Generalised Phase Diversity Wavefront Sensing

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Format for this presentation

- Brief introduction to Phase Diversity (PD) and curvature sensing.
- Generalised Phase Diversity (GPD) - basic principles.
- GPD as a null sensor -
  - The error signal.
  - Simulation results.
  - Discussion of different aberration filter functions.
- Gureyev-Nugent (GN) Algorithm.
- Preliminary experimental results and set-up.
- Conclusions and future work.
- References and Acknowledgements.

Basic Background

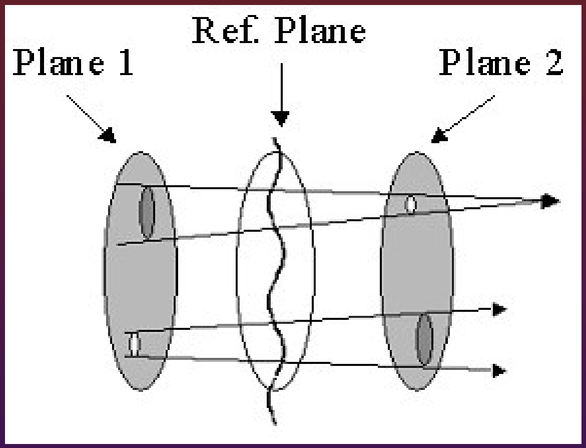


Figure 1: Shows the relationship between intensity and curvature

$$-\frac{k}{I}\frac{\partial I}{\partial z} = \nabla^2\varphi \quad \text{I.T.E}$$

- Two-defocus method.
- Wavefront curvature is related to axial intensity derivative.
- Phase retrieval using ITE and Green's function solution [1].
- Problem: limiting assumptions placed on the wavefront

PD with Diffractive Optics

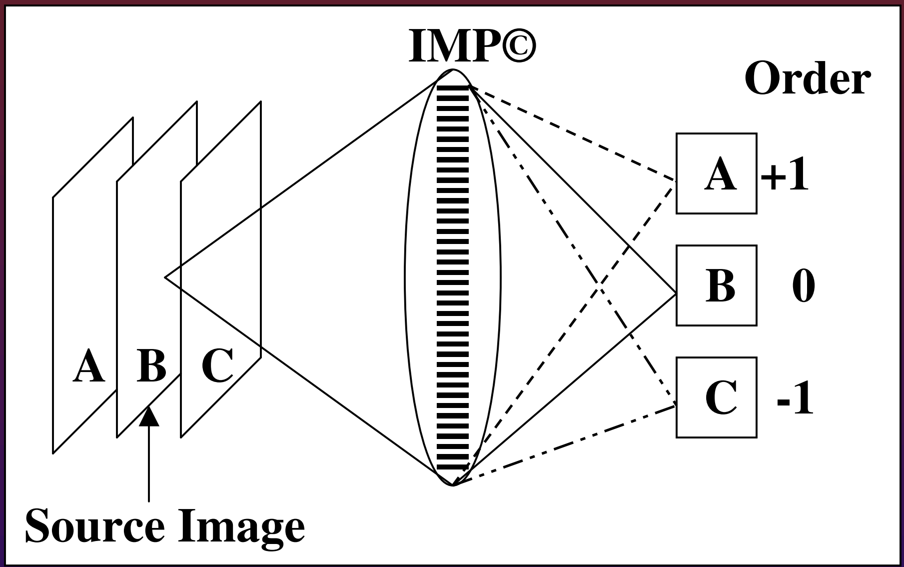


Figure 2: Shows the design of the current wavefront sensor.

Note: IMP© is a DERA (now QinetiQ) trademark

- Quadratically distorted defocus grating.
- Images of different object layers are recorded on the same focal plane [2].
- The plane separation and image locations are determined by the properties of the grating.

Generalised Phase Diversity

- Requires two intensity images each convolved with different, but related, aberration functions (in a DOE).
- For a null sensor we restrict the permitted functions to ones which satisfy the necessary and sufficient conditions [3]:
  - must provide a null output for plane wavefronts, and an error signal for distorted wavefronts.
  - Filter function must be complex with 'same symmetry'

The Error Signal

- Formed by the difference between the intensity images in the ±1 diffraction orders.

$$d(r) = j_+(r) - j_-(r)$$

Simulation Results:

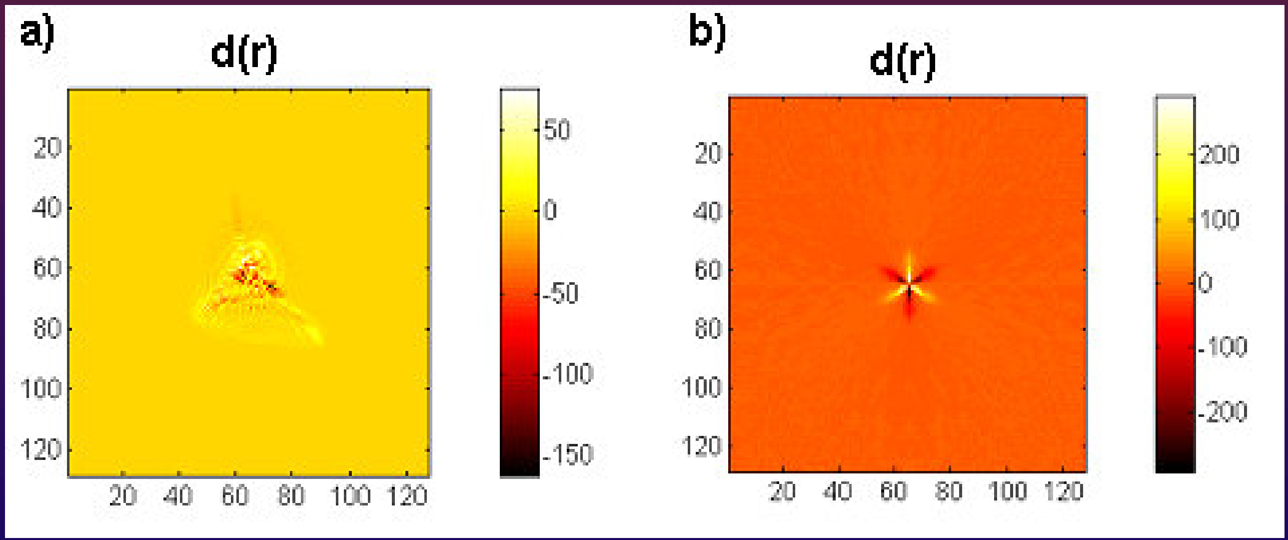


Figure 3: Difference signal for a) distorted wavefront with even filter b) plane wave with mixed filter

The Filter Function

- Convolution of the input wavefront with the FT of the filter function.

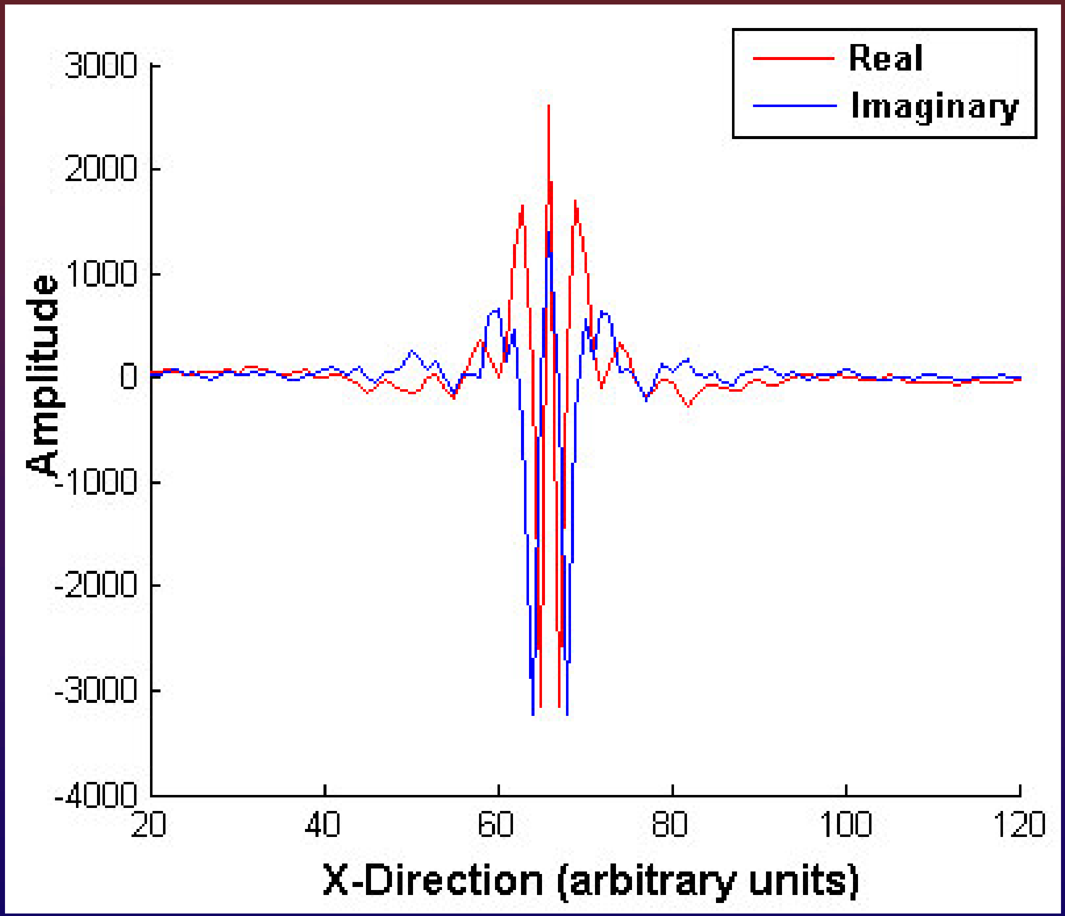


Figure 4: FT of a Defocus Filter function

Comparison of Defocus and S.A

- The profiles of the side lobe functions will be different - What does this mean for GPD wavefront sensing?

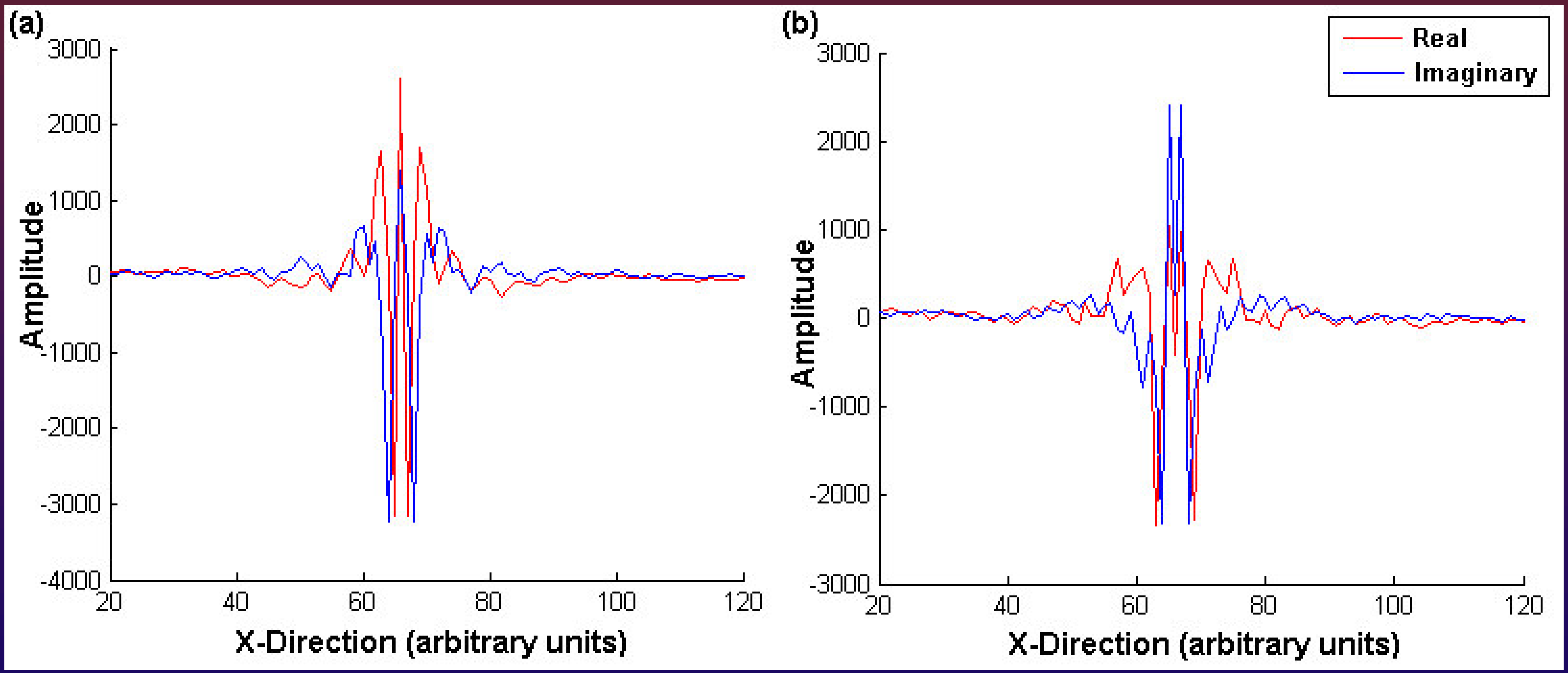


Figure 5: FT of the filter function for a) Defocus b) S.A

Simulation Results

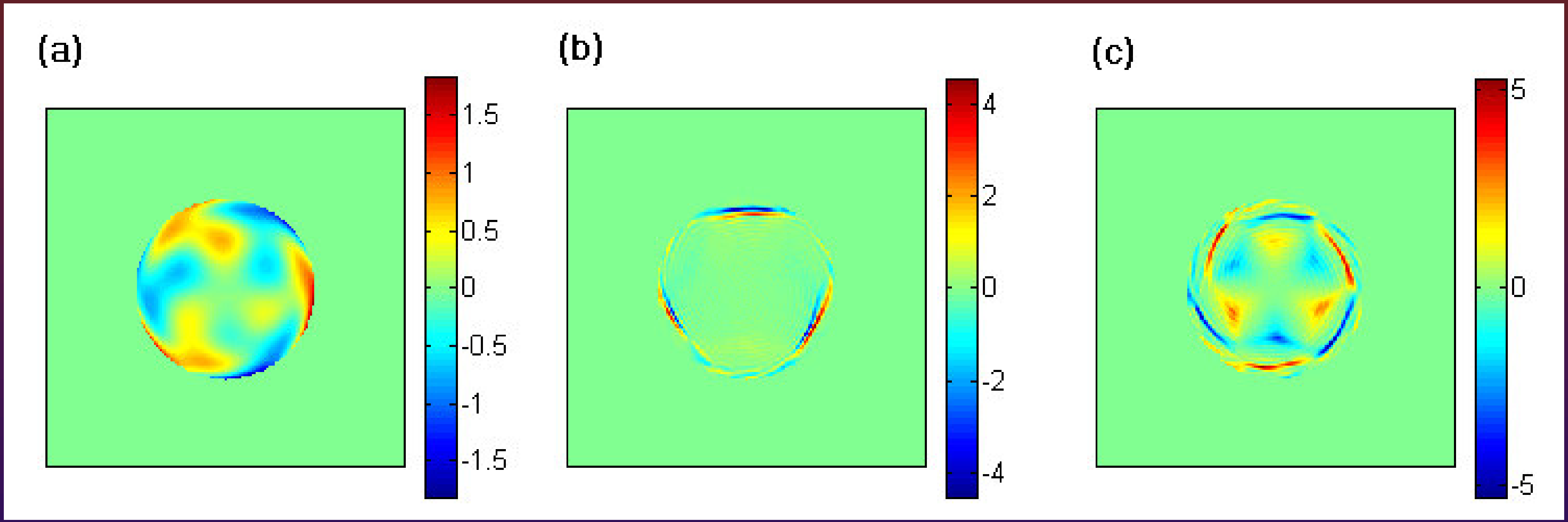


Figure 6: The error signals generated for a) distorted wavefront with b) Defocus and c) S.A filter functions

Gureyev-Nugent Algorithm

- Phase retrieval algorithm - based on decomposition of the ITE into a series of Zernike Polynomials [4,5].
- Could be used with other orthonormal series.
- This algorithm can be used in the presence of non-uniform illumination [5].

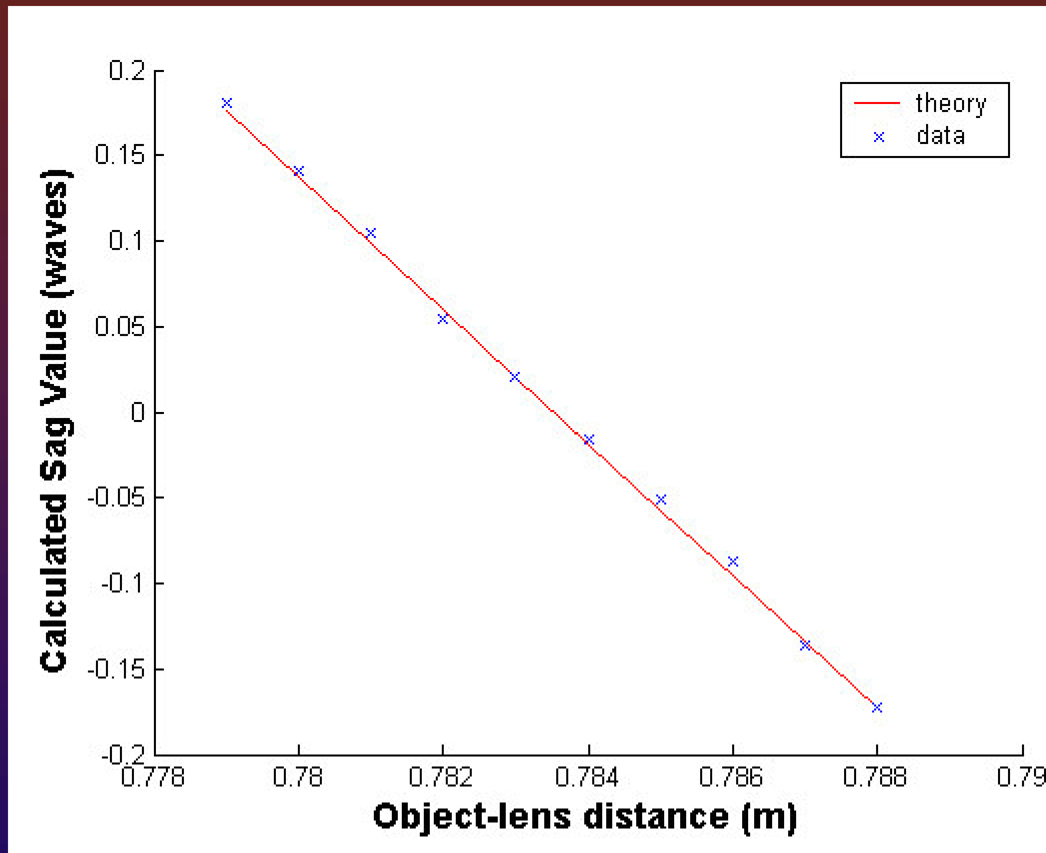
Preliminary Experimental Work

- A defocus based wavefront sensor was built to test the GN algorithm accuracy.
- New DOE have been designed are being fabricated.

Experiment:

- Point source was translated about the focal position or the system and intensity images were recorded at these displaced positions.
- The GN algorithm was used to reconstruct the pupil phase from these images.

Defocus Sensor - Results



R.M.S fit to theory ≈ λ/200

(≈3nm accuracy)

Figure 7: Comparison between calculated and measured values for defocus vs. source position

The Interferometer

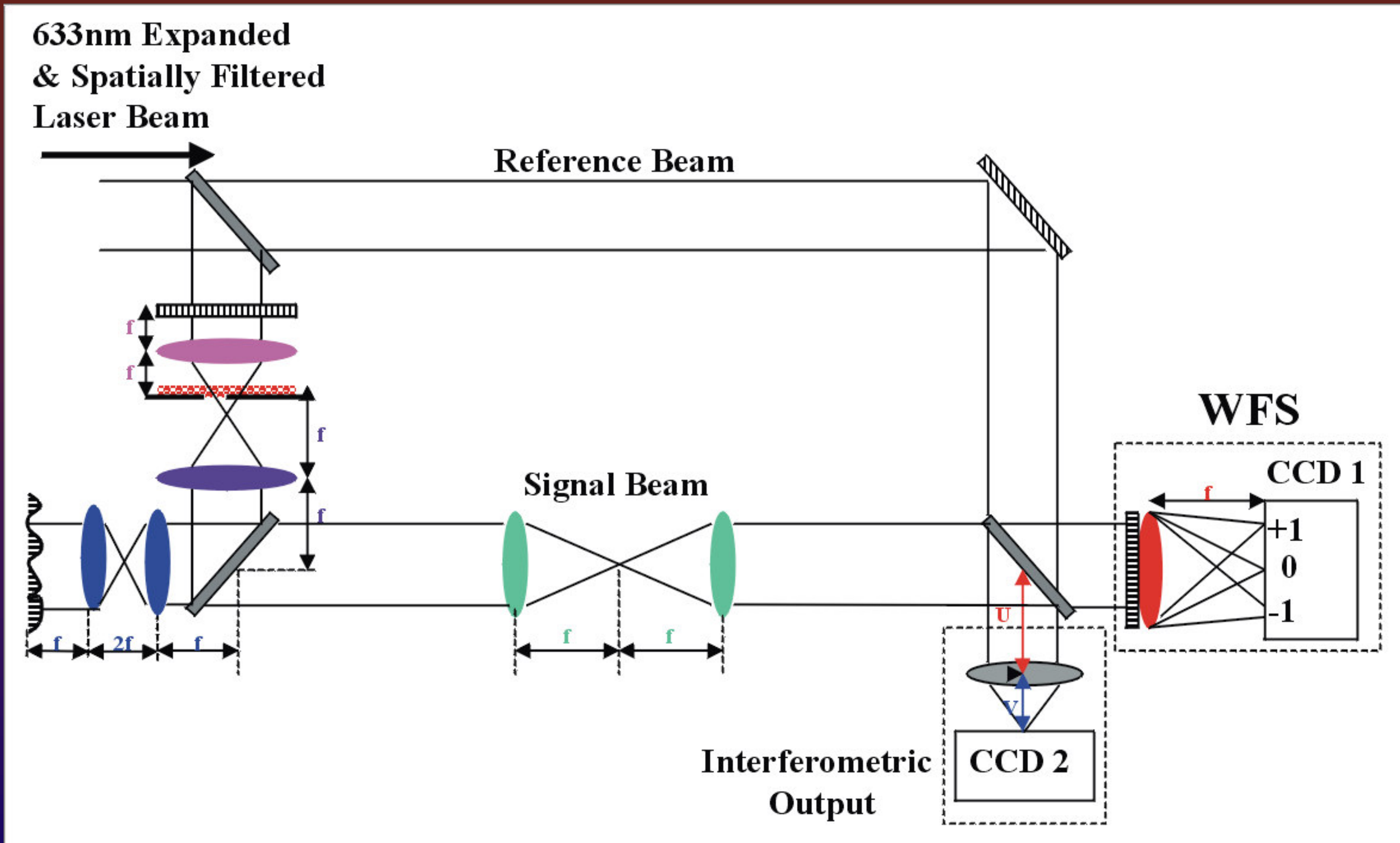


Figure 8: Mach-Zehnder Interferometer, test bed for the GPD WFS and DM's

Conclusions

- There is a need for a more general approach to PD, to overcome the limitations of the defocus-only method.
- It is possible to build a GPD null sensor with any filter function that satisfies the symmetry conditions.
- The width of the filter function FT directly relates to the sensitivity of a wavefront sensor based on this filter function.
- Preliminary experimental results from the defocus DOE and the GN algorithm compare favourably with the theoretical results.

Future Work

Experimental:

- Building of a GPD WFS.
- Incorporation of the new DOE's into the interferometer.
- Design and fabrication of more DOE's.

Theory:

- Further development to look at small angle expansions.
- Study of optimisation of the filter function given *a priori* information about the wavefront aberration.

Software:

- Increased accuracy of reconstruction?
- Conversion to C

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