The feasibility of dynamic full-field earthquake measurements from space: a laboratory study

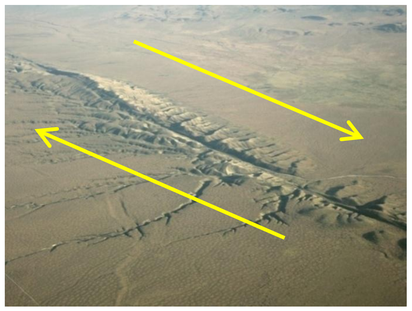
Vito Rubino, Nadia Lapusta, Ares Rosakis
California Institute of Technology

Research goals

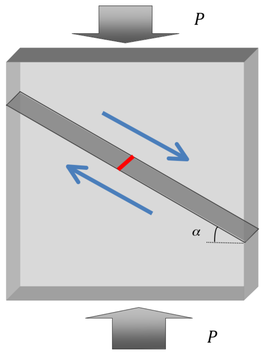
- Investigate the feasibility of dynamic full-field earthquake measurements from space through laboratory studies.
- First, employ digital image correlation techniques (such as VIC-2D and COSI-Corr) to study the final static deformation of a dynamic crack with 'before' and 'after' event images of specimens undergoing dynamic frictional sliding.
- Next, extend digital image correlation to high speed photography to capture dynamic rupture propagation.

Background

From real earthquakes to… laboratory earthquakes

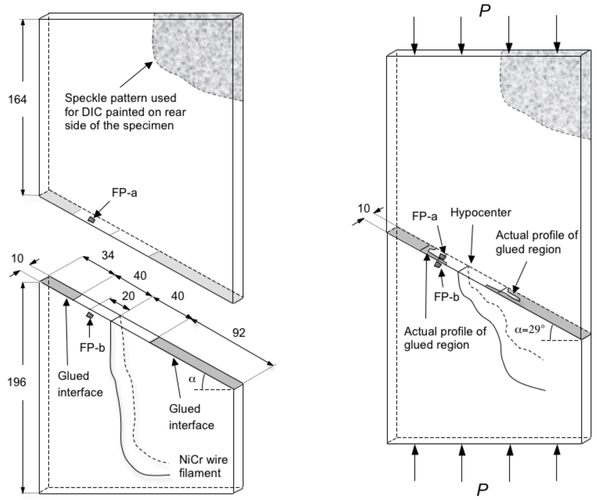


San Andreas strike-slip Fault, Carrizo Plain
(http://tharsisgallery.com/san-andres-fault-pictures)



Earthquakes are mimicked in the laboratory by the dynamic rupture propagating along an inclined frictional interface formed by two Homalite quadrilateral plates under compression (Xia et al., 2004). The static compressive stress *P*, applied to the test specimen assembly, provides resolved shear and normal stresses on the fault, simulating tectonic stresses applied to a strike-slip frictional fault within the Earth's crust. Dynamic rupture is triggered through the electrical discharge provided by a NiCr wire filament.

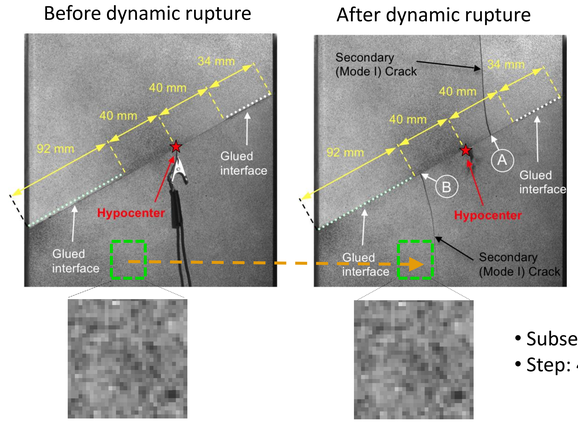
Experimental Method



Test specimen geometry and loading configuration. The interface is partially glued in order to confine the rupture before it reaches the ends of the specimen. The glue smears over an irregular profile such as that shown on the right hand side. Front side of the specimens has reflective tapes for laser interferometer measurements (FP-a and FP-b) and rear side is painted with a speckle pattern for digital image correlation. All quotes are in mm.

Digital Image Correlation

Digital Image Correlation (DIC) is an optical method to measure the deformation on a specimen surface. DIC technique identifies gray level patterns in small pixel subsets and tracks their motion during deformation. Two methods are used in this study: VIC-2D (Correlated Solutions Inc.) and COSI-Corr (Leprince et. al, 2007).

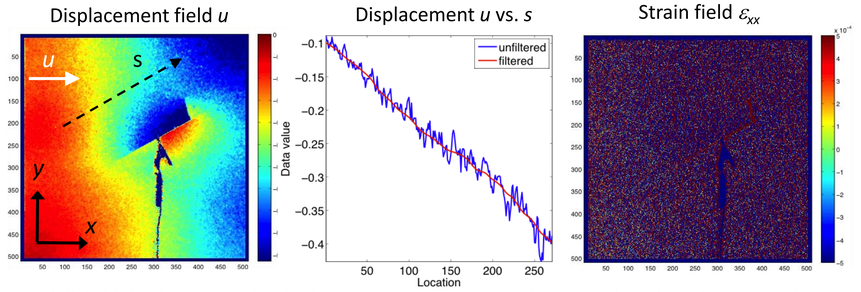


- Subset size: 32x32
- Step: 4

Experimental Results

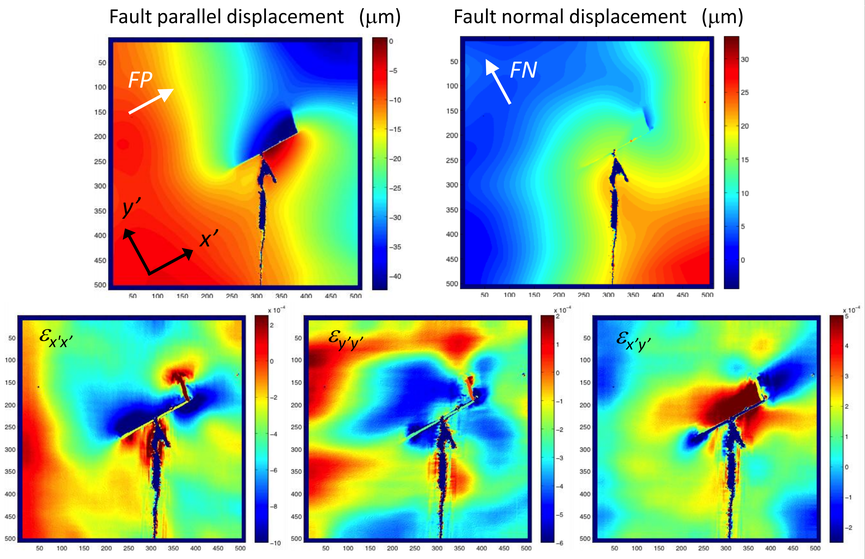
Test 1, P = 5 MPa (COSI-Corr)

Before Filtering



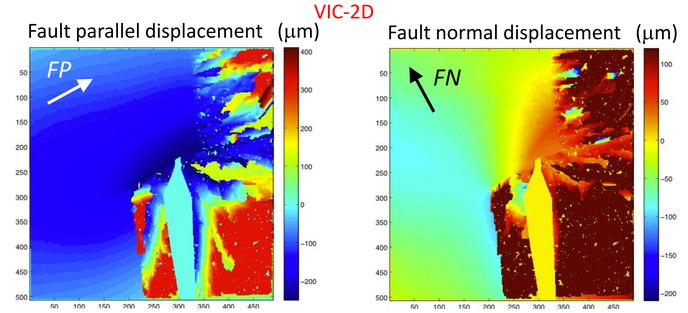
The full-field displacement clearly shows relative motion on the two sides of the fault. In order to compute strains, we denoise the displacement field using the tool available in COSI-Corr, based on Buades et al (2008).

After Filtering



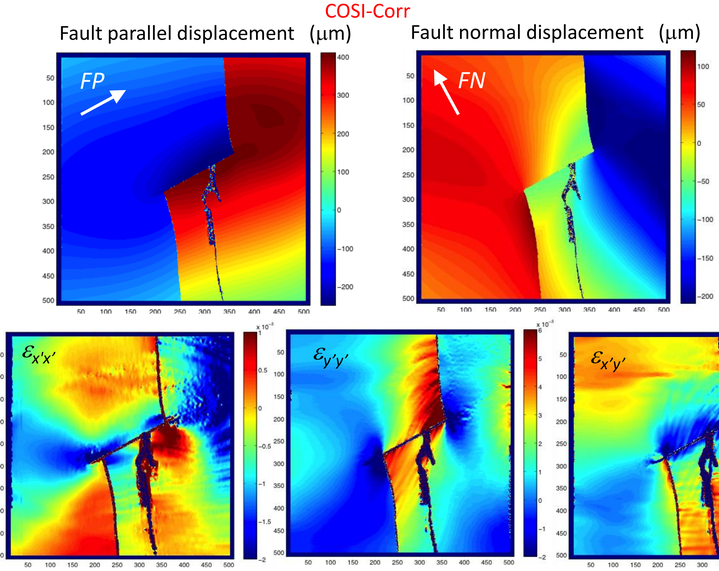
Test 2, P = 15 MPa (VIC-2D vs. COSI-Corr)

VIC-2D

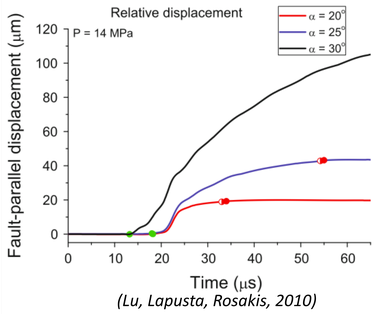


Due to the presence of secondary mode I cracks, VIC-2D correlation does not converge. In contrast, COSI-Corr discards subsets where the correlation does not converge. As a result, COSI-Corr analysis accurately shows (i) the propagation of the dynamic rupture along the frictional interface, (ii) the rupture arrest on the glued boundaries, (iii) the presence of two wing cracks.

COSI-Corr



Towards dynamic measurements



(Lu, Lapusta, Rosakis, 2010)

The error analysis of the static measurements suggests that useful dynamic measurements should be feasible.

- Estimated method error e_{im} =0 .04 pixels
- Displacement to capture: $d \approx 20$ μm
- Allowable error: e_o = 10% of d = 2 μm
- Needed pixel size: e_o / e_{im} = 0.05 mm / pixel
- High speed camera resolution: 574x767 pixels
- Observation window: 30x40 mm

=> Adequate window for meaningful study

Conclusions and Future Work

- Successfully characterized full-field static displacements and strain of a dynamic crack with digital image correlation techniques.
- Two DIC software packages have been tested: COSI-Corr outperforms VIC-2D, especially in the presence of opening cracks, such as in Test 2.
- Next, perform dynamic measurements with high speed camera in order to capture the time dependent behavior.