Laboratory earthquakes: Measuring surface displacements with high-speed DIC

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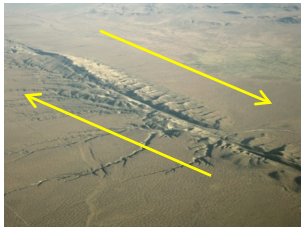
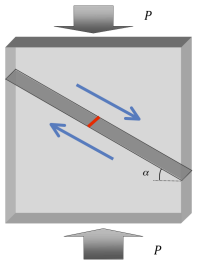
Research goals

- 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.

From real earthquakes to laboratory earthquakes

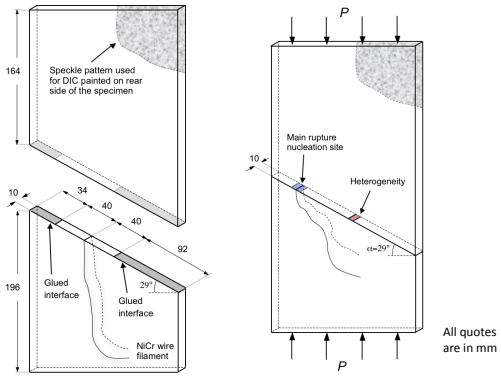


San Andreas strike-slip Fault, Carrizo Plain
(http://tharsisgallery.com/san-andres-fault-pictures)



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.

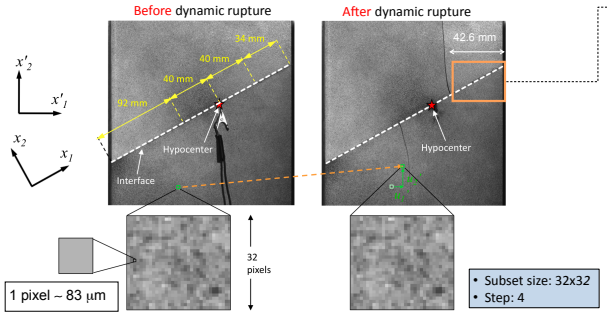
Specimen configurations



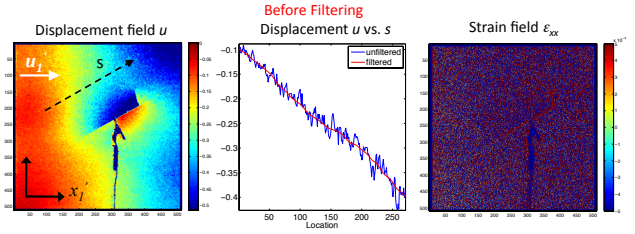
- Study discussed in this poster: interface is either uniform or partially glued in order to confine the rupture before it reaches the ends of the specimen.
- Ongoing work: interface contains a patch of heterogeneity with lower strength, higher stress, or pre-existing subcritical crack. The aim is to study dynamic triggering of a secondary rupture on a patch of heterogeneity and explore potential transition to supershear speeds (Liu and Lapusta, 2008).

Digital Image Correlation (DIC)

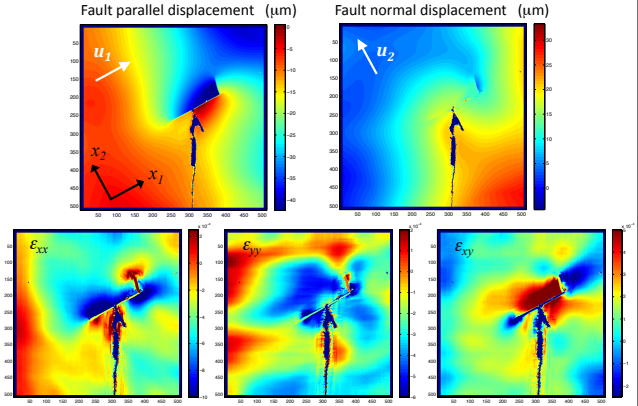
Digital Image Correlation (DIC) is an optical method to measure the deformation on a specimen surface. DIC technique identifies gray level patterns in small pixel subsets and tracks their motion during deformation. Two methods are used in this study: VIC-2D (Correlated Solutions Inc.) and COSI-Corr (Leprince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



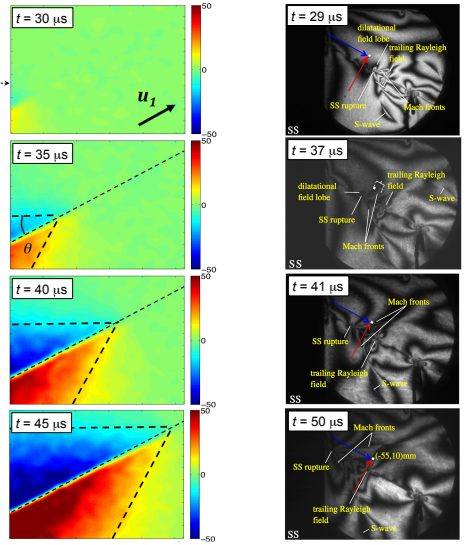
Static Measurements



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).



Dynamic Measurements



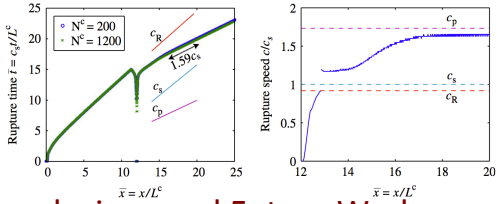
- Interface length (shown in frame): ~40 mm
- Rupture goes through interface in t < 20 μs
- Computed rupture speed: v_r ~ 2.5 mm/μs
- Compare to Homalite wave speeds:
  - c_s = 1.29 mm/μs
  - c_p = 2.61 mm/μs
- Mach cone angle is given by:
  $\sin\theta = c_s / v_r$, $\theta \sim 30°$
- Mach cone will advance ~ 12.5 mm

Subset: 21 pixels
Step: 1 pixels

High-speed photoelastic images from Mello et al, 2010.

Fault Heterogeneities

We are currently investigating supershear transition by dynamic triggering of a secondary rupture on a patch of heterogeneity, such as a preexisting subcritical crack or a patch of higher prestress, to extend and experimentally validate the study of Liu and Lapusta,2008.



Conclusions and Future Work

- Successfully characterized full-field static displacements and strain of a dynamic crack with digital image correlation techniques (COSI-Corr and VOC-2D).
- Performed dynamic measurements by coupling high speed photography and digital image correlation.
- Designing experiments to study potential transition to supershear speeds due to favorable heterogeneity.