TPF Cryogenic Delay Line
FY 03 Development
10/15/03

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PZT stage Measured Transmissibility: Warm vs. Cold

PZT Stage Transfer Function: Warm Vs. Cold

- Magnitude, dB
- Frequency, Hz

- Phase, Degrees
- Frequency, Hz
PZT stage Modeled Transfer Function: Cold & Warm

Modeled Cold Transfer function:

\[ H_{cold}(z) = \frac{0.01548 z^5 + 0.006353 z^4 + 0.0004211 z^3 + 0.003859 z^2 + 0.007086 z + 0.01277}{z^6 - 3.176 z^5 + 5.211 z^4 - 5.172 z^3 + 3.105 z^2 - 0.9679 z} \]

Sampling time interval = 0.0002 seconds

Modeled Warm Transfer function:

\[ H_{warm}(z) = \frac{0.03498 z^5 + 0.01582 z^4 + 0.00337 z^3 + 0.0109 z^2 + 0.01724 z + 0.02886}{z^6 - 3.087 z^5 + 4.979 z^4 - 4.87 z^3 + 2.893 z^2 - 0.915 z} \]

Sampling time interval = 0.0002 seconds
Kalman Signal Generation Model for Cold Motor Error in Open Loop:
difference equation
(use Gaussian sequence, $\sigma = 1$, as input to this linear model)

\[
0.0001874z^{15} - 0.002013z^{14} + 0.009784z^{13} - 0.02822z^{12} + 0.05299z^{11} - 0.06552z^{10} + 0.04759z^9 - 0.003393z^8 - 0.04071z^7 + 0.0608z^6
\]
\[\]
\[\]
\[
- 0.05388z^5 + 0.03362z^4 - 0.01506z^3 + 0.004641z^2 - 0.0008814z + 7.764e-005
\]
\[H(z) = \frac{z^{15} - 13.57z^{14} + 86.51z^{13} - 344.5z^{12} + 960.3z^{11} - 1990z^{10} + 3173z^9 - 3972z^8 + 3938z^7 - 3093z^6 + 1908z^5 - 906.2z^4 + 320.1z^3}{z^{15} - 79.23z^2 + 12.26z - 0.8916}\]

Sampling time: 0.0002 seconds

So, a realization of the estimate of the open loop OPD would be
($n$ is the discrete time variable):
Opd($n$) $\sim$ (0.1mm/sec)\*n + $J(n)$, where $J(n)$ is the output of the
Kalman signal generation filter specified above. Positive ramp only.
OPD Estimate Realization using specified signal generation model
Units = μm

Time & PSD Trace(s)

PSD

set 1: 2.745 Units-rms

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OPD Measured Realization with Cold Model
Units = μm
Cryogenic Delay Line’s Control Flow-Diagram

Target Position

\[ C(z) = \frac{3.559 z^3 - 5.702 z^2 + 5.768 z - 2.985}{z^3 - 1.281 z^2 + 0.4666 z - 0.1856} , \ dt = 0.0002 \text{ seconds} \]

De-saturation Stage

\[ X(t) dt \]

Motor Stage

\[ \int X(t) dt \]

Gauge Reading

PZT Stage

\[ \int X(t) dt \]

Motor Amplifier

Motor Stack

OPD

PZT Amplifier

\[ \int X(t) dt \]

Integrator

Loop Shape Filter

\[ J(n) \]

Target Position = 0

\[ \int X(t) dt \]

Integrator

\[ K_{pzt} \]

\[ K_{motor} \]
Background Noise
Background Noise

Cold Environment - Background Noise: Forward and Backward Integration of the PSD

OPD, mm vs Frequency, Hz
Cold Static – Best Result

![Cold Static - Best result](image)

- **OPD, nm**
  - Time, Seconds

![PSD](image)

- **dB, nm²/Hz**
  - Frequency, Hz

**set 1: 11.4138 nm-rms**
Cold Static – Best Result
Cold Vs. Warm @ 0.1 mm/sec
Cold Vs. Warm @ 0.1 mm/sec
Best Warm Performance using high torque motor @ 0.1mm/sec
Best Warm Performance using high torque motor @ 0.1mm/sec
Photo of the cryo delay line.
Proposed delay line concept.