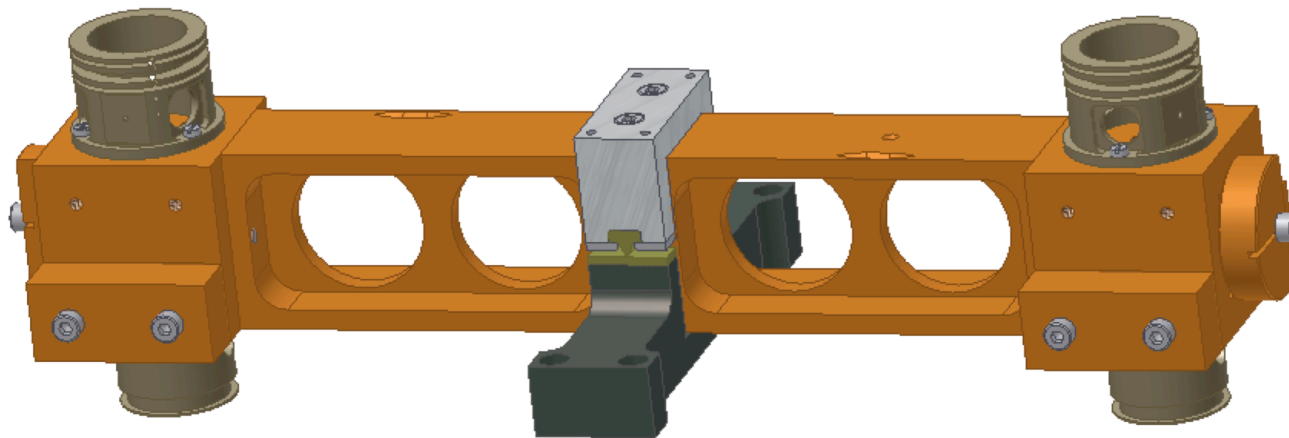




Tiltmeter Knife-Edge Development



A. O'Toole, F. Peña, G. Pu, A. Rodionov, M. Shaner,
E. Sobacchi, M. Asadoor, A. Bhawal, V. Dergachev,
R. Desalvo, C. Kim, Y. Minenkov, C. Murphy

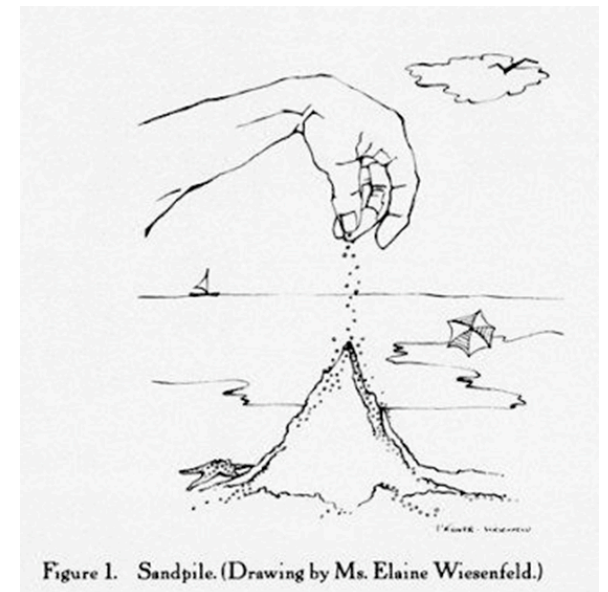
LIGO-G1001035

LIGO Tiltmeter Performance Limits

- Existing mechanical tiltmeters
- $1/f$ noise at low frequency
- Self Organized Criticality dislocation movement explains this excess noise

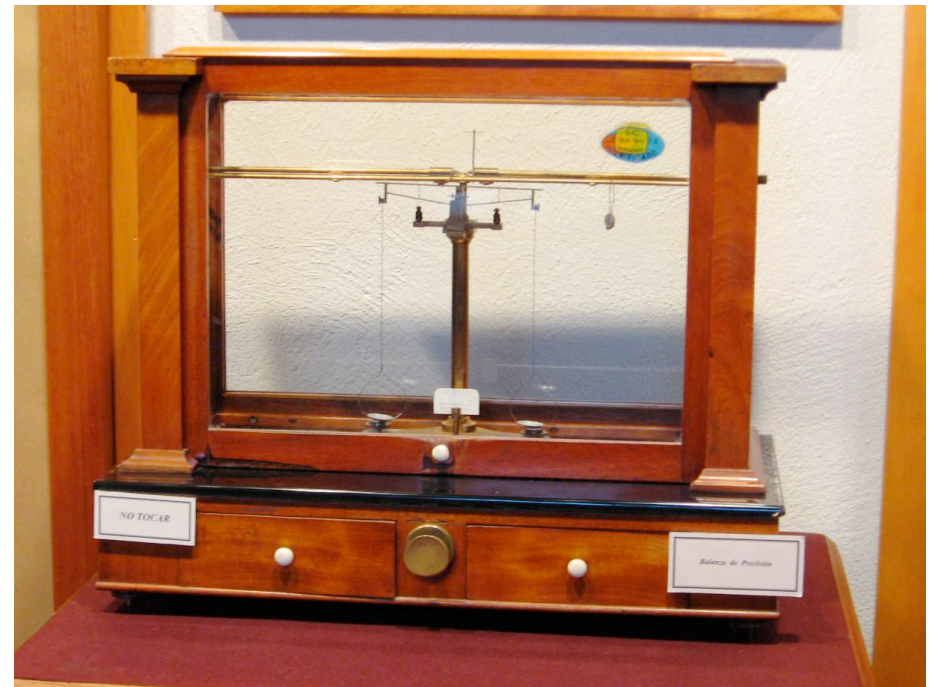
Per Bak 1996, How nature works: The Science of Self-Organized Criticality

• **R. DeSalvo** (2010) “The Role of Self Organized Criticality in Elasticity of Metallic Springs; Observations of a new Dissipation Regime.” LIGO-P1000105



LIGO How to Avoid the Limitation

- Solution: replace flexure with a non metallic hinge
→ Back to the future, return to the knife edge design of precision scales

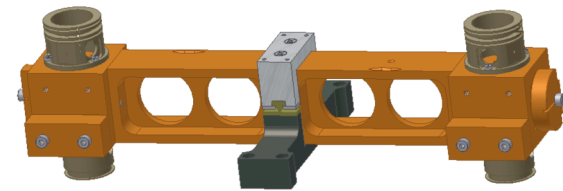




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Beyond the old Knife-edge Design

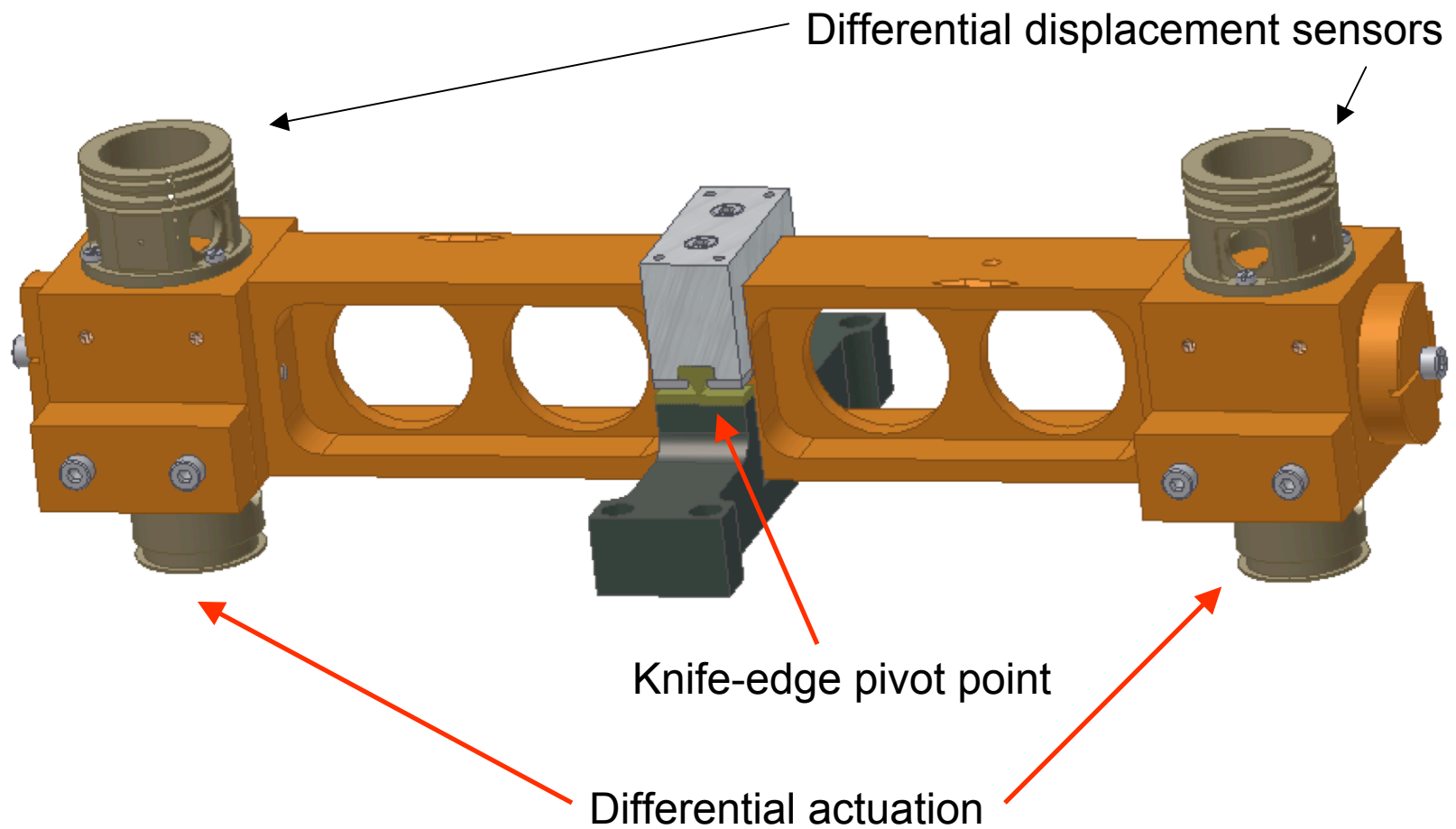
- Old design based on natural hard stones to manufacture low loss knife edge hinges
- Tungsten carbide (WC) is a high tech, precision machinable, very hard stone
- Advanced coating (TiN, DLC, Diamond...) allow for even harder stones and less losses





Tiltmeter design

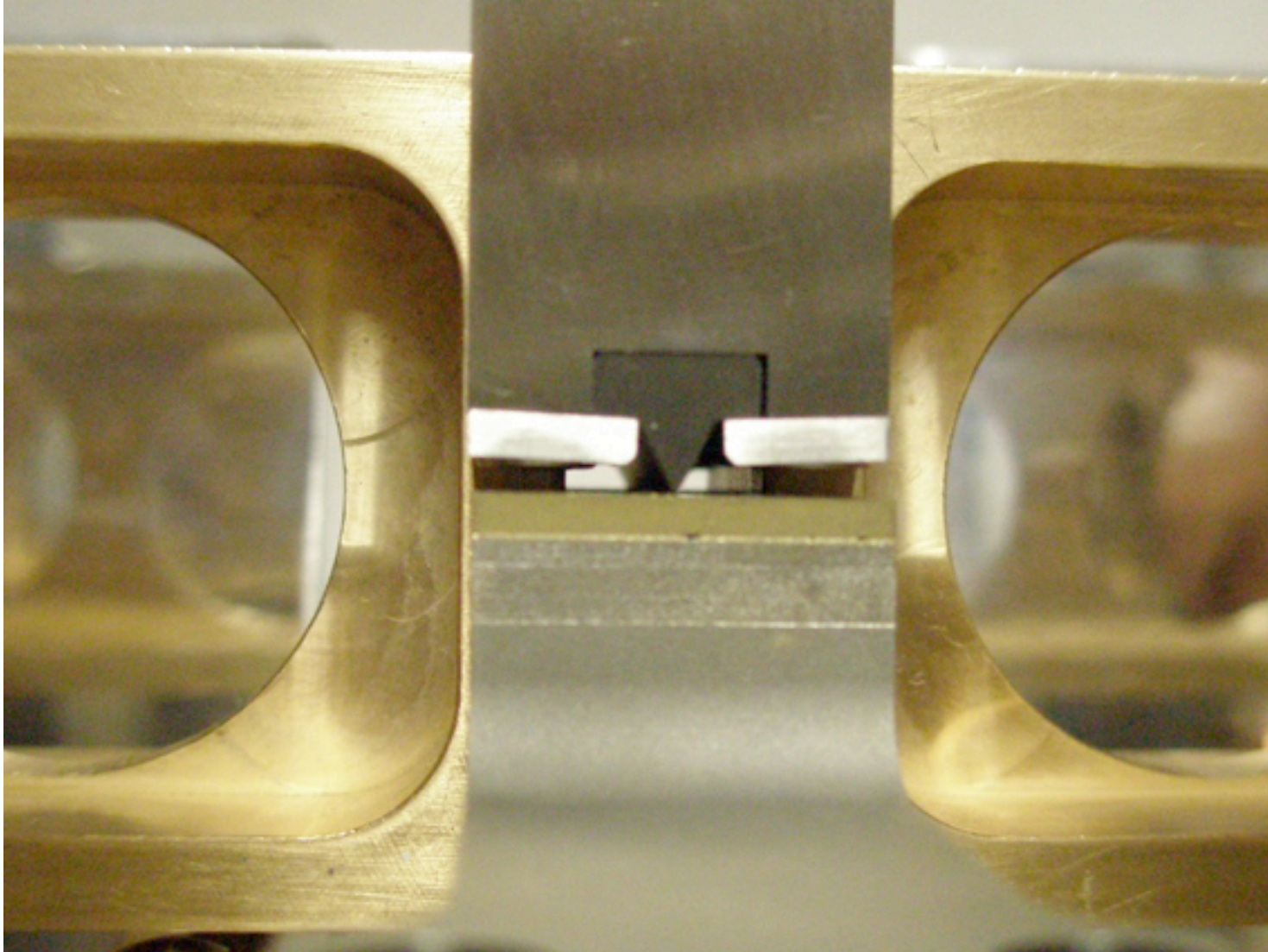
- Gravitational frequency tuning



To do a good tiltmeter,
we need a good knife edge.



LIGO Knife-edge Development



LIGO Knife-edge Manufacturing

- Knife edge cut from tungsten carbide block using wire Electrical Discharge Machining (EDM).

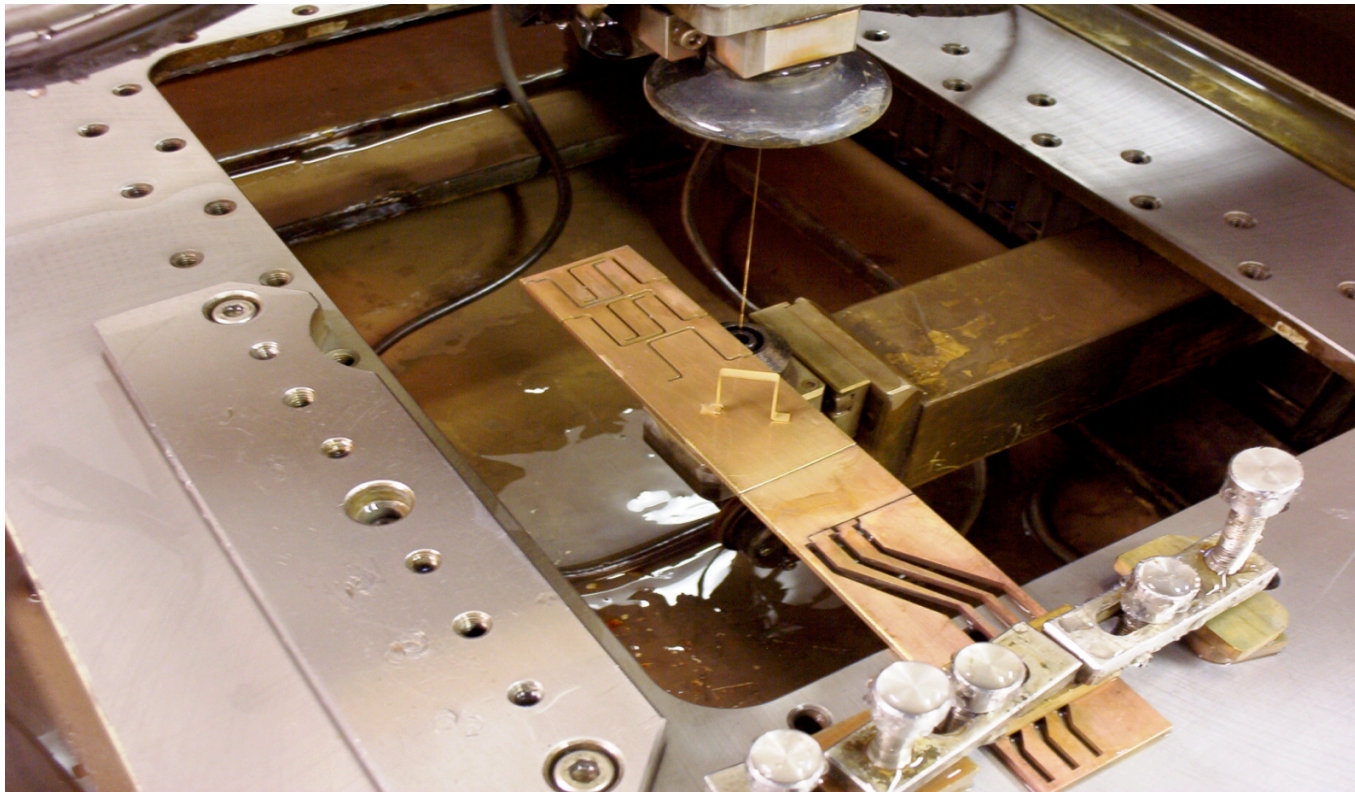
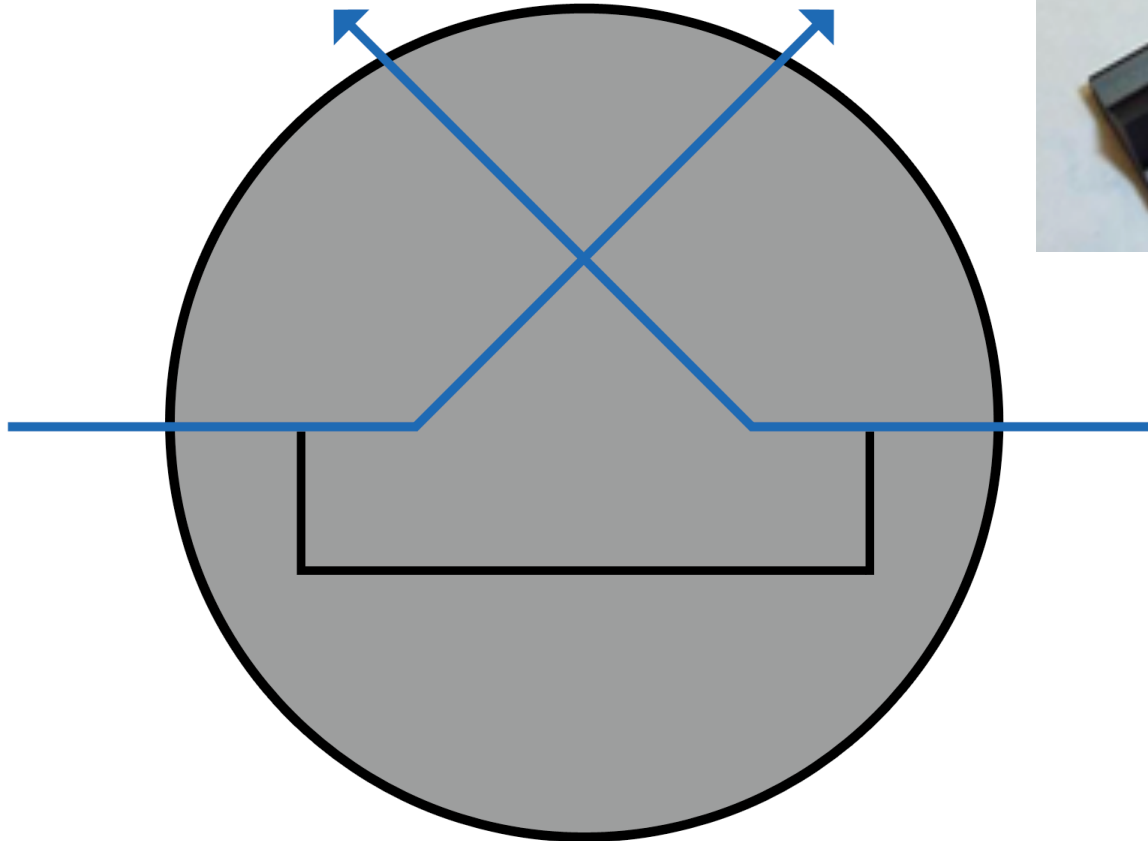
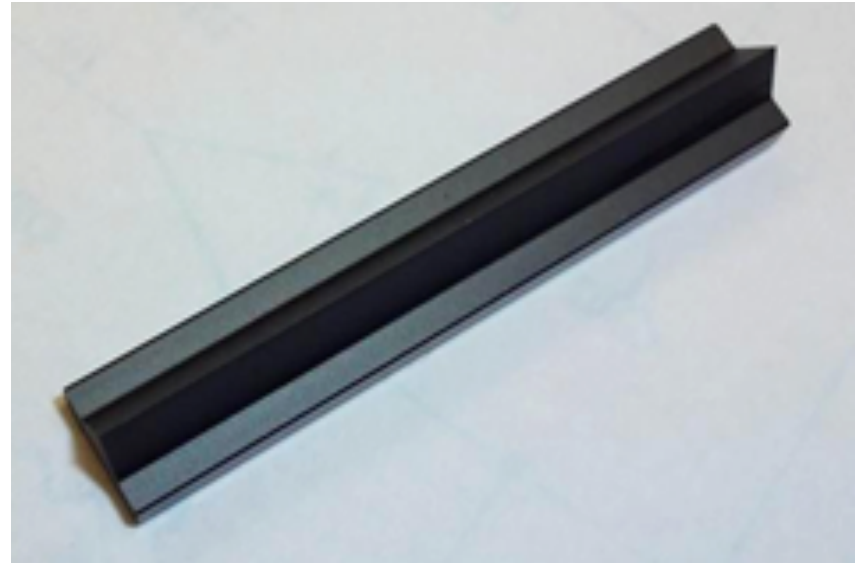


Image source: <http://www.cumberlandmodelengineering.com/>



LIGO Knife-edge Manufacturing

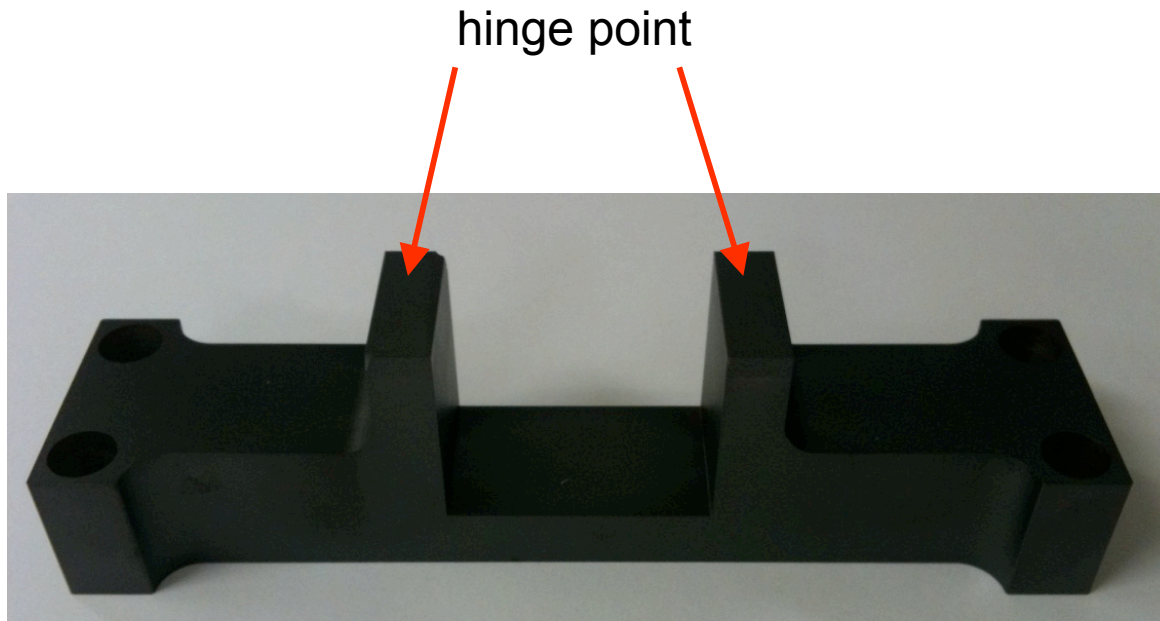
- Cutting profile first implemented.





Anvil Development

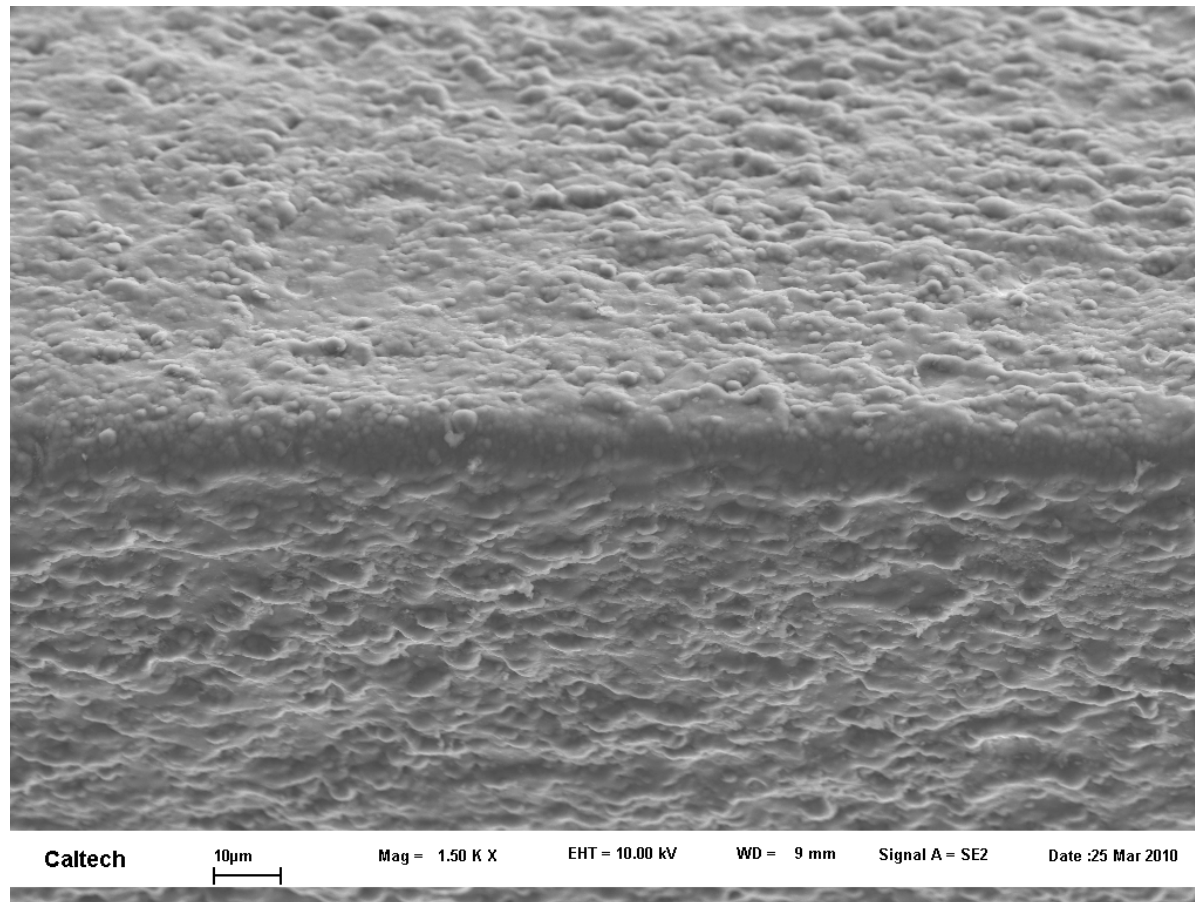
- 16mm of pivot contact on standard anvil
- Tungsten Carbide anvil





LIGO Knife-edge Development

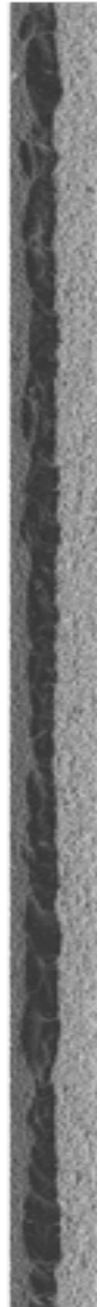
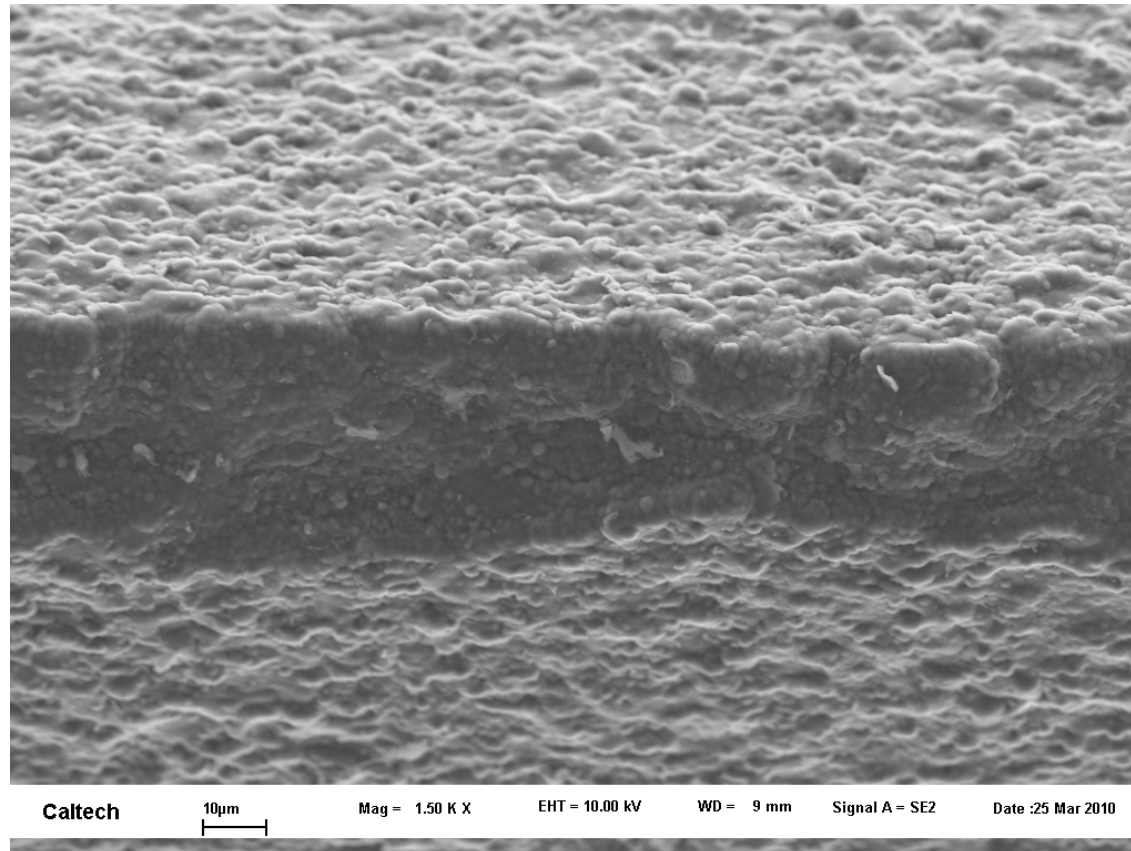
- Clean sharp edge gives low noise.
- Analysis was performed using SEM.





Knife-edge Problems

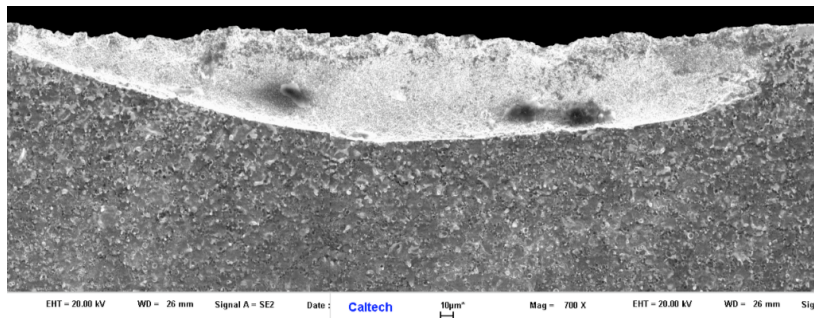
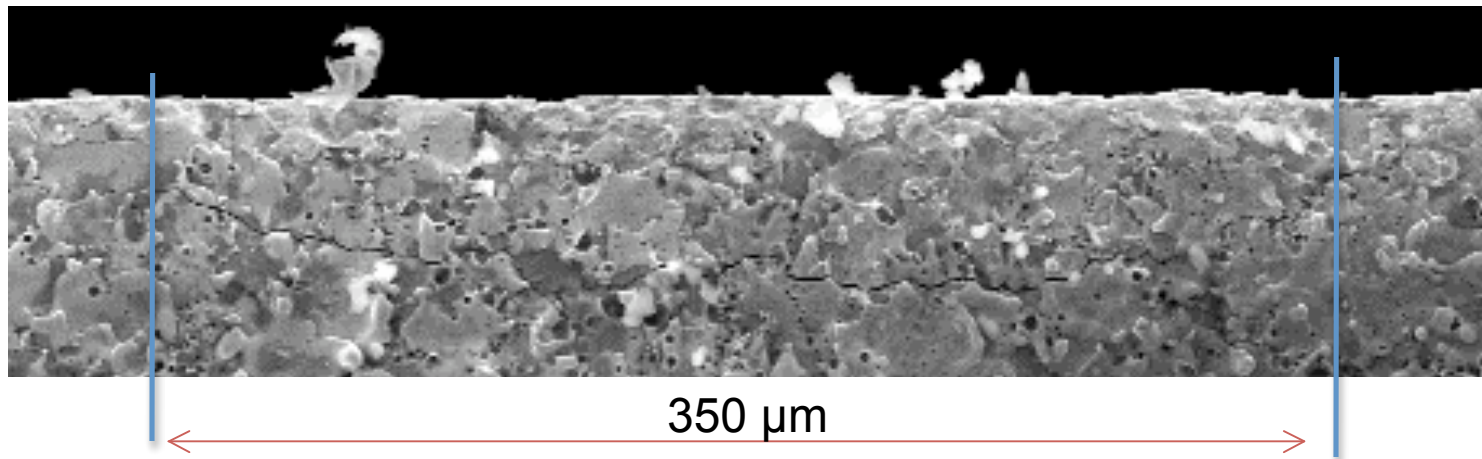
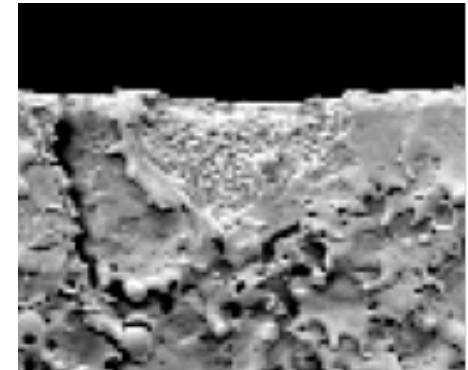
- Major cracks were found on some edges!
- Mean crack width: 34 μm





Knife-edge

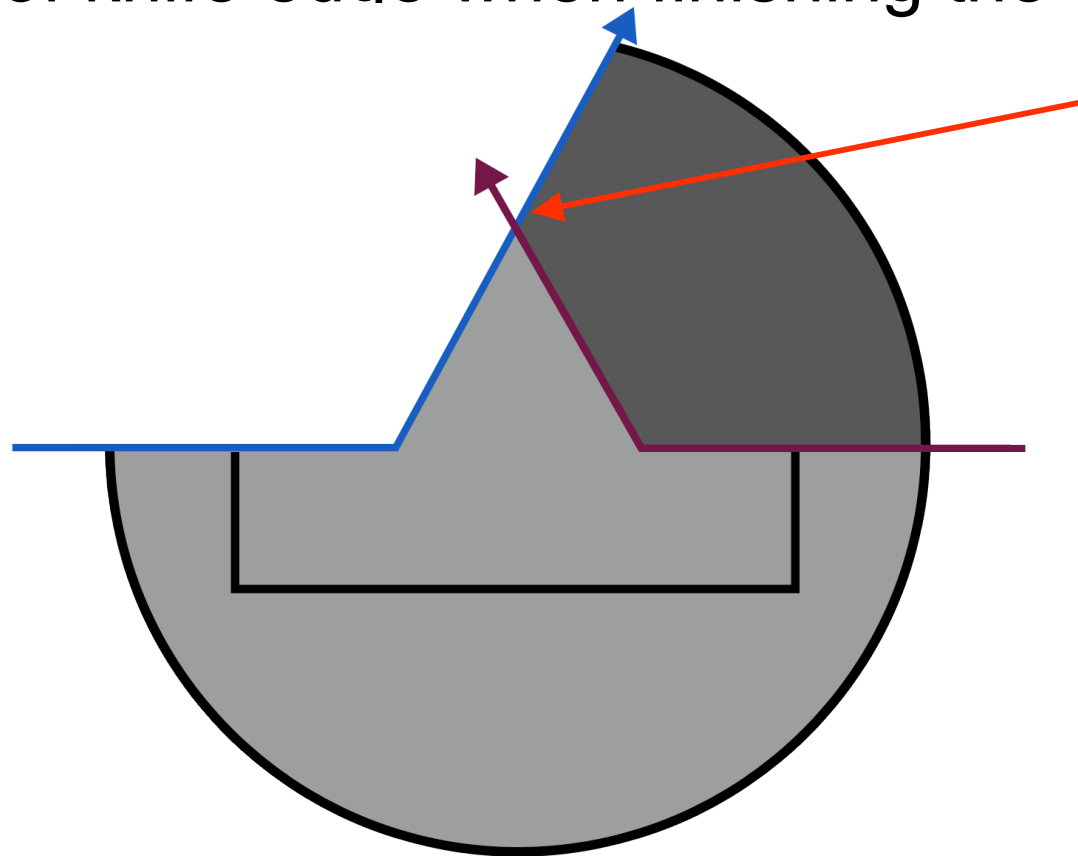
- Underlying cracks were also found!





Source of the Crack

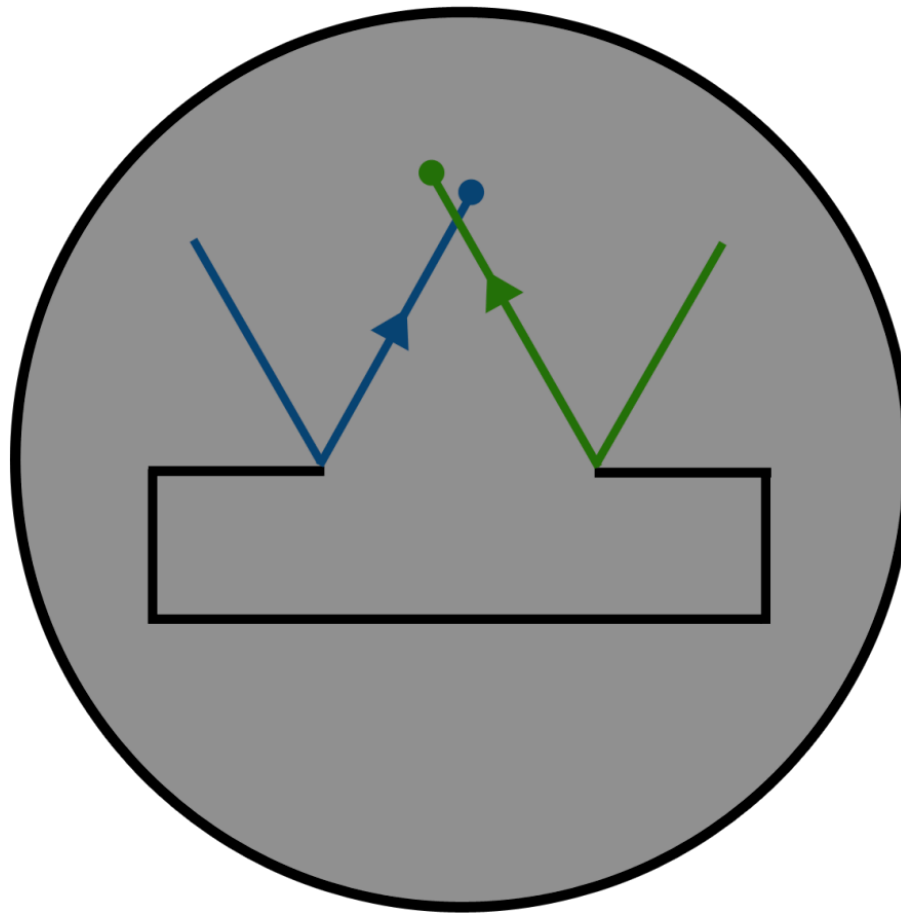
- Cutting scheme first employed is to blame for the crack.
- Huge force concentration on the business end of knife edge when finishing the cut





Knife-edge Solution

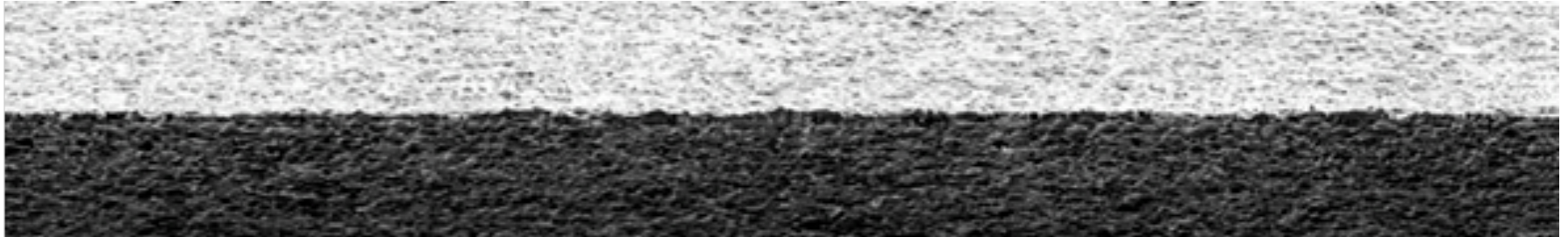
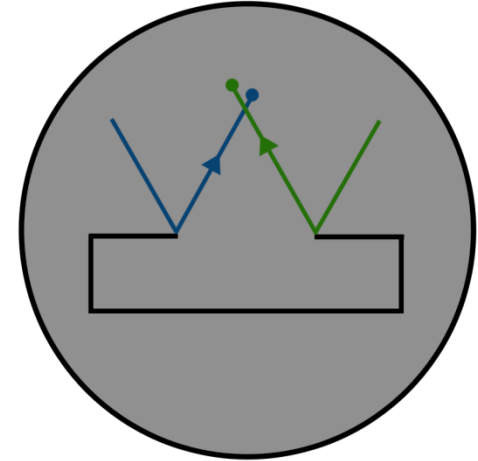
- New cutting scheme avoids the large force concentration on the tip of the knife edge.





Result:

- Wedge cut with new scheme was found to not contain the crack defect.

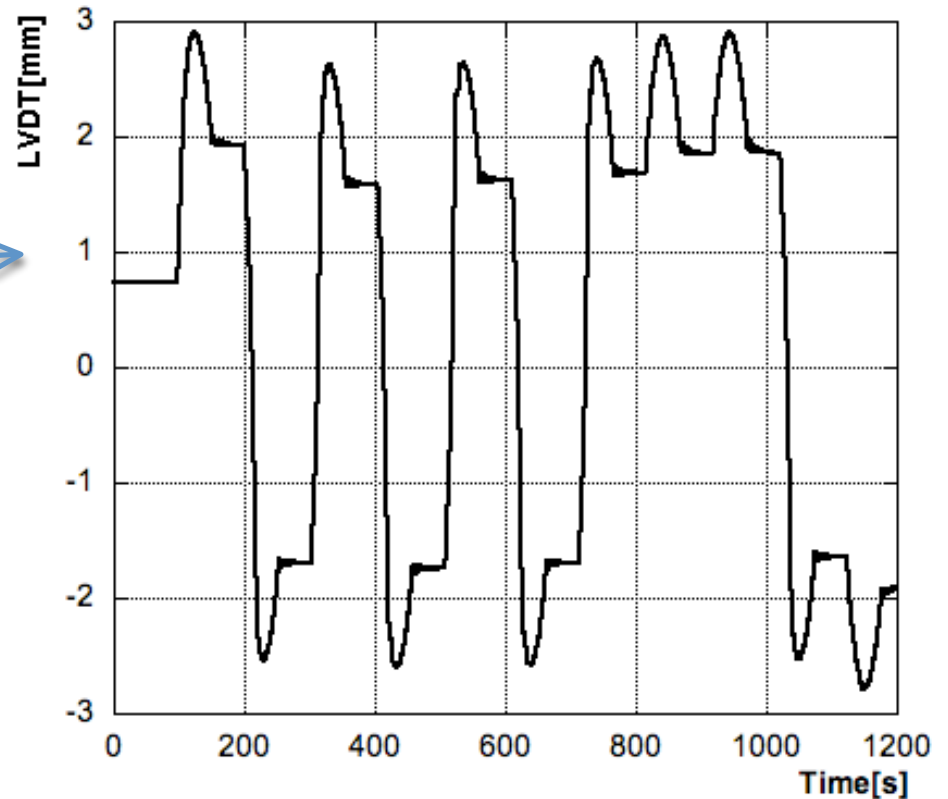




Experimental Results

- Knife edge was implemented to avoid hysteresis

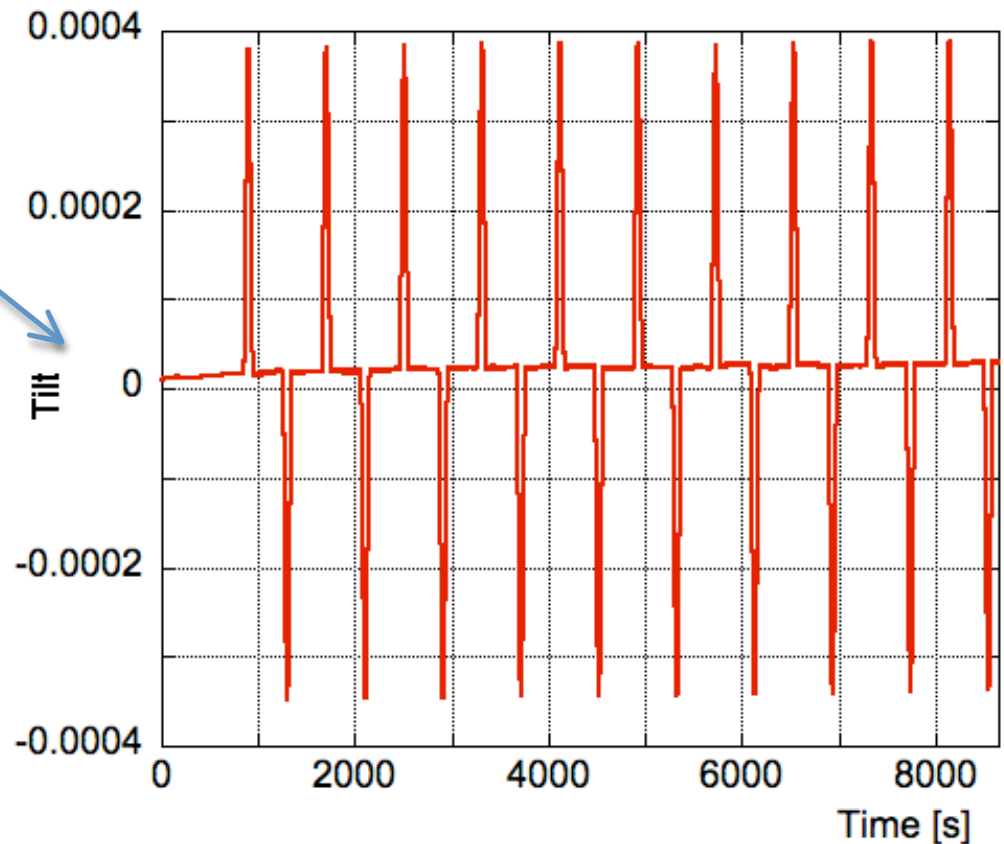
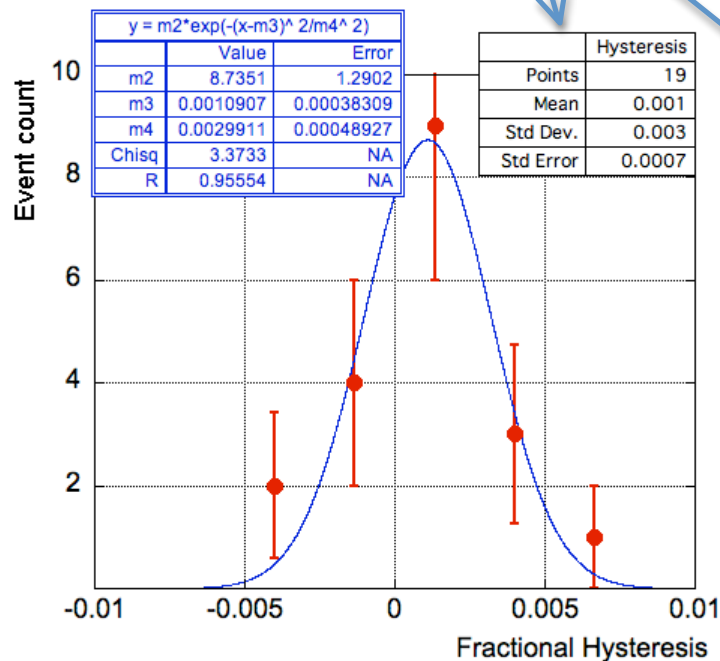
- Example:
Hysteresis in a
Maraging filter





Recent Results

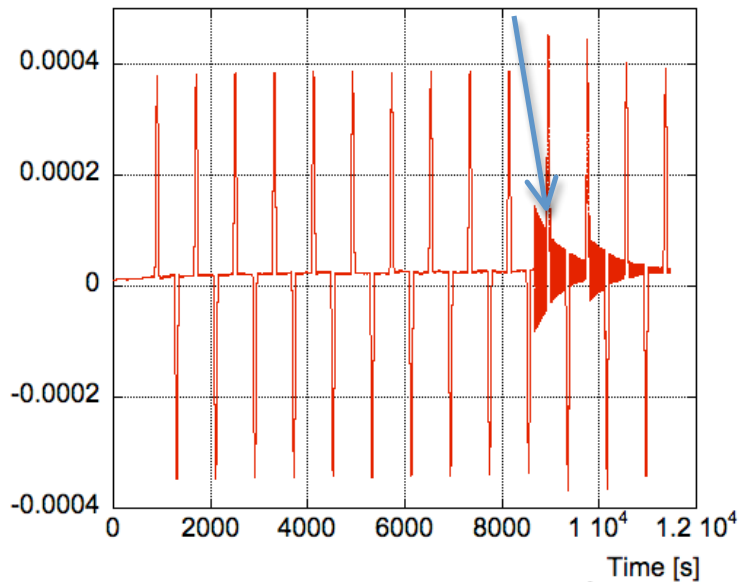
- Knife edge implemented to avoid hysteresis
- ~ No Hysteresis in tiltmeter



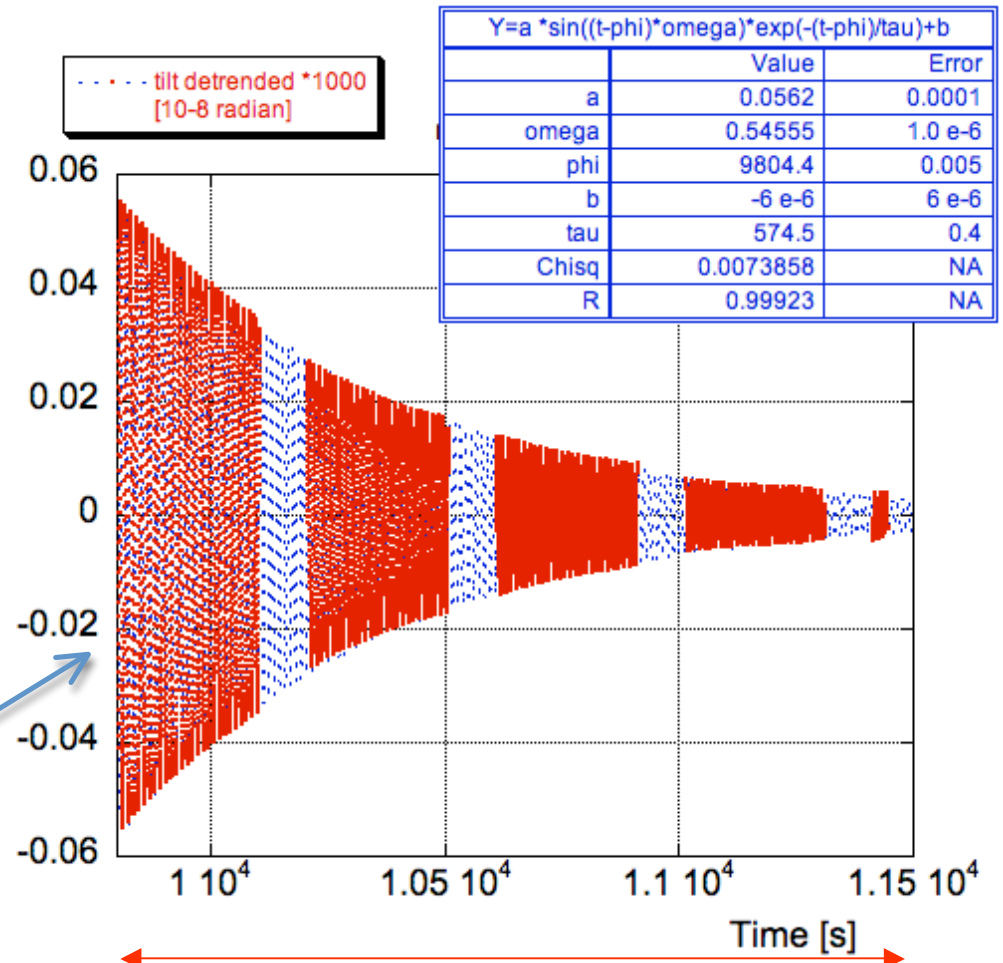


Quality Check

- Seismic event



- Very good fit
 - Coherent decay
- Through excitations



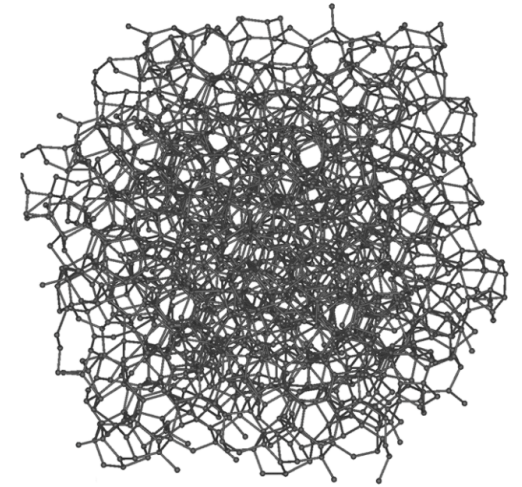
half an hour!



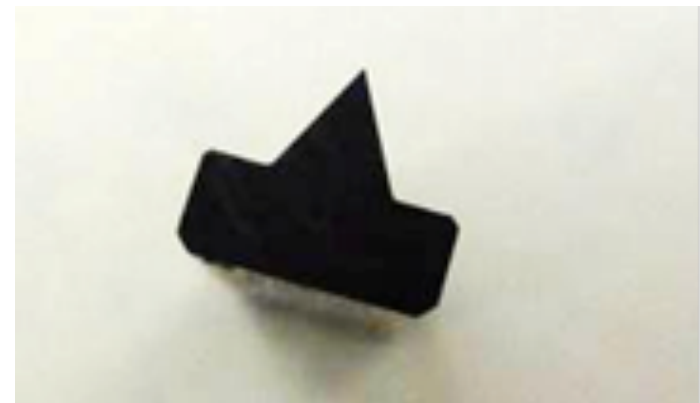
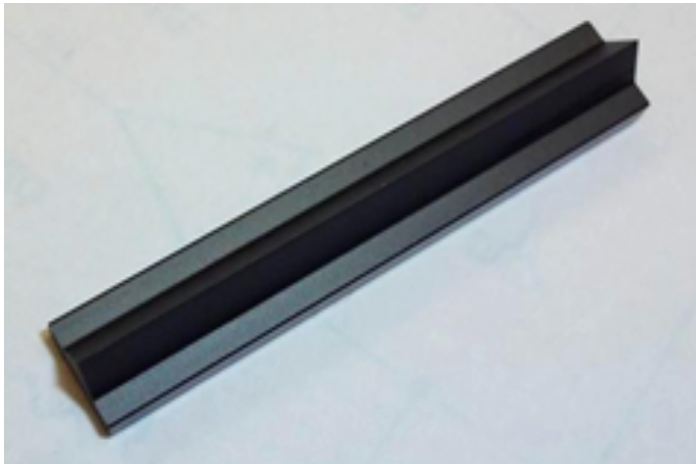
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Further Developments

- Currently implemented 45mm WC blade is uncoated, “naked”
- Future coating options:
 - PVD Diamond Like Carbon (DLC)
 - CVD DLC
 - Tungsten carbide (Glass)
 - Titanium Nitride
 - Diamond



Source: Wikipedia-
Amorphous carbon



End of talk.