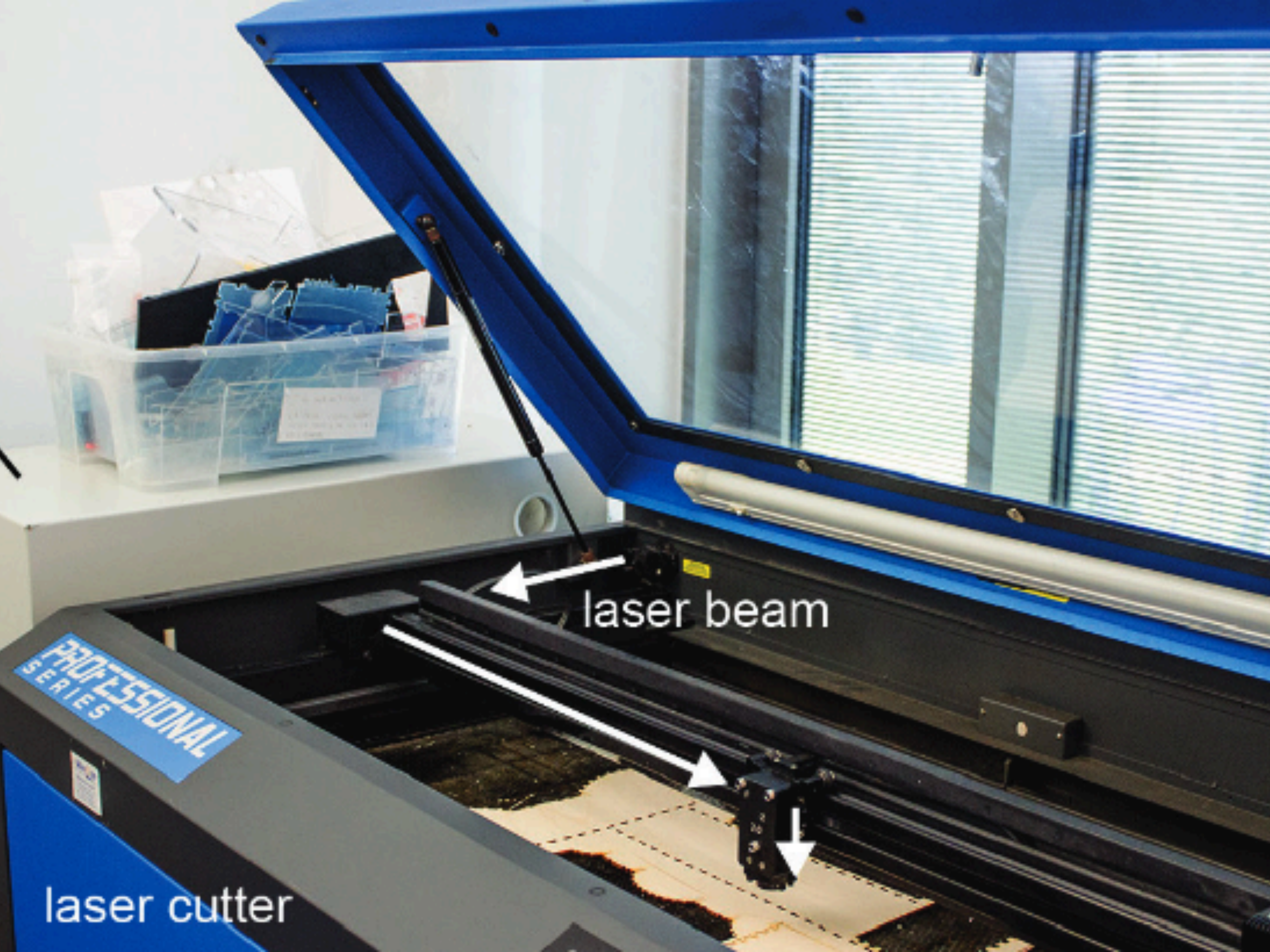
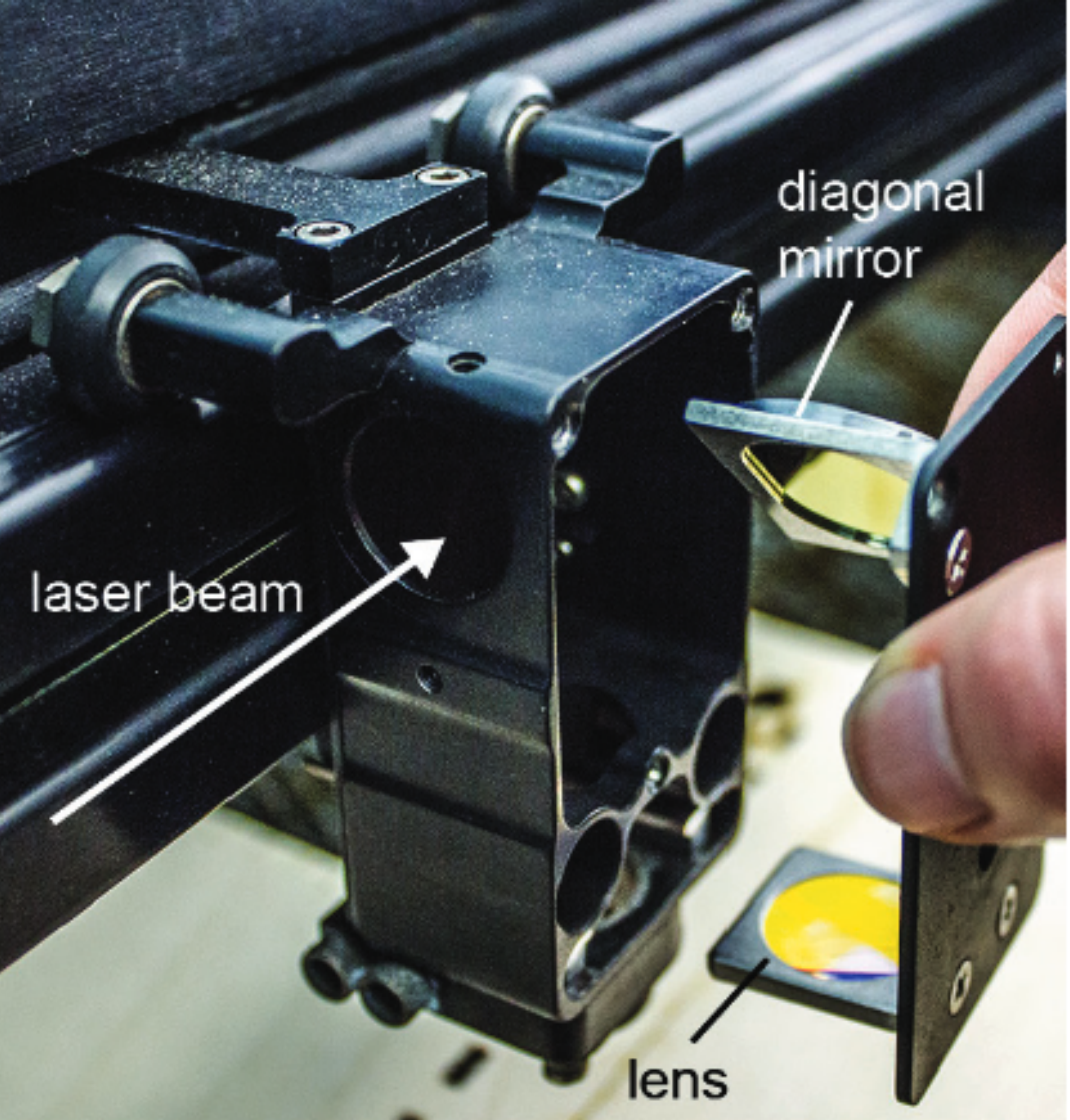
Laser Cutting Tips and Tricks

6.810 Engineering Interaction Technologies

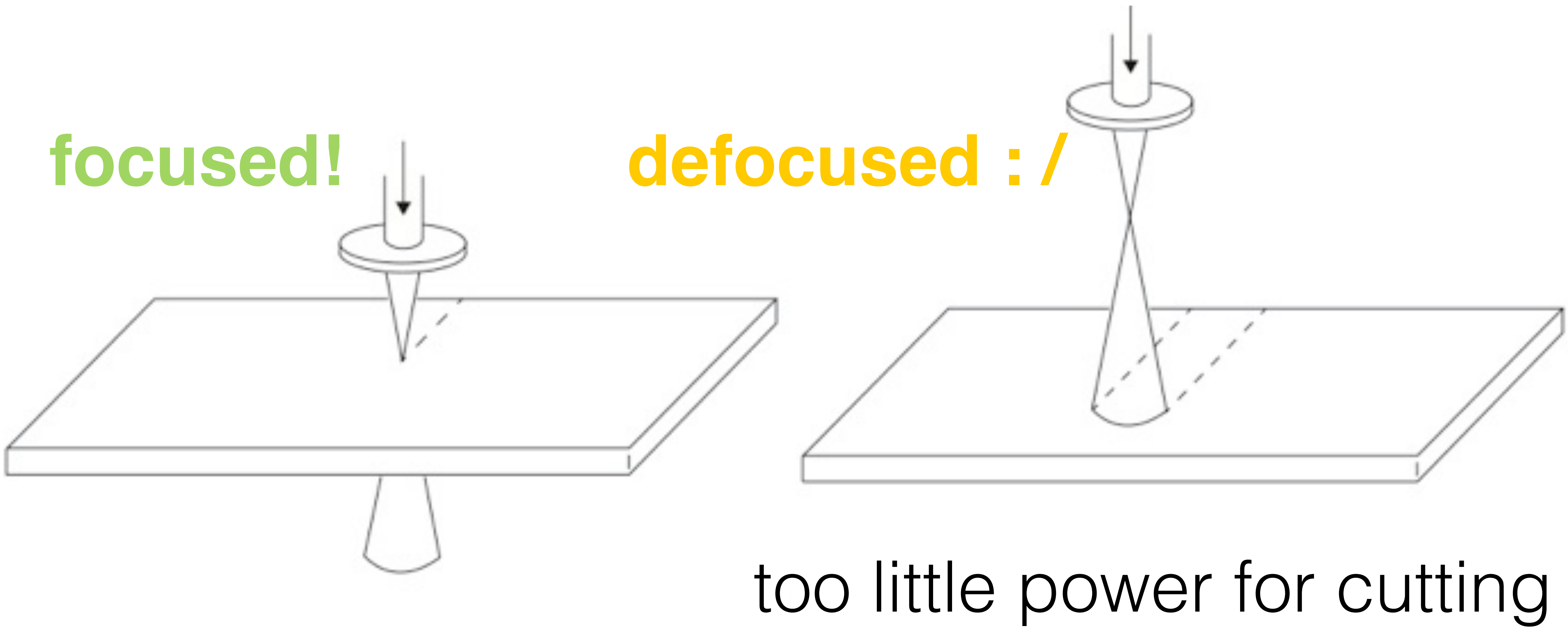
Prof. Stefanie Mueller | MIT CSAIL | HCI Engineering Group

how does
a laser cutter work?


laser beam
laser cutter
PROFESSIONAL
SERIES


diagonal
mirror
laser beam
lens

distance of sheet to lens is important
(focal length of lens)



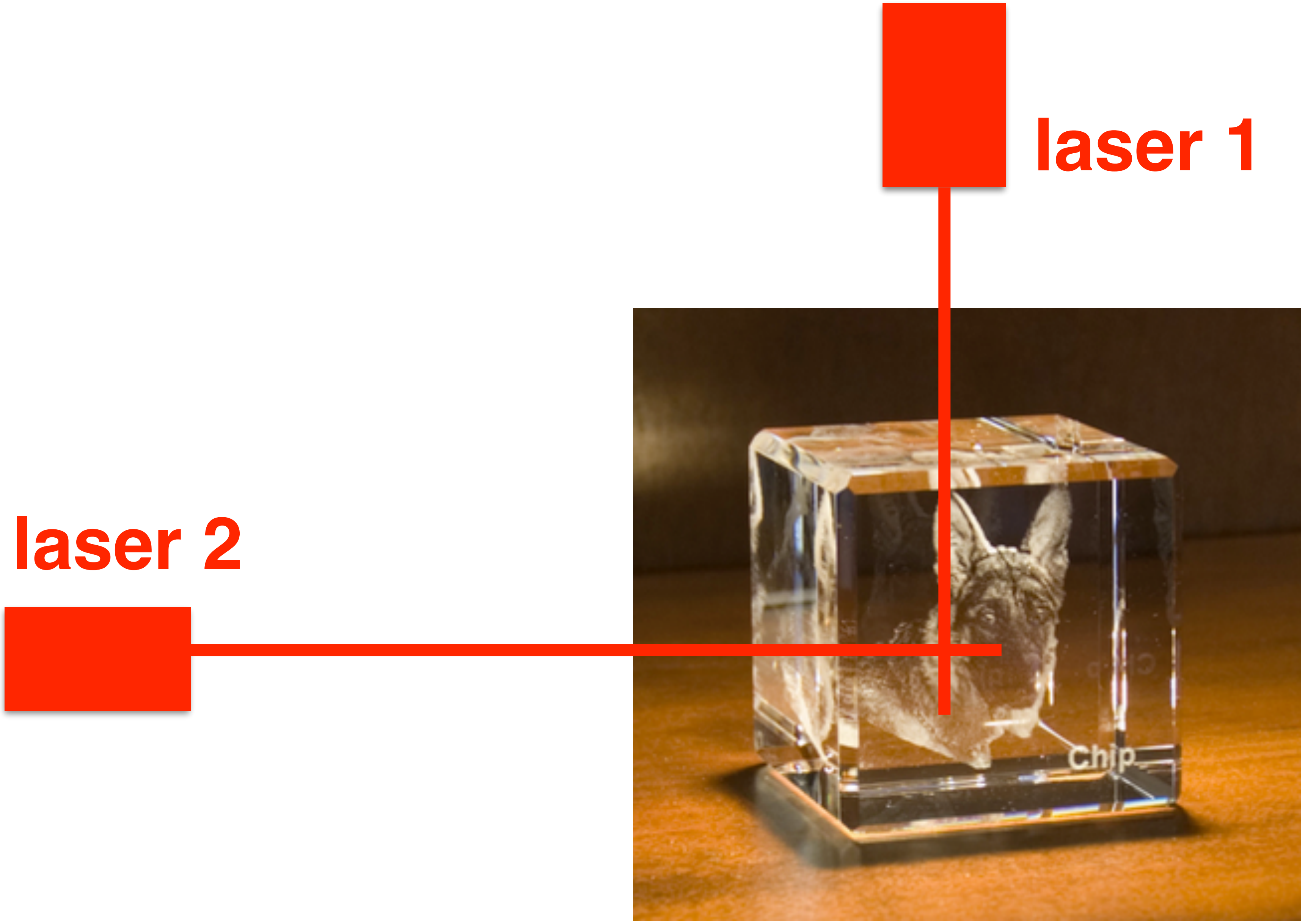
can we use a laser cutter
to make these **3D reliefs?**

<30 second brainstorming>

can we laser engrave 3D reliefs?

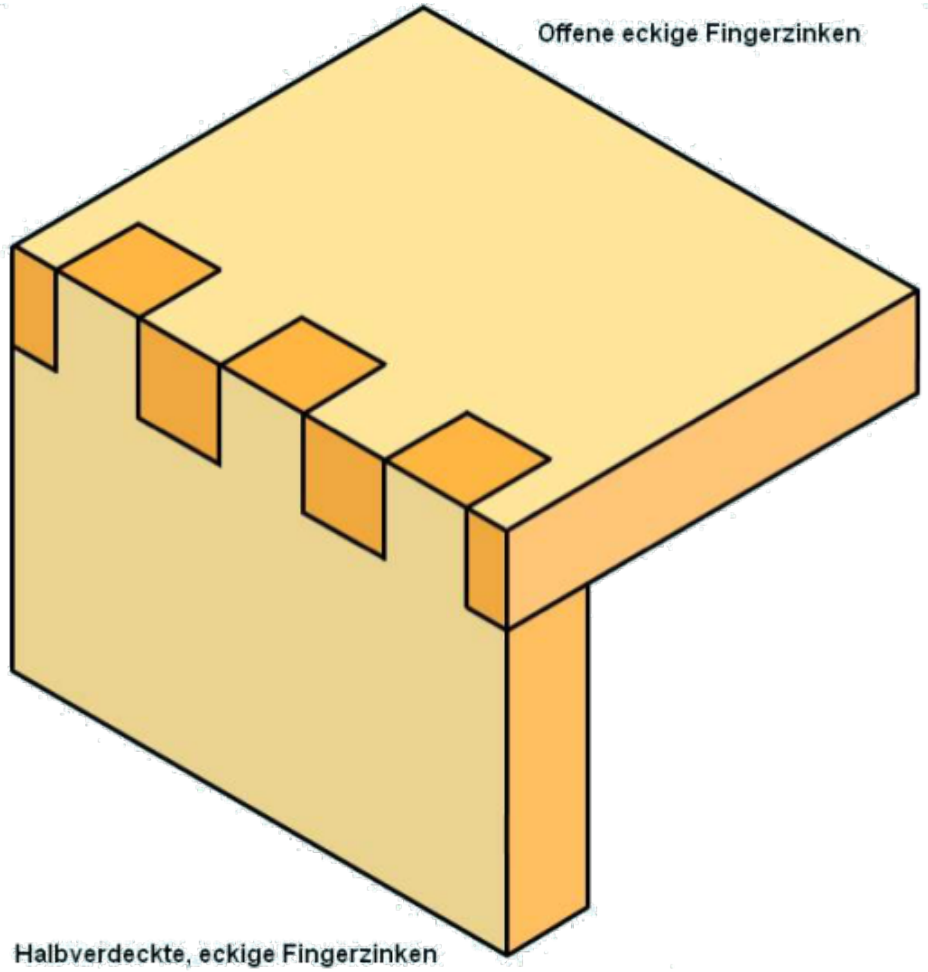
no, they are made with a different type of machine.

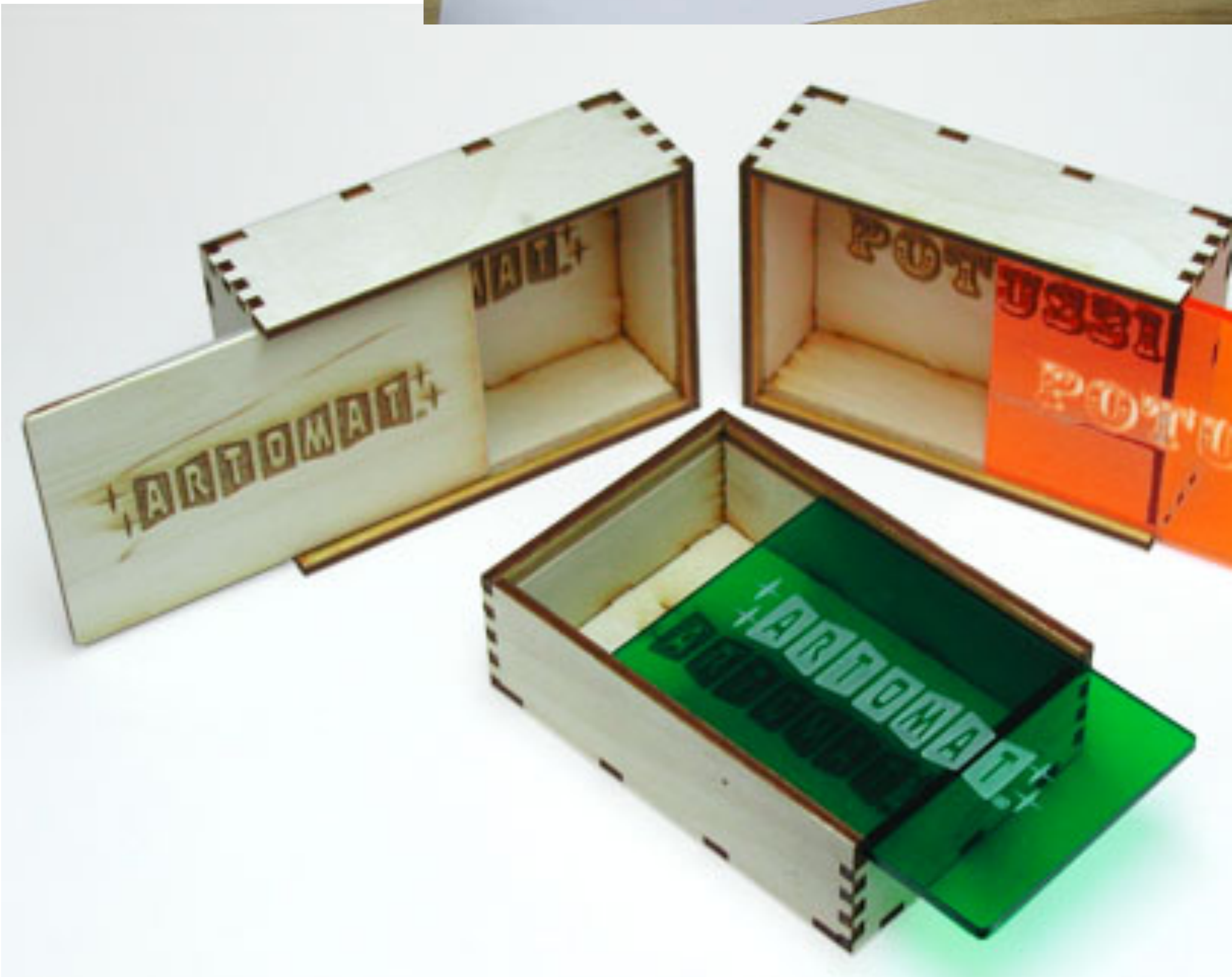
- two lasers from different sides aim at same spot.
- where they interfere, the power is high enough to break the glass and create a ‘dot’.

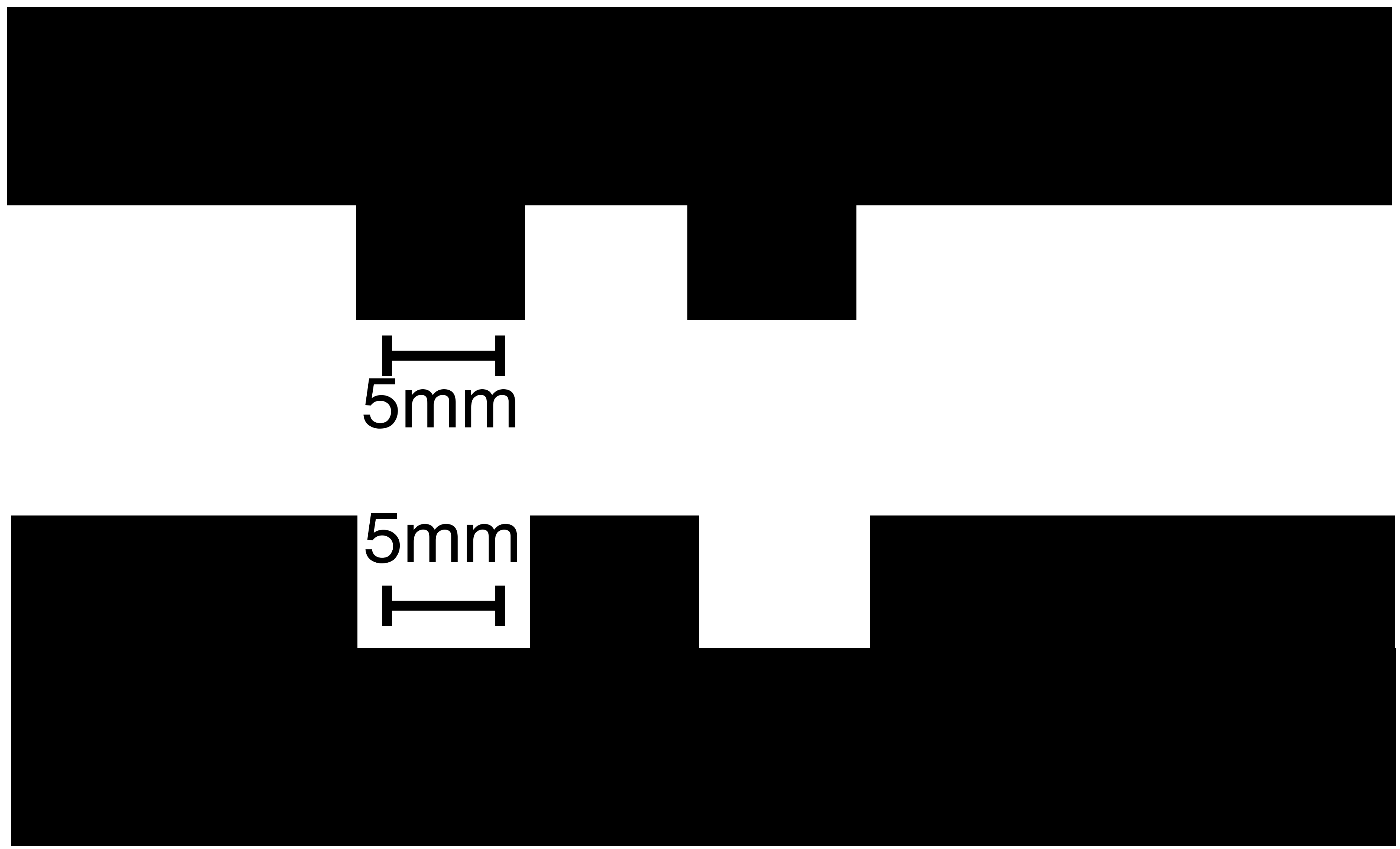


joints:
creating 3D objects

finger joints::

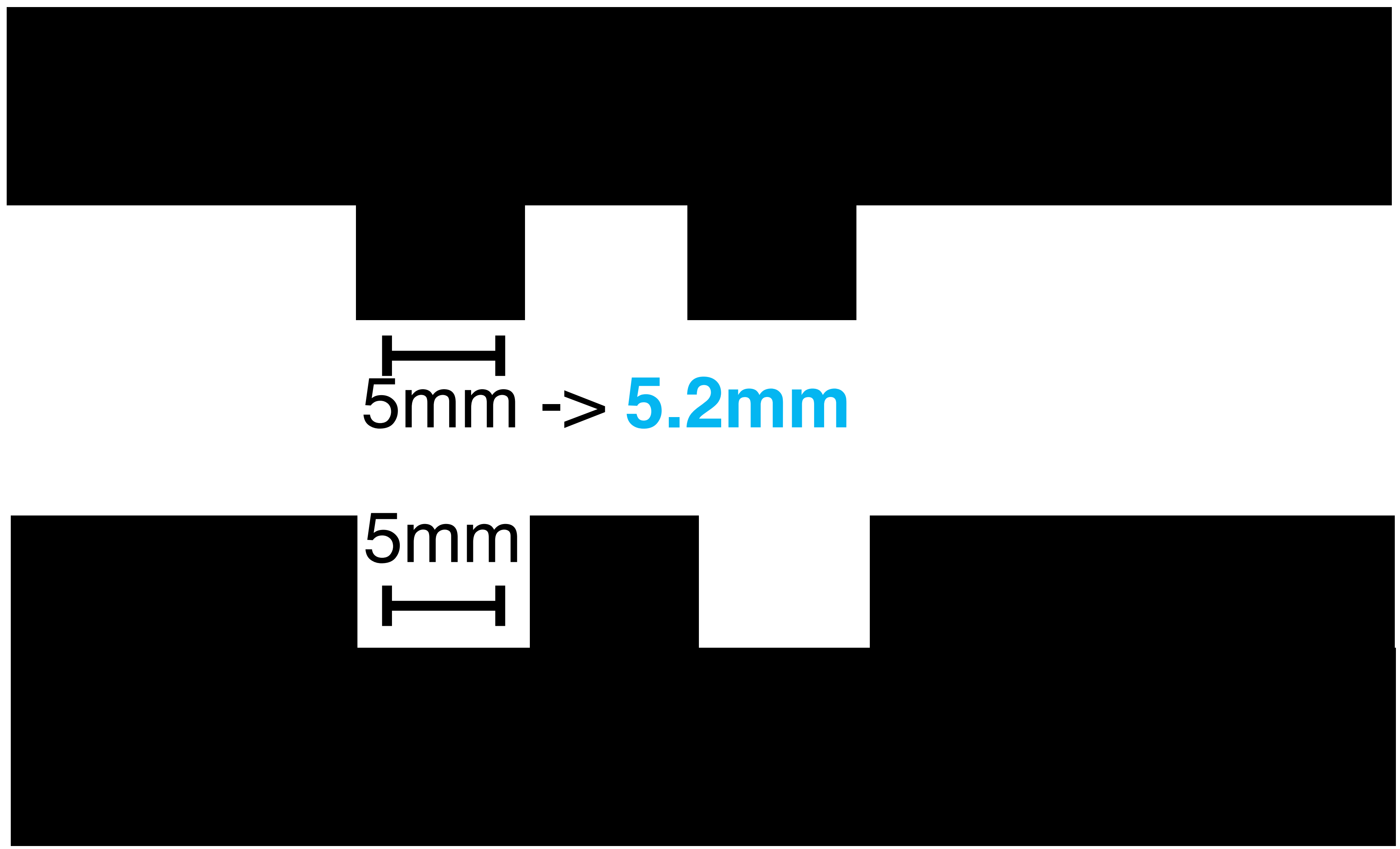






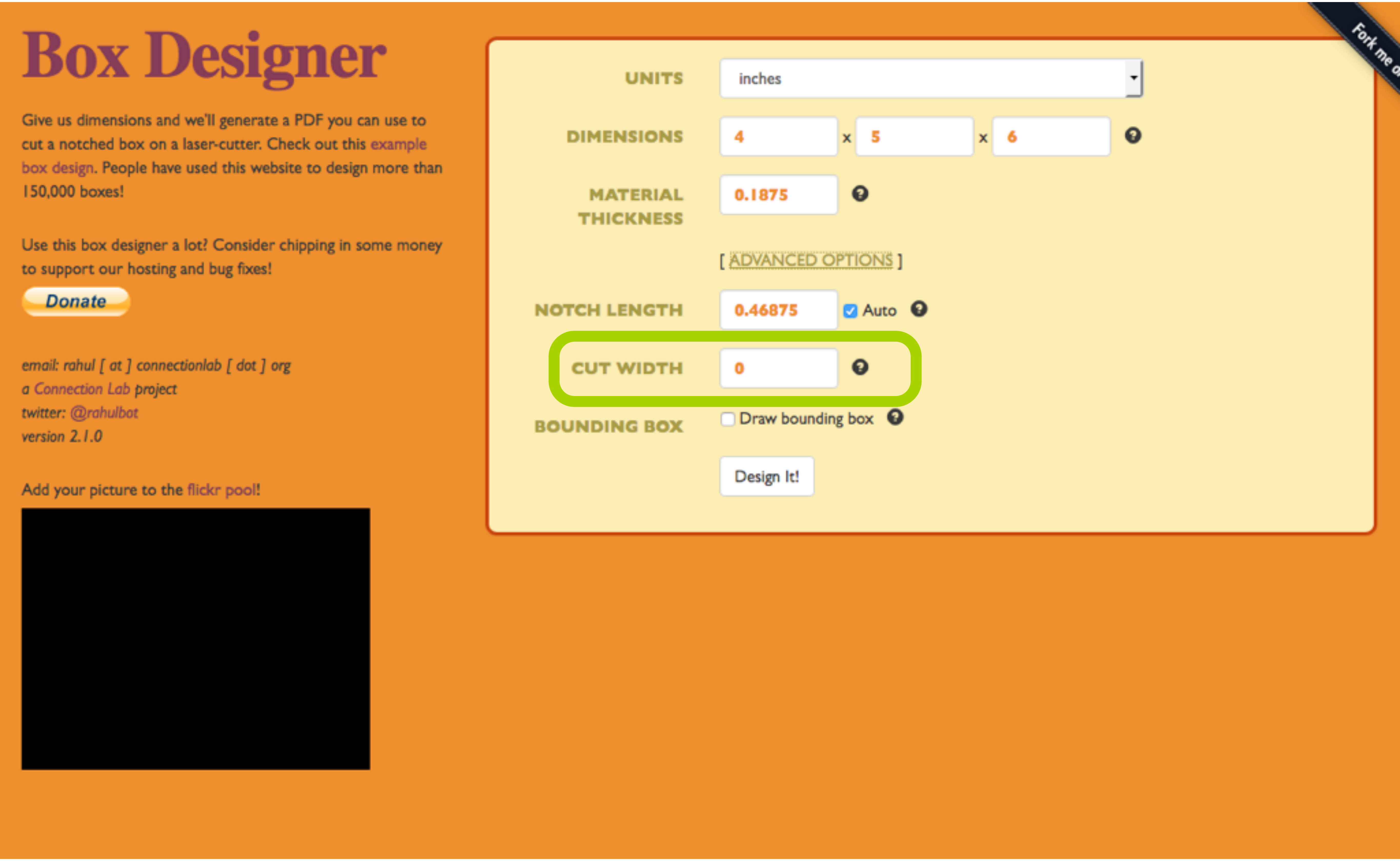
will this fit and hold together?

<30 second brainstorming>



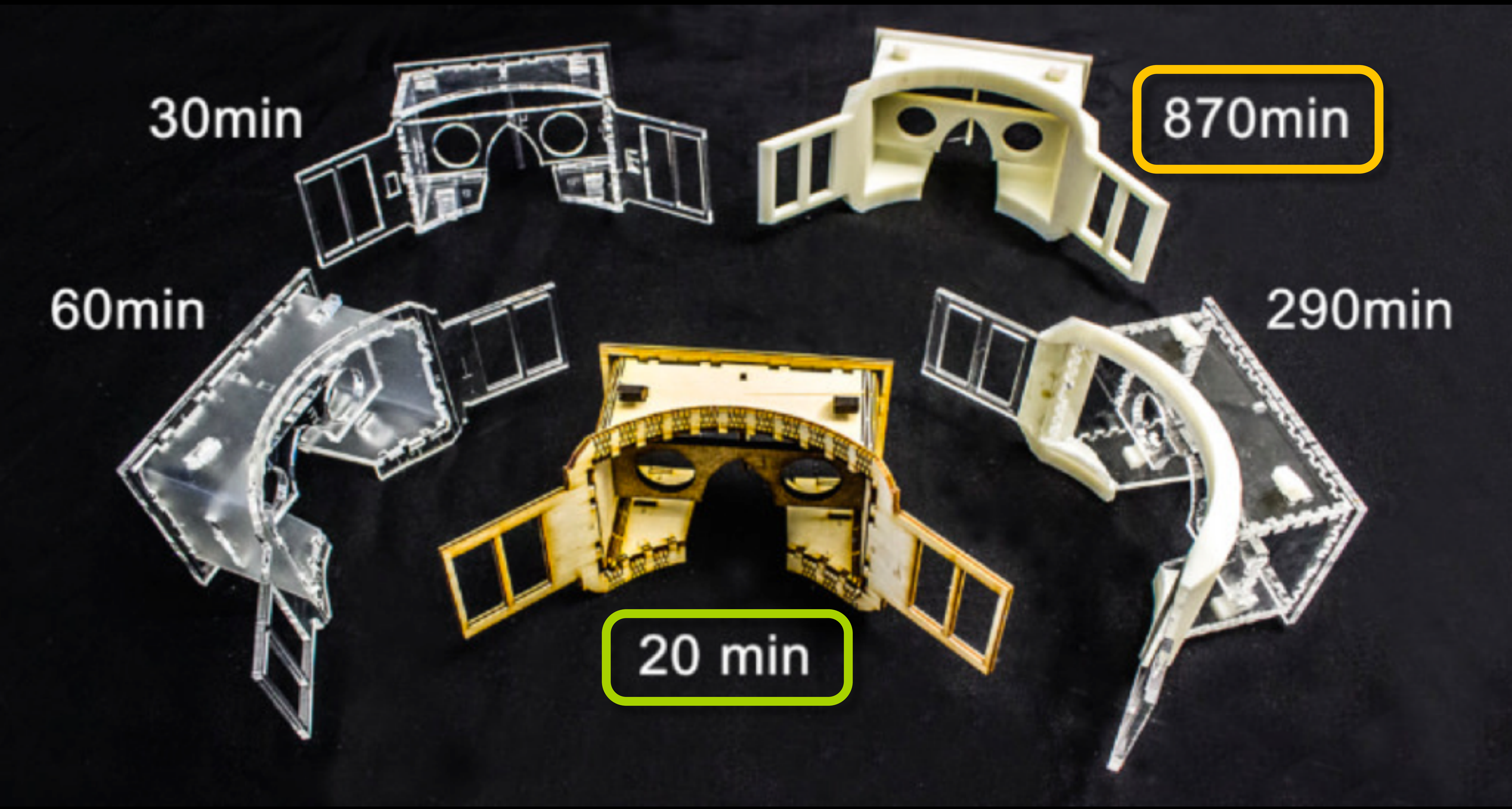
no, it will not fit.
it will be very loose.

material evaporates during cutting.
you need to make the **joint larger than the gap**



http://boxdesigner.connectionlab.org/

replace 3D print with laser cut 2D plates:



[Beyer, Chen, Mueller, Baudisch: Platener, CHI 2015]

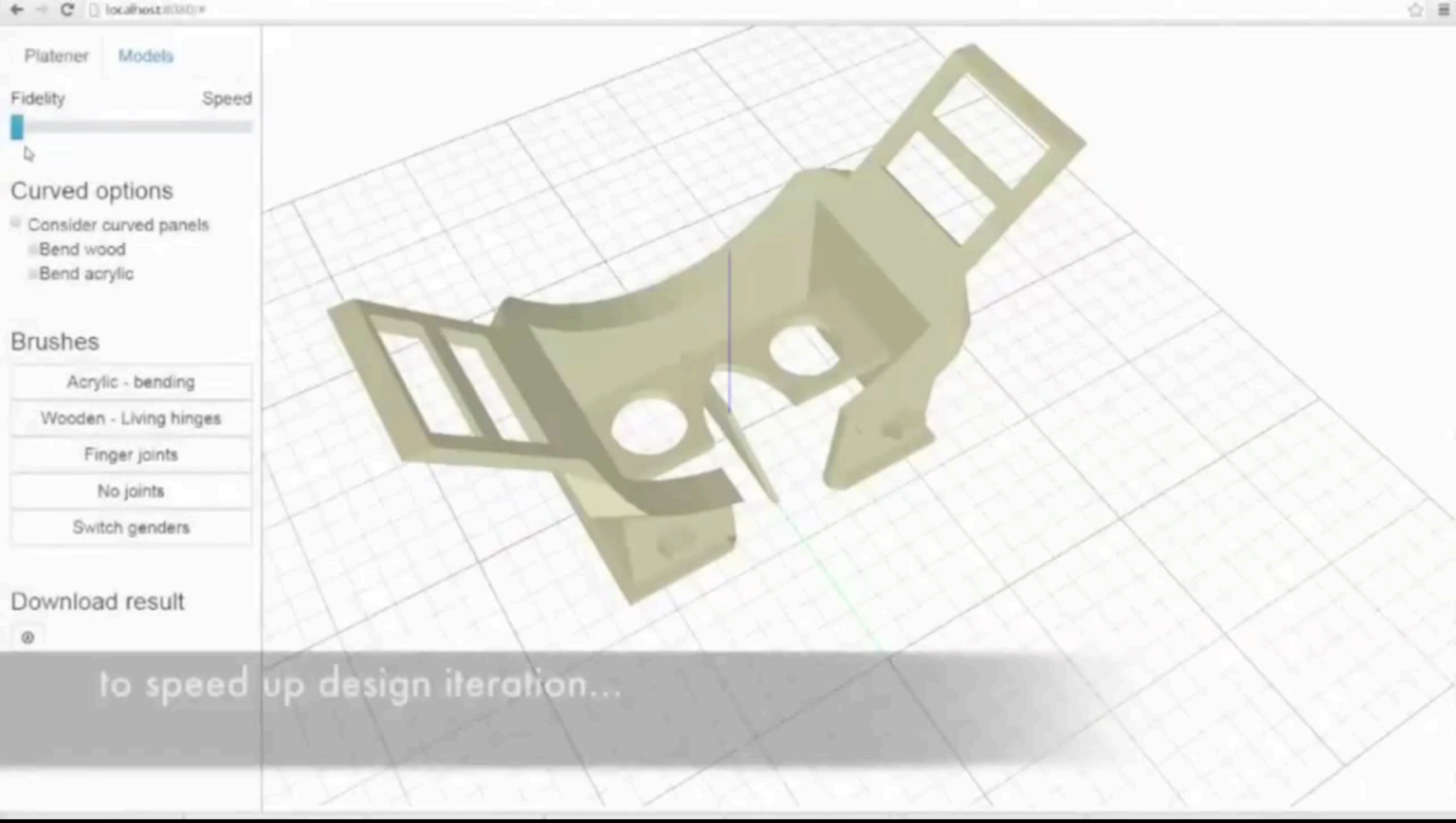
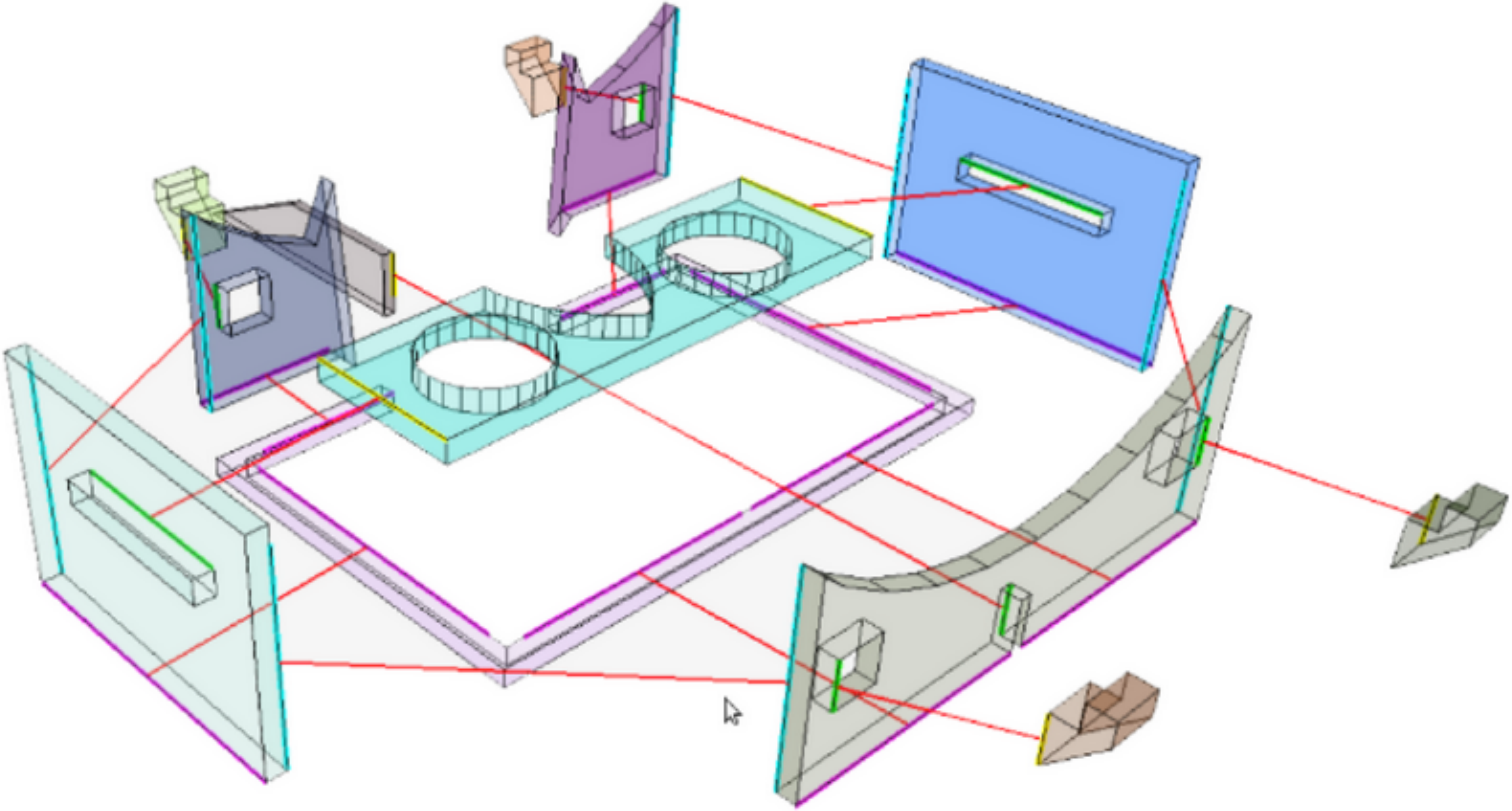
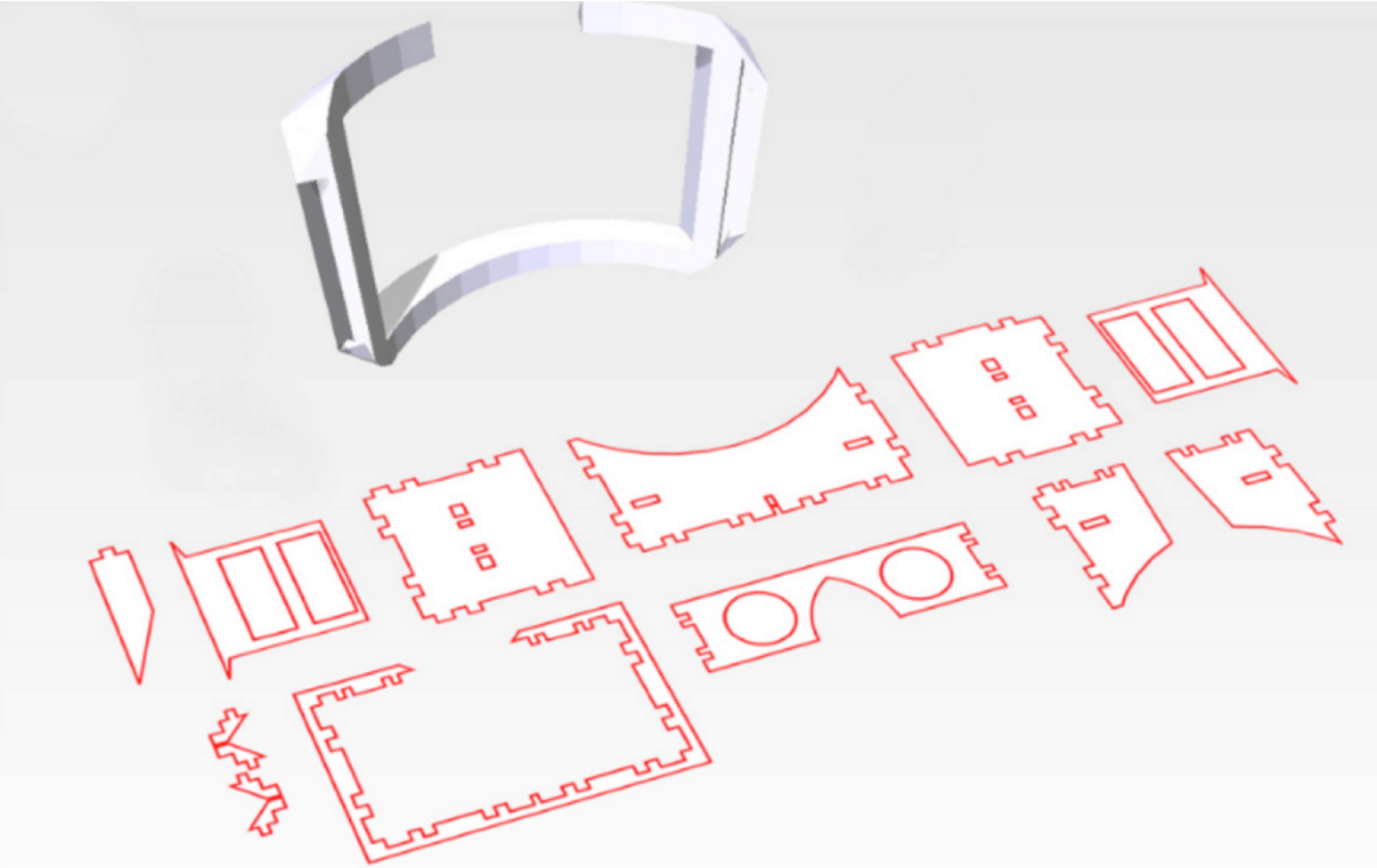

localhost
Platener
Models
Fidelity
Speed
Curved options
Consider curved panels
Bend wood
Bend acrylic
Brushes
Acrylic - bending
Wooden - Living hinges
Finger joints
No joints
Switch genders
Download result
to speed up design iteration...

plate-joint **graph**





Platener: Low-Fidelity Fabrication of 3D Objects by Substituting 3D Print with Laser-Cut Plates

Dustin Beyer, Serafima Gurevich, Stefanie Mueller, Hsiang-Ting Chen, Patrick Baudisch
Hasso Plattner Institute, Potsdam, Germany
{firstname.lastname}@hpi.uni-potsdam.de

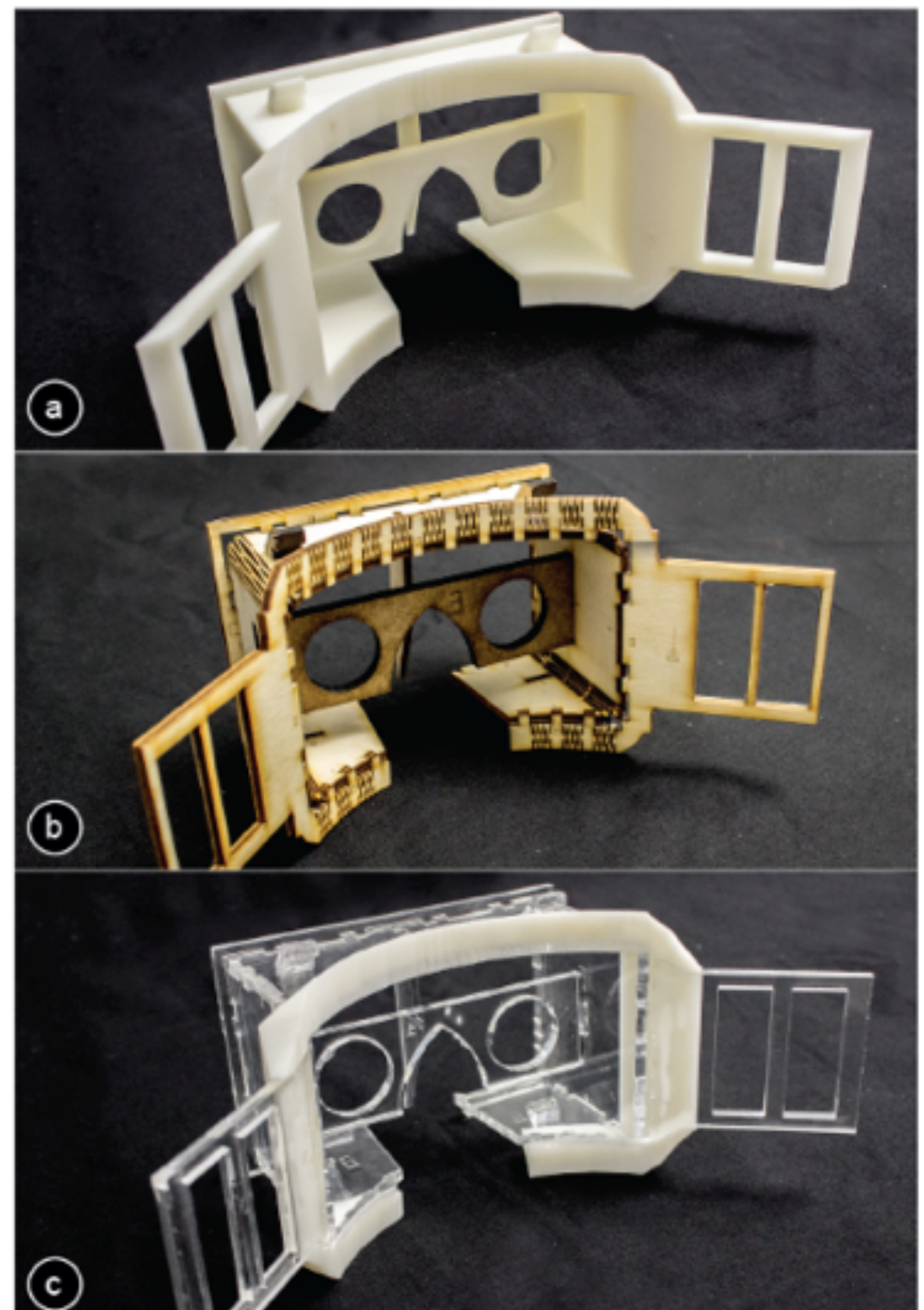
ABSTRACT

This paper presents Platener, a system that allows quickly fabricating intermediate design iterations of 3D models, a process also known as low-fidelity fabrication. Platener achieves its speed-up by extracting straight and curved plates from the 3D model and substituting them with laser cut parts of the same size and thickness. Only the regions that are of relevance to the current design iteration are executed as full-detail 3D prints. Platener connects the parts it has created by automatically inserting joints. To help fast assembly it engraves instructions. Platener allows users to customize substitution results by (1) specifying fidelity-speed tradeoffs, (2) choosing whether or not to convert curved surfaces to plates bent using heat, and (3) specifying the conversion of individual plates and joints interactively.

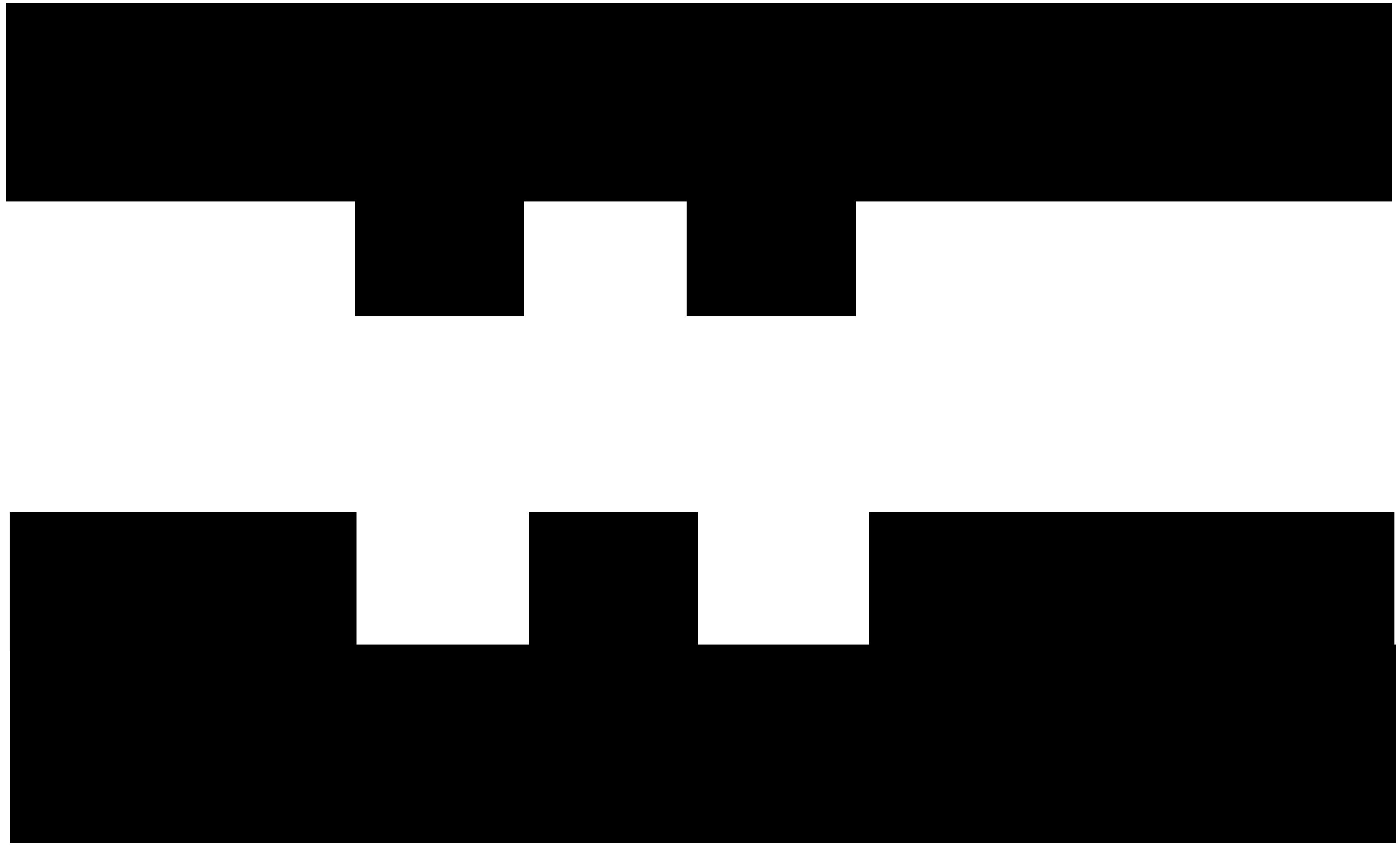
Platener is designed to best preserve the fidelity of *functional* objects, such as casings and mechanical tools, all of which contain a large percentage of straight/rectilinear elements. Compared to other low-fab systems, such as faBrickator and WirePrint, Platener better preserves the stability and functionality of such objects: the resulting assemblies have fewer parts and the parts have the same size and thickness as in the 3D model.

To validate our system, we converted 2,250 3D models downloaded from a 3D model site (*Thingiverse*). Platener achieves a speed-up of 10x or more for 39.9% of all objects.

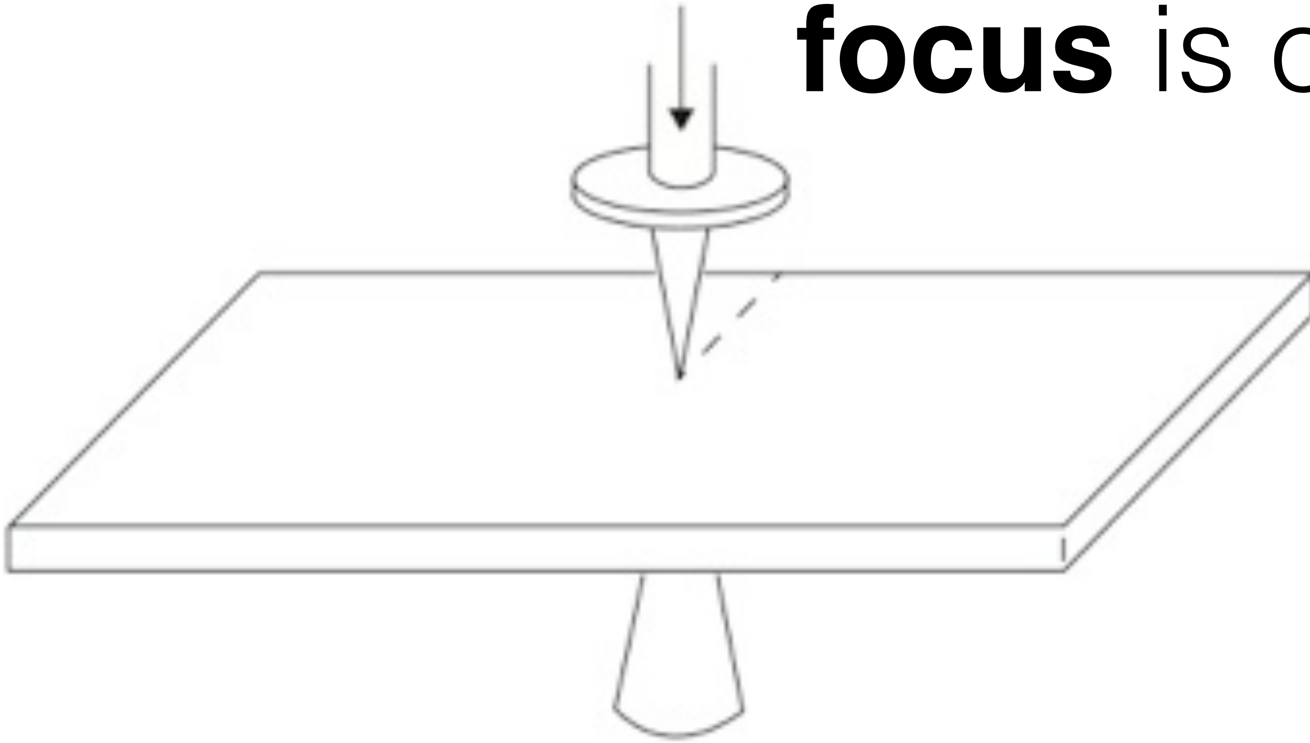
Author Keywords: rapid prototyping; 3D printing; building blocks; physical prototyping.



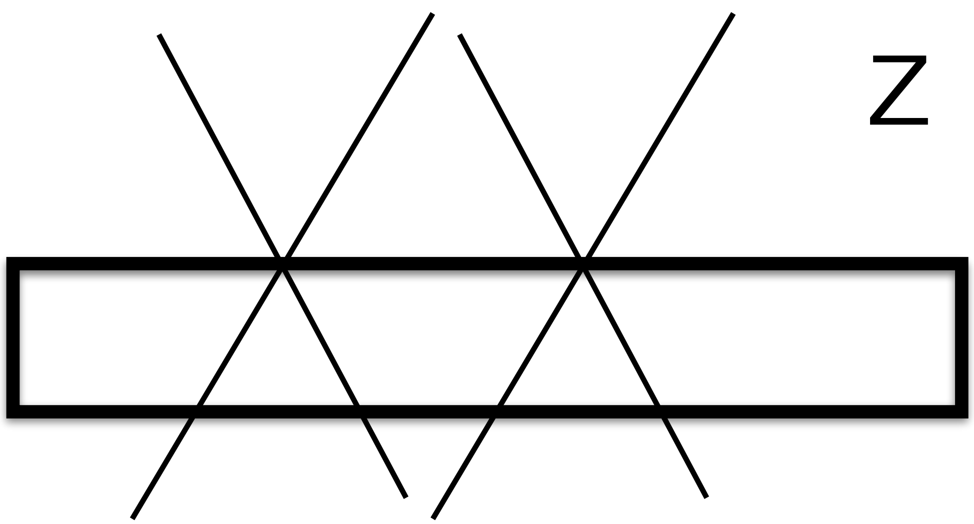
there are other problems
when laser cutting this…



focus is on top of the workpiece



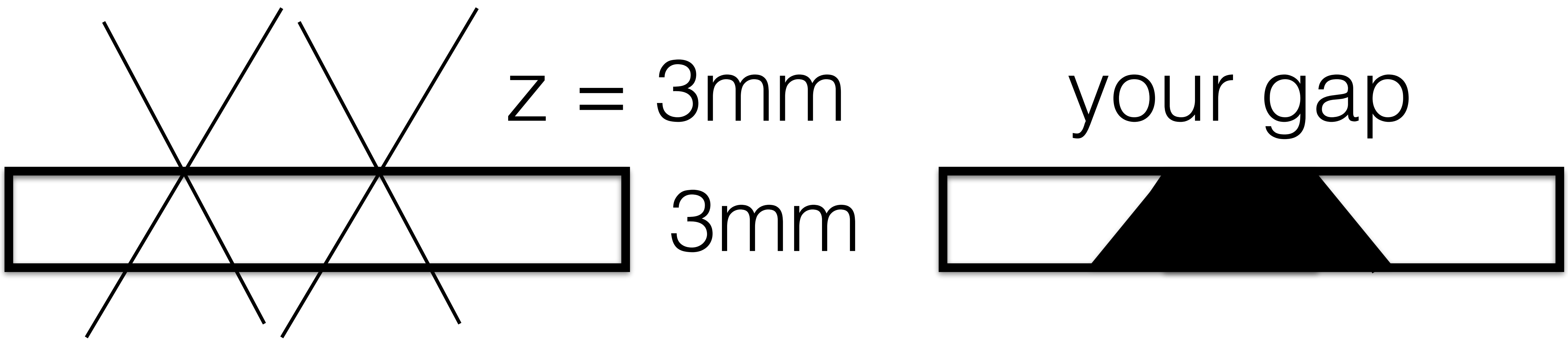
z = 3mm



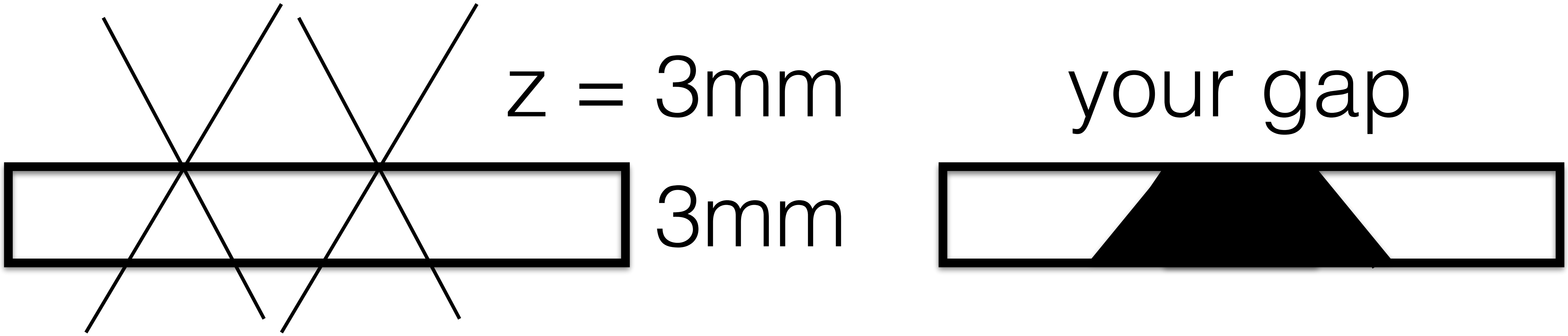
3mm

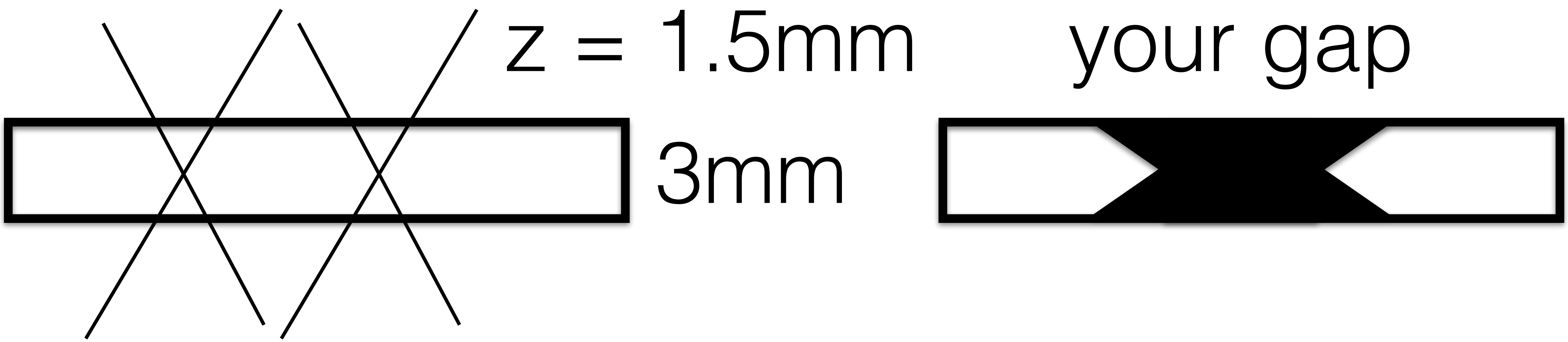
your gap
will **not be straight**

it actually matters
in which direction you assemble your joints!



would this be any better if you put z = 1.5mm?

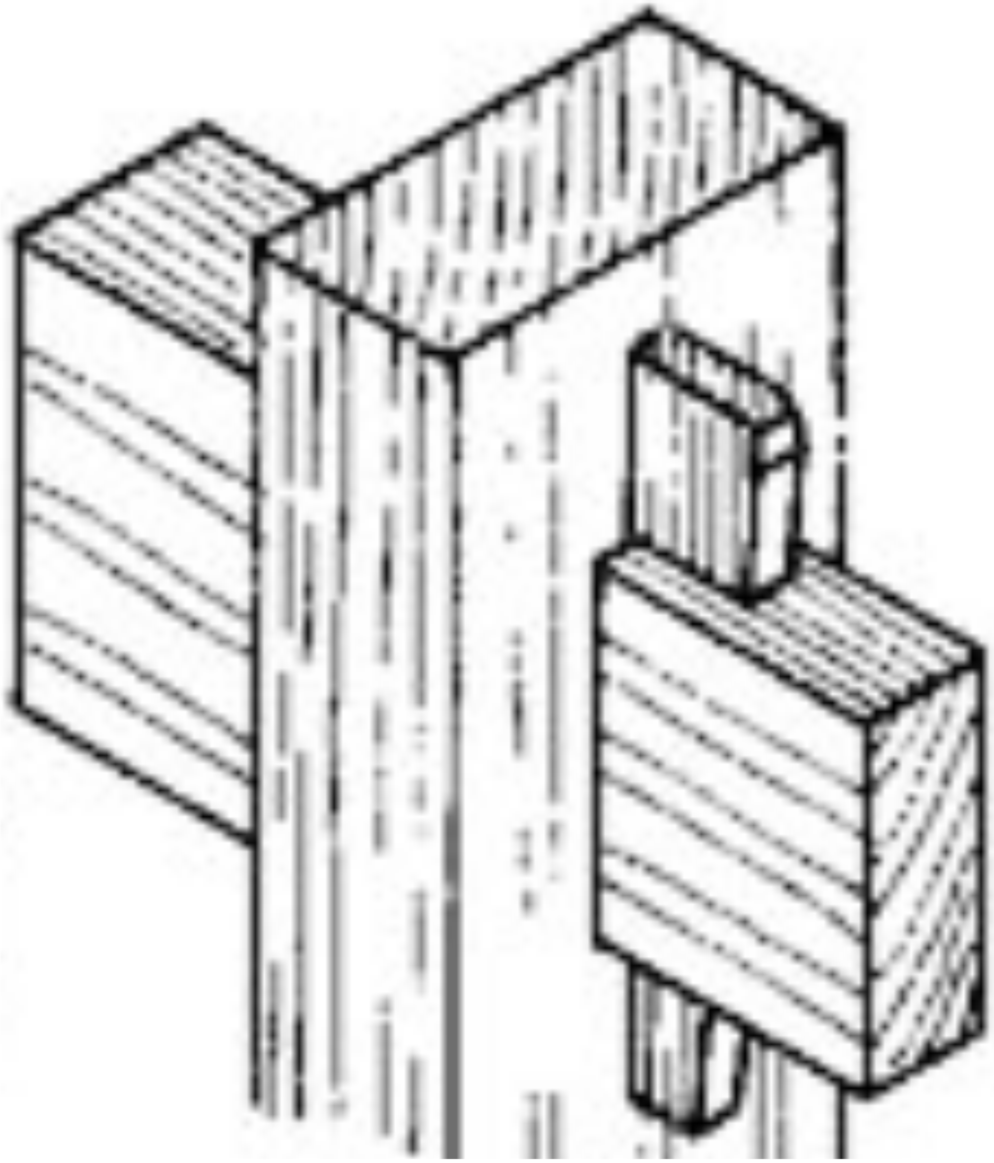


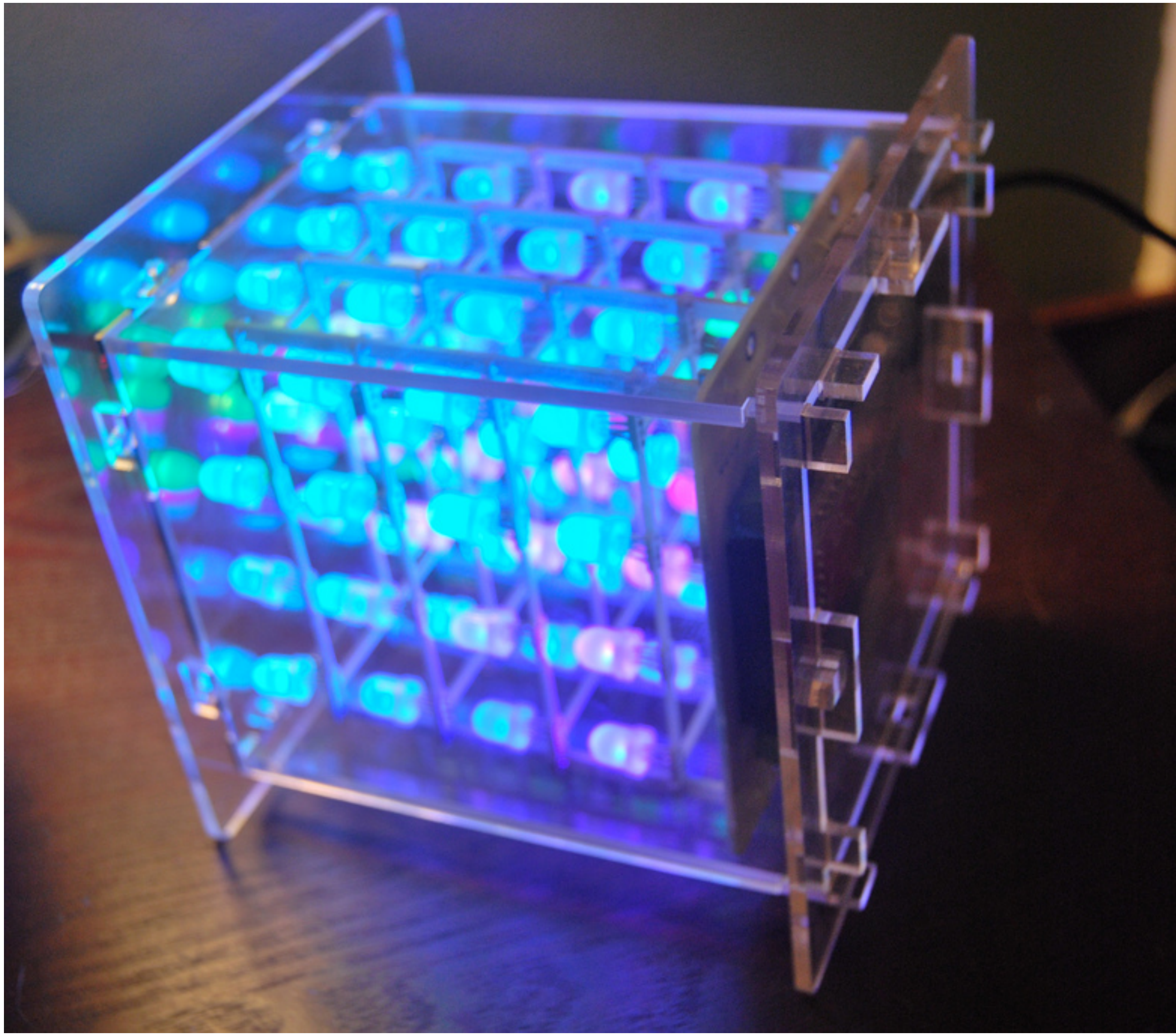


well, a bit maybe… **direction doesn't matter anymore,**
but there's no way to get the cut perfectly straight

lot’s of **other connection joints….**

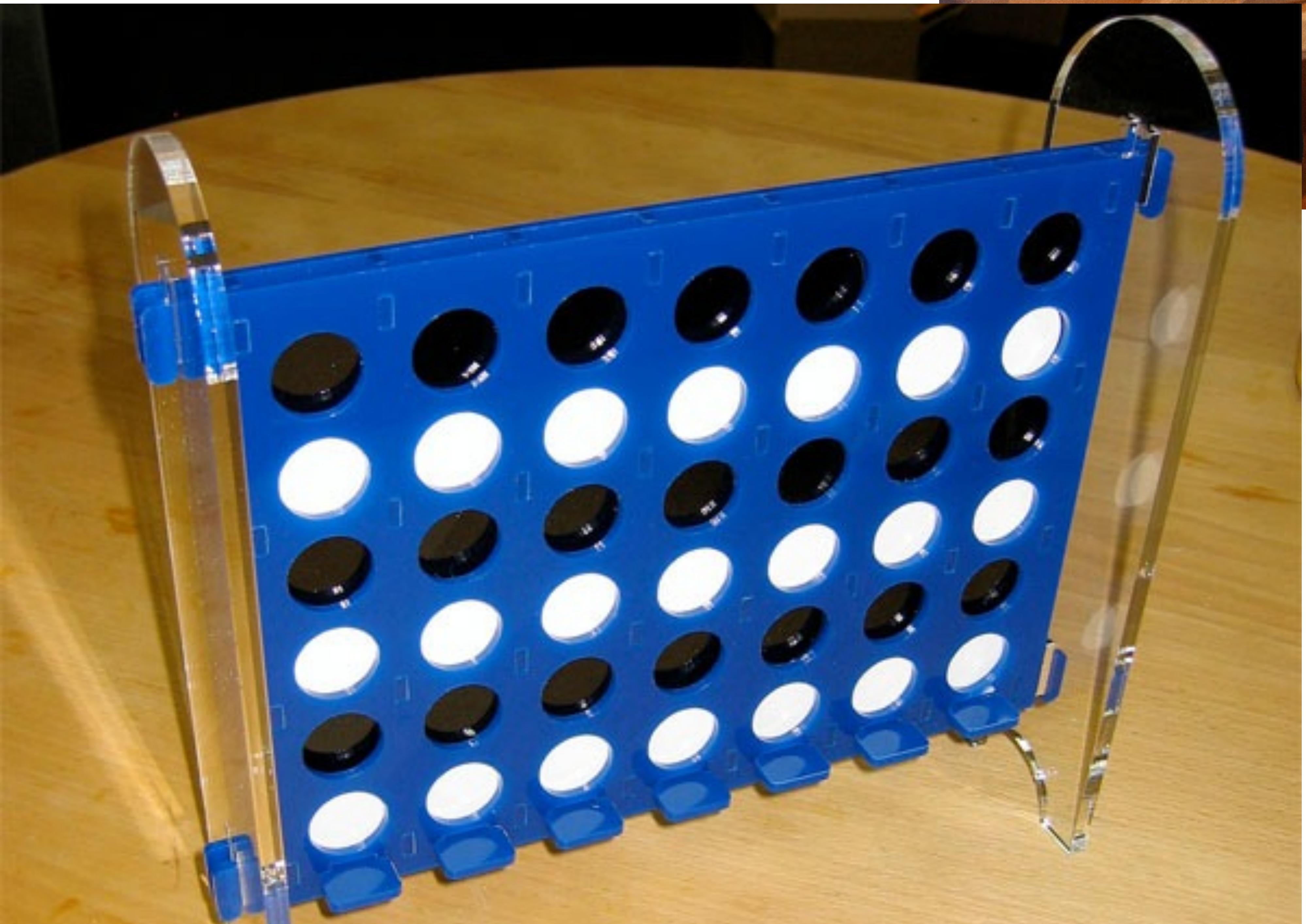
lock in place::





slide to lock::

gravity or other force holds it

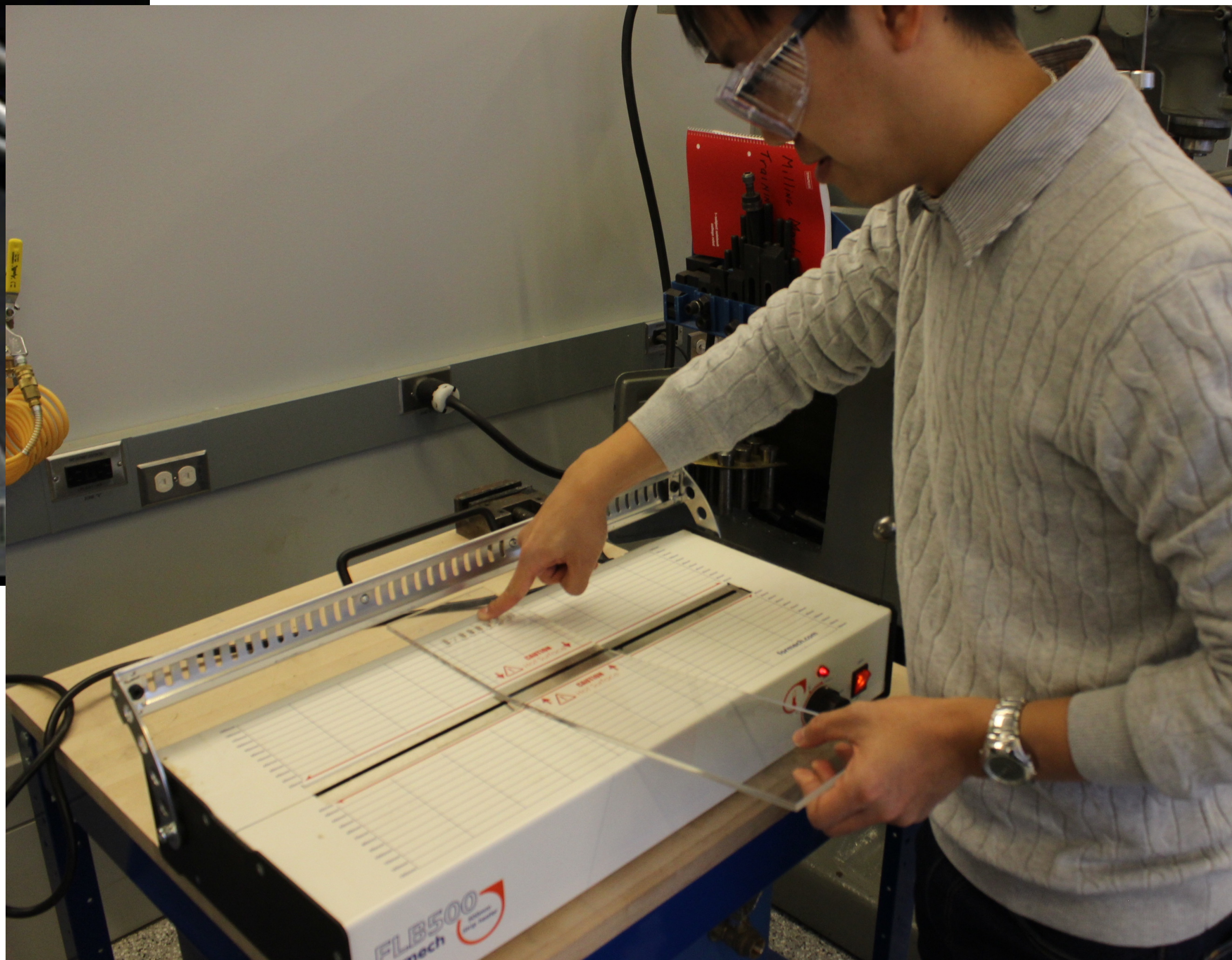


bending

bend acrylic::

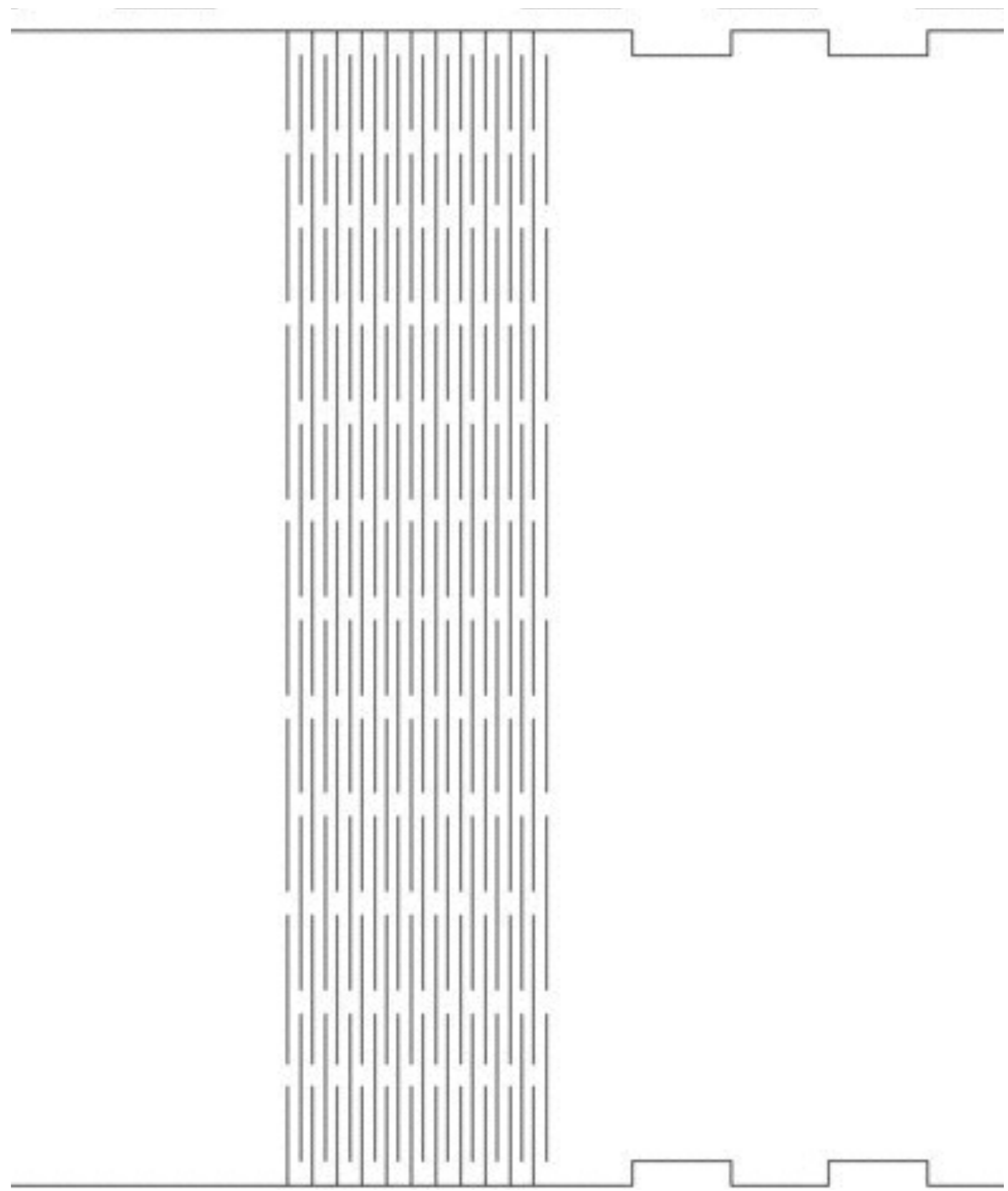
to bend acrylic use a **heatgun**

or **strip heater**



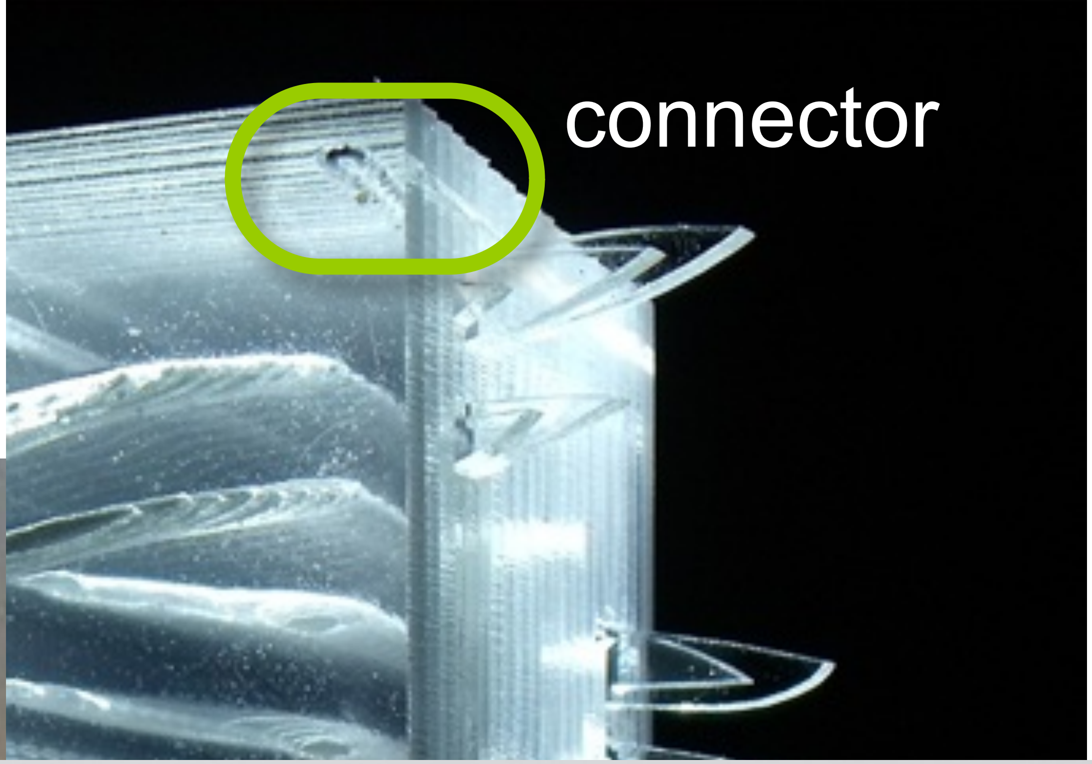
living hinges::

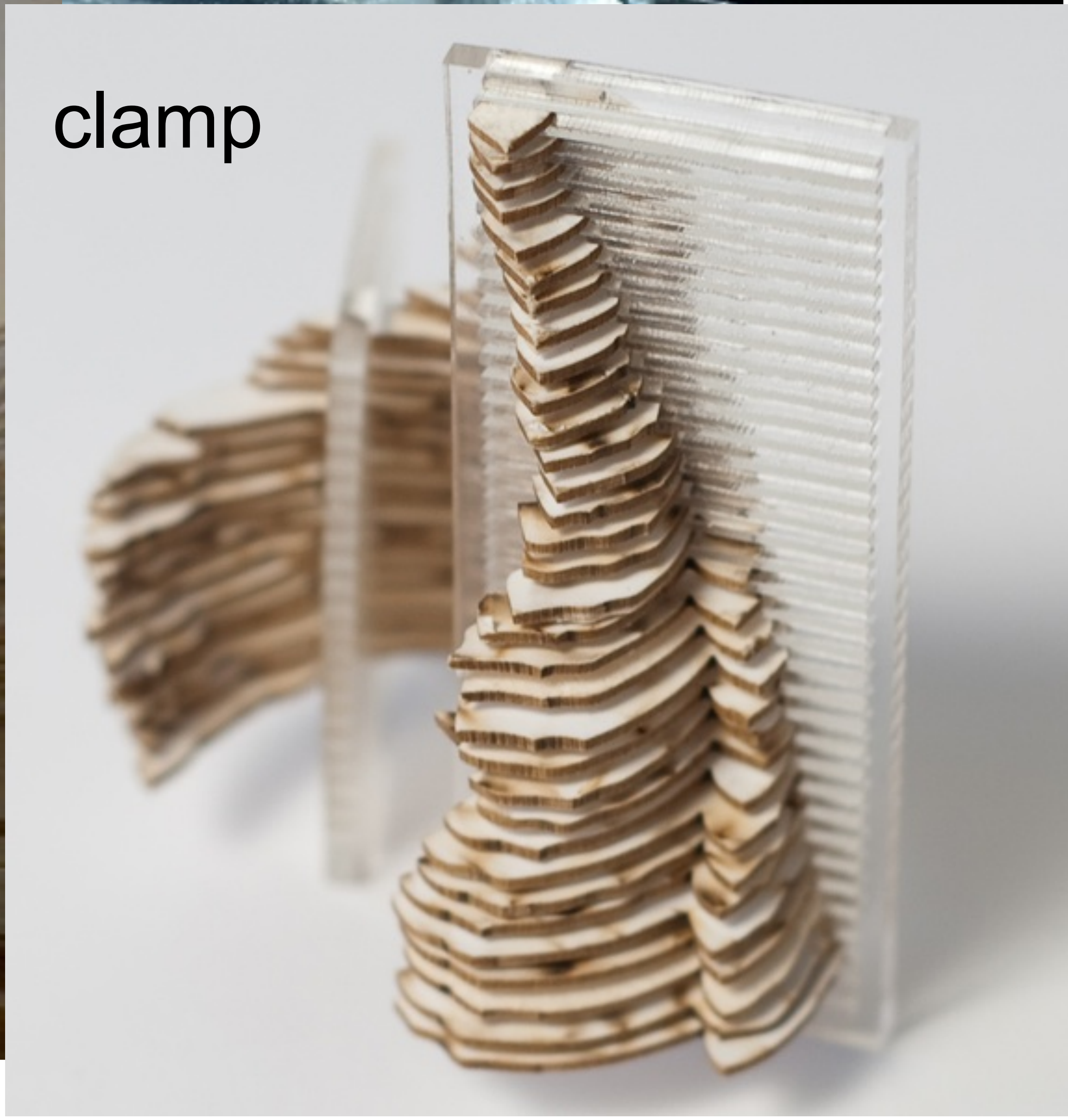
living hinges::



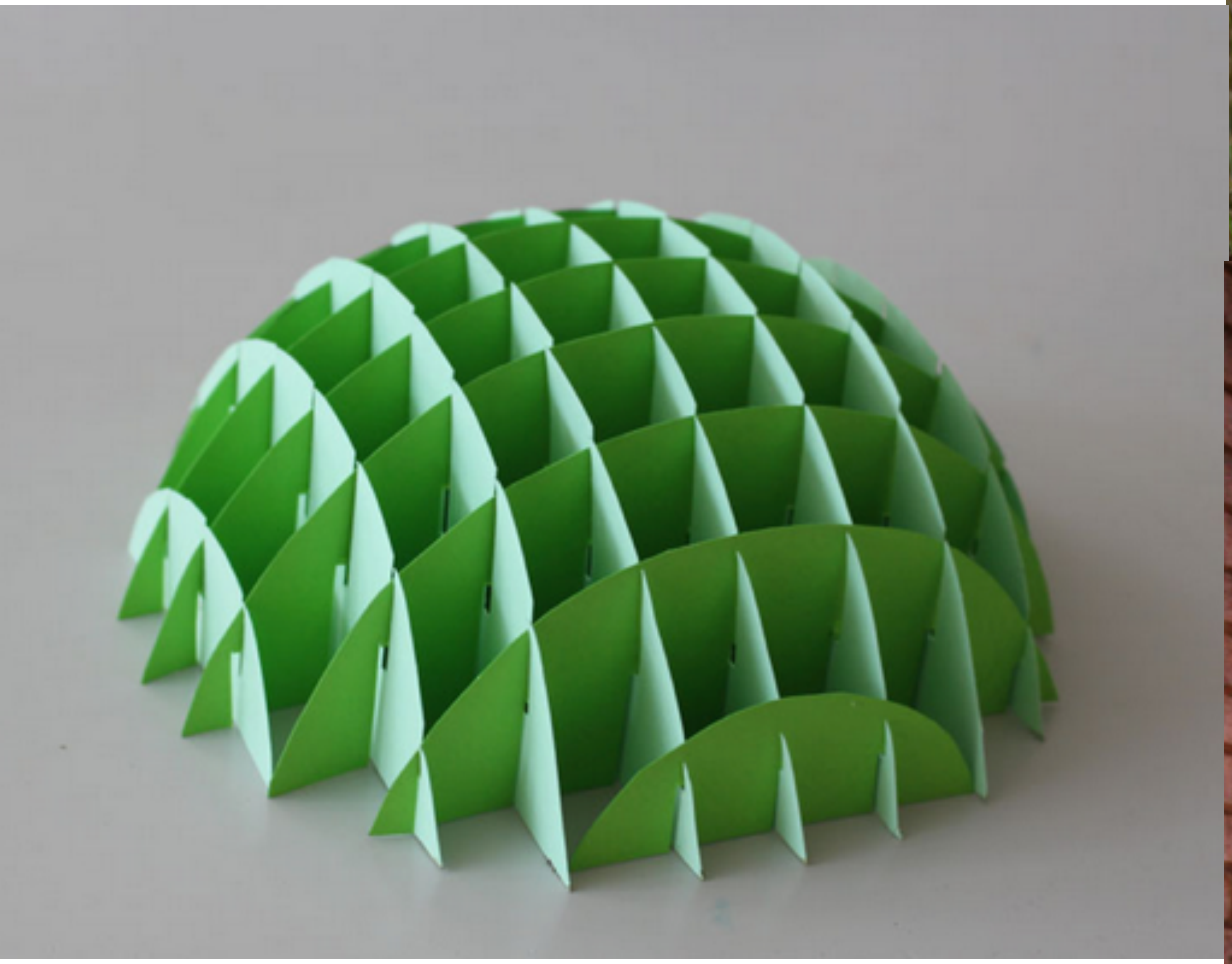
other ways to make 3D

stacking::



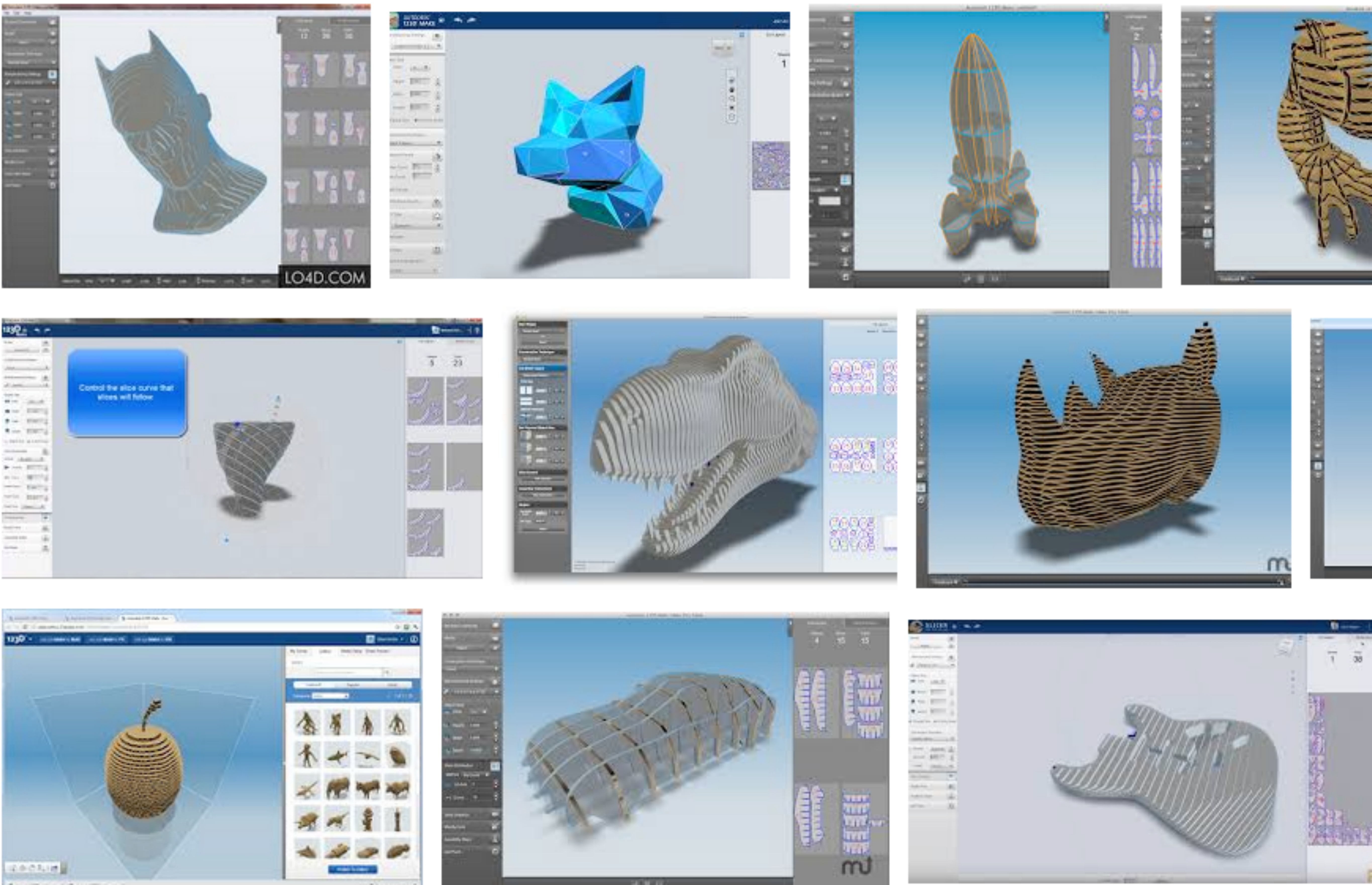


intersecting::



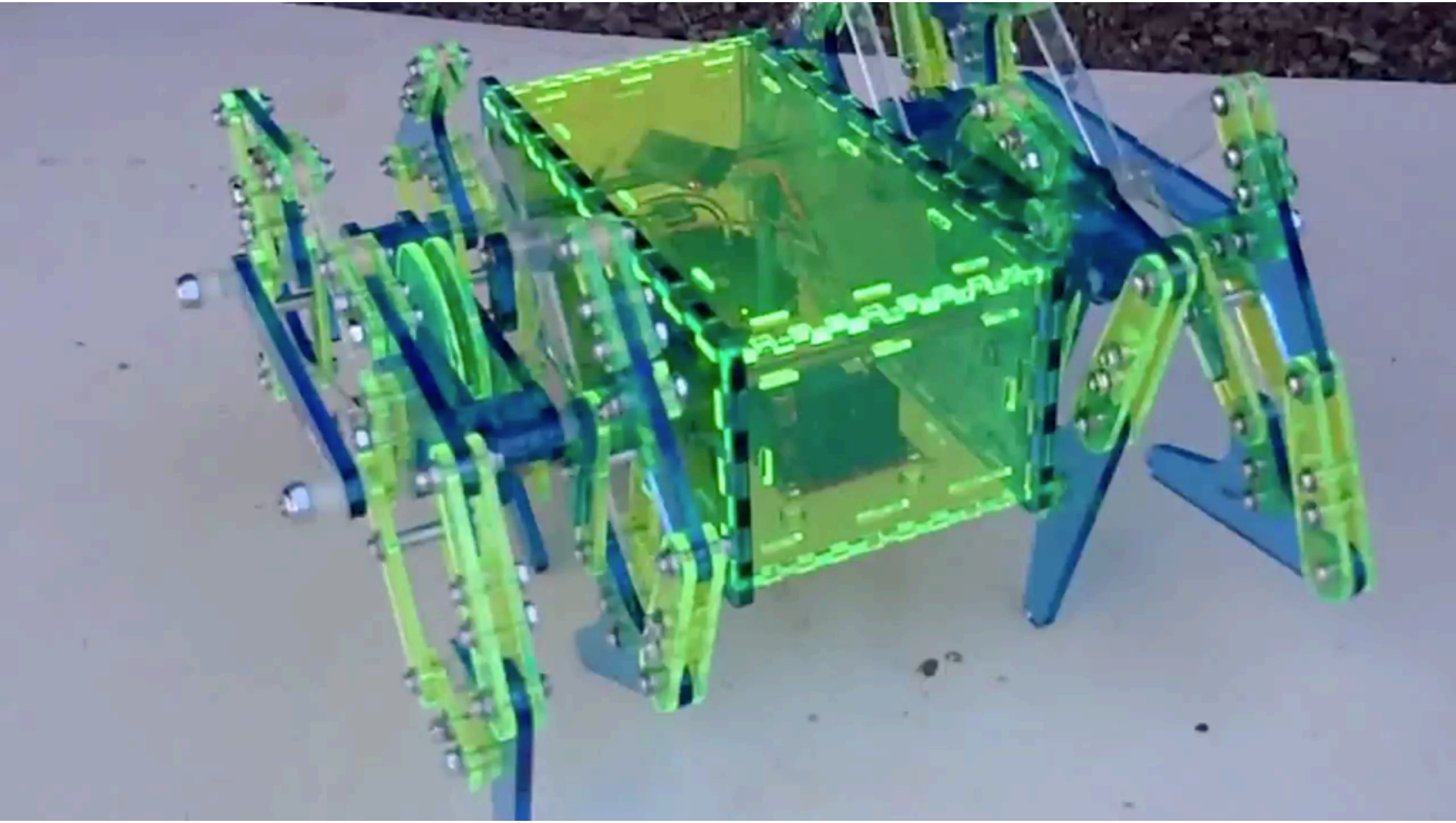
surface folding::

Autodesk 123D Make::



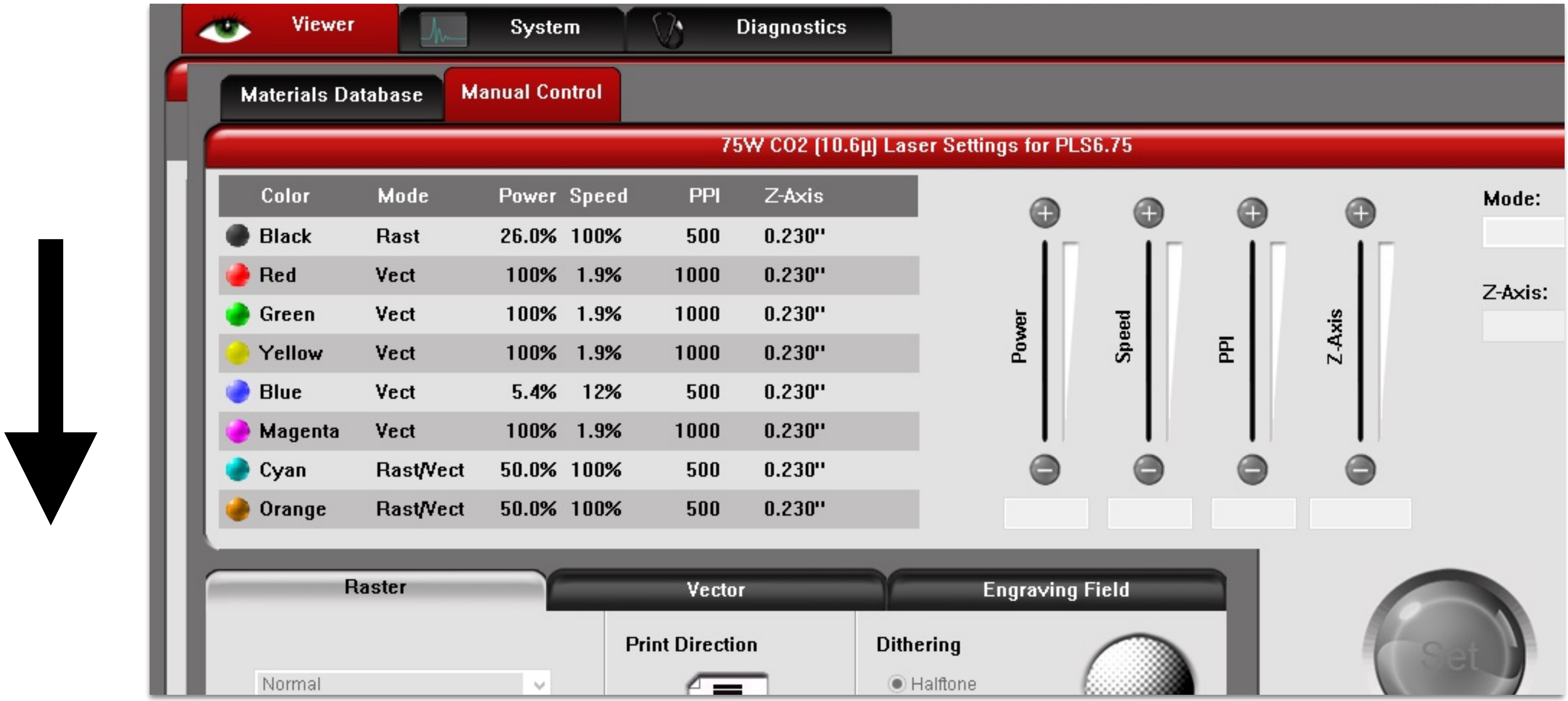
moving parts

gears & linkages::

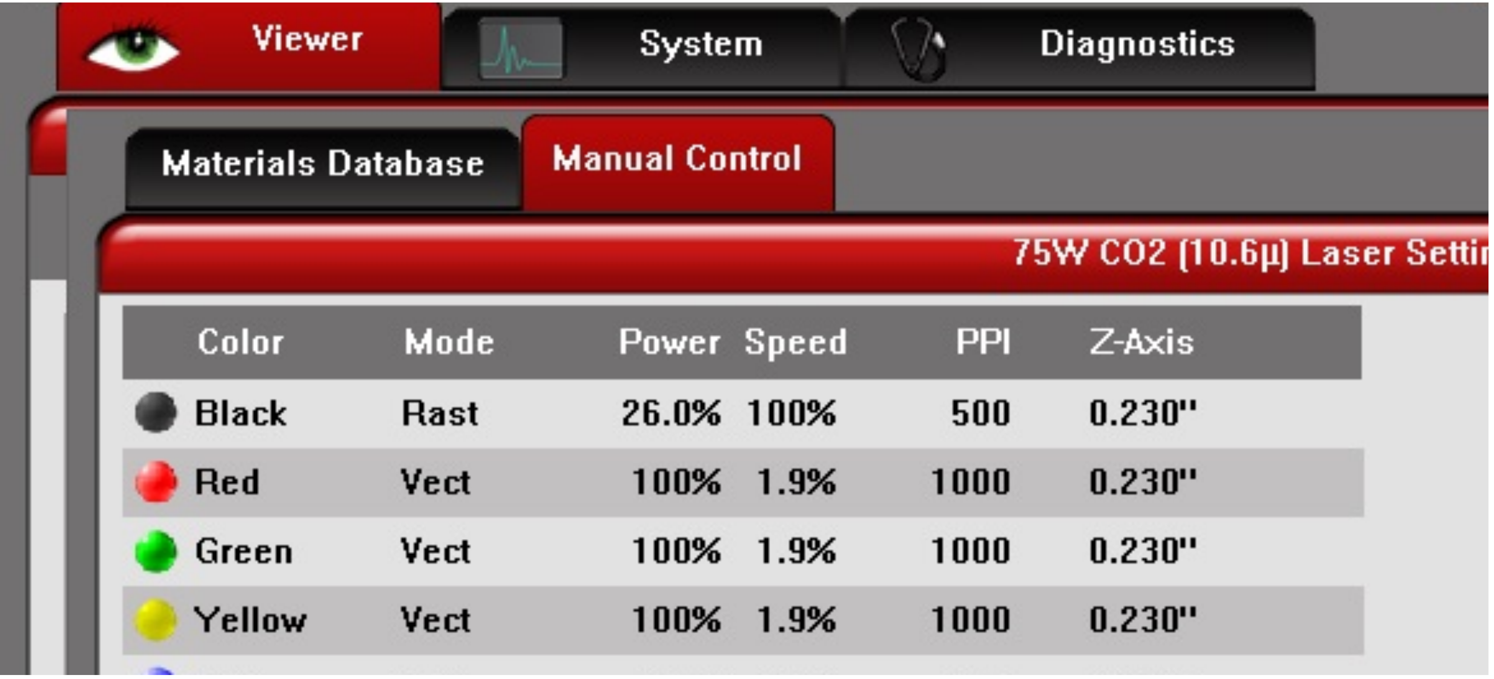


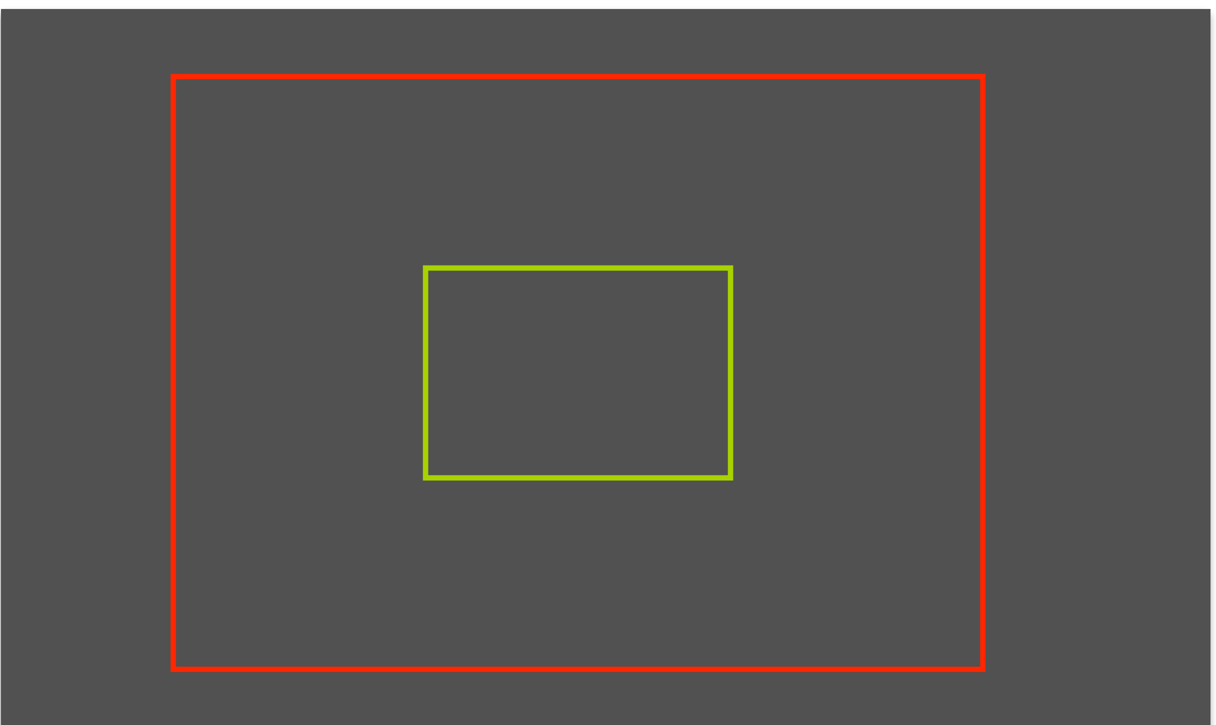
tips & tricks:

line color…

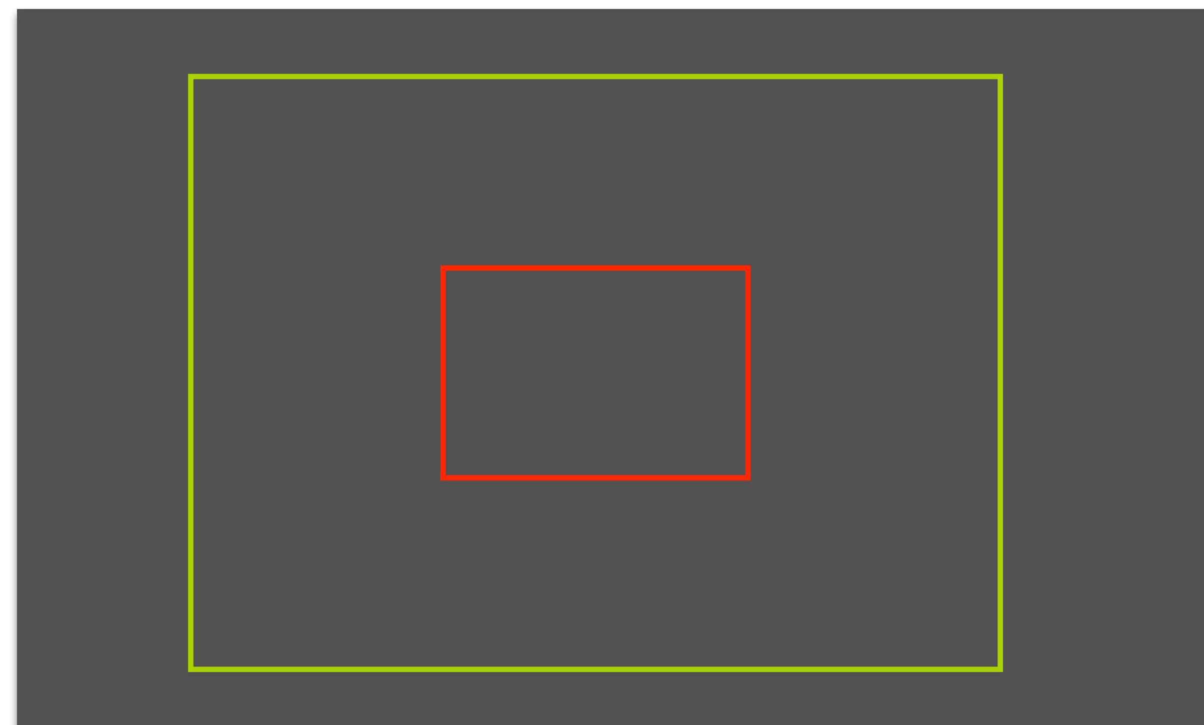


laser cuts colors **in order from top to bottom:** black first, then red, green, yellow





vs.



which one is better and why?

<30 second brainstorming>

what laser cutters exist?

industrial laser cutter
$20k - 50k


consumer laser cutters
$3,000 (e.g., GlowForge)

hacker laser cutters < $1,000

water pump under the desk!

MicroSlice ca. $200
Arduino, super low-power laser
(cuts paper and makes light engravings)

coding for laser cutters

LAOS board
(open source controller board)

https://redmine.laoslaser.org/projects/laos/wiki/SimpleCode

[Eickhoff, Mueller, Baudisch CHI 2016]

Destructive Games: Creating Value by Destroying Valuable Physical Objects

David Eickhoff, Stefanie Mueller, and Patrick Baudisch
Hasso Plattner Institute, Potsdam, Germany
{david.eickhoff, stefanie.mueller, patrick.baudisch}@hpi.de

ABSTRACT
While personal fabrication tools, such as laser cutters and milling machines, are intended for construction, we are exploring their use for *de*struction. We present a series of games that result in valuable physical objects being destroyed—objects owned by the players. Interestingly, we found that we can design these games to be desirable to play, despite the loss of the object, by instead producing social value. As part of a user study, twelve students played a destructive game in which a laser cutter cut up their own money bills. Surprisingly, 8 out of 12 participants would play again. They shared their post-game stories with us.

Author Keywords: destruction; laser cutting; games; personal objects; interactive art.

ACM Classification Keywords: H.5.2 [Information interfaces and presentation]: User Interfaces.

INTRODUCTION
While the primary objective of engineers is to *create*, artists and researchers have occasionally reversed this main underlying principle and explored *destruction*. This approach of reversing a central question has a long tradition as it can help understand the original question.

In the virtual world, game designers have explored destruction as a tool for increasing excitement by adding irreversible consequences to otherwise generic and replicable experiences [7]. In the physical world, artists and researchers picked up on the topic, creating artifacts that either allow users to destroy physical objects [14], or that self-destroy themselves after a limited period of time [9] or usage [12].

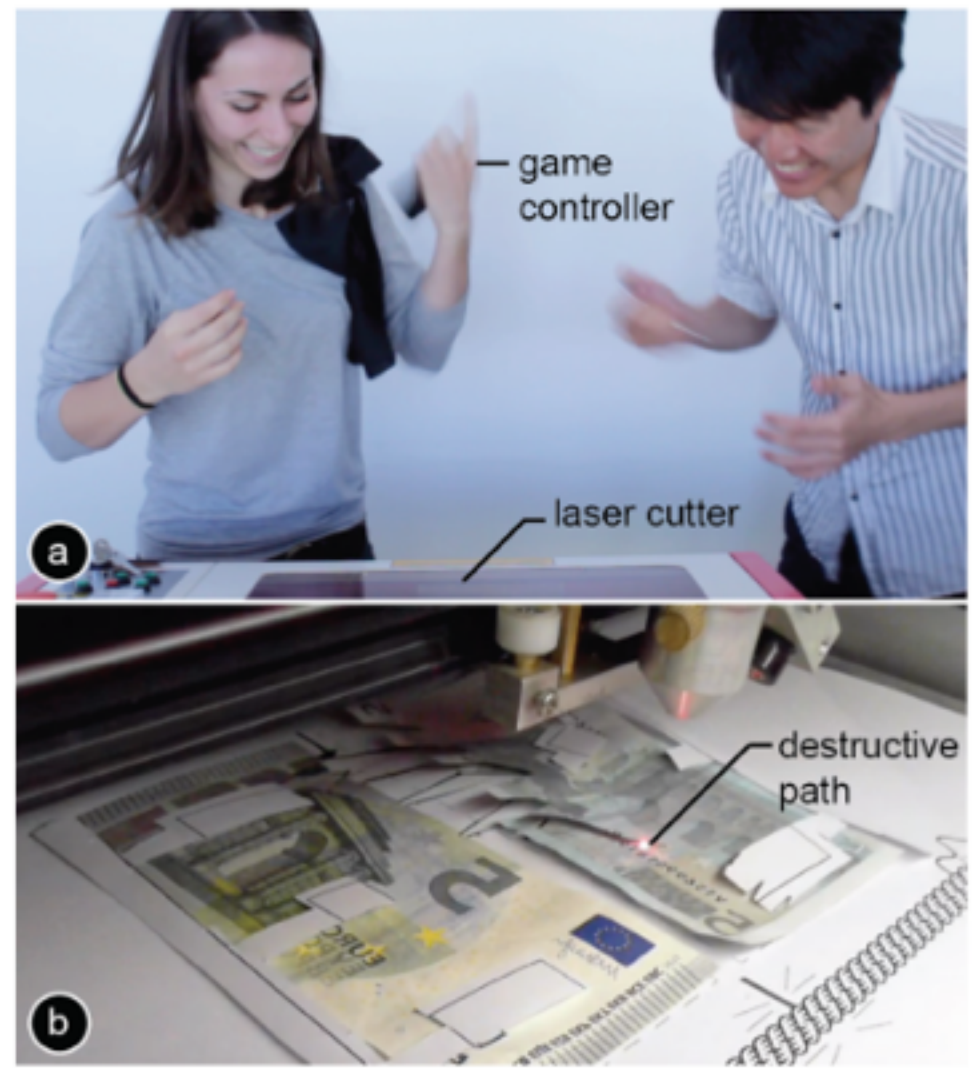


Figure 1: Destructive games are games that result in valuable physical objects being damaged or destroyed. To play destructive *Tug-of-War,* each player places a money bill into the laser cutter, and then tries to direct the laser into the other player's bill. Surprisingly, we found that 8 out of 12 players would play again.

gcode::

programming language for controlling industrial machines such as mills, lathes and cutters as well as 3D-printers

move

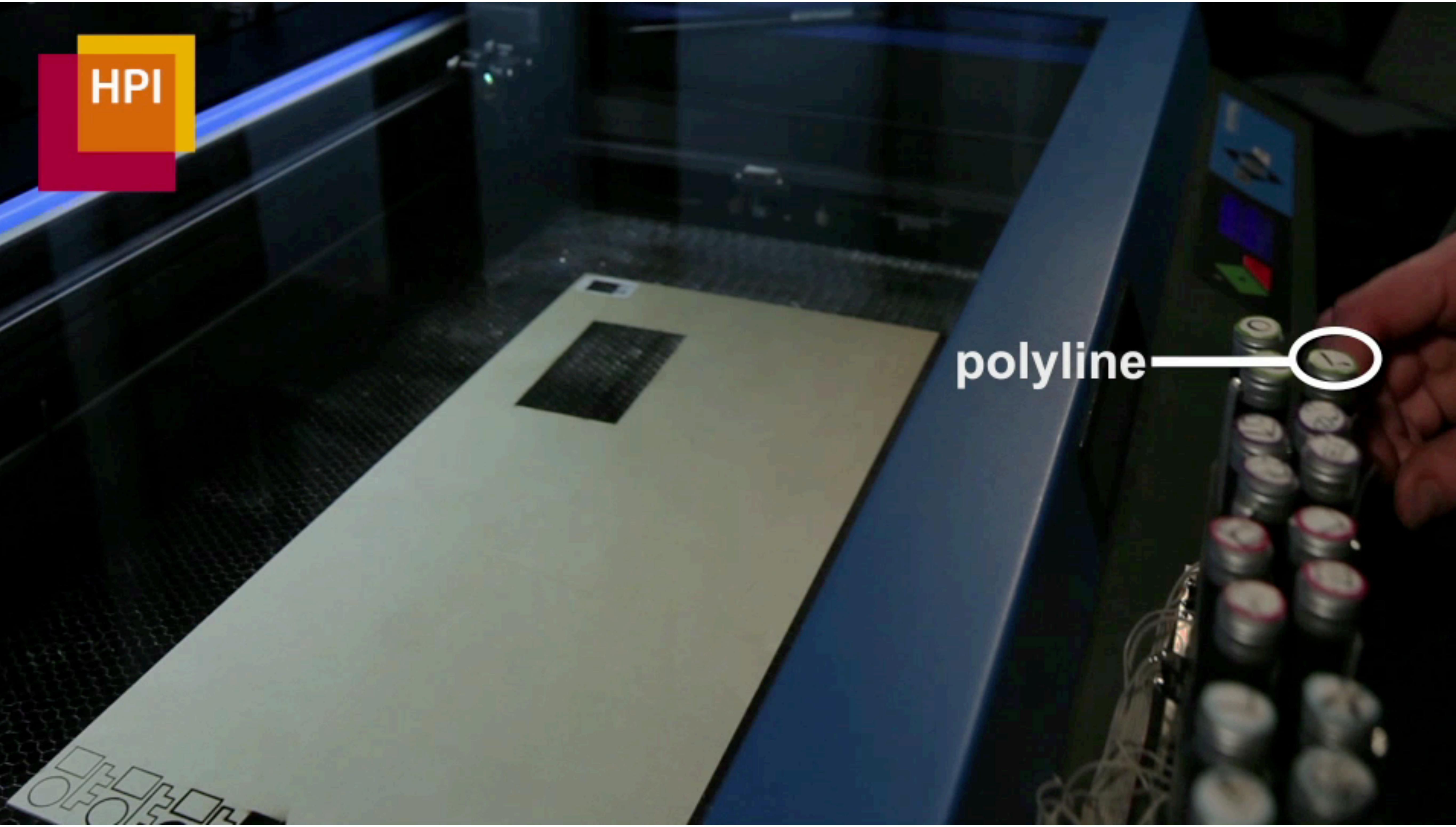
$\boxed{\text{G1 X0 Y0 Z3 F500}}$ **speed**

coordinates

https://www.norwegiancreations.com/2015/08/an-intro-to-g-code-and-how-to-generate-it-using-inkscape/

draw on the workpiece
with a laser pointer

[Mueller, Lopes, Baudisch UIST 2012]



[Mueller, Lopes, Baudisch UIST 2012]

Interactive Construction: Interactive Fabrication of Functional Mechanical Devices

Stefanie Mueller, Pedro Lopes, and Patrick Baudisch
Hasso Plattner Institute, Potsdam, Germany
{stefanie.mueller, pedro.lopes, patrick.baudisch}@hpi.uni-potsdam.de

ABSTRACT
Personal fabrication tools, such as laser cutters and 3D printers allow users to create precise objects quickly. However, working through a CAD system removes users from the workpiece. Recent interactive fabrication tools reintroduce this directness, but at the expense of precision.

In this paper, we introduce *constructable*, an interactive drafting table that produces precise physical output in every step. Users interact by drafting directly on the workpiece using a hand-held laser pointer. The system tracks the pointer, beautifies its path, and implements its effect by cutting the workpiece using a fast high-powered laser cutter.

Constructable achieves precision through tool-specific constraints, user-defined sketch lines, and by using the laser cutter itself for all visual feedback, rather than using a screen or projection. We demonstrate how Constructable allows creating simple but functional devices, including a simple gearbox, that cannot be created with traditional interactive fabrication tools.

Author Keywords: interactive fabrication; laser cutting; rapid prototyping; sketching; construction; mechanics.

ACM Classification Keywords: H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

General Terms: Design; Human Factors.

INTRODUCTION
Rapid prototyping/personal fabrication tools, such as 3D printers and computer controlled milling machines help users create one-off prototypes rapidly.

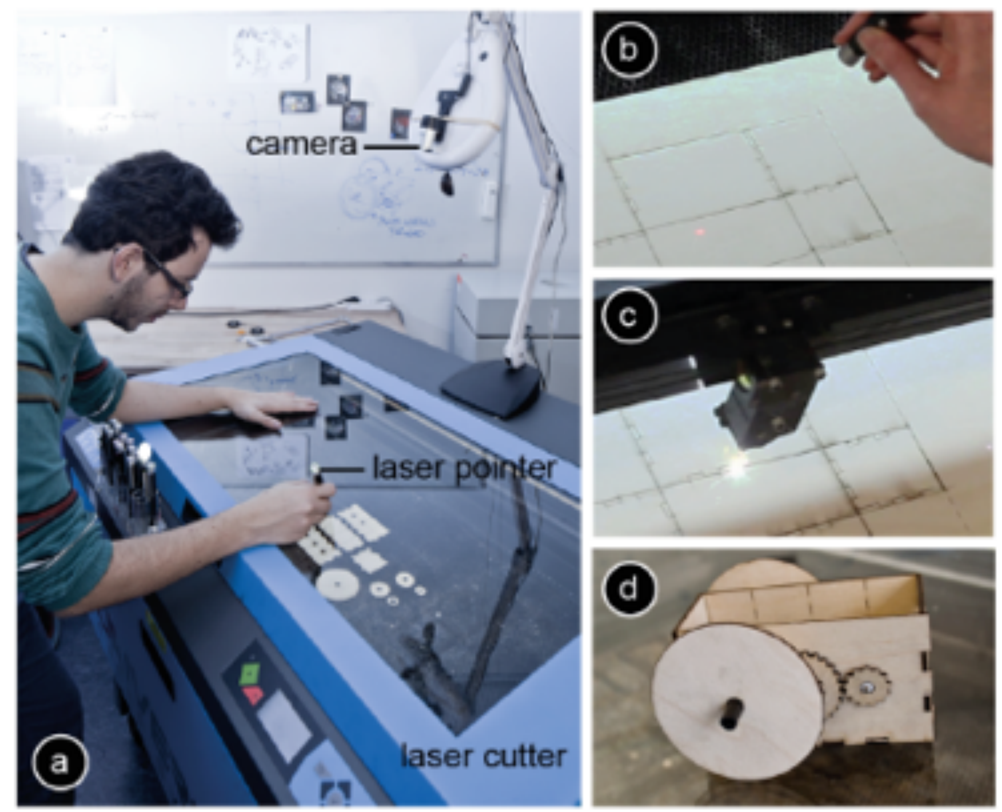
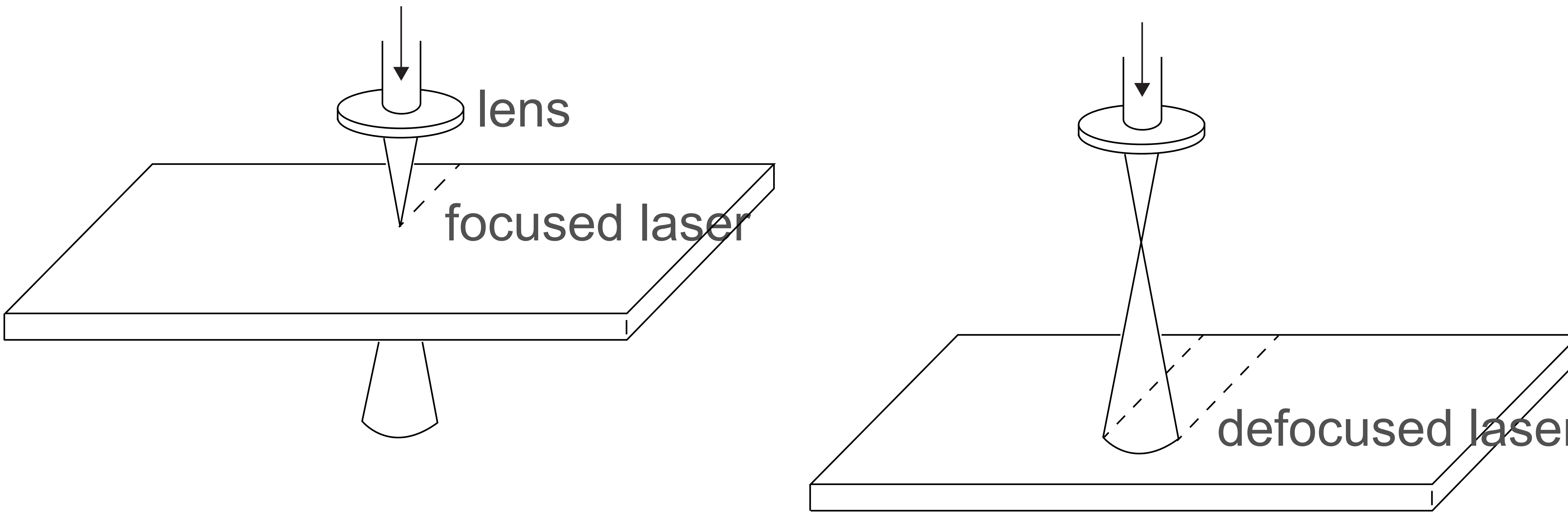


Figure 1: (a) *Constructable* users interact by drafting directly on the workpiece with hand-held lasers. (b) Here the user sketches a finger joint across two objects (c) The system responds by cutting the desired joint using the cutting laser. (d) Constructable allows creating precise & functional mechanical objects, such as this simple motorized vehicle.

(3) *Precision:* constructions aids, such as constraints allow users to precisely manufacture pieces that can perform mechanical functions.

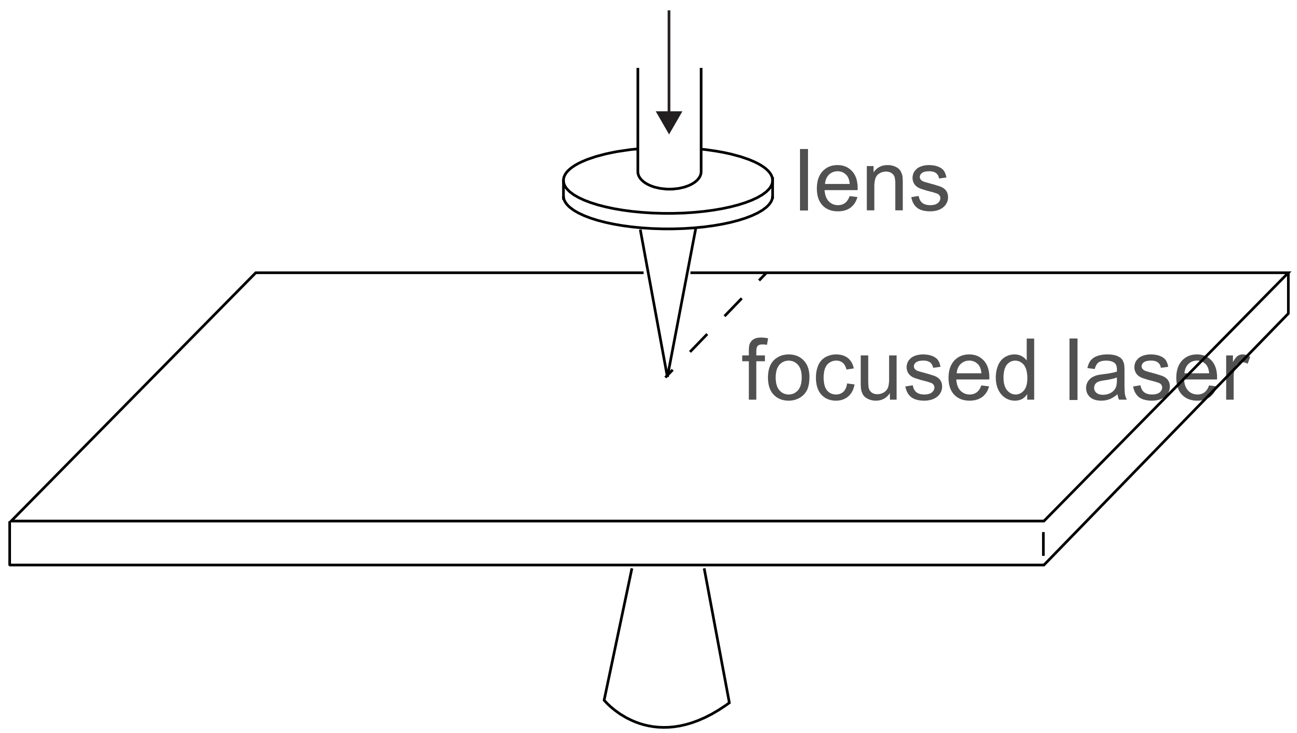
On the flipside, the transition from traditional tools to personal fabrication tools means that all editing is now done on a computer screen, which removes users from the work-

advanced tricks
with defocused laser

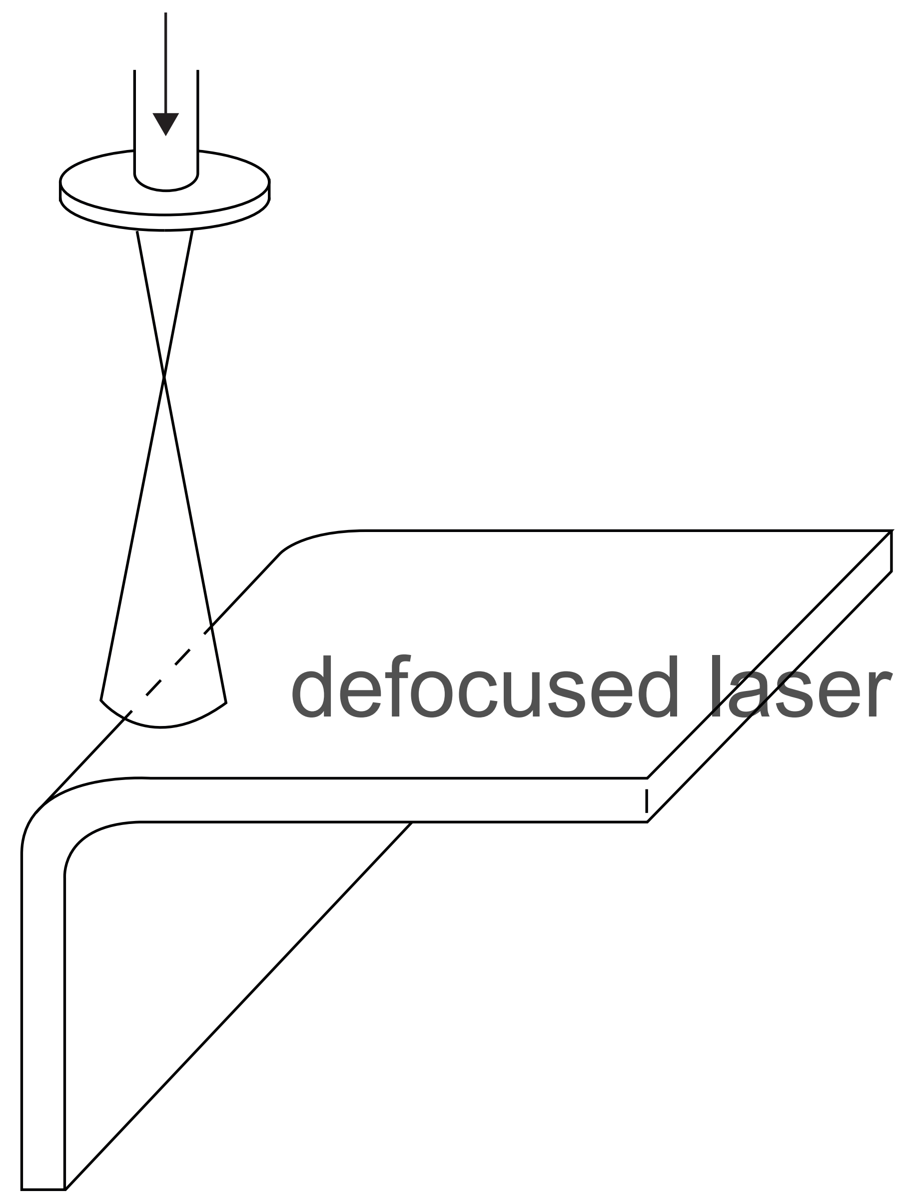


[Mueller, Kruck, Baudisch, LaserOrigami CHI 2013]

laser cutting:



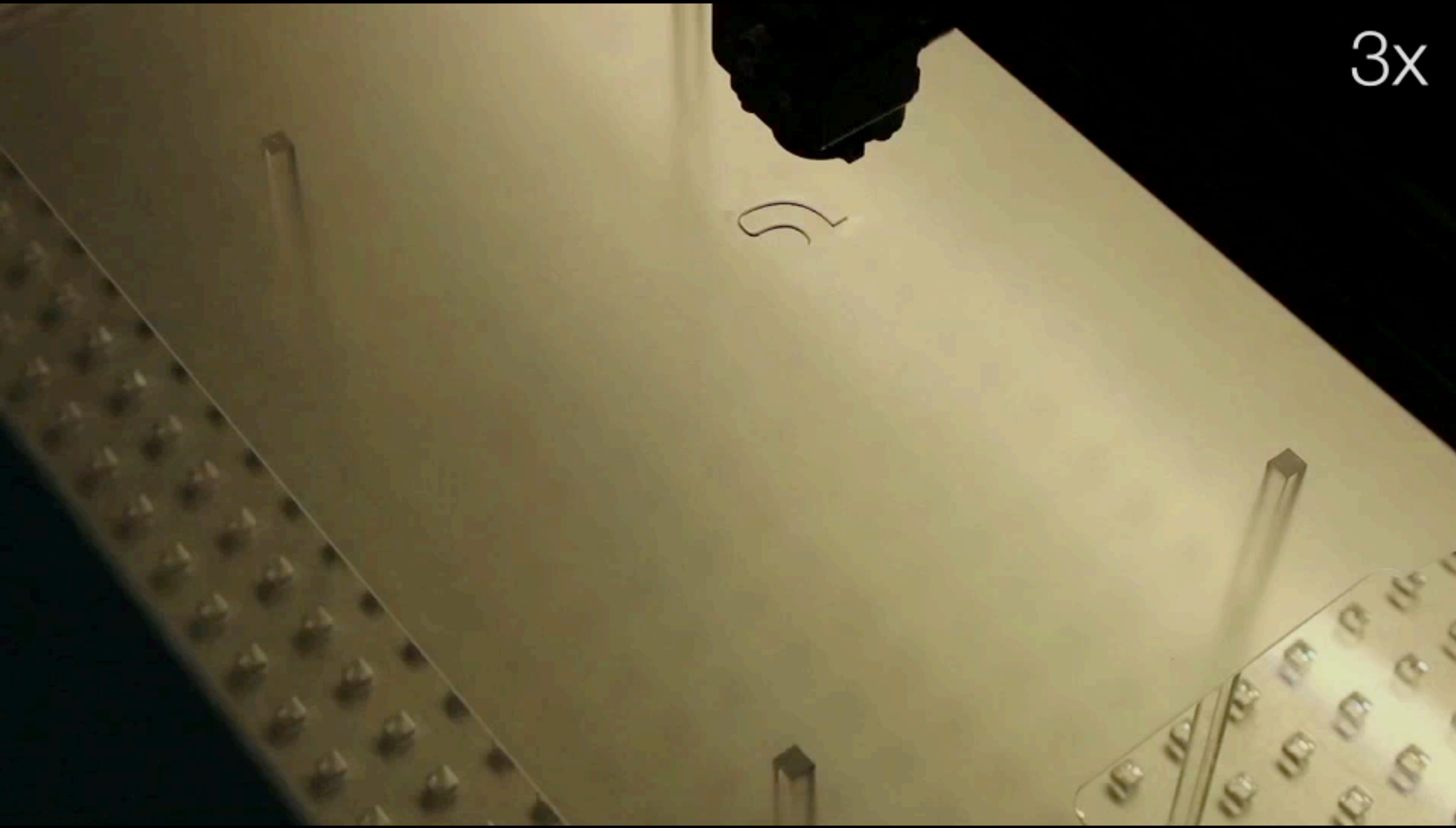
our idea: bending



[Mueller, Kruck, Baudisch, LaserOrigami CHI 2013]

[Mueller, Kruck, Baudisch, LaserOrigami CHI 2013]

[Mueller, Kruck, Baudisch, LaserOrigami CHI 2013]



[Mueller, Kruck, Baudisch, LaserOrigami CHI 2013]

LaserOrigami: Laser-Cutting 3D Objects

Stefanie Mueller, Bastian Kruck, and Patrick Baudisch
Hasso Plattner Institute, Potsdam, Germany
{stefanie.mueller, bastian.kruck, patrick.baudisch}@hpi.uni-potsdam.de

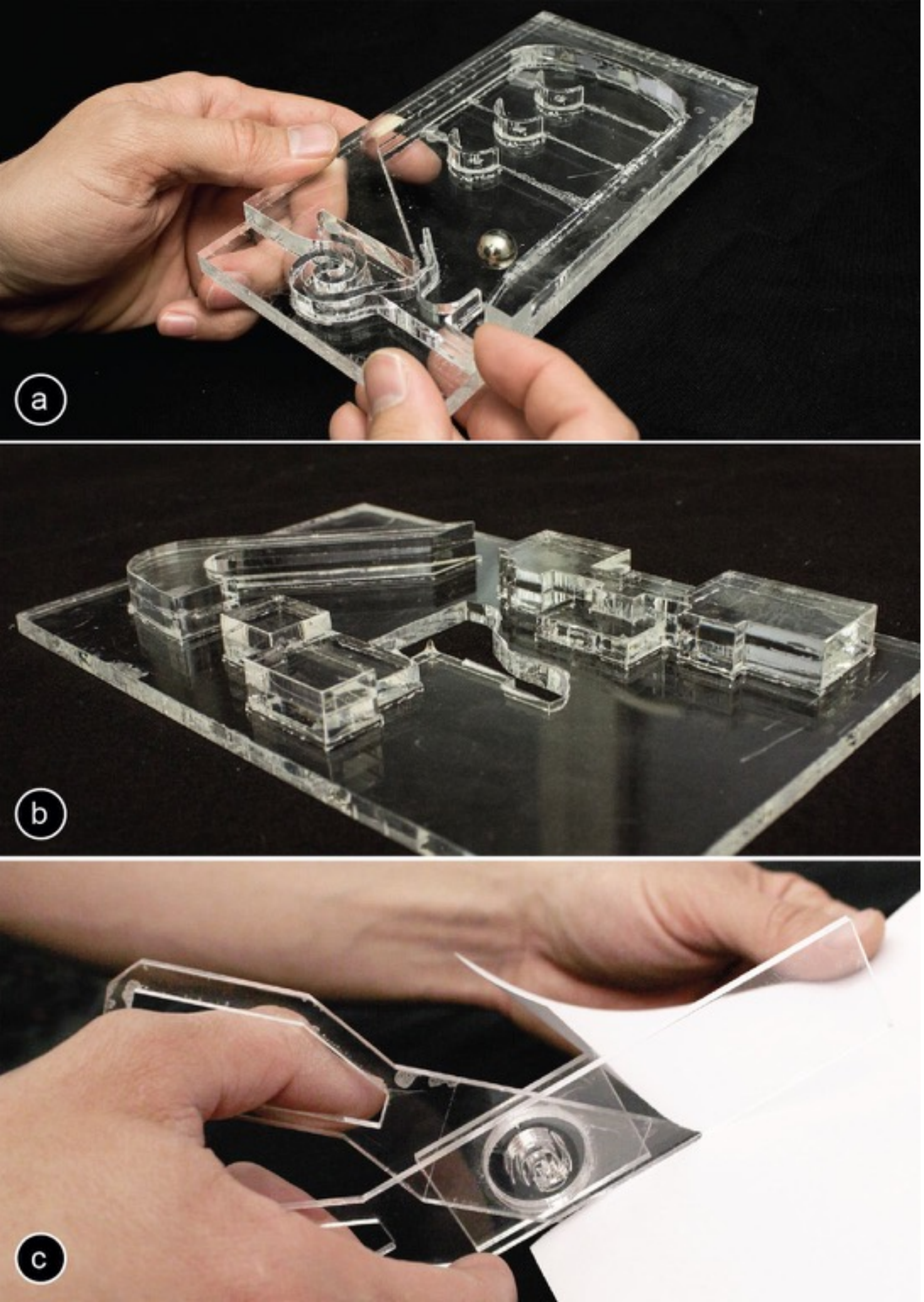
ABSTRACT
We present LaserOrigami, a rapid prototyping system that produces 3D objects using a laser cutter. LaserOrigami is substantially faster than traditional 3D fabrication techniques such as 3D printing and unlike traditional laser cutting the resulting 3D objects require no manual assembly. The key idea behind LaserOrigami is that it achieves three-dimensionality by folding and stretching the workpiece, rather than by placing joints, thereby eliminating the need for manual assembly. LaserOrigami achieves this by heating up selected regions of the workpiece until they become compliant and bend down under the force of gravity. LaserOrigami administers the heat by defocusing the laser, which distributes the laser's power across a larger surface. LaserOrigami implements cutting and bending in a single integrated process by automatically moving the cutting table up and down—when users take out the workpiece, it is already fully assembled. We present the three main design elements of LaserOrigami: the bend, the suspender, and the stretch, and demonstrate how to use them to fabricate a range of physical objects. Finally, we demonstrate an *interactive fabrication* version of LaserOrigami, a process in which user interaction and fabrication alternate step-by-step.

Author Keywords: rapid prototyping; laser cutting; interactive fabrication; 3D; physical prototyping.

ACM Classification Keywords: H5.2 [Information interfaces and presentation]: User Interfaces.

General Terms: Design; Human Factors.

Figure 1: LaserOrigami fabricates 3D structure by bending, rather than using joints, thereby eliminating the need for manual assembly. Here it fabricates a mobile phone screen cam by (a) cutting the contour lines

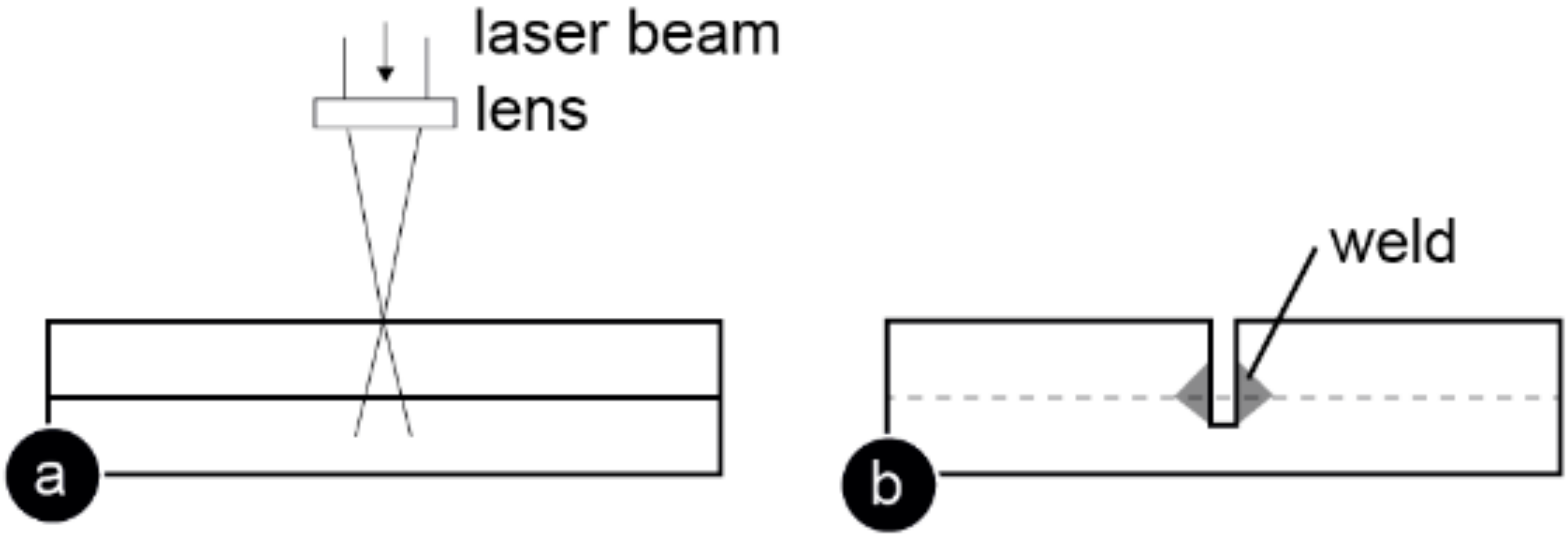


LaserStacker

locally welding multiple sheets together

[Umapathi, Chen, Mueller, Seufert, Wall, Baudisch, UIST 2015]

[Umapathi, Chen, Mueller, Seufert, Wall, Baudisch, UIST 2015]



[Umapathi, Chen, Mueller, Seufert, Wall, Baudisch, UIST 2015]

LaserStacker: Fabricating 3D Objects by Laser Cutting and Welding

Udayan Umapathi, Hsiang-Ting Chen, Stefanie Mueller, Ludwig Wall, Anna Seufert, Patrick Baudisch
Hasso Plattner Institute, Potsdam, Germany
{firstname.lastname}@hpi.de

ABSTRACT

Laser cutters are useful for rapid prototyping because they are fast. However, they only produce planar 2D geometry. One approach to creating non-planar objects is to cut the object in horizontal slices and to stack and glue them. This approach, however, requires manual effort for the assembly and time for the glue to set, defeating the purpose of using a fast fabrication tool.

We propose eliminating the assembly step with our system *LaserStacker*. The key idea is to use the laser cutter to not only cut but also to *weld*. Users place not one acrylic sheet, but a stack of acrylic sheets into their cutter. In a single process, LaserStacker cuts each individual layer to shape (through all layers above it), *welds* layers by melting material at their interface, and *heals* undesired cuts in higher layers. When users take out the object from the laser cutter, it is already assembled.

To allow users to model stacked objects efficiently, we built an extension to a commercial 3D editor *(SketchUp)* that provides tools for defining which parts should be connected and which remain loose. When users hit the *export* button, LaserStacker converts the 3D model into cutting, welding, and healing instructions for the laser cutter.

We show how LaserStacker not only allow making static objects, such as architectural models, but also objects with moving parts and simple mechanisms, such as scissors, a simple pinball machine, and a mechanical toy with gears.

Author Keywords: rapid prototyping; laser cutting.

ACM Classification Keywords: H5.2 [Information

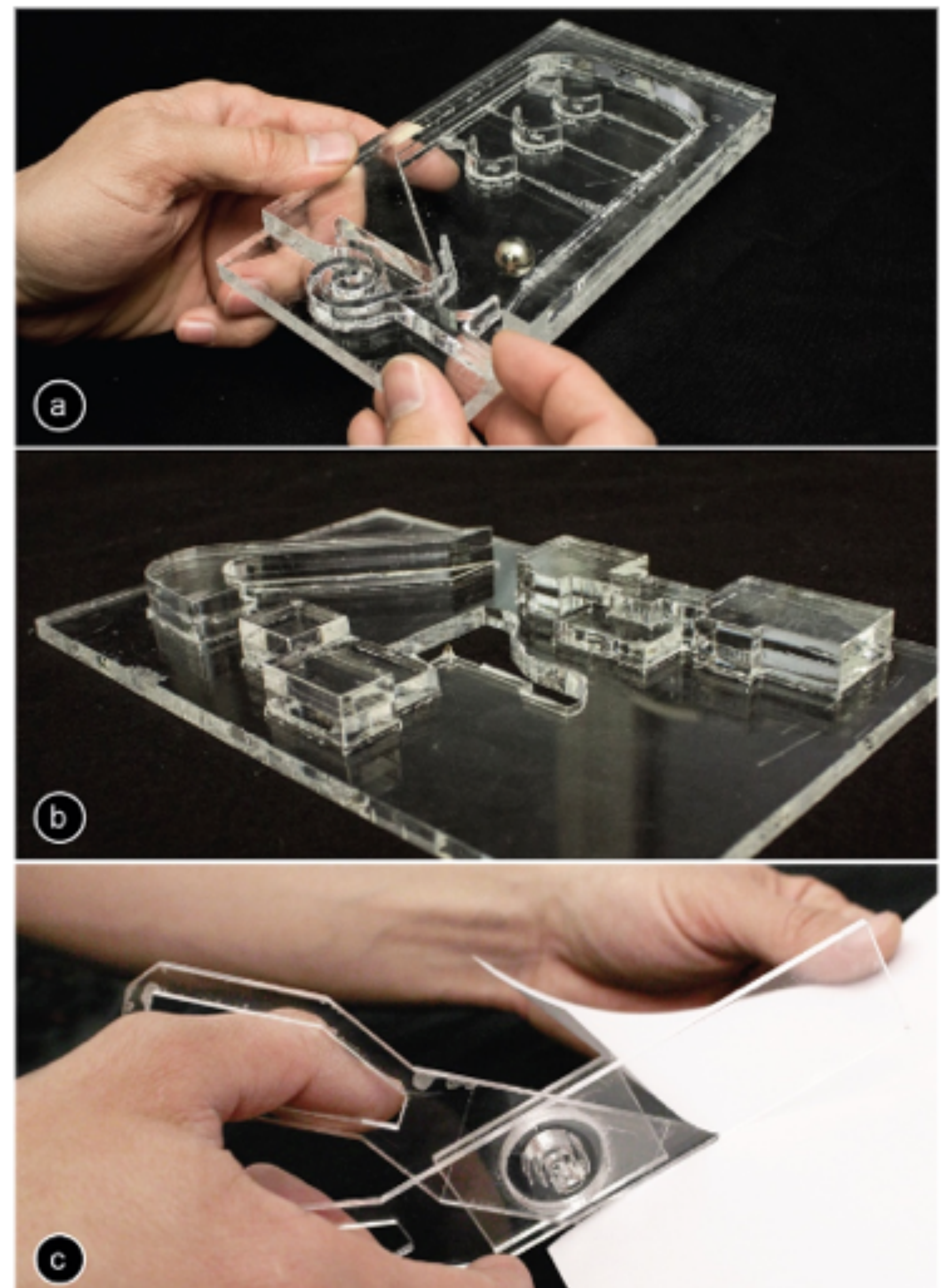


Figure 1: ***LaserStacker*** **produces laser cut objects consisting of**


lens array: locally melting with defocused laser
[Mike Sinclair]


haptic features, e.g. a mini keyboard
[Mike Sinclair]

summary

although only 2D, laser cutters are very versatile!

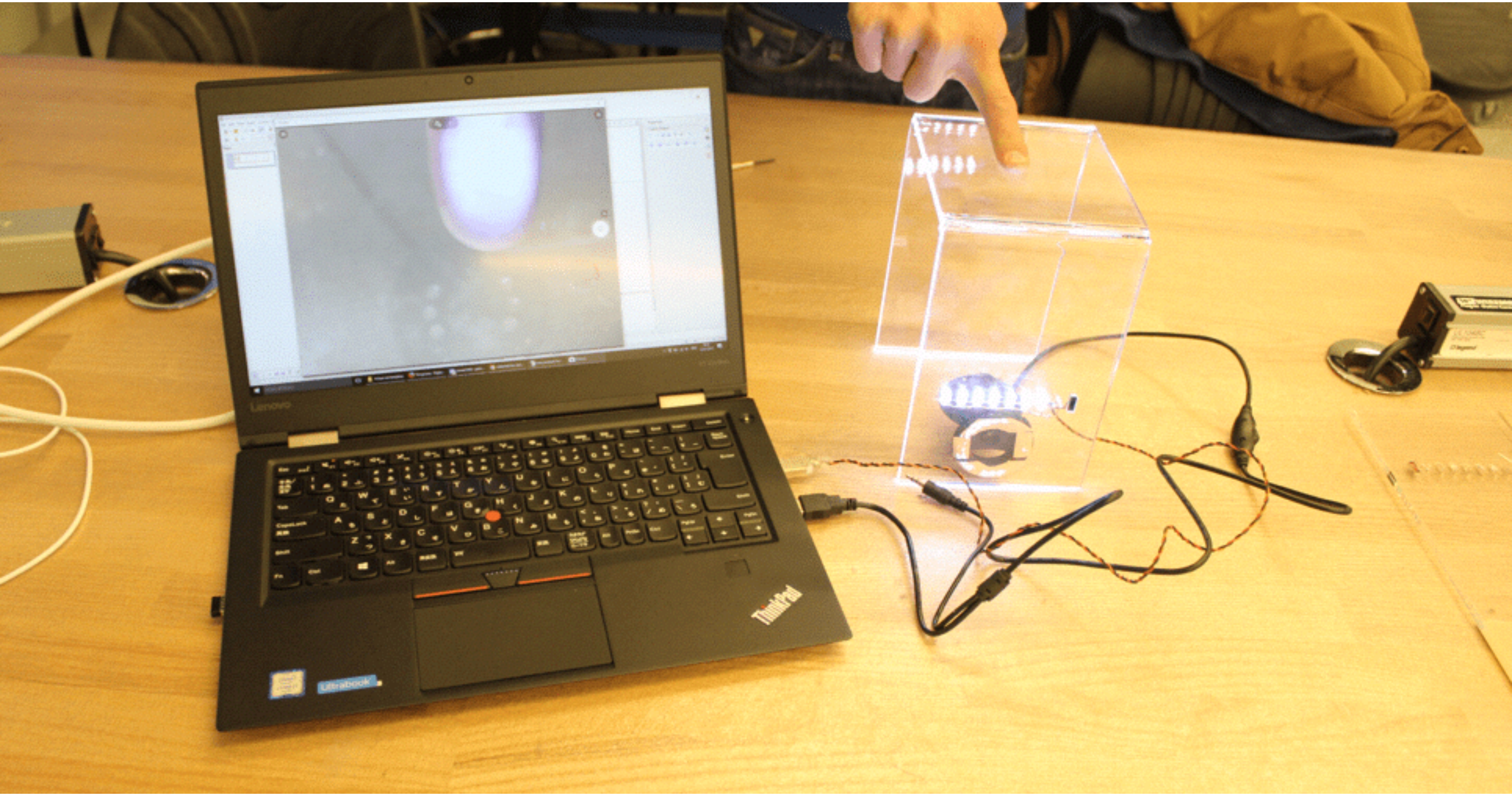
organization stuff

this friday

- Computer Vision skills lab (needed for pset3)

this friday

- please bring your multi-touch pad (grading pset1/2)



group project: TA assignment

- each team has a TA assigned

Lotta	Mark	Dishita
10	1	8
13	2	9
14	3	11
15	4	12
17	5	16
19	6	18
21	7	20
22	24	23

group project: ordering parts

- order your parts!

	A	B	C	D	E	F
1	**Your Name**	**Part Name**	**Contact Email**	**Part Number**	**Team Number**	**URL (of par**
2						
3	Stefanie Mueller	Small Piezo Buzzer	mueller_@mit.edu	1740	0	https://www.adafruit.com/proc
4	Martin Winton/ Wei Chen	Rasberry Pi		1	3	- https://www.amazon.com/Ra
5	Martin Winton/ Wei Chen	IR Distance Sensor		GP2Y0A21YK	3	https://www.sparkfun.com
6	Jordyn Mann/ Jocelyn McGhee	IR Break Beam Sensor		485-2167	20	https://www.mouser.com/Pro
7	Jordyn Mann/ Jocelyn McGhee	Distance Sensor		497-16538-1-ND	20	https://www.digikey.com/prod
8	Bernard Snowden/ Jini Gabbidor	Piezo Element	jini@mit.edu, bsnov	SEN-10293	22	https://www.sparkfun.com/pr
9	Bernard Snowden/ Jini Gabbidor	Force Sensitive Resistor	jini@mit.edu, bsnov	1075	22	https://www.adafruit.com/proc
10	Bernard Snowden/ Jini Gabbidor	Arduino Nano	jini@mit.edu, bsnov	A000005	22	https://store.arduino.cc/usa/a
11	Andrew Wong/Janice Chui	Flex Sensor 4.5"	andrewwo@mit.edu	SEN-08606	19	https://www.sparkfun.com/pr
12	Andrew Wong/Janice Chui	Ultrasonic Sensor	andrewwo@mit.edu	SEN-13959	19	https://www.sparkfun.com/pr
13	Andrew Wong/Janice Chui	Motor, 2.5 in. CIM with Pinio	andrewwo@mit.edu	am-0255_15T	19	http://www.andymark.com/Cl
14	Andrew Wong/Janice Chui	Climbing Harness	andrewwo@mit.edu	B016NOWD1A	19	https://www.amazon.com/Clir
15	Andrew Wong/Janice Chui	Wall/Ceiling Mount Single P	andrewwo@mit.edu	N233-247 3219BC	19	https://www.amazon.com/Nat
16	Christina Liao/ Adrian Sy	Ultrasonic Sensor	adriansy@mit.edu	HC-SR04	8	https://www.amazon.com/HC
17	Gabe Fields / Miguel Vega	Juggling Balls	gabef@mit.edu, mv	B00GXZJDCW	24	https://www.amazon.com/Qu

group project: milestone #1

- copy your first milestone over to the milestone grading spreadsheet

change-this-weekly-detailed-milestone-spreadsheet

File Edit View Insert Format Data Tools Add-ons Help Last edit was on September 2

fx We will mount the piezo on a board and write an algorithm to detect hits/misses on the board.

	A	B	C	D	E	F
1	**Week**	**Date**	**Requirements**	**Person**	**What we will implement during the week:**	**What we will show in the video to demonstrate that it actually works:**
2	1	October 5	first sensor	Stefanie	We will wire up the piezo-microphone and write the raw data to the Arduino Serial Monitor.	We will talk to the microphone and show that the Serial Monitor displays the raw sensor values.
3		October 5	first sensor	Lotta	We will mount the piezo on a board and write an algorithm to detect hits/misses on the board.	We will throw some balls at the board and show in the Serial Monitor that it detects 'hit' or 'miss'.
4	2	October 12	first actuator			
5		October 12	first actuator			
6	3	October 19	your choice			
7		October 19	your choice			
8	4	October 26	your choice			
9		October 26	your choice			
10	5	November 2	midterm			
11		November 2	midterm			
12	6	November 9	no deliv. veteran's day			

feedback for previous assignments

- next week, so you know where you stand!

preview of next weeks

- 3D modeling + Firefly
- making 2D drawings
- making photos
- editing video
- making a website

end.