SIM astrometric demonstration at the 150 picometer level using the MAM testbed.

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Outline
- MAM Simplified Layout
- Chopping Scenario
- Data Analysis Tools
- Status (Pre-Independent)
- 3 Star test (Pre-Independent)
- Lessons learned
- Conclusions

SIM Simplified Layout

SIM Simplified Layout: IPS Slew

The MAM experiment in the vacuum chamber

Chopping Scenario

- Instead of staring at the Target star for 300 seconds.
- Integration
- Slew and settle
- 300 seconds
- We stare 30 seconds at a time and chop back and forth backwards between the Target and Reference stars 10 times.
The interference intensity model we used in our algorithms:

\[ I_{\text{obs}} = I_{0} \{ 1 + V_{\text{bias}}(k, x, C_{j}) \} \]

- \( k \) is the index for dither positions (bins) within the frame.
- \( j \) is the index for spectral pixels, for white light (i.e., \( j \rightarrow 0 \)), which is the spectral pixel index on a CCD.
- \( I_{\text{obs}} \) is the CCD intensity measured at each spectral channel \( j \) for each dither position \( k \).
- \( x_{i} \) is the dither position for each bin measured by the metrology.
- \( V_{\text{bias}} \) and \( C_{j} \) are fixed intensity, visibility and wave number, respectively, all assumed to be constant over a given dither cycle, i.e., over all dither positions \( x \) at given wavelength.
- \( C_{j} \) is the value of interest: the fitted phase (or delay) + wave number between the interference fringes from the spectral channel \( j \) and the dither cycle wave. It is assumed to be constant over a given dither cycle.
RT Allan deviation of the optical path difference between white light and SAVV

- RT Allan deviation \( \sigma_{RT}(\tau) \) is defined by:
  \[ \sigma_{RT}(\tau) = \frac{1}{2} \left( \Delta \phi_{RT}(\tau) \right) \]

- \( \Delta \phi_{RT}(\tau) = \left( \phi_{mean}(\tau) - \phi_{mean}(\tau + \Delta \tau) \right) \)

- \( \phi_{mean}(\tau) \) is the mean value of \( \Delta \phi_{RT} \)

- \( \phi_{mean}(\tau + \Delta \tau) \) is the mean value of \( \Delta \phi_{RT} \)

- No overlapping between the averaged chips.

Pathlength error between starlight and metrology averaged down to 30 second single numbers (chop observation time).

Error between white light and metrology paths as a function of the number of 30 second chops averaged together for the field independent test.
Three-star field dependent test sequence

\[ T \, S \, R_1 \, S \, T \, S \, R_2 \, S \, T \, S \, R_1 \, S \, T \ldots \]

- **SIM**

Delay line position as measured by the metrology during the 3-star field dependent test.

- The valid part of the data after each slew is highlighted in red.
- One can see the two reference stars on each side of the target star.

**SIM**

White light versus metrology OPD for the three-star field dependent test after removal of the slew.

- The first star of the sequence is the target star.
- The two reference stars are located on each side of the target star.

**SIM**

Chopping Equations

- Single "TRT" chop:
  \[ D_{11} = \langle \mathbf{R}_1, \mathbf{T} \rangle \cdot \langle \mathbf{R}_1, \mathbf{T} \rangle = \mathbf{R}_1 \cdot \mathbf{T} \cdot \mathbf{T} \]
  \[ D_{12} = \langle \mathbf{R}_2, \mathbf{T} \rangle \cdot \langle \mathbf{R}_2, \mathbf{T} \rangle = \mathbf{R}_2 \cdot \mathbf{T} \cdot \mathbf{T} \]
- Multiple star chop:
  \[ \varepsilon = \langle \mathbf{D}_{11}, \mathbf{D}_{12} \rangle \]
  \[ \varepsilon = \langle \mathbf{R}_1 \cdot \langle \mathbf{T}, \mathbf{T} \rangle, \mathbf{R}_2 \cdot \langle \mathbf{T}, \mathbf{T} \rangle \rangle \]
  \[ \varepsilon = \langle \mathbf{R}_1, \mathbf{R}_2 \rangle - \langle \mathbf{T}, \mathbf{T}, \mathbf{T}, \mathbf{T} \rangle \]

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Relative position of the three stars in term of error between starlight and metrology for the field dependent test.

- One can see the 1.5 cm field dependent error between the target and each reference star.
Error between white light and metrology paths as a function of the number of chops averaged together for the field dependent test.

Future Tests

- Repeat NA for other star spacing.
- Repeat NA for the other axis.
- Increase the view speed of the pseudo-star for WA.
- Build new SPRs with no backups.
- Demonstrate WA basic performance (50 μas).
- Demonstrate full independent performance at the goal.
- Demonstrate WA calibrators (10 μas).
- Drive NA performance to the goal (15 μas).
- Drive WA performance to the goal (4 μas).