An Optical Sensor and Wireless Mesh Network

Advanced Instrumentation for the Large Laminar Soil Box

David McCallen, Floriana Petrone, Patrick Laplace, Maryam Tabbakhha

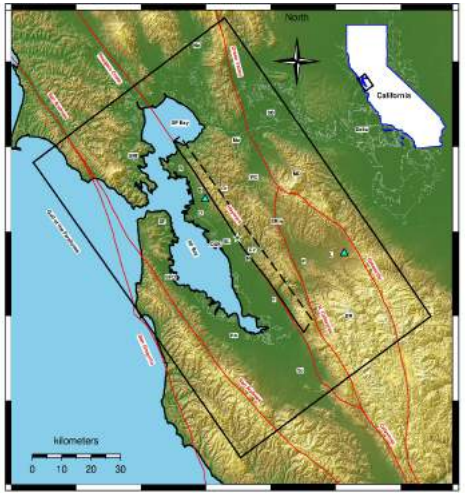
Lawrence Berkeley National Laboratory
University of Nevada

BERKELEY LAB

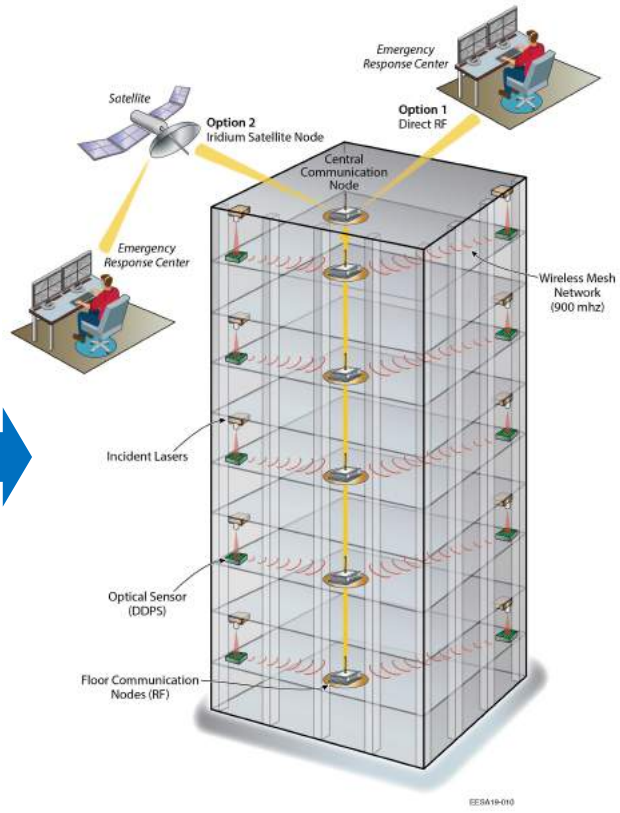
NUCLEAR SAFETY RESEARCH AND DEVELOPMENT
U.S. DEPARTMENT OF ENERGY

The objective is to provide the *prompt* actionable data for post-event response

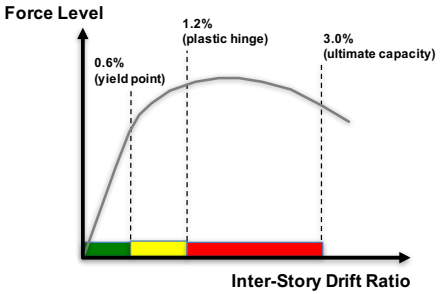
Earthquake event occurs

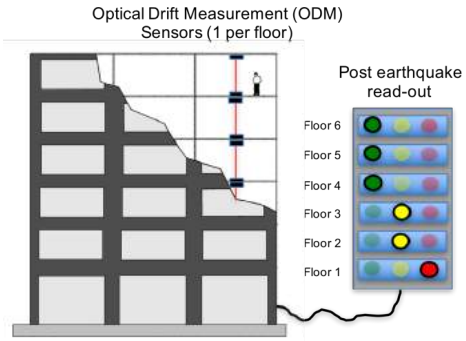


Rapid real-time measurements with reliable data transmission



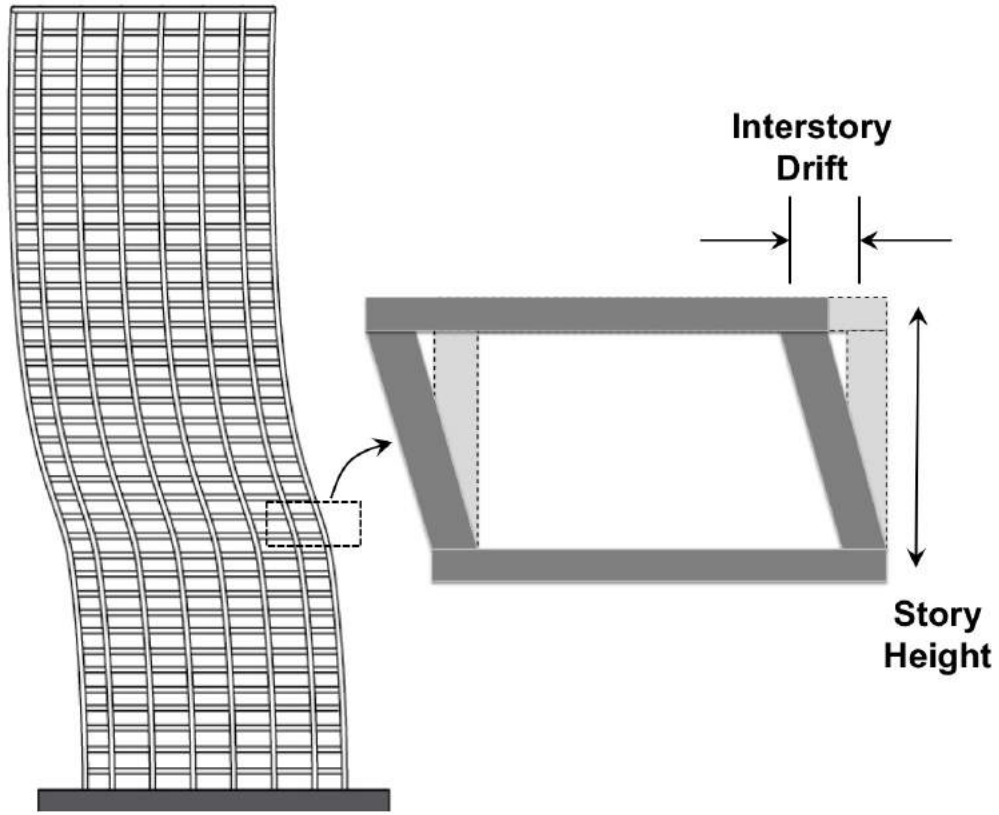
Immediate data to inform response decisions

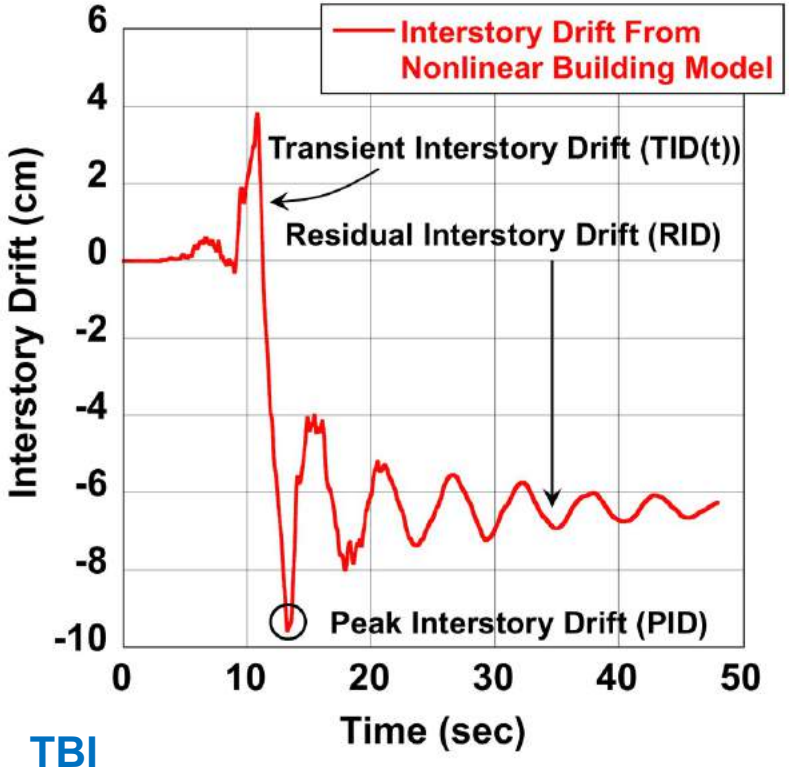




- Emergency responders
- Re-occupancy
- Continuity of operations
- Guidance for detailed inspections

Interstory drift is an essential earthquake demand parameter





Current uses of interstory drift in engineering standards

ASCE 43-05

Limit States

(PID)

TBI
ASCE 7-02
EN 1998-01

Not-to-Exceed Drift Limits

(PID)

FEMA P58

Damage State Drift Limits

(RID)

The challenges of accurately measuring interstory drift have been well documented

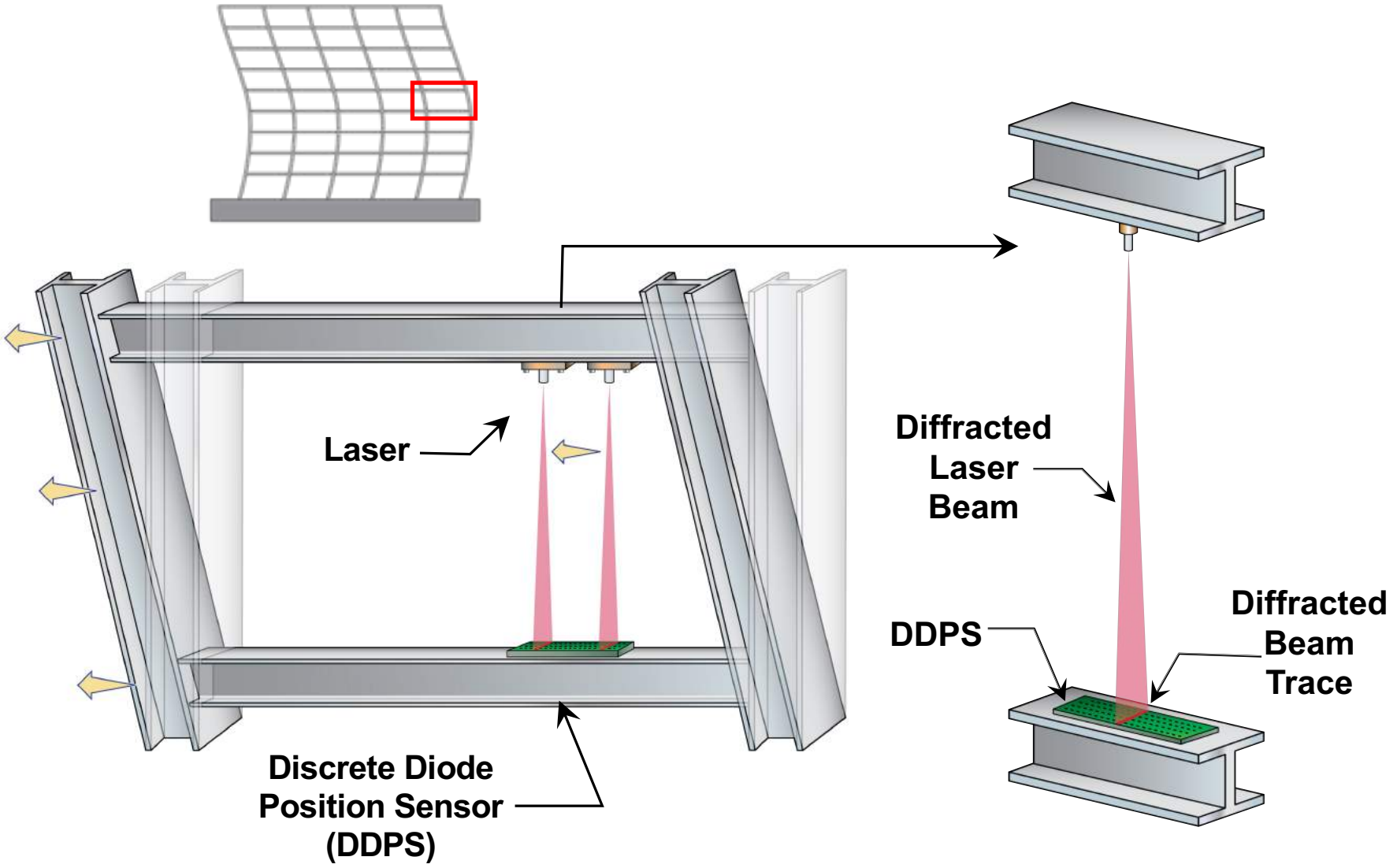
Critical Assessment of Interstory Drift Measurements

Derek A. Skolnik, M.ASCE[1]; and John W. Wallace, M.ASCE[2]

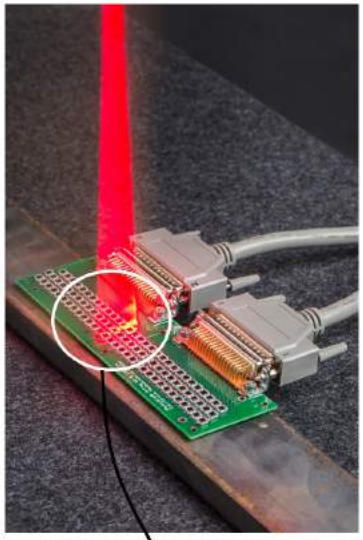
Abstract: Interstory drift, the relative translational displacement between two consecutive floors, is an important engineering demand parameter and indicator of structural performance. The structural engineering community would benefit well from accurate measurements of interstory drift, especially where structures undergo inelastic deformation. Unfortunately, the most common method for obtaining interstory drift, double integration of measured acceleration, is problematic. Several issues associated with this method (e.g., signal processing steps and sparse instrumentation) are illustrated using data from shake table studies and two extensively instrumented buildings. Some alternative contact and noncontact methods for obtaining interstory drift are then presented.

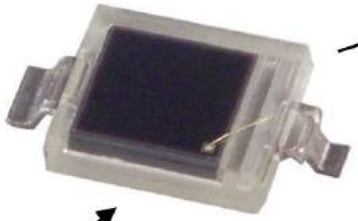
"Interstory drift, the relative translational displacement between two consecutive floors, is an important engineering demand parameter and indicator of structural performance. The structural engineering community would benefit well from accurate measurements of interstory drift, especially when structures undergo inelastic deformation. ***Unfortunately, the most common method for obtaining interstory drift, double integration of measured acceleration is problematic***"

The concept - exploit the physics of light for direct, broad-band drift measurement

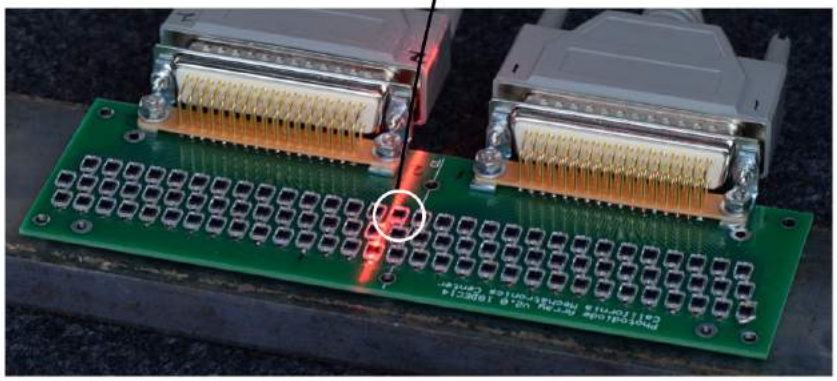


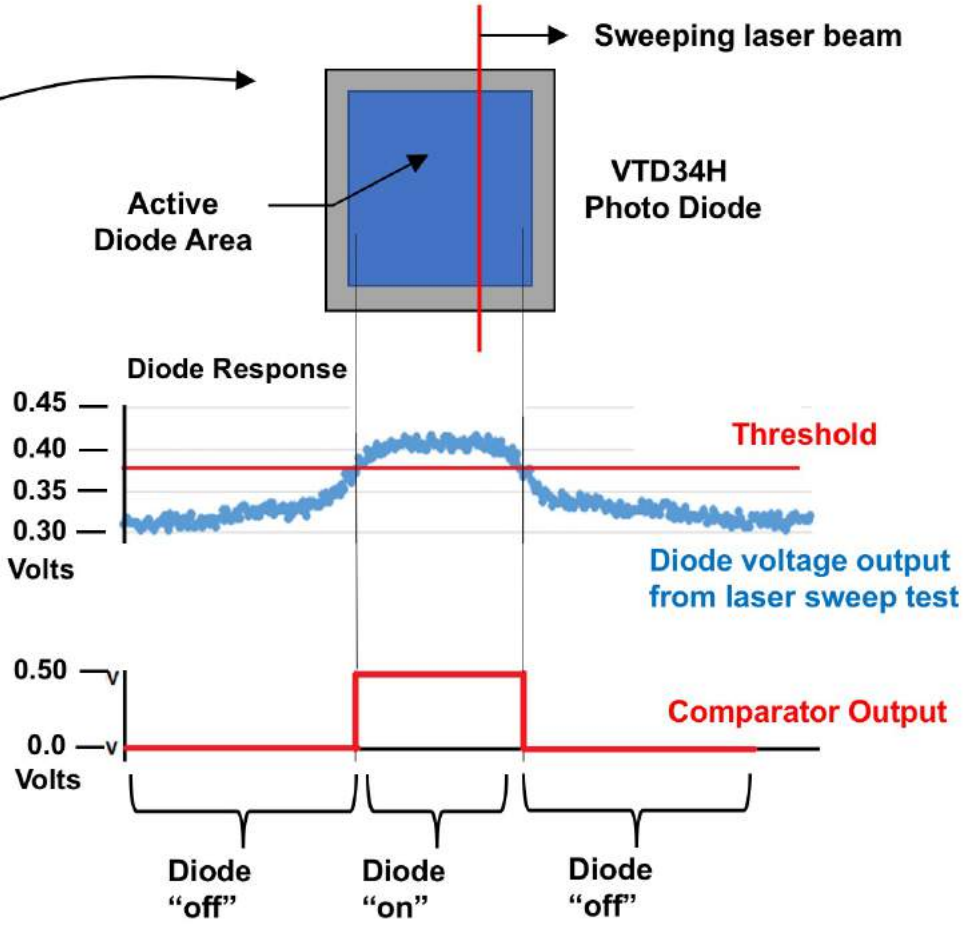
Inexpensive light-sensitive diodes are at the heart of our sensor concept



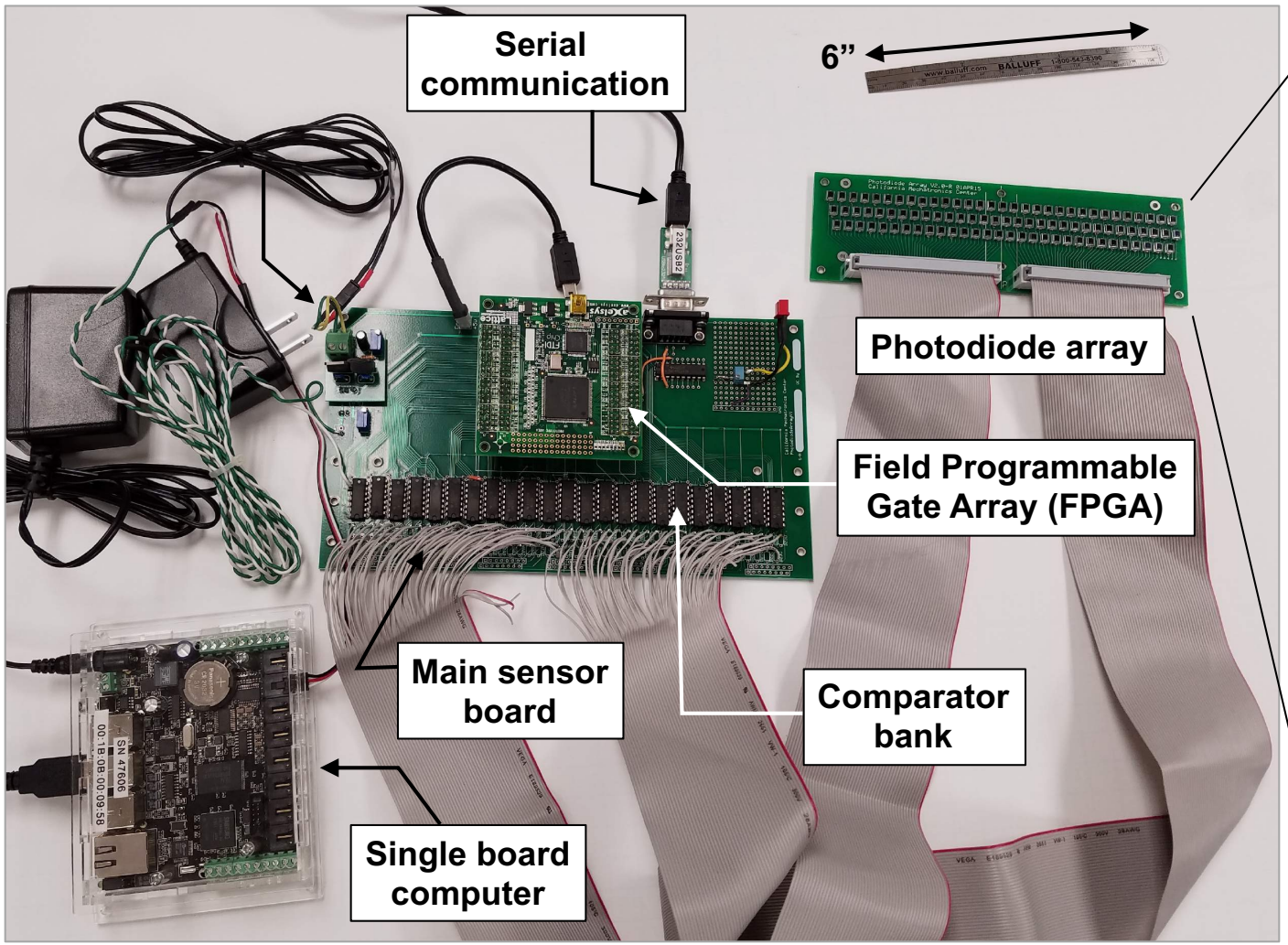


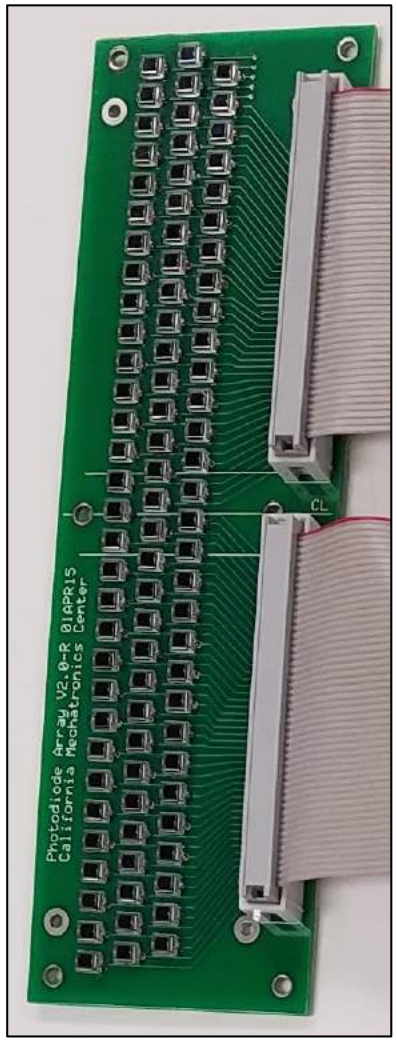
Individual Photodiode



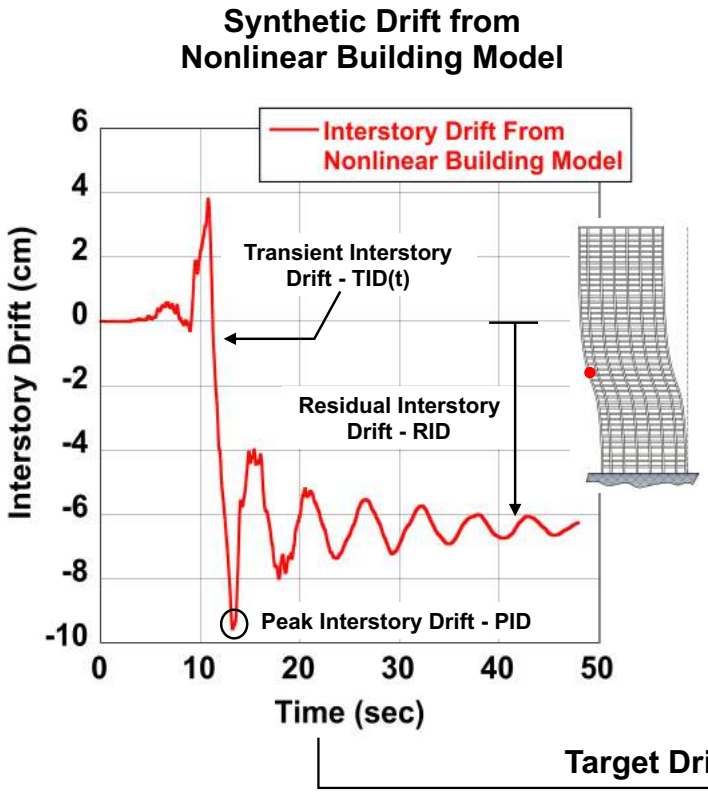


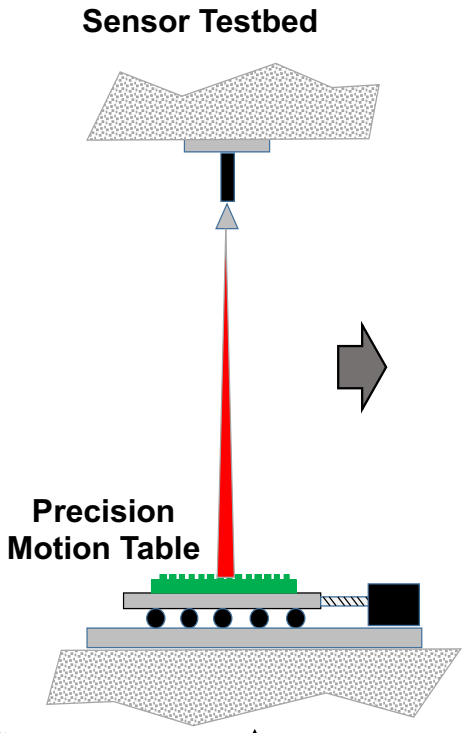
Generation 1 - a prototype sensor for proof of concept

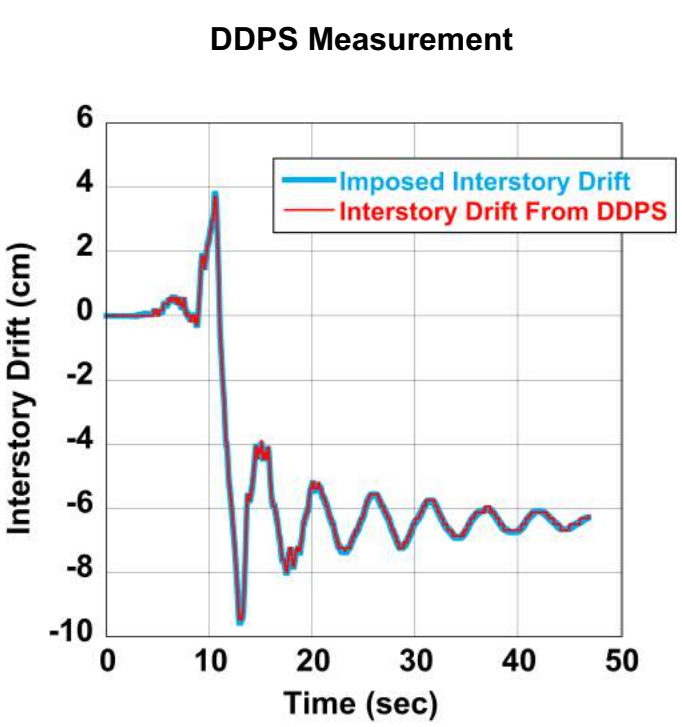


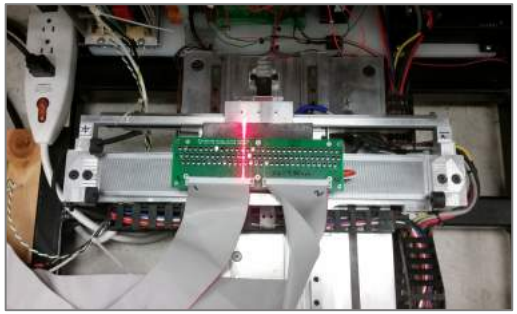


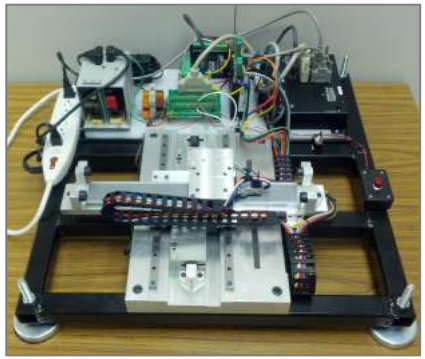
Testbed #1 - a motion table for generating realistic interstory drifts was developed







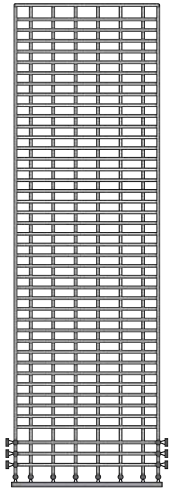


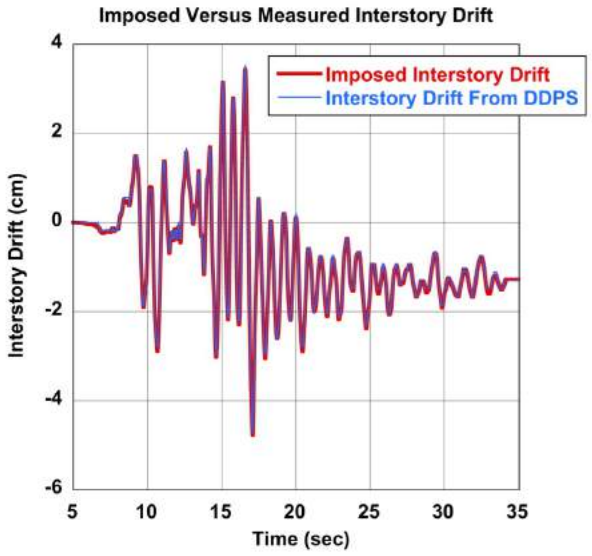


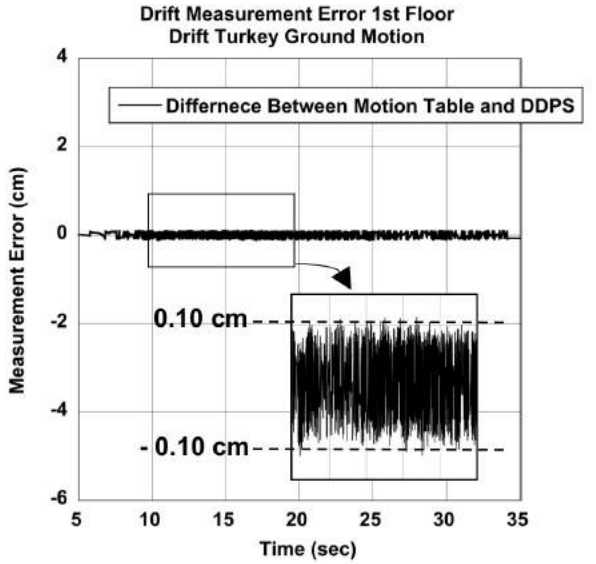
Prototype sensor measurements demonstrated excellent drift measurement

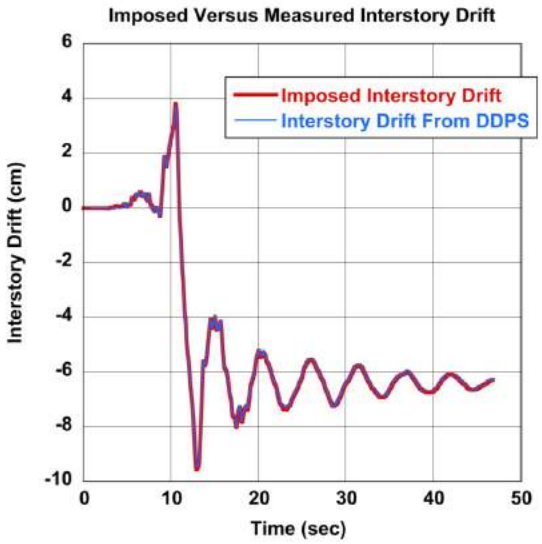
3 story

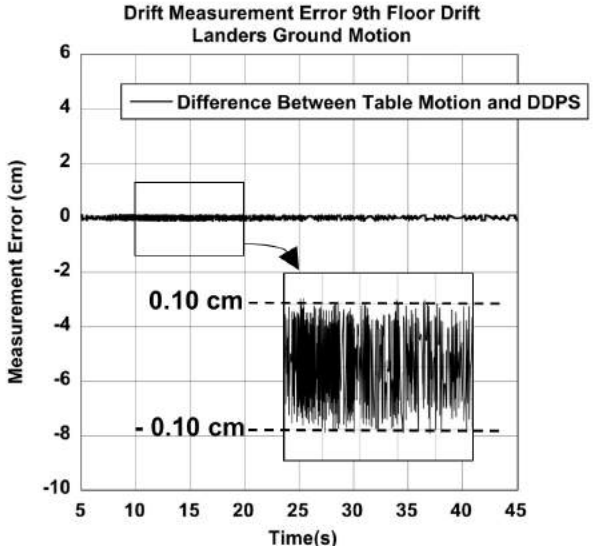
40 story





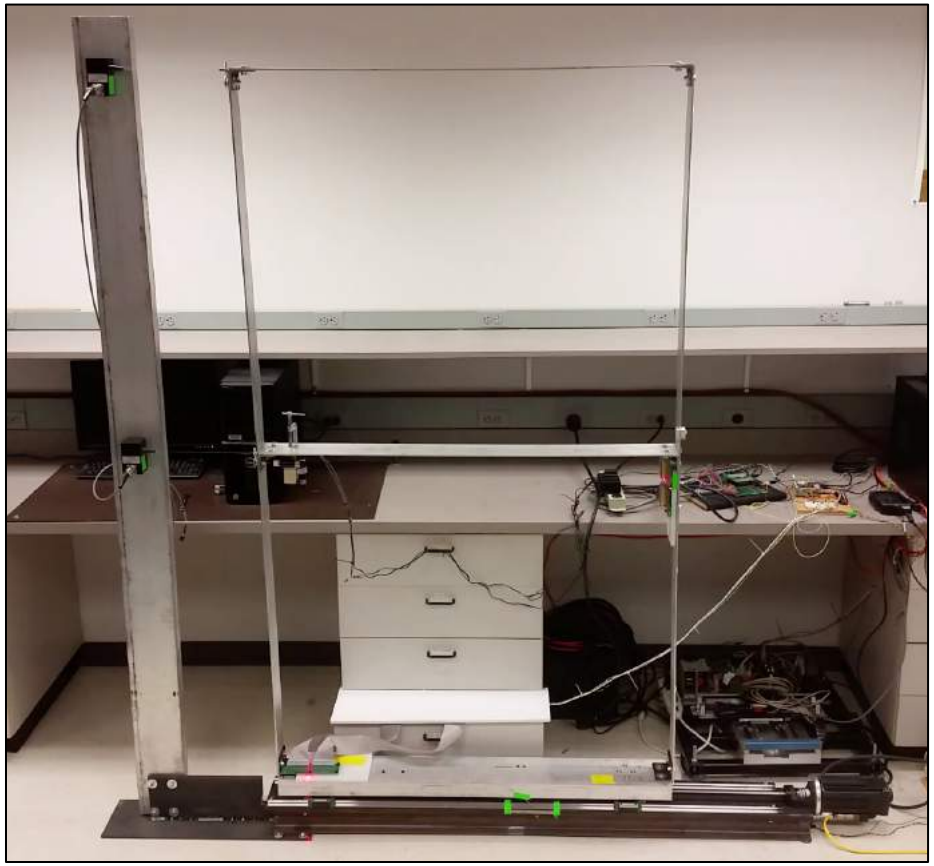


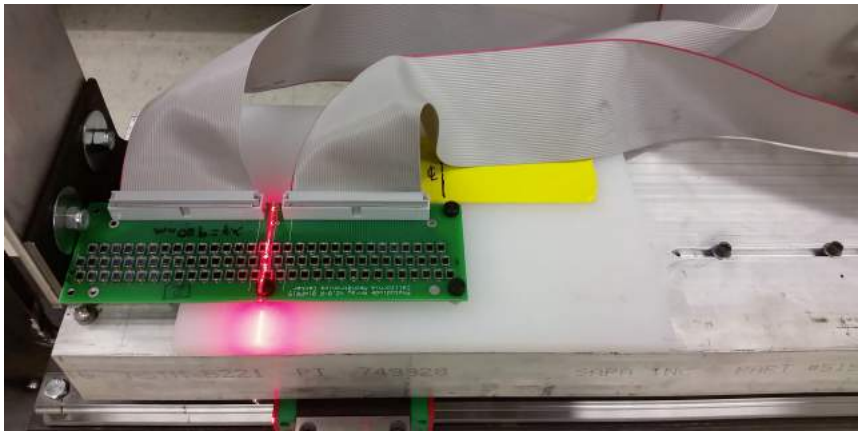




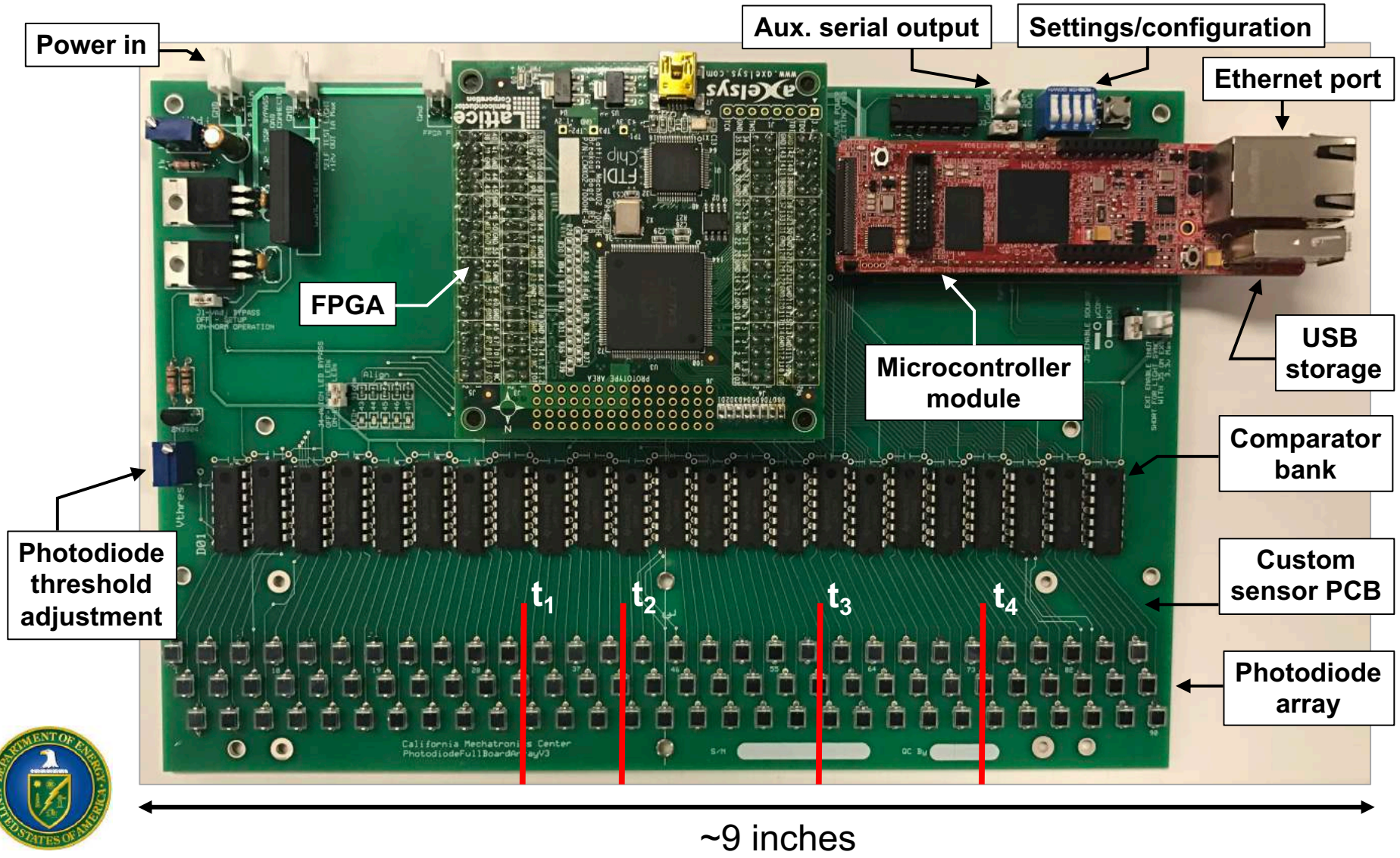
Testbed #2 - a simple laboratory scale frame structure

El Centro motion test



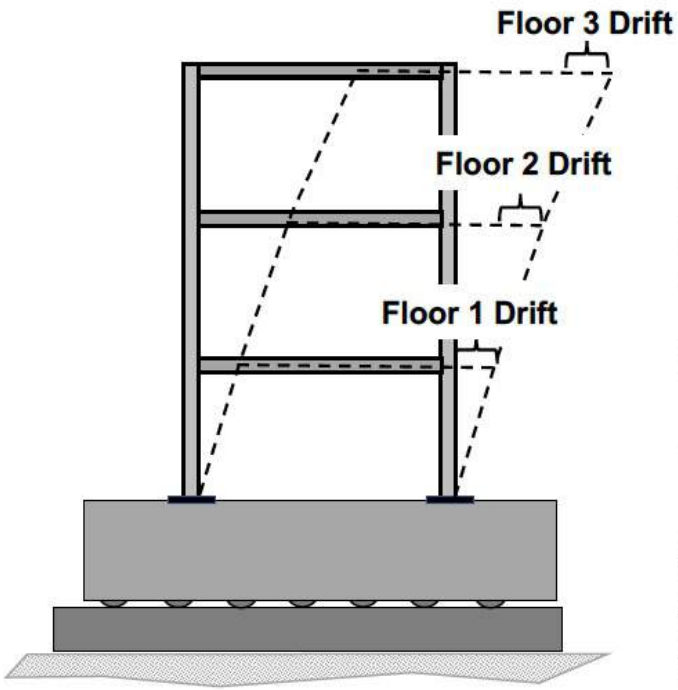


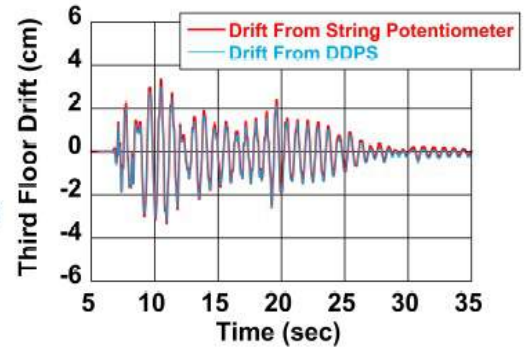
Generation 2 - an integrated sensor on a single circuit board (NSRD)

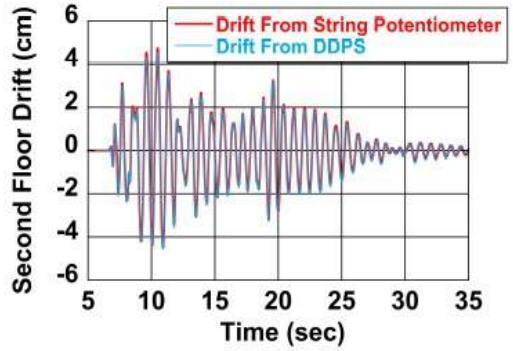


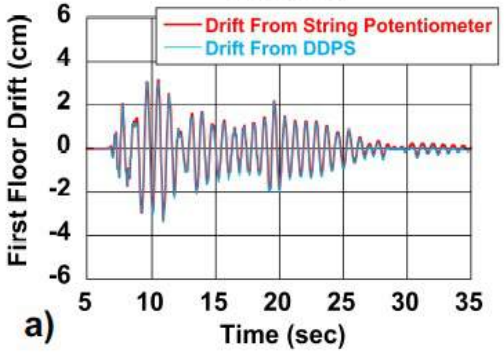
Testbed #3 - the DOE Office of Nuclear Safety supported a larger 3D test at UNR in 2017

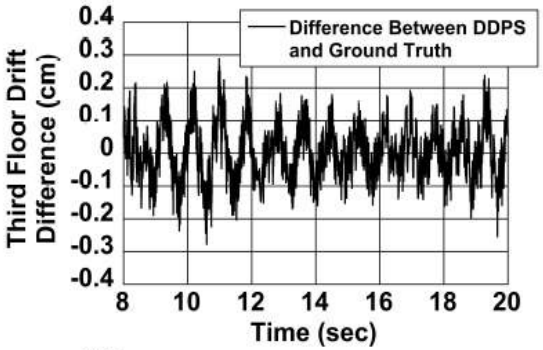
Drift measurements - ground truth versus DDPS

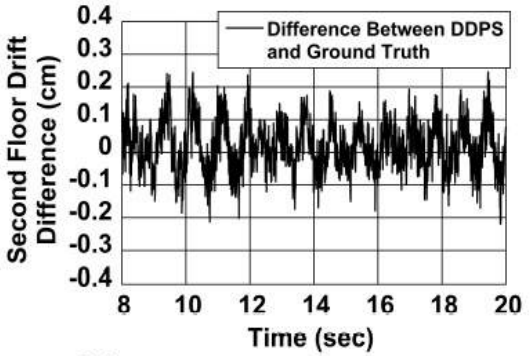


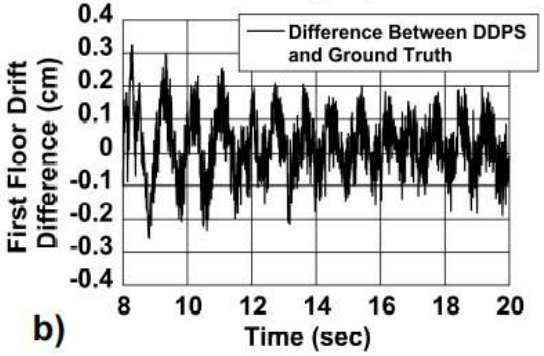




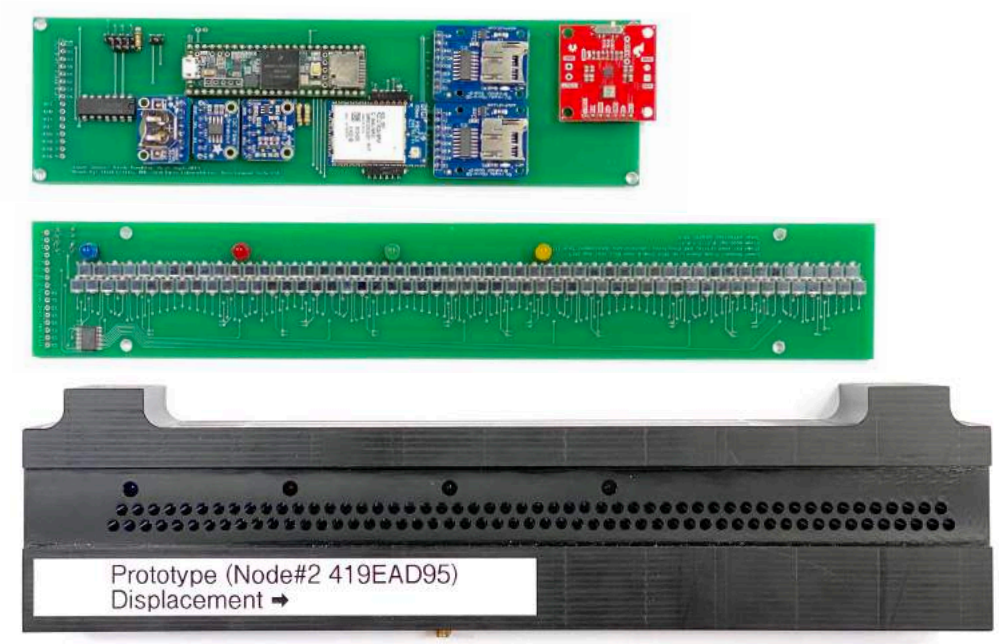






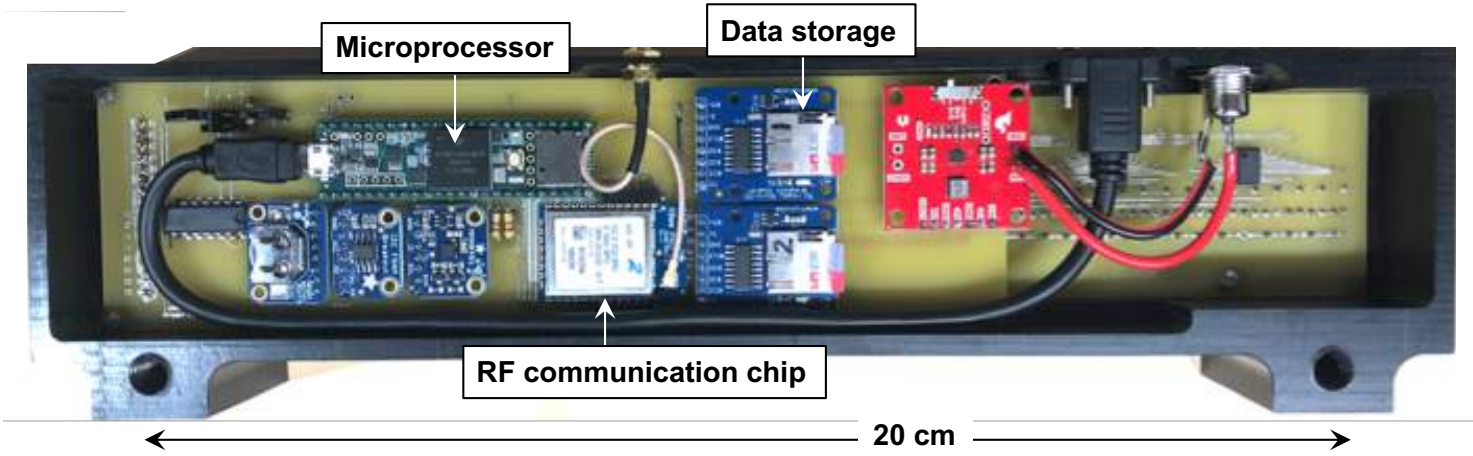


Generation 3 - a deployable sensor based on value engineering and lessons learned



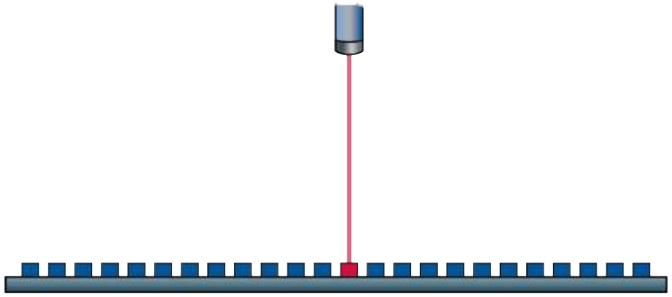
Simplicity = Reliability

Low power laser

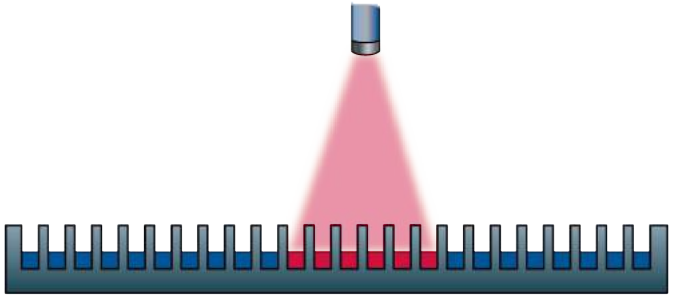


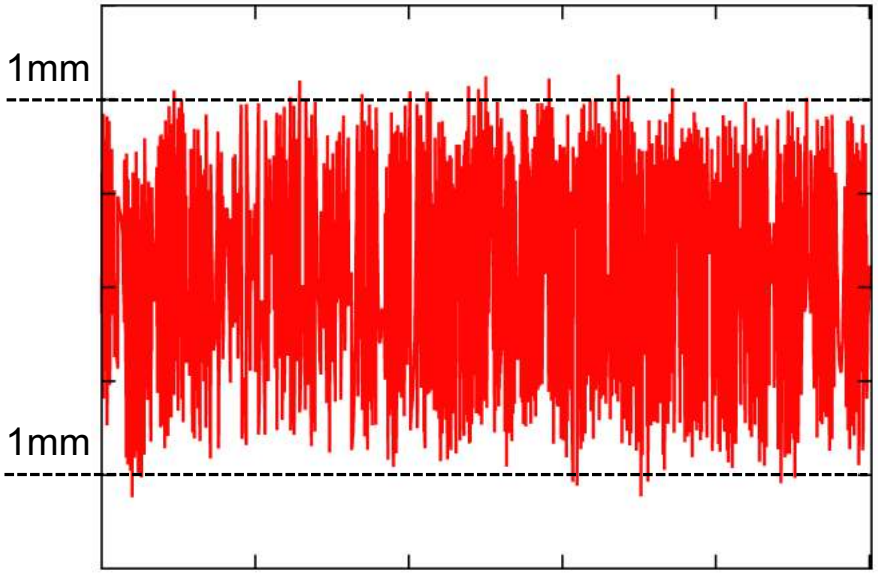
Discovery – a diffuse laser is much better than a sharply focused laser

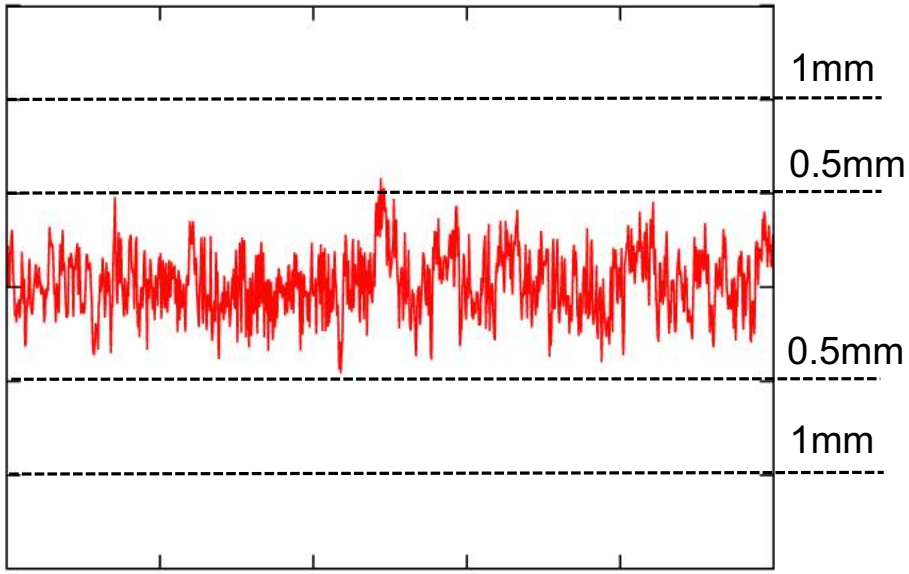
Generation 2



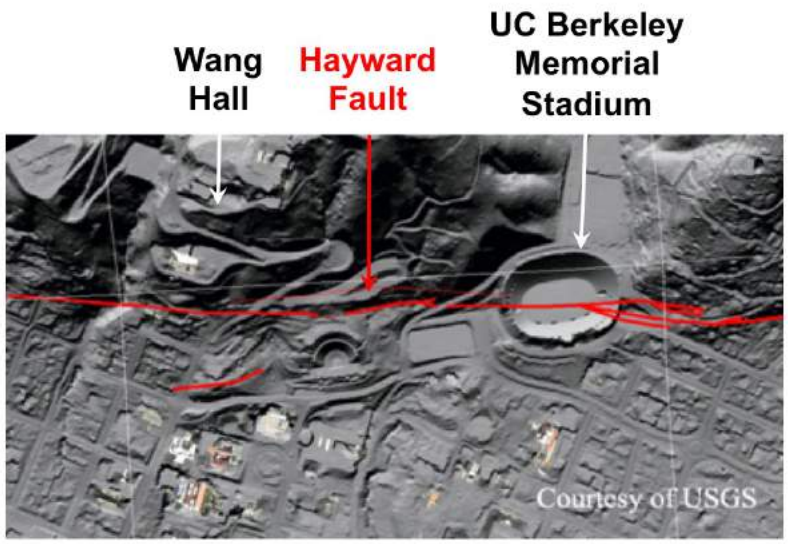
Generation 3

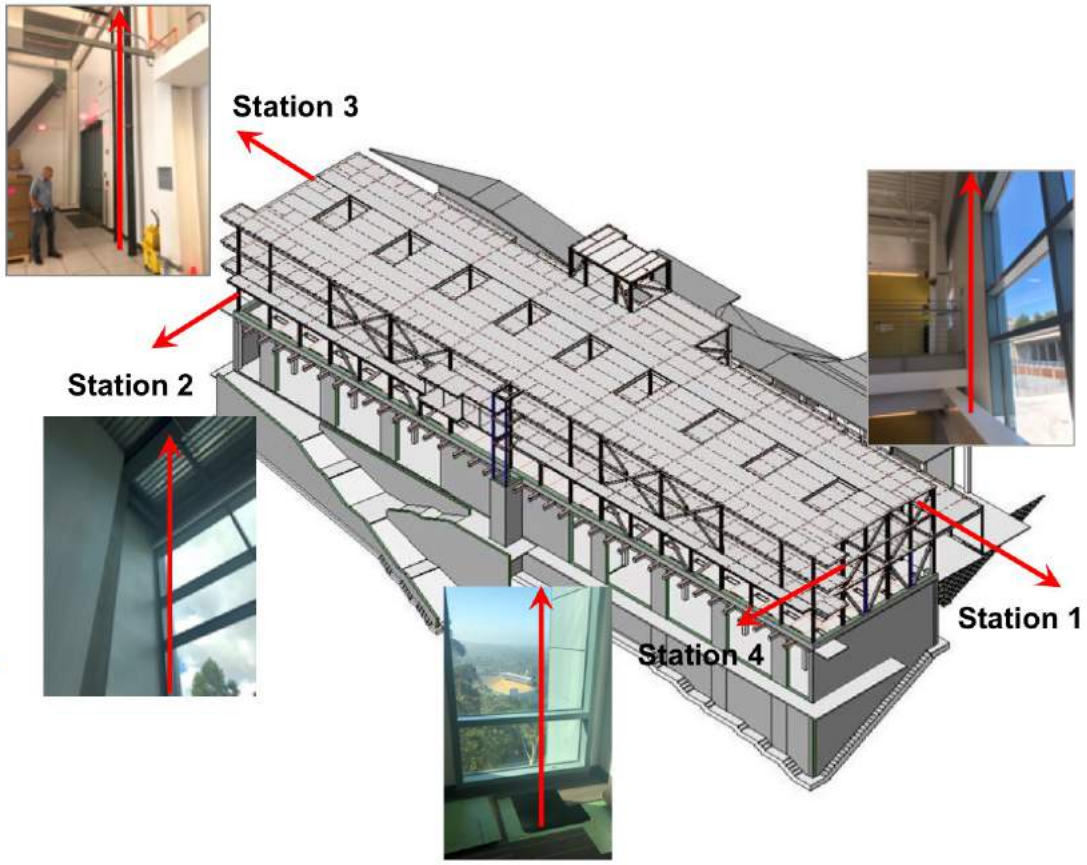




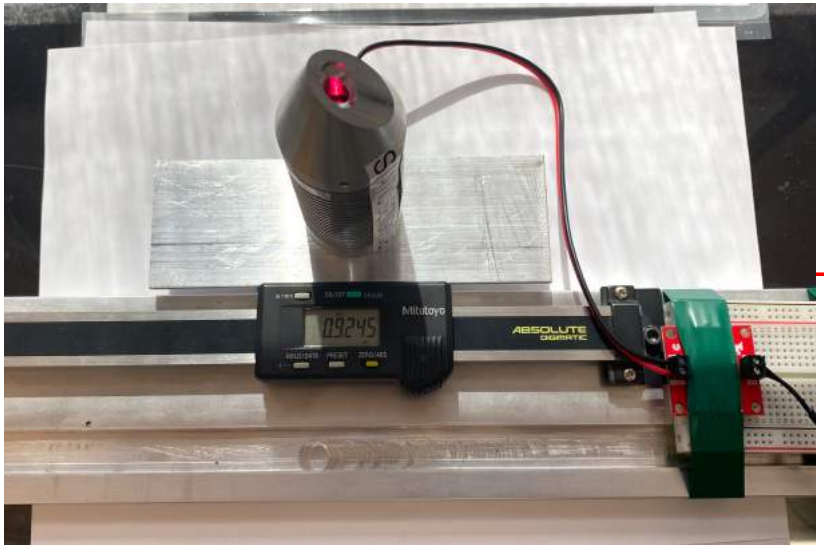


Four sensors were deployed in Wang Hall at Berkeley Lab in September 2019



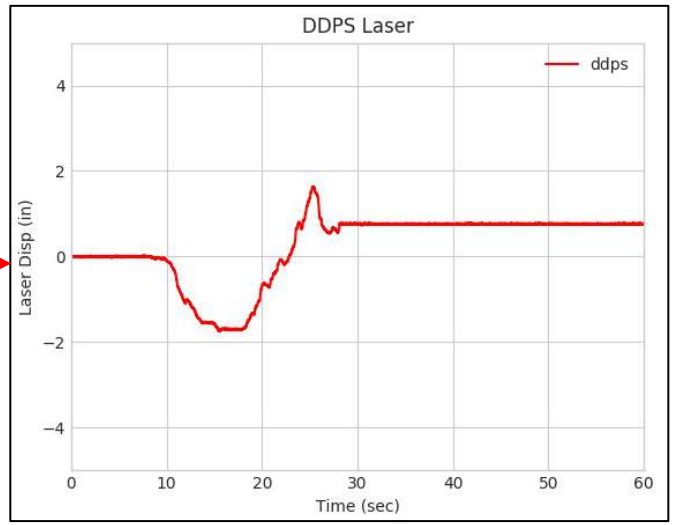


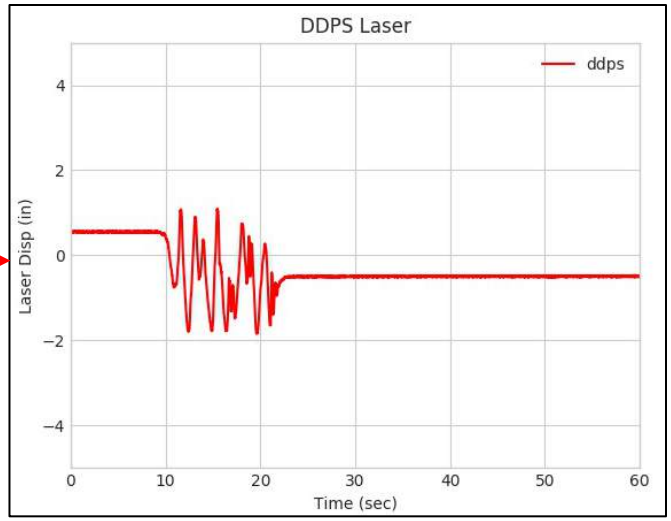
The sensors have continuously operated very reliably for 14 months



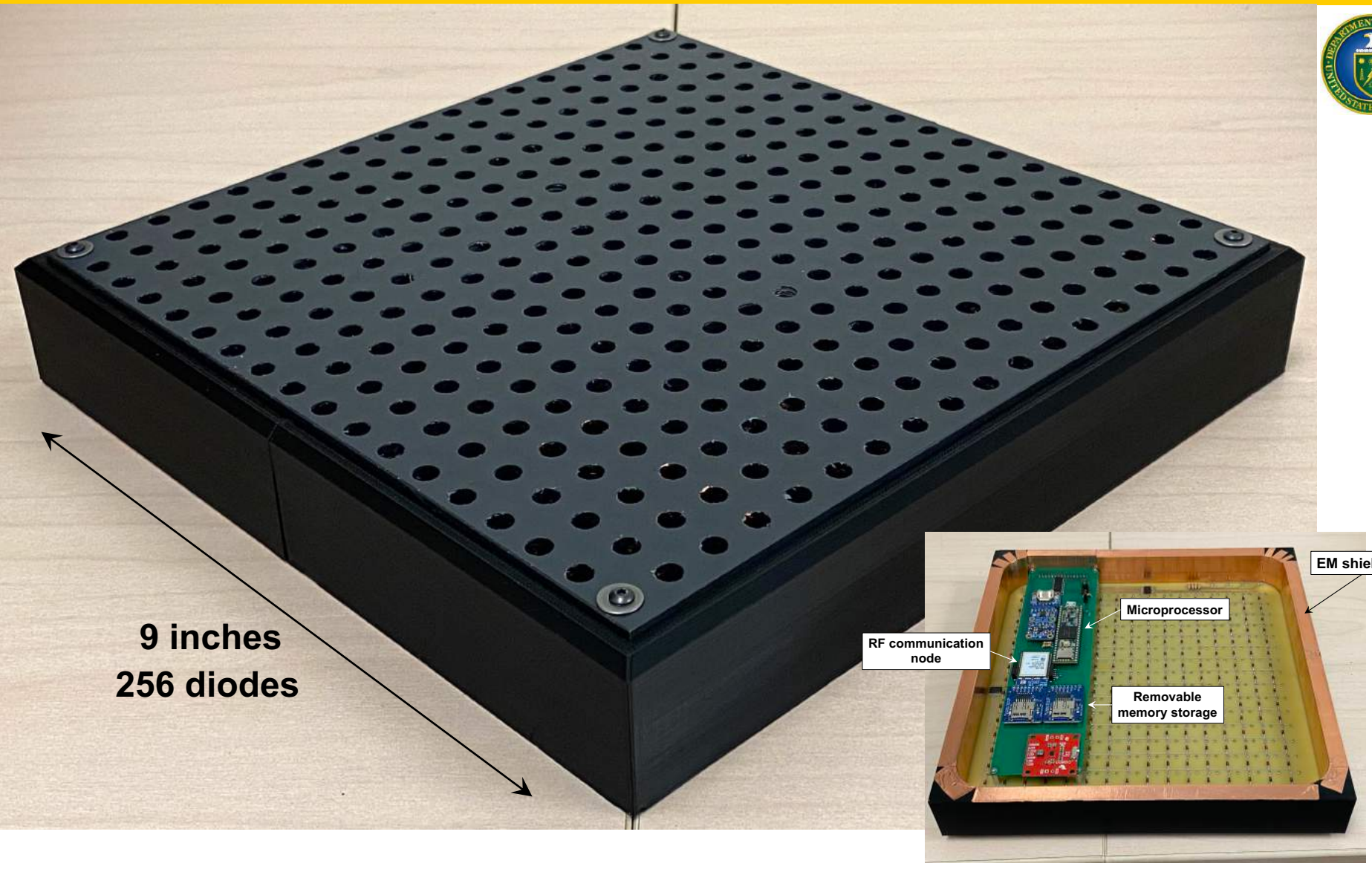
Triggered earthquakes

Automated email delivery of data

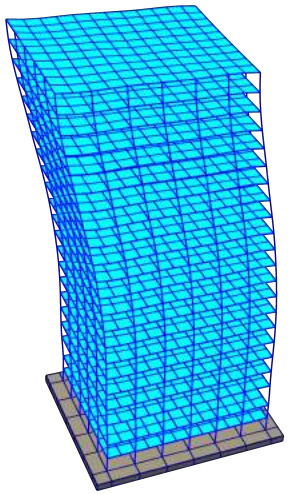




Hardware for the first prototype of a new bi-axial sensor version has been completed

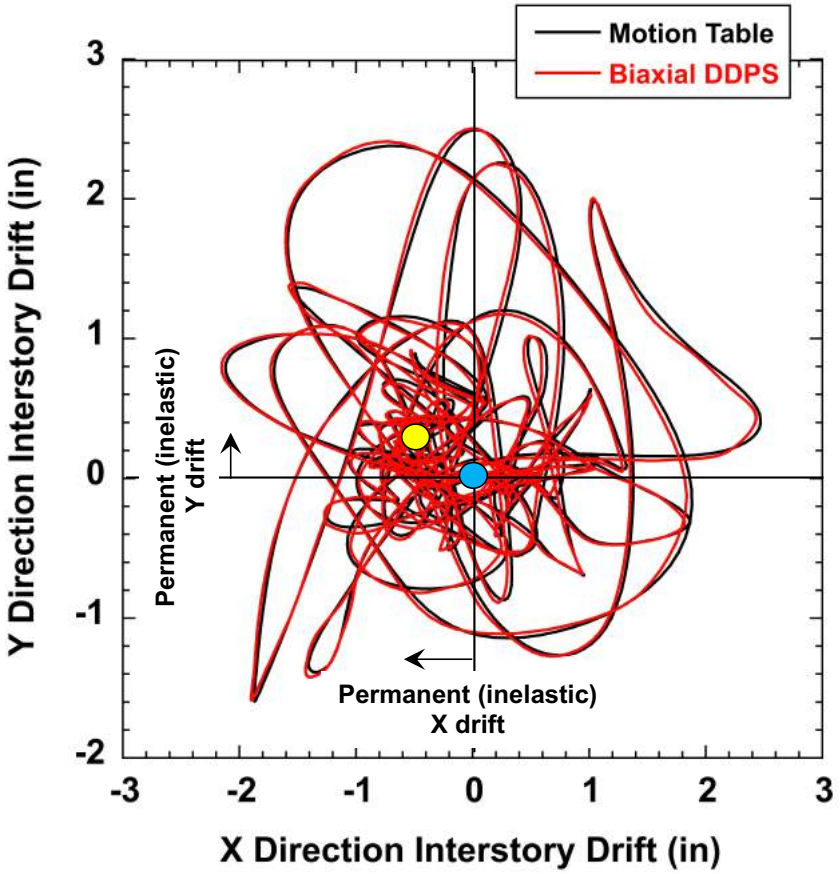


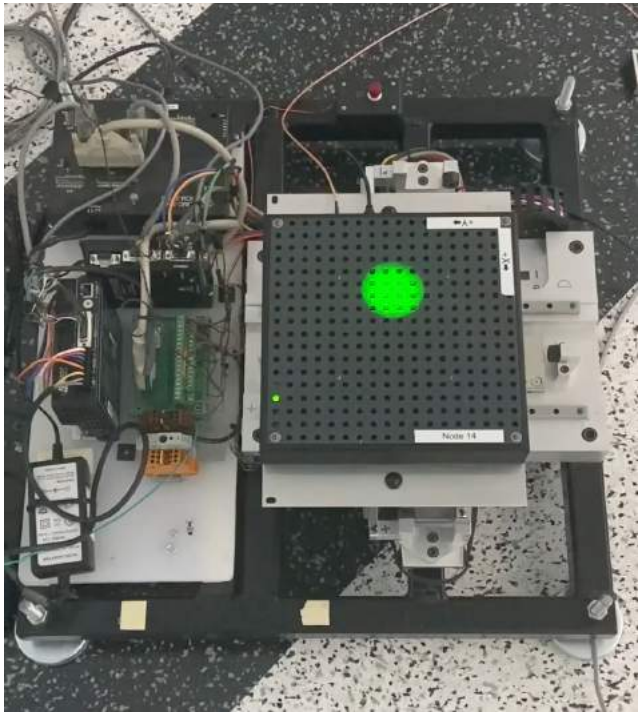
Orbit plot for 20 story building subjected to strong near-field motions



Start of earthquake

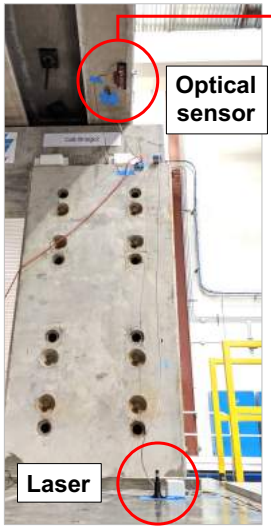
End of earthquake

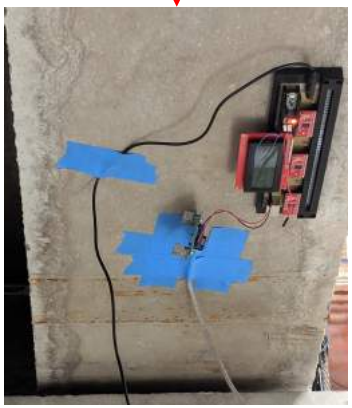


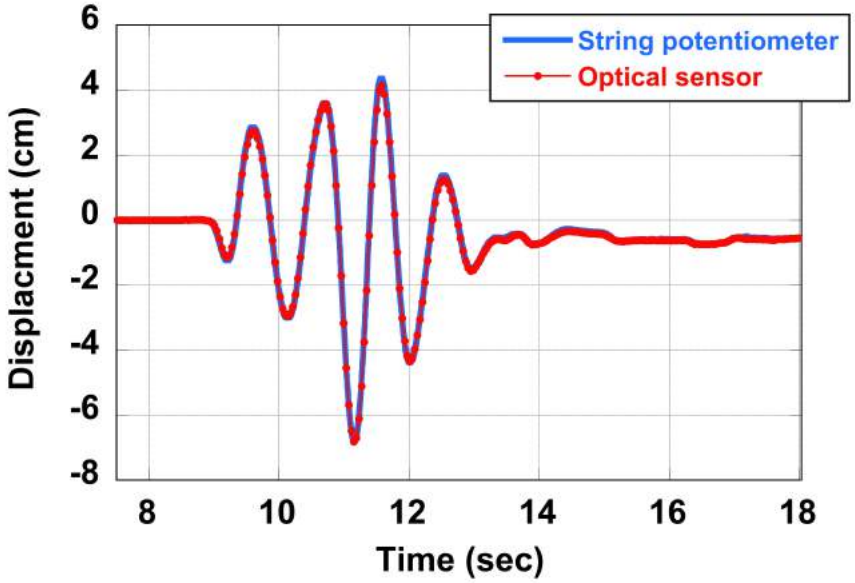


Another use case - we have tested the optical sensor concept as an agile laboratory sensor

Multi-table bridge system test







There is the potential to deploy as part of the soil box system diagnostics