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Designing a Microfluidic Sorting Network with Heat Treated Plastic

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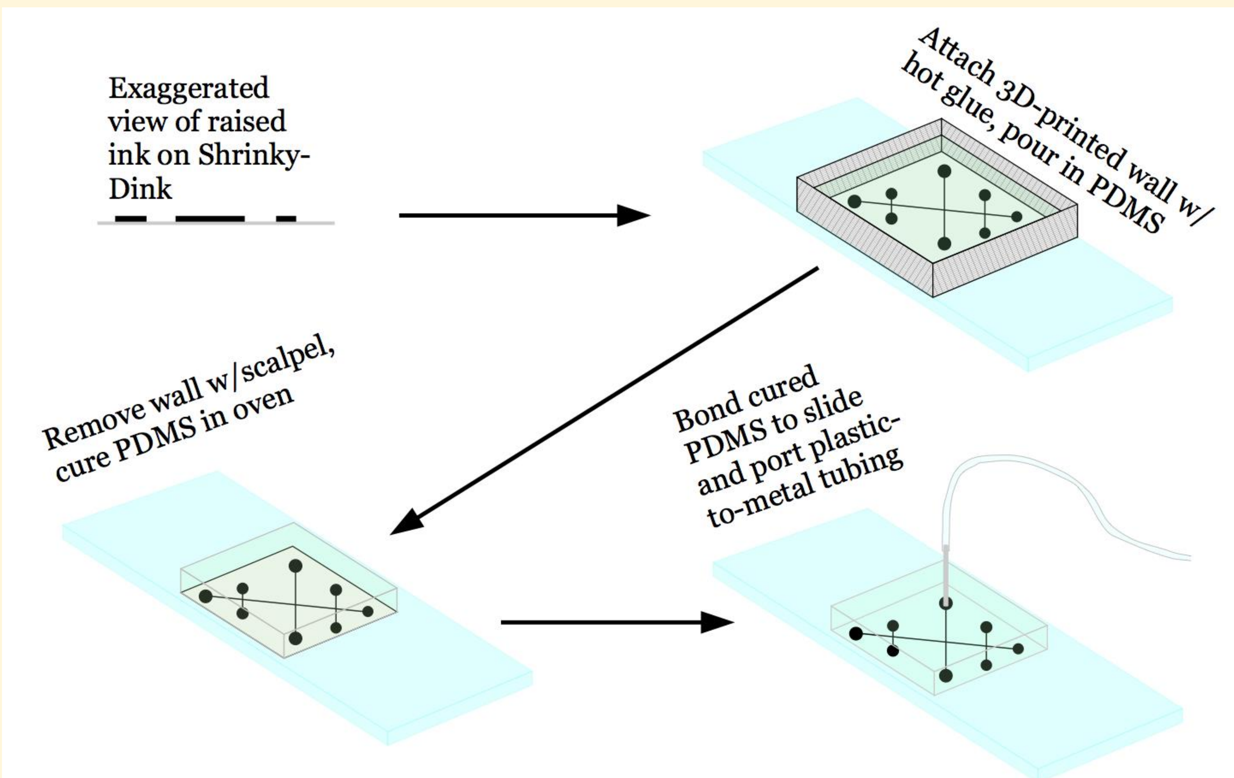
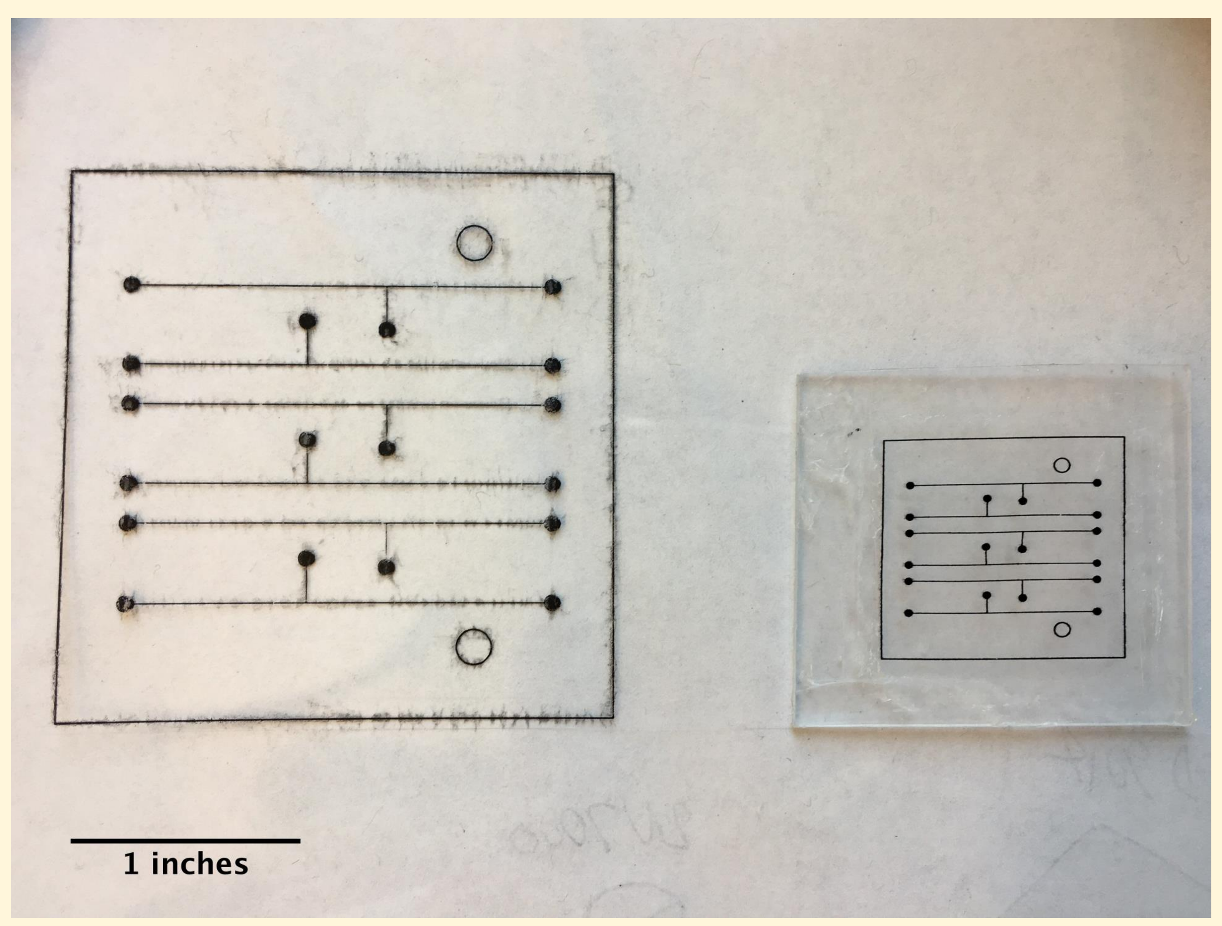
Abstract

A microfluidic device is necessary to sort nanodiamonds based on their luminescence. We explored utilizing the repeatable shrinkage of heat-treated Shrinky-Dink (polystyrene) sheets in an effort to find an easier, cheaper alternative to the traditional photolithography process. Our work found encouraging results but the plastic's capabilities must be further studied to decisively determine its usefulness.

Making a Device



As seen in the top-left corner of the diagram, the design actually has a distinct height at the microscale which will actually create a negative PDMS mold when the latter is made solid through curing.



Test designs on Shrinky-Dink before and after shrinking. Their area decreases significantly but their thickness also increases.

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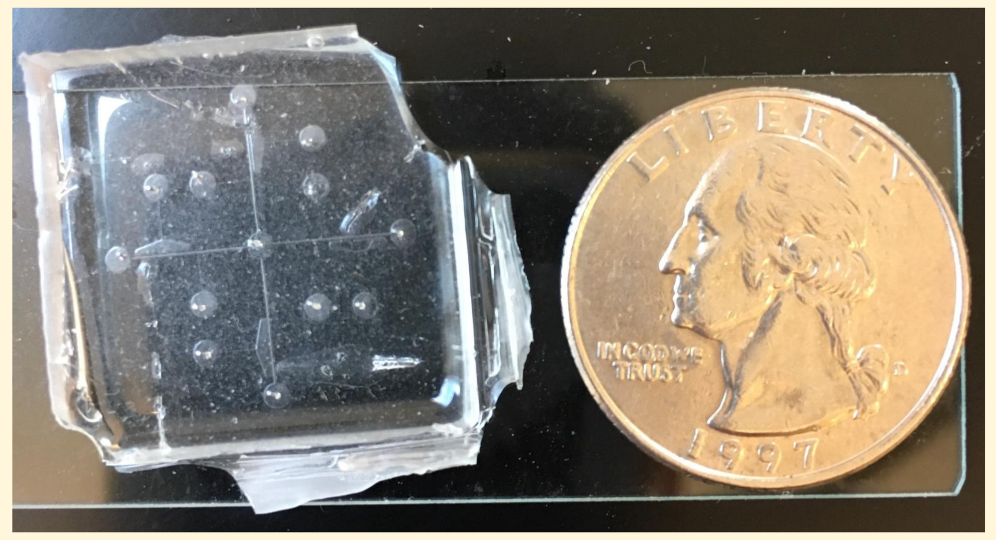
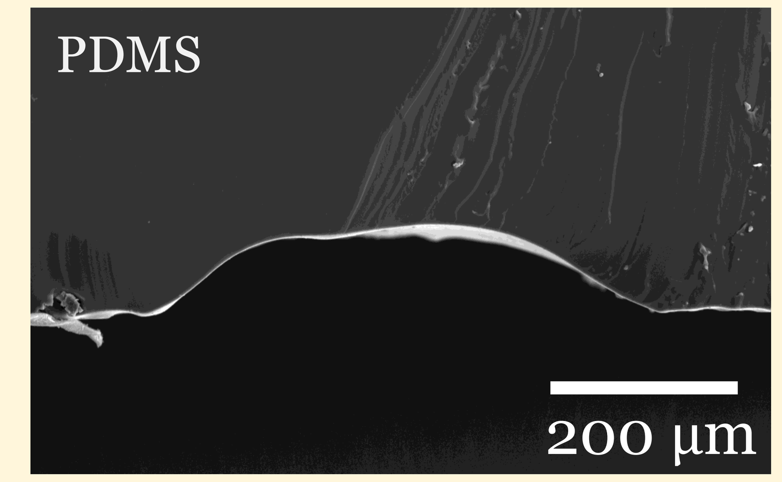
Results

An example of a final microfluidics device is shown below:



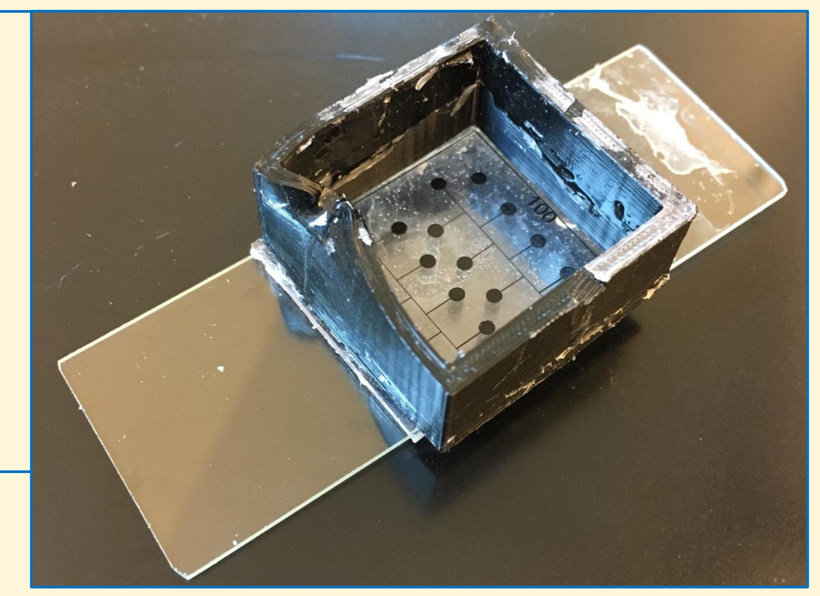
Microfluidic device, including inked design, ports, and bond irregularities

Side view of channel (SEM)

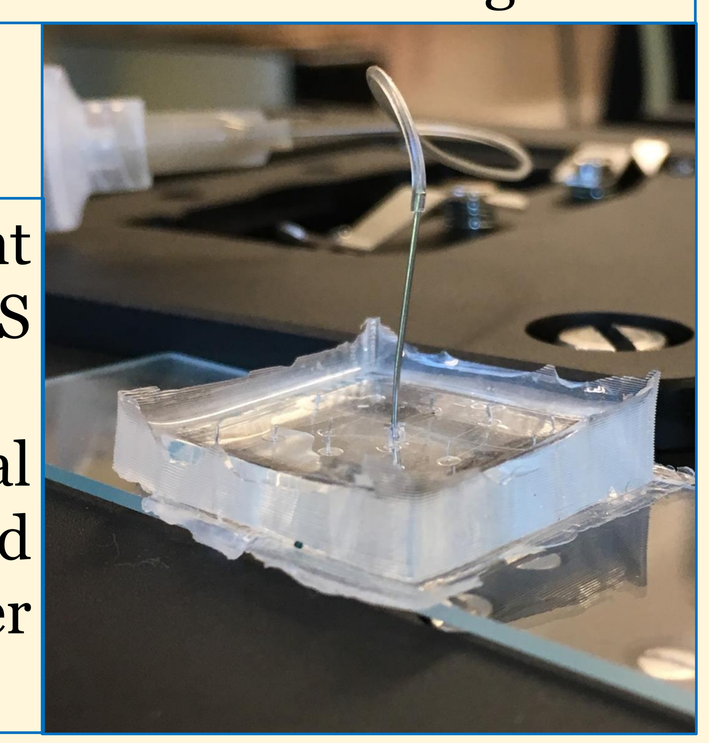


We also found many ways to optimize the device manufacturing process and achieve a greater percentage of successful devices. Questions we asked ourselves included: **How can we...**

1: Ensure liquid PDMS stays on Shrinky-Dink master for oven curing?
A: Attach 3D-printed square wall to master w/hot glue gun to enclose PDMS



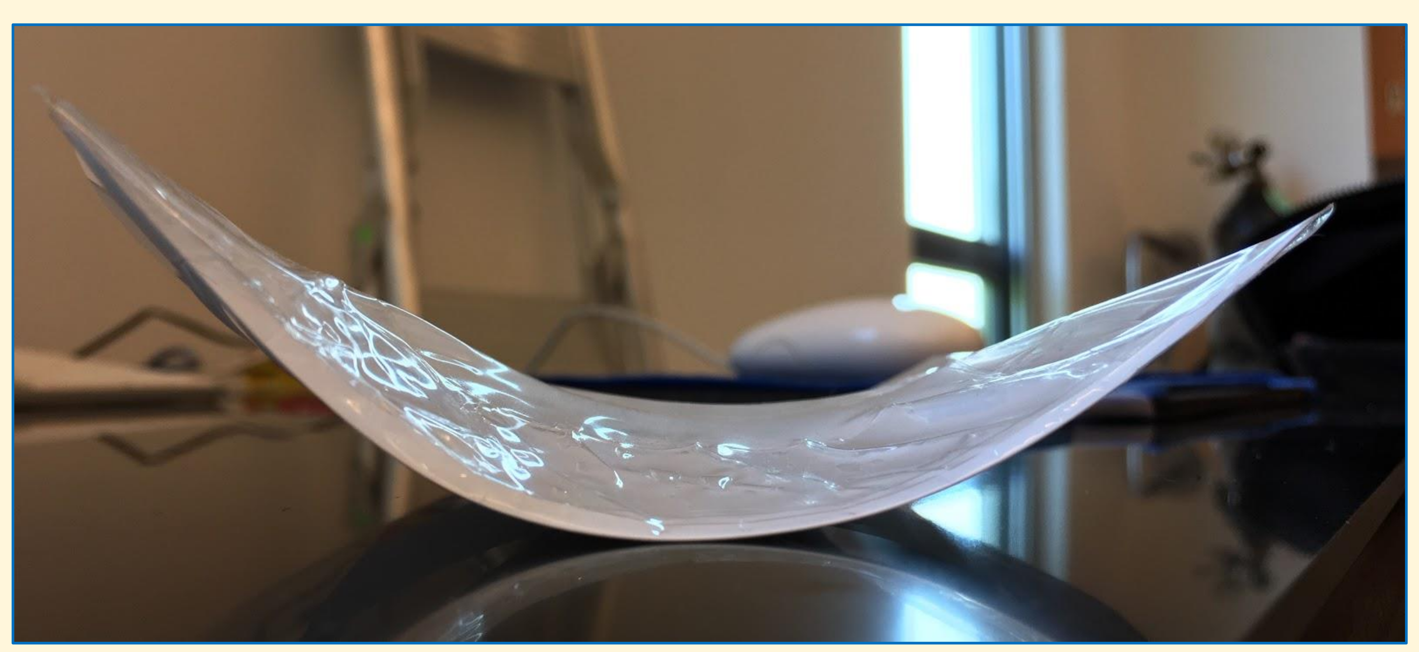
2: Create stronger bonds between PDMS molds and glass slides more reliably?
A: Clean slide w/isopropanol then rinse w/RO water to remove dust & chemicals that compromise bond strength

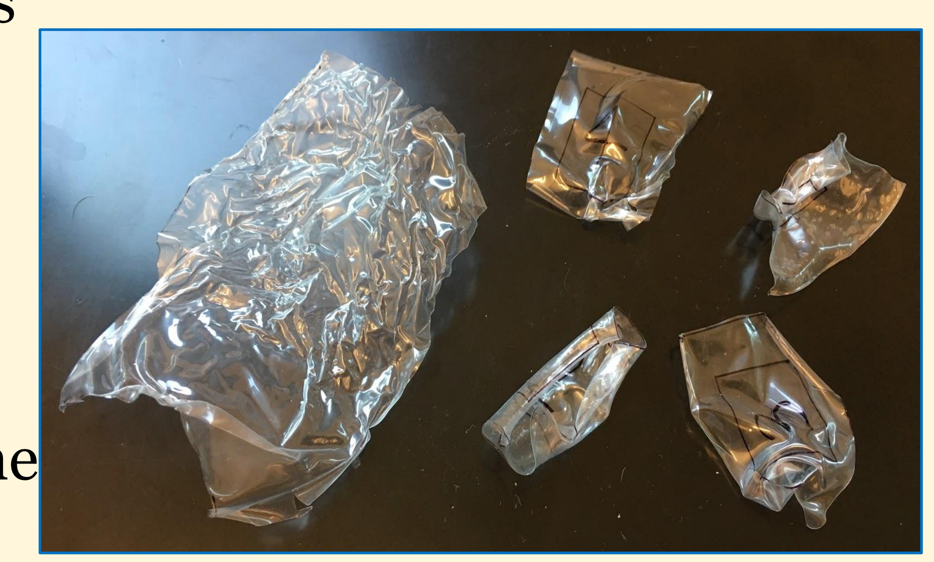


3: Yield more consistent ports to maintain PDMS integrity?
A: Port stiffer metal tubing into PDMS instead of plastic tubing for easier entry & more stability

4: Improve the percentage our designs shrink by?
We tested polyolefin, a different kind of heat-shrink plastic

- Reported 95% shrinkage by area (vs. ~84% for Shrinky-Dinks)
- Lower shrink temp. led to deformation, jamming in printer
- Oven-baked results did not achieve acceptable flatness for devices





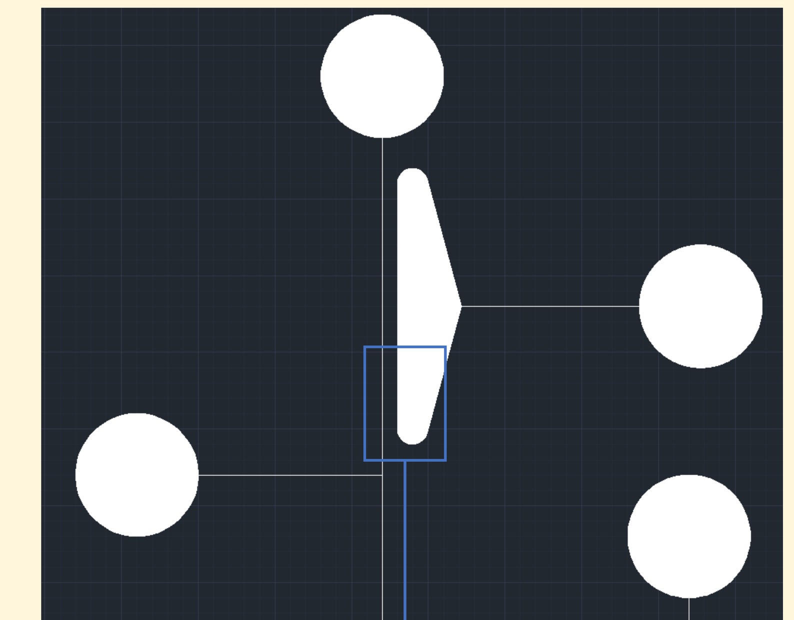
(Left) The air bubbles and curving show the extent that PO film shrank mid-print and pulled on its backing.

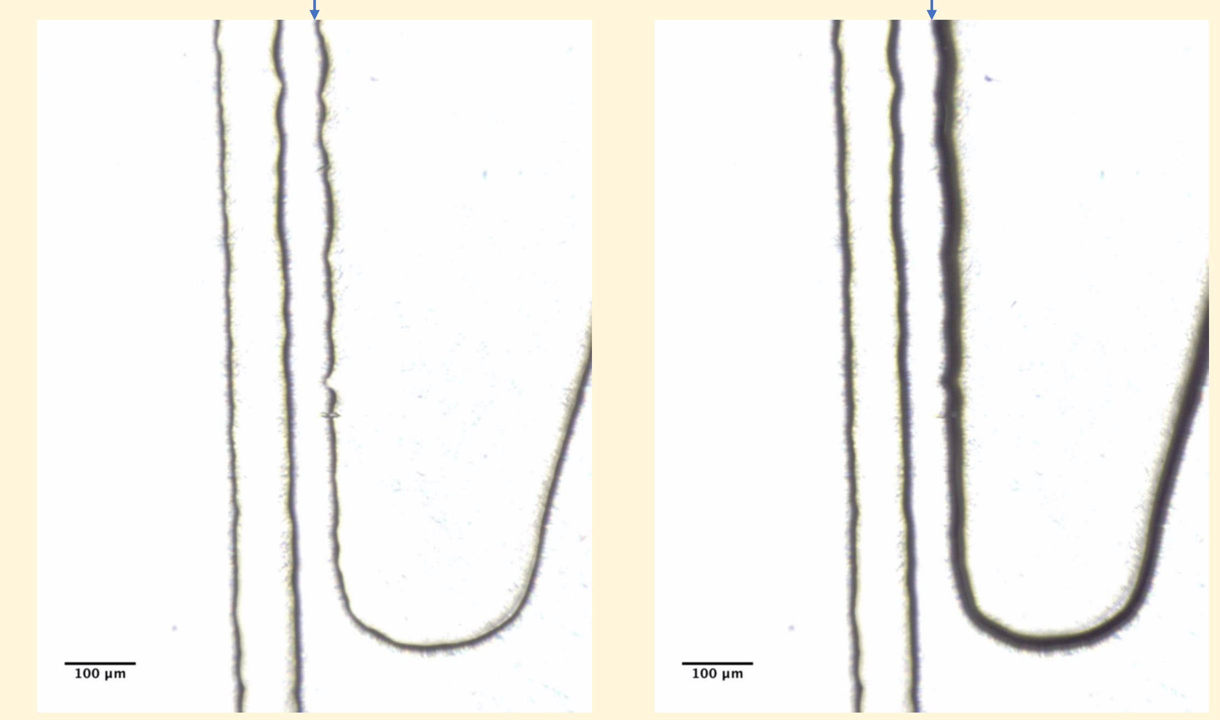
A: Polystyrene's overall ease of use worth minor loss of area shrinkage

Conclusions

- We have a tested method of producing working microfluidic devices on heat-shrink plastic with a relatively high success rate
- Our tests also find evidence to suggest working valves for flow control are also possible

An AutoCAD plunger-channel test file. The gap between the two is 340 µm pre-shrunk.





(Left) An unpressurized plunger < 100 µm from a channel. (Right) The same plunger with pressure applied. The bolder outline is from a shift out of focus due to upwards elastic deformation of the plunger.

- Flaws to address for future optimization include:
  - Random printer/print quality error
  - Ineffective PDMS-glass bonds
  - Speed of PDMS curing procedure

Going Forward

- A laser will be directed through a beam magnifier of lenses and mirrors to activate nanodiamonds' quantum defects
- Their luminescence will be measured with an external photon counter controlled by a Python program
- More valve tests examining different shapes, pressures, etc.