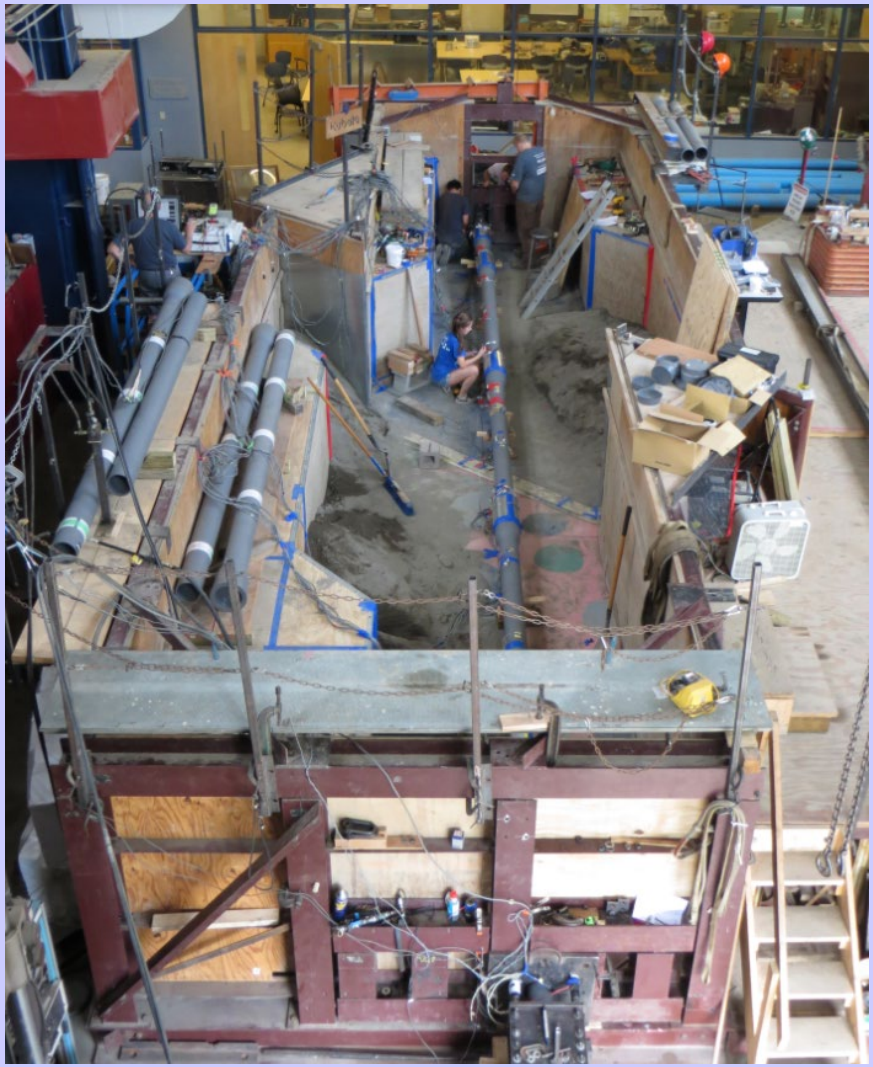
Cornell Qualifications

- 40 Years R&D for Gas Distribution & Transmission Systems
  - Cast iron pipelines, railroad/highway crossings, pipeline rehabilitation, aging protocols, reinforced polymer linings, risk reduction, seismic performance
- Cornell Large-Scale Lifelines Testing Facility
- 40 Years R&D, Design, and Construction Experience for Large Geographically Distributed Systems

CORNELL LARGE-SCALE LIFELINES TESTING LABORATORY



CURED IN PLACE LININGS AND PIPES

AWWA classifies the linings based on their ability to carry loads due to internal pressure and external loads into CIPLs that are semi-structural linings, and CIPPs that are structural.

- **The Starline 2000 CIPL is a flexible semi-structural lining with a seamless woven polyester hose and thin interior polyurethane layer. The polyester hose is saturated with a two-part polyurethane that bonds to the inside surface of the pipe.**

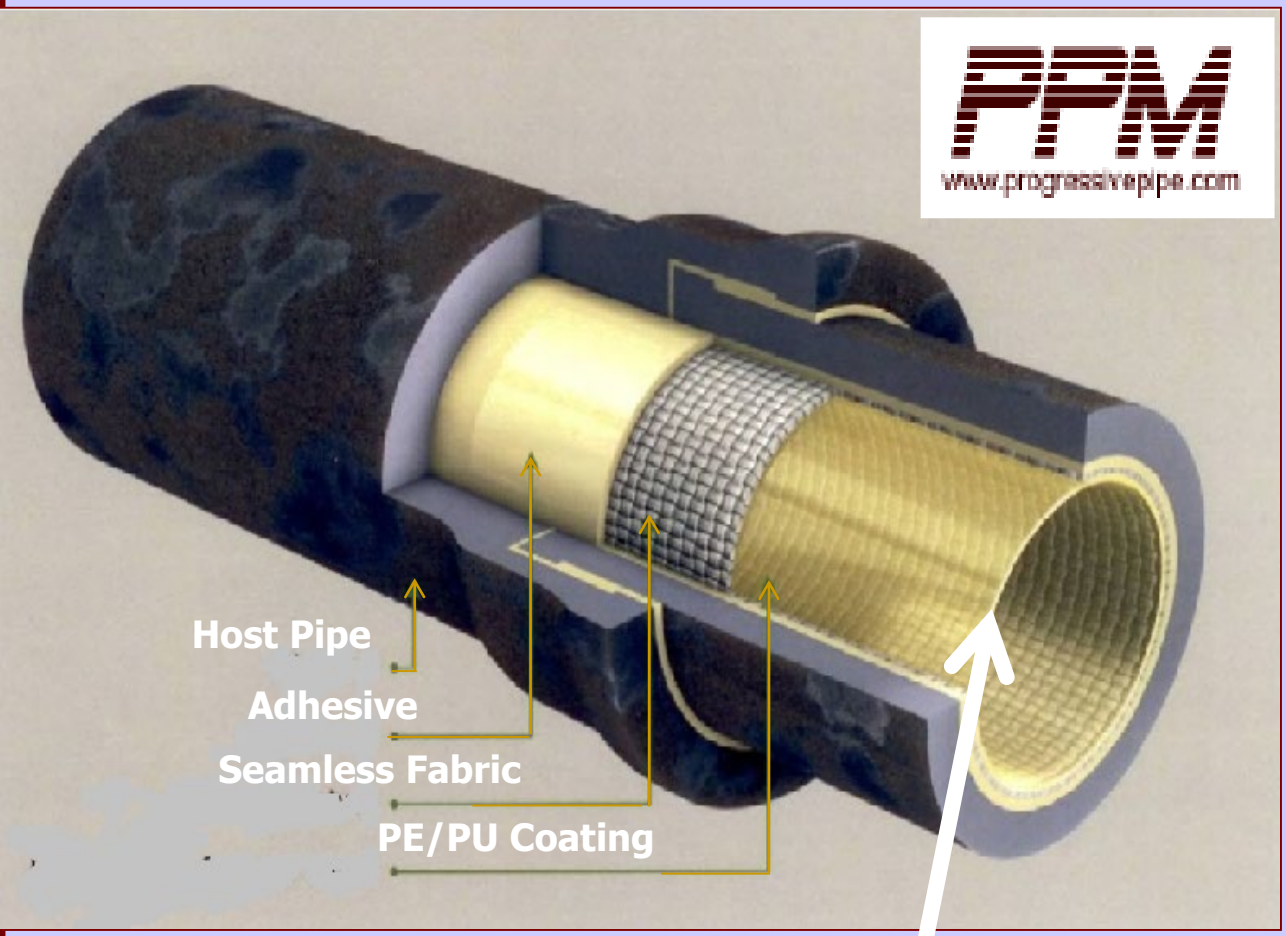
- **A CIPP is composed of woven/unwoven polyester hose or felt impregnated with epoxy resin with and without fiber glass reinforcement.**

- **Installation is performed by the "inversion method", in which the lining is inverted into an existing previously cleaned pipe, or the lining is pulled into place.**

Repetitive Loading Effects

- Jeon et al. (2004), demonstrate the effectiveness of CIPLs (Paltem-GR and Ammex) for cast iron (CI) pipelines that have full circumferential cracks and weak joints. Jeon et al. (2004) performed large-scale laboratory tests on 6-in. pipe that imposes 2 million cycles of traffic load, 50 cycles of thermal (40F°), undermining excavation, and the effects of 8 in. of maximum settlement induced by parallel trench construction. During those tests, a CIPL-reinforced CI pipeline with a round crack was able to accommodate the excavation-induced soil movements.

CIPP LININGS: STARLINE



Diameter Range	4 - 48 in. & services
Pipe Section Length	2500 ft maximum
Bends	YES
Host Pipe	Cast Iron, Ductile Iron, & Steel
Thickness	0.05 - 0.1 in.

Tough, impervious polyurethane membrane

KEY CIPP RESEARCH FINDING

- Local de-bonding required to accommodate movement at cracks & weak joints
- De-bonding confined to a distance of one diameter from crack
- Installation engineered for local de-bonding

Performance Testing of Field-Aged Cured-in-Place Liners (CIPL) for Cast Iron Piping Stewart, O'Rourke, Wham, Netravali, et al. 2015

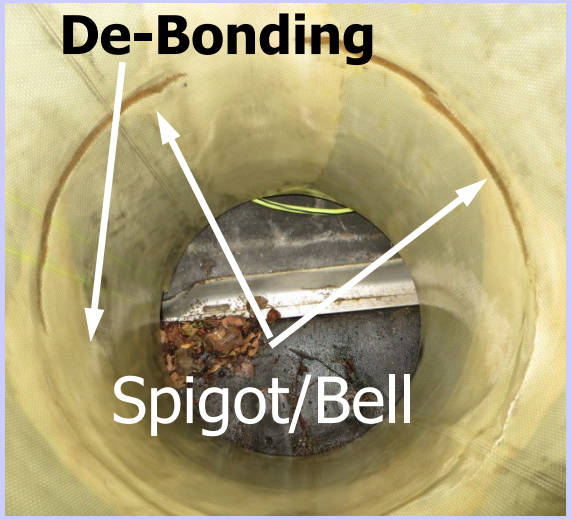
- 2 million cycles of traffic load, 100 cycles of thermal (40F°) deformation, & undermining excavation. No damage to 6-in. CI pipe w/ 16-yr lining and some thread tearing in 12-in. CI pipe w/ 10-yr lining. Polyurethane membrane intact. Pressure testing at 150 psig (6-in. CI pipe) and 90 psig (12-in. CI pipe).
- No tensile strength difference in longitudinal & hoop directions where damage absent, but some reduction where threads damaged.
- No significant difference in lap shear strengths of field, field mechanically aged, and 2000 unaged specimens.
- No difference in 6-in. peel strengths. 12-in. not comparable.

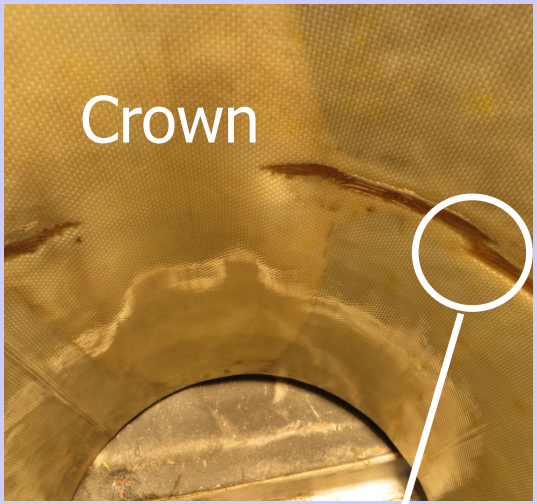
Slow Cooling of Cured-In-Place Liners for CI and Steel Pipelines Stewart, Weinberg, Berger, & Strait, 2019

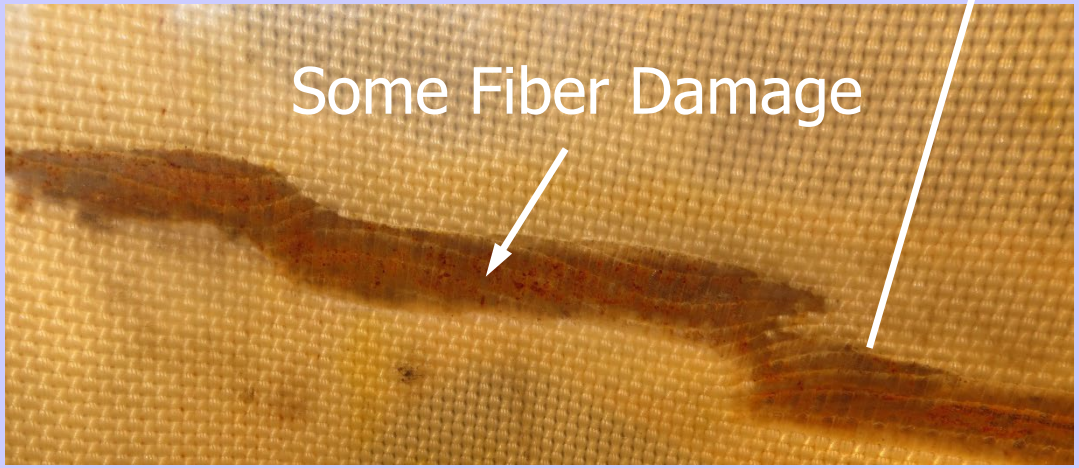
- Slow cooling in environmental chamber over months ~ 80 days, not rapid thermal deformation
- No leakage or thread damage at 20 psig in 12-in. CI specimens with 18-yr lining life. Specimens intact.
- No leakage or thread damage at 20 psig in 12-in. steel specimens with new lining. Specimens intact.
- Slow cooling eliminates the thread damage associated with rapid thermal deformation

12 in. CI Lined Pipe Joint

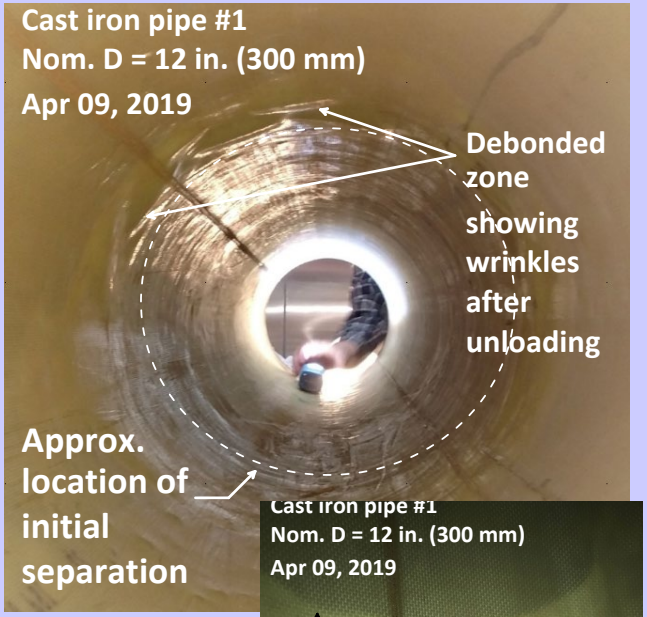
Post-Mechanical Aging Tests

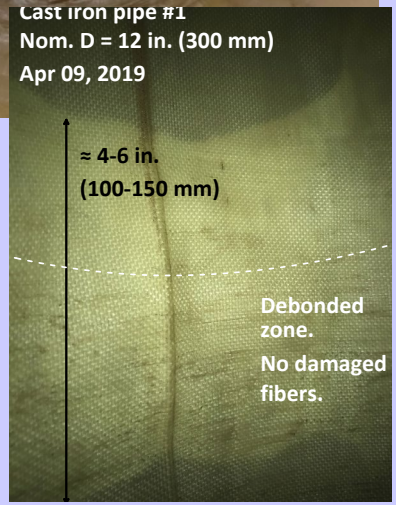




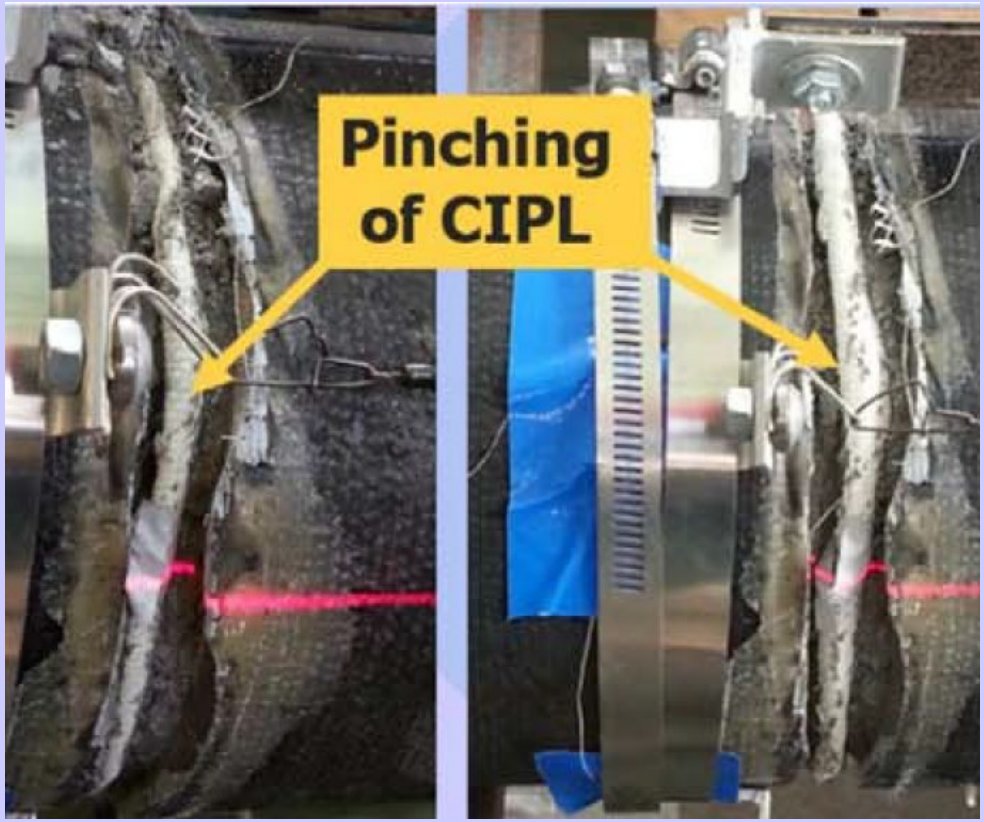


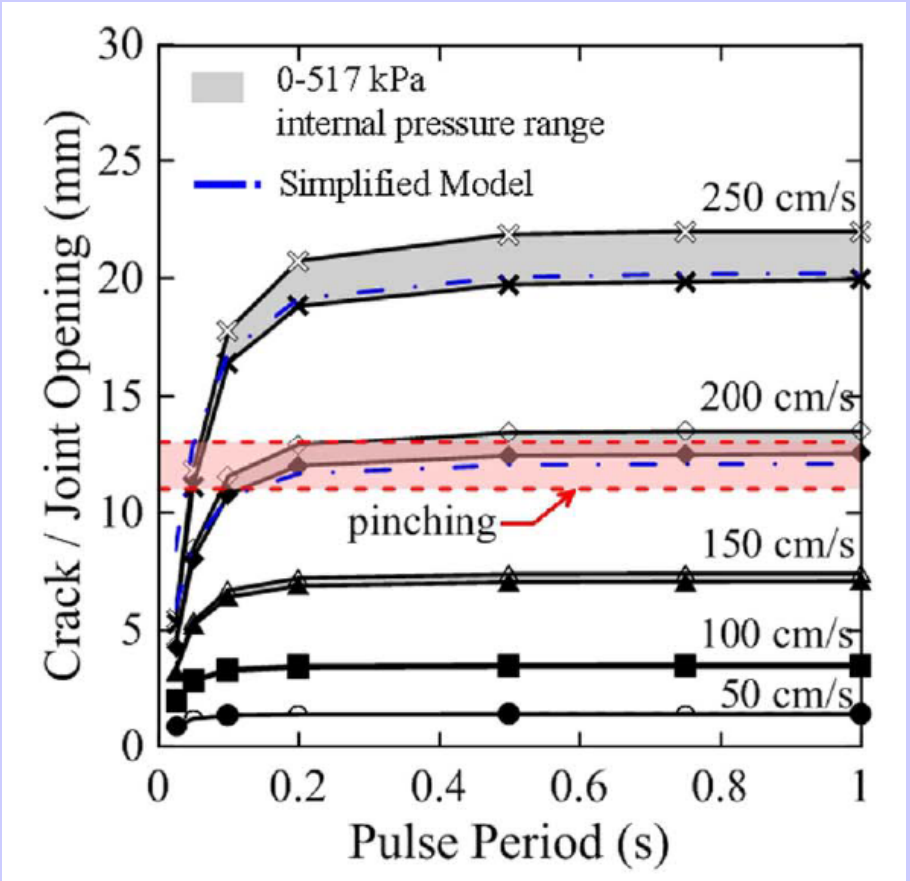
Slow Cooling



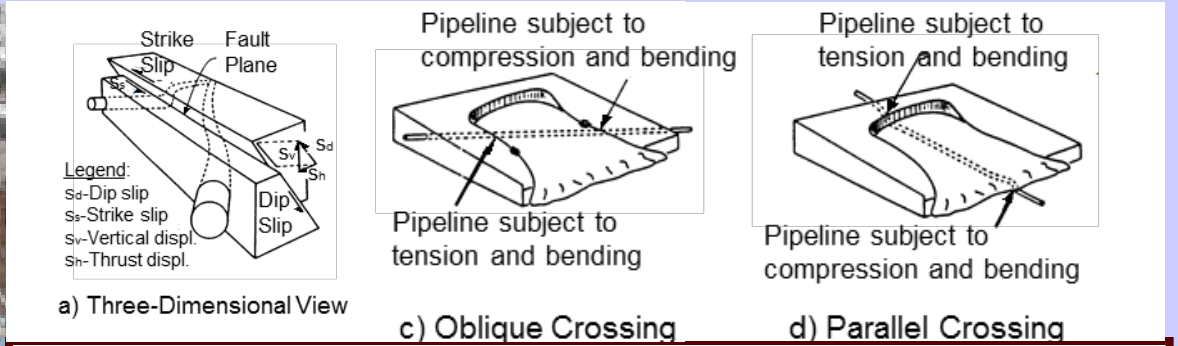


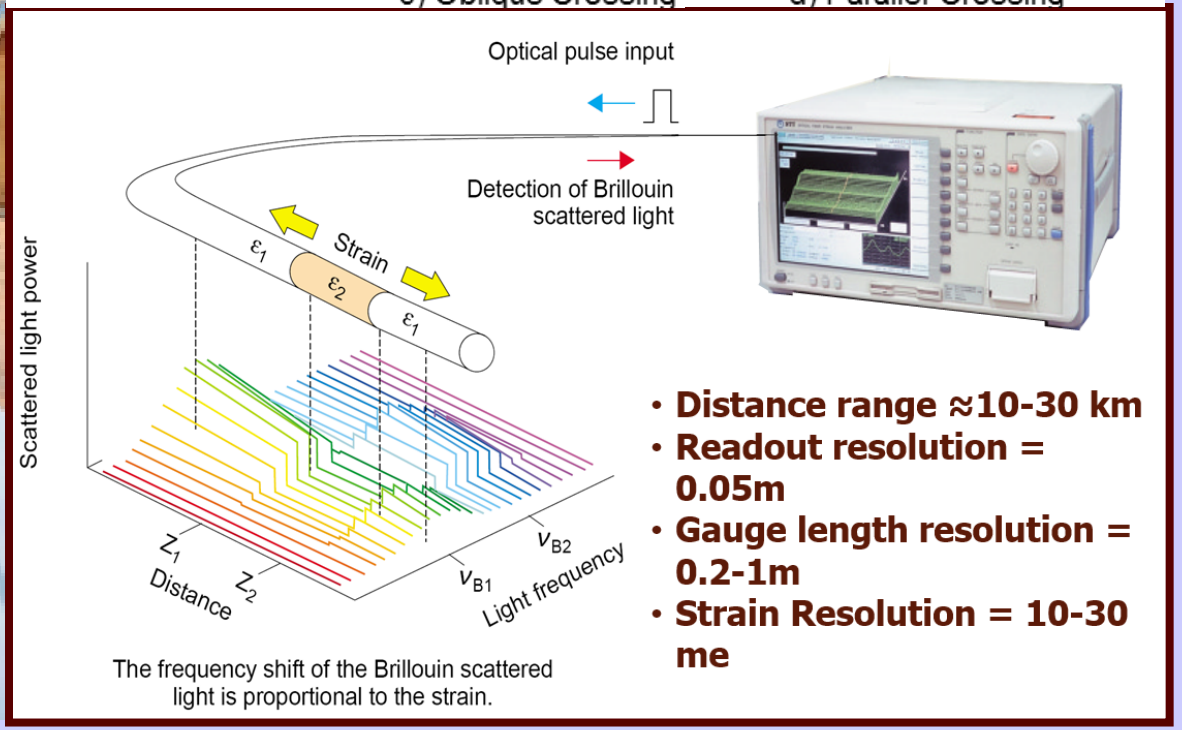
Earthquake Response of CIPLs





Intelligent CIPP





- **Distance range ≈10-30 km**
- **Readout resolution = 0.05m**
- **Gauge length resolution = 0.2-1m**
- **Strain Resolution = 10-30 me**