

# Fourier Transform Reconstruction: advanced techniques and validation

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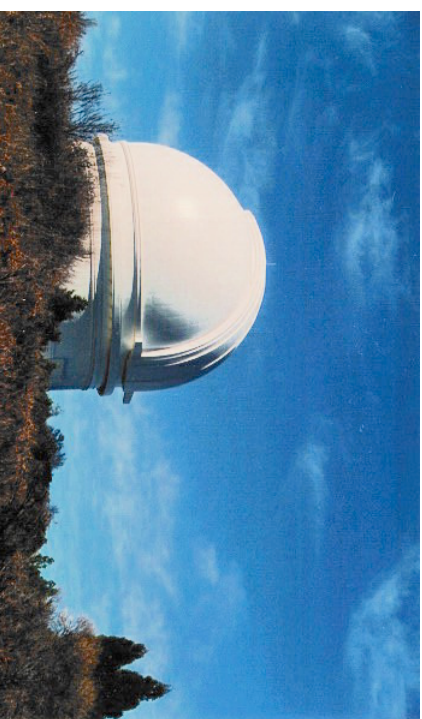
UCRL-PRES-?

Auspices



# FTR has gone from theory to reality in the last year

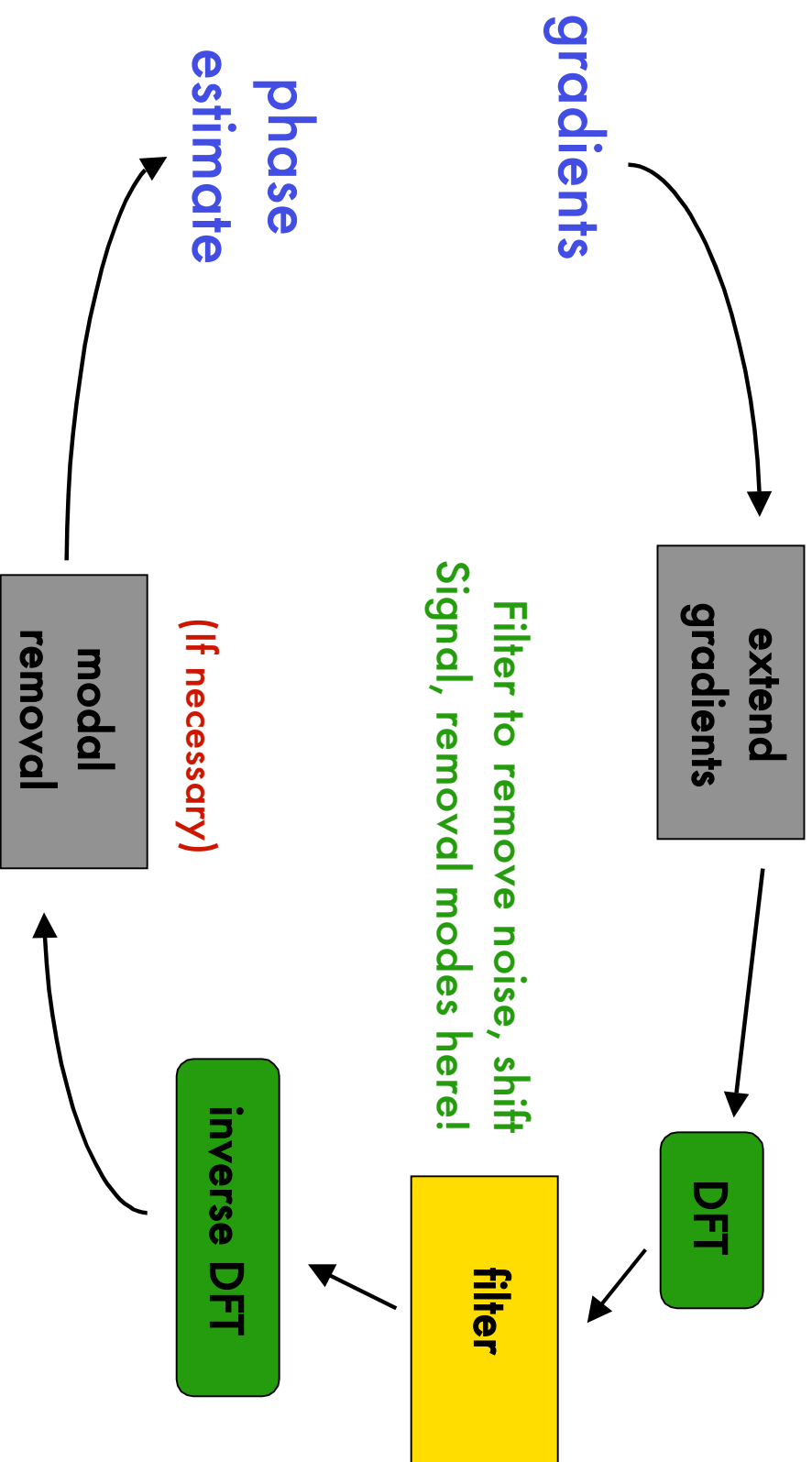
- Methodologies established and performance analyzed
- New filters developed
- Method experimentally validated at Palomar.



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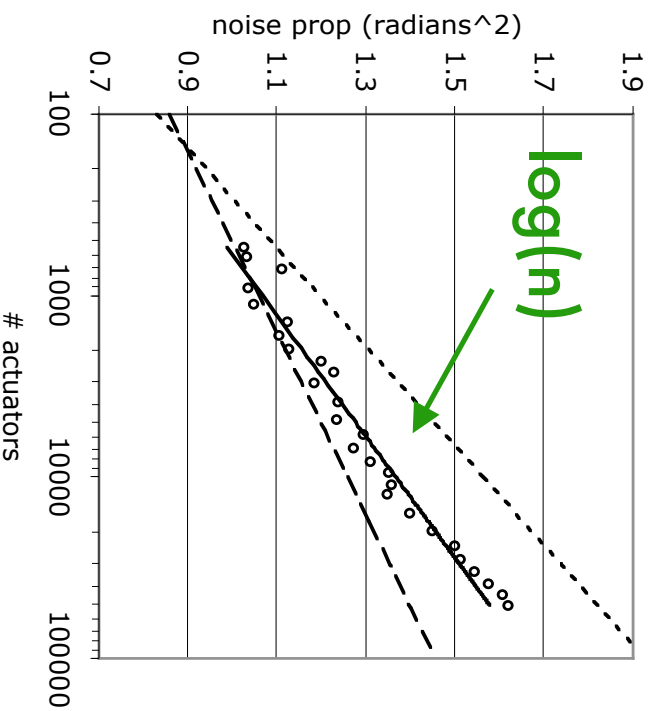
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# FTR filters the gradients quickly by using the FFT

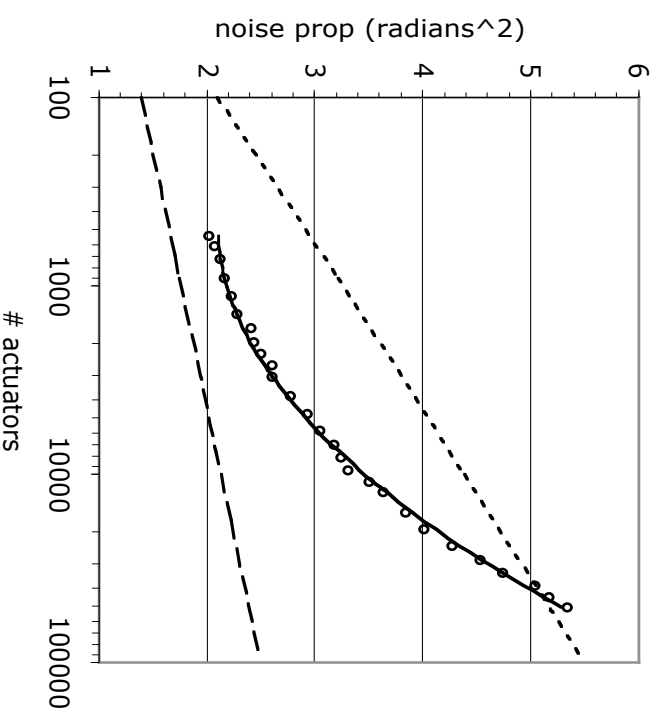


# Noise propagation is favorable for correctly-sized apertures

Noise propagation, Hudgin geometry, DFT



Noise propagation, Fried geometry, DFT



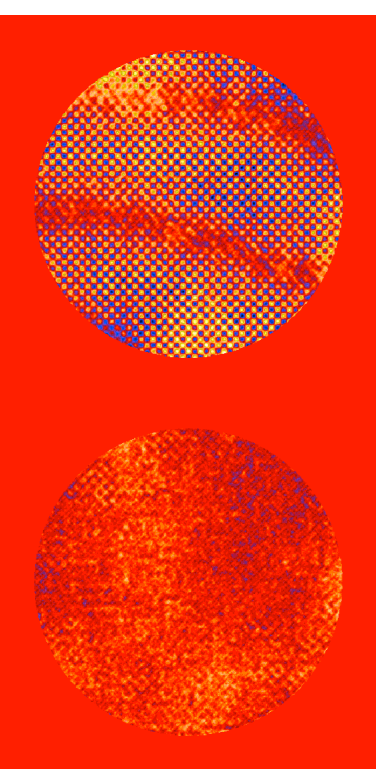
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# Filtering is a powerful tool

- Corrects misalignment
- Shifts gradients to improve Huddgin FTR performance
- Shifts signal (frozen flow hypothesis)
- Removes local waffle
- Reduces noise



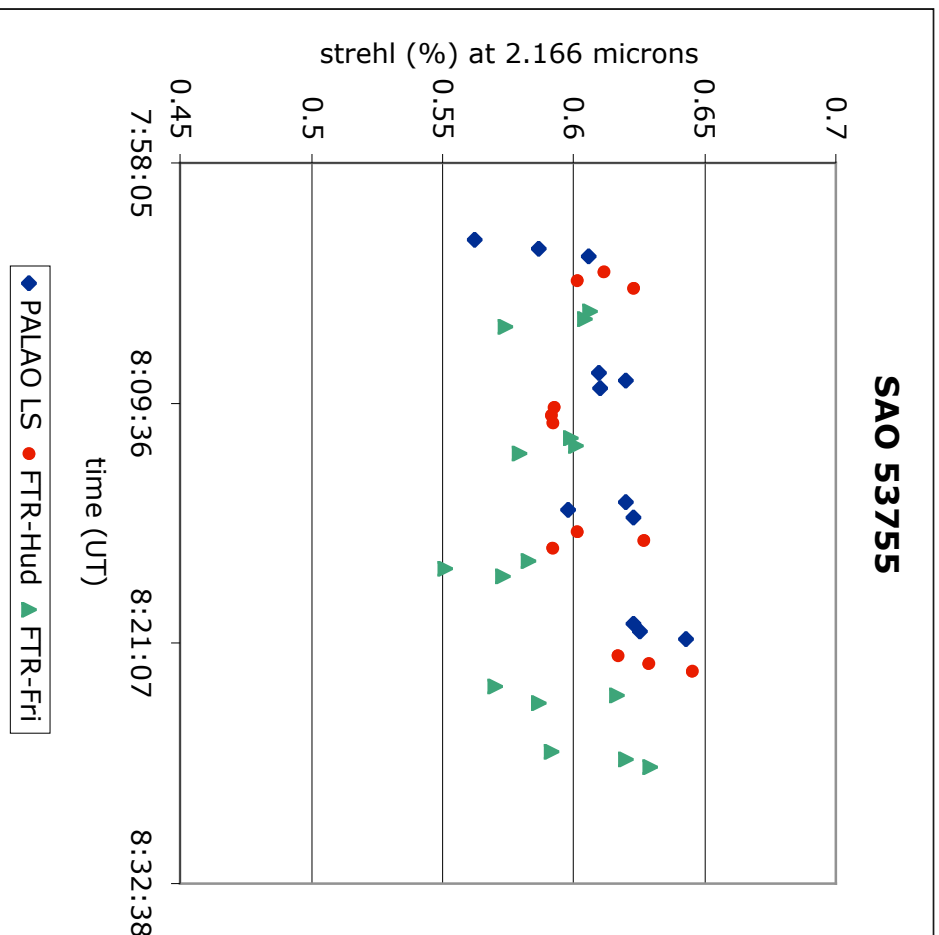
Simulation: Closed loop residual for Fried-geom FTR, with and without local waffle removal



# Experiment at Palomar

- FTR can be represented as a matrix, so many varieties were created.
  - Best Hudgin method was *gradient-shift filtering*.
  - Best Fried method had *local waffle removal*.
  - Both tested rigorously against PALAO least-squares VMM.
- **Goals:**
    - Show that FTR works
    - Discover performance differences amongst the various filtering options and geometries.





- PALAO LS and FTR-Hud had same average Strehl - 0.61
- FTR-Fri had average Strehl of 0.59
- Analysis shows this is a statistically significant difference.



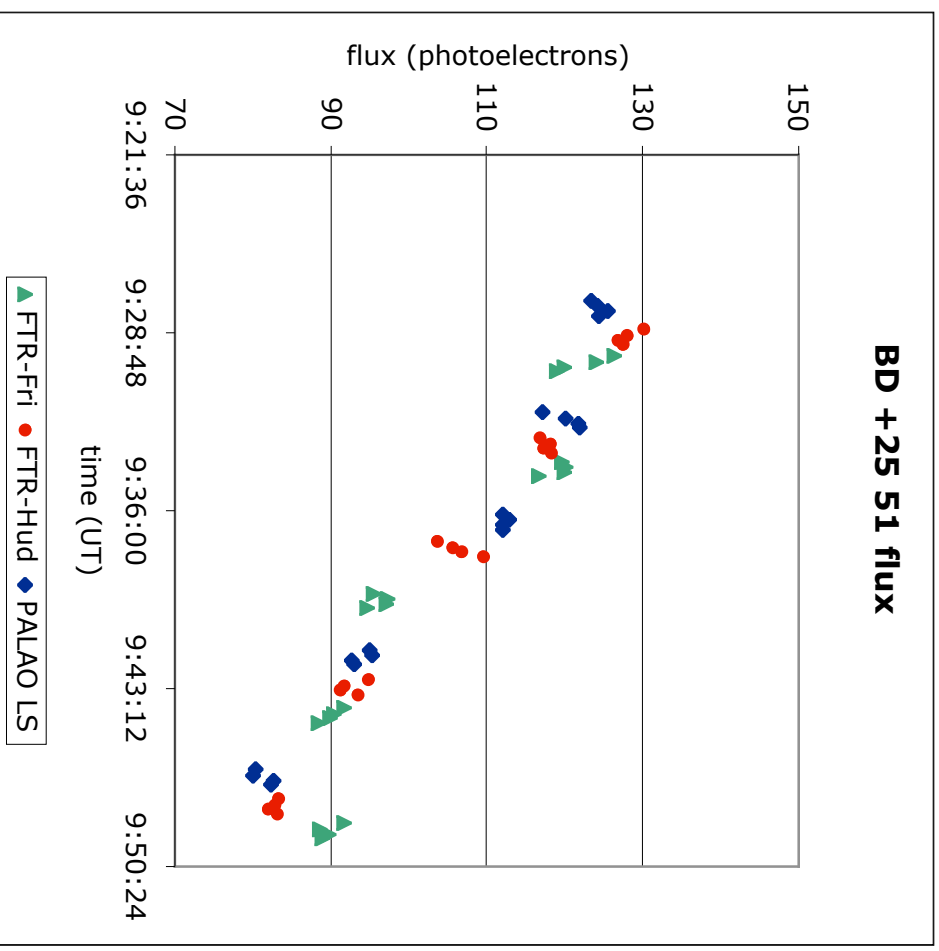
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# Strehl ratio is a function of flux and the reconstructor

- We were very lucky to get this regular drop off in flux - probably high cirrus clouds.
- Strehl formula based on PALAO system:

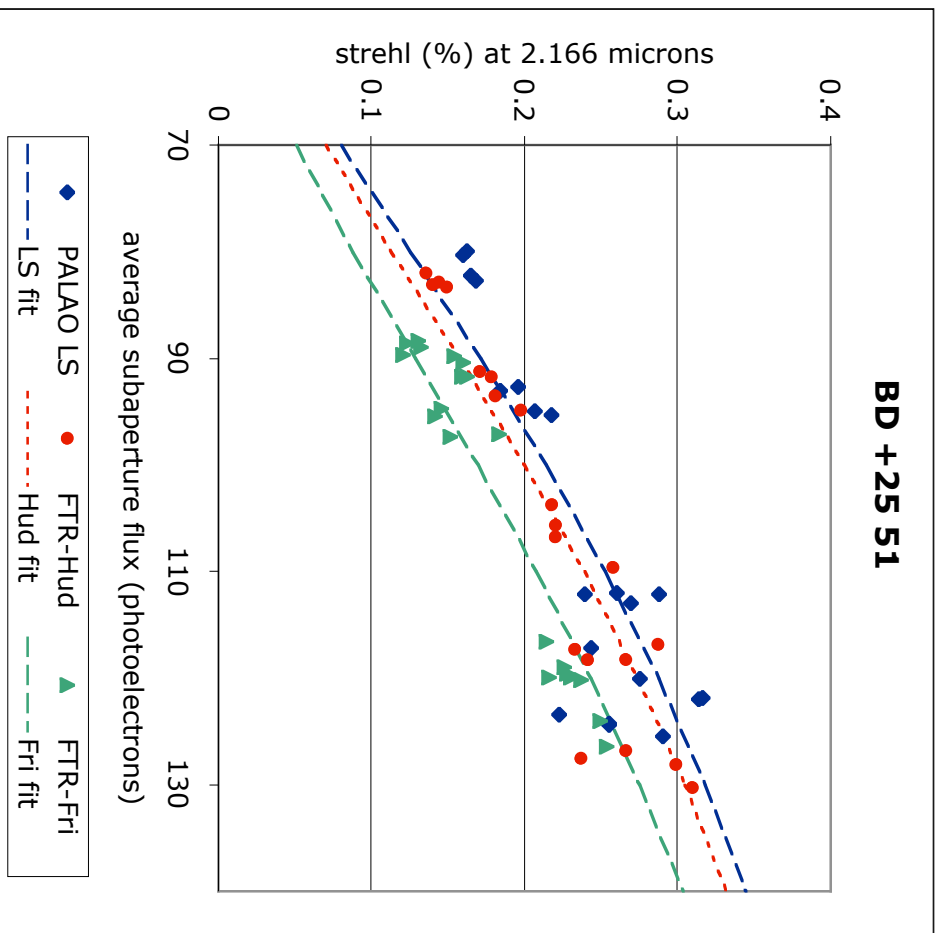
$$S(n_p) = \text{Exp} \left[ -0.5 + k_1 \frac{n_p + 16(5.7^2)}{n_p} \right]$$



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# On dim star, there were clear performance differences



- No significant difference shown between PALAO LS and FTR-Hud.
  - Less confidence of data fit (lower correlations with flux)
- FTR-Fri had worse performance
  - Strehl worse by 4%
  - FTR-Fri data points uniformly worse than nearly all others



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# Local waffle removal filter is used with Fried geometry

- Comparison of DM positions shows that local waffle removal filter works.



FTR-Fri

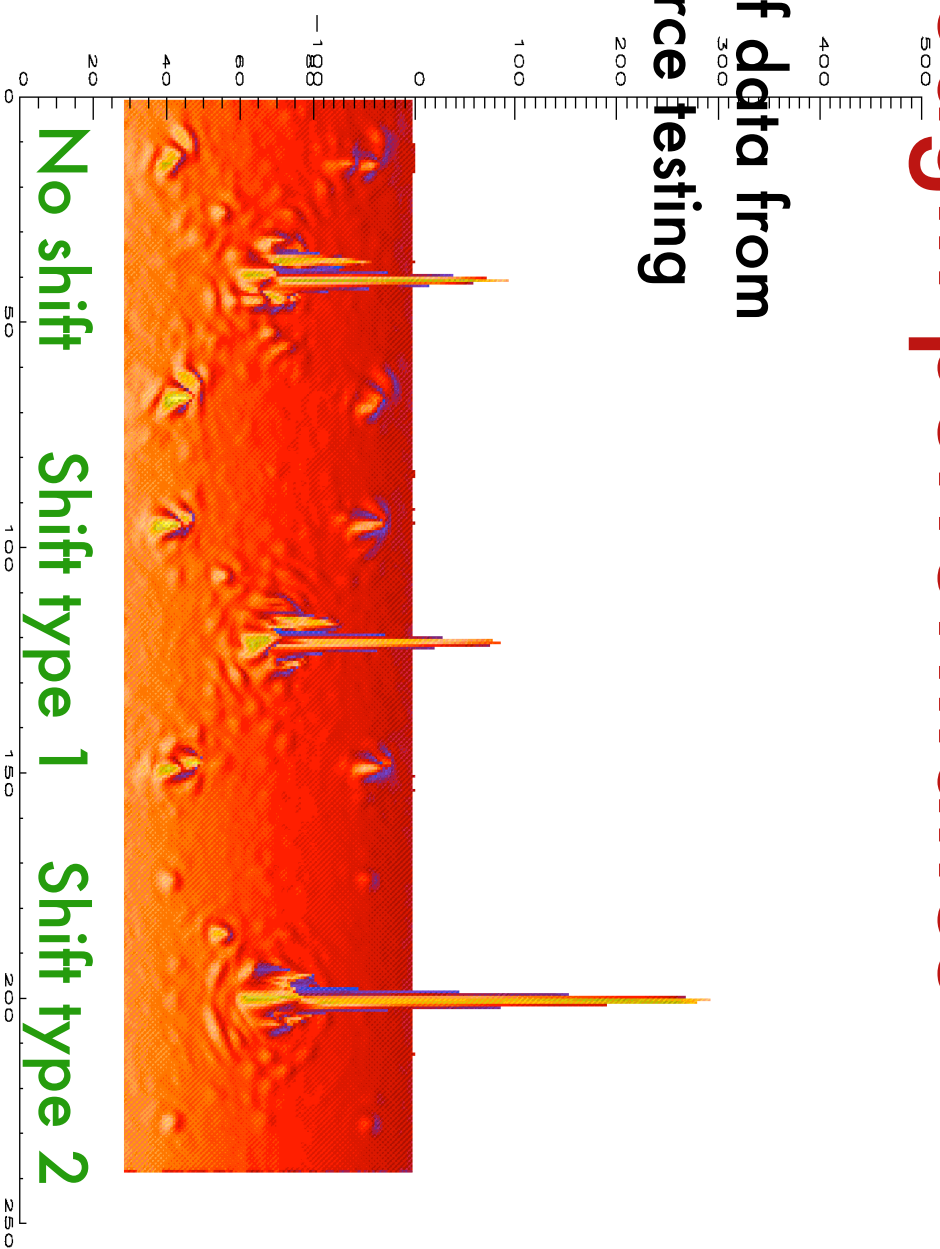


With local waffle removal



# Gradient shifting improves Hudgin performance

Surface plots of data from  
calibration source testing



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# FTR is a fast, flexible and verified method of WF recon

- Experiment has **confirmed** that method works very well and that the **filters** do what we think they should.
- Wide range of filtering options and speed make for an **adaptable controller**.
- The **fastest** option (FTR-Hudgin) is the **best** performing.



# FTR publications

- L. Poyneer, D. Gavel and J. Brase, “Fast wave-front reconstruction in large adaptive optics systems with use of the Fourier transform”, JOSA A 19 2100-11 (2002)
- L. Poyneer “Advanced techniques for Fourier transform wavefront reconstruction” SPIE 4839 (2002)
- L. Poyneer, M. Troy, B. Macintosh and D. Gavel, “First experimental validation of Fourier transform wave-front reconstruction at Palomar” LLNL preprint, submitted to Optics Letters (2002)

