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# Silicate Bonding Research at Caltech

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**Caltech**

**LSC Meeting**

**August 14, 2001**

# Hydroxide-catalysis bonding

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**In the Advanced LIGO Interferometer, the masses will be suspended by silica fibers or ribbons.**

**Fibers or ribbons will be welded to prisms attached to the masses.**

**Silicate bonding will be used to attach prisms to masses.**

**Hydroxide-catalysis bonding is the process by which an hydroxide (K or Na in our application) catalyzes a silica surface by hydration and dehydration.**

**Because the surfaces are required to be in close contact to bond, a flatness of 1/10 wave is desired to maximize bond strength.**

# Hydroxide-catalysis bonding

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**Good cleaning of the surfaces is critical to promote high density of Si-OH groups hence, creation of Si-O-Si networks.**

**As the bonding solution dries between the two surfaces (dehydration), a siloxane bridge forms that eventually connects the two surfaces.**

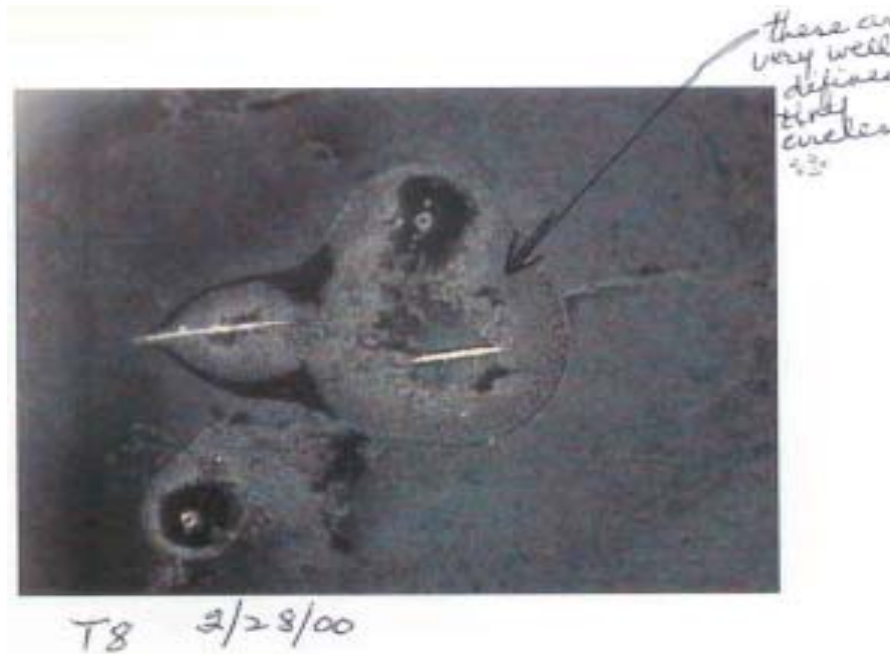
**Fringes can be seen when the bonding surfaces are brought into contact; they spread over the entire bonding area within seconds and can be observed for a few minutes.**

**Adjustment of the parts needs to be done within seconds, a firm bond results within less than a minute.**

# What have we learned?

## ② Effects of cleaning

- » **First bonds showed lots of defects and were weaker.**



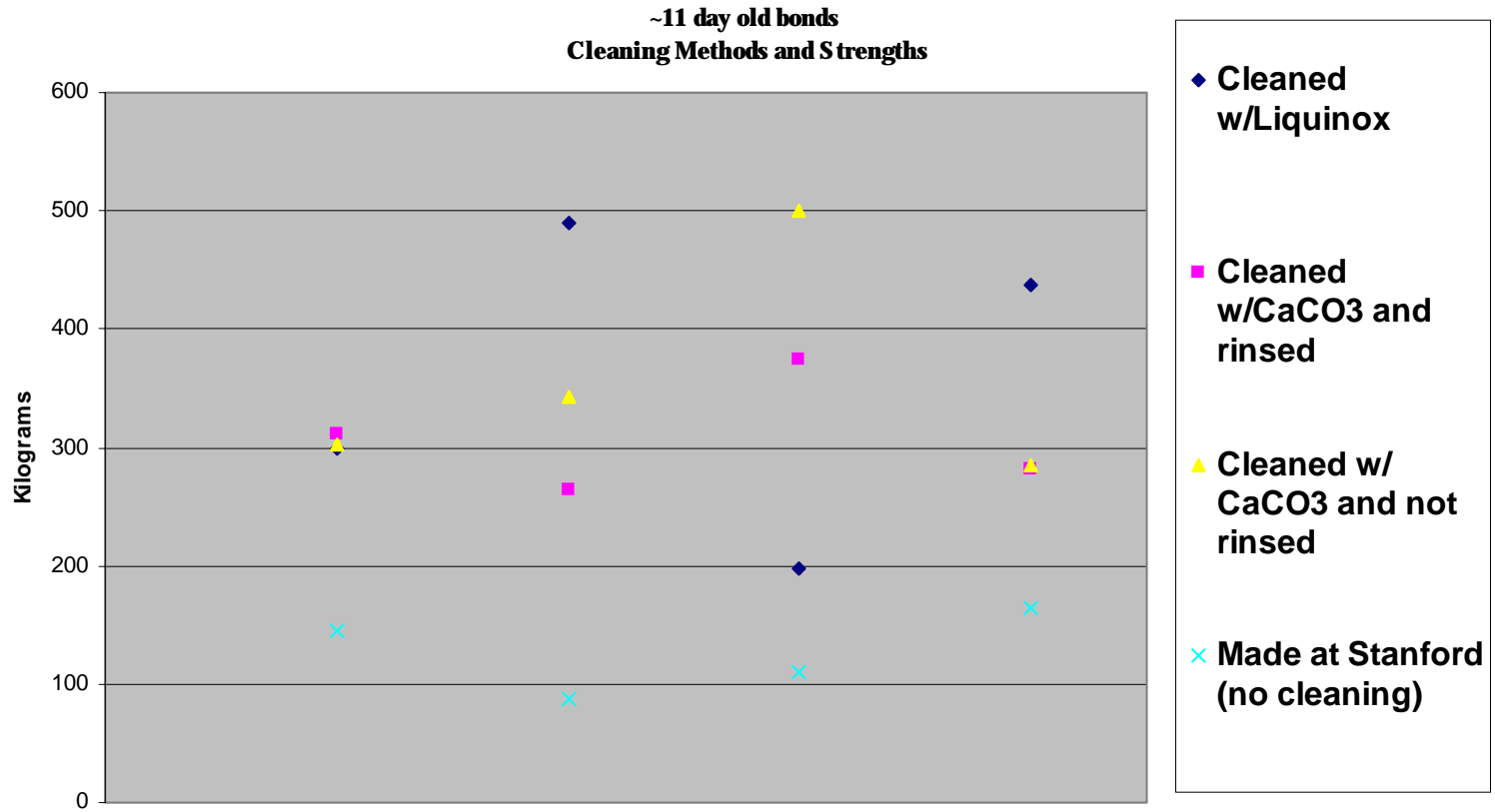
# What have we learned?

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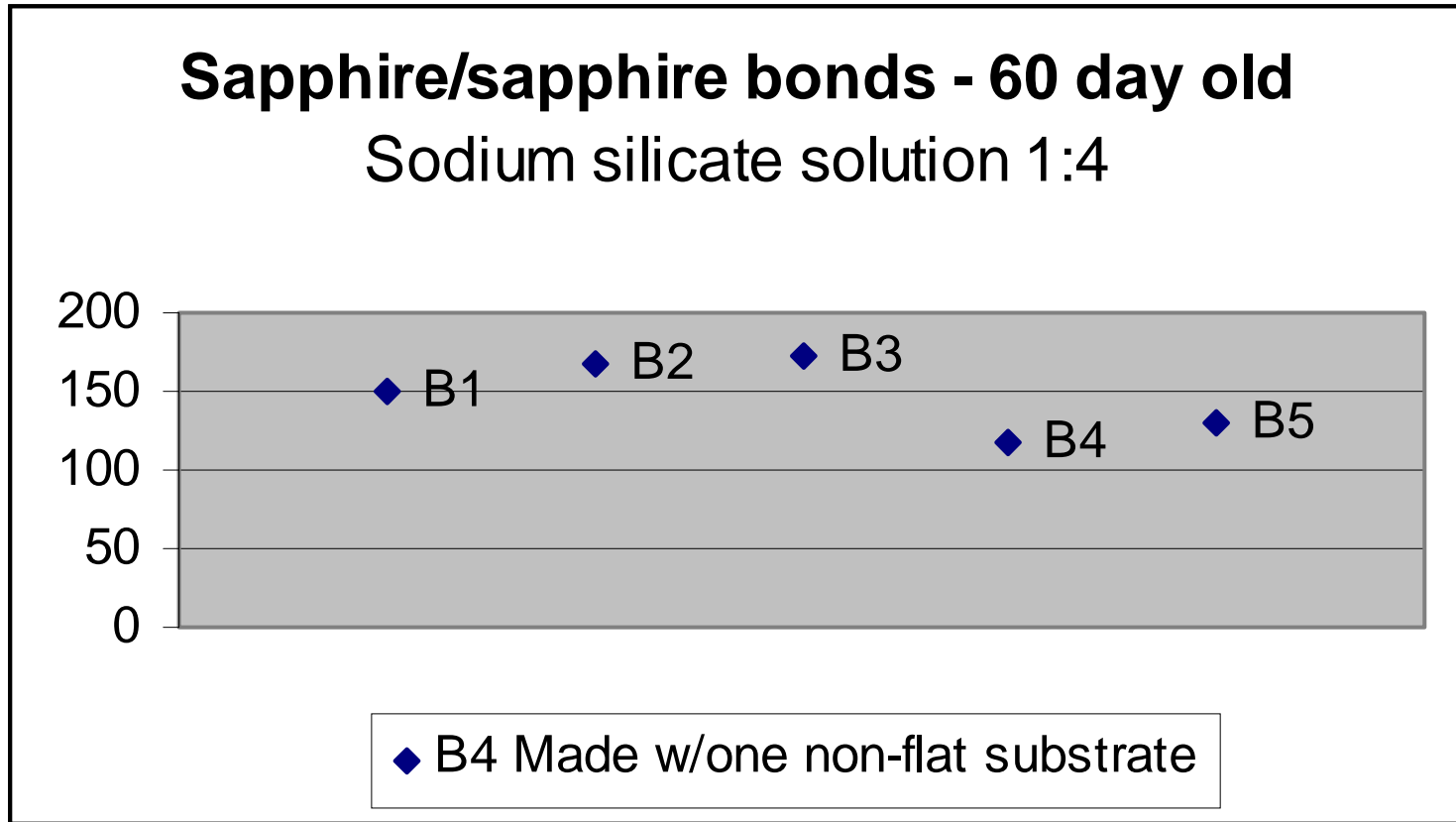
- » **As cleaning procedures developed and were implemented bond's features became lighter and strength increased.**



# Cleaning methods/effect



# Sapphire/sapphire bonds



# What have we learned?

- **Humidity effects**

- » **A humid environment arrests the bond's cure. We were able to see the growth of crystals in real time when the bonded substrates were removed from the humid environment and the moisture started to dry.**
- » **Pictures taken one minute apart.**





# What have we learned?

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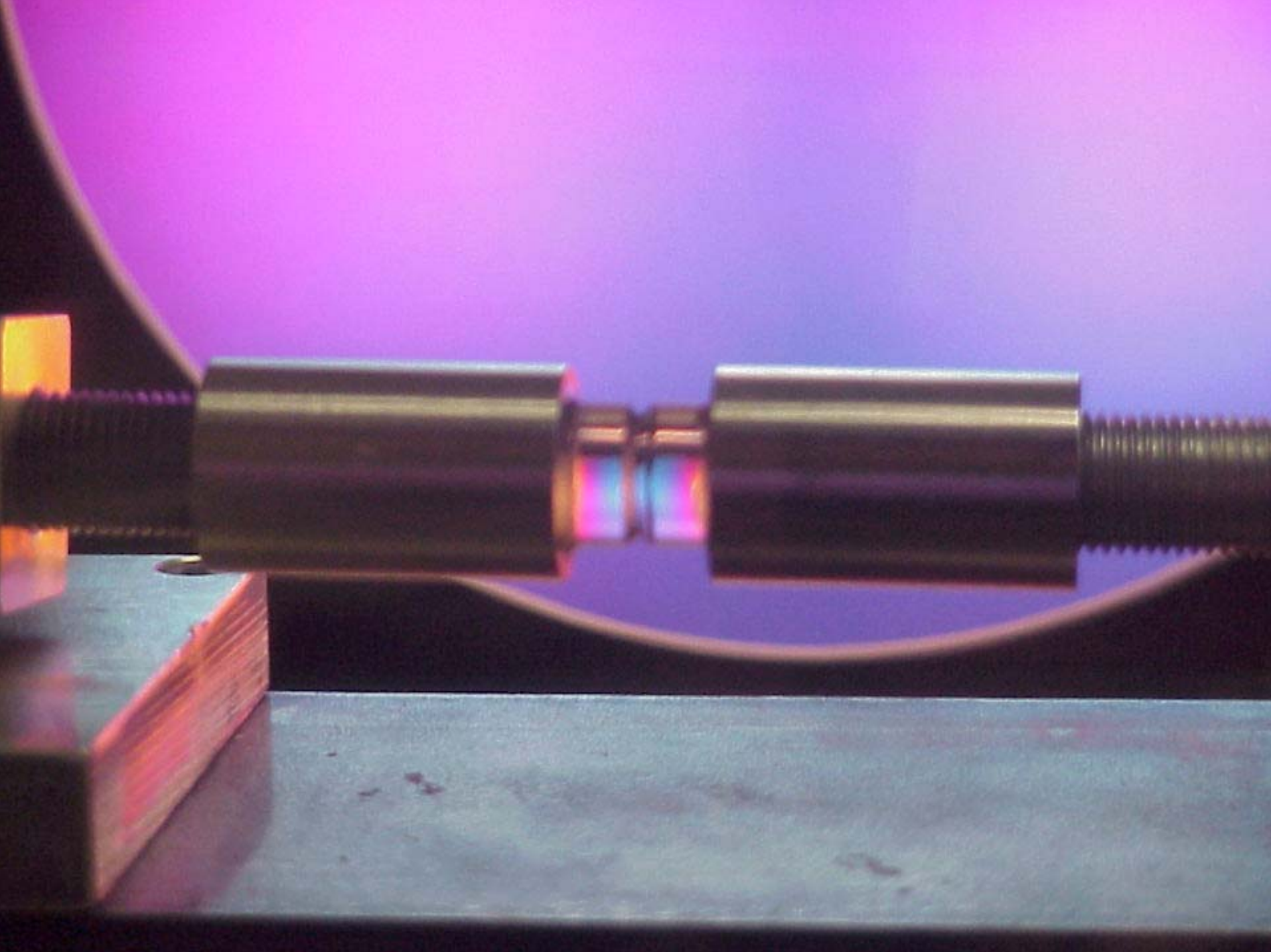
- **Importance of substrate surface quality**
  - » **Scratches, even heavy scratches, do not have an effect on bond strength.**
- **Aging of bonding solution**
  - » **pH of the bonding solution decreases when it is exposed to air. It is believed that is caused by absorption of CO<sub>2</sub> from the environment. (Further studies may be required).**
  - » **In our tests we used freshly prepared bonding solution every time.**

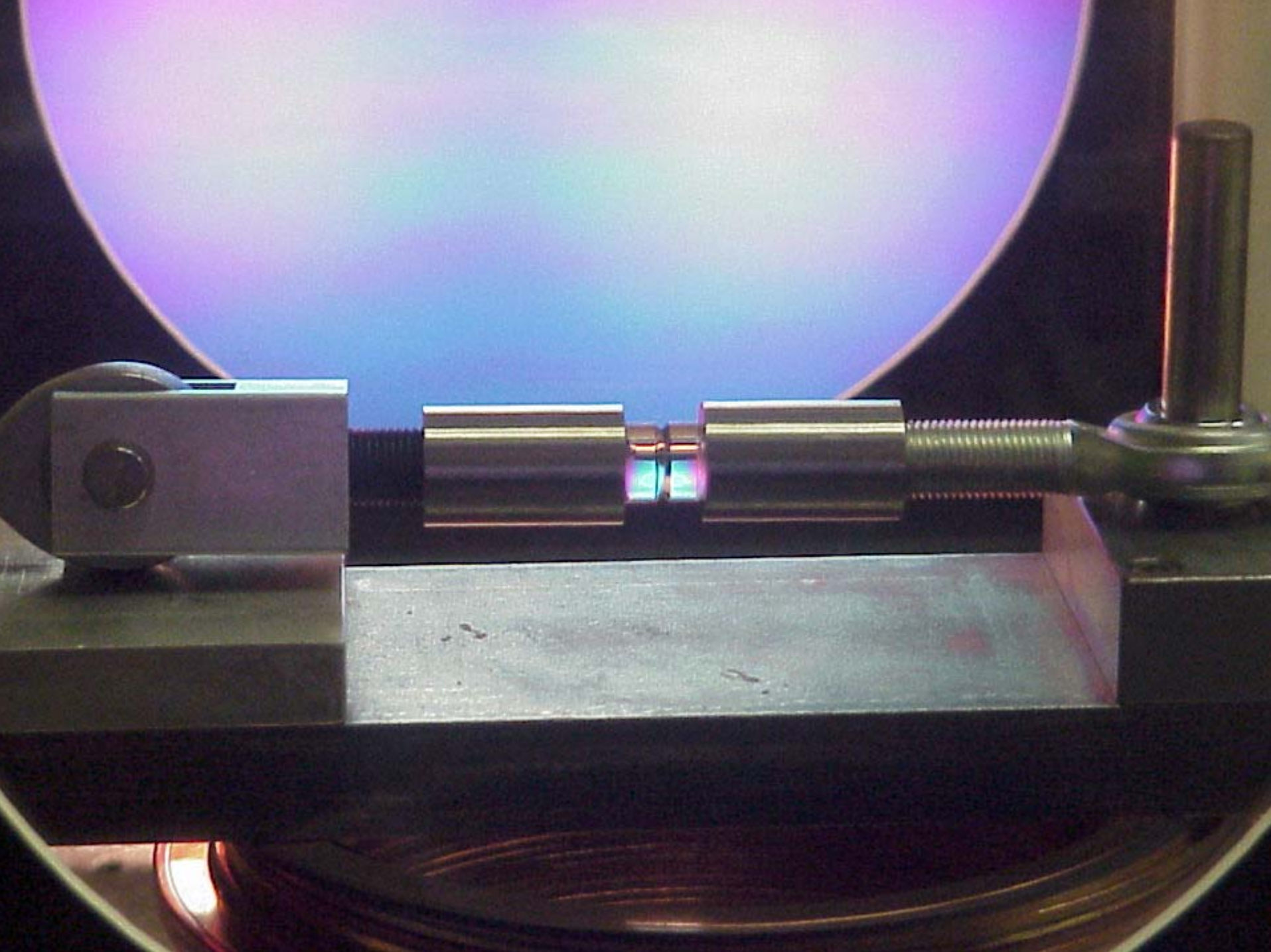
# Caltech Tester and Polariscope

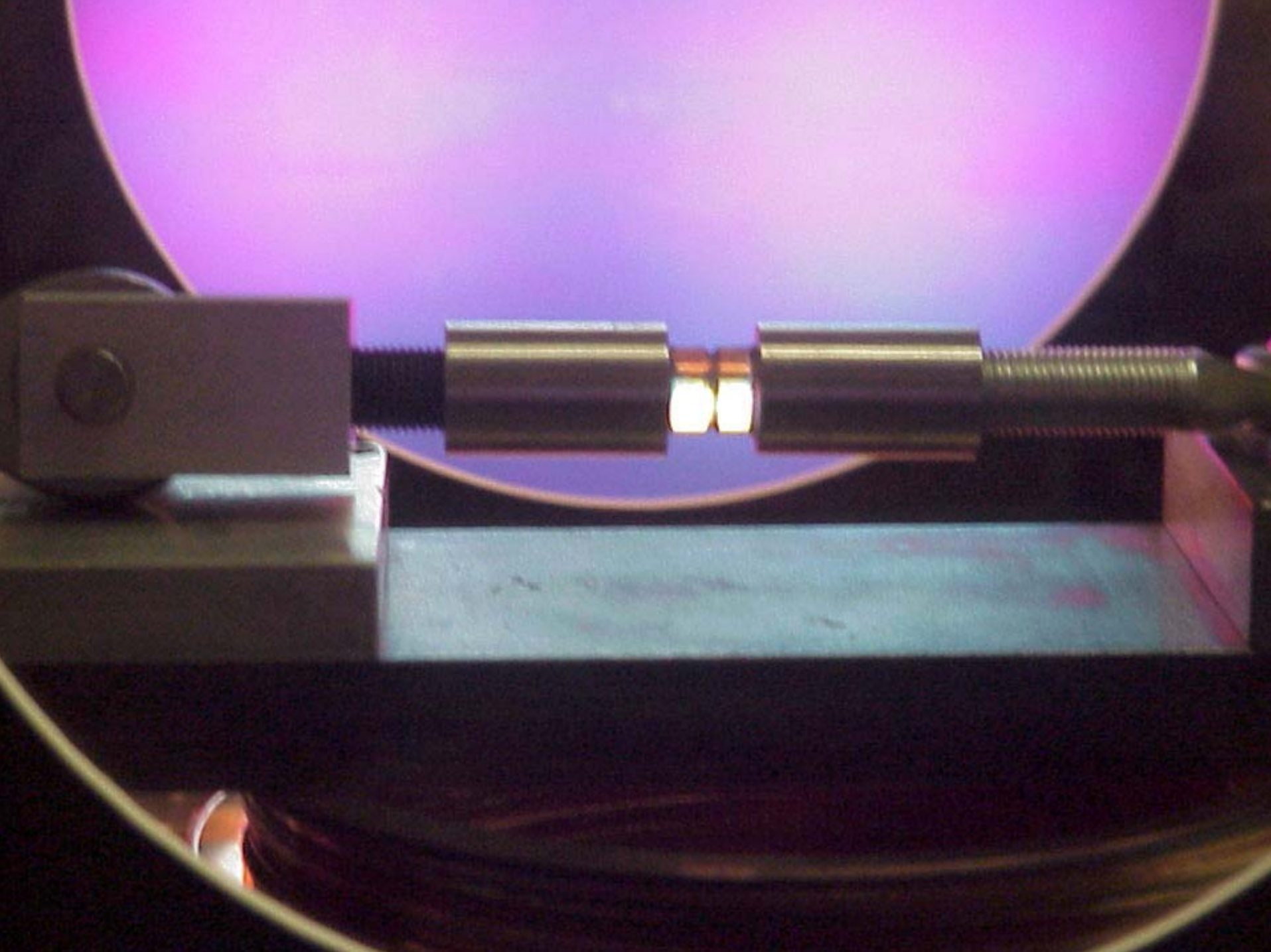
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- **As a tool for non-destructive testing we acquired a polariscope to observe stress on bonds.**

**The following sequence of pictures show how the color on the bonded substrates changes as tension is applied to them.**



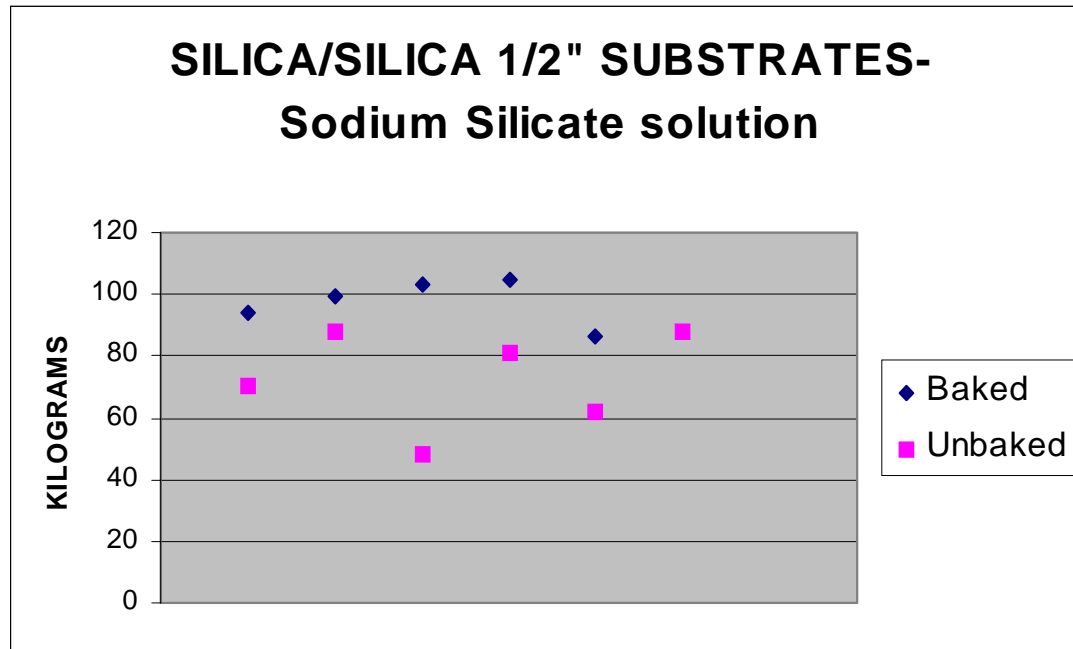




# Sodium Silicate Solution

(Baked / Unbaked Silica/Silica Bonds)

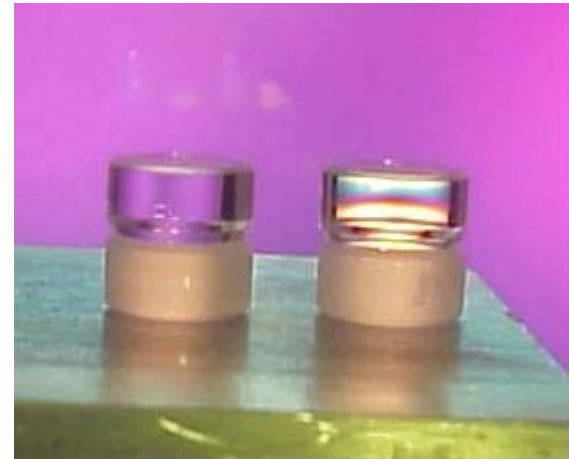
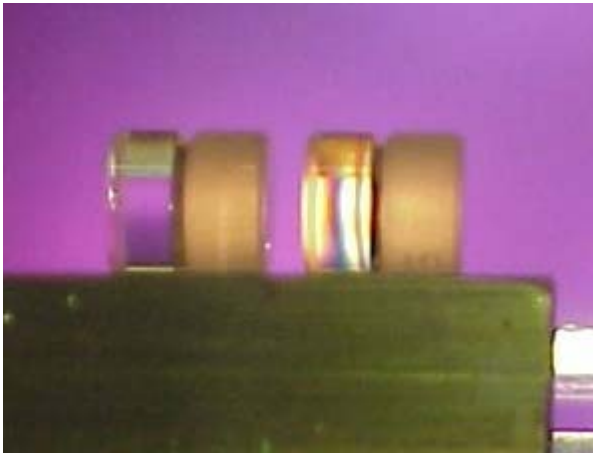
**Bonds were baked at 120 degrees C for 24 hours**



# Sodium Silicate Solution

(Baked / Unbaked Silica/Sapphire Bonds)

**Stress could be observed on the silica/sapphire baked bonds.  
(Baked bond shown at right).  
Bonds baked the same day they were manufactured.**



# Sodium Silicate Solution

(Baked / Unbaked Silica/Sapphire Bonds)

**One bonded part shattered during the baking cycle**

**(24 hours @ 120 degrees C)**

**The bond separated after little handling**





- **Hang weights on prisms (ears) and monitor stress**
- **Look into different solution concentrations and curing temperatures**
- **Define the optimum curing time for baked and unbaked bonds**
- **Investigate the effect of applying pressure to the bonded parts**
- **Ear design for optimum stress distribution**