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Control Design for the SERC Experimental Testbeds

Steering Committee Presentation

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Approaches

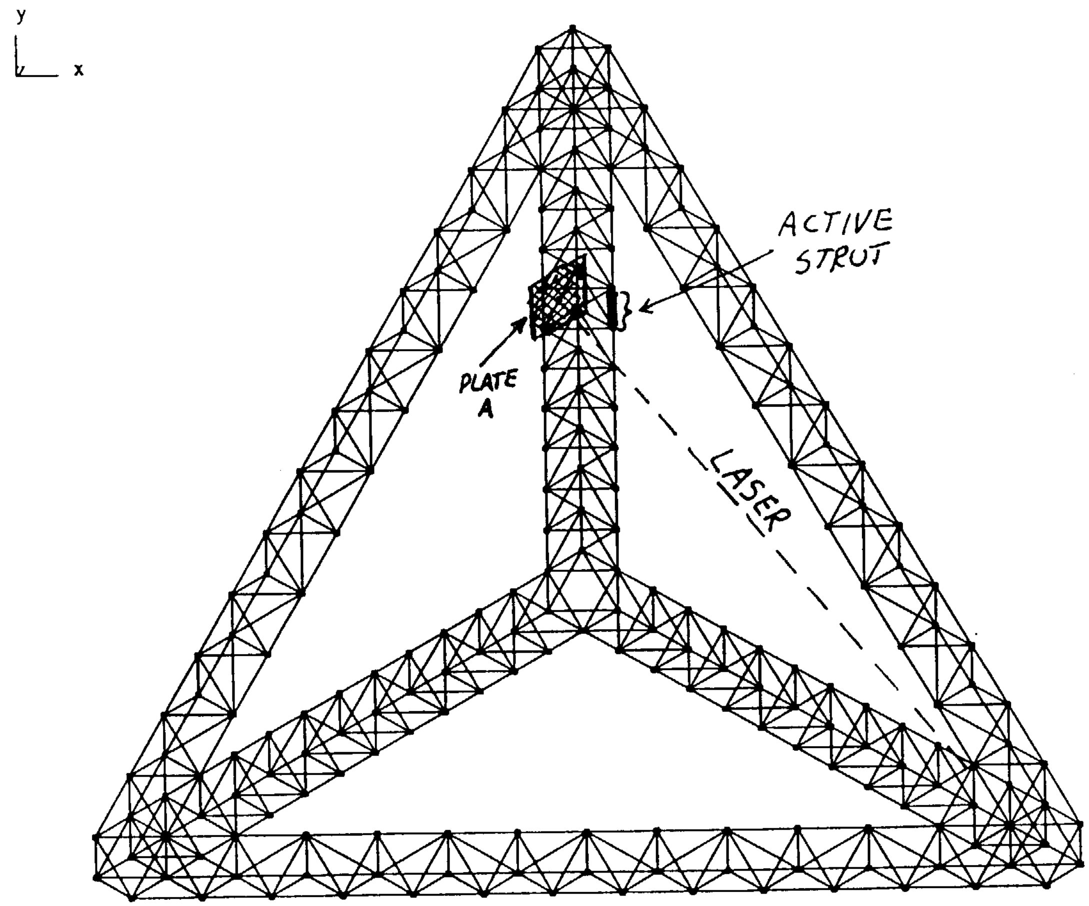
- Global control loops from lasers to active struts
- Local control loop wrapped around active struts
- Isolation at the performance outputs
- Phase 0 testbed

SISO Control Design and Results

- Hardware:
  - Actuator: active strut
  - Sensor: Laser Leg
- Assumptions
  - Disturbance source and actuator collocated
  - Performance metric and sensor collocated
- Control design method
  1. Measure transfer function from actuator to sensor
  2. Use nonlinear curve fitting technique to obtain state space model of system
  3. Reduce model order
  4. Design LQG controller
  5. Remove dynamics from controller which do not contribute to stability and affect the performance only slightly

Sensor and Actuator Locations

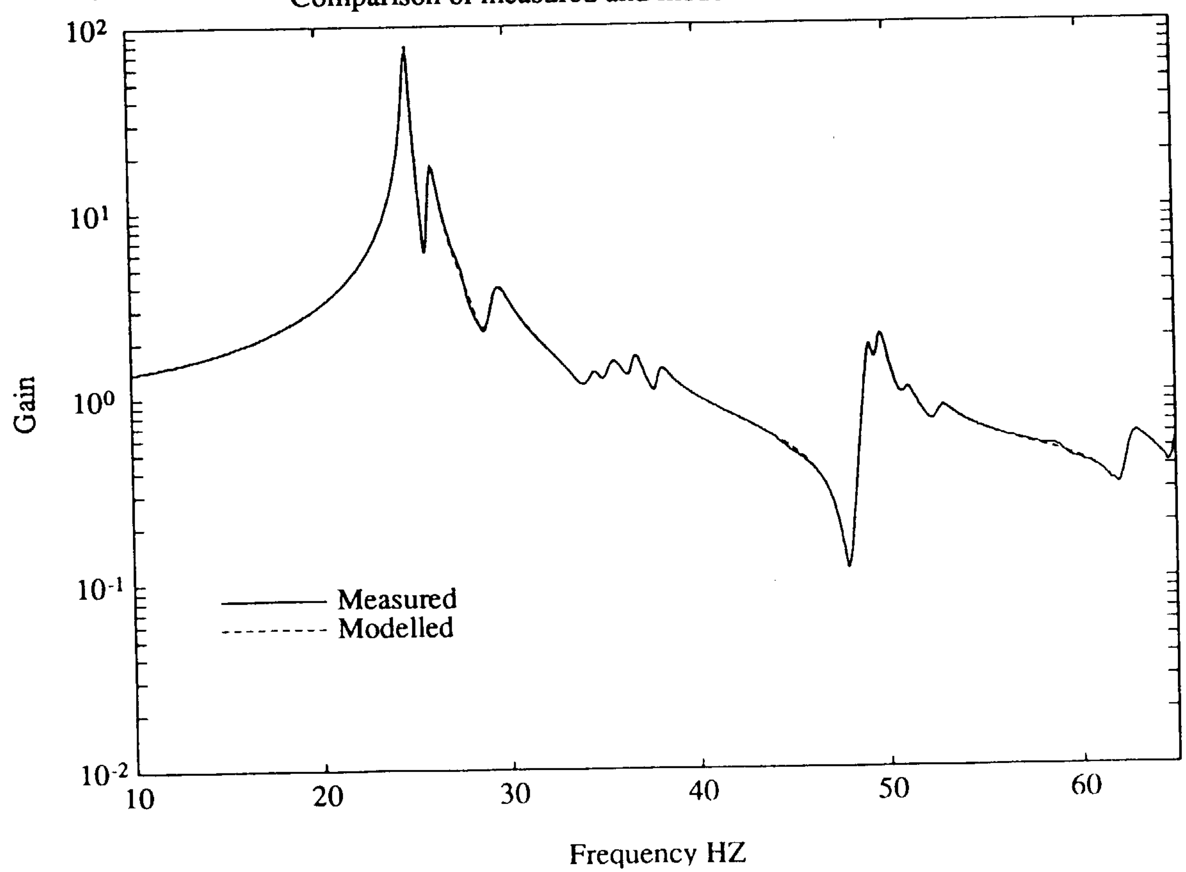
- Sensor: Laser from fourth vertex to plate A
- Actuator: Active strut placed to maximize modal residues in transfer function from strut to laser



Model Identification

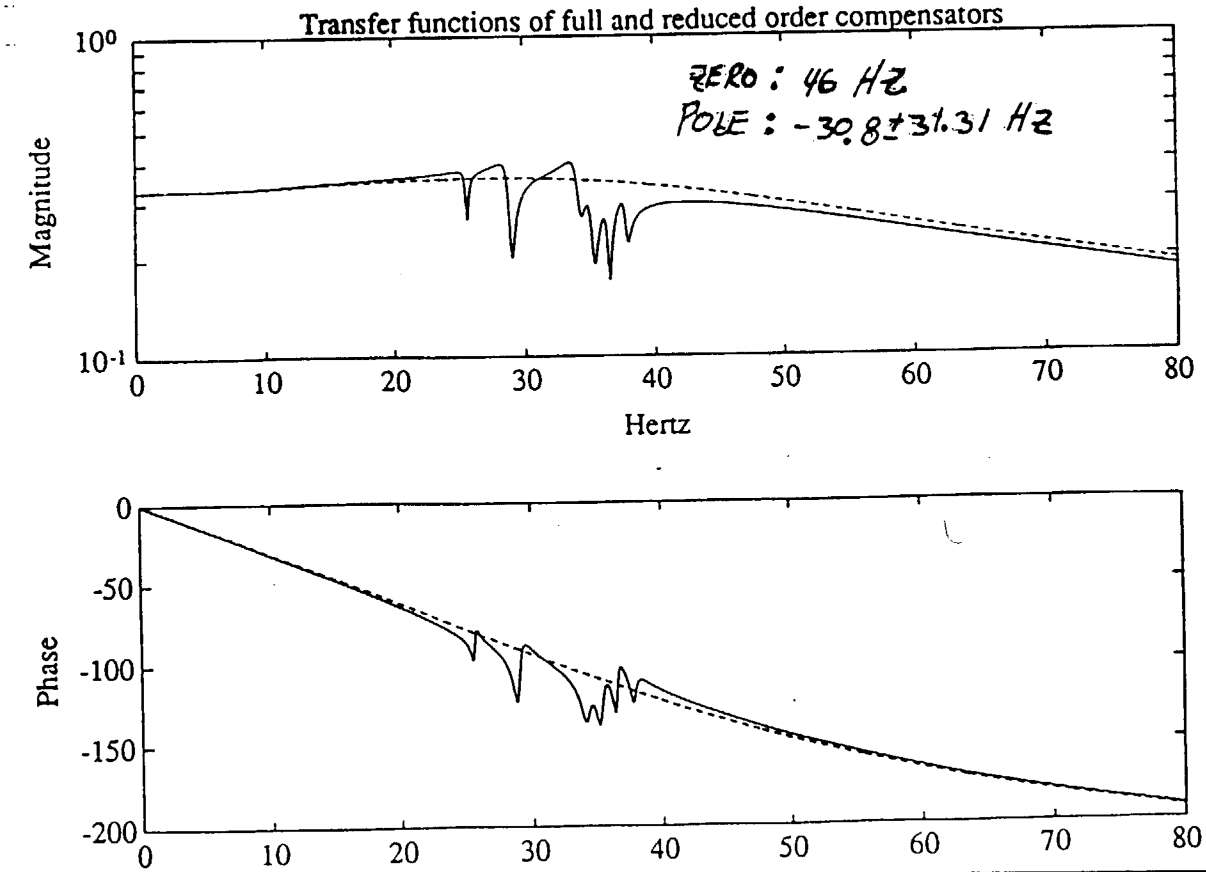
- Averaged empirical transfer function estimate from actuator to sensor obtained using Tektronix box.
- Nonlinear algorithm used to fit poles and zeros to transfer function.

Comparison of measured and modelled transfer functions



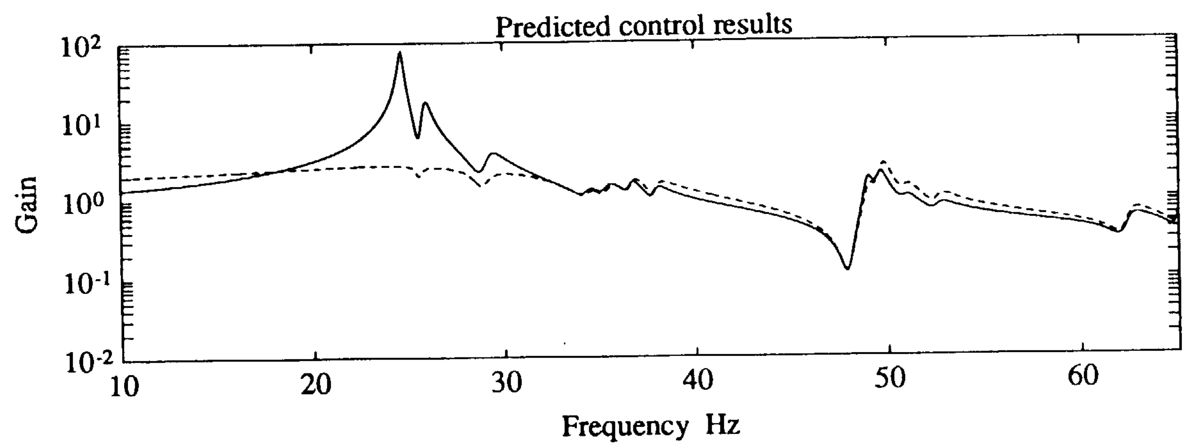
Control Design

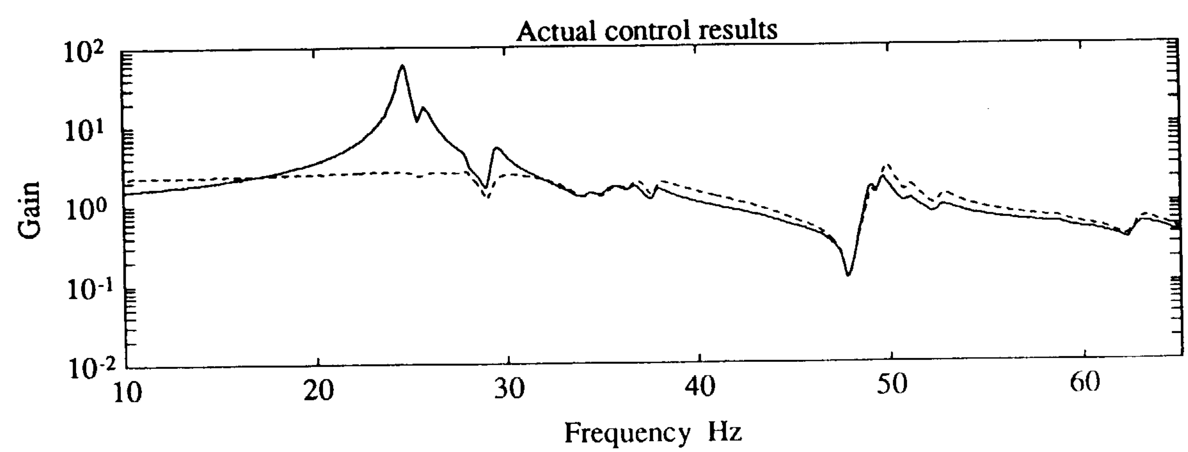
- Model truncated at 80 Hz
- LQG controller had some slight notching which did not improve stability and affected the cost slightly. These dynamics were removed from the controller.



Experimental Results

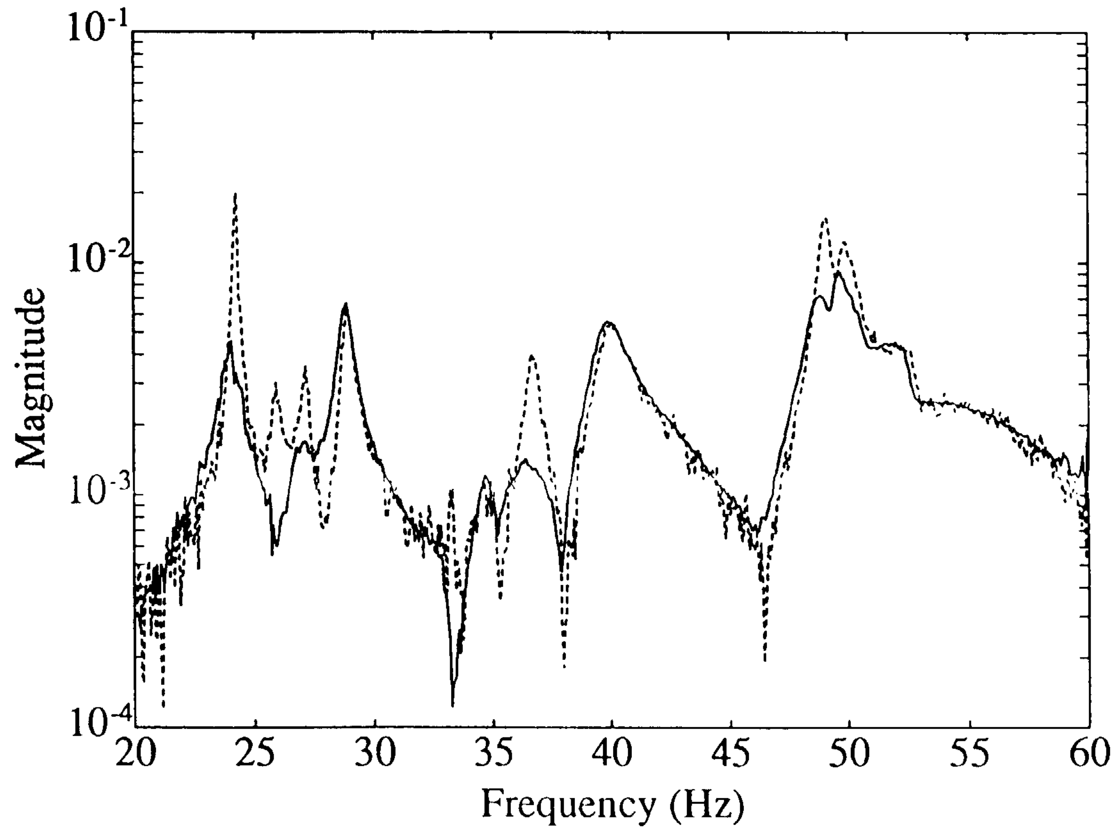
- Controller digitized and implemented on real time computer at 2000 Hz.





Preliminary LAC Experimental Results

- Single collocated rate feedback loop closed around active strut to demonstrate active damping.
- Open and closed loop transfer functions from disturbance source to siderostat acceleration.

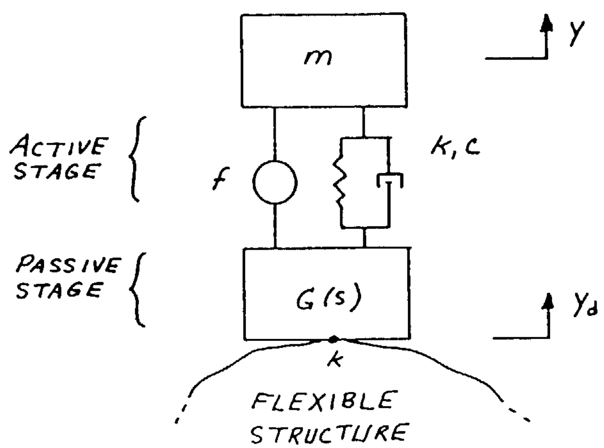


Active Vibration Isolation
Problem Statement

Problem A: Given the prescribed displacement disturbance of a flexible base structure, design an active interface to reduce transmissibility of displacement to a rigid payload. 214z
Problem B: Given the prescribed clamped force and output impedance of a vibrating machine, design an active interface to reduce transmissibility of force to a flexible base structure.
Thesis will study:

- relative performance of passive and active isolation designs
- choice of feedback sensors and passive design to decouple flexible base dynamics
- active isolation as an element of CST process:
  - disturbance attenuation
  - simultaneous isolation mounts
  - isolation and pathlength control together
- implementation of MDOF isolators on testbed

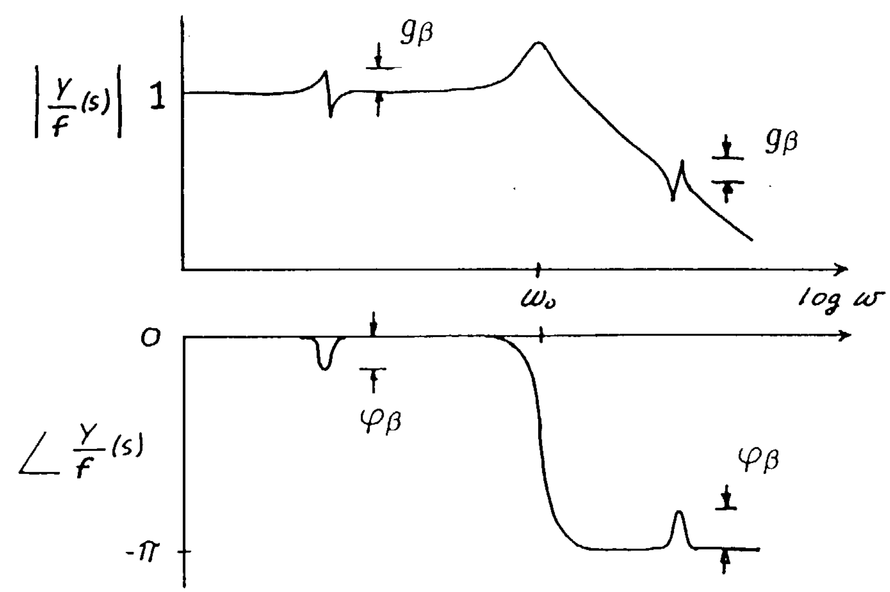
Model: Base Flexibility Coupling into Isolation Feedback Loop



Structural admissibility at k :

$$H_k(s) = \sum_{i=1}^{\infty} \frac{(\phi_i)^2}{s^2 + 2\zeta_i\omega_i s + \omega_i^2}$$

$$\omega_o = \frac{k}{m}$$



- Plant transfer function: $y(s)/f(s)$
- Non-dimensional parameter governing flexible coupling of i^{th} mode:

$$\omega_r \ll \omega_o : \quad \beta_L = \frac{m(\phi_i)^2}{2\zeta_i}$$

$$\omega_r \gg \omega_o : \quad \beta_H = \frac{m(\phi_i)^2}{2\zeta_i}\left(\frac{\omega_r}{\omega_o}\right)^2$$

$$g_\beta = (1+\beta)^{1/2} \qquad \varphi_\beta = 2atan(\beta/2)$$

A Phase 0 Testbed

- 33 cm cantilevered beam, initially developed as a deformable mirror testbed.
- Designed to test the sensor, actuator, modelling, and control issues associated with nanometer resolution requirements.
- Sensors/actuators: tip laser displacement, PZT, and PVDF.
- High Authority/Low Authority controller:
  - passive damping (resistive piezoelectric shunting)
  - LAC: strain rate feedback (PVDF to PZT), applied to same actuators as HAC, analog
  - HAC: constrained order LQG (4), two loop feedback (laser measurement to PZT), digital.

Closed Loop Results

- Transfer function from disturbance (mid beam) to tip displacement: