Internet Photonic Sensing (IPS): Using Internet Optical Transport Signals for Vibration and Deformation Sensing

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Motivation

- Measuring deformations and vibrations is essential for seismology, structural health, and security.
- Existing sensors are expensive, limited, and sparse.
- Idea: Leverage existing Internet fiber as a massive global-scale sensor network.

Core Idea of IPS

- IPS uses ordinary Internet optical transport signals to detect deformation and vibration.

- Vibrations cause measurable variations in (available by APIs):
    - Optical Signal Strength (OSS)
    - Bit Error Rate (BER)

- Uses standard SNMP-accessible metrics — no specialized sensors needed.

Related Works

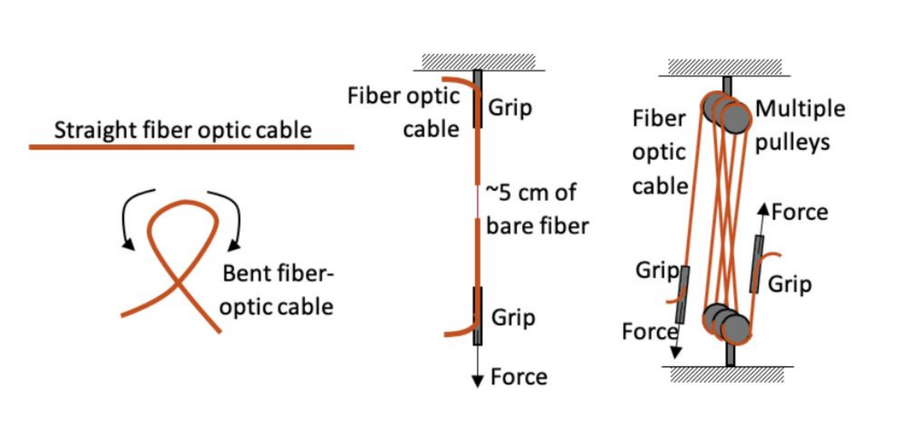
- FBG: Reflective wavelength shift, discrete sensors
- DAS (C-OTDR): Backscattered phase, distributed sensing, specialized hardware
- IPS: Forward Internet signals, opportunistic sensing, commodity hardware

Coherent Optics in the Internet

- Modern Internet uses coherent optical communication (1550 nm).
- DSPs recover and equalize signals — normally suppressing phase variations.
- IPS repurposes this 'communication noise' as vibration signal.

Experiment Setup

- Goal: Determine OSS and BER response to stress.
- Hardware: Infinera coherent transponders + BMM (Bandwidth Multiplexing Module) modules.
- Fiber:
    - 7m bends
    - 1.5m short pull
    - 12.1m long pull (pulleys)
- Data collected via SNMP every 1s



Hardware Pictures

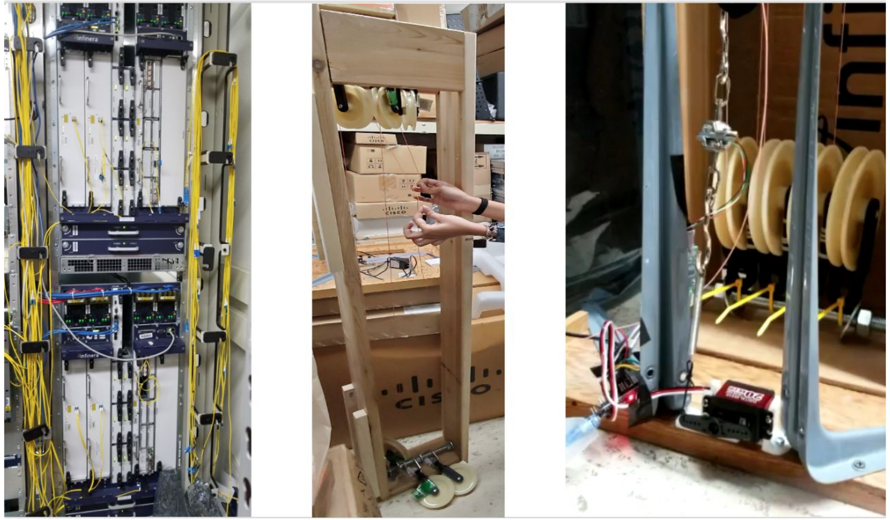
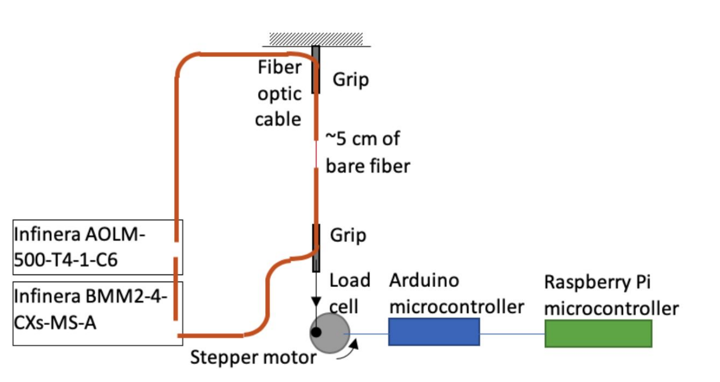


Figure 4: Lab setup for applying stress to optical fiber: (left) Infinera AOLM and BMM, (center) pulley system with fiber, and (right) Atmega servo motor and Arduino controller.

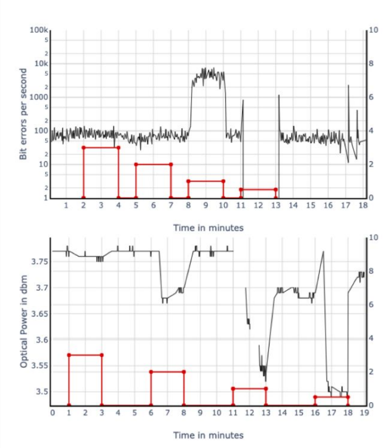
Controlled Strain Application

- Custom setup: Arduino servo + HX711 load cell
- Forces: 490 mN – 1.37 N (~100 μstrain)
- Recorded load, OSS, BER time series
- Designed for realistic ground vibration magnitudes.



Results: Bend Tests

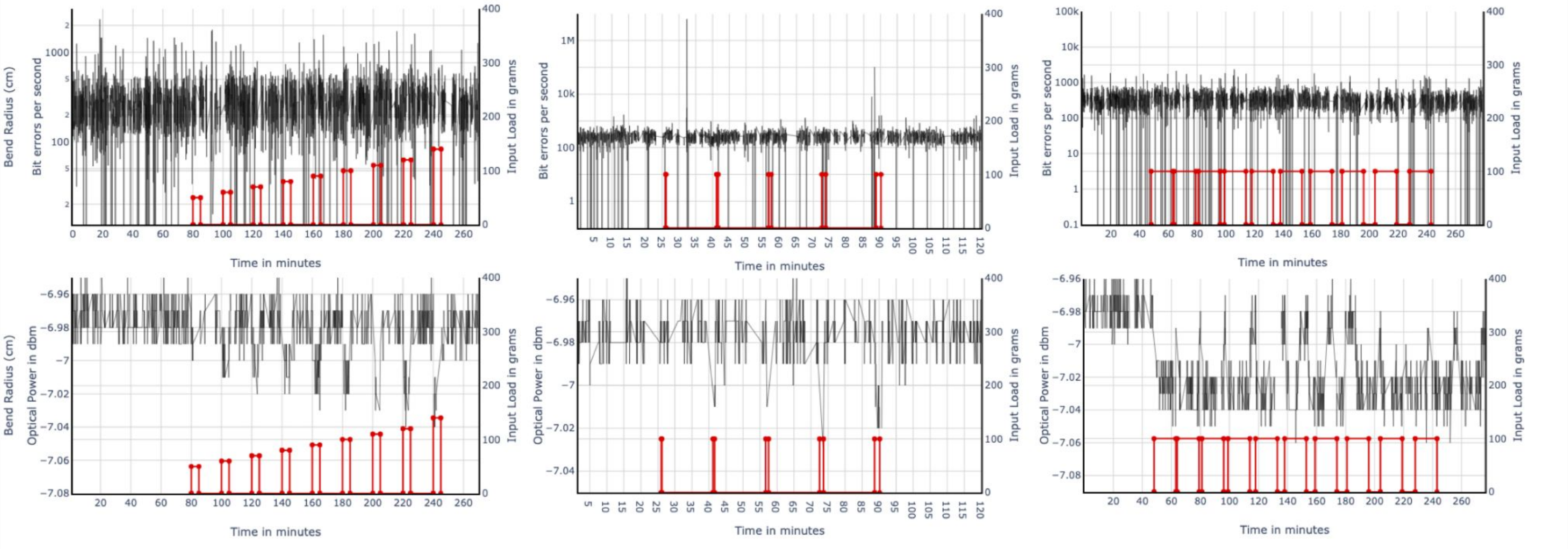
- BER stable for 3–2 cm bends, rises 100× at 1 cm, total loss at 0.5 cm.
- OSS decreases even with mild stress.
- Strong correlation between stress and signal degradation.



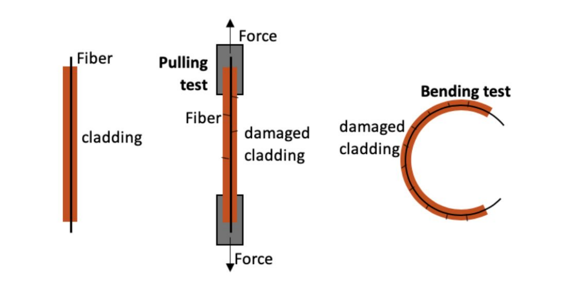
Results: Pull Strain Tests

- Loads 490 mN–1.37 N:
    - BER unaffected (DSP masks small noise)
    - OSS degrades proportionally
- Longer stress duration → stronger OSS response
- Recovery: 7–15 min after stress removal

Results: Pull Strain Tests



Mechanisms



- Effects likely due to:
  - Microbending losses (light leakage)
  - Shear stress between coating/cladding

- OSS more sensitive than BER under current hardware access

Mechanisms

- Coherent systems (1550 nm) can detect nanostrain-level changes.
- DSP phase recovery (μs scale) could enable high-resolution IPS.

Future Works

- Access phase/polarization data from DSPs
- Test higher-order modulations (e.g., 16-QAM)
- Study two-way transmission and localization
- ML-based fusion of multiple MIB signals
- Field tests on operational fiber routes