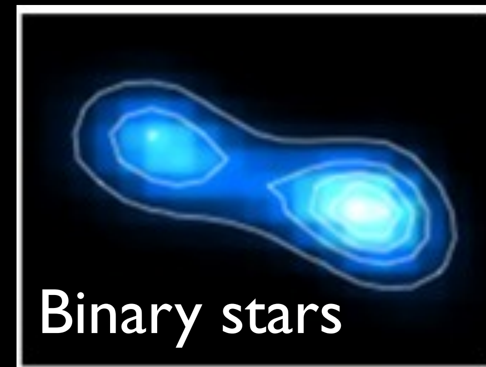


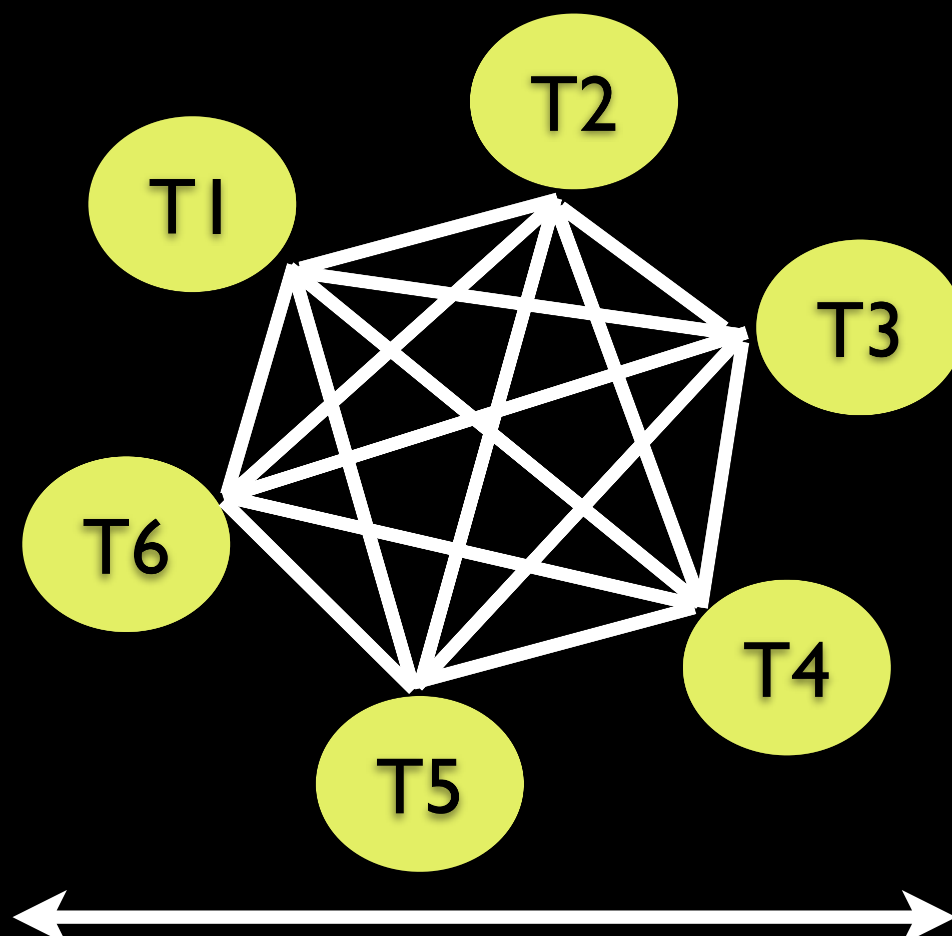
Equivalent Telescope Diameter



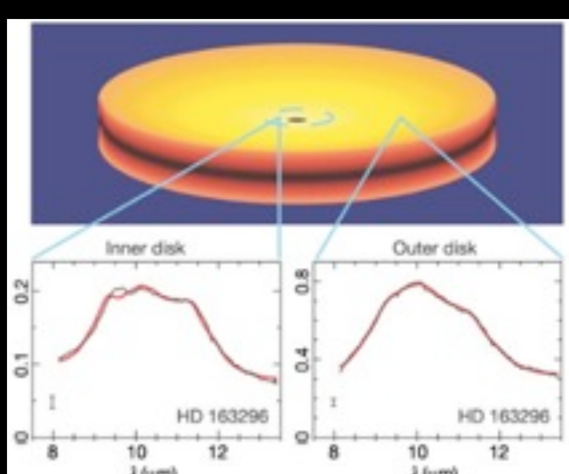
Protoplanetary disks

Aperture synthesis via interferometry

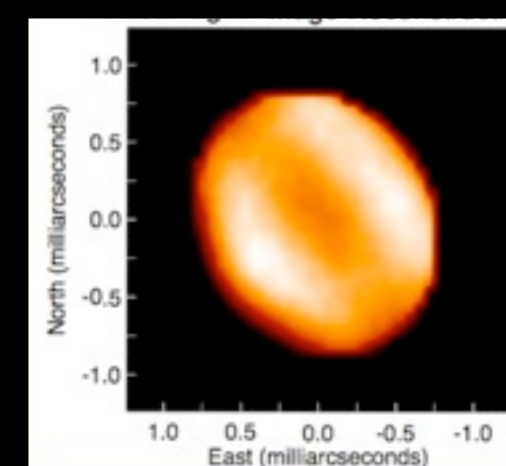




Equivalent Telescope Diameter

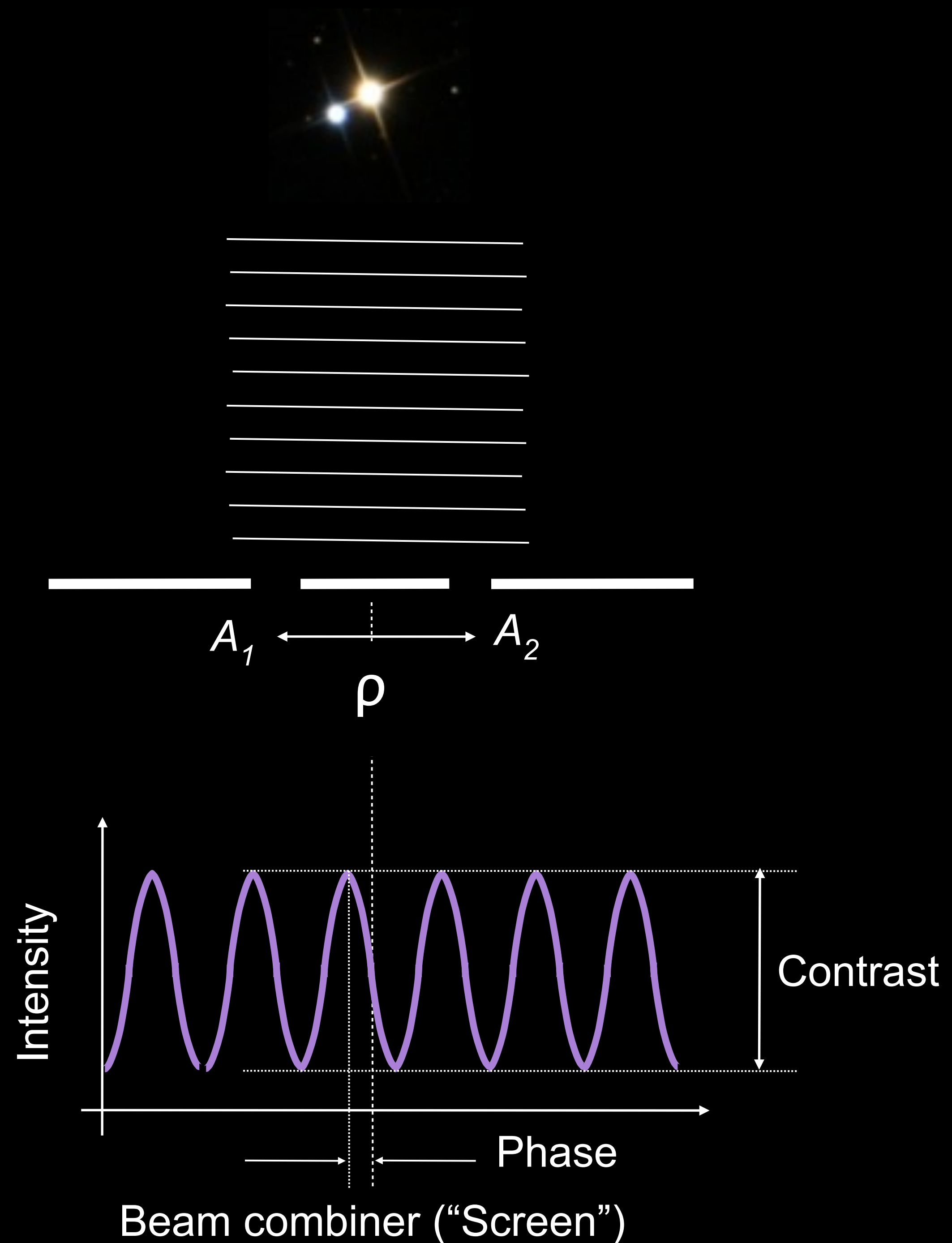


Protoplanetary disks

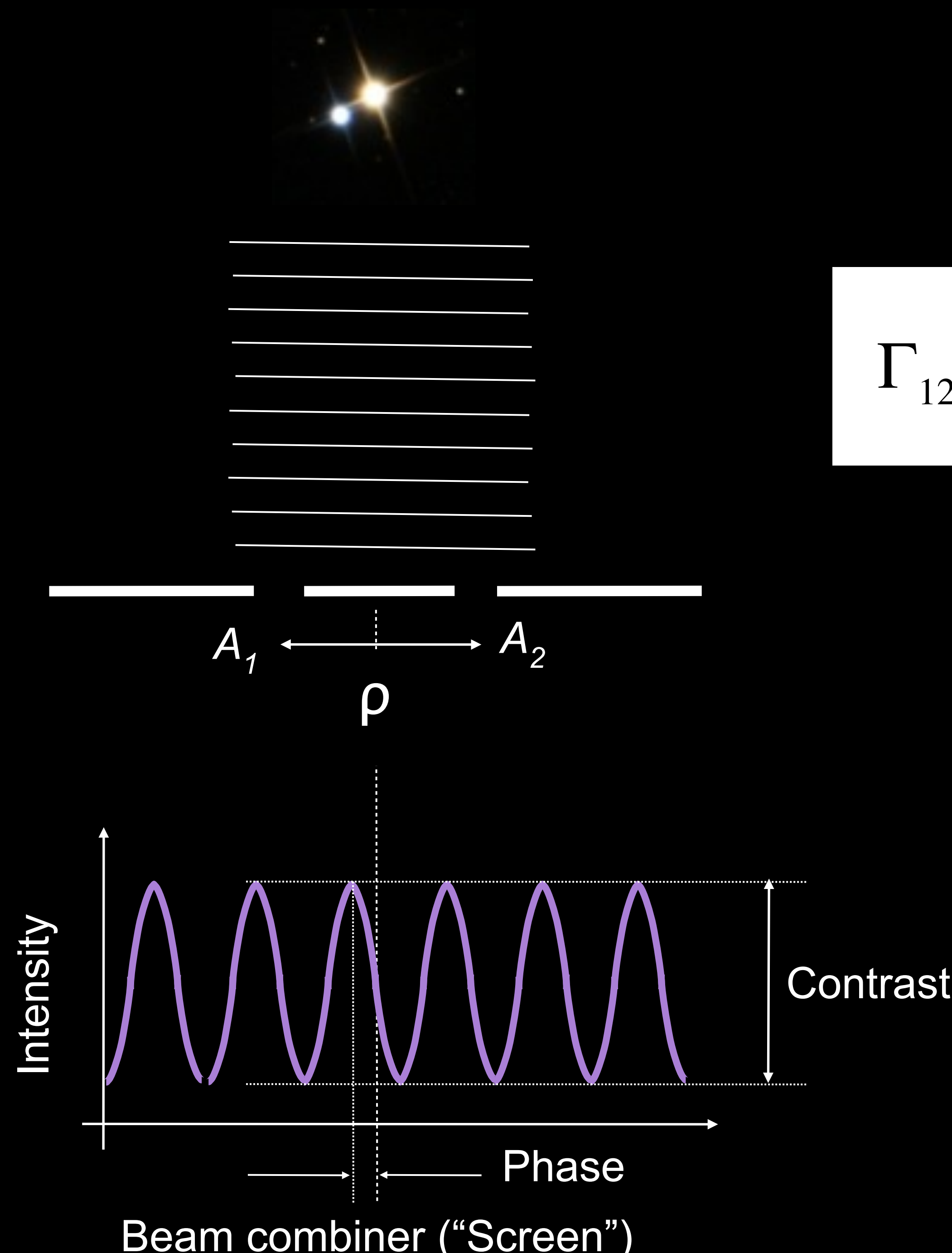


Star Photospheric Images

Principle of interferometry



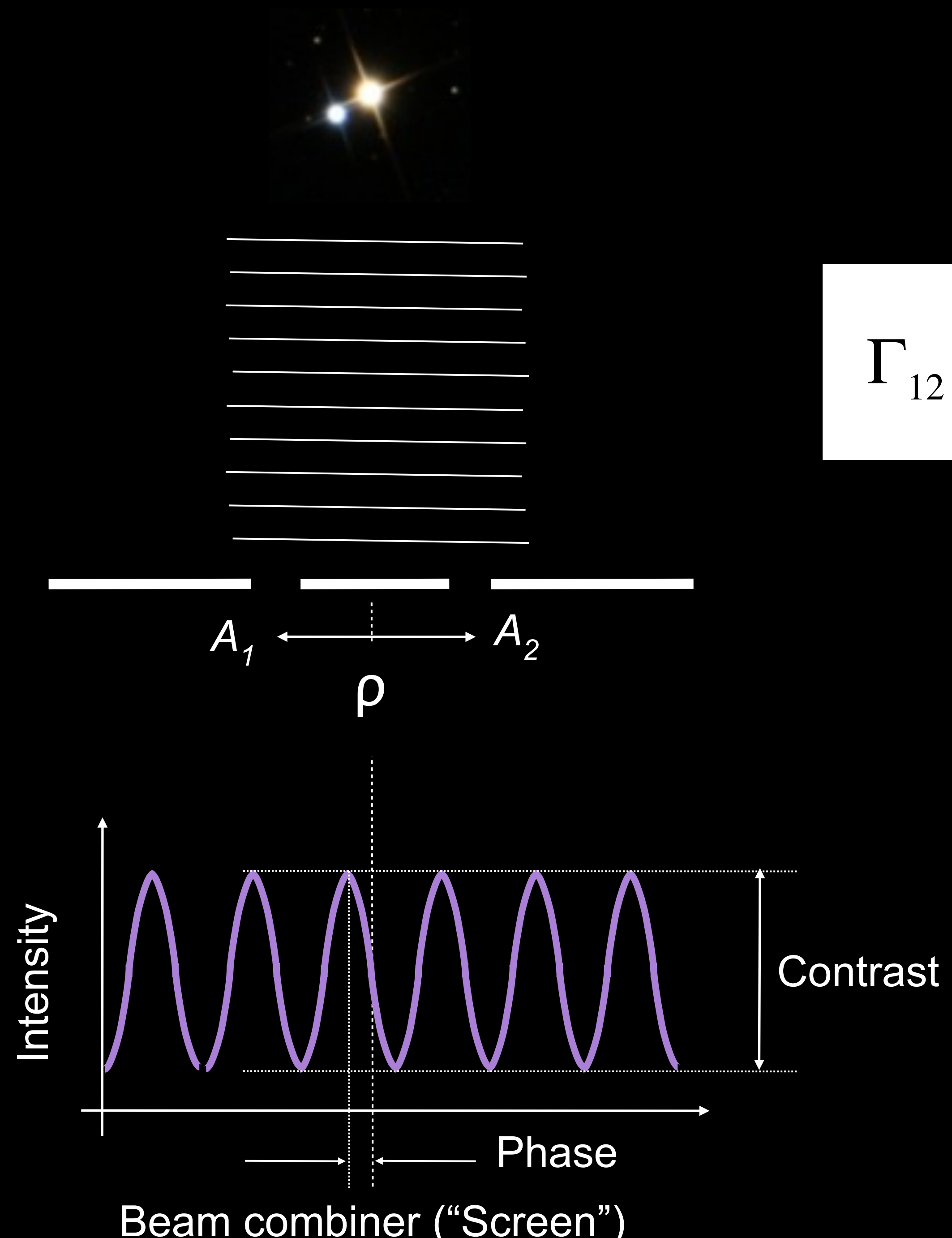
Principle of interferometry



$$\Gamma_{12}(\rho) = \langle A_1(t) A_2(t) \rangle = \int I(\alpha,\delta) e^{-i\frac{2\pi}{\lambda}(\rho_x \alpha + \rho_y \delta)} d\alpha d\delta$$

Van Cittert Theorem

Principle of interferometry



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Van Cittert Theorem

Measurement of
phase and amplitude
of the visibilities is crucial

Vibrations and interferometers

Interferometric set-ups are extremely sensitive to vibrations of mirrors.

Vibrations and interferometers

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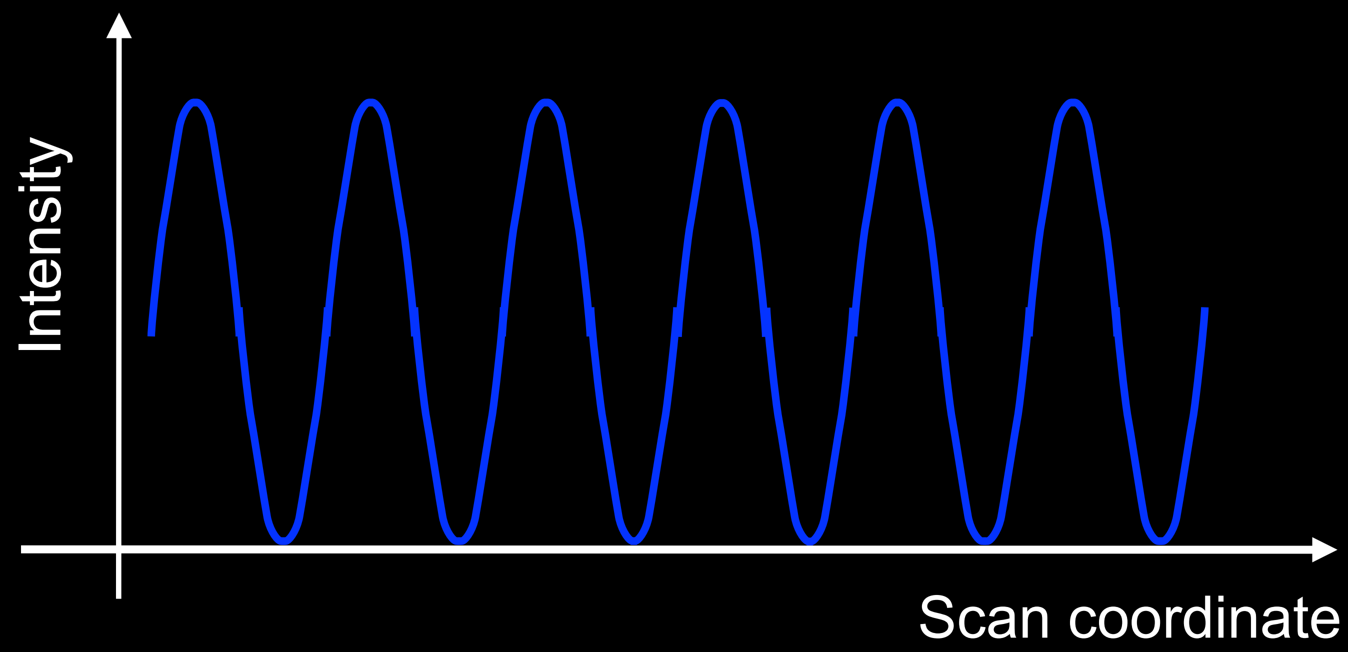

Vibrations and interferometers

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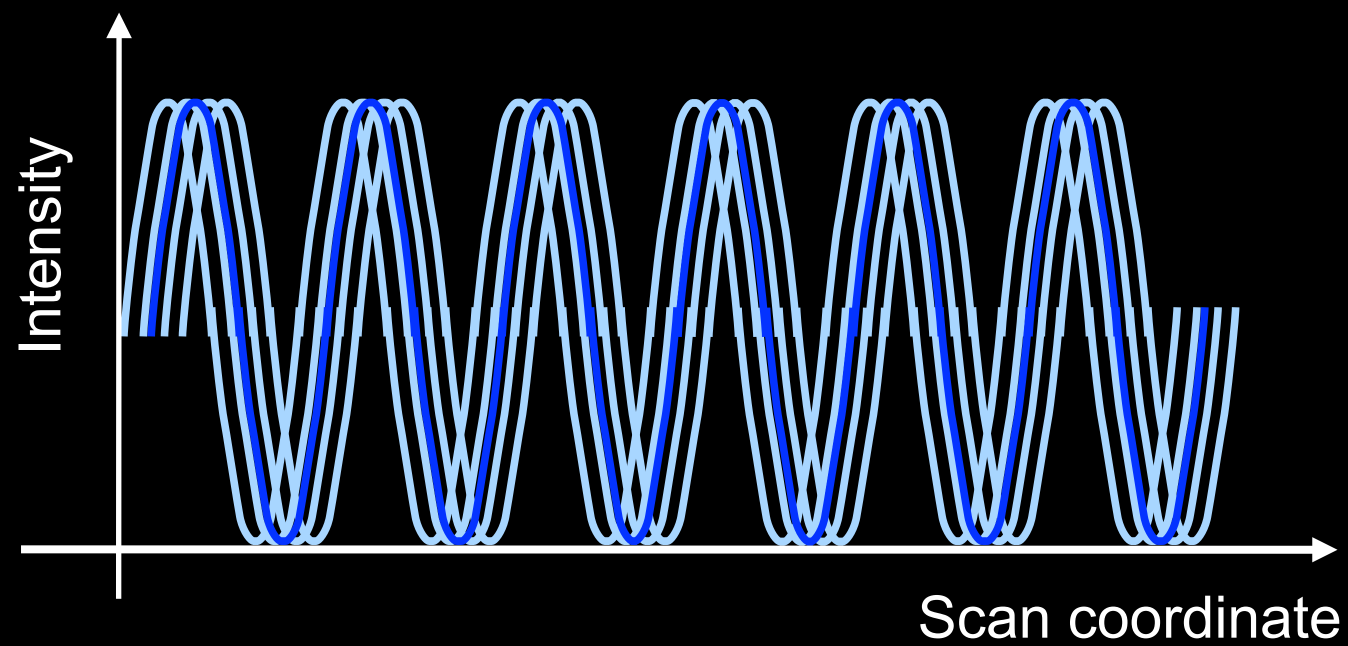

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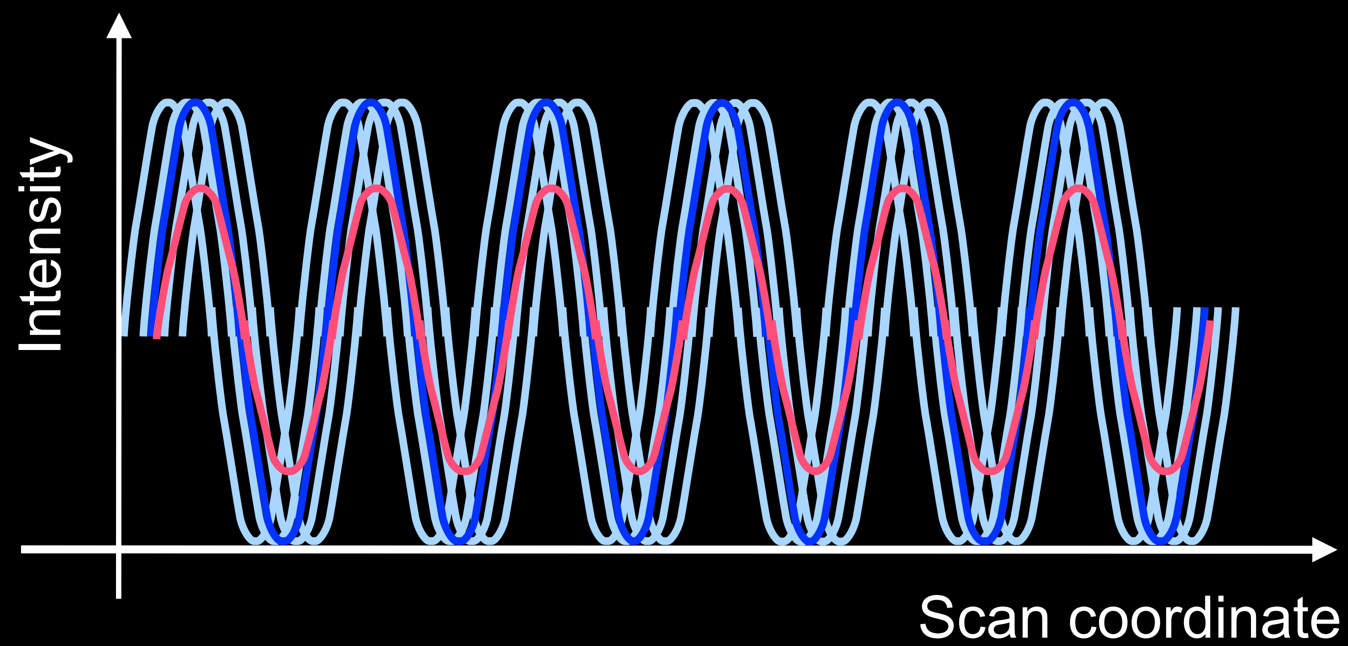


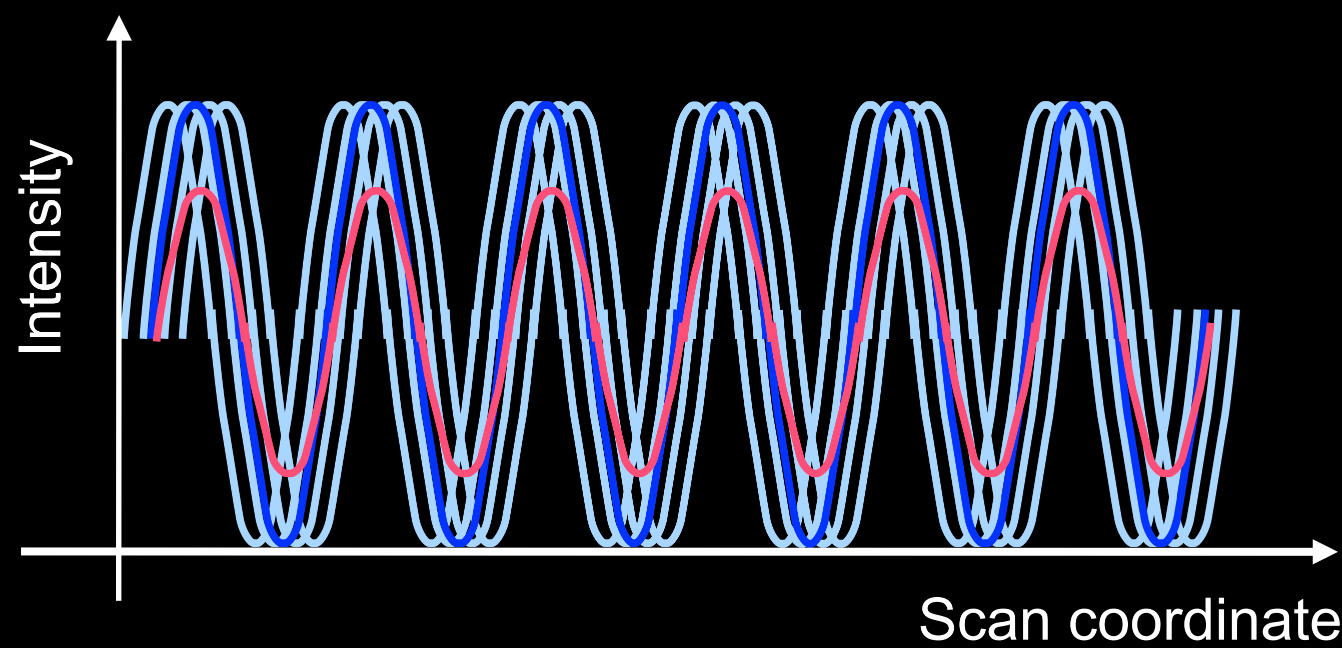
$$\Gamma_{12}(\tau) = \langle A_1(t) A_2(t+\tau) \rangle$$

↑

Non-constant phase relationship
=
smaller coherence

Vibrations and interferometers

Interferometric set-ups are extremely sensitive to vibrations of mirrors.



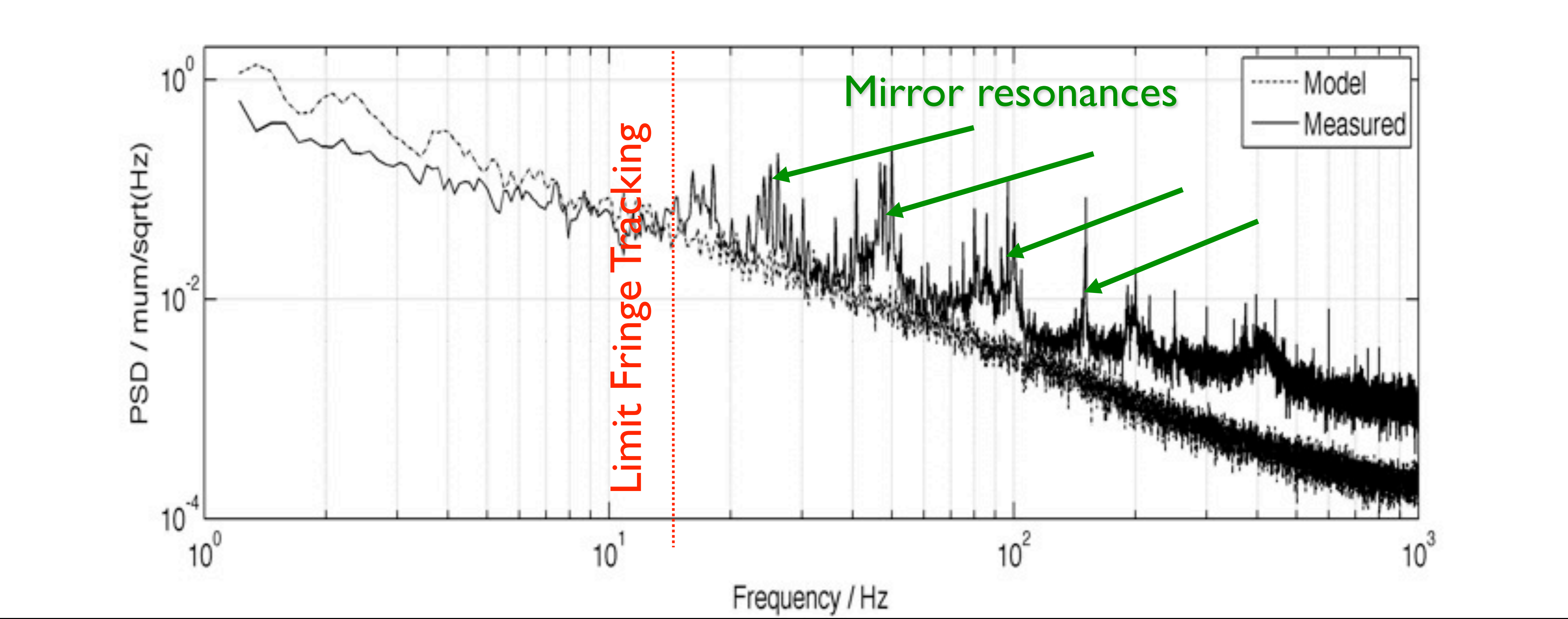
$$\Gamma_{12}(\tau) = \langle A_1(t) A_2(t+\tau) \rangle$$

Non-constant phase relationship
=
smaller coherence

Vibrations faster than detection time:

- Reduce contrast of fringes.
- Reduce detection dynamic.
- Make fringe tracking more difficult.

Motivation: vibrations at VLTI



10 Hz < Vibration frequency <1000 Hz

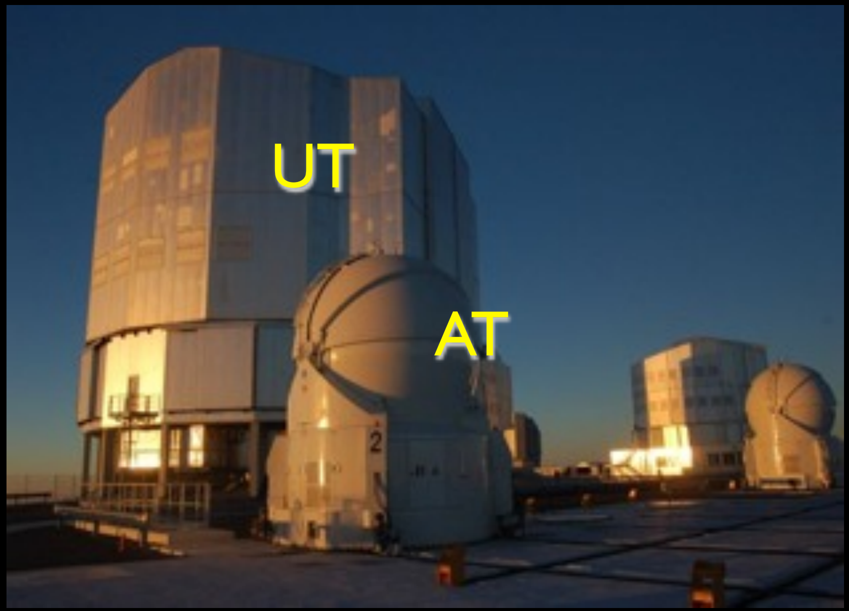
The problem:

* Residual OPD of 400 nm r.m.s. originating in UT's

* Mirrors M9-20 are monitored by PRIMA metrology.

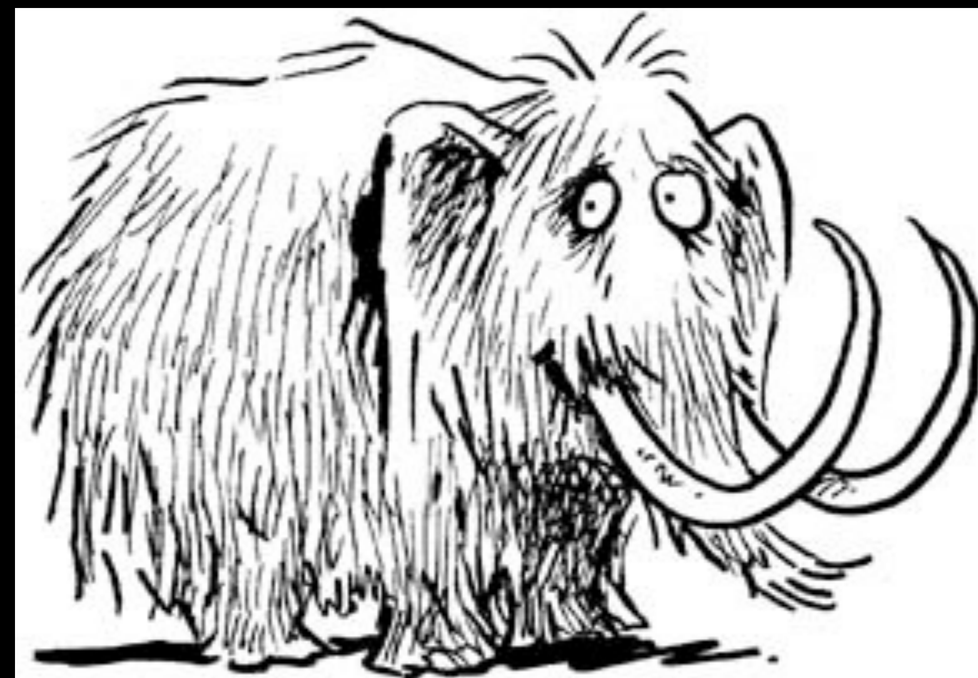
* Mirrors M1-M8 partially monitored by accelerometers.

* Mirrors M1-M8 are moving to follow the stars.



The MAMMUT project

Mirror
vibrAtion
Metrology
systeM for
the Unit
Telescope



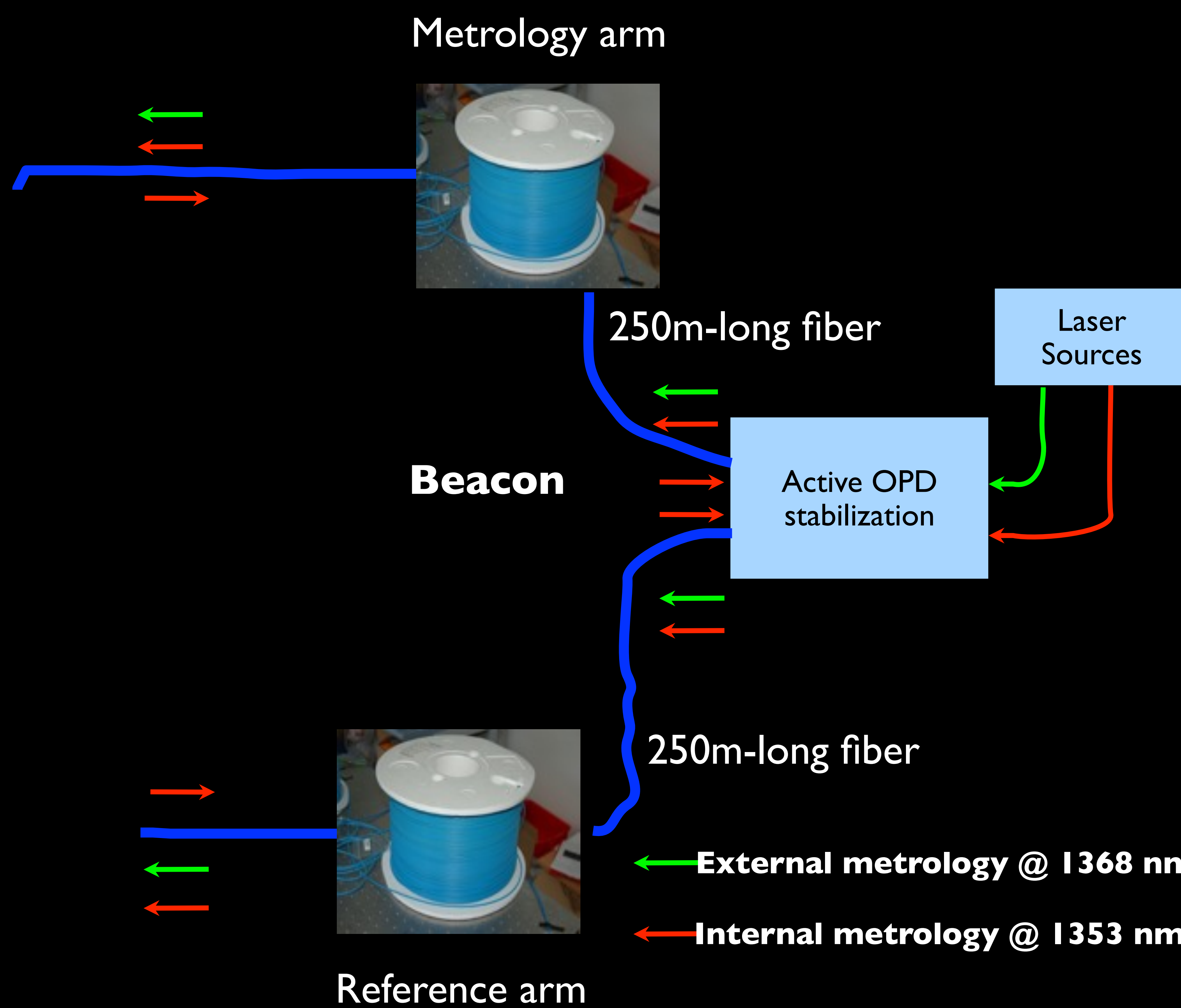
MAMMUT is a metrology system for VLTI based on telecom fiber technology designed and developed for ESO.

It mainly addresses the need for:

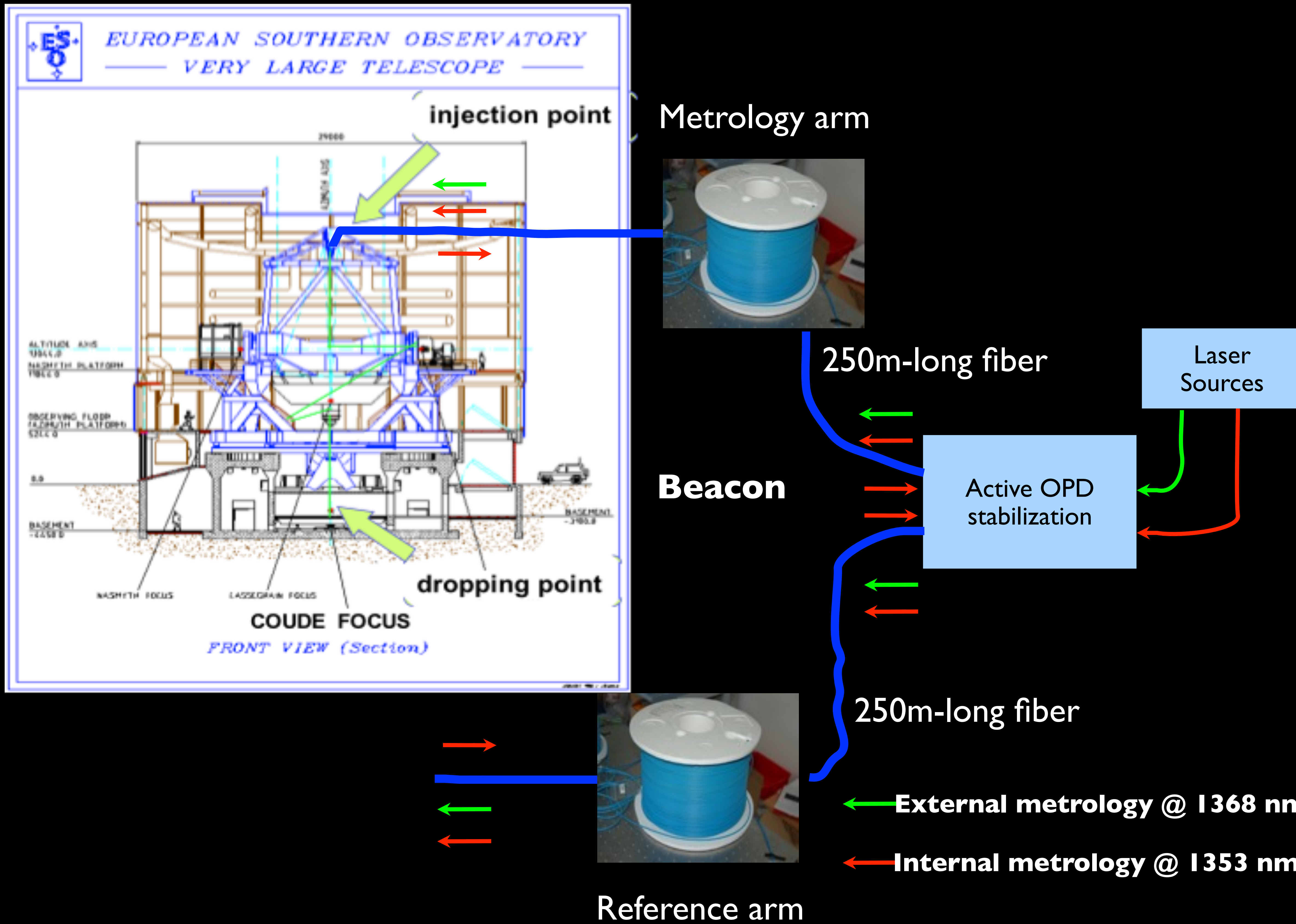
a) A metrology system accessing the moving parts of the UT.

b) High speed vibration tracking with nanometric accuracy.

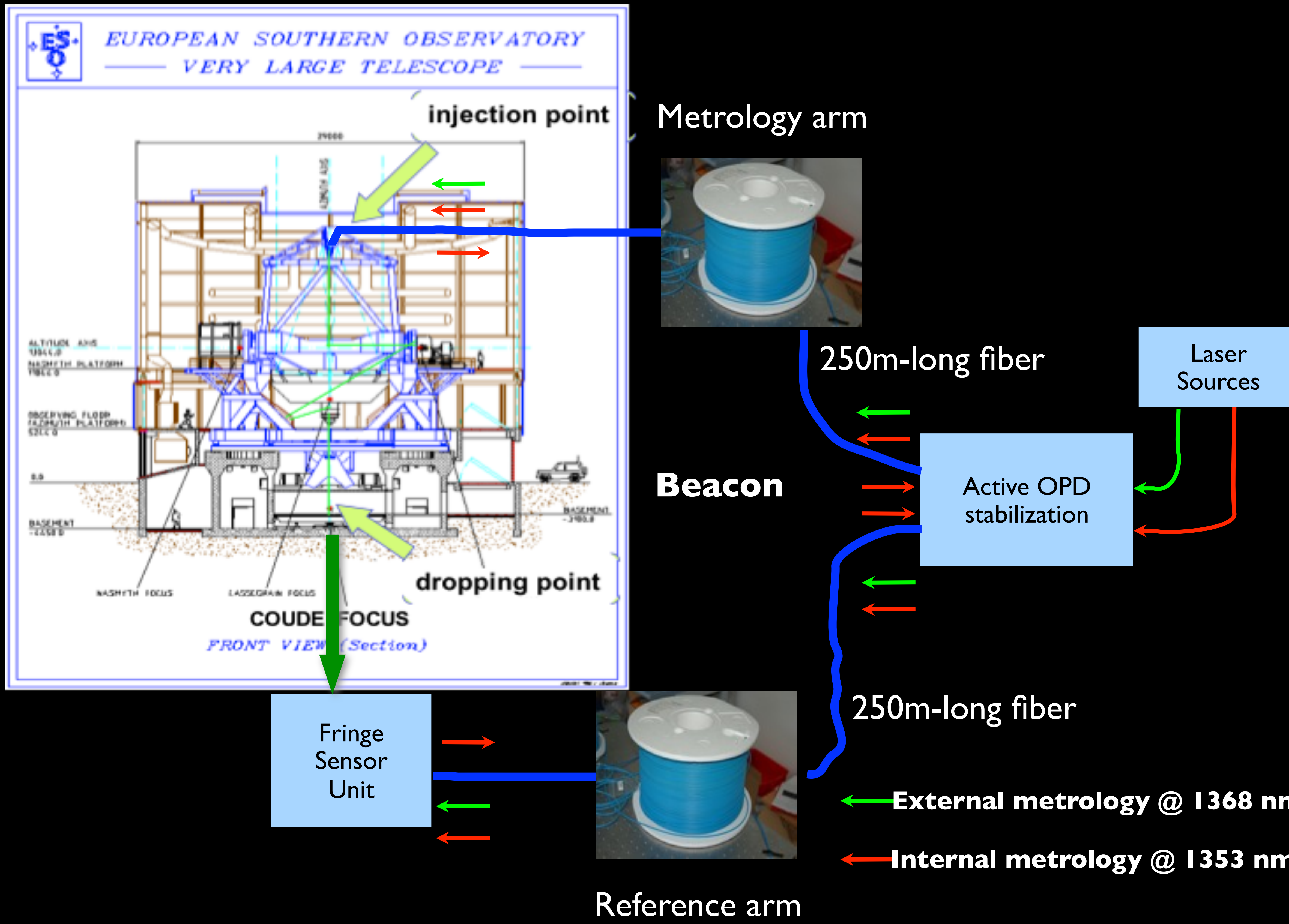
MAMMUT concept



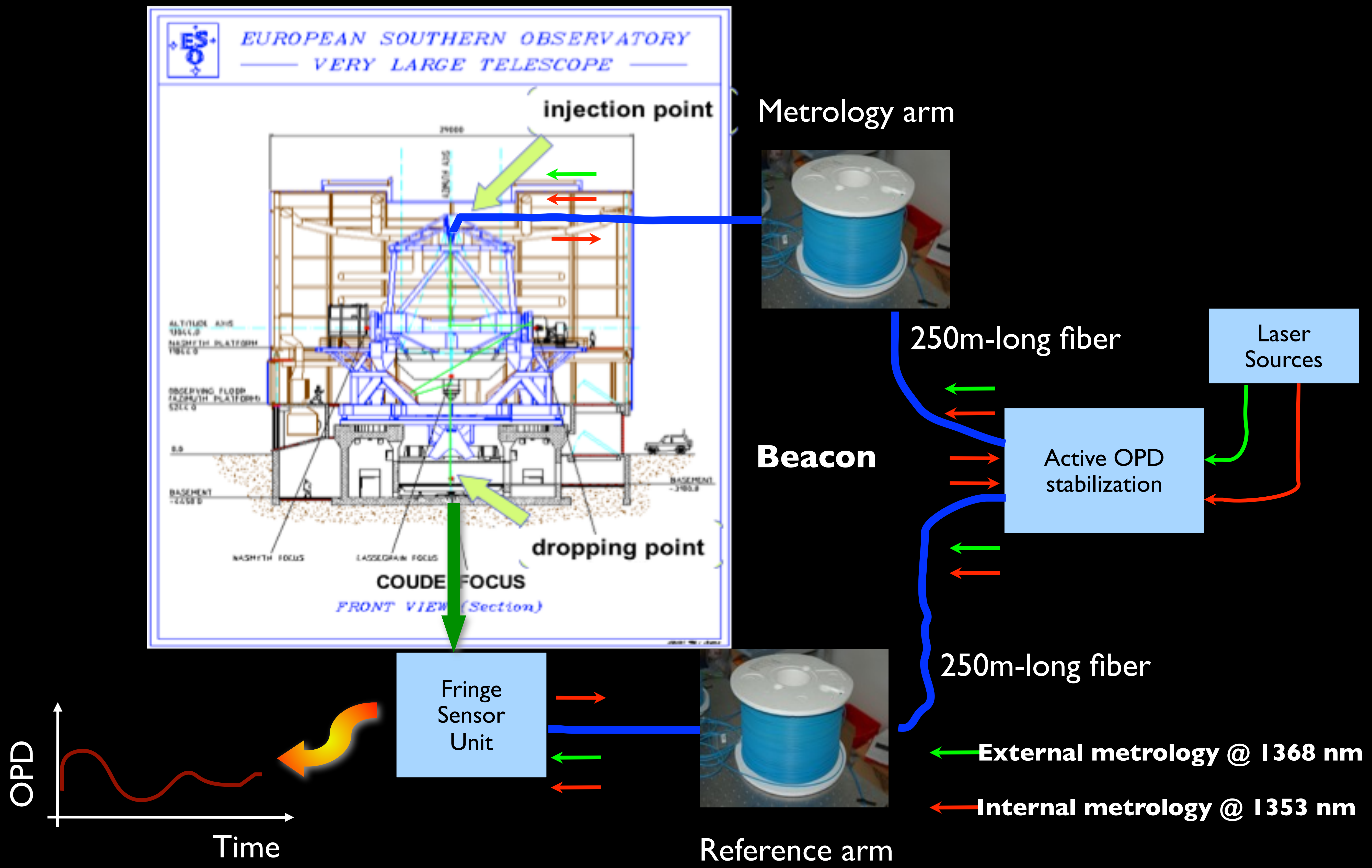
MAMMUT concept



MAMMUT concept



MAMMUT concept



MAMMUT requirements

Frequency response (-3 dB): 1 - 100 Hz
Pure delay: < 100 µs

Resolution: < 1 nm

Linearity: 1%

Range (excluding DC component): ±5 µm

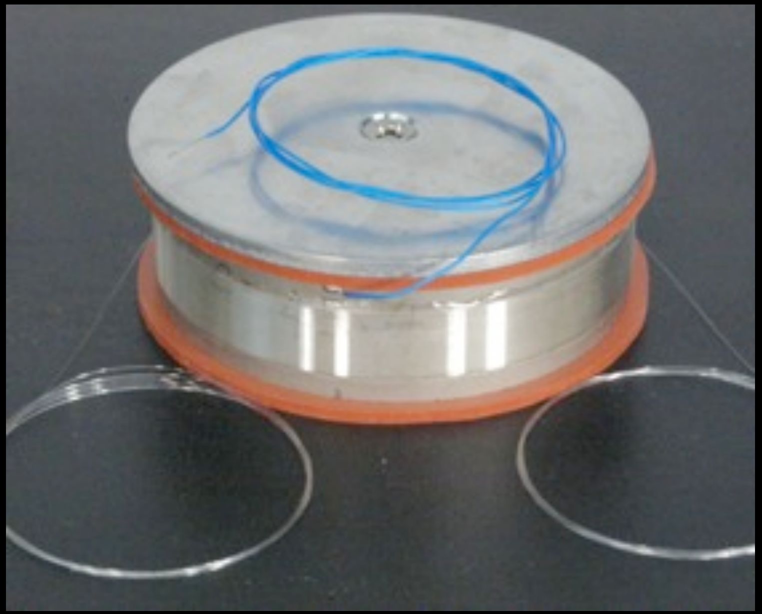
Noise PSD: < 1 nm^2/Hz (=10 nm r.m.s.)

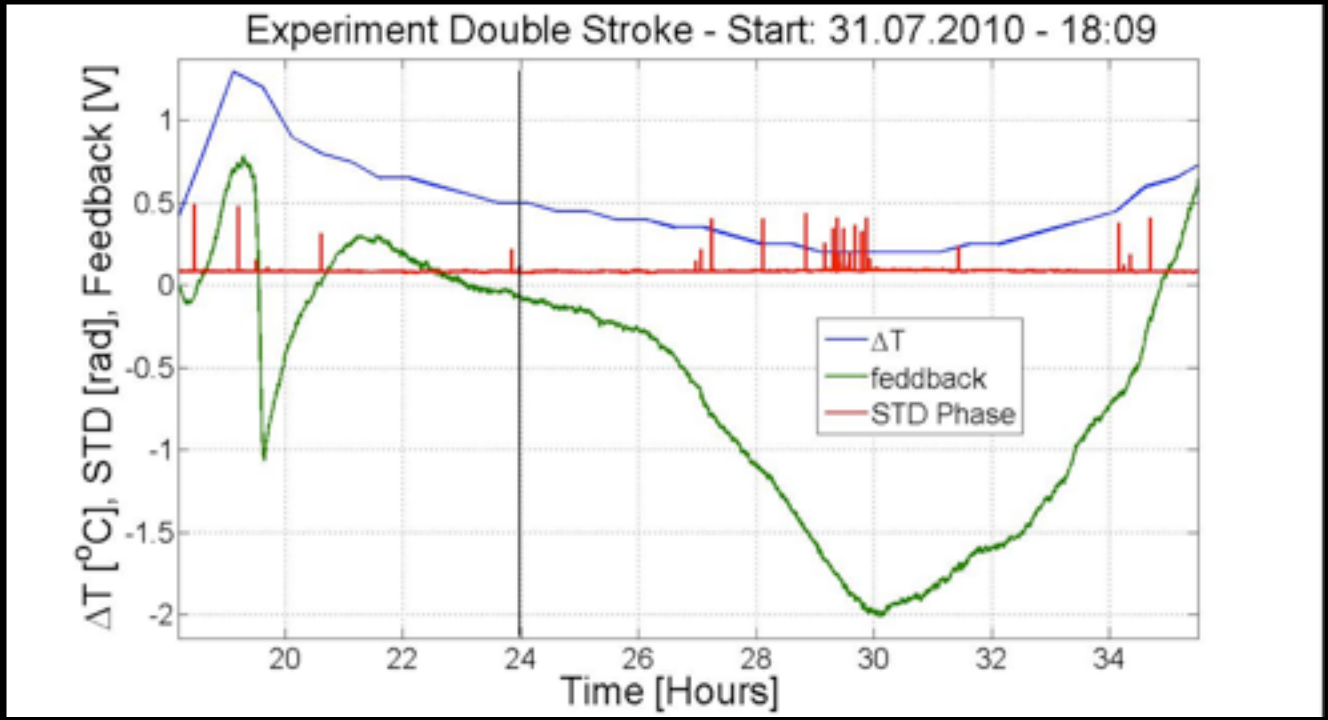
Laser wavelength: between 1350nm and 1400 nm

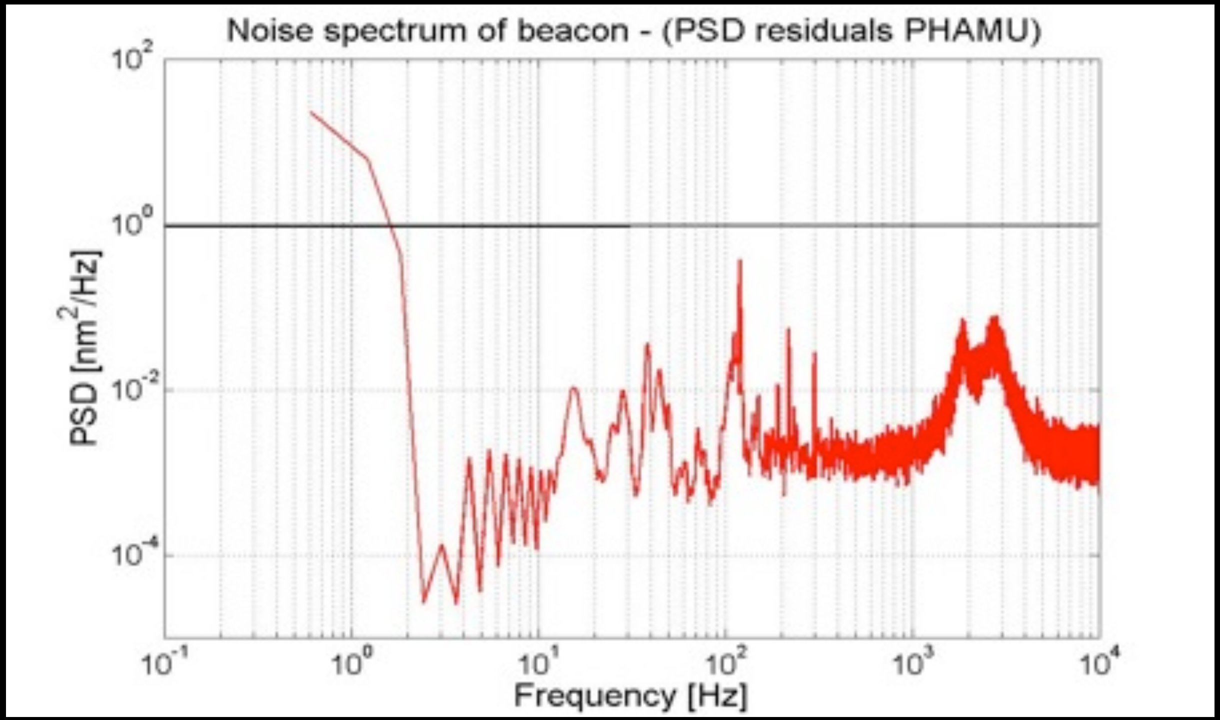
Length of fiber interferometer: 250+250 m

MAMMUT beacon

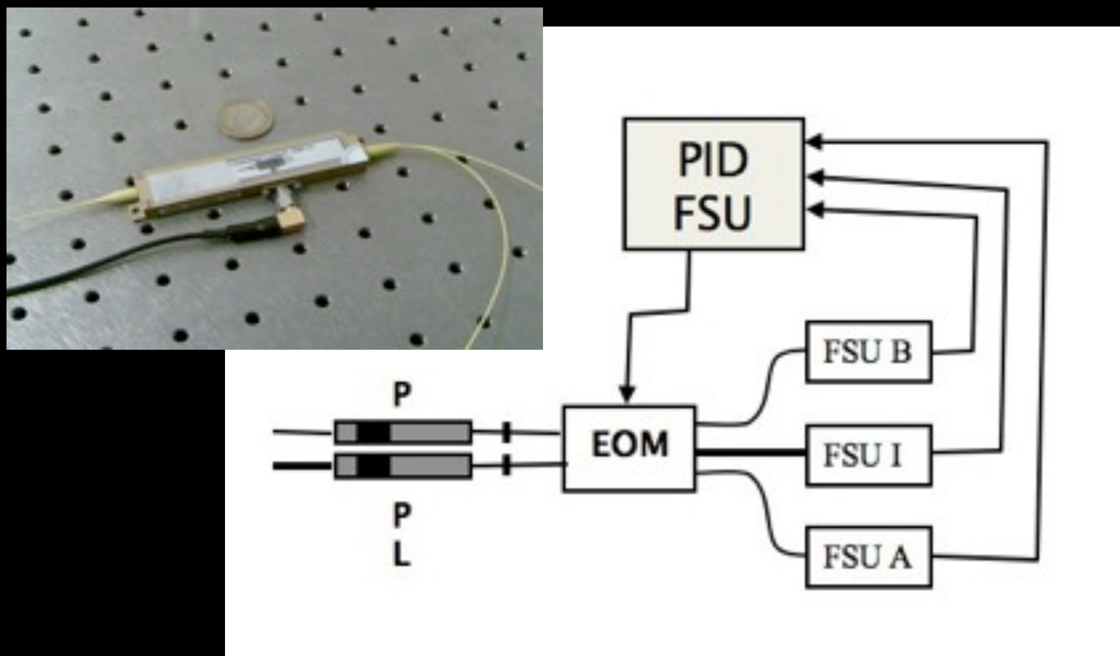
- Active phase modulation achieved via fiber-stretchers
- Keeps the OPD constant for several hours
- Phase noise level is below 20 nm r.m.s.
- PSD < 10^{-1} nm^2/Hz







MAMMUT fringe sensor

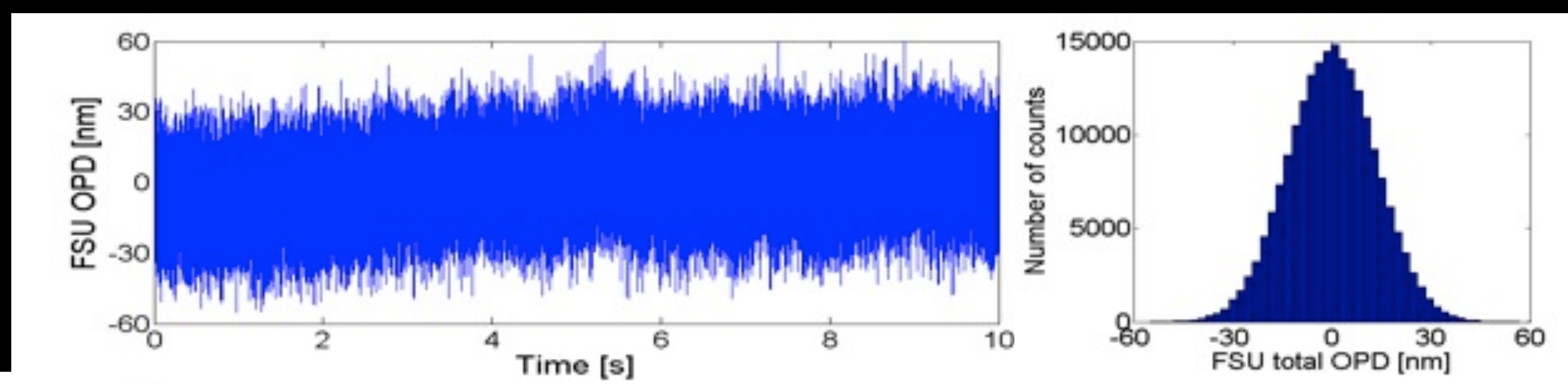


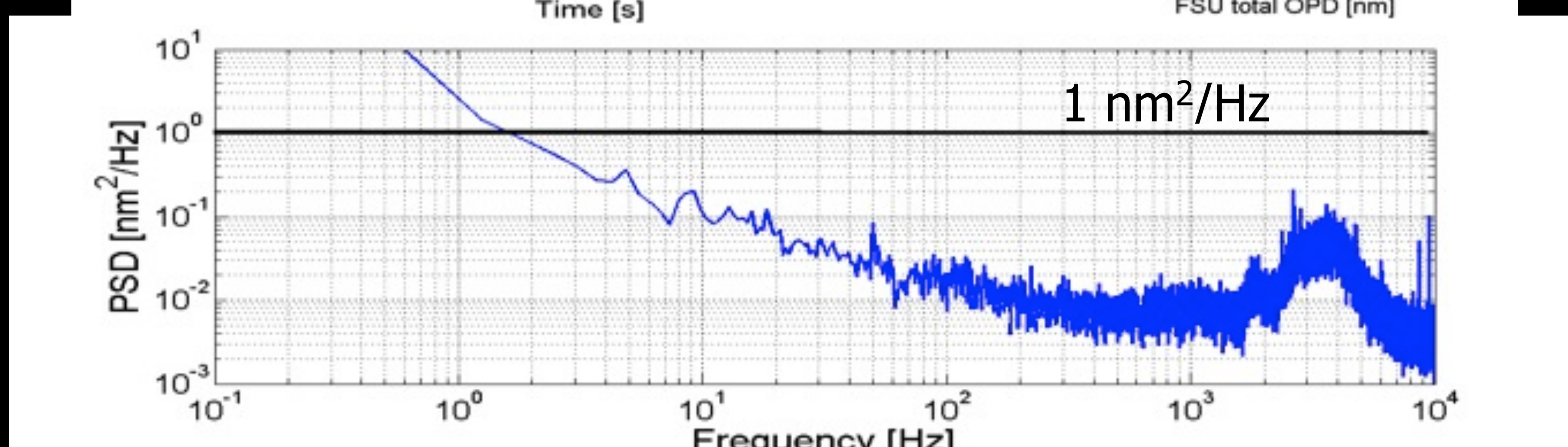
Measures the phase from feedback signal required to track fringes

Automatic phase unwrapping

Phase control via Electro-Optical Modulator

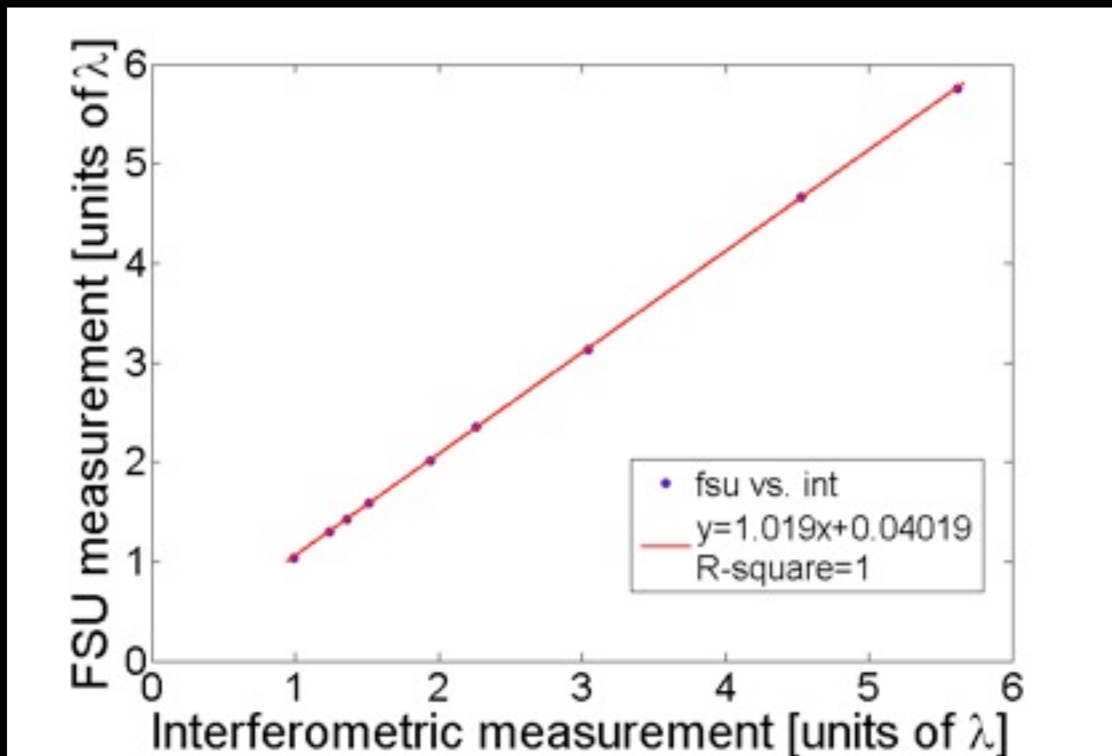
Low noise



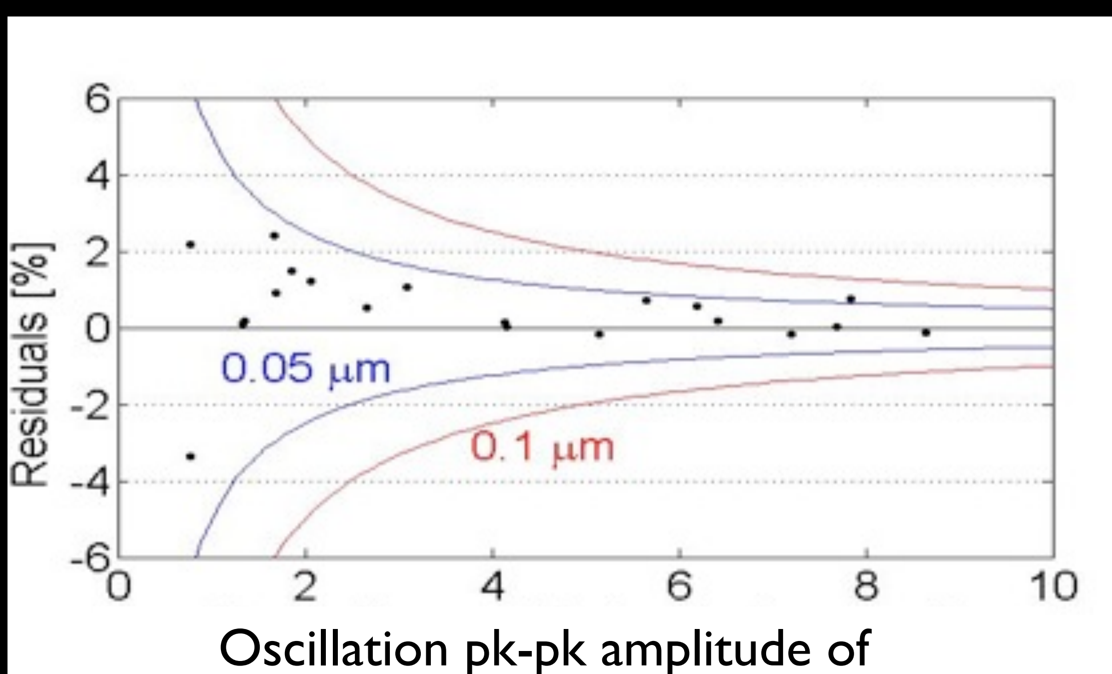


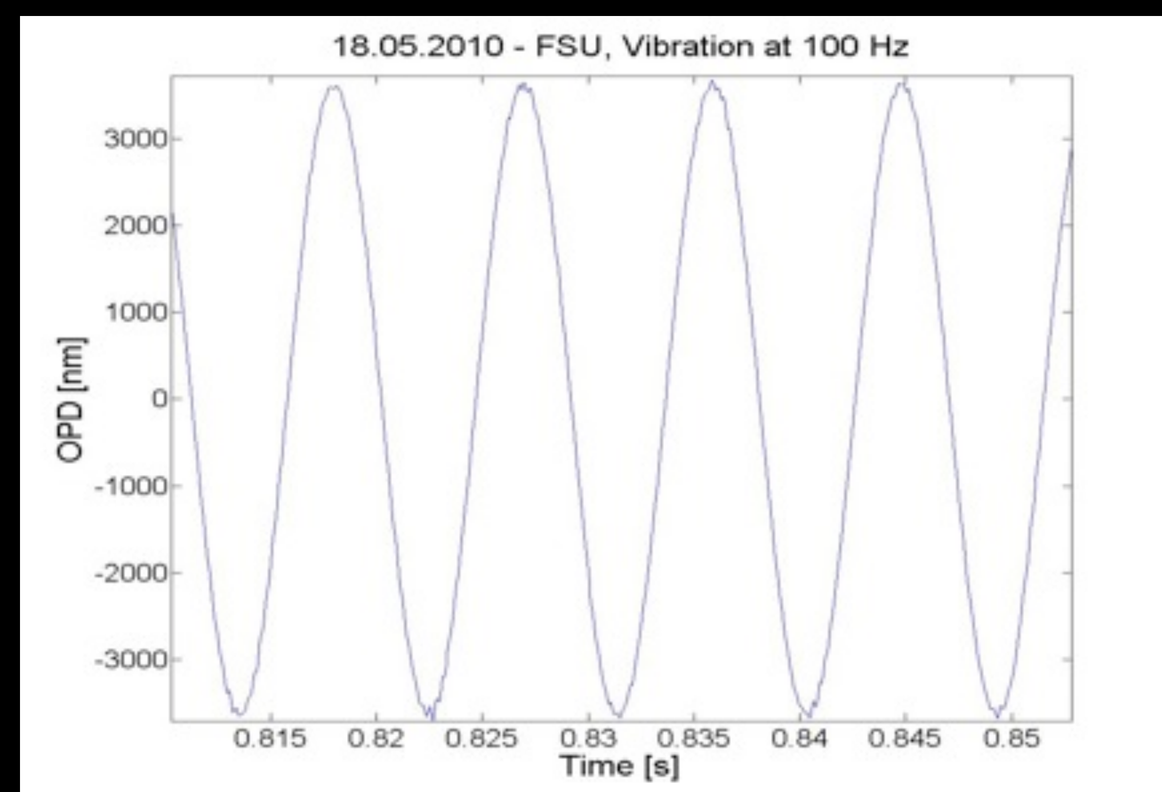
Minardi et al. Astr. Nach. 330, 518 (2009).
Spaleniak et al. SPIE 7734-145 (2010).

MAMMUT fringe sensor



- Linearity better than 1%
- Range up to 10 µm
- Frequency response >300 Hz





New directions:

The discrete beam combiner

Motivation: fast astronomical events

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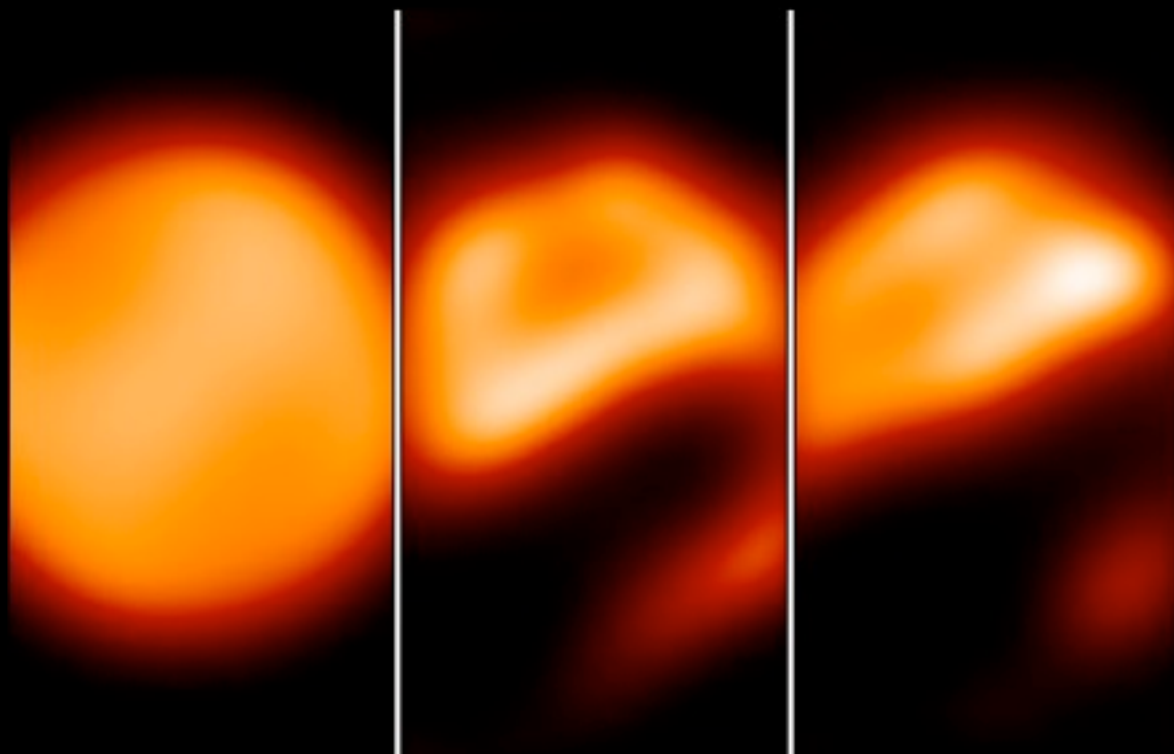
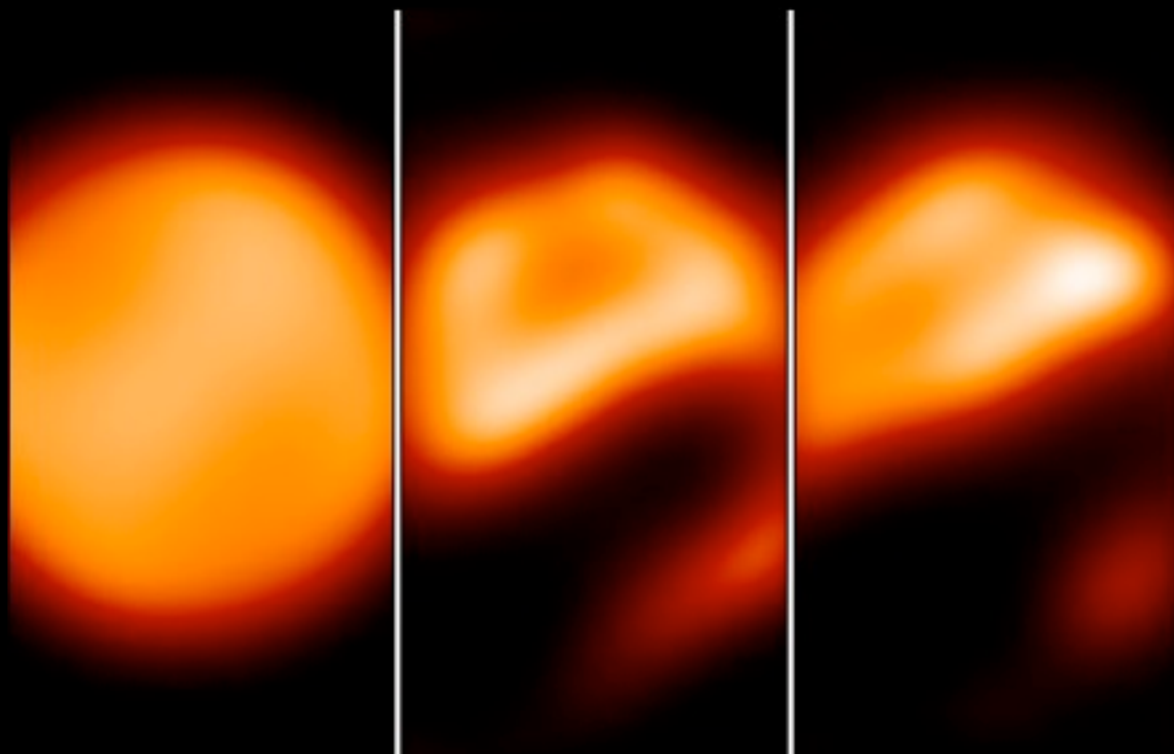


Exoplanet transits

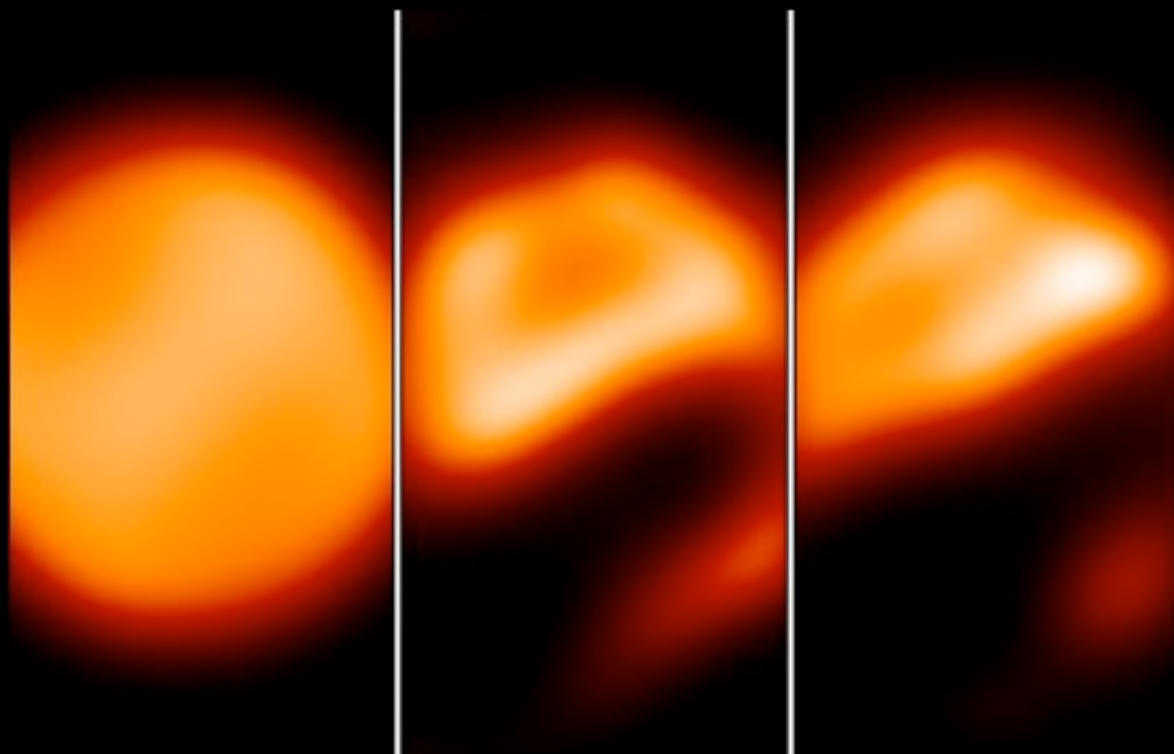
Motivation: fast astronomical events



Exoplanet transits

Nova/Supernova explosion

Motivation: fast astronomical events

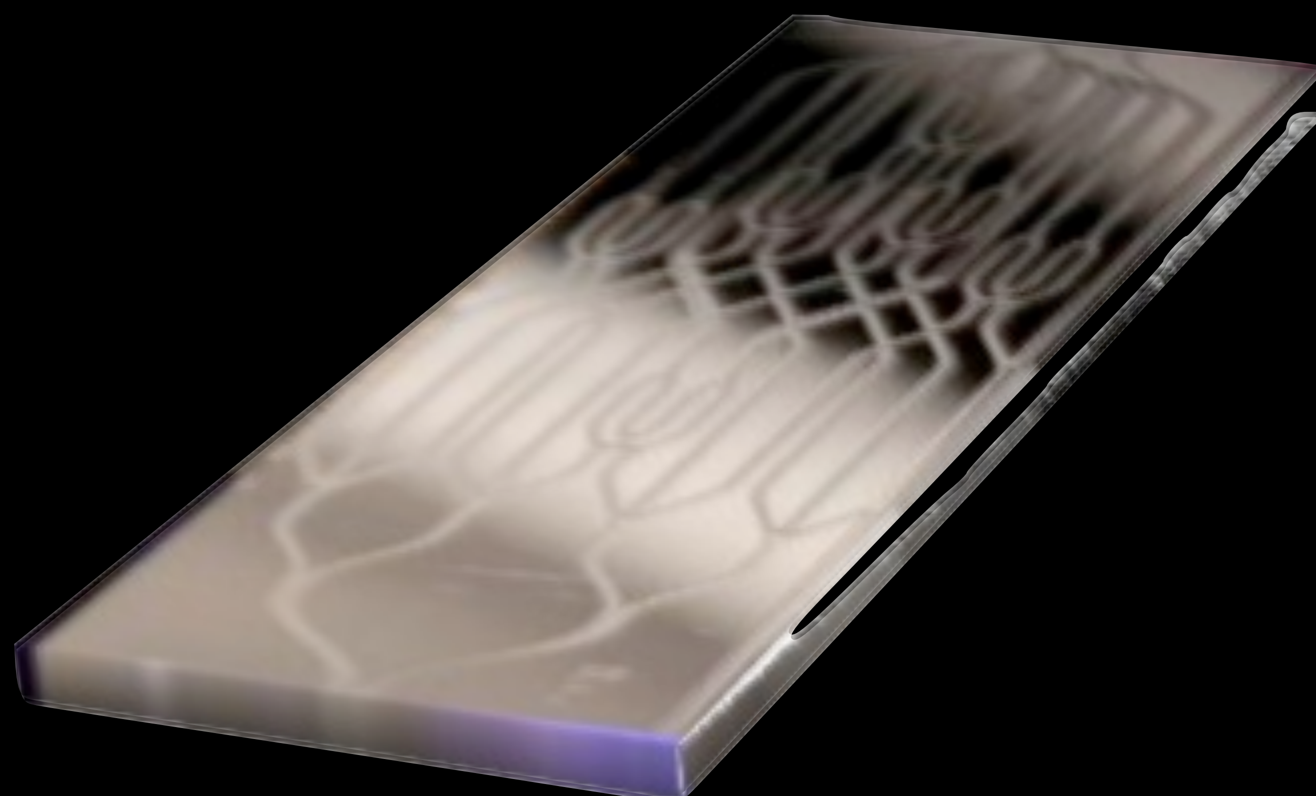


Exoplanet transits

Nova/Supernova explosion

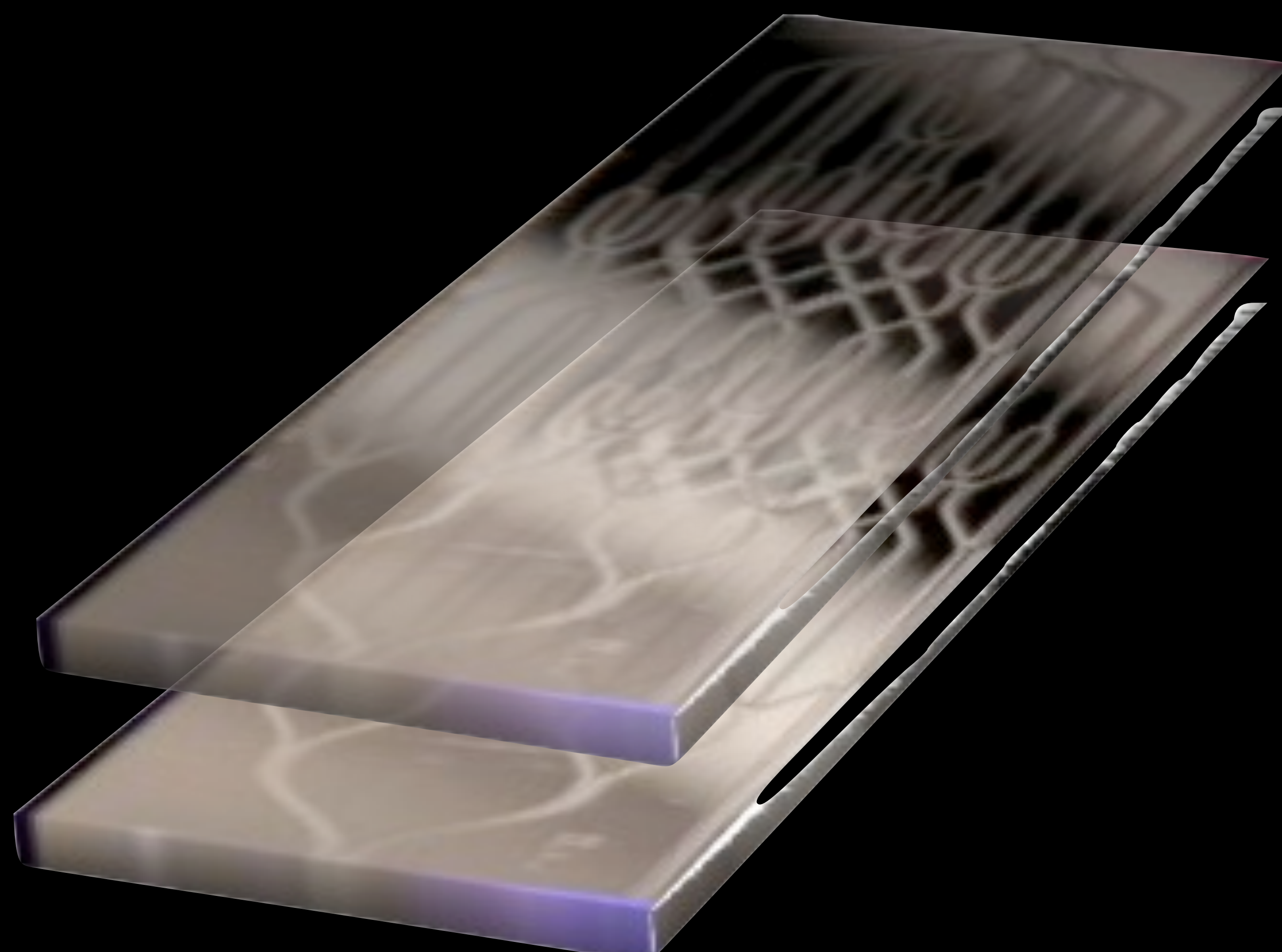
Require simultaneous beam combination of many telescopes

Beyond 4-Telescope Combination



Benisty et al. A&A **498,** 601 (2009).

Beyond 4-Telescope Combination



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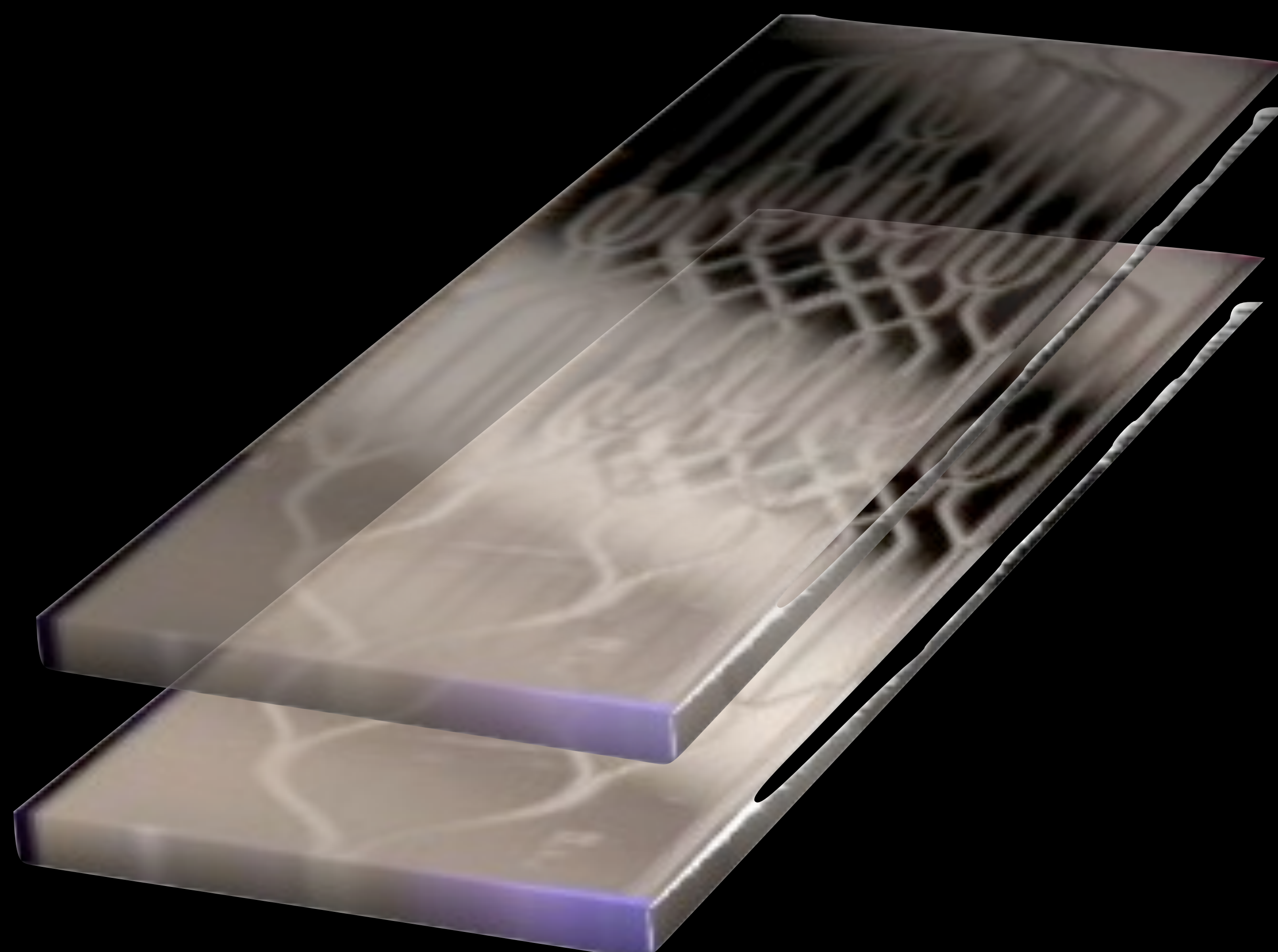
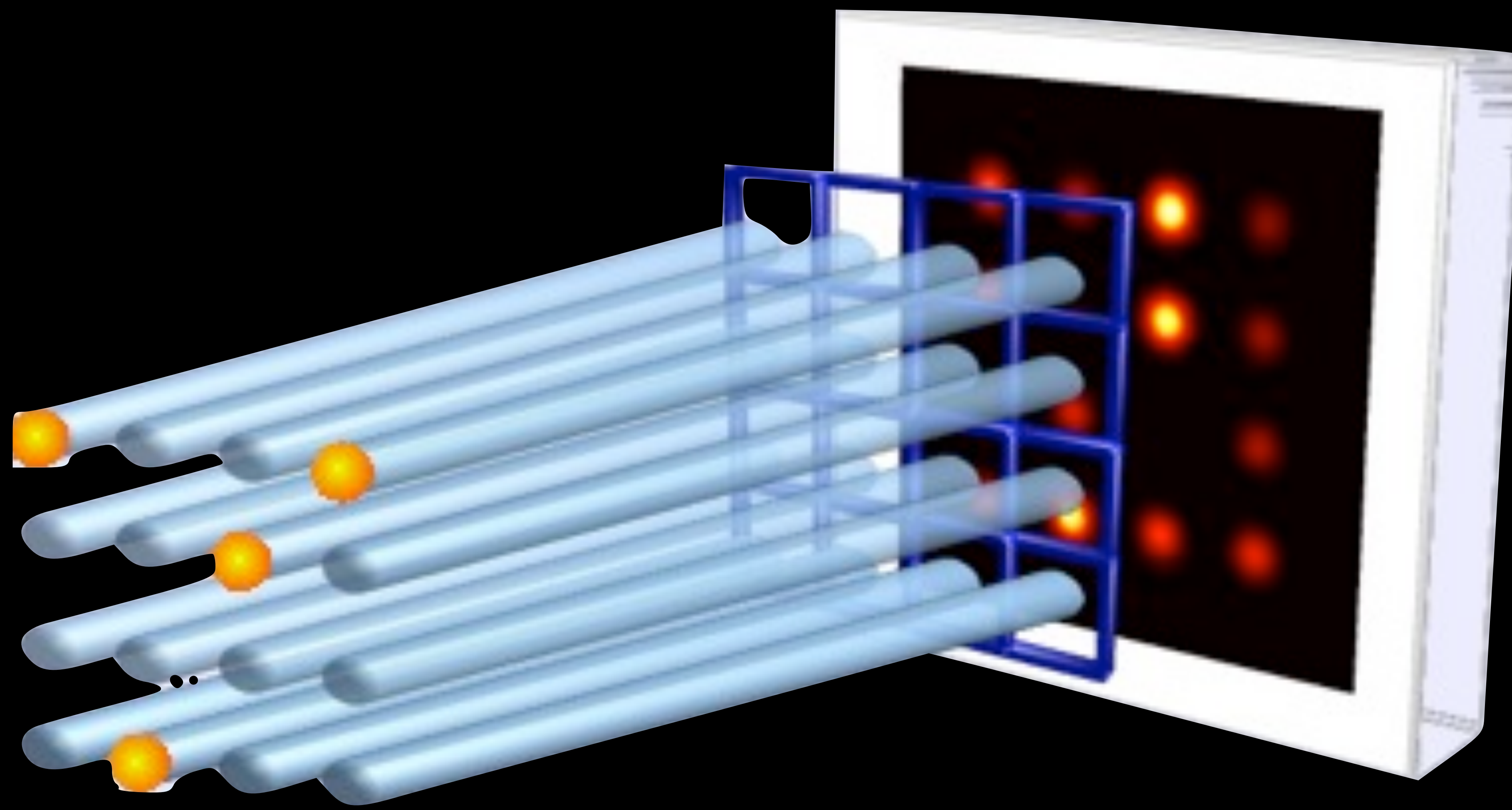
Beyond 4-Telescope Combination



Can 3D geometry ease scalability?

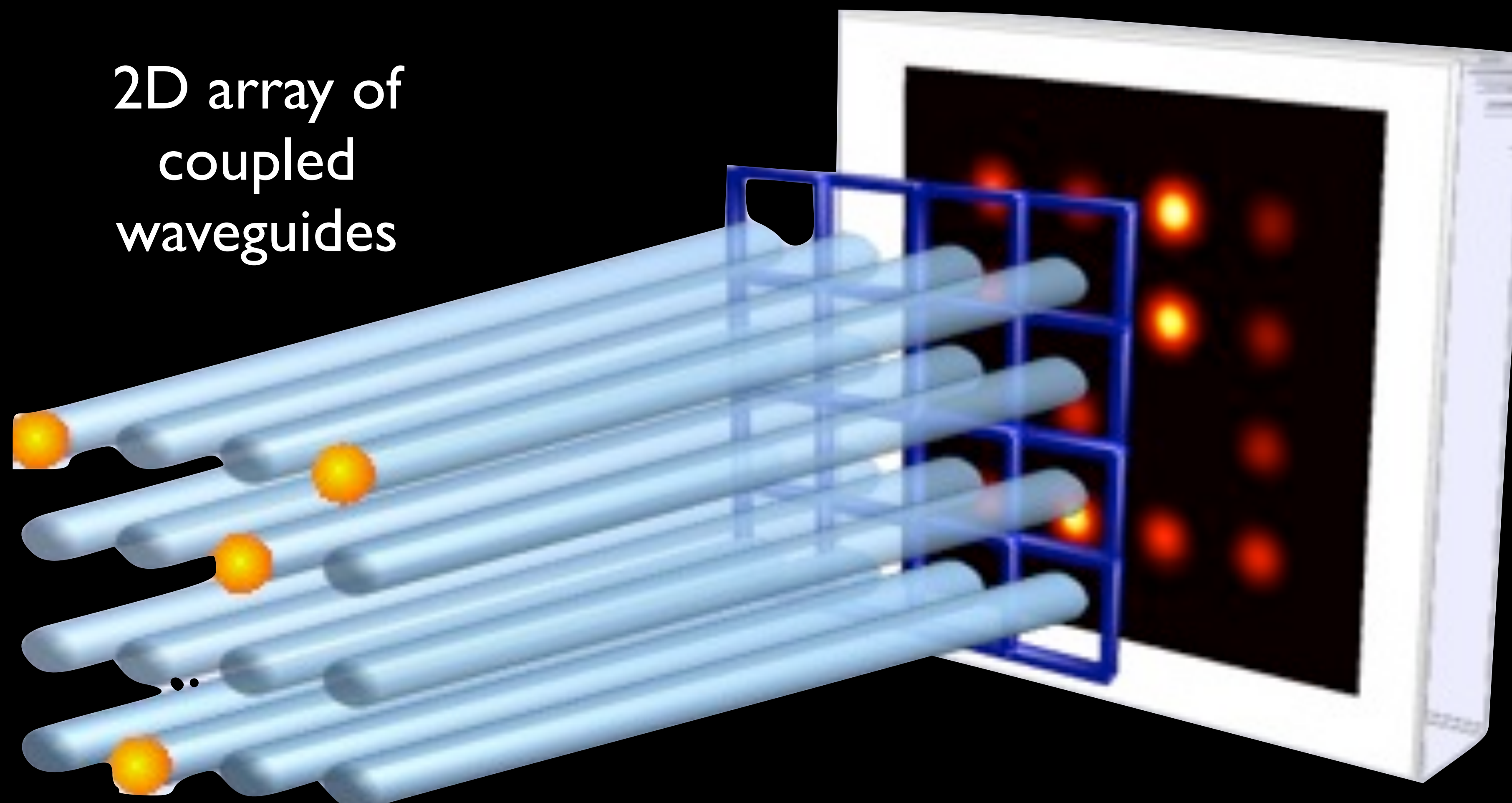
Benisty et al. A&A **498,** 601 (2009).

The discrete beam combiner



Minardi, Neuhauser, Pertcsh *SPIE* **7034**-136 (2010).
Minardi, Pertsch *Opt. Lett.* **35,** 3009 (2010).

The discrete beam combiner



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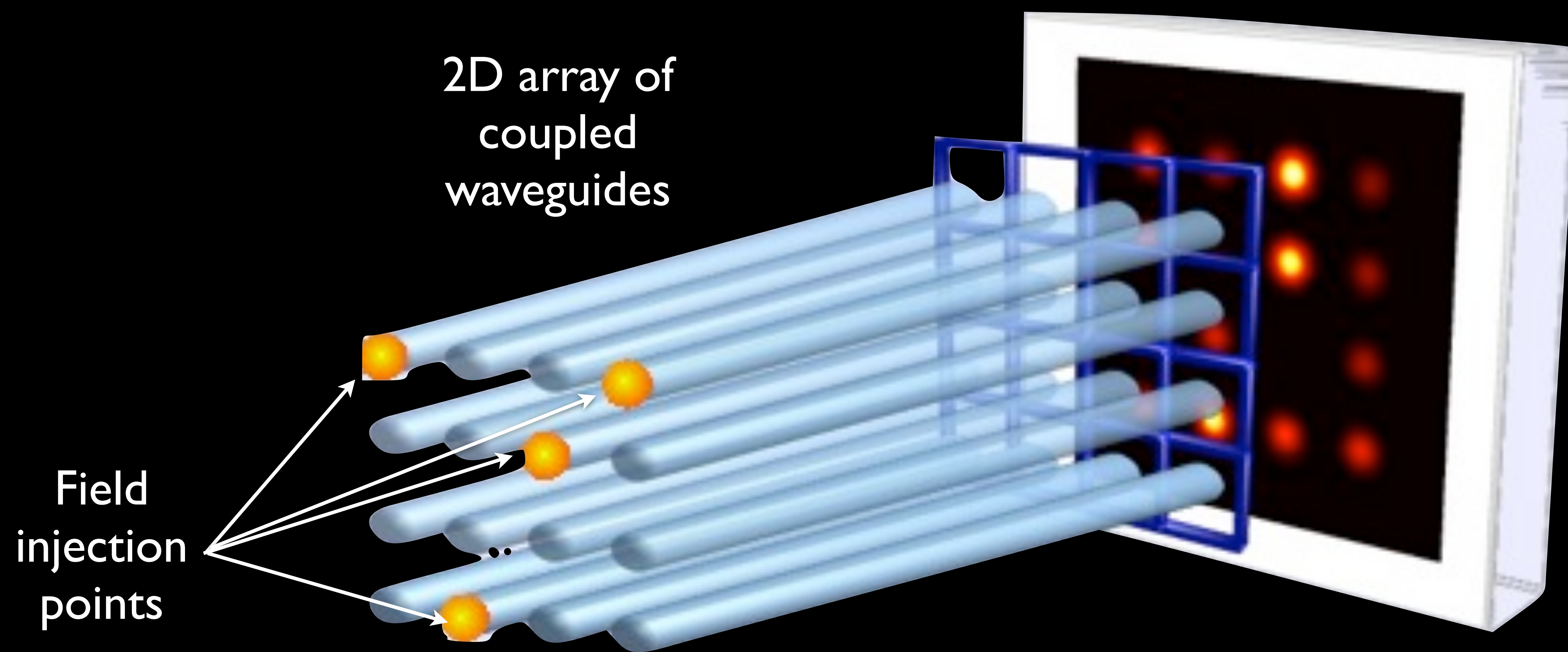
The discrete beam combiner



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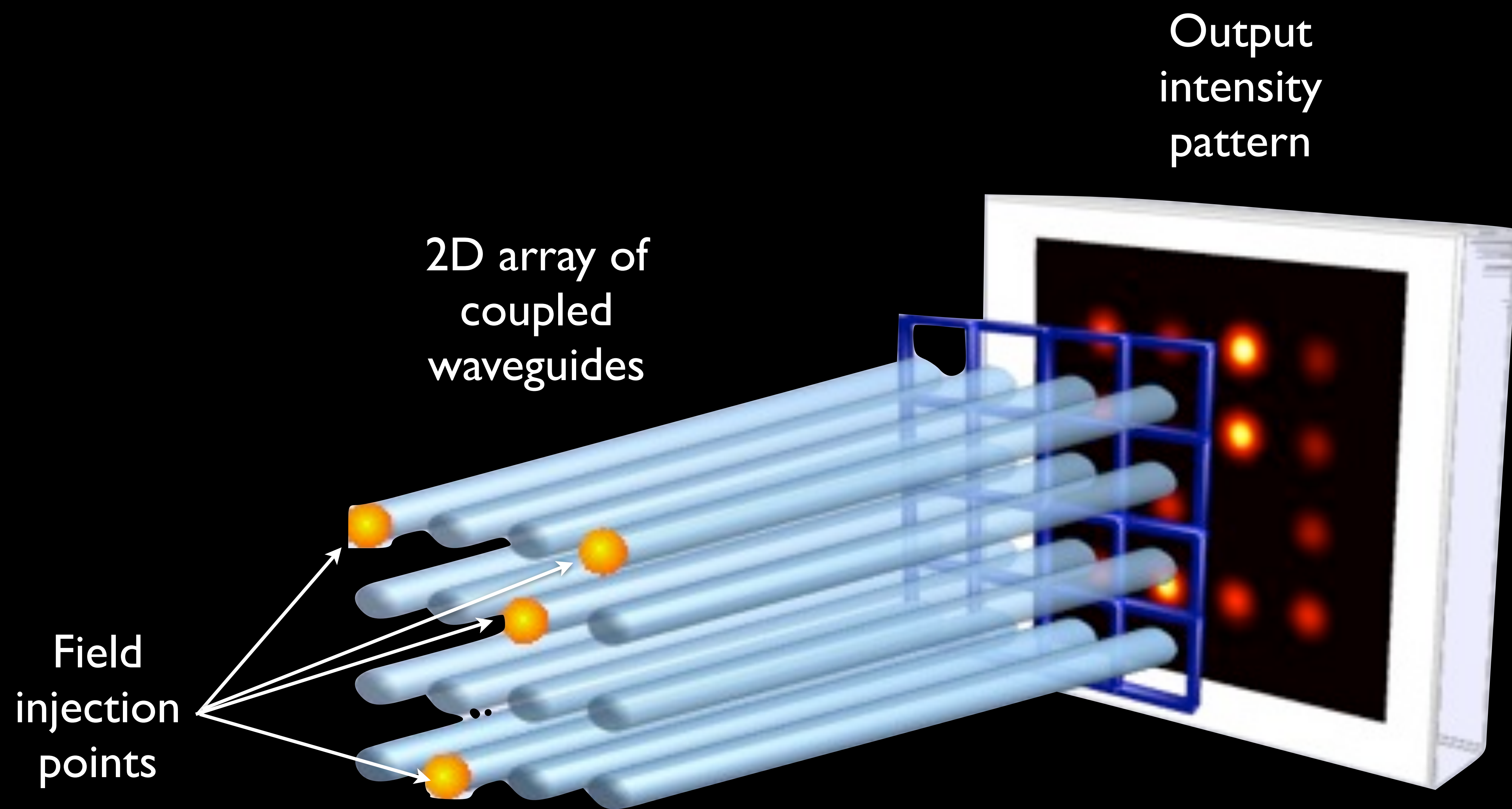

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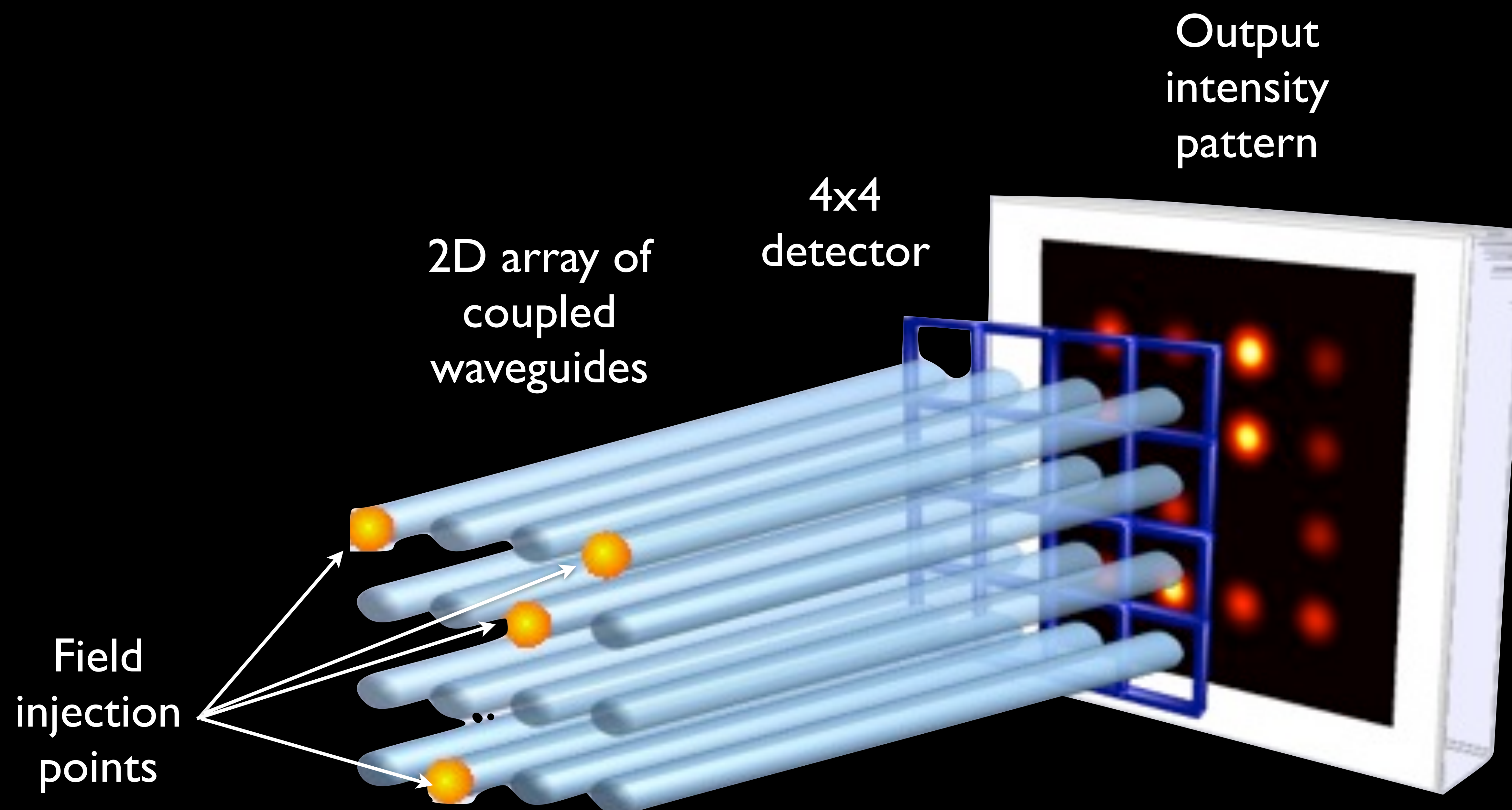

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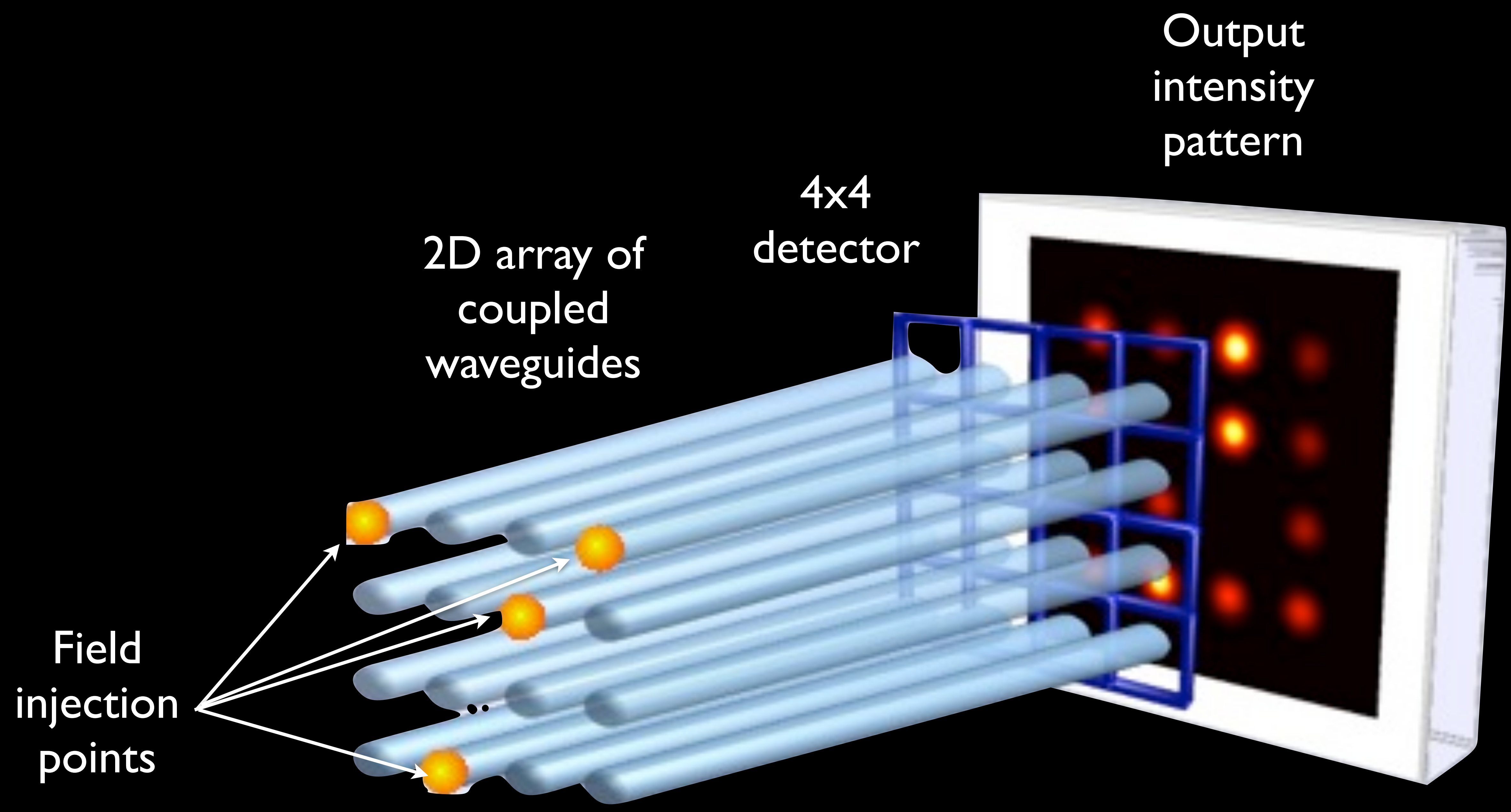
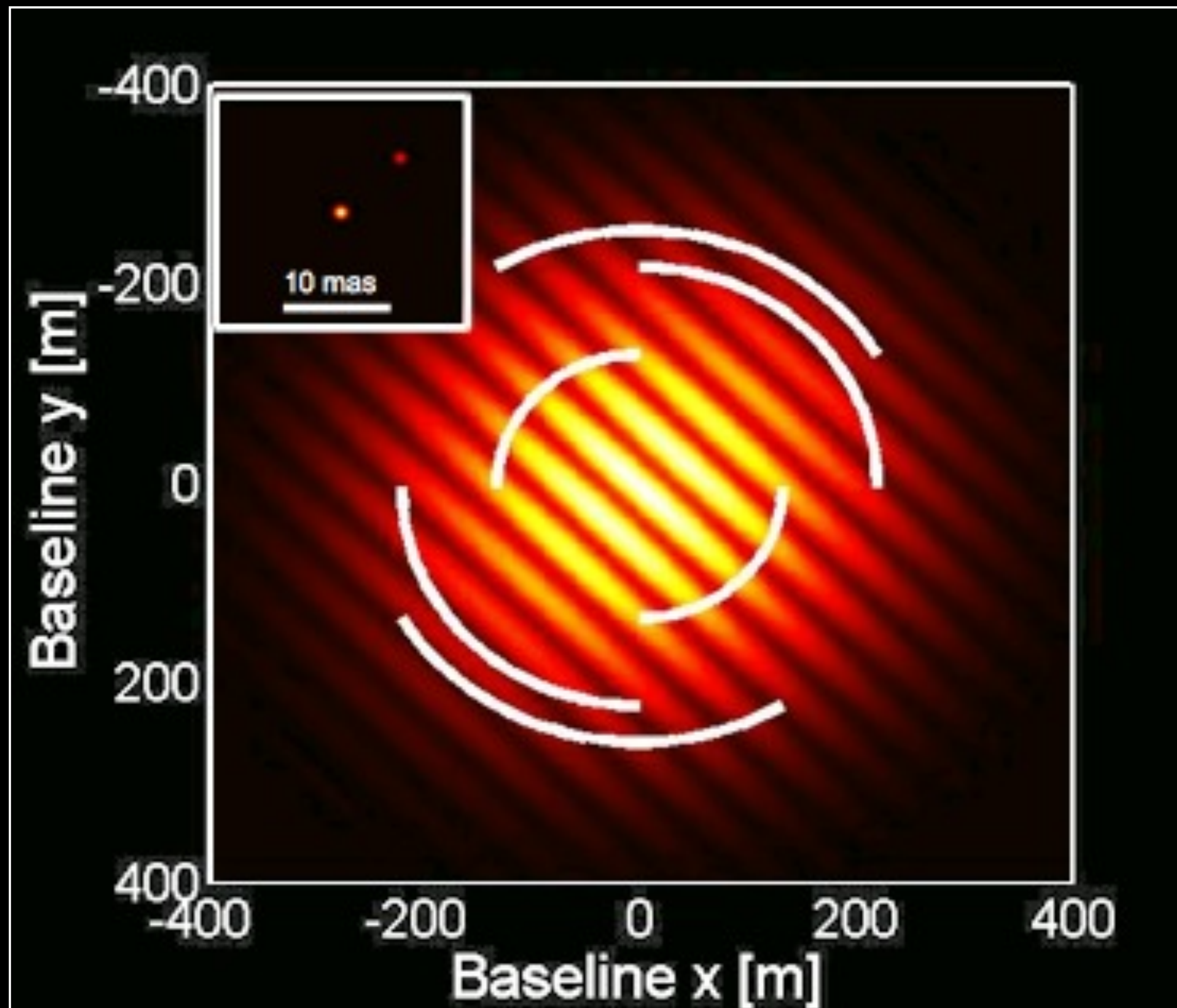
The discrete beam combiner



Complex visibilities over all baselines obtained from linear transformation of output intensities

Minardi, Neuhauser, Pertcsh *SPIE* **7034**-136 (2010).
Minardi, Pertsch *Opt. Lett.* **35,** 3009 (2010).

3x3 DBC performance



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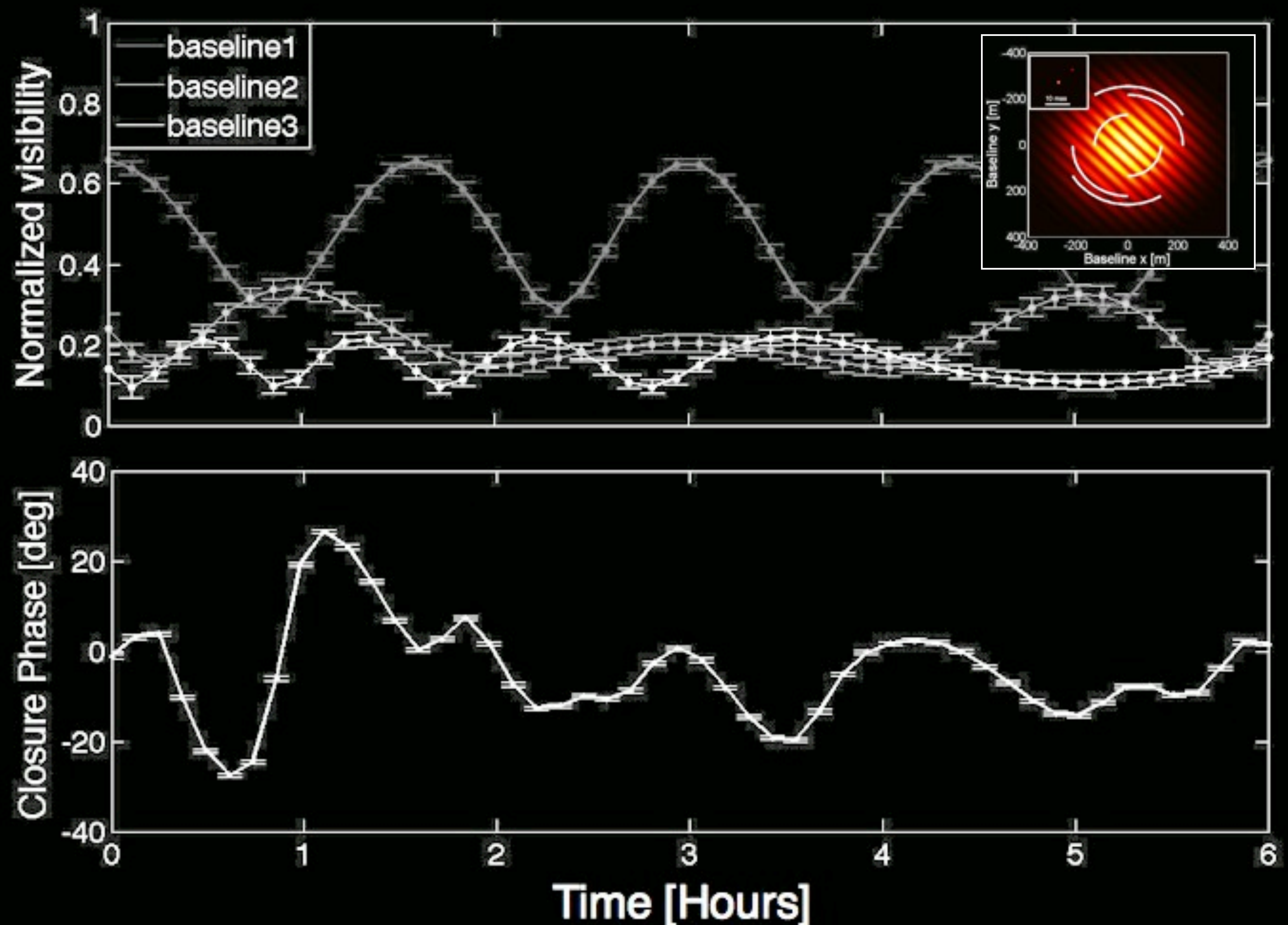
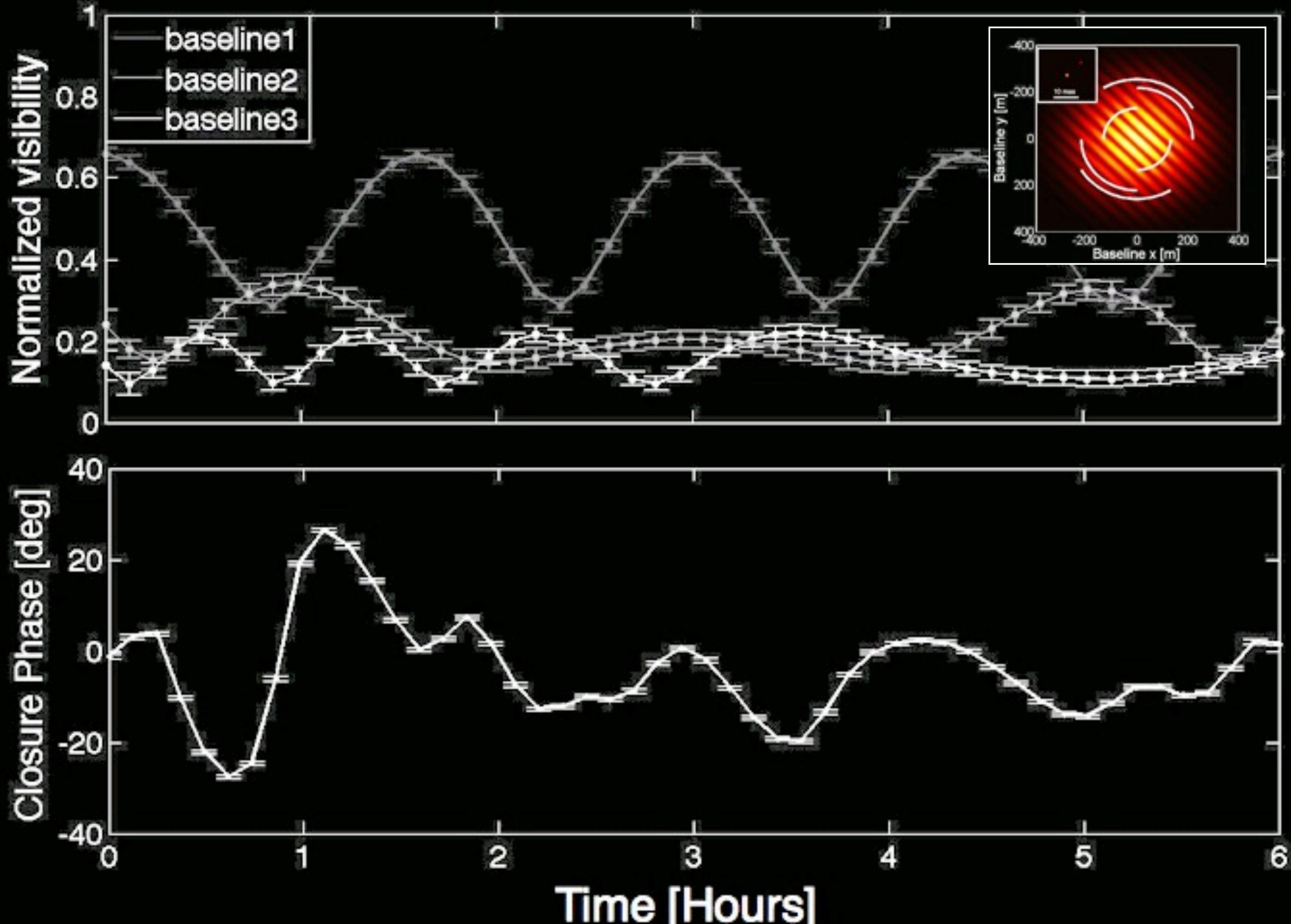


3x3 DBC performance



Could reach performance of existing beam combiners

Conclusions

- Photonic technologies can be profitably used for internal metrology of moving telescopes
- MAMMUT can deliver a stable phase reference with +/-10 nm jitter over a baseline of up to 500 m
- We have started investigating the potential of 3D photonics for the combination of an arbitrary large number of telescopes

Thanks to ...


Prof. Ralph Neuhauser


Thomas Pertsch


Arkadi Chipouline


Stephan Kraemer


Lourdes Patricia Ramirez


Frank Giessler


Manfred Rothhardt


Martin Becker


Izabela Spaleniak


Reinhardt Geiss


Nadya Chakrova


Martin Hohmann