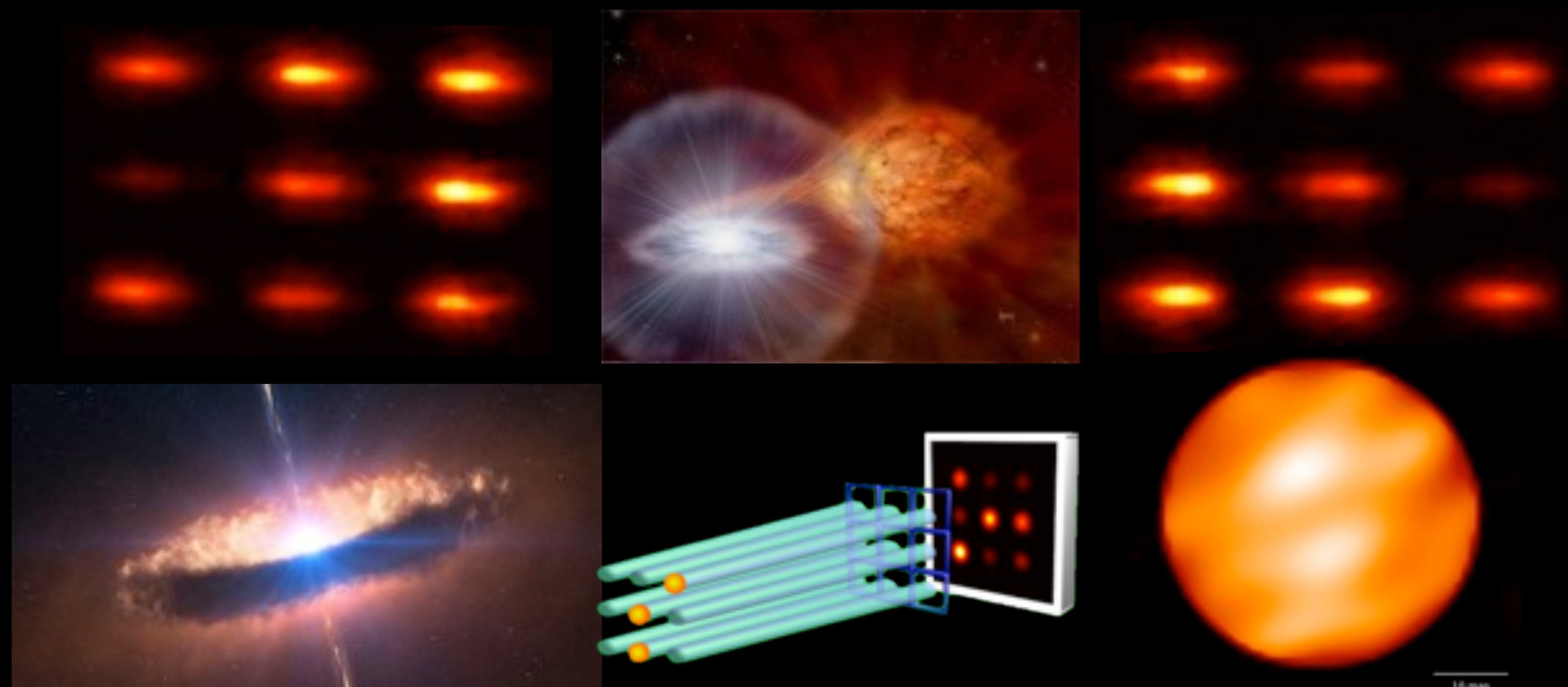
Discrete Beam Combiners:
exploring the potential of 3D-photonics for interferometry



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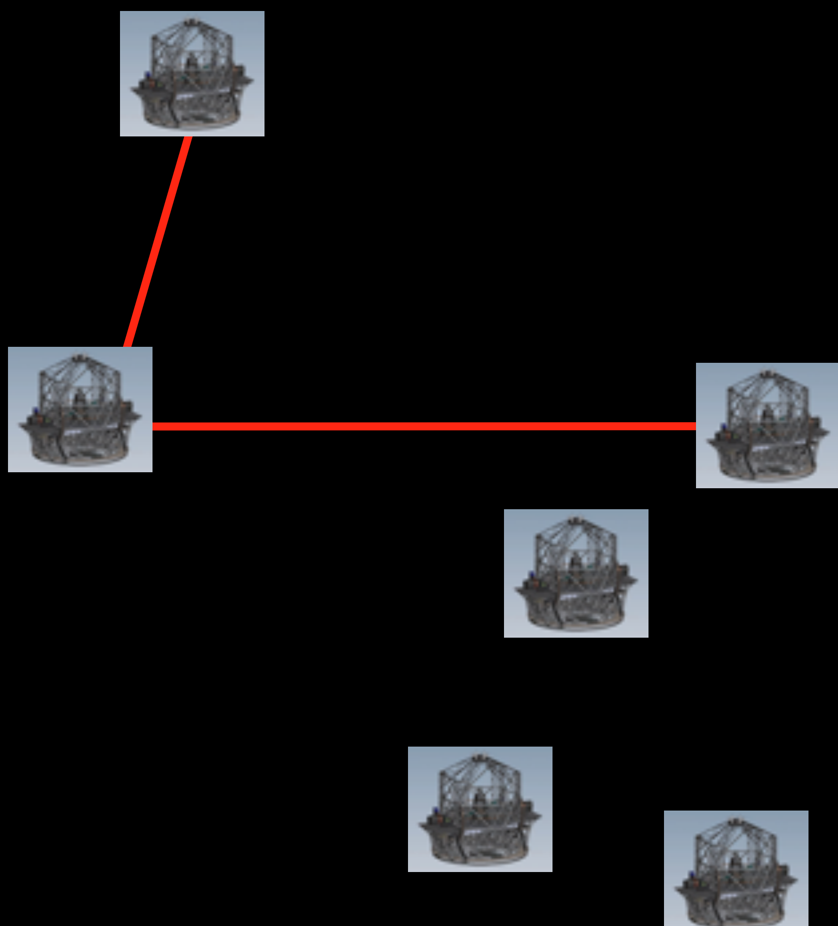
Institute of Applied Physics - Friedrich Schiller University, Jena - Germany

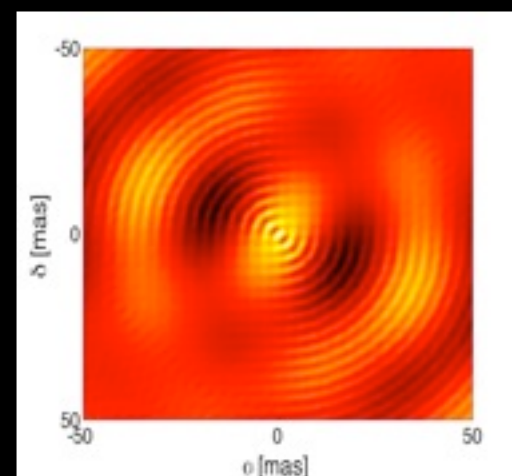
Lucas Labadie

1st Physics Faculty - University of Cologne, Cologne - Germany

The importance of baselines

Point spread function of images improves with # of baselines





2 baselines

Haniff New Ast. Rev. 51, 565 (2007).

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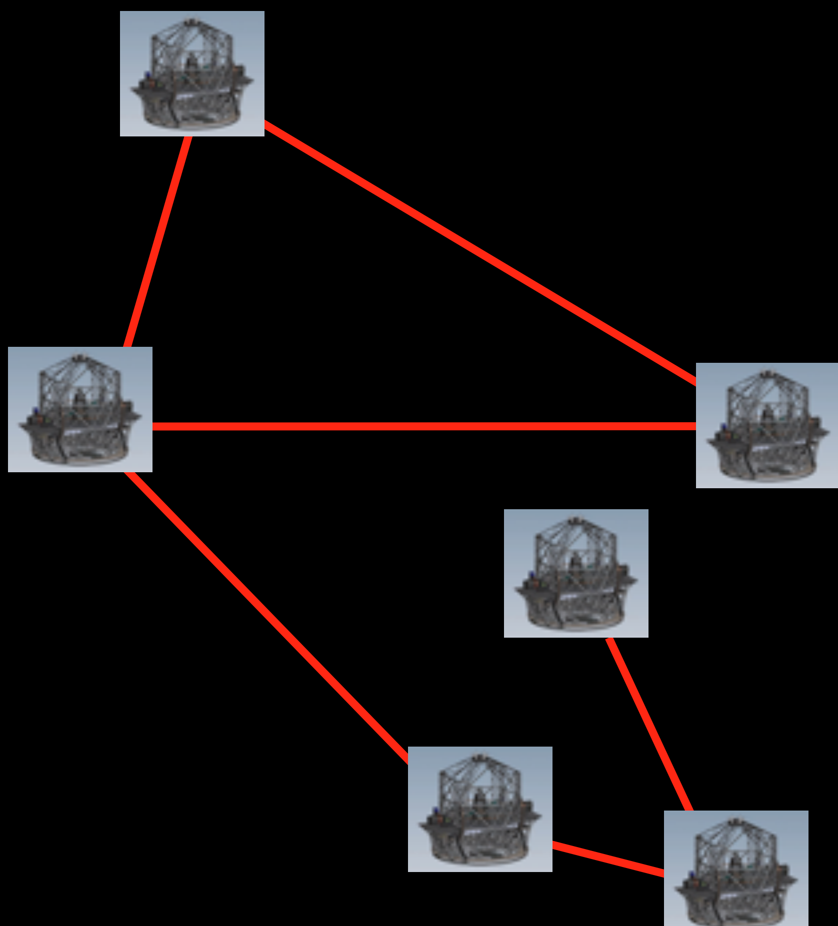

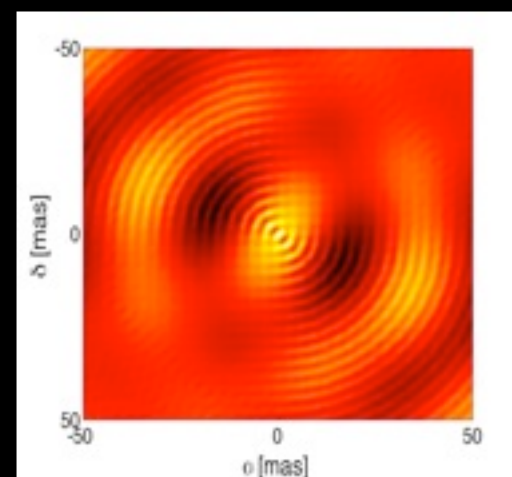

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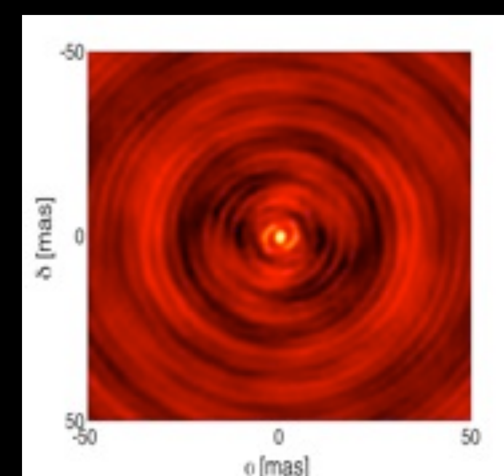

6 baselines

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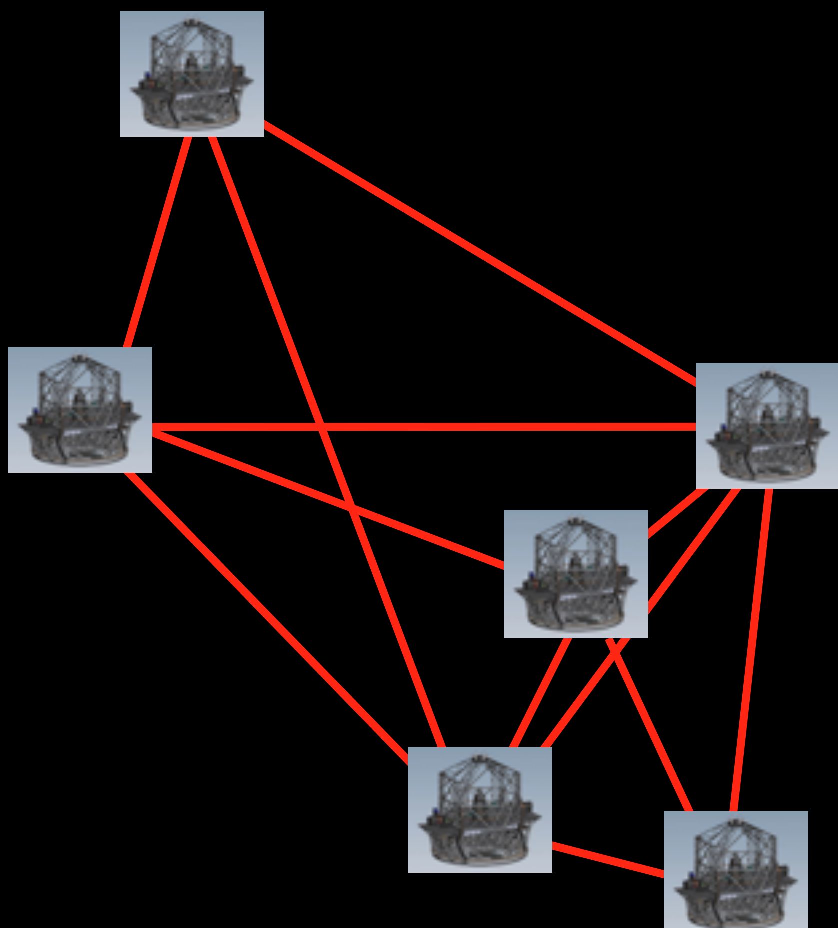
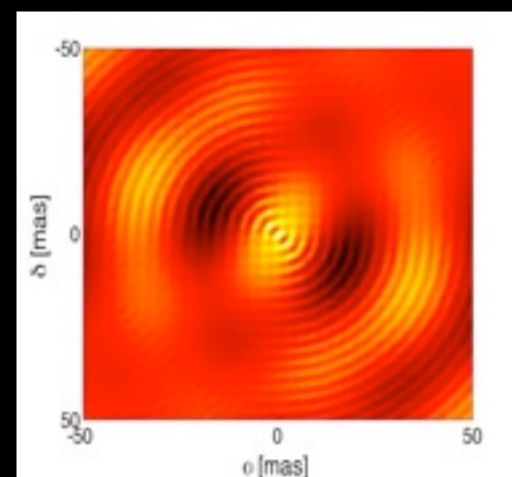
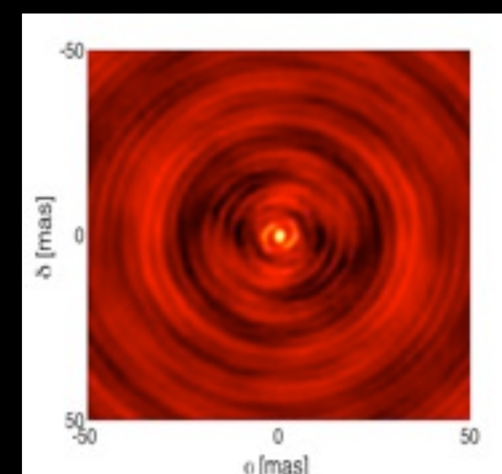
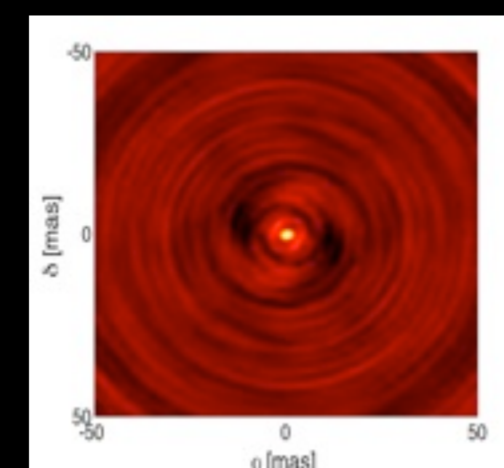




2 baselines



6 baselines

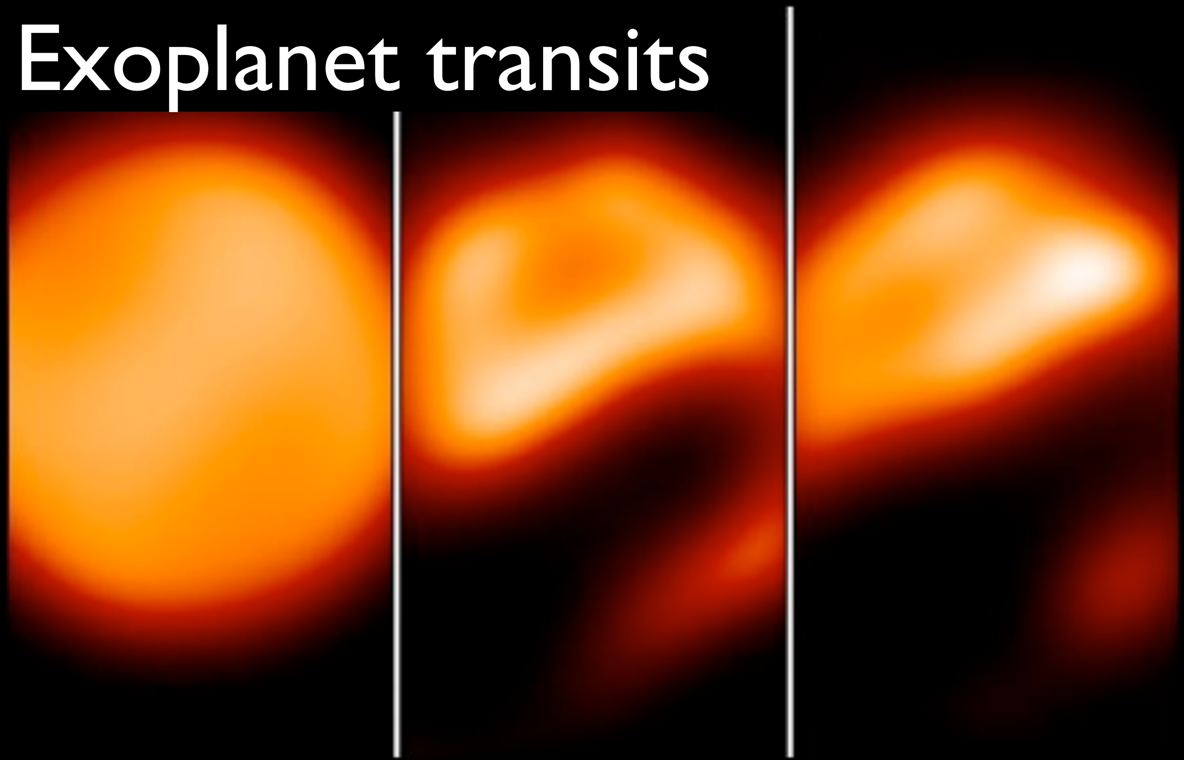


12 baselines

Haniff New Ast. Rev. 51, 565 (2007).

The importance of baselines

Exoplanet transits

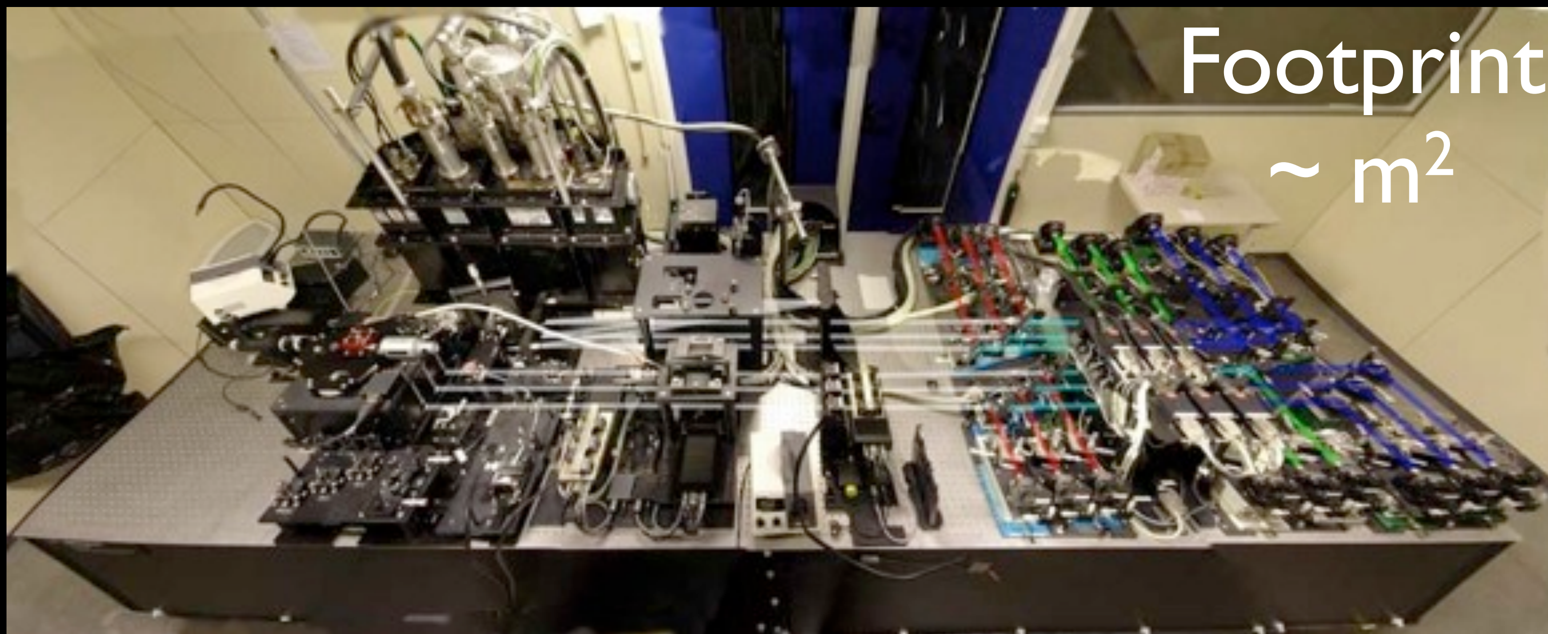


Kloppenborg, et al., Nature 464, 870 (2010)

Nova/SN explosion

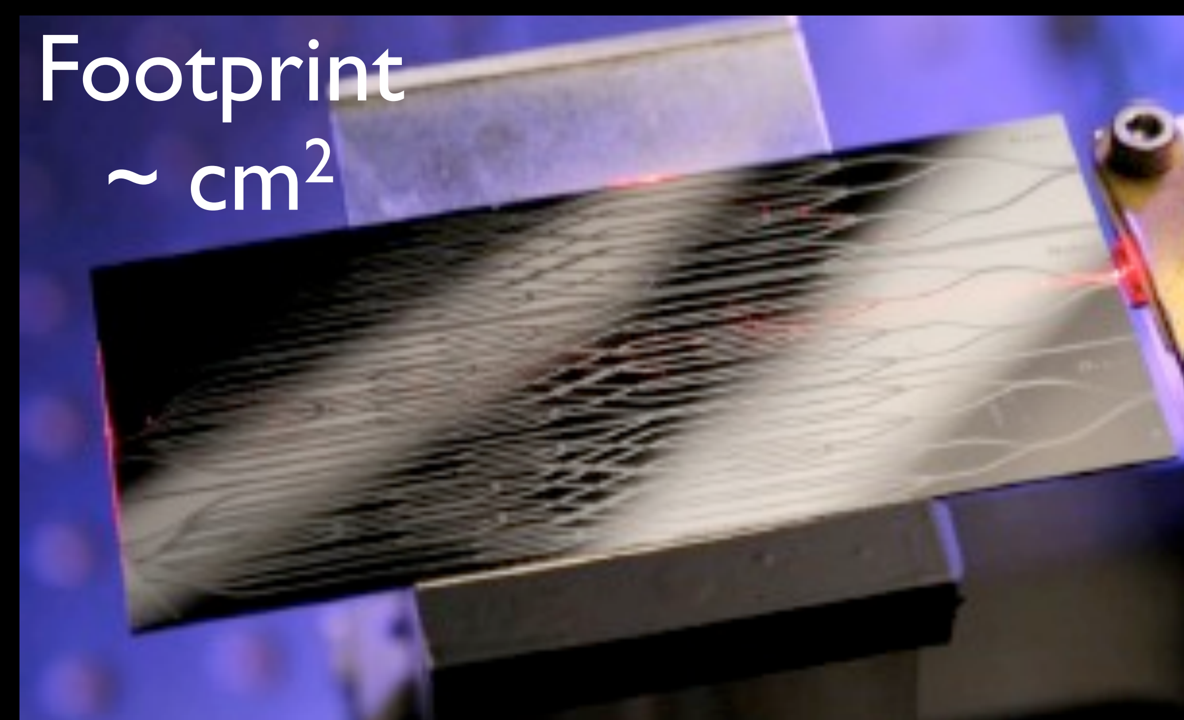
Simultaneous fringe measurements on many baselines enables imaging of fast astronomical events

Integrated optics



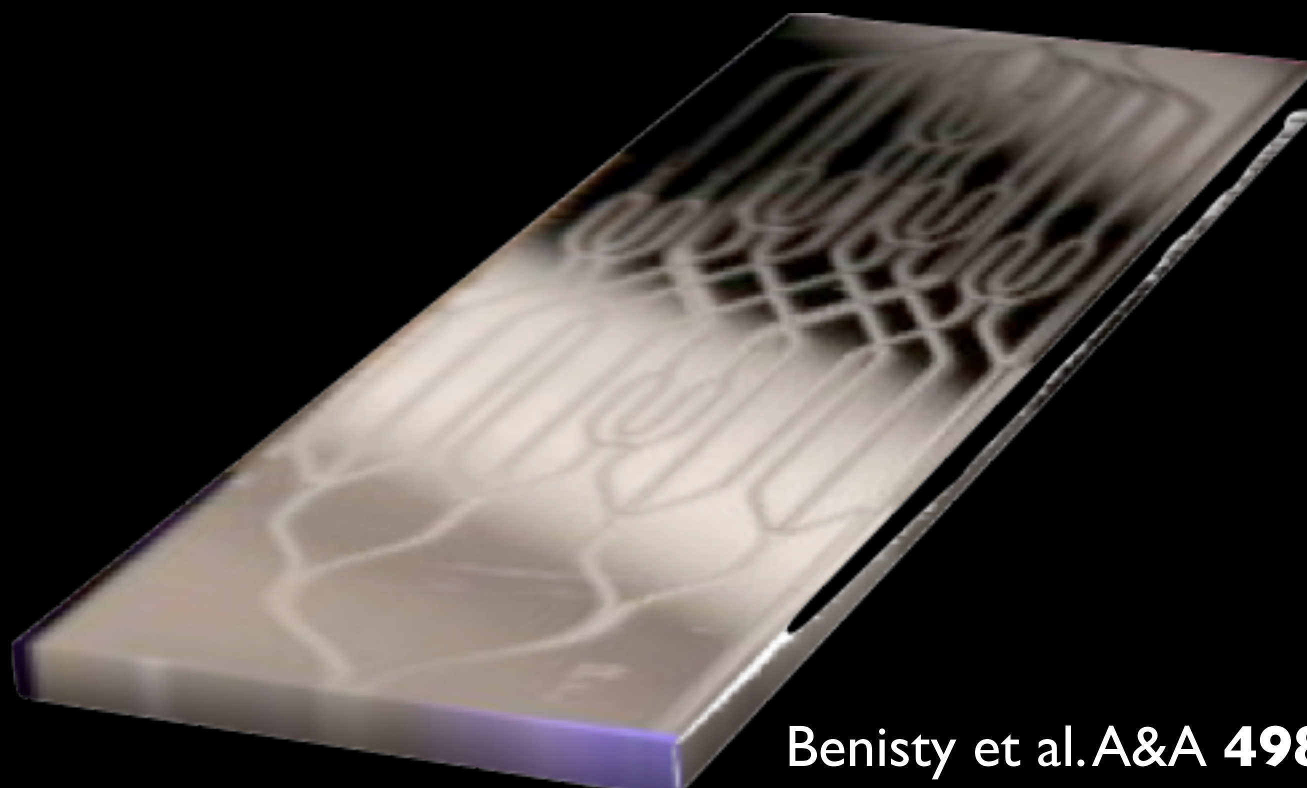
AMBER - VLTI - Petrov et al. A&A 464, 1 (2007).

✓Miniaturization
✓Stability
✓Scalability



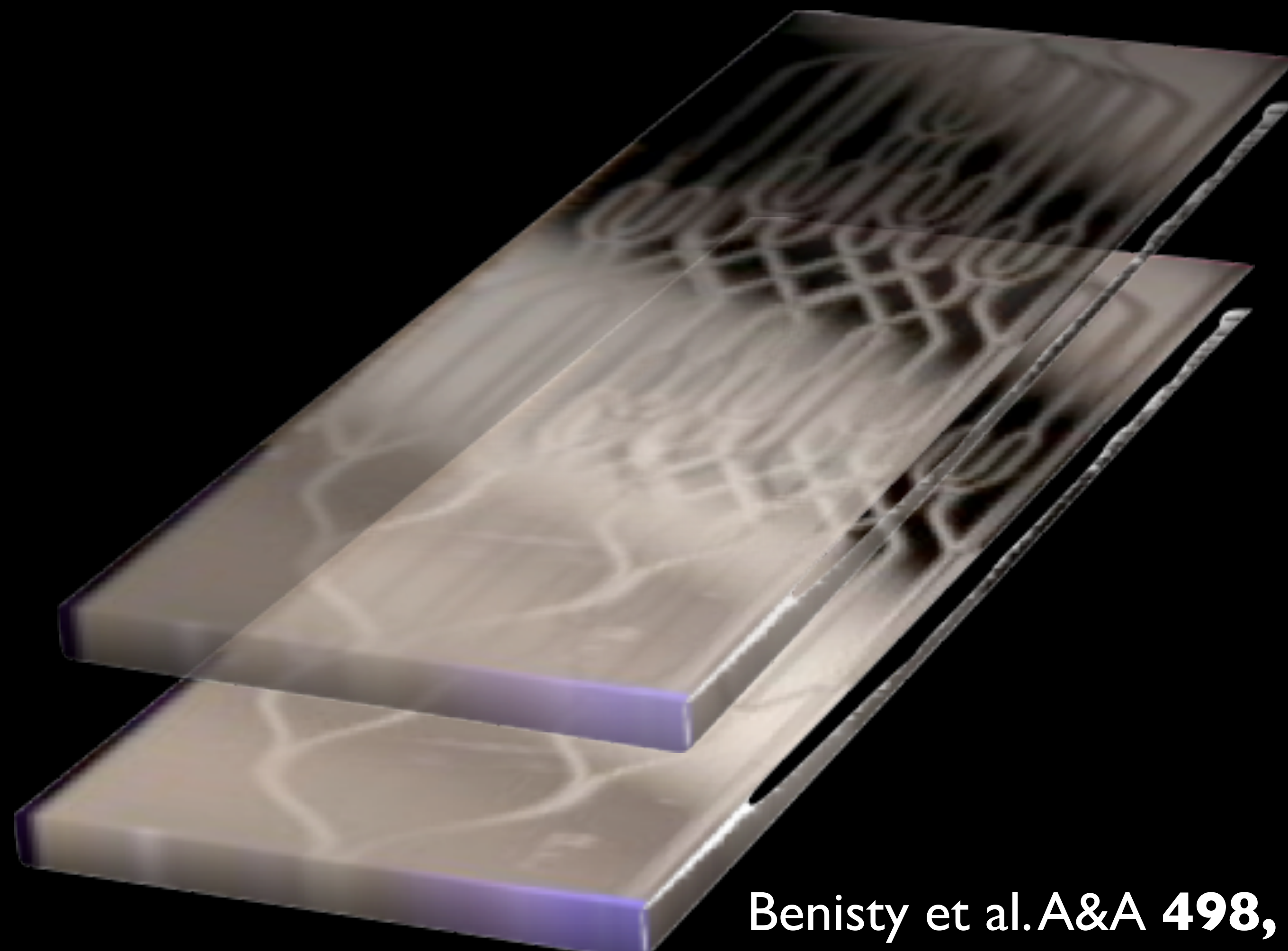
PIONIER - VLTI - Berger et al. SPIE 7734-114 (2010).

2D photonic components



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

2D photonic components

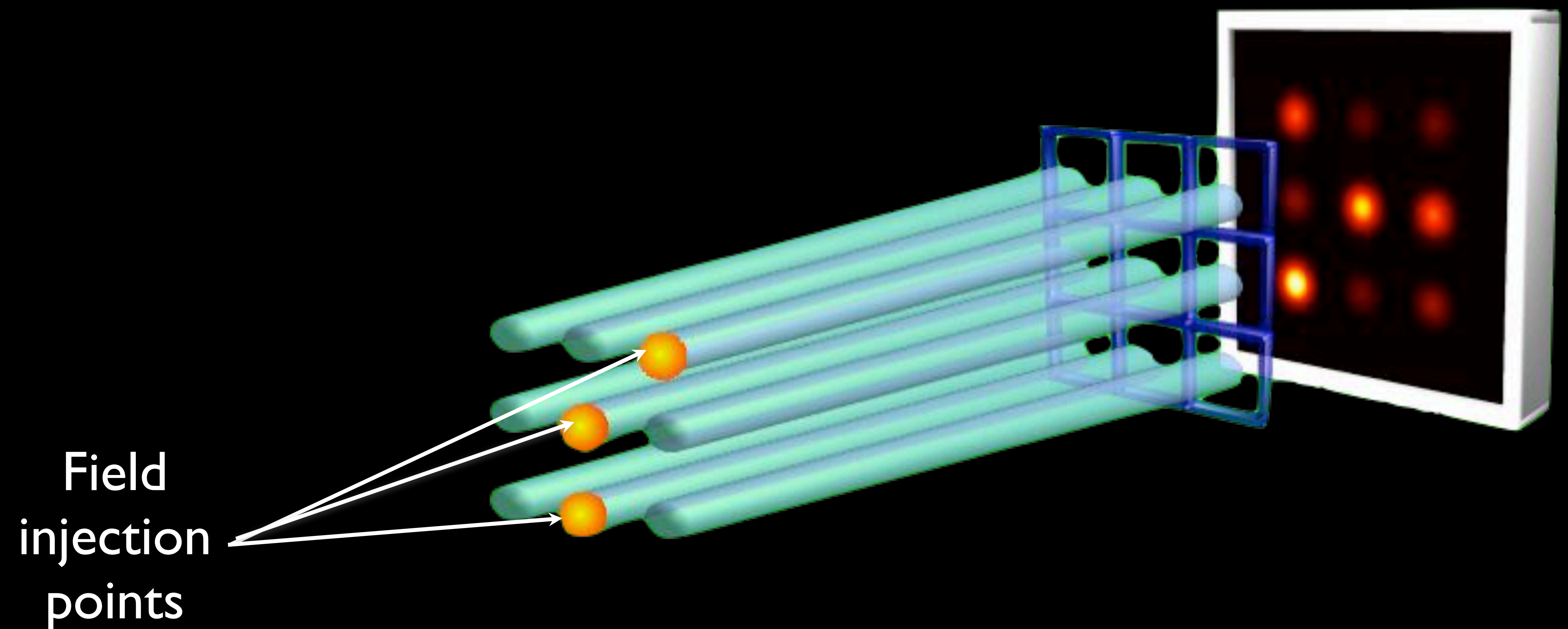


Benisty et al. A&A **498,** 601 (2009).

To which extent 3D photonics could simplify design?

The discrete beam combiner

N telescopes ➡ NxN waveguides



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

The discrete beam combiner

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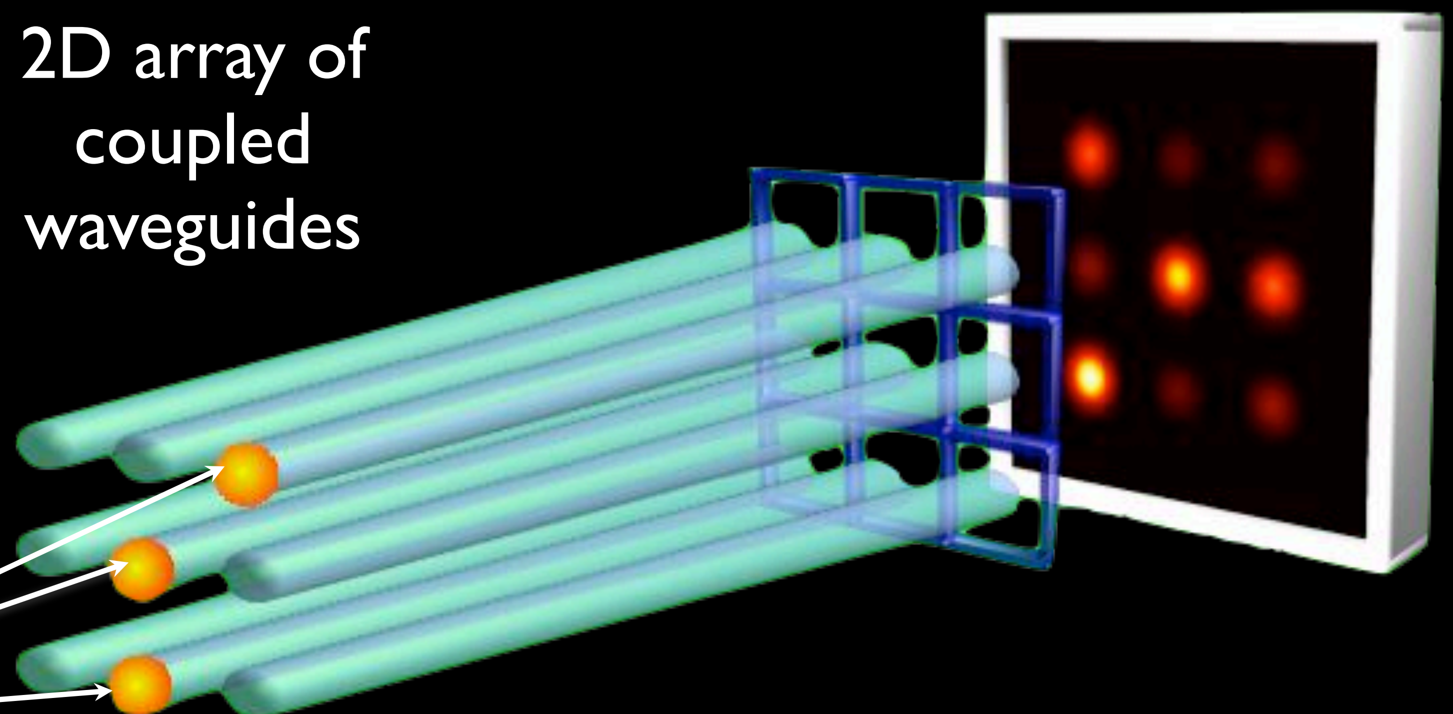

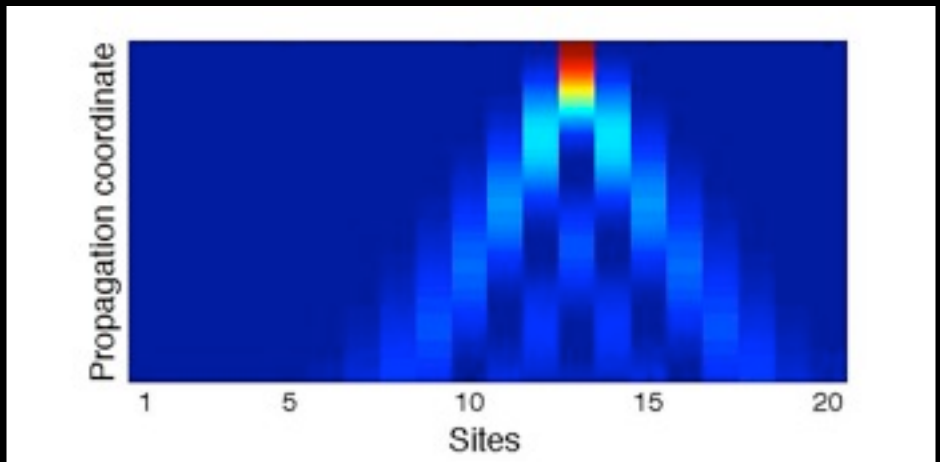

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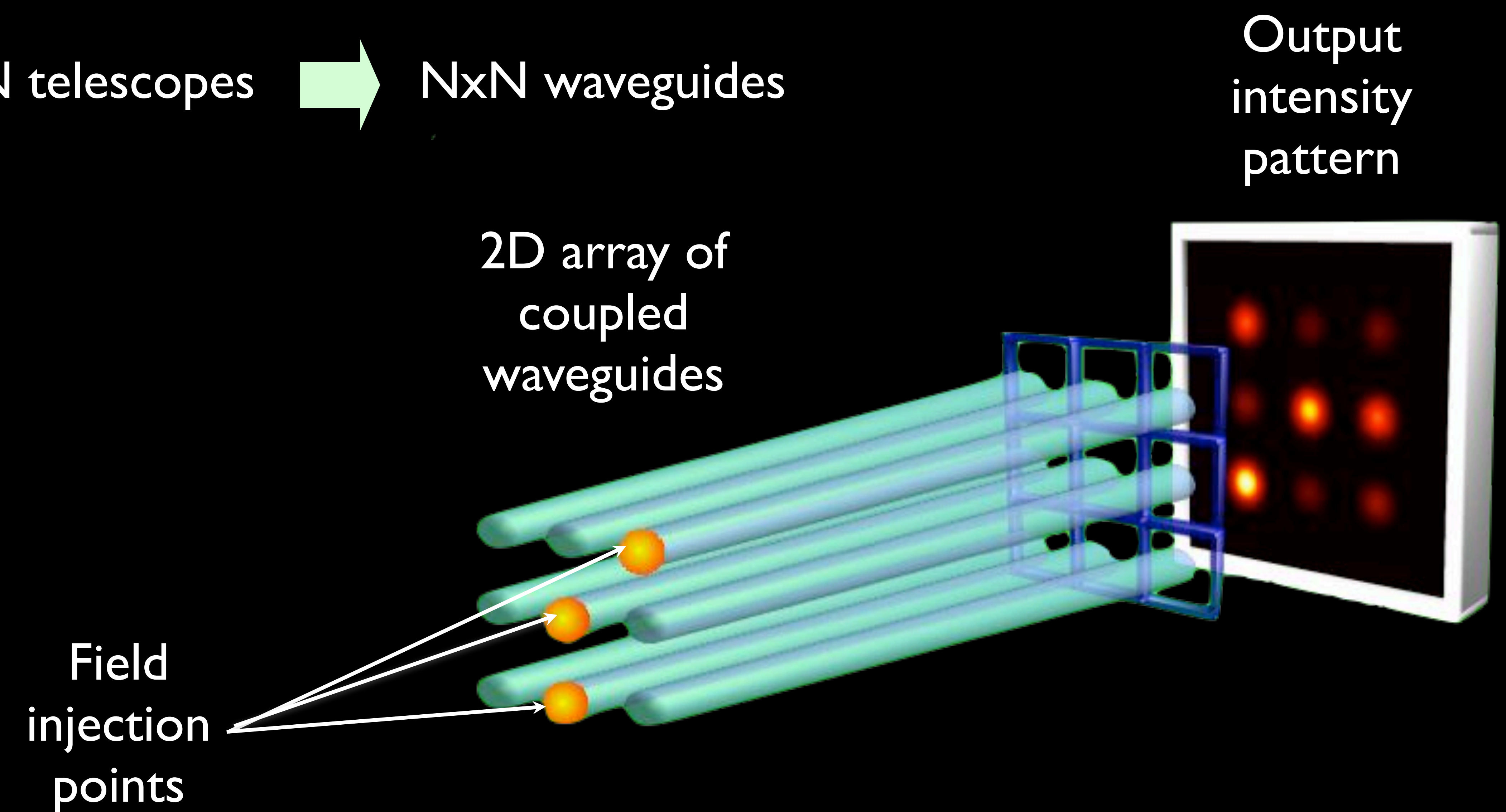

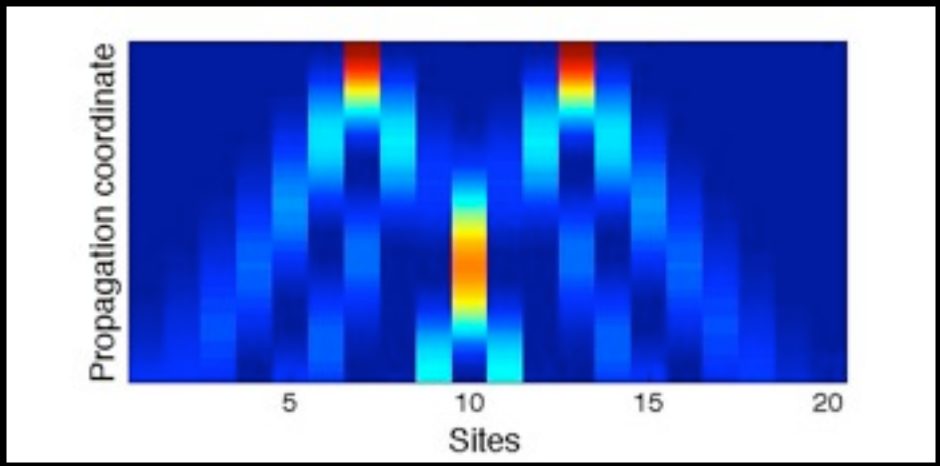

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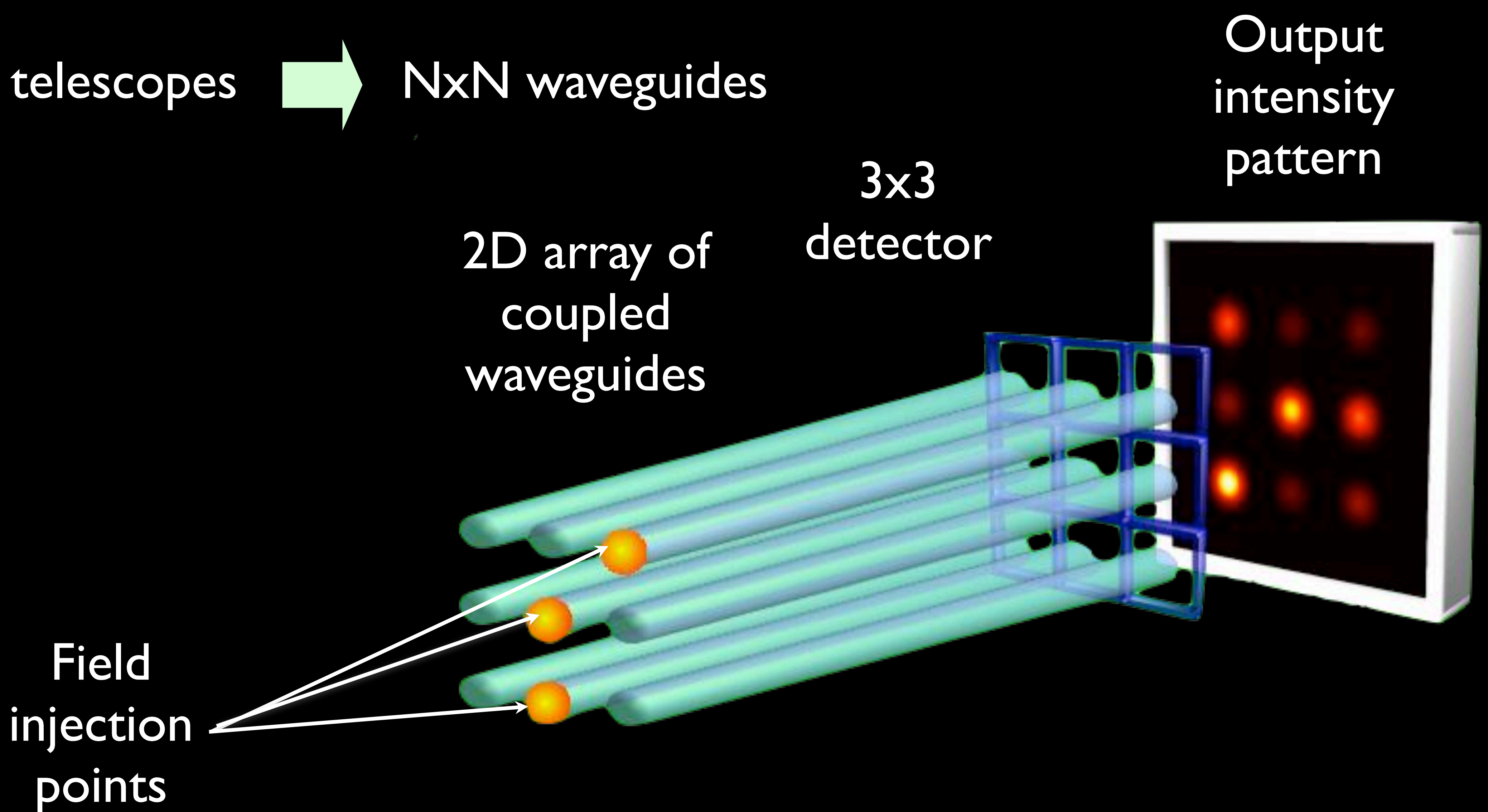

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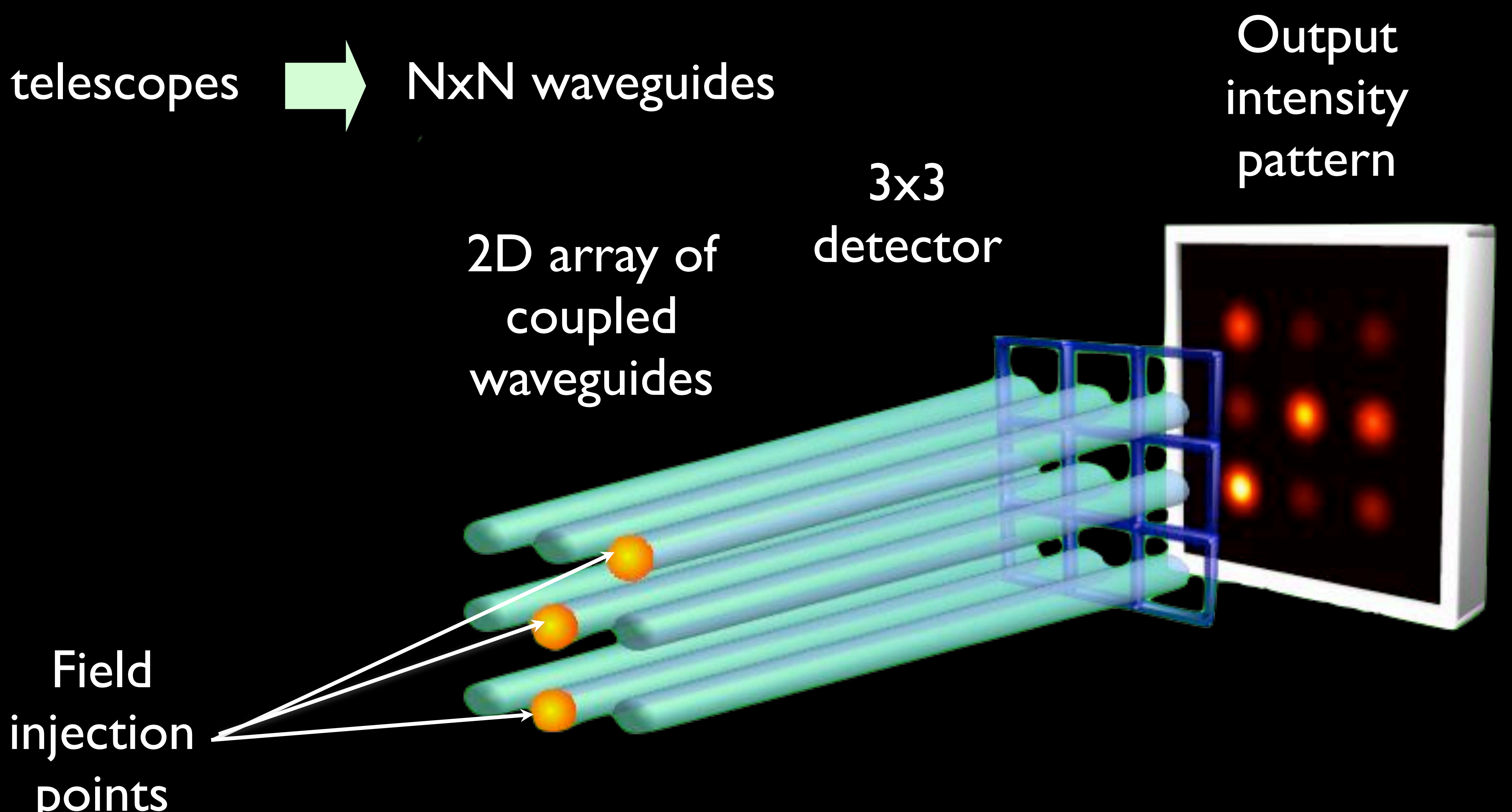


Complex visibilities over all baselines obtained from linear transformation of output intensities

Scheme verified for up to 6 telescopes, 15 baselines

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

How does the DBC work

The NxN output intensities I_j of the excited modes are a linear combination of products of the input fields A_k, $k=1...N$

$$I_n = \sum_{j=1}^{N} \sum_{k=1}^{N} \alpha_{n,f(j,k)} \left\langle A_j A_k^* \right\rangle$$

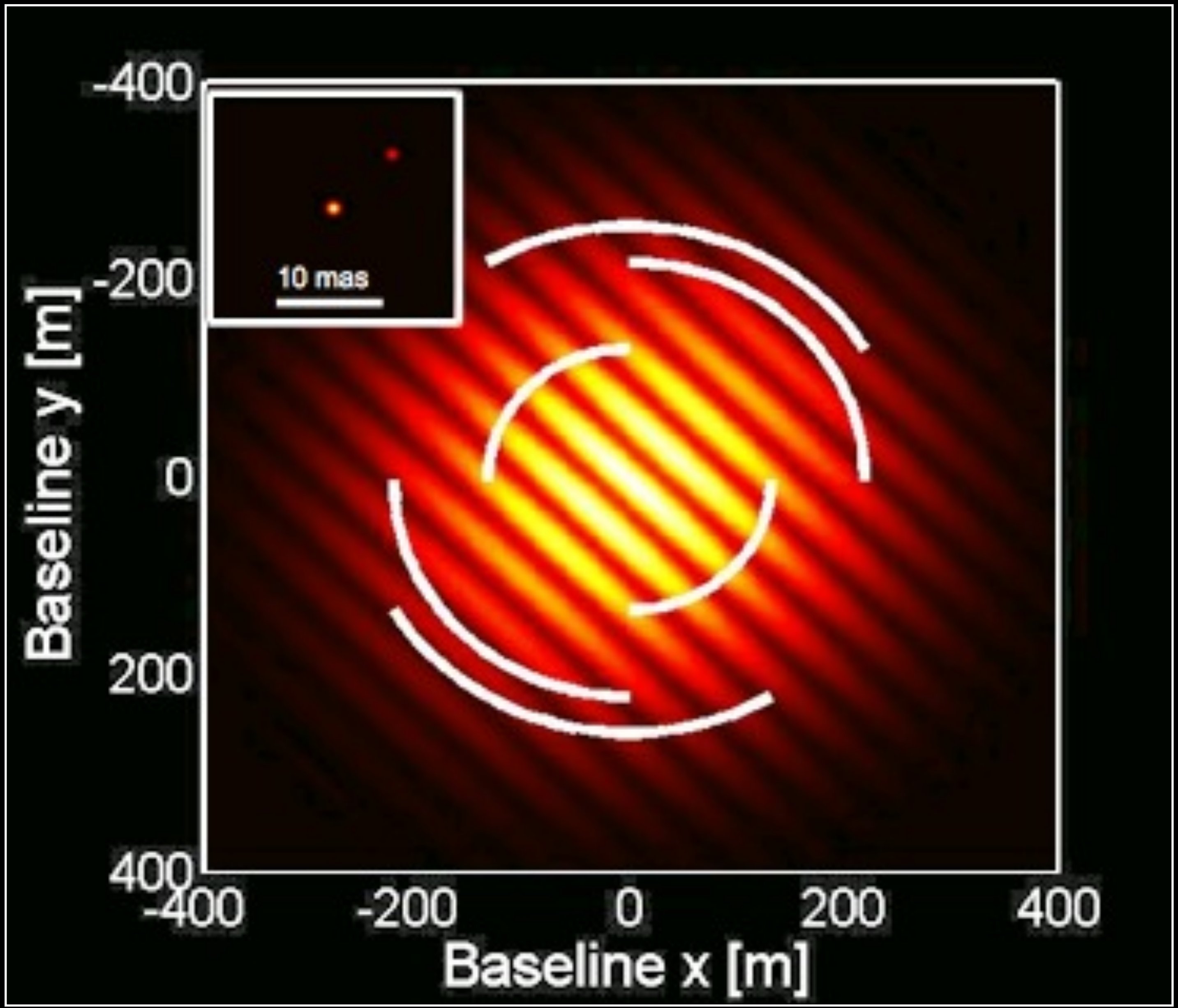
Coefficients of matrix $\alpha_{n,f(j,k)}$ (V2PM) determined by:

- Injection points of the fields A_k
- Geometry of coupling between waveguides

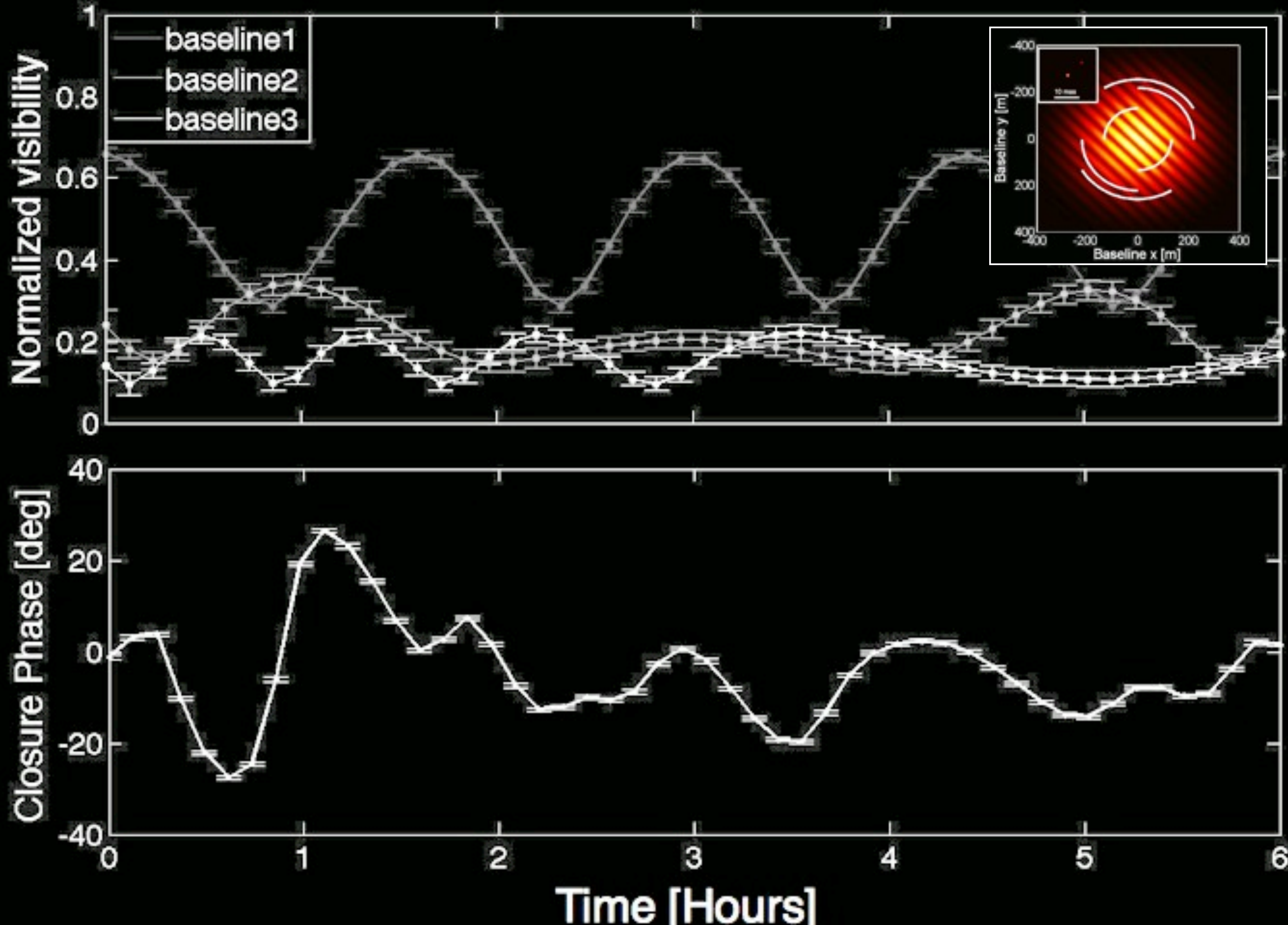
Optimal matrix: invertible and well conditioned

Minardi, Pertsch *Opt. Lett.* **35,** 3009 (2010).

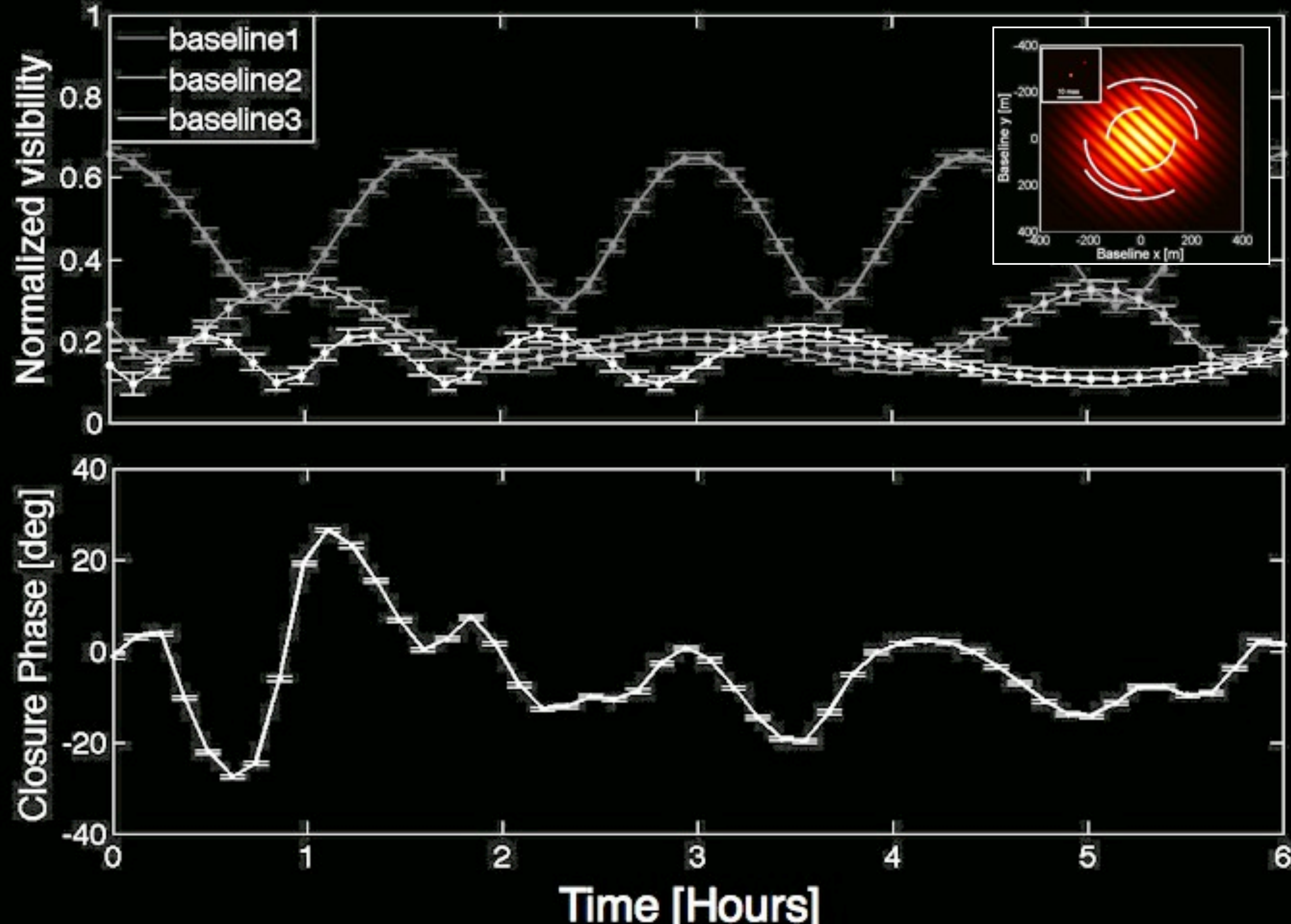
3x3 DBC performance



3x3 DBC performance



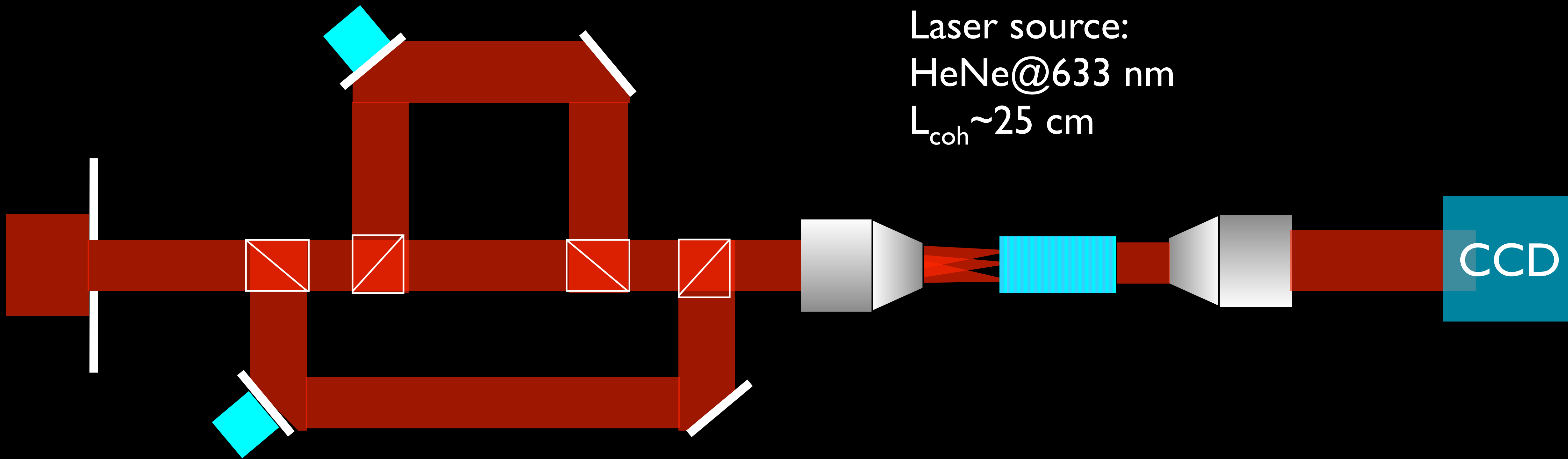
3x3 DBC performance



Could reach performance of existing beam combiners

Experimental setup

Laser source:
HeNe@633 nm
L_{coh}~25 cm



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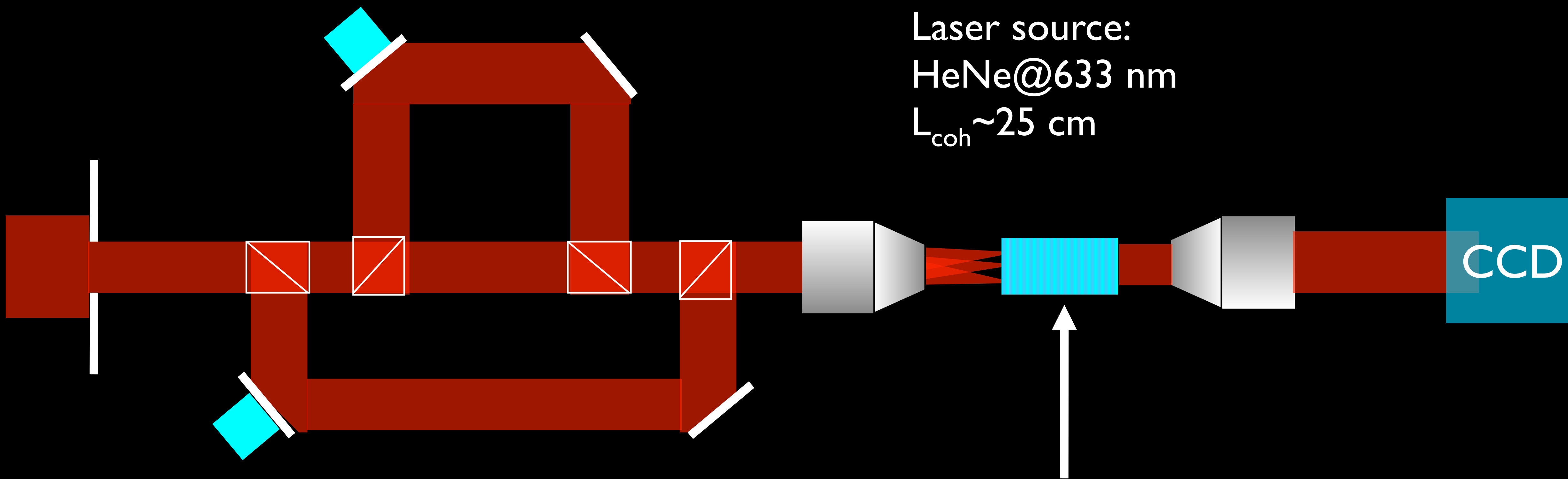
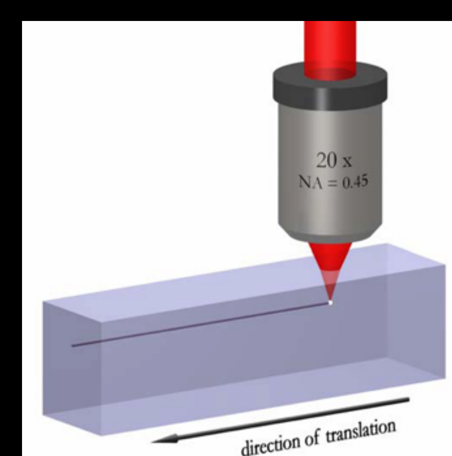
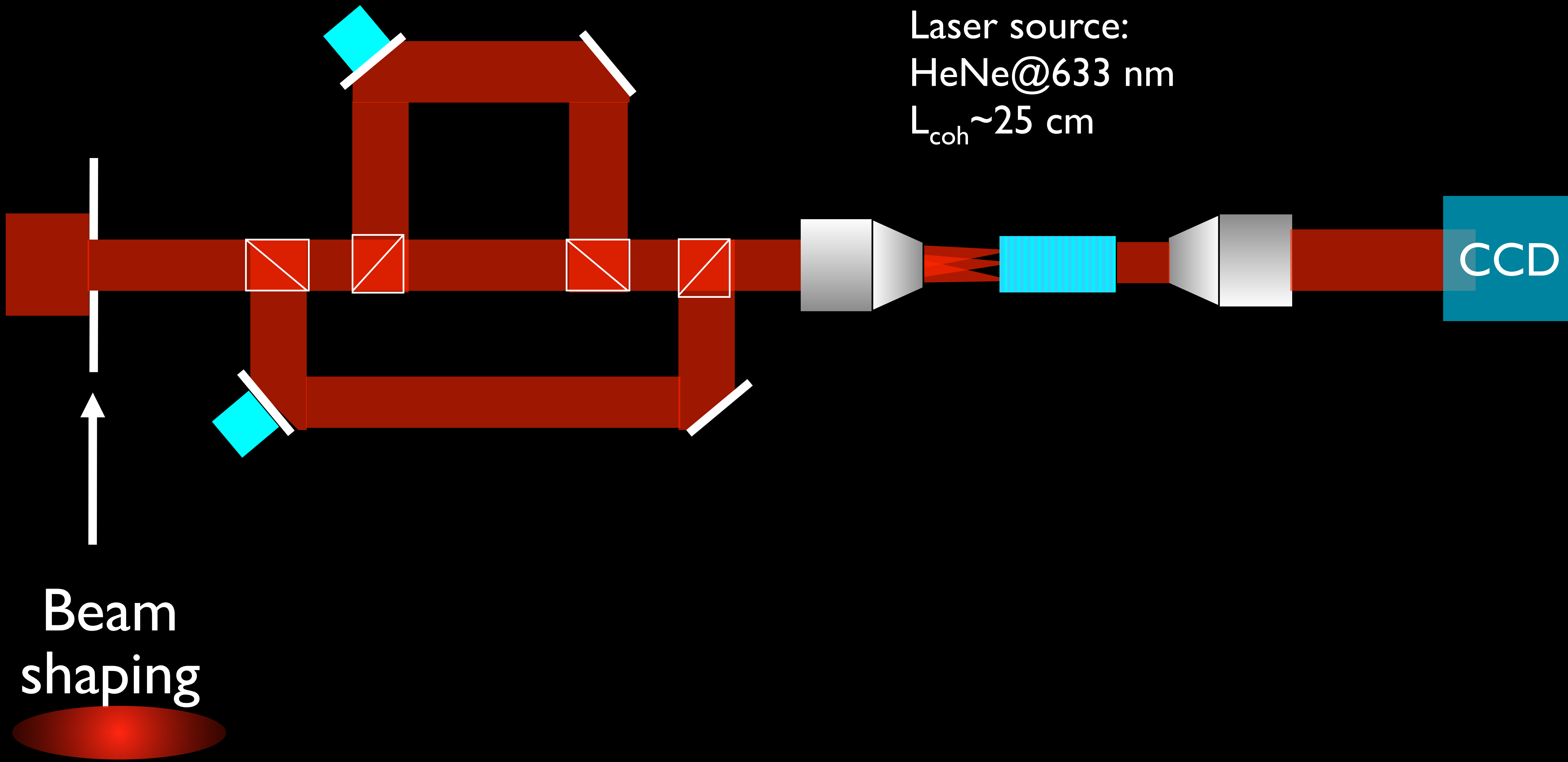


3x3
Laser-written array



Pertsch, et al. Opt. Lett. 29, 468 (2004).

Experimental setup



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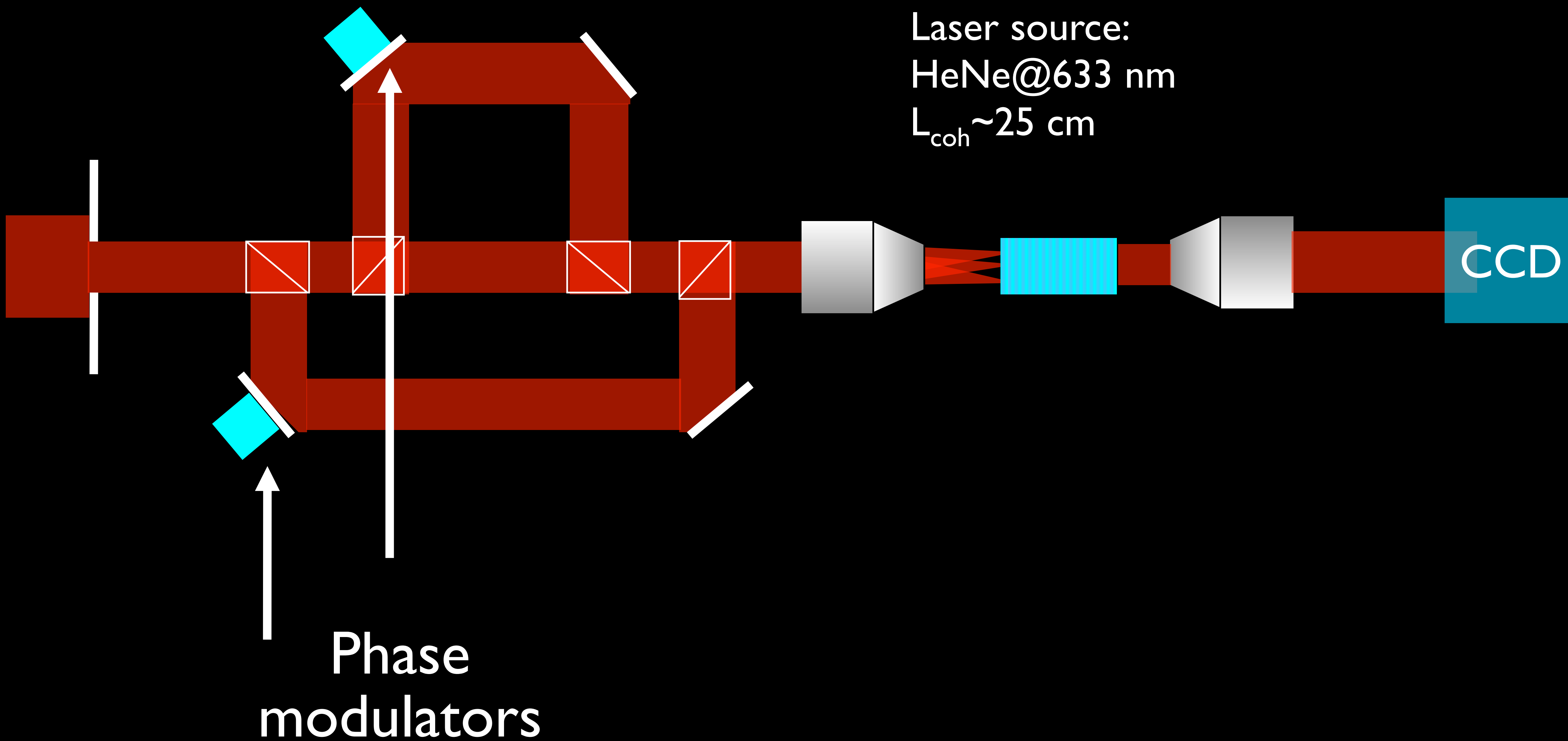

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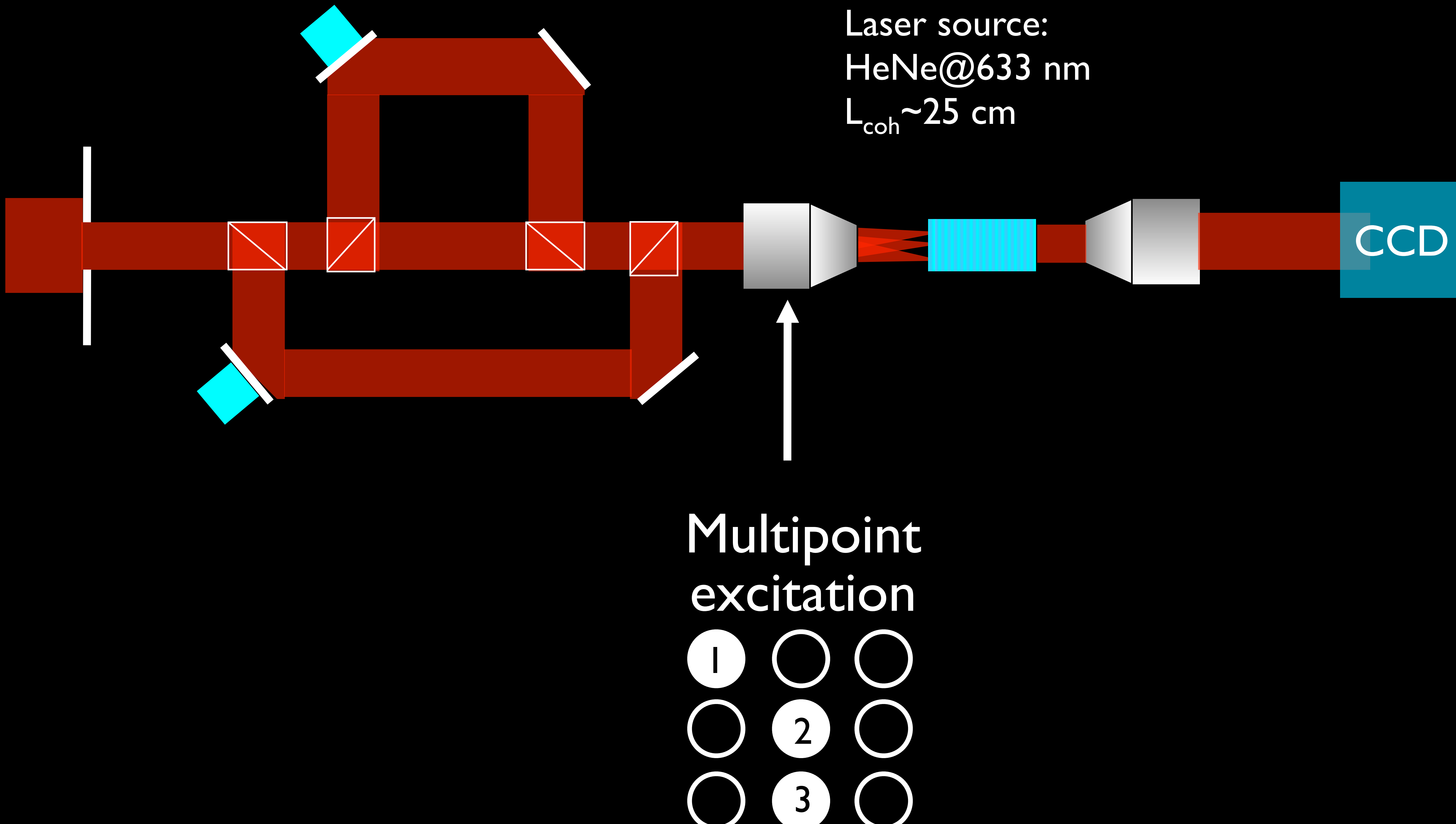

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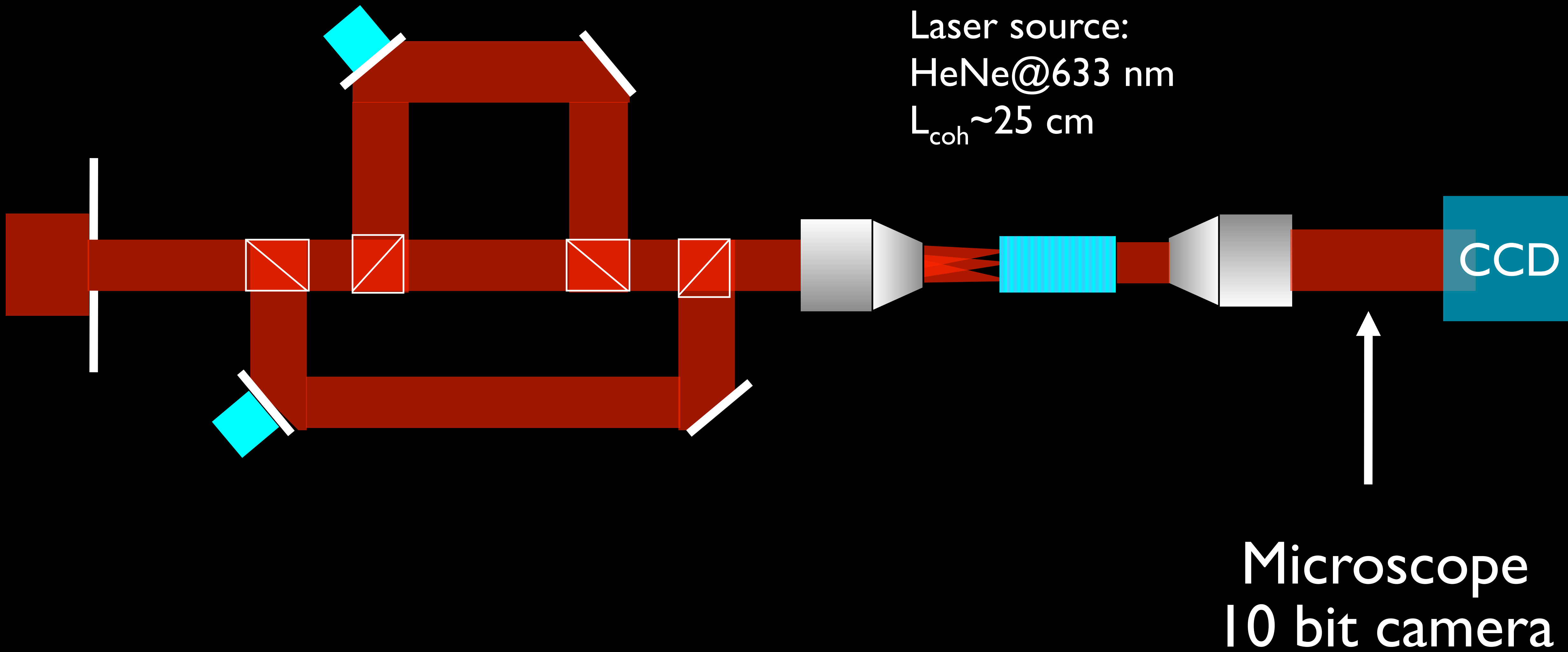
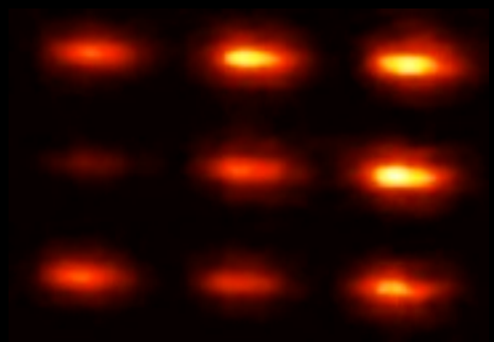
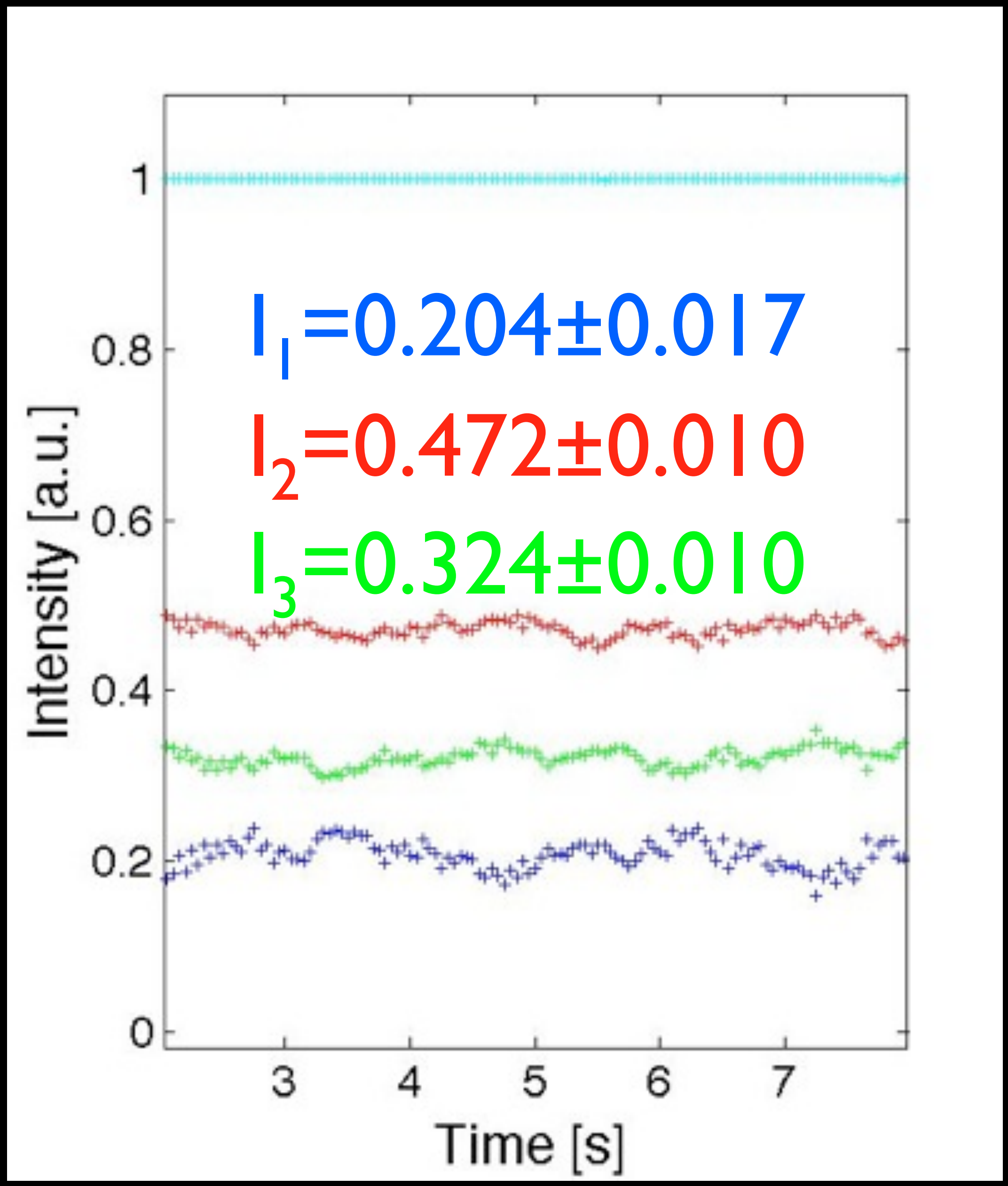




First experimental results: photometry

Calibration procedure adapted from: Lacour et al. SPIE 7013-16 (2008).



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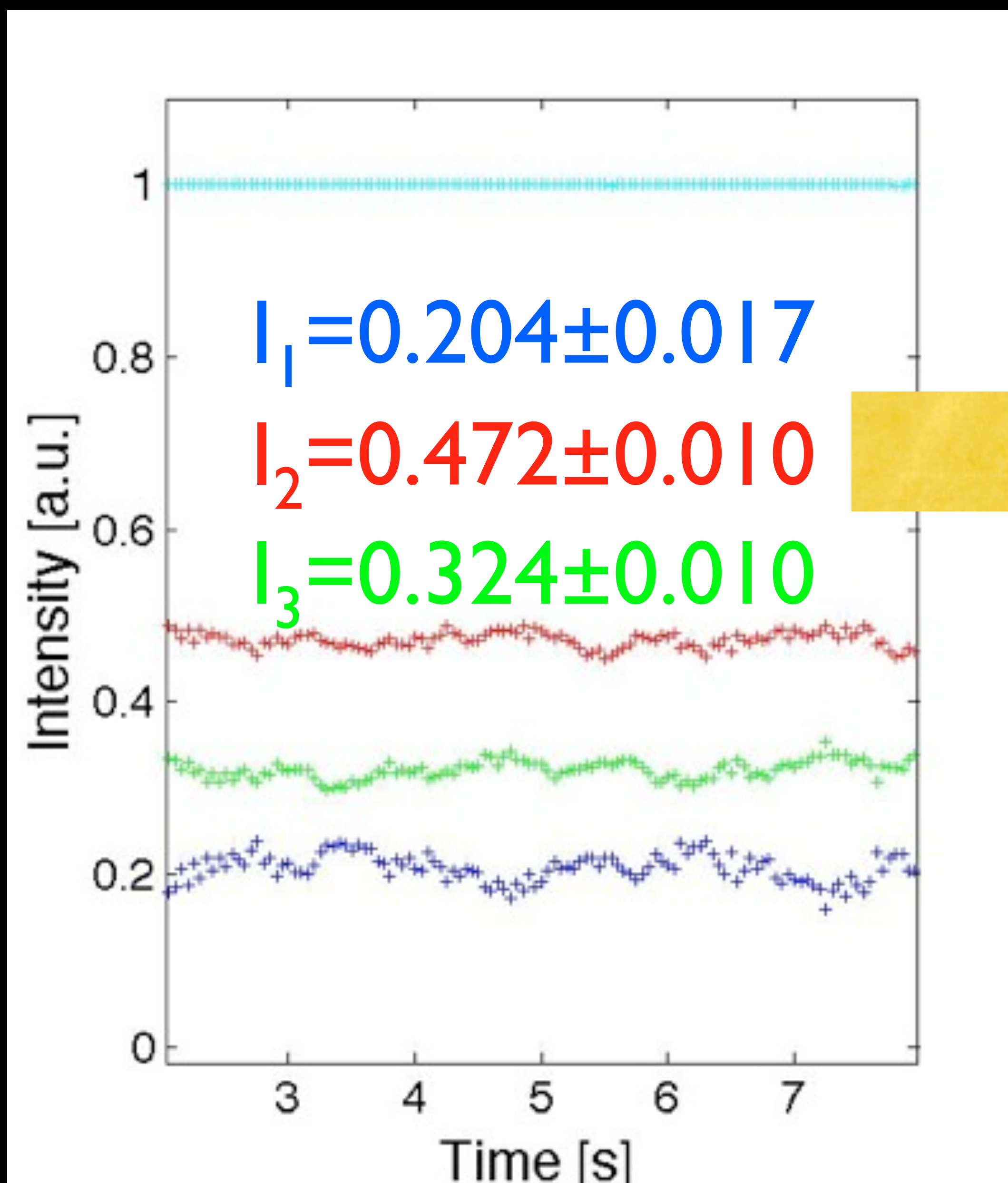


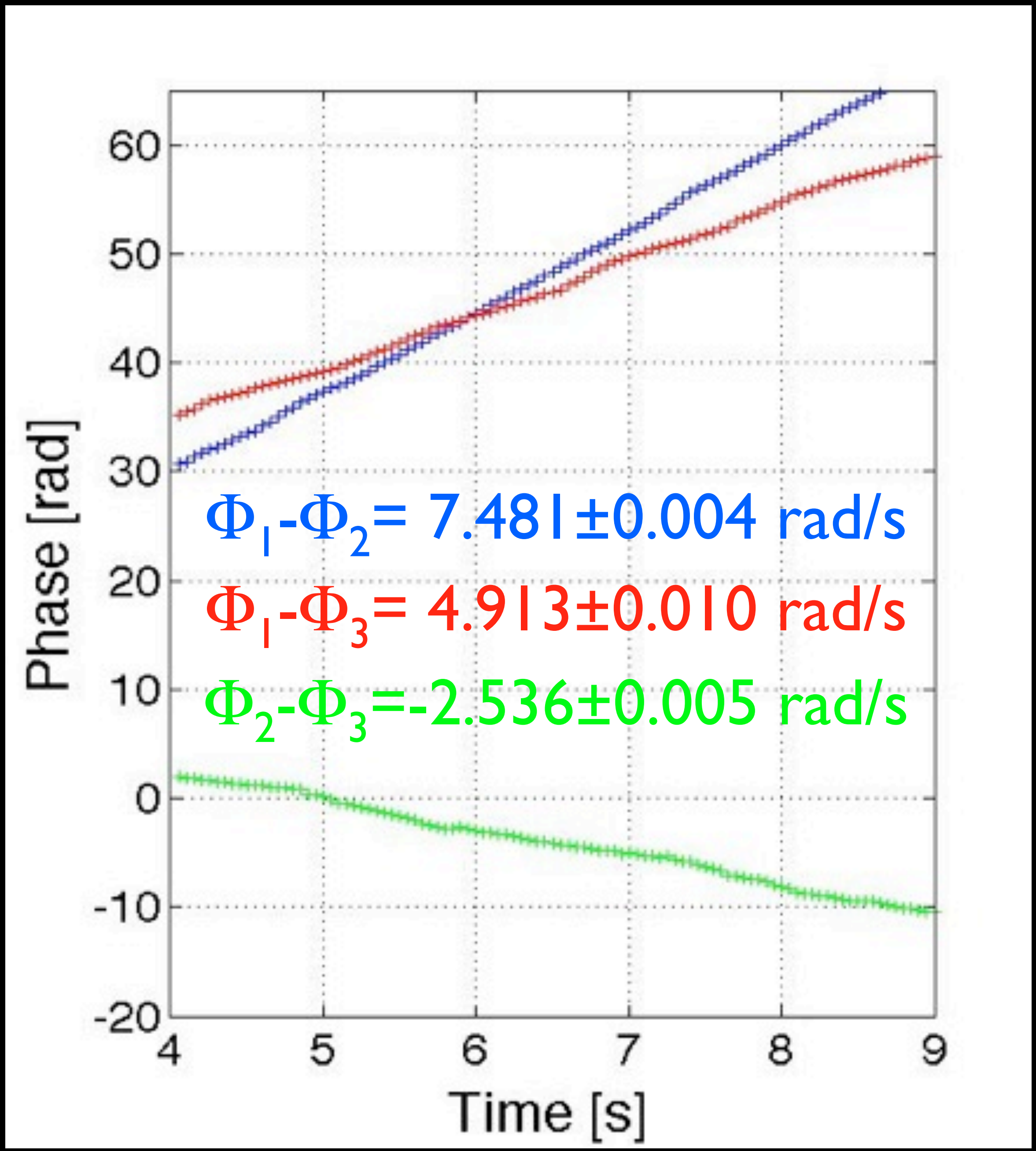
Expected:

I_1=0.207

I_2=0.464

I_3=0.334

First visibilities experimental results:



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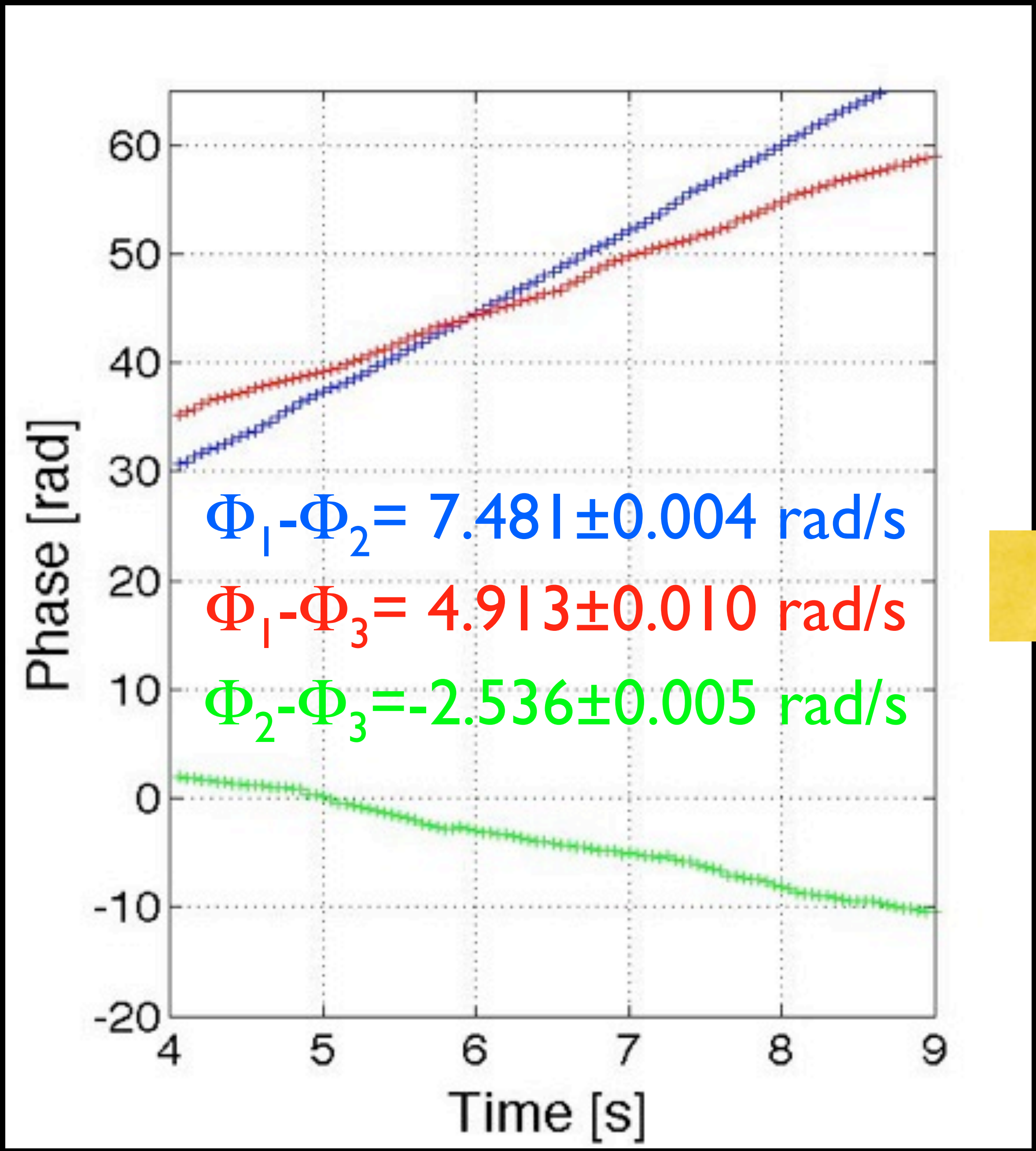


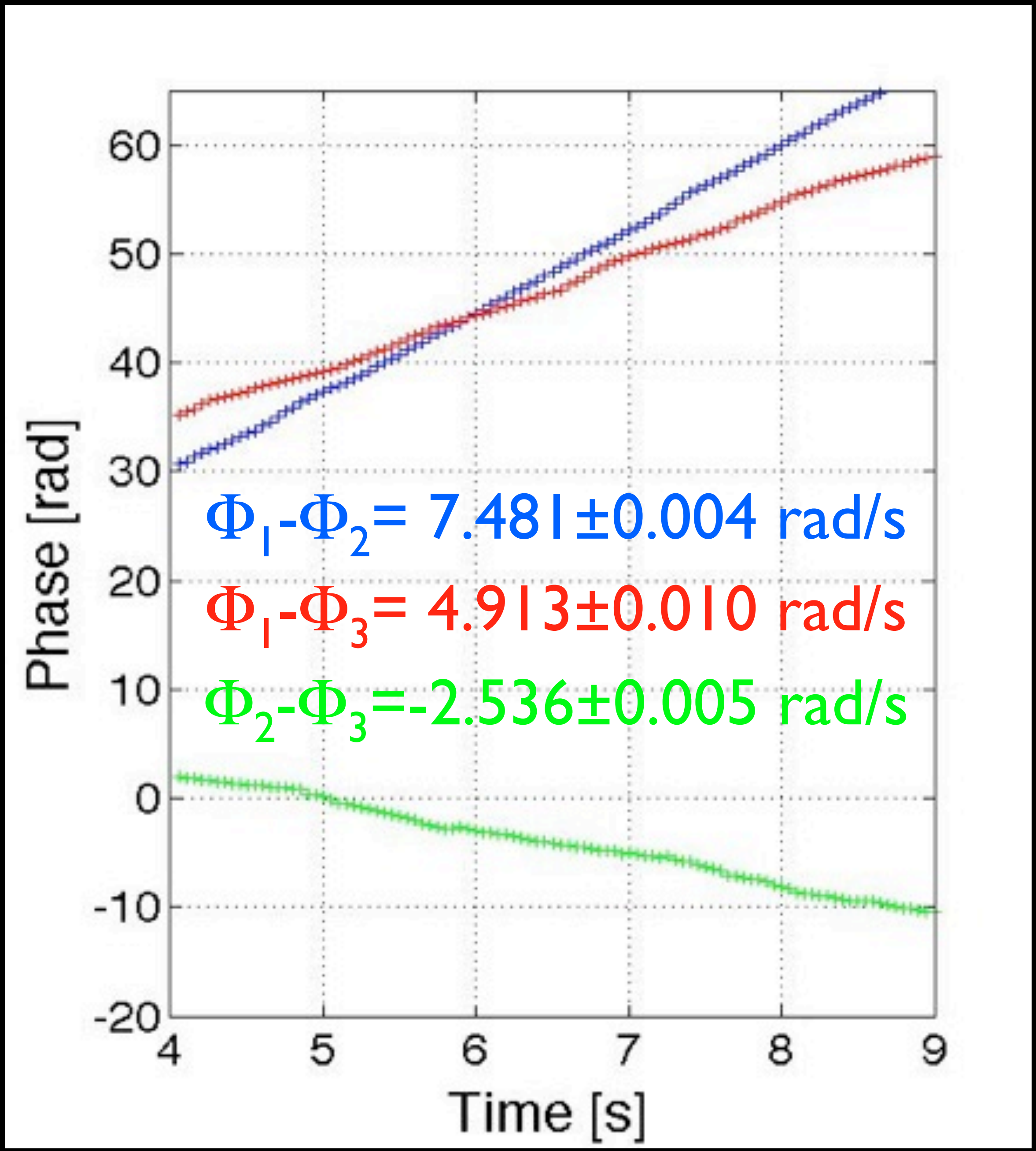
Expected:

Φ_1-Φ_2= 7.30 rad/s

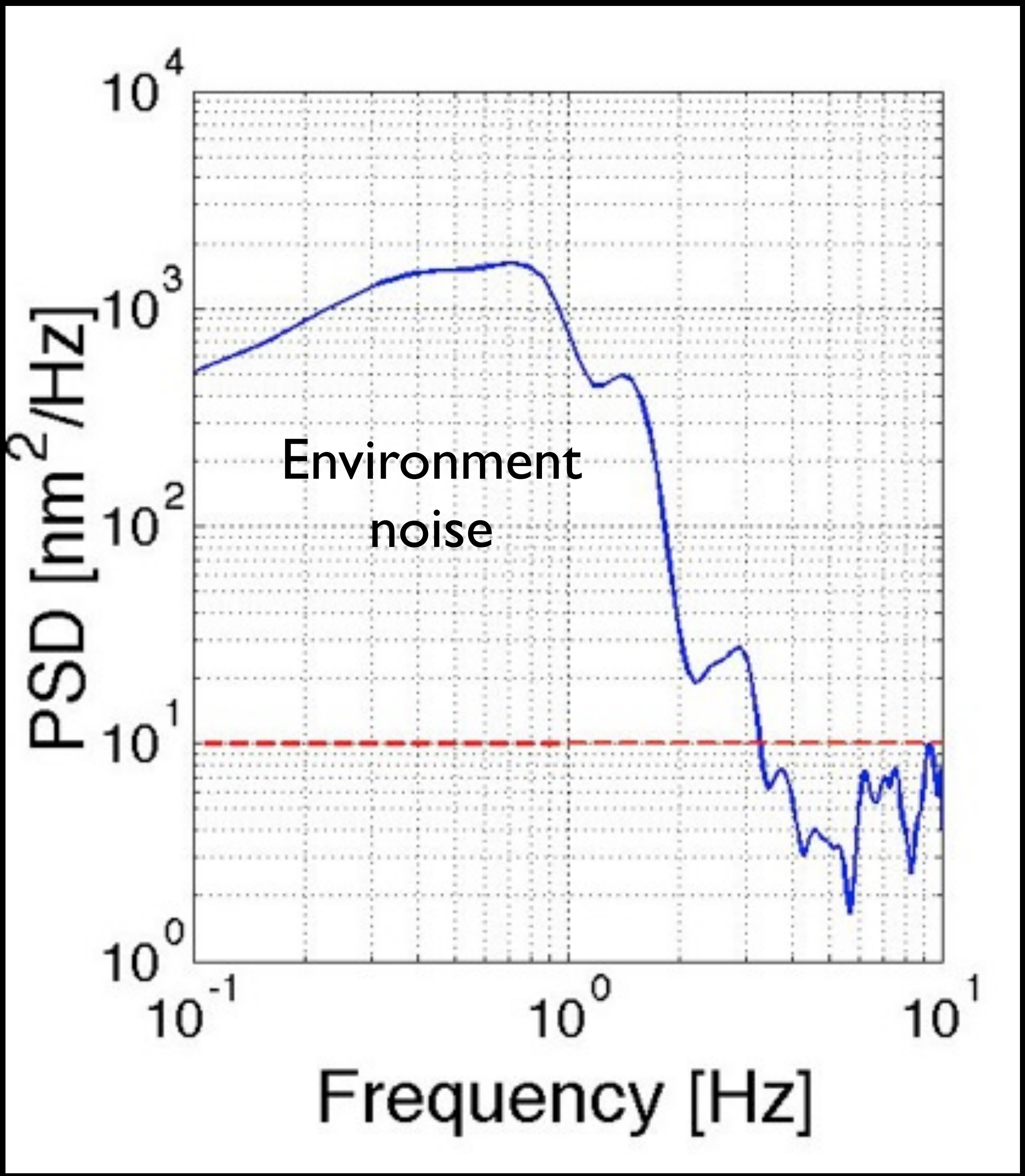
Φ_1-Φ_3= 5.05 rad/s

Φ_2-Φ_3=-2.52 rad/s

First visibilities experimental results:



Closure phase noise



High-frequency PSD<10 nm^2/Hz

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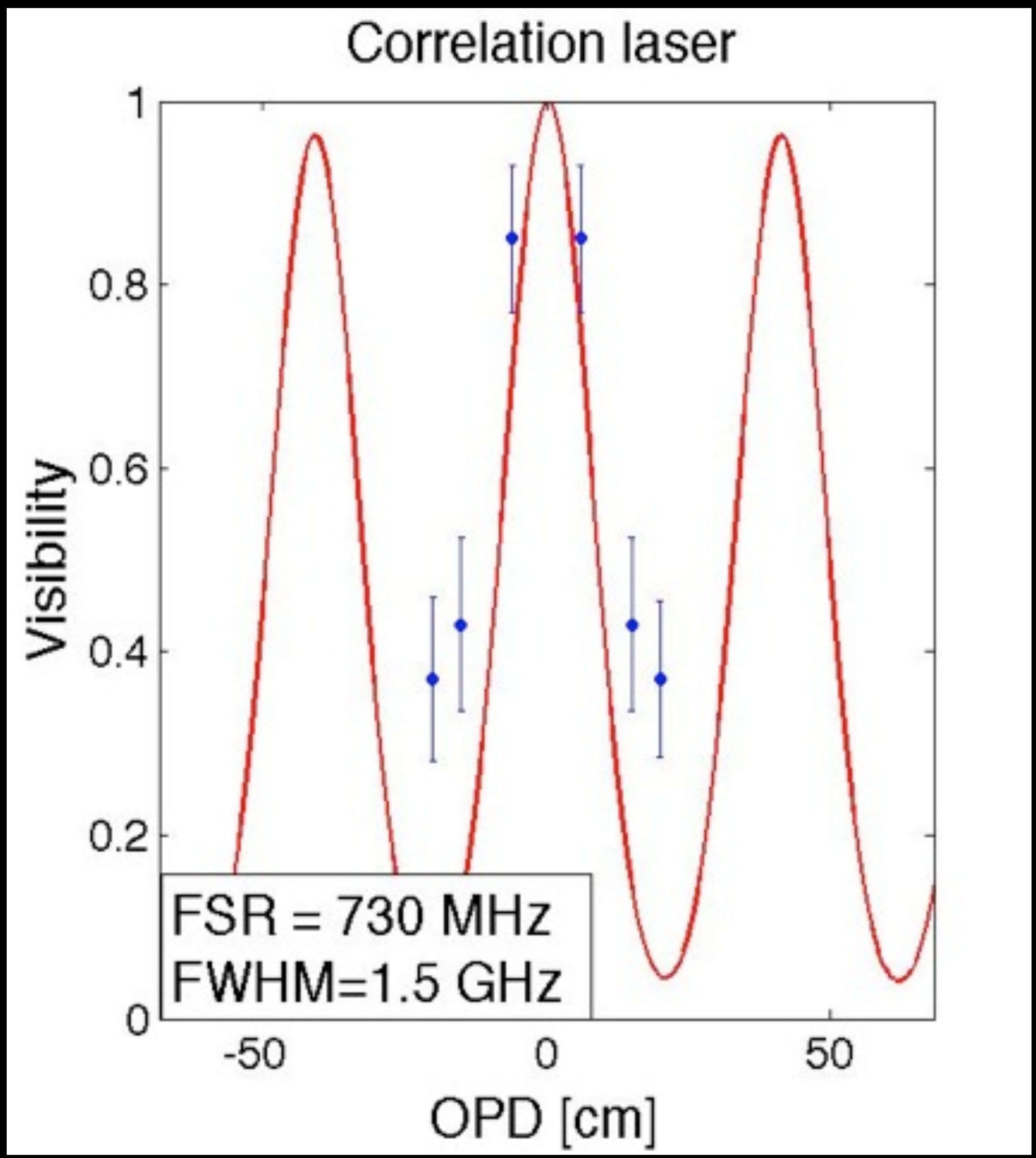

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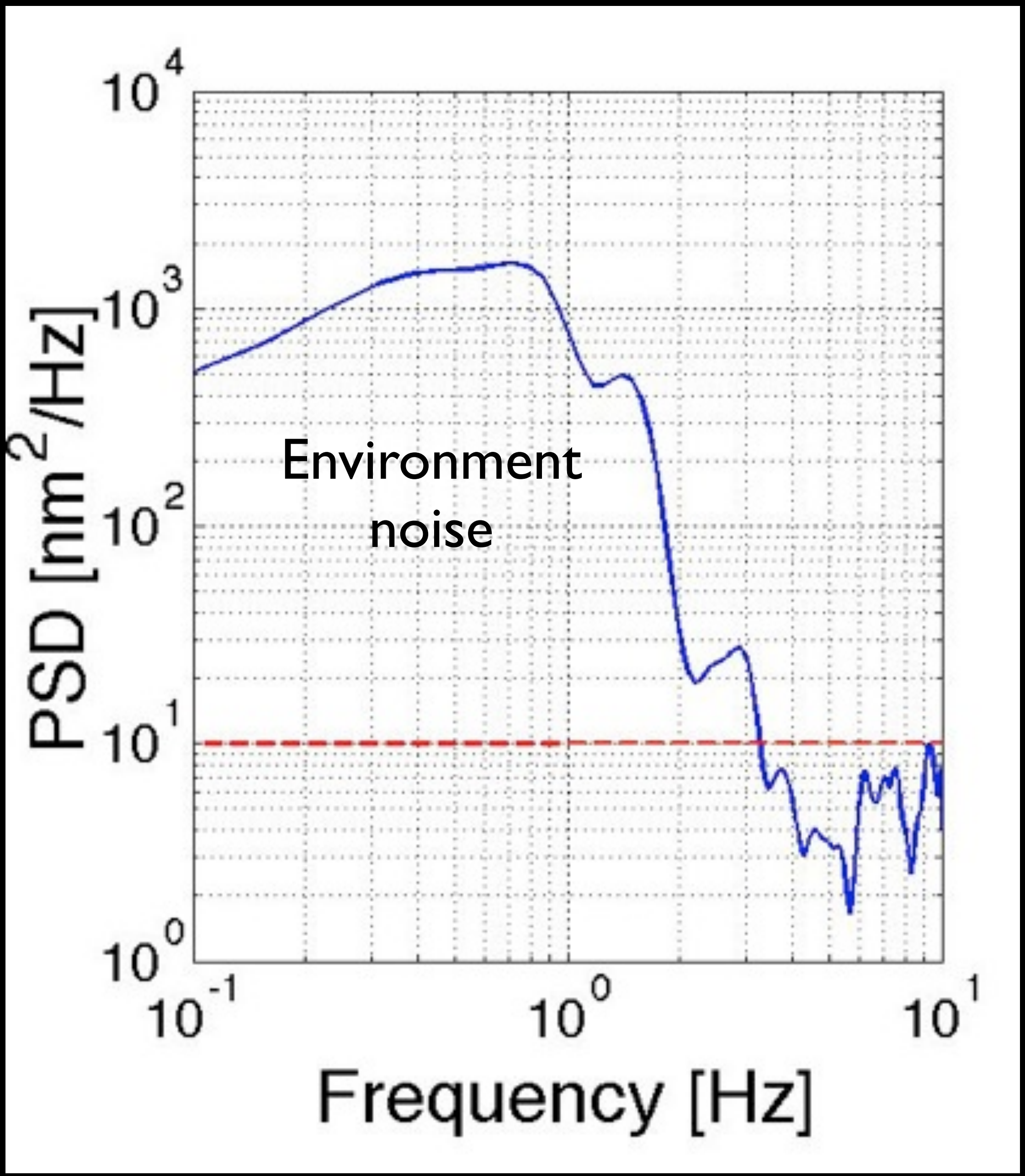
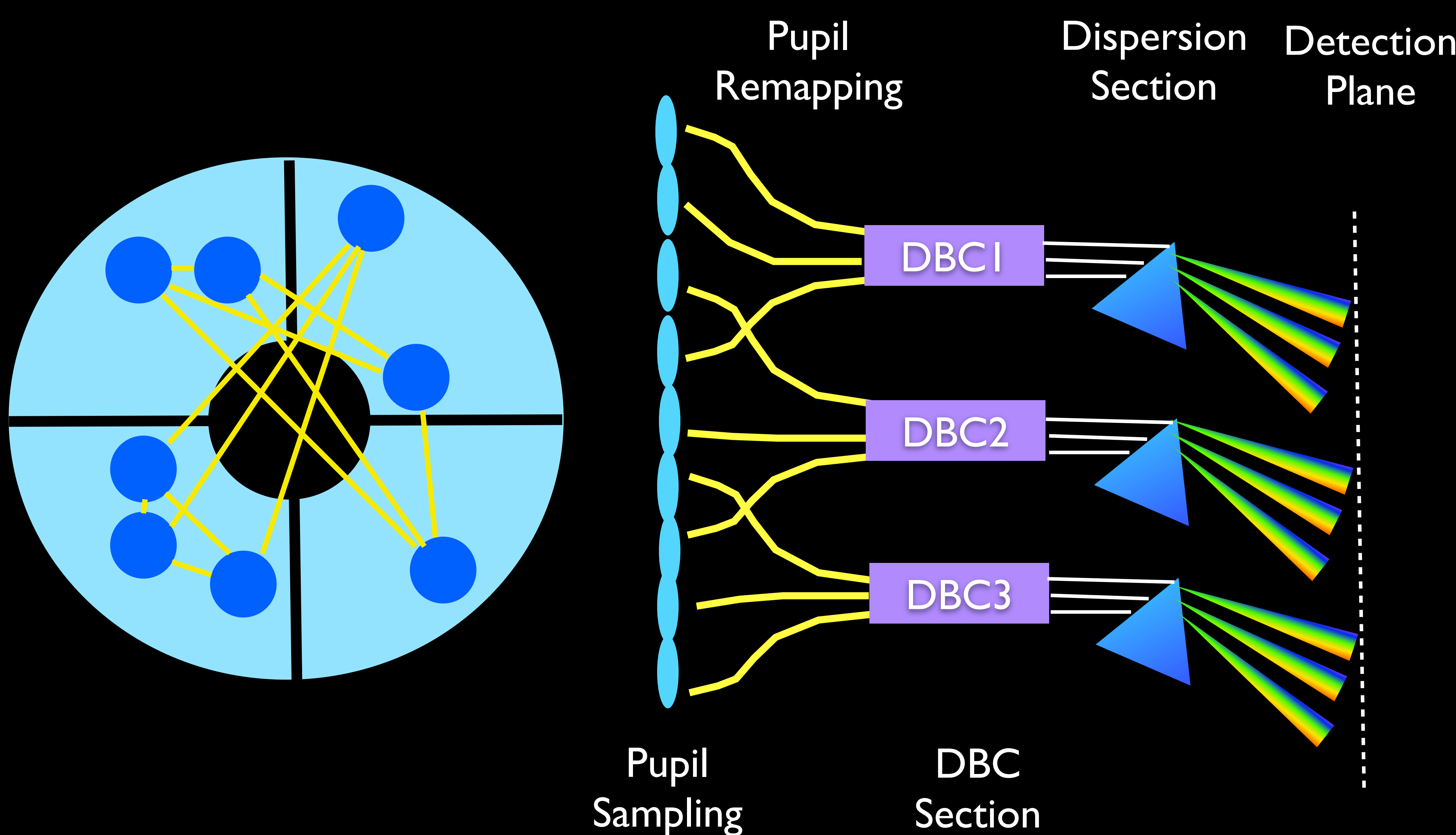


High-frequency PSD<10 nm^2/Hz

A possible application: pupil remapping



Light distributed over minimal number of pixels = high sensitivity
On-sky demonstrator under evaluation

Conclusions and perspectives

- First test of a 3D photonic combiner for Astrointerferometry. Optimization of performance in progress.

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- Simple design potentially scalable to a large number of telescopes.

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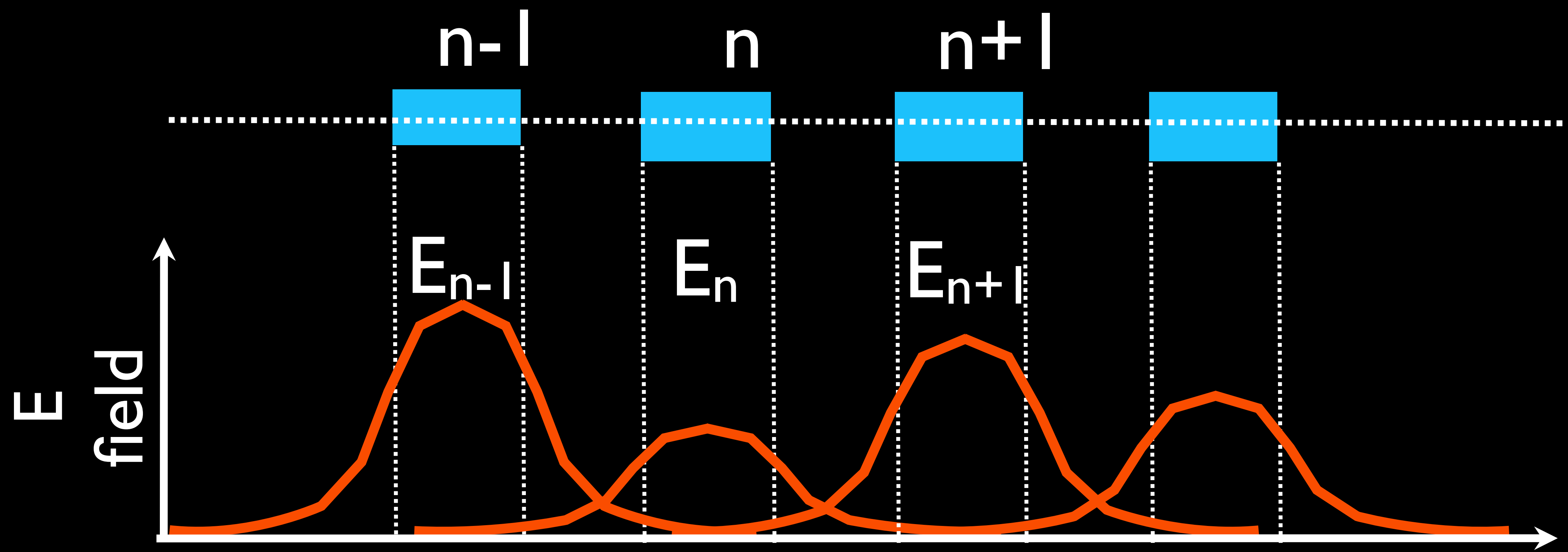
- First test of a 3D photonic combiner for Astrointerferometry. Optimization of performance in progress.

- Simple design potentially scalable to a large number of telescopes.

- Can find applications in intra-pupil interferometric instruments (e.g. FIRST/Dragonfly).

Arrays of coupled waveguides



Jones JOSA 55, 261 (1965),
Pertsch et al. Opt. Lett. 23, 1701 (1998).
Christodoulides et al. Nature 424, 817 (2003).

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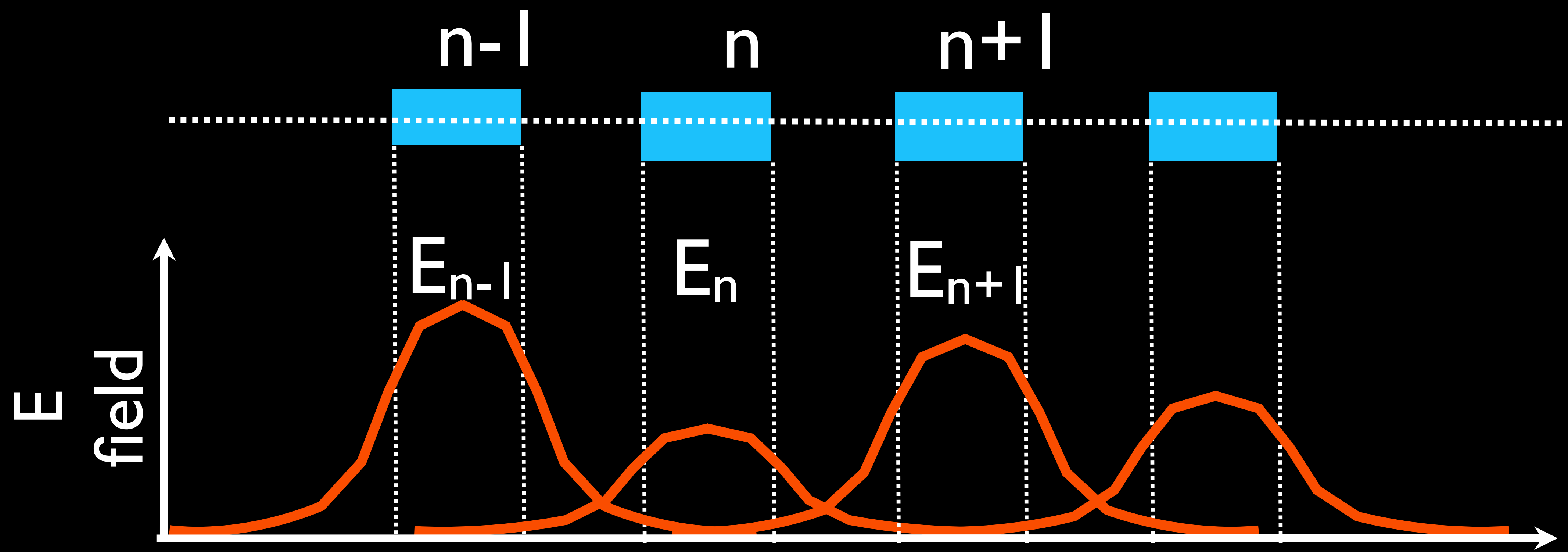

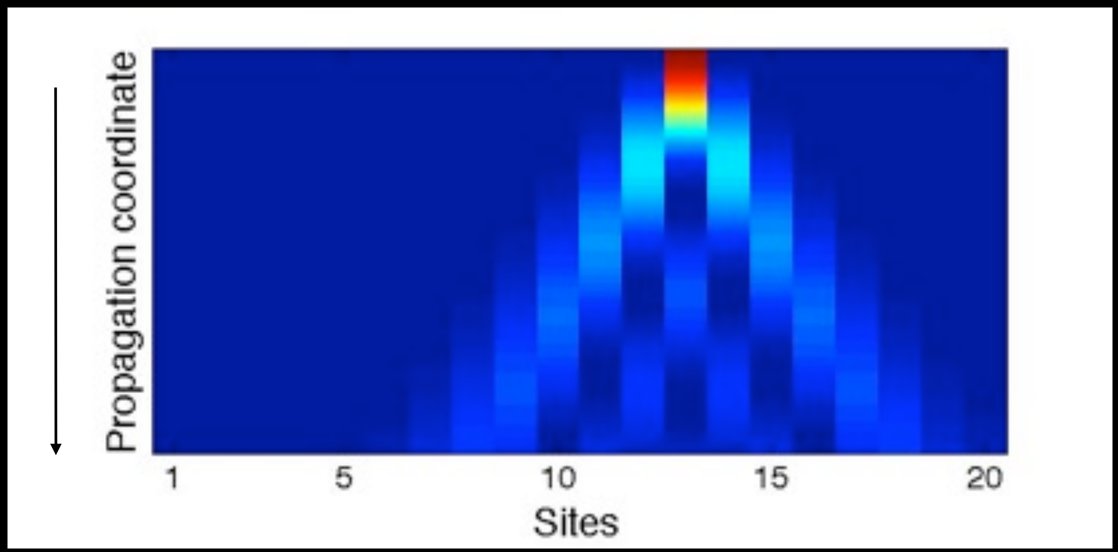

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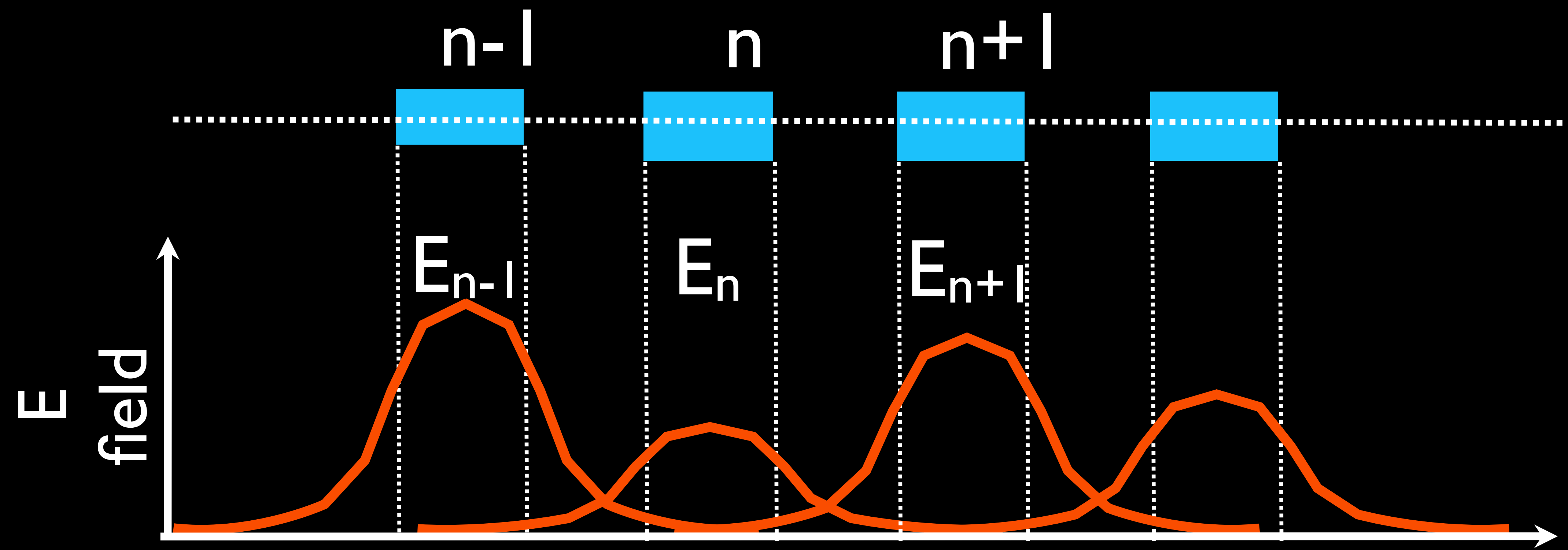

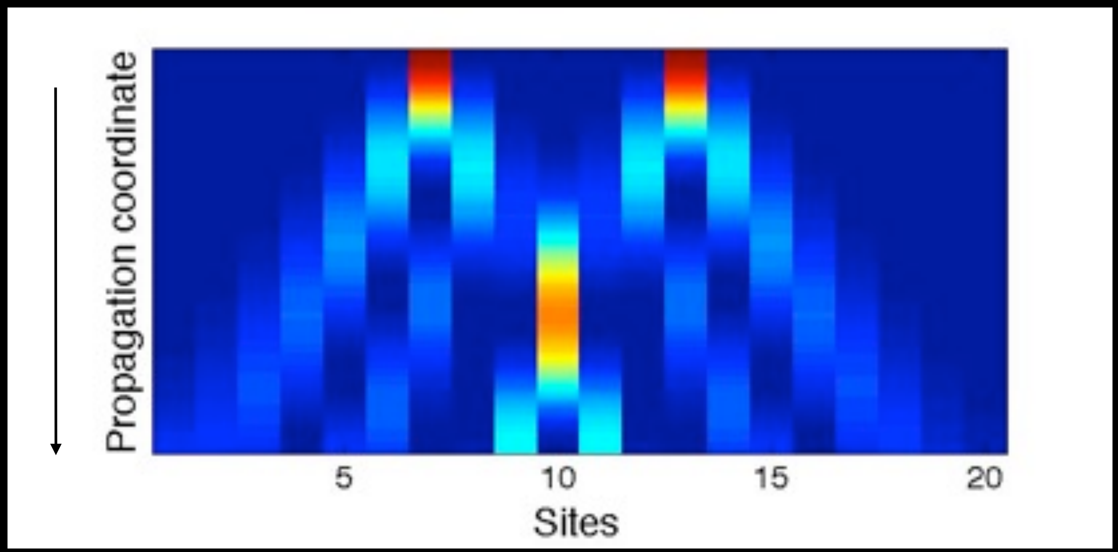

Interference pattern bound to a fixed array of waveguides

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Pertsch et al. Opt. Lett. 23, 1701 (1998).
Christodoulides et al. Nature 424, 817 (2003).