Generalised Phase Diversity – Initial Tests

Sijiong Zhang, Heather I Campbell and A H Greenaway

Physics, School of Engineering and Physical Sciences,
Heriot-Watt University, Edinburgh, Scotland, UK EH14 4AS

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Outline

- Numerical experiments to validate theory for generalised phase diversity.
- Description of error reduction algorithm.
- Simulation showing possible optimisation using *a priori* information
- Conclusions

Necessary and Sufficient Conditions

The necessary and sufficient conditions for a null wave-front sensor, which was presented in the morning by Heather Campbell, are as following

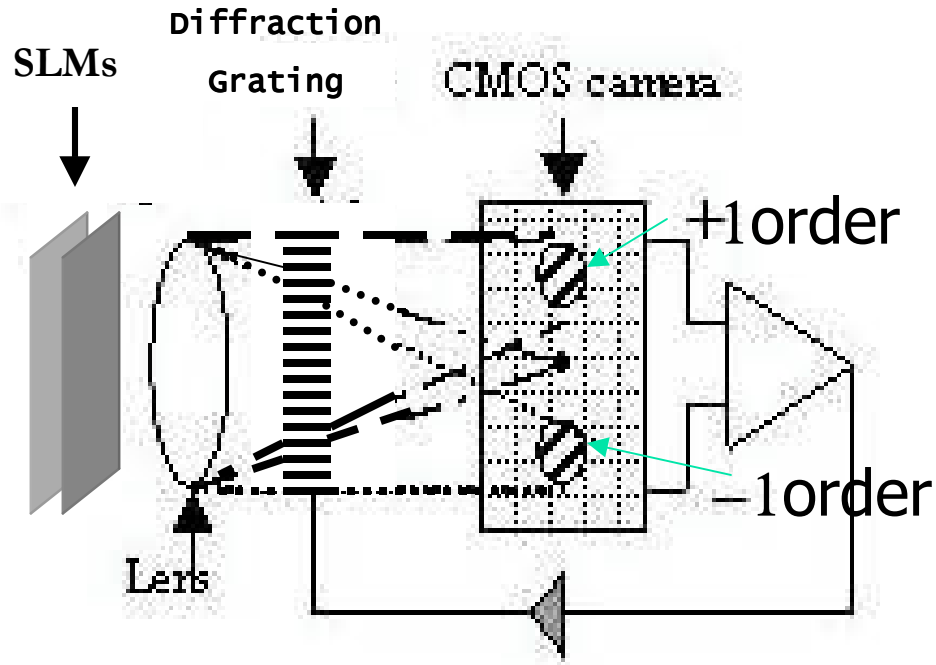
Sufficient Conditions:

The difference between two aberrated diversity images is null if the input wave-front is plane wave and is non-null for non-plane wave-fronts

Necessary Conditions:

The filter function must be complex.
Mixed symmetries of the filter function must not be used

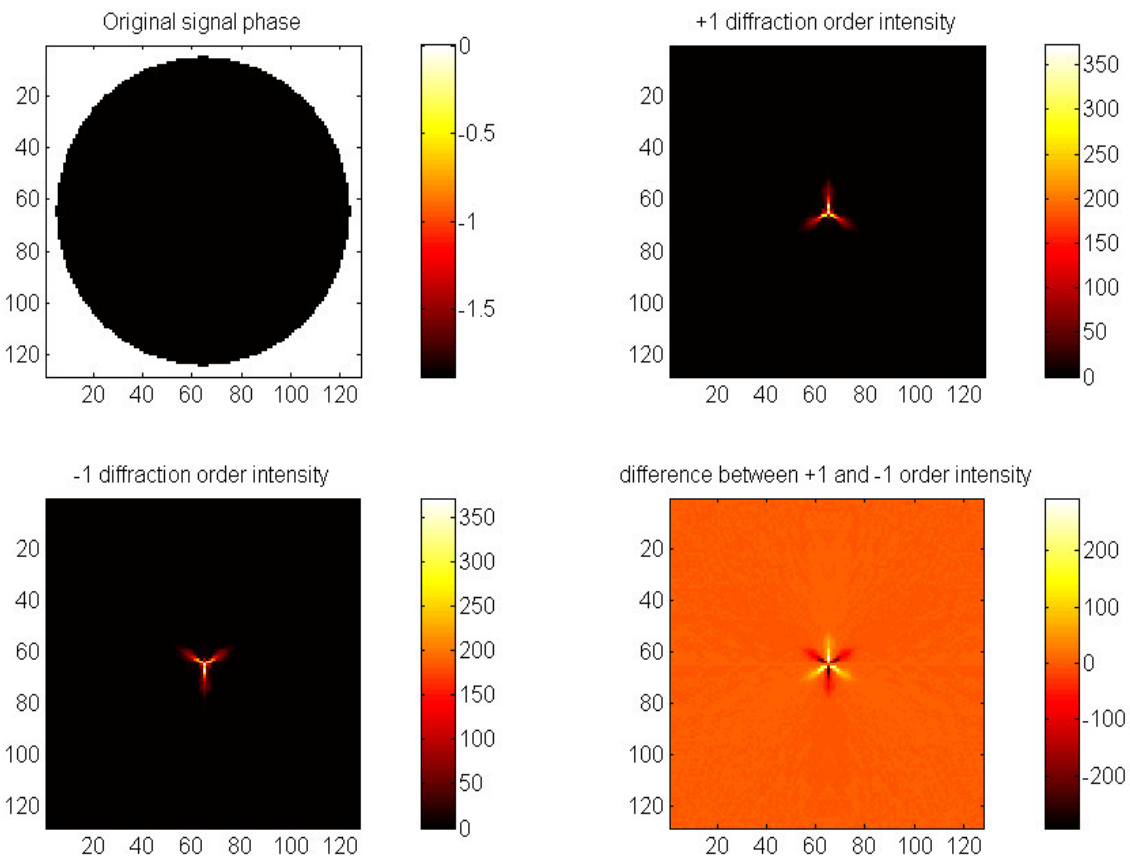
Schematic of the wave-front sensor



A suggested Compact AO System (CAOS)

- SLMs provide modulation.
- DoE provides phase-diverse data and image wave-front for correction by SLMs
- CMOS camera

Numerical Experiments for validating Theory



1 Plane wave input

exp(j*1.4*π)

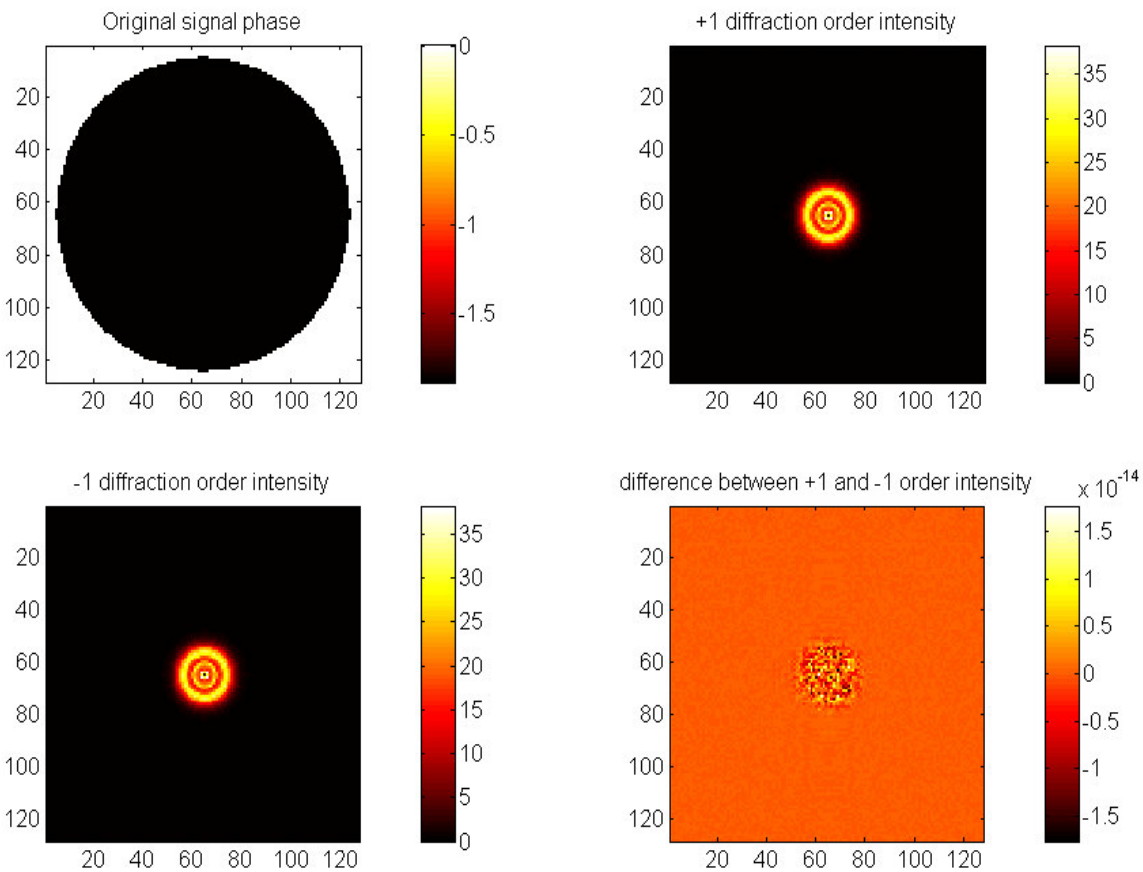
a) Mixed symmetry phase diversity:

$$z_2^0 + z_3^{-3}$$

(Defocus+Astigmatism)

Difference value for plane wave input is not zero. So mixed symmetry phase diversity is not suitable to a null sensor (Necessary Condition)

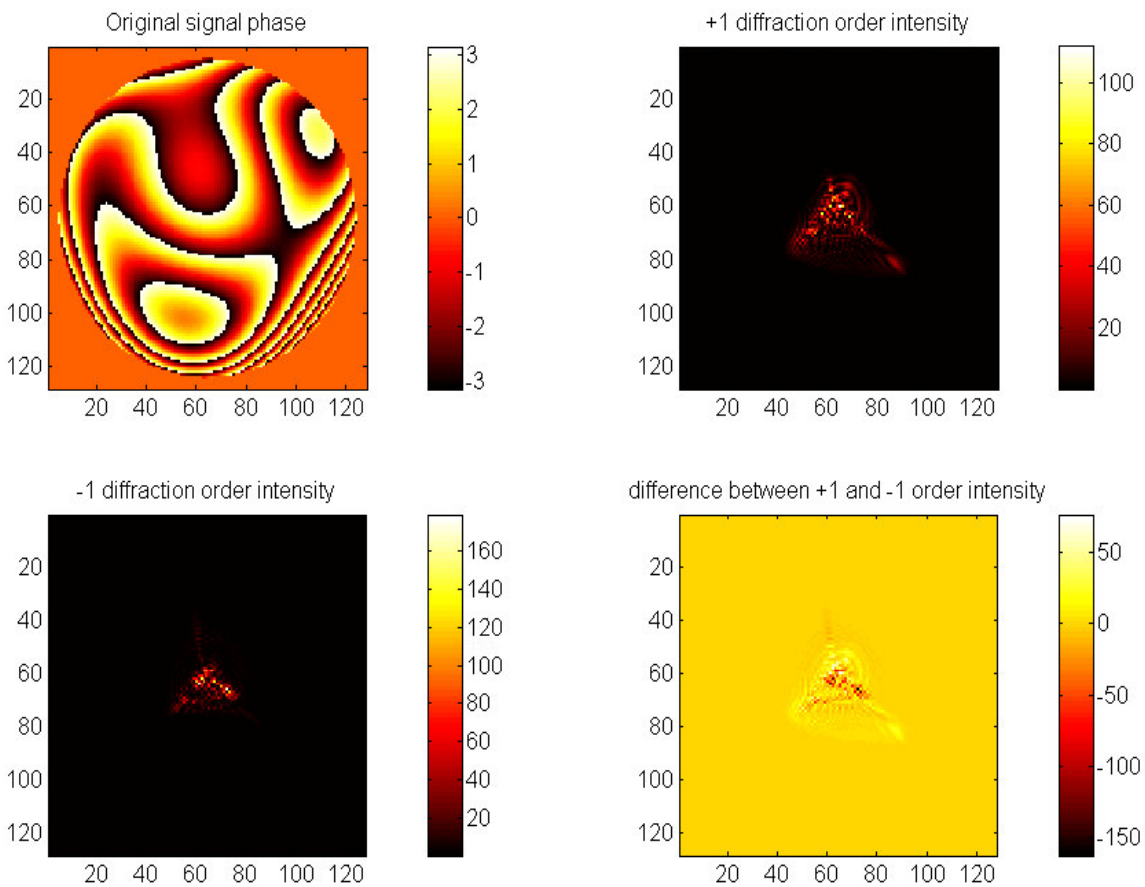
Numerical Experiments for validating Theory



b) Even symmetry phase diversity:
Z_2^0 (Defocus)

Difference value for plane wave input is zero. So even symmetry phase diversity satisfies the sufficient condition for a null sensor

Numerical Experiments for validating Theory



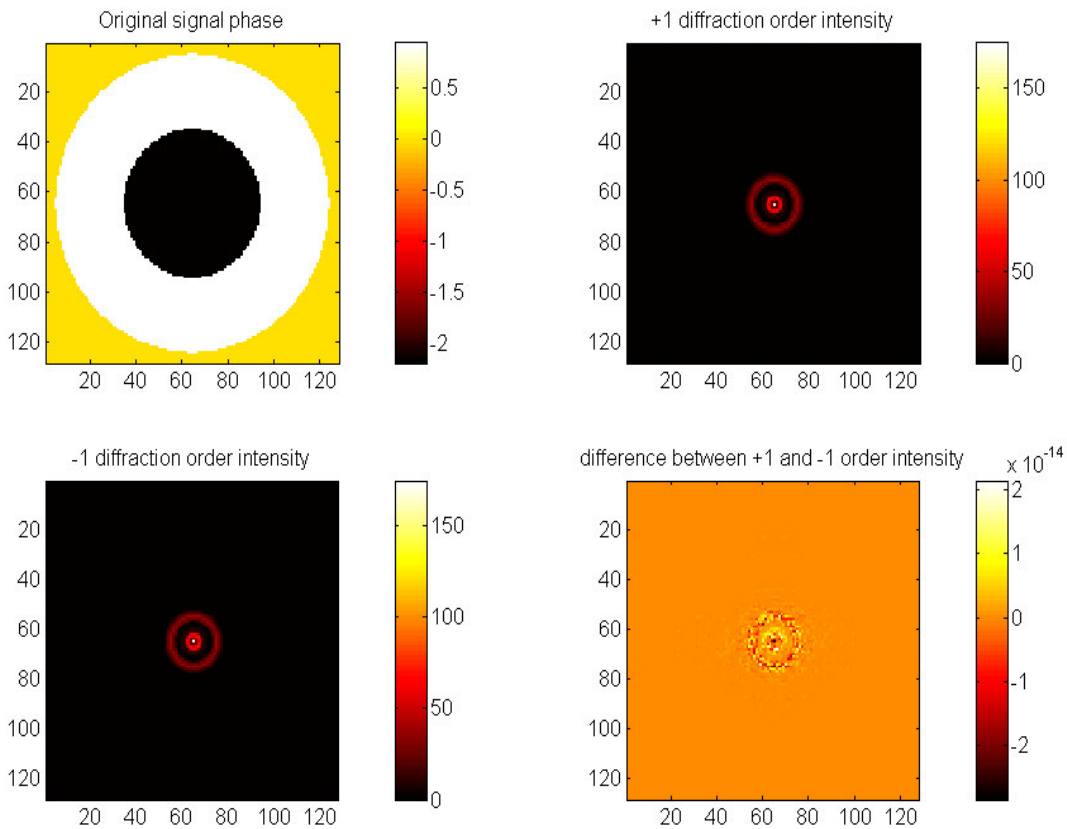
2 Non-plane wave input : exp(j*1.4*π* Z)

Even symmetry phase diversity:

z_{10}^{0} (Zernike)

The difference between two aberrated diversity images is non-null for non-plane wave-fronts(sufficient condition)

Input wave-front with π discontinuity



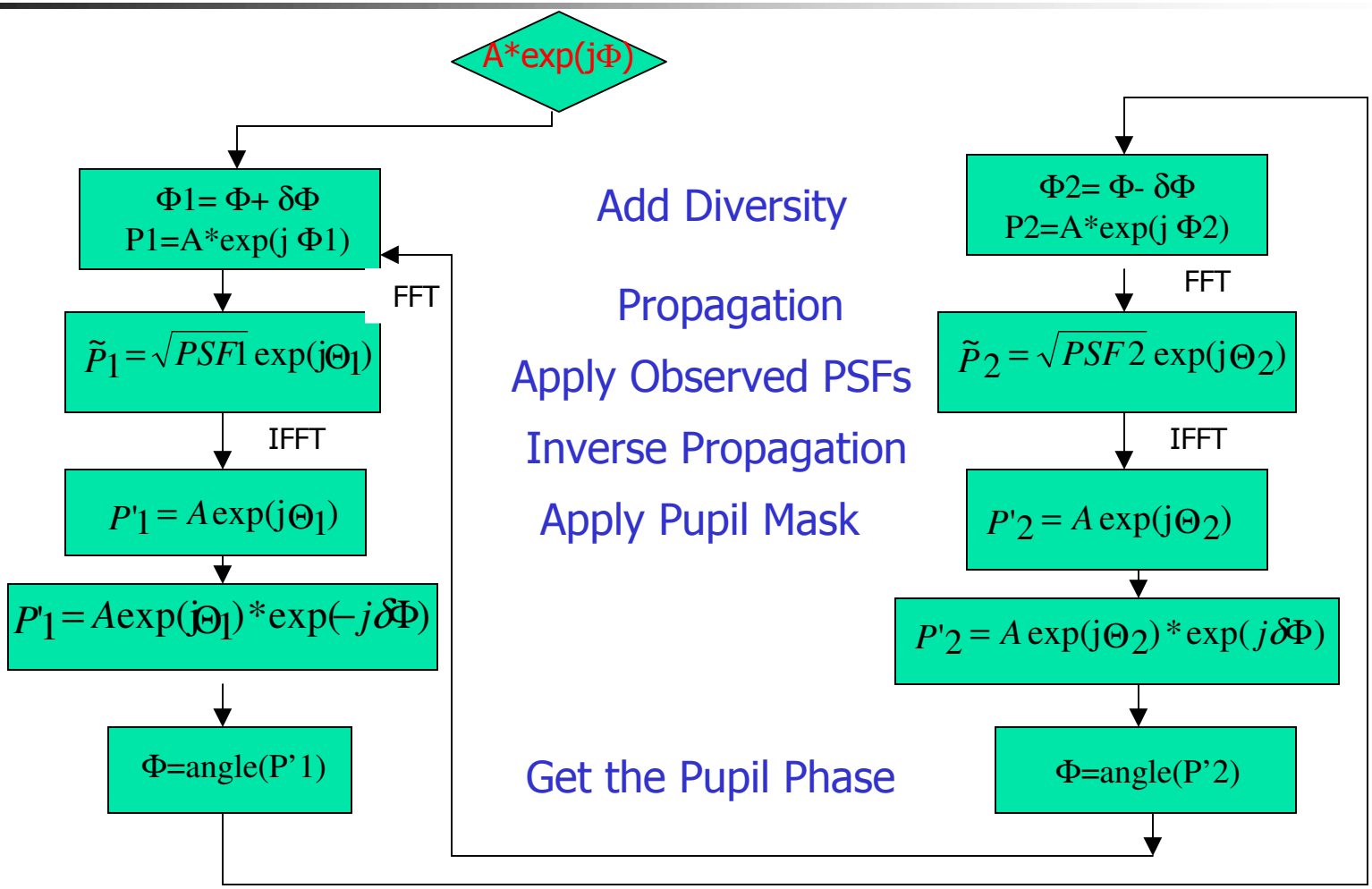
(black -1.3*π; white -0.3*π)

This real wave-front is unimportant for astronomy but potentially important when using the wave-front sensor in metrology applications

Even symmetry phase diversity: z_2^0

This is one of results derived from theory

Error Reduction Algorithm for Generalised Phase Diversity



Definition of the error metric function

The error metric function used in simulation :

$$RMSE = [\sum(I_+ - \tilde{I}_+)^2 / (\sum(I_+{}^2) + \sum(I_- - \tilde{I}_-)^2 / \sum(I_-{}^2)] / 2$$

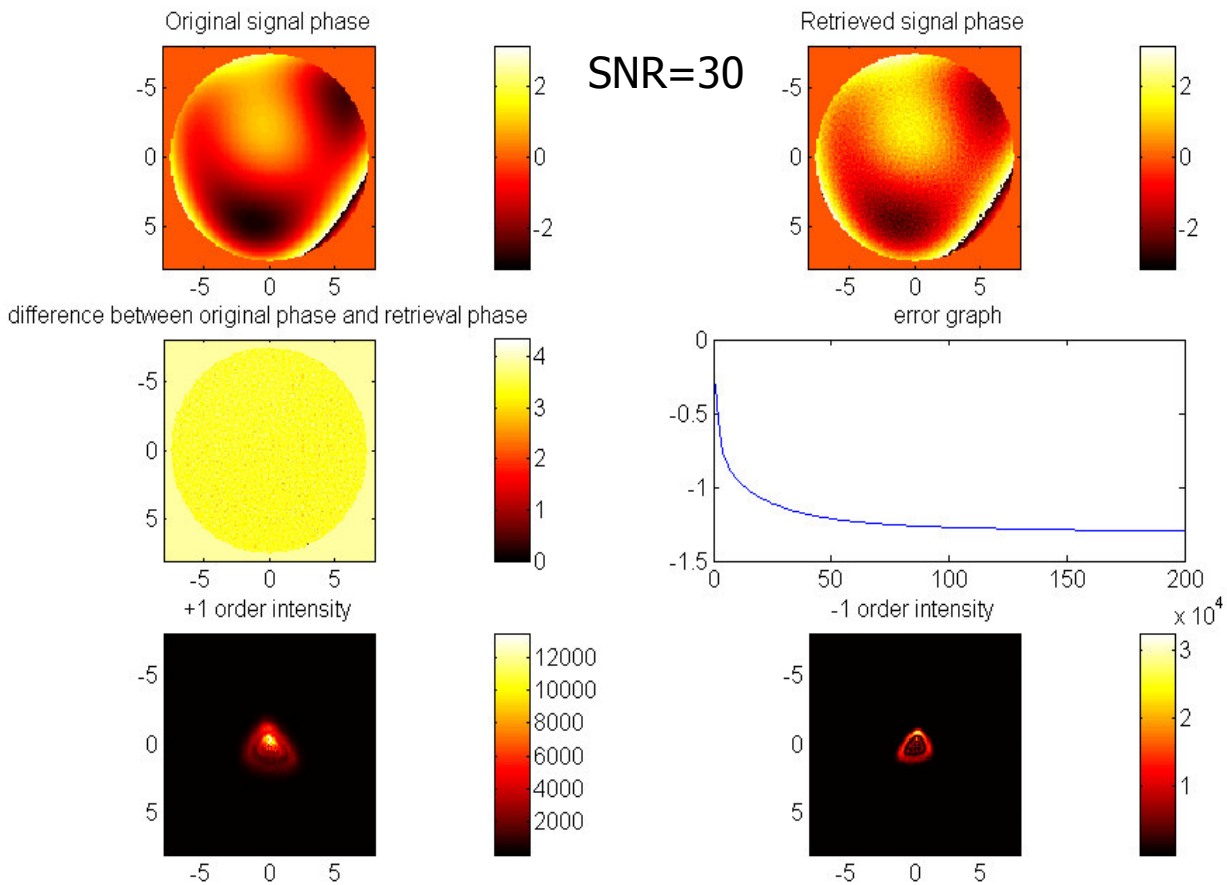
where I_+ and I_- represent measured intensity data in the +1 and -1 diffraction order

$\tilde{I}_+$ and $\tilde{I}_-$ represent an estimate of the phase diversity data intensity from the reconstructed wave-front

In simulation, we are comparing error reduction algorithm and looking for the fastest, most robust convergence properties.

Development of analytic methods for data reduction is 'in hand'

Simulation Results for possible optimisation using a priori information

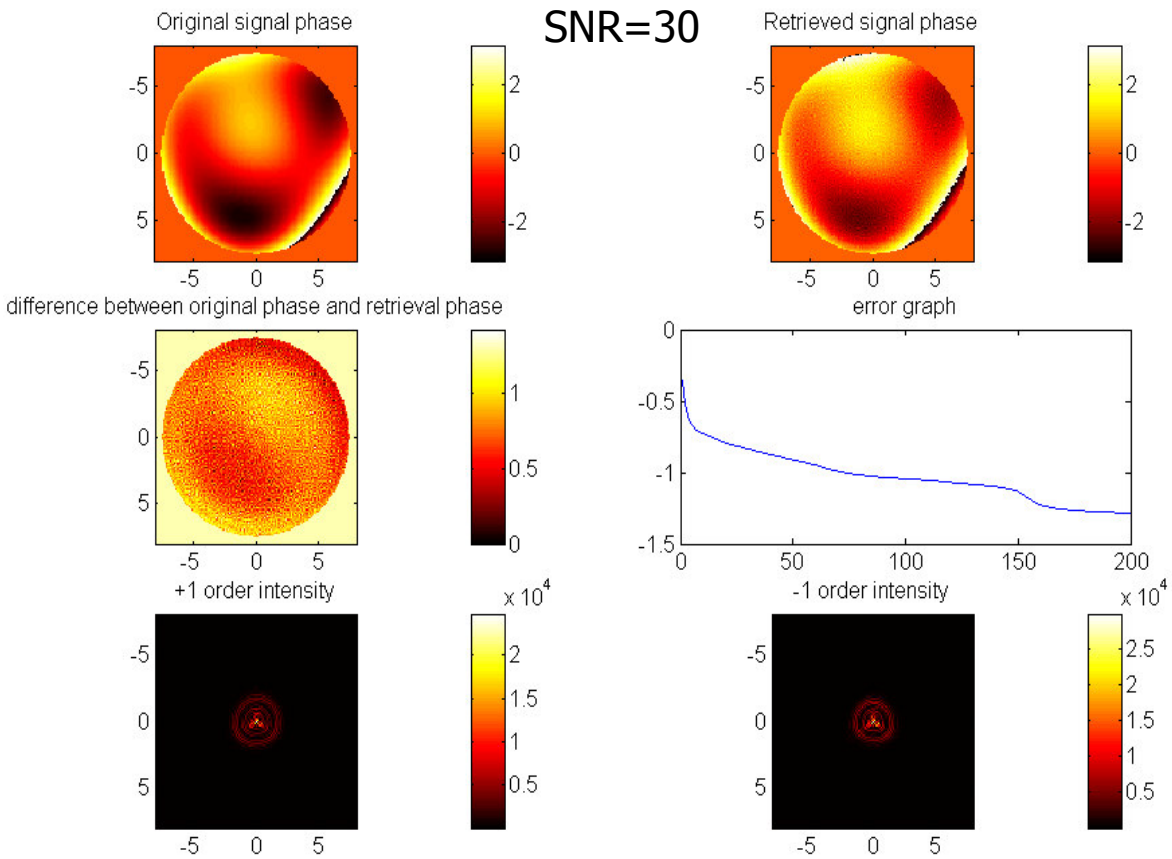


Input wave-front: defocus+astigmatism +coma+trefoil+ spherical aberration.

Diversity filter: z_2^0

(Defocus)

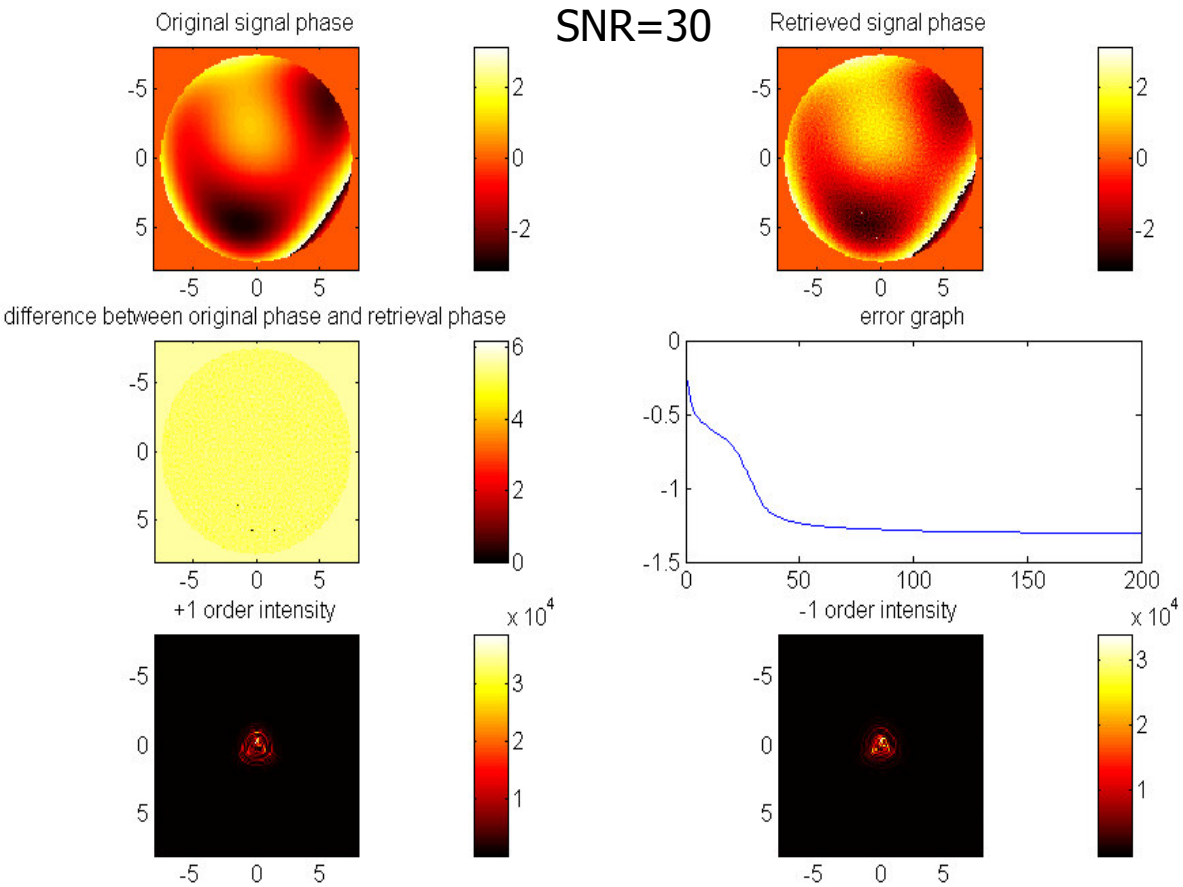
Simulation Results(continued)



Input wave-front: defocus+astigmatism +coma+trefoil+ spherical aberration

Diversity filter: Z_4^0 (spherical aberration)

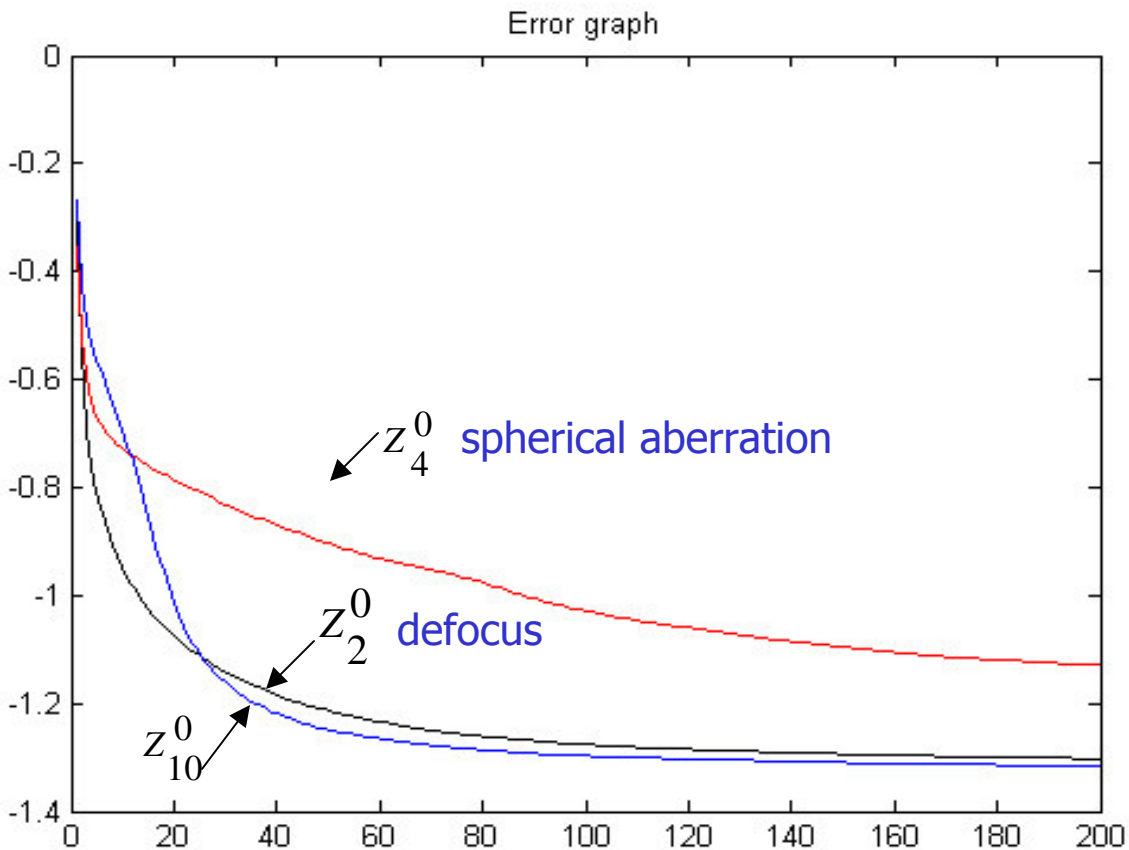
Simulation Results(continued)



Input wave-front: defocus+astigmatism +coma+trefoil+ spherical aberration.

Diversity filter: Z_{10}^{0}

Comparison for three diversity cases



Shows that z_{10}^0 is marginally better than defocus, although initial convergence is slower.

However, this does illustrate that different diversity kernels can be used to achieve different results

Conclusions:

We used numerical experiments to validate theory for the necessary and sufficient conditions for construction of a null wave-front sensor based on the principles of a generalisation of phase-diversity wave-front sensing.

So far we find no deviations numerical experiment results from theoretical results.

Describing generalised error reduction algorithm.

Simulation results illustrated that the generalised wave-front sensor can be optimised to exploit *a priori* information in order to maximise sensitivity of wave-front sensor.