Nanometer motion control for space optical instruments

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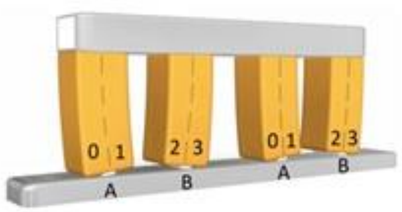
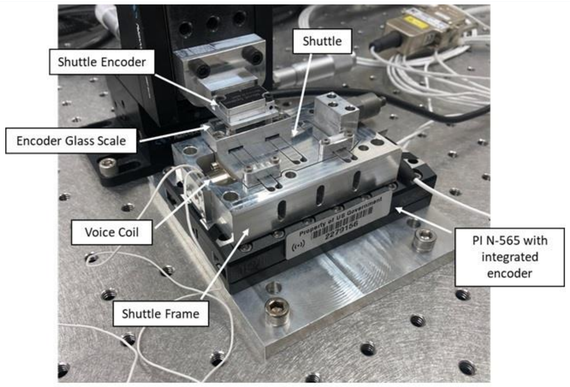
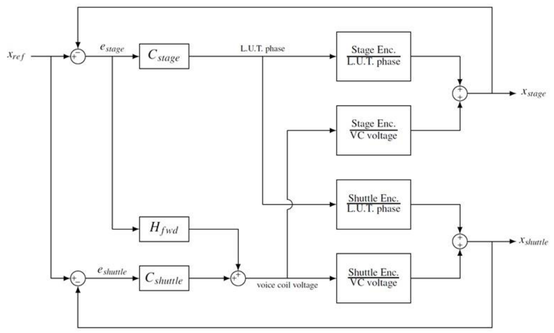
Program: FY21 SURP **Strategic Focus Area: Coherent Detectors and Arrays, Remote Sensing Instruments**

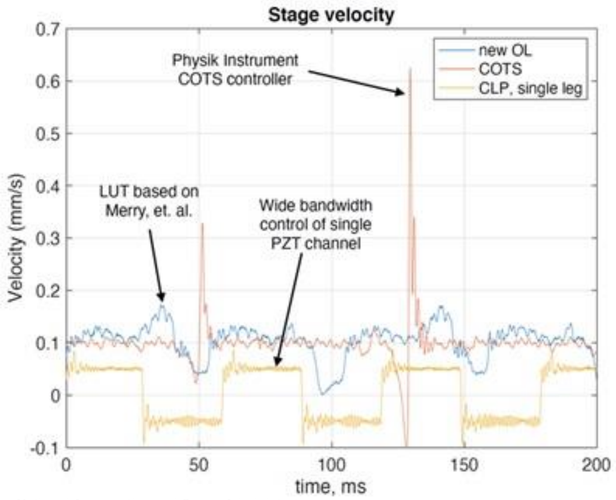


PI N-565 is a new type of linear actuator. It coordinates the individual piezao actuators to move a runner with alternating clamping and shearing motions. At the highest level, this arrangement enables centimeter level travel range with nanometer precision. However, the two pairs of coordinated piezo actuators are 180 degrees phased apart. When the two pair of coordinated piezo actuators are "handing over" to each other, there is a very short period of time when the runner has very low clamping force and axial stiffness. In that short period, the runner experiences significant acceleration/deacceleration. This exceeds the minimum tolerable velocity ripple required for an IFTS.



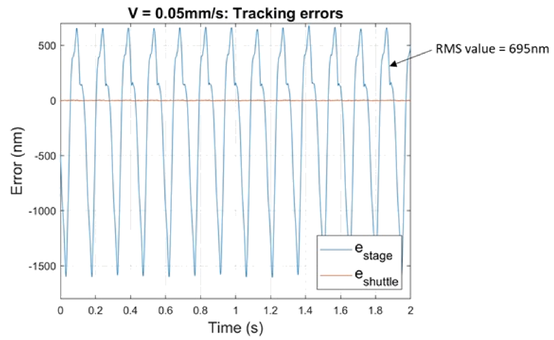


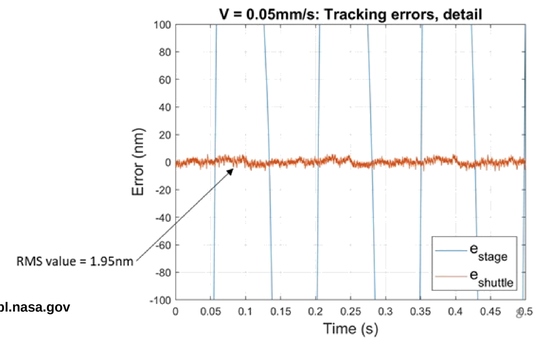
1-DOF Shuttle:
- Shuttle designed to have 1-DOF in the direction of PI stage
- The shuttle is connected to the frame via thin flexures
- Shuttle flexures have low spring rates, so only a small voice coil is necessary to reject the disturbances transmitted to the shuttle from the PI stage
- Shuttle has a low resonant frequency (45Hz) relative to the PI stage (840Hz) that provides passive filtering of PI stage motion
- Separate encoder instrumented on the shuttle so the global position of the shuttle (where payload is located) is measured



Limitation: Due to the discrete nature of walking mechanics, the stage is not adequate for constant velocity applications.

Modification of the PZT voltage waveforms results in only minor improvement of position tracking since large velocity excursions from mean value occur when the legs engage/disengage the runner





Closed-Loop Shuttle Position Control:
- 2 feedback control loops around the stage and shuttle positions are used to track a position reference
- Low bandwidth stage controller ensures asymptotic tracking of the velocity
- Wide bandwidth shuttle controller corrects for stage disturbances
- Feedforward filter further improves tracking error by canceling stage position disturbances (which can be measured in real time) applied to the shuttle.

Results: 0.05mm/s Tracking
- Closed-loop results of the stage and shuttle position errors are provided for a reference speed of 0.05 mm/s
- The inclusion of the shuttle improves position tracking capabilities by a factor of >300x, from 695 nm RMS to 1.95 nm

RMS position residual error over the tested millimeter travel range.

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