Laboratory Results in High Contrast Imaging with the Shaped Pupil Coronagraph

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Contrast: $2.5 \times 10^{-9}$
Bandwidth: 10\% @ 800nm
IWA: $4 \lambda/D$
Outline/Acknowledgements

1. Shaped Pupil design
   - Original concept and classical designs
     - Vanderbei, Kasdin, Spergel, et. al.
   - Theoretical analysis
     - Ceperley, Lieber, Neureuther, Vanderbei, Belikov, et. al.
   - Final manufacturable designs
     - Belikov, Shaklan, Cady, et. al.

2. Shaped Pupil Manufacturing
   - Balasubramanian, White, Echternach, Dickie, Belikov, Beal, et. al.

3. Testbed design and setup
   - Trauger, Kern, Shi, Kuhnert, Niessner, Belikov, et. al.

4. Wavefront Correction Algorithms
   - Speckle nulling
     - Trauger, Burrows, et. al.
   - Others
     - Give on, Belikov, Borde, Traub, Pueyo, et. al.
   - Designing experiments, analyzing results
     - Belikov, Kasdin, Give on, et. al.

1. Shaped Pupil Design

- Focal plane
- Entrance Pupil
- Apodization $A(x,y)$
- PSF $B(\xi,\zeta)$
- $\text{IFT}^2$
- $\text{IFT}^2$
Image plane stop (Bowtie)

New design based on "Shaklan Dashing"

Ideal, last year (zoom)  Actual, last year (zoom)  This year (zoom)
2. Manufacturing

- Manufactured by JPL's MDL
- DRIE etching of SOI wafer
  - New this year: improved process
- 30mm diameter, active area 50\(\mu\)m thick
- Simulation results
  - Vector interactions with sidewalls: \(10^{-9}\)
  - Nanofabrication Center, JPL
  - Manufacturing error: \(10^{-9}\) contrast
  - Tapered sidewalls: \(10^{-10}\)
  - 3x larger masks: \(10^{-10}\)

Photos courtesy of K. Balasubramanian

3. JPL's High Contrast Imaging Testbed

- State-of-the-art facility
- Vacuum chamber
- Light source
  - 760-840nm (10%)
  - 5 2% filters
- Years of painstaking work to make sure there are no artifacts and things are stable at \(10^{-10}\) level

Image courtesy of J. T. Trauger
4. Wavefront Correction Algorithms

- DM diversity concept
  - Use the DM to throw known EF onto the science camera, thus "probing" the EF in the dark zone
- Algorithms
  - Classical Speckle nulling (Trauger and Burrows)
  - Others (Give’on, Borde, Traub, Belikov)
- Broadband experiment
  - Correct at 2% at 800nm
  - Switch to the other 2% filters and 10%

2% @ 768nm
2% @ 784nm

2% @ 800nm
2% @ 816nm

2% @ 832nm
Contrast: $2.5 \times 10^{-9}$
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Speckle contrast vs. detection limit

- Automatic incoherent light detection
- Other tricks
  - SDI
  - Rotating the telescope
  - Matched filtering

Data courtesy of Amir Give'on

Conclusions and Significance of Results

- 2.5 x 10^{-9} contrast at 4 λ/D in 10% BW
- Shaped pupils require at least a 4m telescope to do TPF, so who cares?
  - Studying high contrast physics
  - Better IWA/throughput are possible
  - Especially with hybrid systems
  - Demonstrate that we can get to TPF-level contrast in time for decadal survey!!

6/15/07