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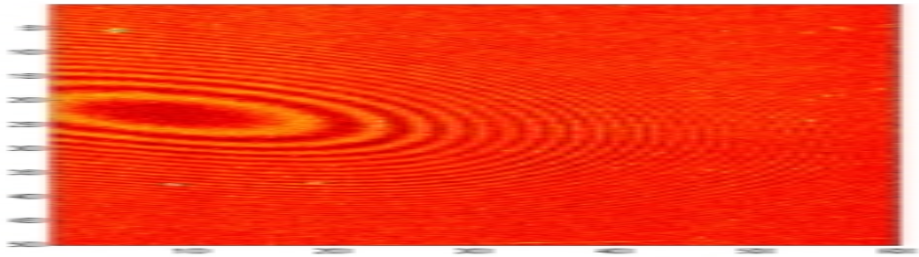

X-Ray Micro-densitometry of Amorphous MoRuB for LIGO Flex-Joint Mirror Suspensions

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Overview

- Gravity waves, LIGO, and Suspensions

  - quick overview

- X-Ray Micro-densitometry

  - why it is necessary

- The Process

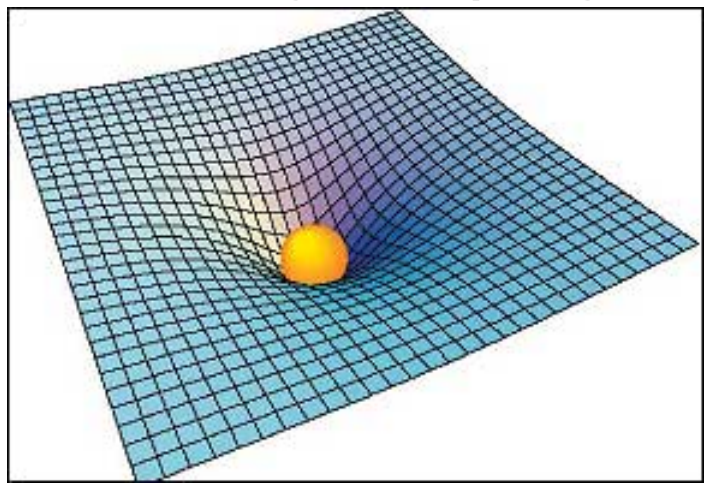
  - how x-ray micro-densitometry is done

- Results

  - what we were and will be able to certify with this technique

Gravity waves, LIGO, and Suspensions

Einstein: Gravity is described by warping in space-time.



http://www.npr.org/programs/atc/features/2002/sept/gravitywaves/index.html

Gravity Wave: *Ripple* created in fabric of space-time that propogates at the speed of light.

(caused by things such as super nova explosions and the big bang)

Gravity waves, LIGO, and Suspensions

LIGO will (hopefully) detect these gravity waves, directly confirming GR and opening a new realm of astronomy

http://www.ligo-wa.caltech.edu/aerial_full.jpg

Detection is done through a Michelson Morley laser interferometer

Gravity waves cause mirror displacement, resulting in length changes in different directions in each arm, producing signals for us to interpret

Gravity waves, LIGO, and Suspensions

However

Gravity Wave displacement very small (~10^{-18}m!!!) (proton's diameter ~10^{-15}m)

Need to hang the mirrors *very* carefully

- Currently- piano wire
- Predicted upgrade- fused silica wires
- Better upgrade?- amorphous metal flex joints

Gravity waves, LIGO, and Suspensions

Amorphous MoRuB currently being manufactured and tested here at Caltech

Looks Promising!!!

Current Plan of flex-joint shape

300 microns long, 3mm wide, and 10 microns thick

Plan to hang tens of kilogram, fraction of a million dollar mirrors off these joints

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X-Ray Micro-densitometry

Must be sure joint is correctly constructed

How?

- Series of tests verifying material properties (stress/strain etc..)
- X-Ray Diffraction

(determines glassiness)

- *X-Ray Micro-densitometry*

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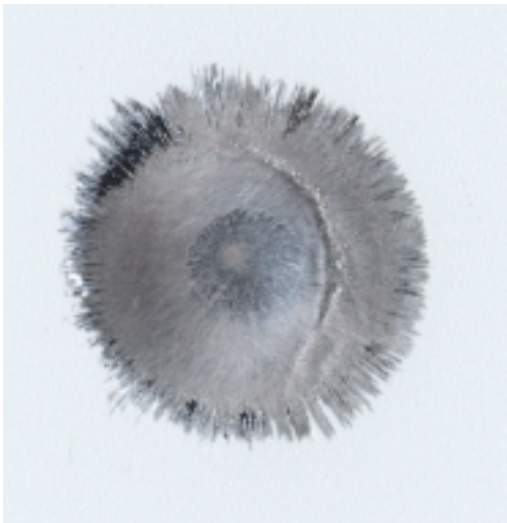
X-Ray Micro-densitometry

4 Incentives for X-Ray Micro-densitometry

- to determine the uniformity of the thickness, compactness, and density of the splat-quenched sample (splat-quenching- technique used to make glassy metals)
- to certify the absence of cracks or holes (larger than the critical defect size) in the splat-quenched sample
- to select a region of the splat-quenched sample suitable to flex-joint creation (glassy and flat)
- to certify the final flex joint is uniform, has the desired shape, and is defect free

Incentives Incentives

Splat-Quenched Sample



(Thanks to Brian Emmerson for the photo)

Each splatted sample is unique

→ Need to know information on each sample to pick a region good for testing and, eventually, good for a flex joint

How does it work? The Process

3 Main Stages:

- X-Ray imaging the sample (thanks to the animal care facility for their help and the use of their machines)

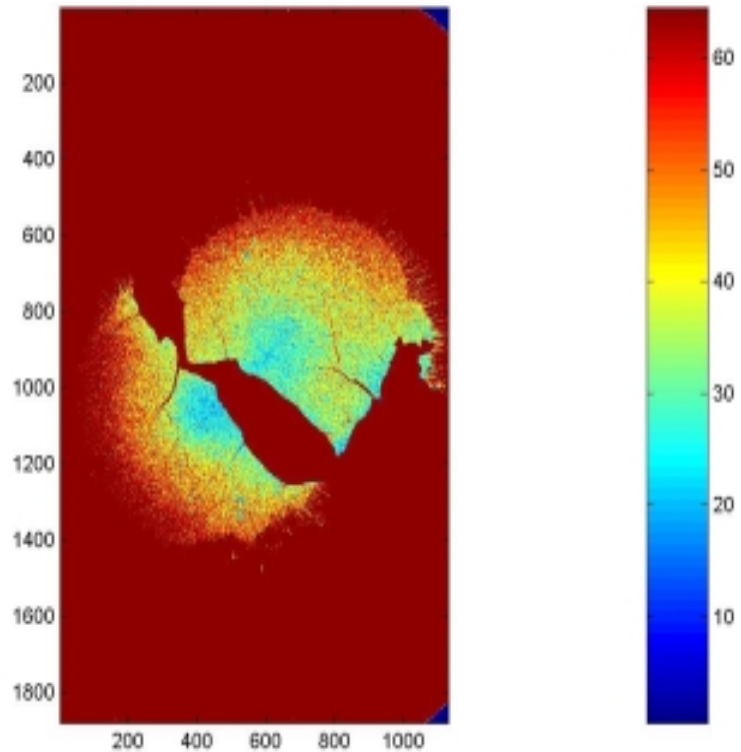
- digitizing the image (thanks to the digital media center for their assistance and the use of their machines)

- analyzing the image in Matlab

The Process: X-Ray Imaging

We used a standard diagnostic X-ray unit (just like what the doctor uses on someone when they break a finger, or what a vet would use to see the babies in a pregnant lemur) and standard mammography film by adjusting power settings we could image our sample so we could see thickness fluctuations, cracks etc..

(thanks to Dr. Russel Rose and Dr. Virginio Sannibale for help with this x-ray session)



Color enhanced x-ray

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The Process: Scanning and Analyzing

Digitizing

used Kodak Slide Scanner (4000ppi, translates to pixel dimensions of ~6x6 microns)

Analysis

done in Matlab

production of color maps, thickness-intensity number corrolation, pixel neighbor corrolation test, 2-d profiles

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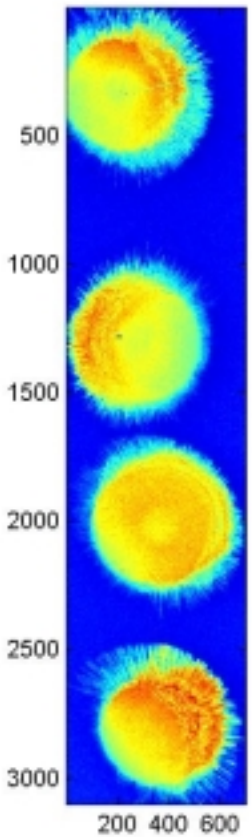
Results

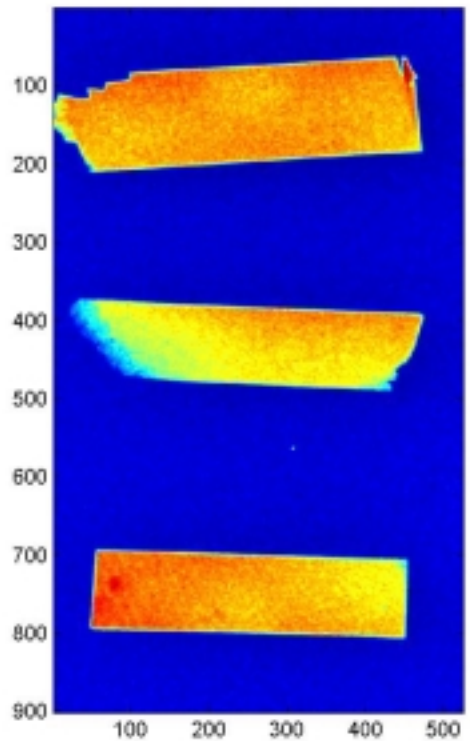
Whole splats

Can select suitable region to cut



Cut strips

Can re-asses cut region



OK

Bad

Bad

Want *Uniform* Strips

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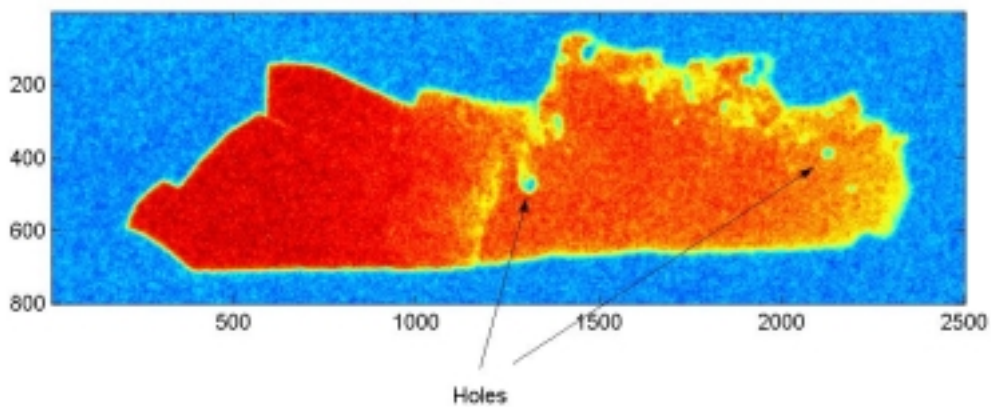
Results

Post Electro-chemically polished sample

(thanks to Stefano Tirelli for poloshing the sample)



Crystals are eaten preferentially, leaving holes which are evident is x-rays, indicating impure sample

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Quantitatively

- Can Detect Defect down to 6x6 microns (critical defect size ~100 microns)
- Locally can resolve surface variations ~4 microns (large scale ~27 microns)

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Conclusions

Success

Have technique which fulfills 3 of 4 designated tasks

- Determine Uniformity
- Locate Cracks/Holes
- Identify Amorphous Regions

4th Task, characterize finished flex joint, is expected to be a straight-forward development

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Acknowledgments

Thanks to:

Dr. Riccardo DeSalvo, Hareem Tariq, Animal Care facility, Digital Media Center, Dr. Russel Rose, Professor Johnson, Dr. Jan Schroer, Stoyan Nikolov, Professor Francesco Fidecaro, Virginio Sannibale, Mike Hall, Yoichi Aso, Kelin Wang, Brian Emmerson, Stefano Tirelli, and the rest of Riccardo's group. Caltech, LIGO, the LIGO REU program, and the SURF office. And, of course, the patient animals that waited in line for their X-rays.