Robotic Fiber Positioners for the Dark Energy Spectroscopic Instrument (DESI)

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Massively multiplexed spectroscopy with MSE,
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DESI (Dark Energy Spectroscopic Instrument)

DESI will conduct a large redshift survey and compile a 3D map of the universe reaching to redshift 3.5 over more than a third of the sky.

- Fiber-fed multi-object spectrograph using Baryon Acoustic Oscillation (BAO) technique to measure the expansion history of the Universe to unprecedented precision.
- Spectra of 35 million galaxies and quasars over 14,000 deg² in five years
- 5000 robotically positioned optical fibers
- 8 sq. deg. FOV
- Ten 3-channel spectrographs (360 - 980 nm)
DESI Science Goals

Precision measurement of dark energy, while making important contributions to the physics of inflation and neutrinos

- Determine as well as possible whether the accelerating expansion is consistent with a cosmological constant.
- Measure as well as possible any time evolution of the dark energy.
- Search for a possible failure of general relativity through comparison of the effect of dark energy on cosmic expansion with the effect of dark energy on the growth of cosmological structures like galaxies or galaxy clusters.

Techniques:
- BAO gives us a ruler in the sky and enables us to measure the expansion of the Universe.
- RSD allows us to measure the pull of gravity and check General Relativity.
DESI is being installed at the Mayall 4-m Telescope at KPNO.

Focalplane consists of 10 petals (500 robots each)
From this …
To here …
19 Jan 2018: First petal was fully loaded...

DESI PETAL, WITH ALL 502 FIBER POSITIONERS AND 10 FIELD FIDUCIALS

FIBER TIPS
PETAL
Positioner ELECTRONICS
CONDUITS TO SPLICE BOX
27 Nov 2018: 8 of 10 production petals are loaded
Positioner Electronics

- Positioner powered and controlled through an attached driver board.
- Motors driven by PWM (motor current 0% - 100%)
- Open-loop control
- Each positioner uniquely addressed by ID on CAN bus
- 10 CAN buses per petal (maximum of 84 nodes/CAN channel)
- Petal controlled by small single-board computer (Beaglebone Black)
DESI Fiber Positioner

- Ferrule holder (on eccentric arm)
- Eccentric axis (Φ) bearing
- Retaining threads
- Θ motor
- Central axis
- Θ bearing
- Control electronics
- 107 μm fiber

Michael Schubnell
DESI Positioners - MSE Meeting
Slide 9
Fiber positioner mass production at Univ. Michigan

- 7,148 built at UM
- 91% integrated production yield at UM (starting from the raw part kits)
Positioner Key Requirements

<table>
<thead>
<tr>
<th>Item</th>
<th>Requirement</th>
<th>Value Achieved</th>
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<tbody>
<tr>
<td>Gross moves (blind) max error</td>
<td>≤ 100 μm</td>
<td>15-55 μm typically (mean 33 μm)</td>
</tr>
<tr>
<td>After correction RMS error</td>
<td>≤ 5 μm</td>
<td>1-2 μm typically (mean 1.6 μm)</td>
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<tr>
<td>Lifetime moves</td>
<td>≥ 100,000</td>
<td>tested &gt; 1,600,000 moves</td>
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<tr>
<td>Peak power</td>
<td>≤ 3W</td>
<td>3.23 W at 7.5 V (while moving) *</td>
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<tr>
<td>Total reconfiguration time</td>
<td>≤ 45 sec</td>
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* With the two motors idle: 24 mA (180 mW at 7.5 V)
  With both motors operating simultaneously at 100% motor current: 431 mA (3.23 W)
  Sleep mode: < 0.1 mA
Positioner performance is excellent

Number of Moves to Reach Target

Only 0.1% of positionings require more than 2 correction moves
78 production positioners were tested between 200,000 and 1.6 million moves (more than 16 time the lifetime move requirement).

91% never failed during the tests.

To assess and project the lifetime expectancy of positioners in the petal, a Weibull lifetime analysis was performed.

Results indicate that 98% of positioners will continue to perform after the DESI five-year survey is completed.
Fiber View Camera looking at back-illuminated petal
Summary

- > 7000 DESI positioners have been built and QA tested at Michigan
  - Average built & test rate 30-35 positioners/day

- > 95% of positioners perform excellent (after assembly yield)

- Accuracy is excellent: < 5 microns (typically 2 moves)

- Lifetime test (and cold tests) show that DESI positioners are robust, reliable and are expected to perform well over the 5 year project.