Status of PIAA-related experiments and projects

Abe L.\textsuperscript{1}, Guyon O.\textsuperscript{2}, Tamura M.\textsuperscript{1}, Enya K.\textsuperscript{3}, Tanaka S.\textsuperscript{3}, Matsuo T.\textsuperscript{4}

\textsuperscript{1}National Astronomical Observatory of Japan
\textsuperscript{2}Subaru Telescope, NAOJ, Hawaii
\textsuperscript{3}Institute of Space and Astronautical Sciences, Japan
\textsuperscript{4}Nagoya University, Japan

In the Spirit of Bernard Lyot Conference, June 3\textsuperscript{rd} – 8\textsuperscript{th} 2007
University of California, Berkeley

Email: abe@optik.mtk.nao.ac.jp
Merits of the PIAA

Phase Induced Amplitude Apodization

- Two-mirror apodization
- In theory, nearly 100% throughput
- 100% search area
- Small Inner Working Angle (<2 \( \lambda/D \))
PIAA Coronagraph Concept

Pupil

Apodization intensity profile (linear scale)

$I_{\text{max}} = 9.78$

On axis image

PSF intensity profile (log scale)

Occulter (focal mask)
Small IWA: the Phase Slope Amplification

For off-axis objects, the phase slope is magnified ($\propto \sqrt{I_{\text{max}}}$)

Typical focal plane intensity distribution of the off-axis point-source ($10 \lambda/D$)
PIAA Lab Demonstrator
(JPL and NAOJ funds)

Optics manufactured by AXSYS

32×32 BMC DM
PIAA Lab Demonstrator
(JPL and NAOJ funds)

PIAA Experiment in Subaru Bldg. Clean Room (Hilo)

Acoustic & Thermal isolation panels

(some panels removed in this picture)

⇒ See J. Totems et al. Poster
Hybrid PIAA/conventional apodization is best

- PIAA optics manufacturing tolerances are relaxed
- Binary apodizer (ring mask)
  See S. Tanaka et al. – poster
- Good achromaticity

PIAA Lab Demonstrator
(JPL and NAOJ funds)

PIAA output pupil image on the 32 x 32 BMC DM
PIAA Lab Demonstrator

- Pointing is critical
  ➔ Continuous pointing corrections

- Annular reflective occulting mask

  ![Focal Plane Occulter (FPO)](image1)

  - Transmissive
  - Reflective
  - Absorptive

![Measured noisy images](image2)

- Estimated best fit images

![Graph](image3)

- Measured

  - Science focal plane
  - LOWFS: inside focus
  - LOWFS: outside focus

- Estimated

  - Science focal plane
  - LOWFS: inside focus
  - LOWFS: outside focus

- RMS WF error in input WF:
  - $1.70 \times 3 \text{ rad} = 0.15 \text{ nm @ 550nm}$

- RMS WF error between input and estimate:
  - $6.45 \times 4 \text{ rad} = 0.056 \text{ nm @ 550nm}$
PIAA Lab Demonstrator
(JPL and NAOJ funds)

DM correction using Phase diversity

Speckle control

Achieved dyn.: 6.10e-7
Future Tests & 2nd Generation PIAA
NASA Ames / TOPS partnership / JPL

- We are acquiring a 2nd generation PIAA improved optical quality & better design (lessons learned with 1st generation PIAA)

- Moving to tests in Vacuum – putting PIAA into HCIT

- Testing PIAA fed by large mirror (~1m) in vacuum for end-to-end tests at 1e10 contrast

⇒ see O. Guyon talk on TOPS (Friday)
HiCIAO is a differential imager combined to a coronagraph

See M. Tamura (Thu. afternoon)

Upgrade plans (MEXT funded):
- Coronagraph: PIAA w/ lenses
- Adaptive Optics: 32×32 MEMS DM + FP WFC
Subaru/HiCIAO Upgrade Plans (II)

- Spider Removal Plate
Subaru/HiCIAO Upgrade Plans (III)

- PIAA Lenses ➔ APLC configuration (i.e. Mask + Lyot Stop) ➔ Small mask (radius 1 λ/D)

- Speckle control ➔ ASICS controller flexibility

▼ PIAA Lenses (Calcium Fluoride)
SPICA Coronagraph (I)

SPace Infrared telescope for Cosmology and Astrophysics

SPICA Mission

- 3.5m on-axis / 4.5K active cooling
- mIR to submm astrophysics (5-200 µm)
  ➔ Complementary to JWST @ >15mic

➔ Coronagraphic mode
- Direct observation of outer self-luminous planets
  (20~100+ UA orbits)
- **Goal contrast** \( >10^{-6} \) within the exploration area
- Benefit from monolithic pupil

➔ Baseline candidate: Checkerboard Pupil Mask
  *(See K. Enya et al. – Thu. afternoon)*

➔ Advanced option: PIAA
SPICA Coronagraph (II)

Preliminary work

- Central obstruction constraint (20~25%)
  - Sensitivity to tip-tilt (phase discontinuity)
  - increased IWA
  - ...Solution for an APLC? (insensitive to central obstruction)

- PIAA Hybridisation
  - Best combination for PIAA optics/apodizer
  - Achromatization issues

λ: 5-7µm / Fresnel propagation simulations
More information:
Subaru testbed & Subaru Extreme-AO project:
http://www.naoj.org/staff/guyon/PIAA/index.html
http://www.naoj.org/staff/guyon/ExtremeAO/index.html

PIAA-related papers, by our team and others:
http://www.naoj.org/staff/guyon/PIAA/Papers.html

Wanted:
Post-doctoral fellow (available funds for at least 2 years)
Subaru Telescope, Hilo, Hawaii

Contact: guyon@subaru.naoj.org