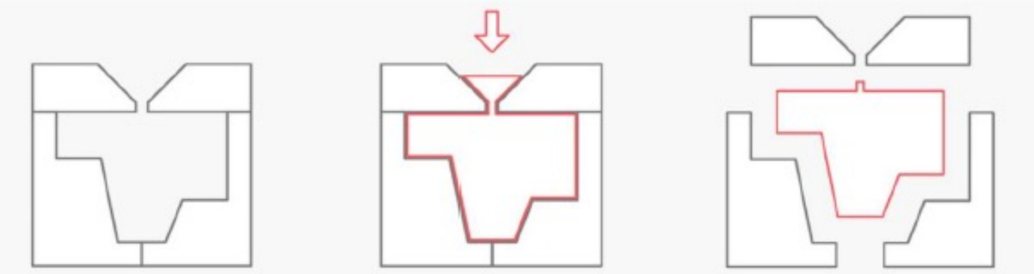
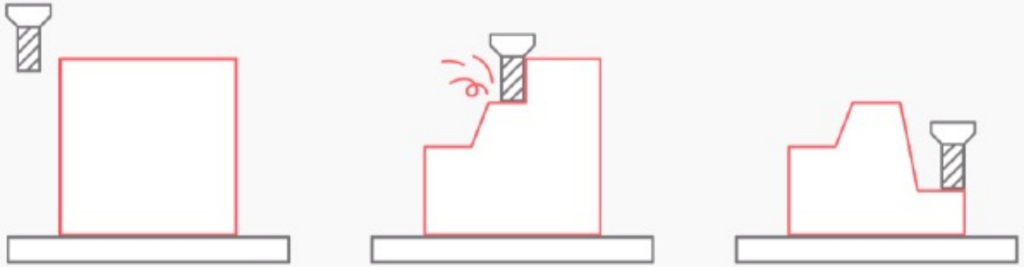
Laser Cutting

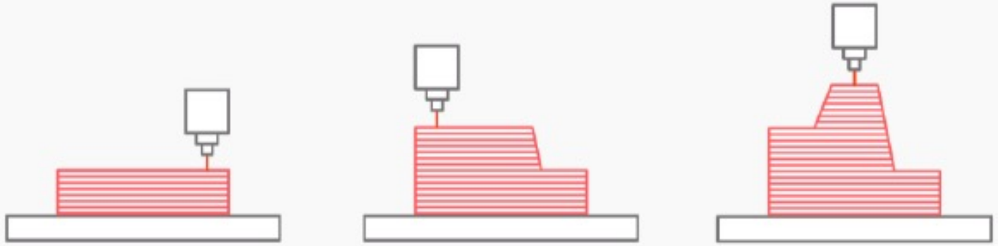
Huaishu Peng | CMSC 730 | Fall 2024



Formative manufacturing

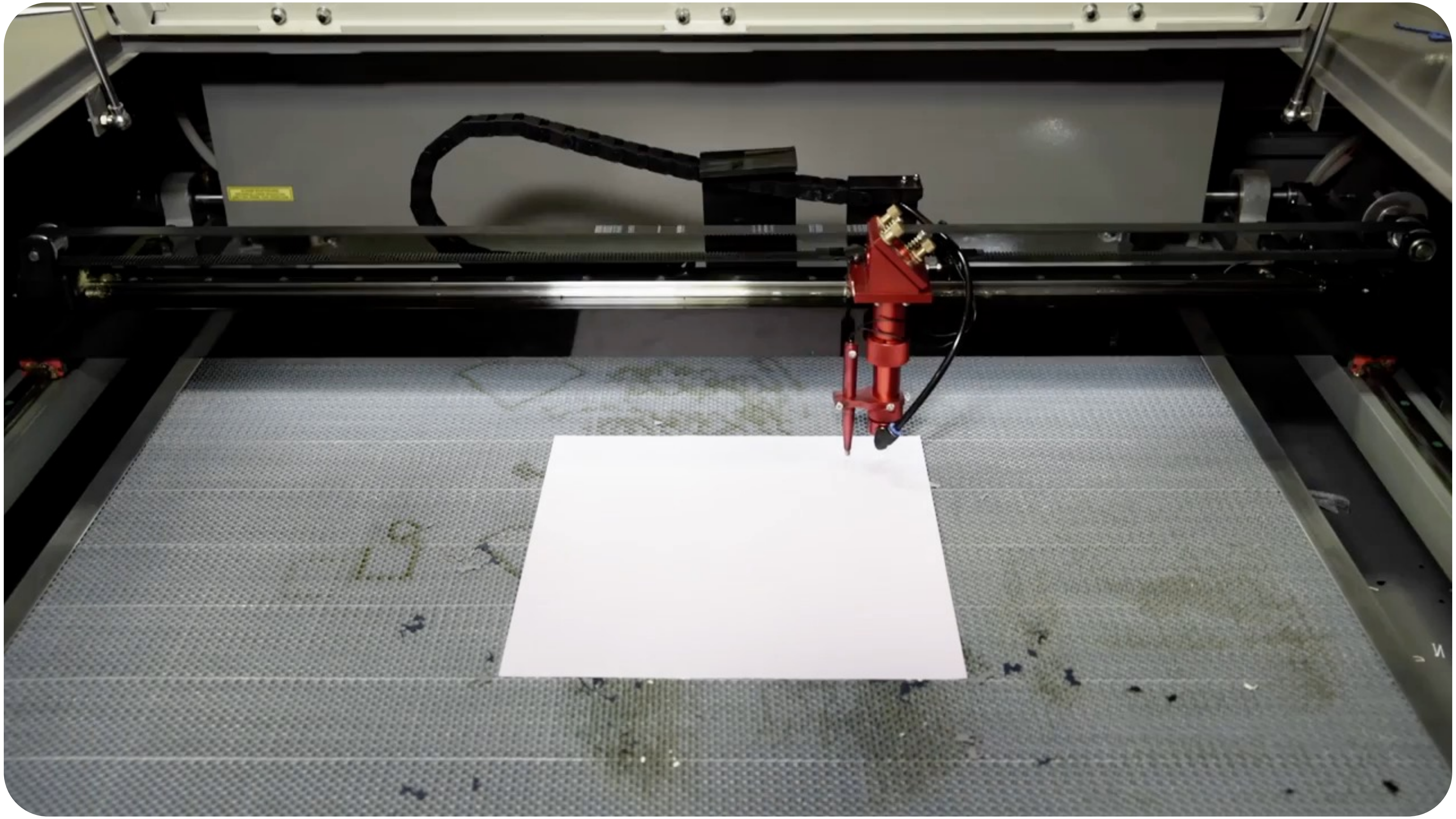


Subtractive manufacturing



Additive manufacturing

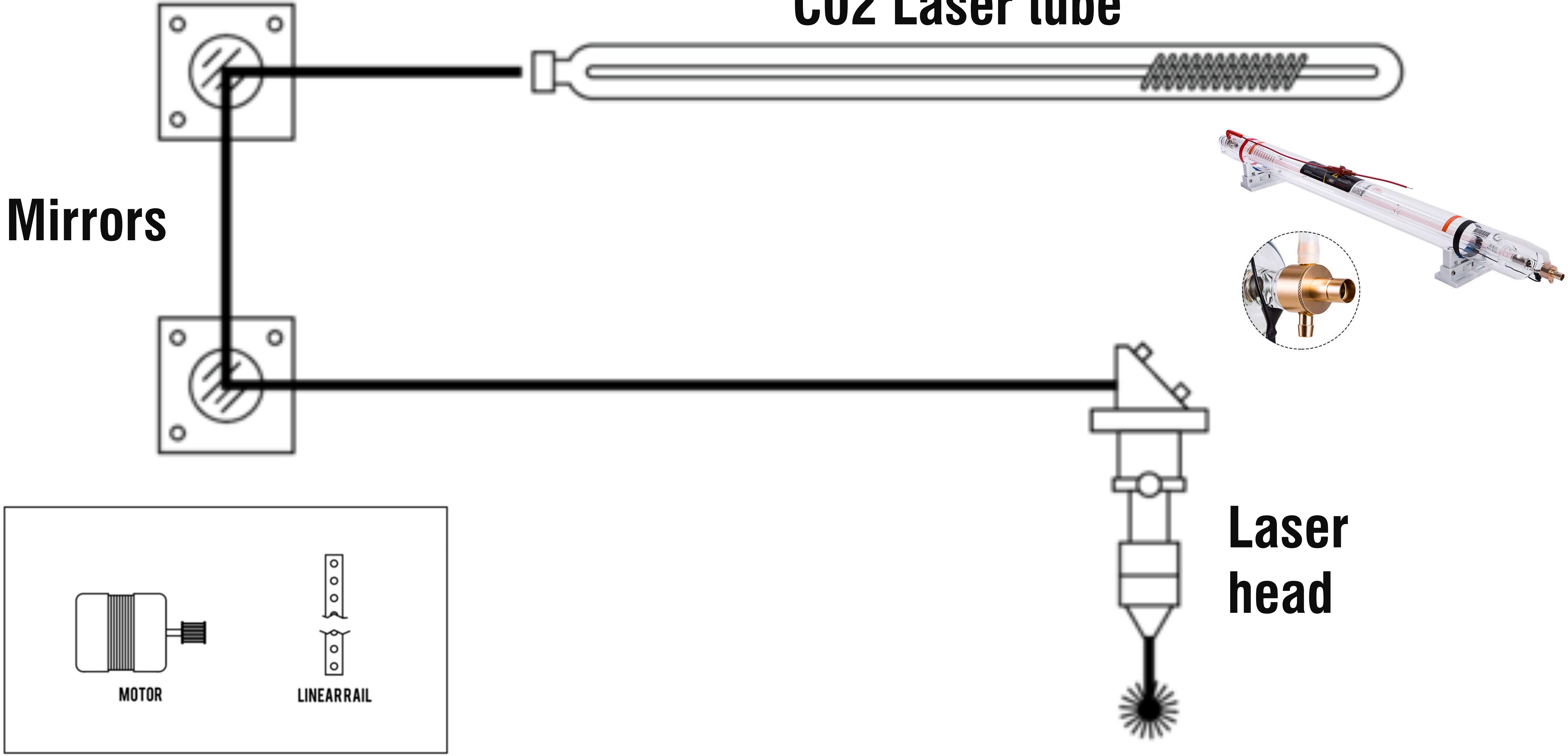

glowforge



We already talked about 3D printing, why laser cutting?

Fast (Good for iteration)
Durable (because there is no layer bonding)
Simple (Similar to 2D paper printing)

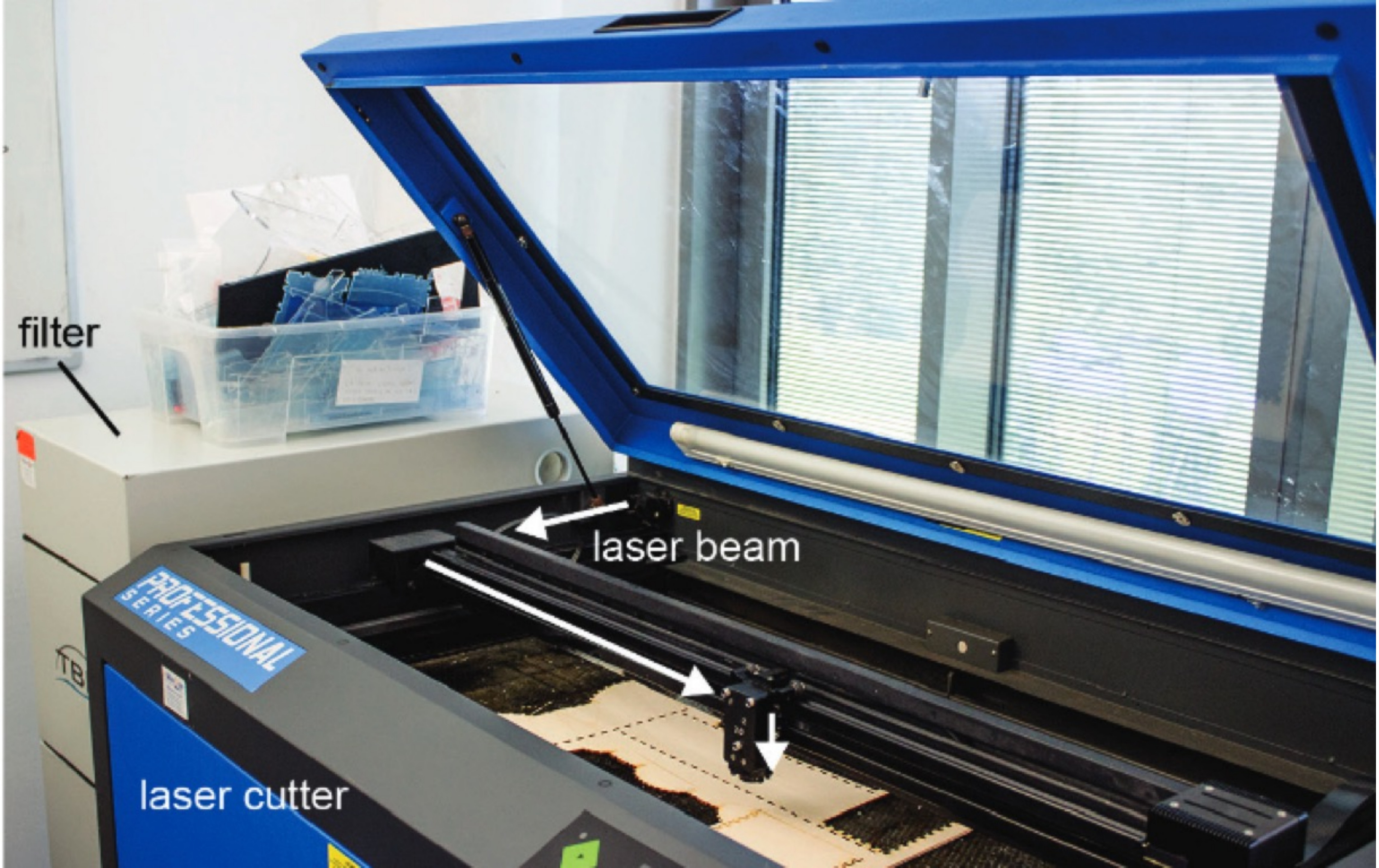
How does a CO2 laser cutter work
What we can do with it

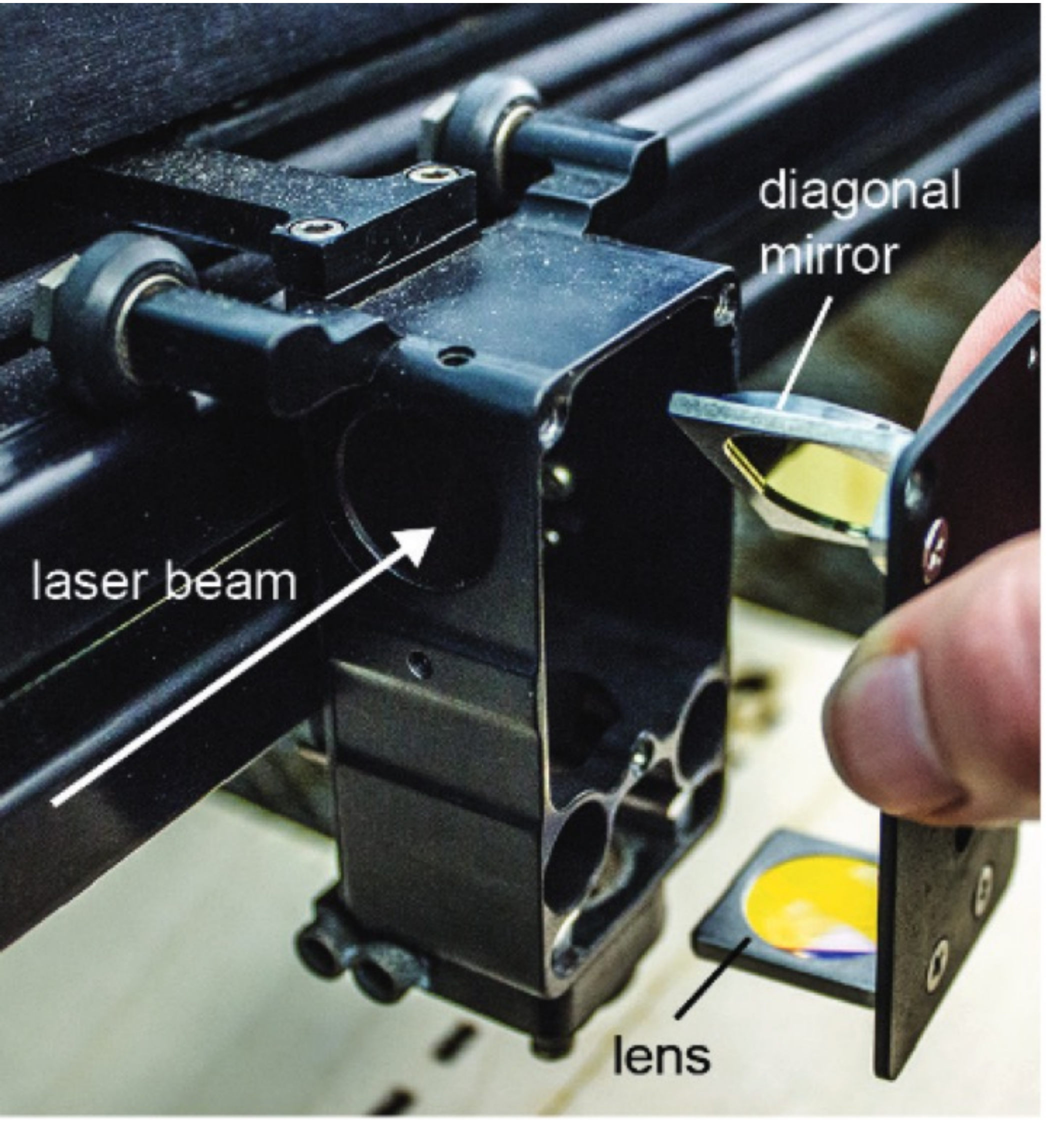


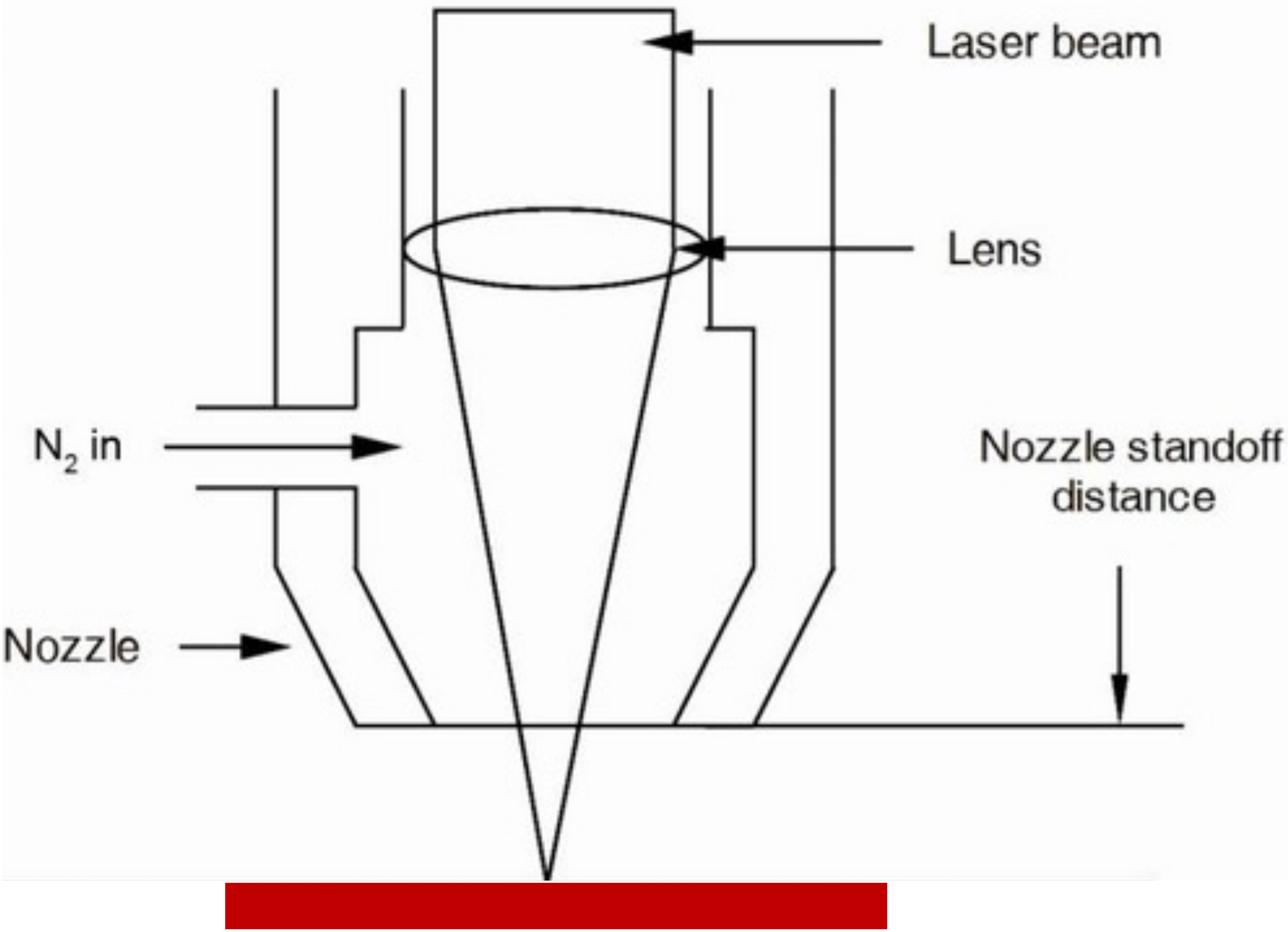
C02 Laser tube

Mirrors

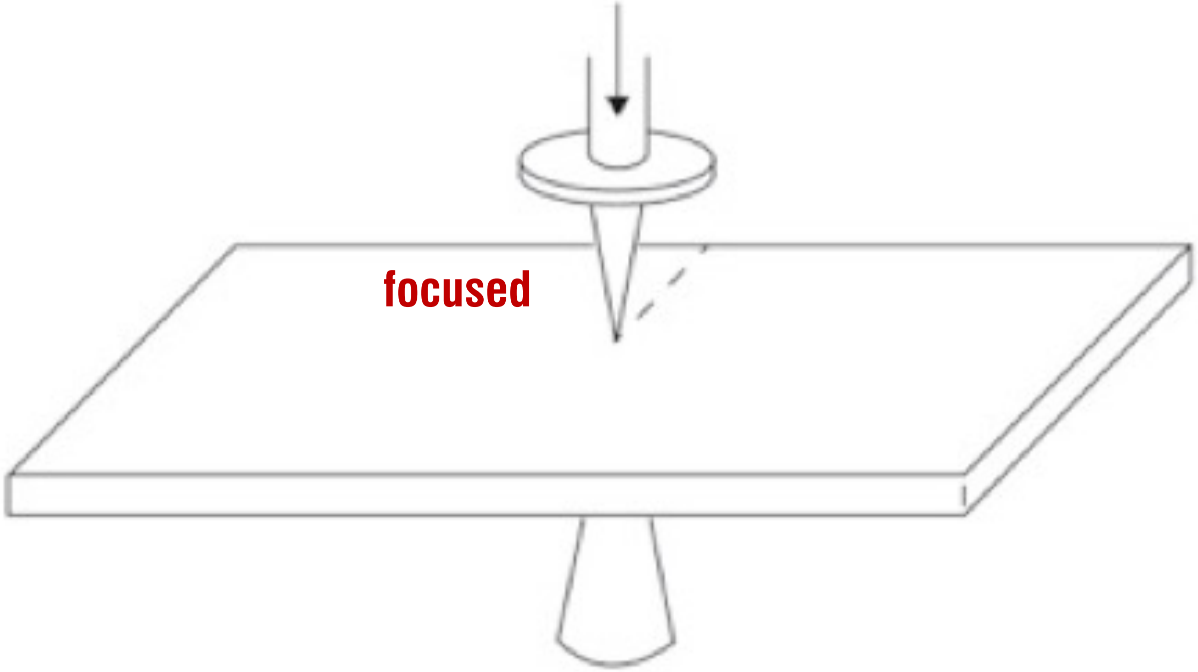
Laser head


filter
laser beam
PROFESSIONAL SERIES
laser cutter

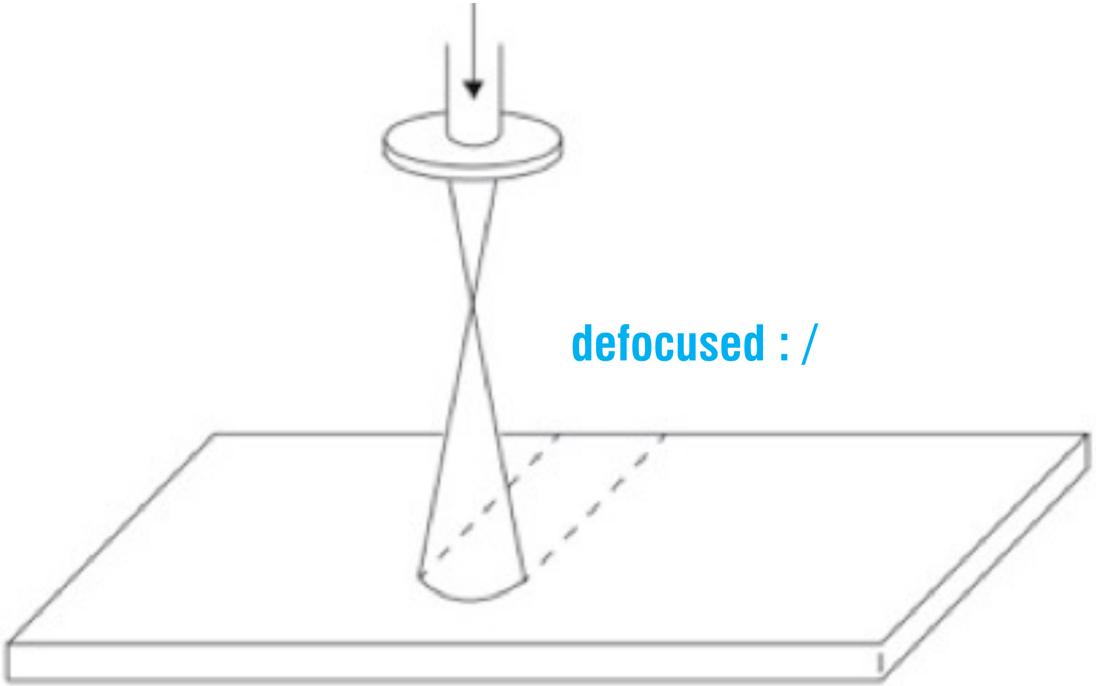

diagonal mirror
laser beam
lens


Laser beam
Lens
N_2 in
Nozzle standoff distance
Nozzle

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



focused



defocused : /

too little power for cutting

how can I laser cut something?

laser features #1

Raster engraving




Engraving takes about half an hour at this size

Raster engraving

This process is the same as used by inkjet printers. A file is printed **line by line**.

Instead of ink being applied, material is **removed** pixel by pixel by the laser

When to use raster engraving?

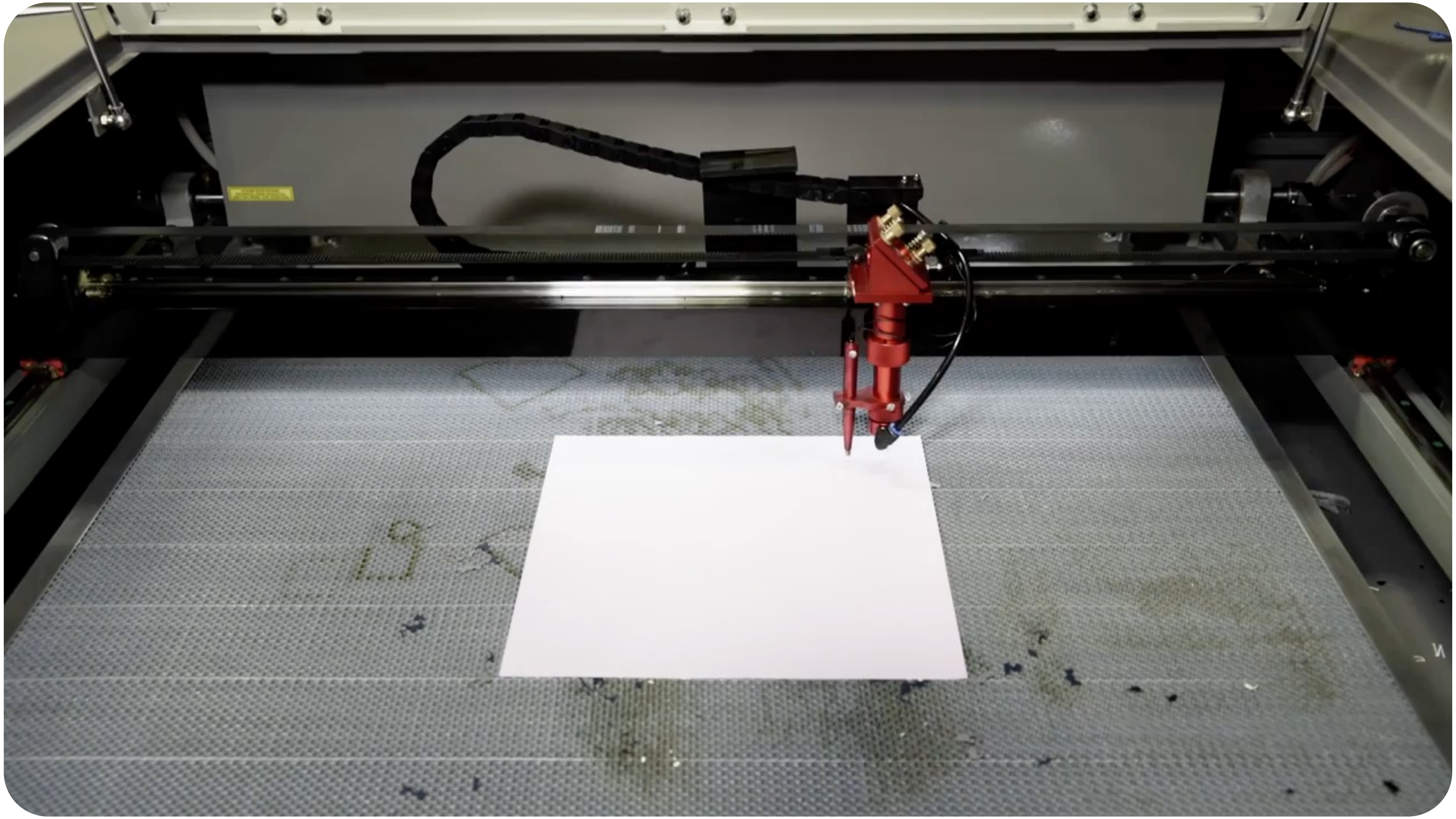
Want to leave “**trace**” on the material,
but doesn’t want to “**cut through**”

Pros/Cons?

Detailed engraving images
Slow in speed

laser features #2

Vector engraving/cutting

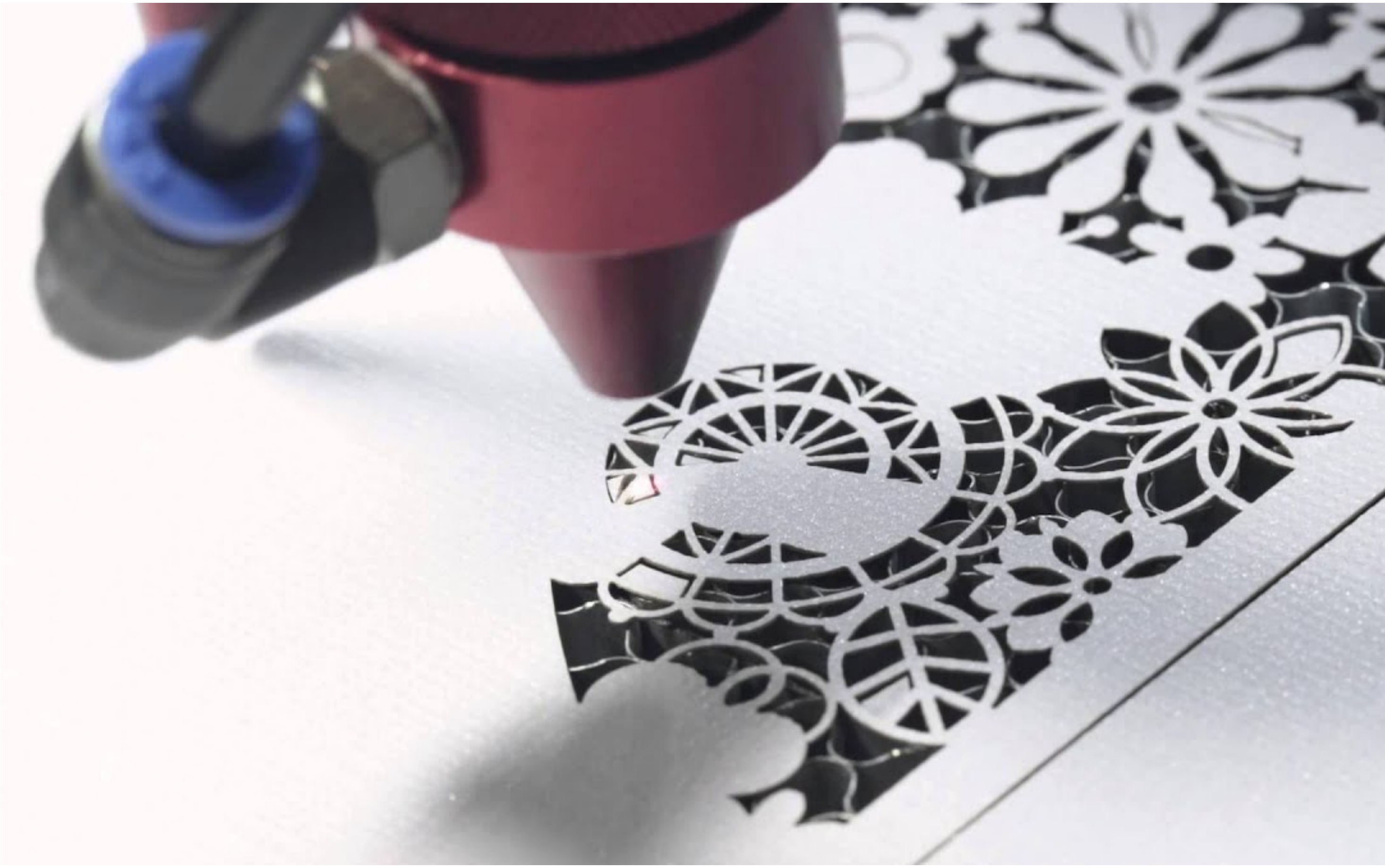


Vector engraving/cutting

The file to be printed is a graphic file consisting of **vectors**, marked as hairlines in the graphics.

Vector by vector is traced by the laser and then engraved.

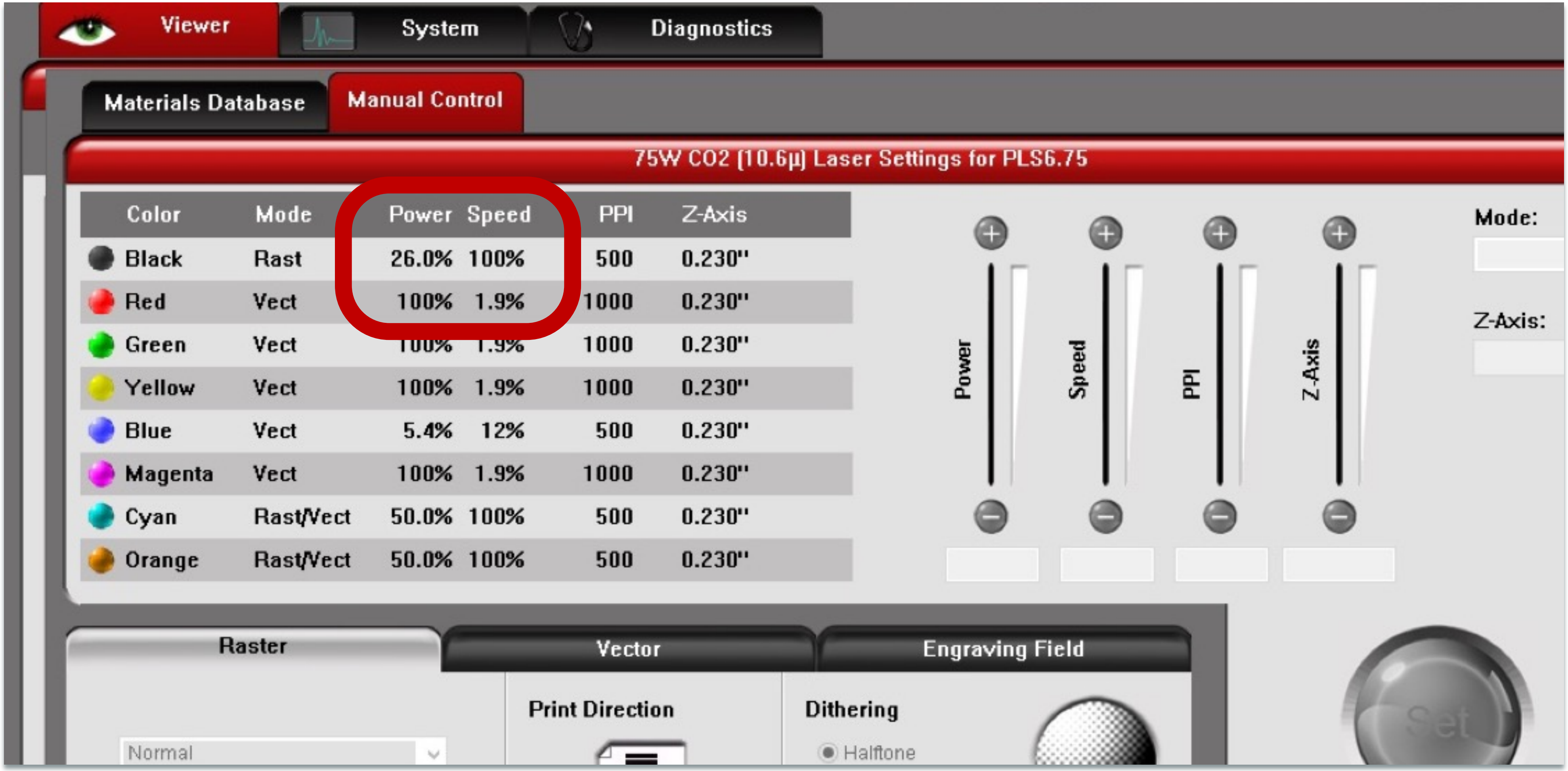
In vector engraving, the axles move simultaneously, and more slowly than in raster engraving.



We can also score lines without cut-through. (folding lines)

We will assign different lines with different power and speed

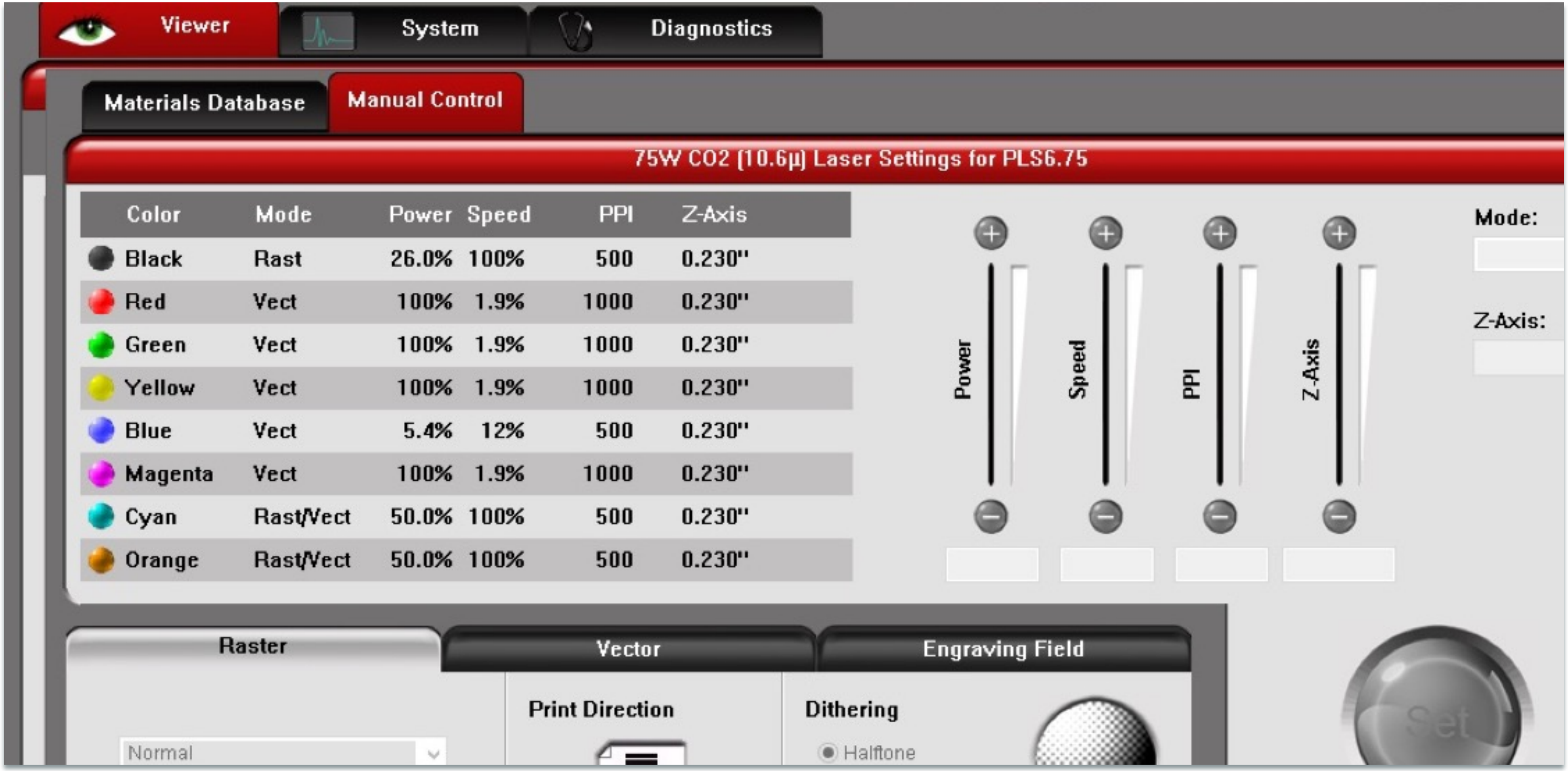
relationship
between power and speed?



75W CO2 (10.6μ) Laser Settings for PLS6.75

Color	Mode	Power	Speed	PPI	Z-Axis
● Black	Rast	26.0%	100%	500	0.230"
● Red	Vect	100%	1.9%	1000	0.230"
● Green	Vect	100%	1.9%	1000	0.230"
● Yellow	Vect	100%	1.9%	1000	0.230"
● Blue	Vect	5.4%	12%	500	0.230"
● Magenta	Vect	100%	1.9%	1000	0.230"
● Cyan	Rast/Vect	50.0%	100%	500	0.230"
● Orange	Rast/Vect	50.0%	100%	500	0.230"

if we increase speed, do we get more of less power?



75W CO2 (10.6µ) Laser Settings for PLS6.75

Color	Mode	Power	Speed	PPI	Z-Axis
● Black	Rast	26.0%	100%	500	0.230"
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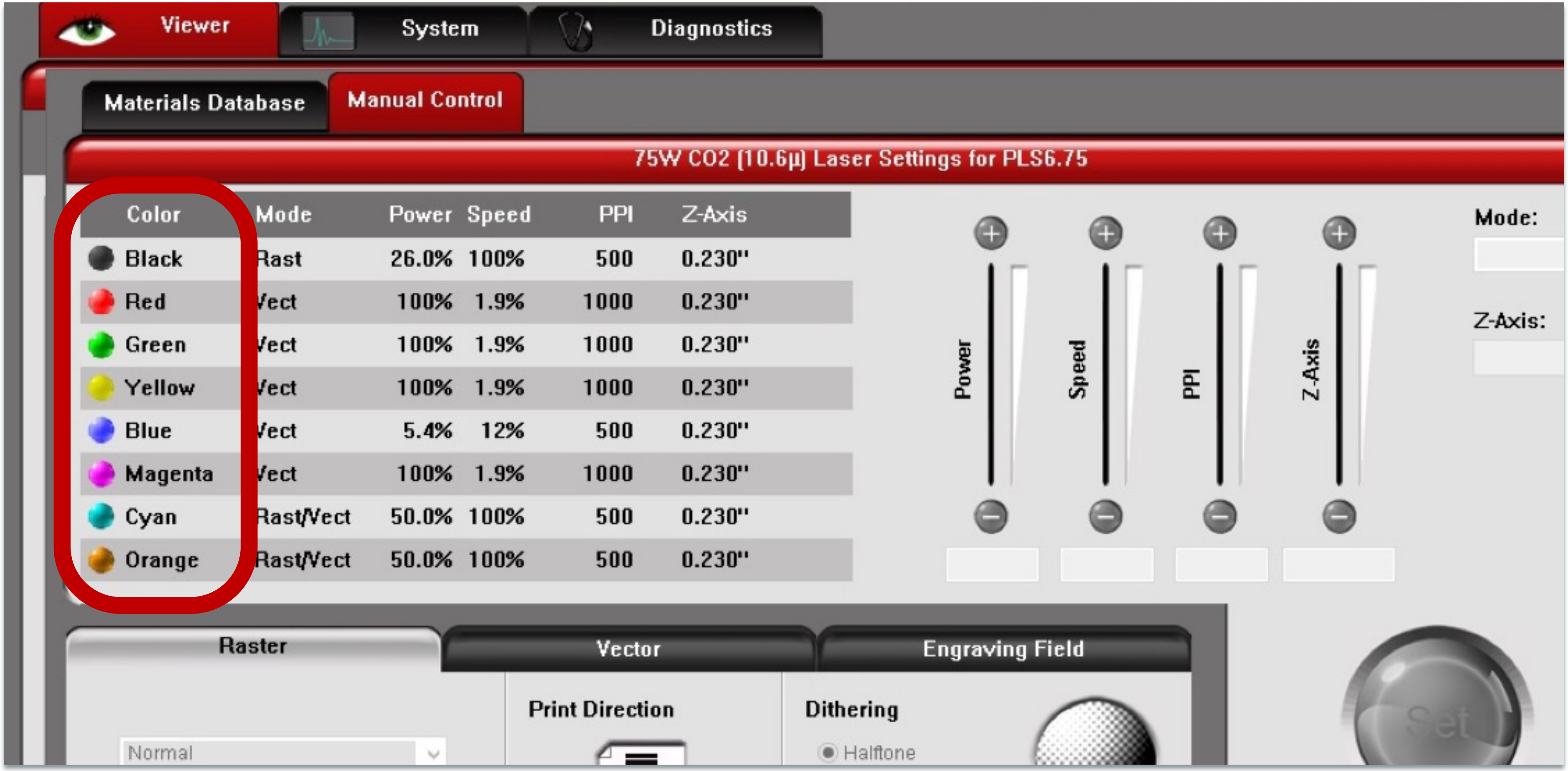
● Green	Vect	100%	1.9%	1000	0.230"
● Yellow	Vect	100%	1.9%	1000	0.230"
● Blue	Vect	5.4%	12%	500	0.230"
● Magenta	Vect	100%	1.9%	1000	0.230"
● Cyan	Rast/Vect	50.0%	100%	500	0.230"
● Orange	Rast/Vect	50.0%	100%	500	0.230"

if we **go faster**
the laser spends less time on a single spot
-> **less power**



75W CO2 (10.6µ) Laser Settings for PLS6.75

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● Black	Rast	26.0%	100%	500	0.230"
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● Green	Vect	100%	1.9%	1000	0.230"
● Yellow	Vect	100%	1.9%	1000	0.230"
● Blue	Vect	5.4%	12%	500	0.230"
● Magenta	Vect	100%	1.9%	1000	0.230"
● Cyan	Rast/Vect	50.0%	100%	500	0.230"
● Orange	Rast/Vect	50.0%	100%	500	0.230"

Normal

Dithering

● Halftone

☑ Color Mapping

Color Mapping

R: 255

G: 0

B: 0

Speed: 14

Power: 82

Freq.: 1925

Focus: 0

☑ Raster

☑ Vector

Color	Speed	Power	Freq.	Focus	Raster	Vector
🟥	14%	82%	1925	0	Yes	Yes
🟩	61%	19%	1054	0	Yes	Yes
🟦	71%	74%	3549	0	Yes	Yes
🟨	14%	100%	2500	0	Yes	Yes
🟪	50%	50%	2500	0	Yes	Yes
🟦	50%	50%	2500	0	Yes	Yes

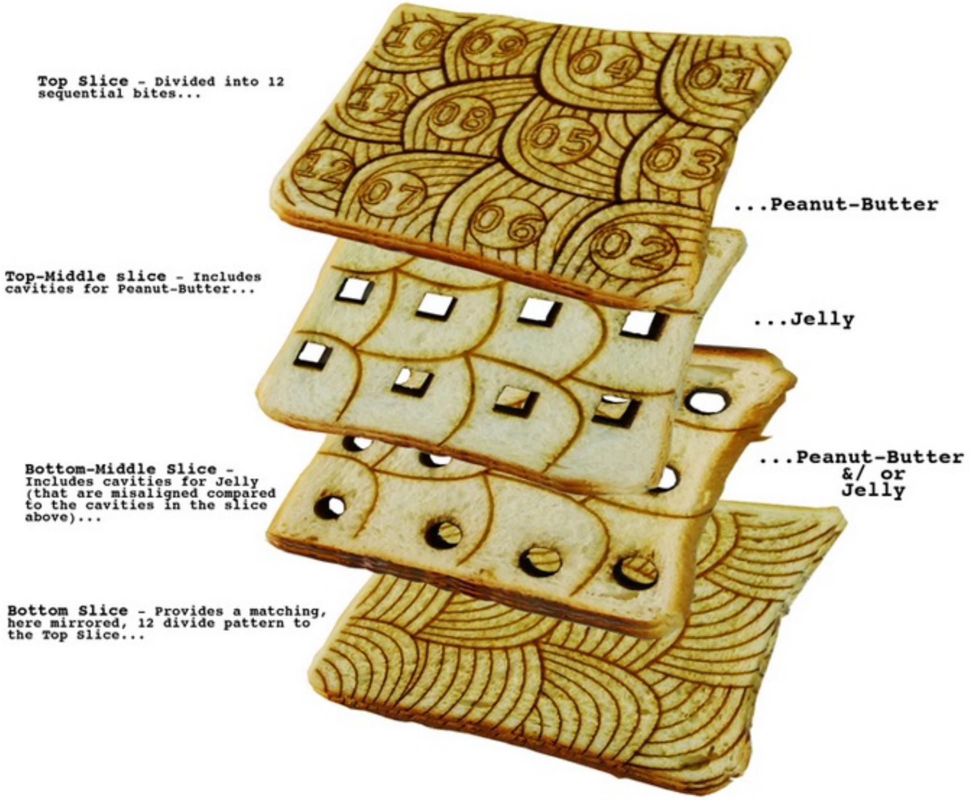
What materials can we cut?

most common materials

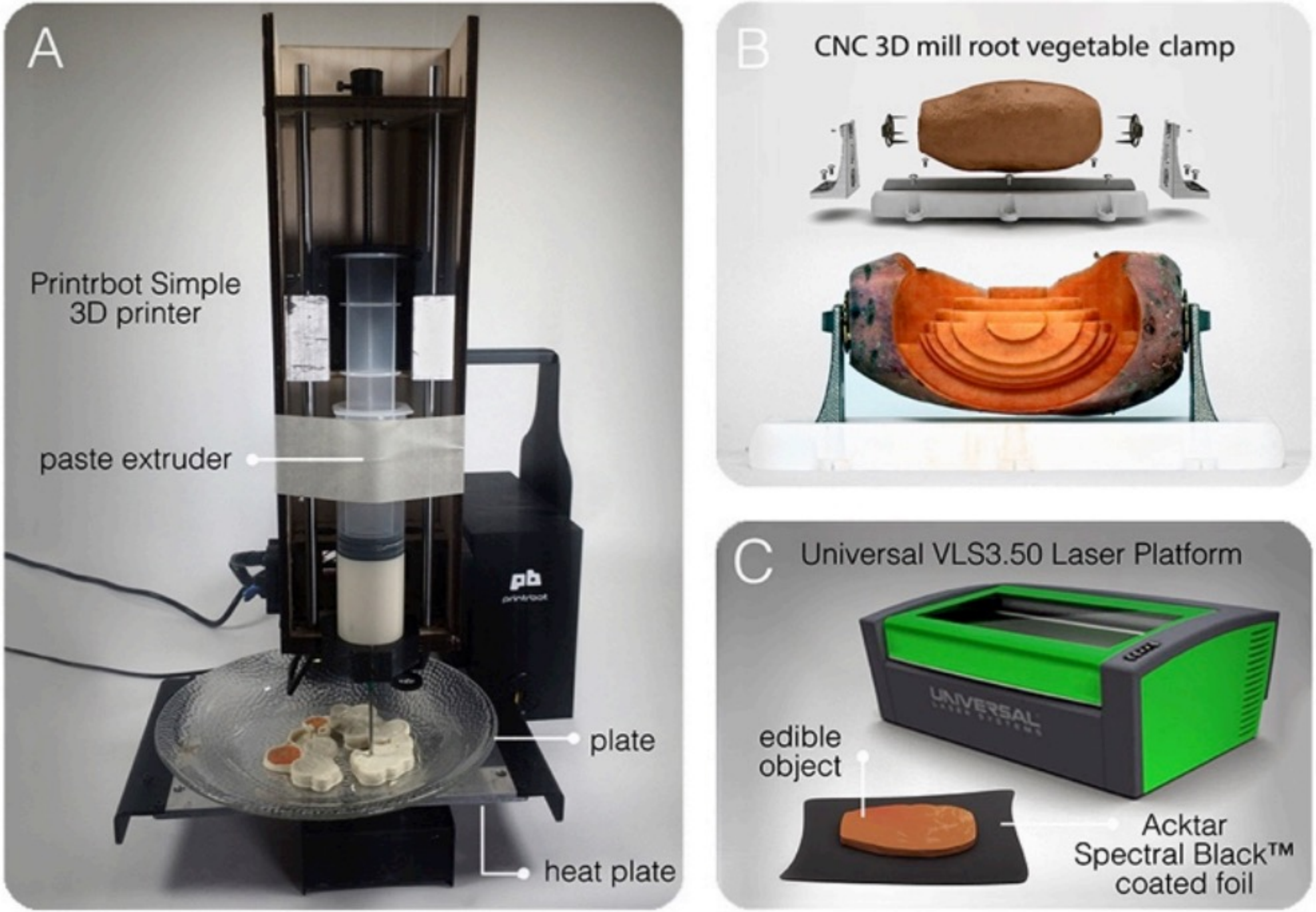
Paper
Cardboard
Acrylic
Solid wood
MDF
Leather

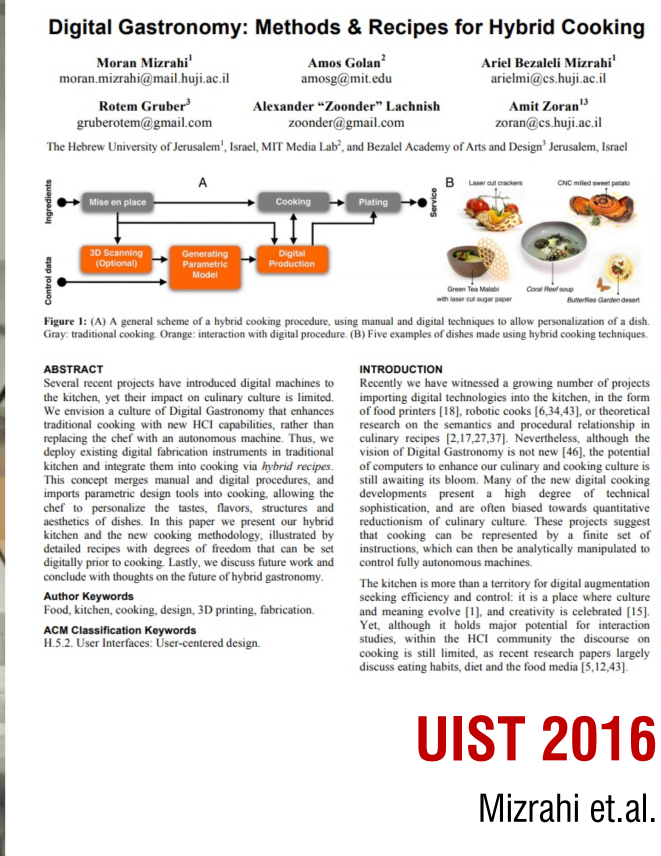
what **other** materials can we laser cut?

unconventional materials




FDM 3D printer & 3D milling machine
Microwave
Refrigerator
Dishwasher
Food Sink
Spices
Storage
Digital fabrication equipment
Laser cutting / cooking machine
Programmer / technician stand
Fire extinguisher
Non-food sink
Cookware
Ingredients
Food processor
Edible paste 3D printer
Powders
Tableware
3D milling machine
Tableware
Oven
Stove
Worktop


A
Printrbot Simple
3D printer
paste extruder
plate
heat plate
B
CNC 3D mill root vegetable clamp
C
Universal VLS3.50 Laser Platform
edible
object
Acktar
Spectral Black™
coated foil



Digital Gastronomy: Methods & Recipes for Hybrid Cooking

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Figure 1: (A) A general scheme of a hybrid cooking procedure, using manual and digital techniques to allow personalization of a dish. Gray: traditional cooking. Orange: interaction with digital procedure. (B) Five examples of dishes made using hybrid cooking techniques.

ABSTRACT

Several recent projects have introduced digital machines to the kitchen, yet their impact on culinary culture is limited. We envision a culture of Digital Gastronomy that enhances traditional cooking with new HCI capabilities, rather than replacing the chef with an autonomous machine. Thus, we deploy existing digital fabrication instruments in traditional kitchen and integrate them into cooking via *hybrid recipes*. This concept merges manual and digital procedures, and imports parametric design tools into cooking, allowing the chef to personalize the tastes, flavors, structures and aesthetics of dishes. In this paper we present our hybrid kitchen and the new cooking methodology, illustrated by detailed recipes with degrees of freedom that can be set digitally prior to cooking. Lastly, we discuss future work and conclude with thoughts on the future of hybrid gastronomy.

Author Keywords

Food, kitchen, cooking, design, 3D printing, fabrication.

ACM Classification Keywords

H.5.2. User Interfaces: User-centered design.

INTRODUCTION

Recently we have witnessed a growing number of projects importing digital technologies into the kitchen, in the form of food printers [18], robotic cooks [6,34,43], or theoretical research on the semantics and procedural relationship in culinary recipes [2,17,27,37]. Nevertheless, although the vision of Digital Gastronomy is not new [46], the potential of computers to enhance our culinary and cooking culture is still awaiting its bloom. Many of the new digital cooking developments present a high degree of technical sophistication, and are often biased towards quantitative reductionism of culinary culture. These projects suggest that cooking can be represented by a finite set of instructions, which can then be analytically manipulated to control fully autonomous machines.

The kitchen is more than a territory for digital augmentation seeking efficiency and control: it is a place where culture and meaning evolve [1], and creativity is celebrated [15]. Yet, although it holds major potential for interaction studies, within the HCI community the discourse on cooking is still limited, as recent research papers largely discuss eating habits, diet and the food media [5,12,43].

UIST 2016

Mizrahi et.al.

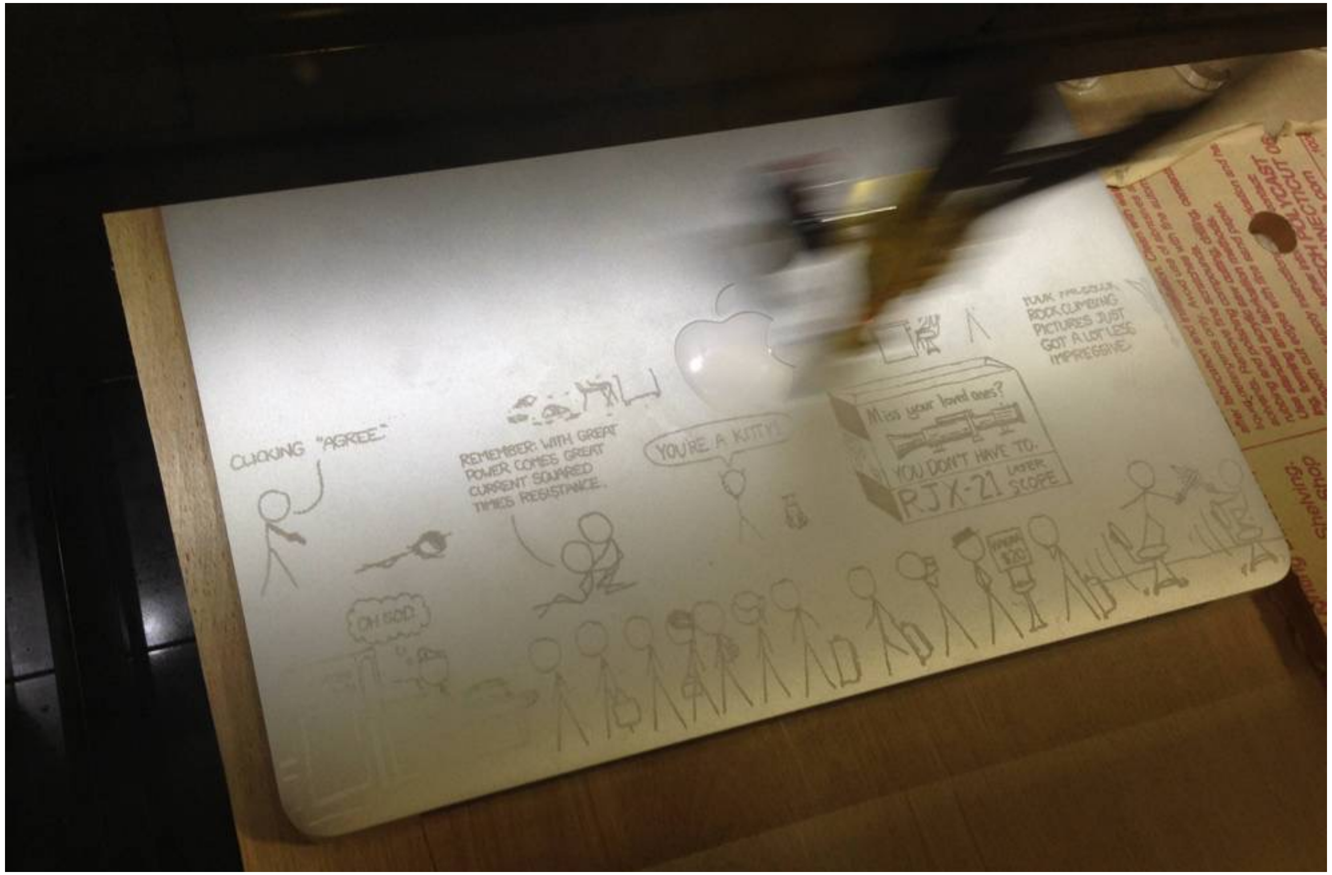
never cut materials
that are **flammable**
create **toxic fumes**

Ask the lab manager (or me) before you try novel materials

can we laser cut metal and glass?

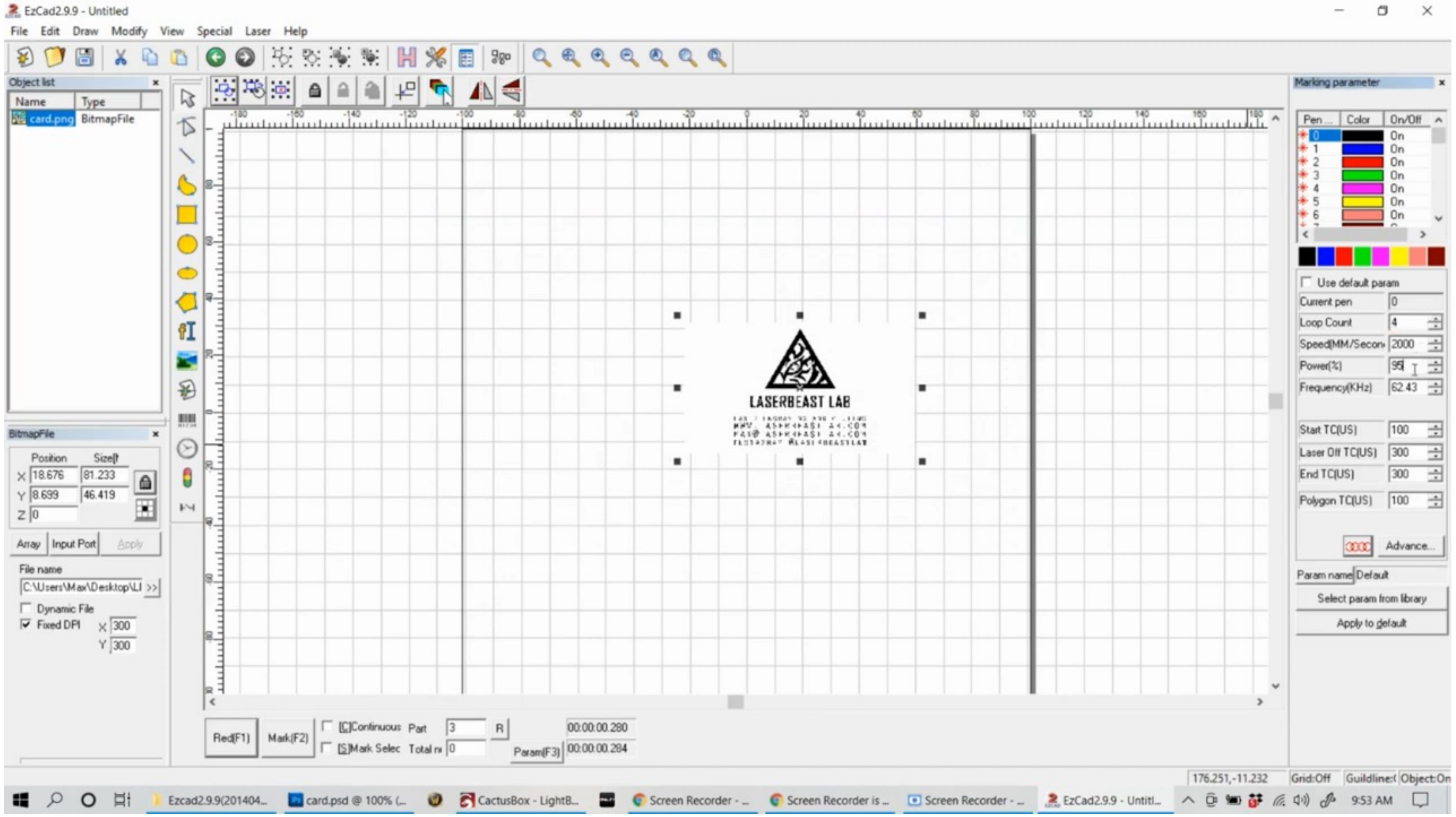
No we can't, at least not with CO2 laser cutter.

We may **engrave** glass, coated metal, marble, anodized aluminum, titanium, some phones, tablets, and laptops



can we laser cut metal and glass?

However, IRB0102 has a fiber laser that allows engraving and cutting on metals



EzCad2.9.9 - Untitled

Name	Type
card.png	BitmapFile

BitmapFile

	Position	Size
X	18.676	81.233
Y	8.699	46.419
Z	0	

File name: C:\Users\Max\Desktop\LI

☐ Dynamic File

☑ Fixed DPI X 300 Y 300

Pen	Color	On/Off
0		On
1		On
2		On
3		On
4		On
5		On
6		On

☐ Use default param

Current pen: 0

Loop Count: 4

Speed(MM/Secon: 2000

Power(%): 95

Frequency(KHz): 62.43

Start TC(US): 100

Laser Off TC(US): 300

End TC(US): 300

Polygon TC(US): 100

Param name: Default

☐ [C]Continuous Part 3

☐ [S]Mark Selec Total n 0

00:00:00.280

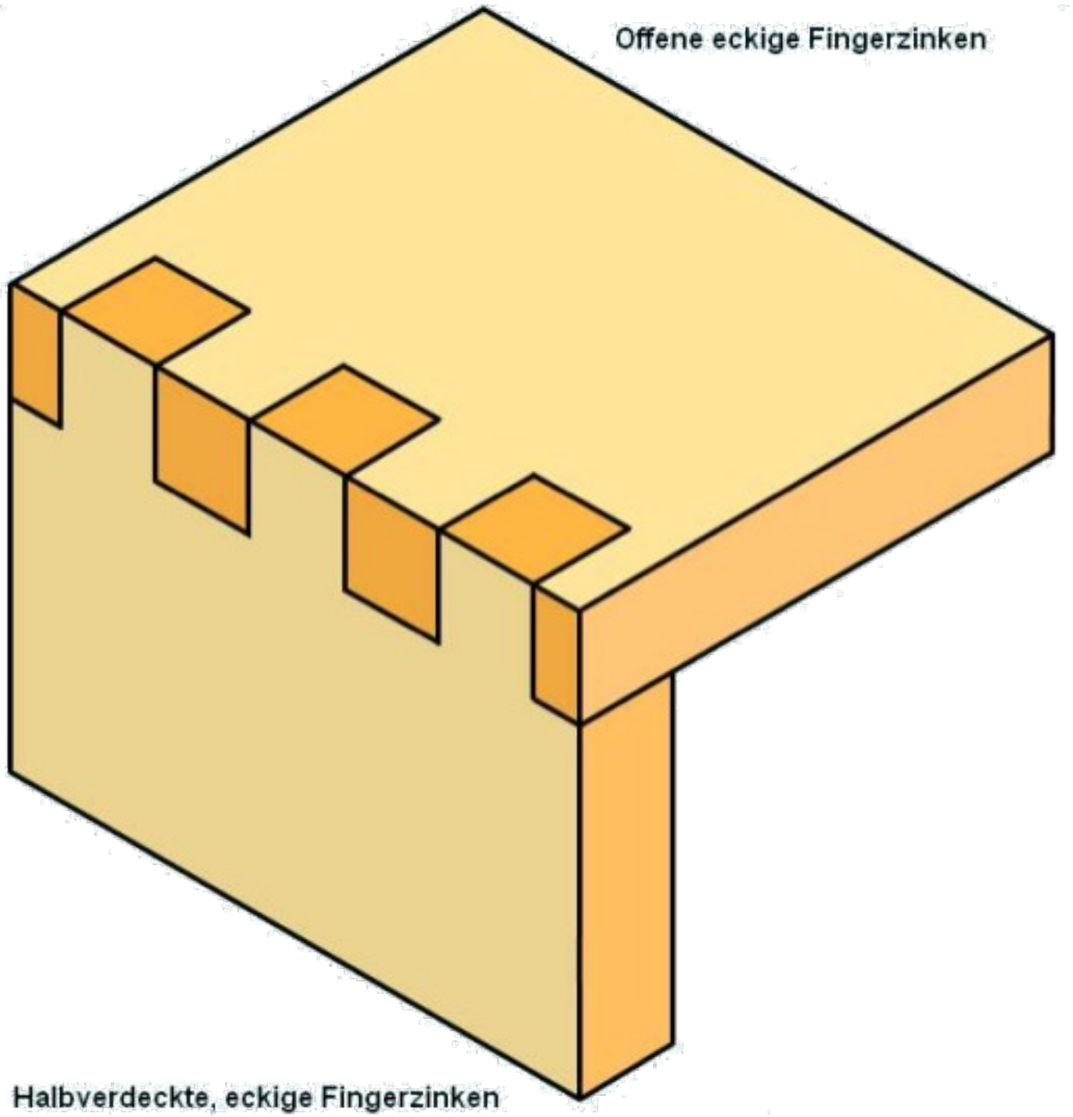
00:00:00.284

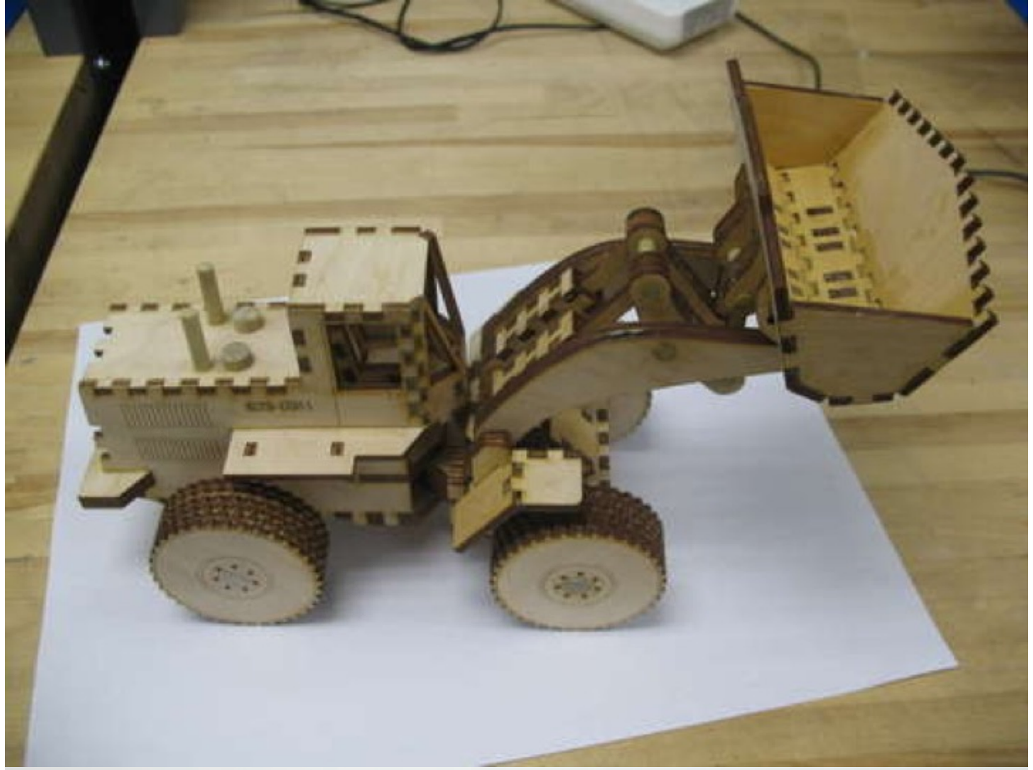
176.251,-11.232 Grid:Off Guildline: Object:On

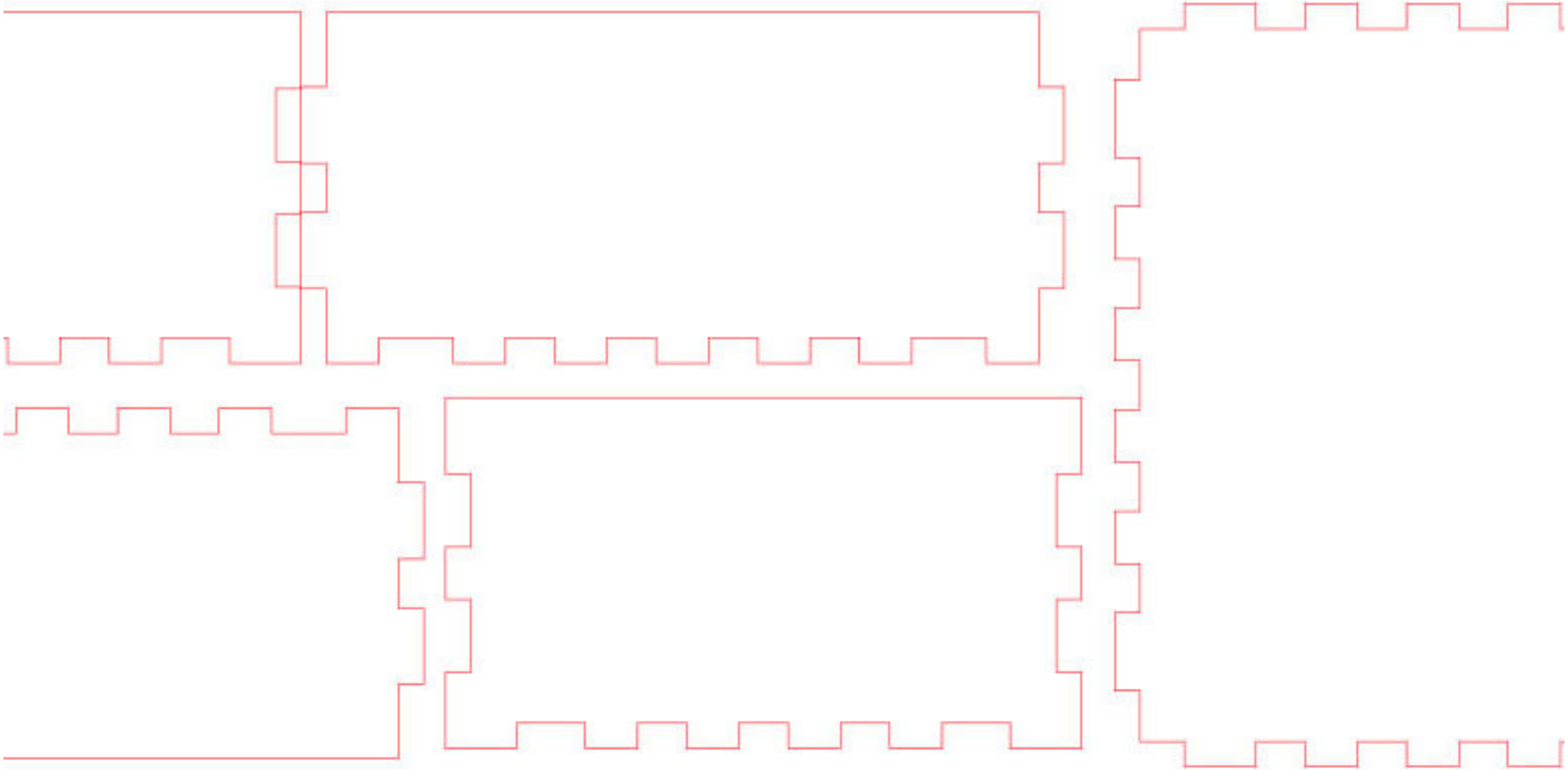
laser features #3

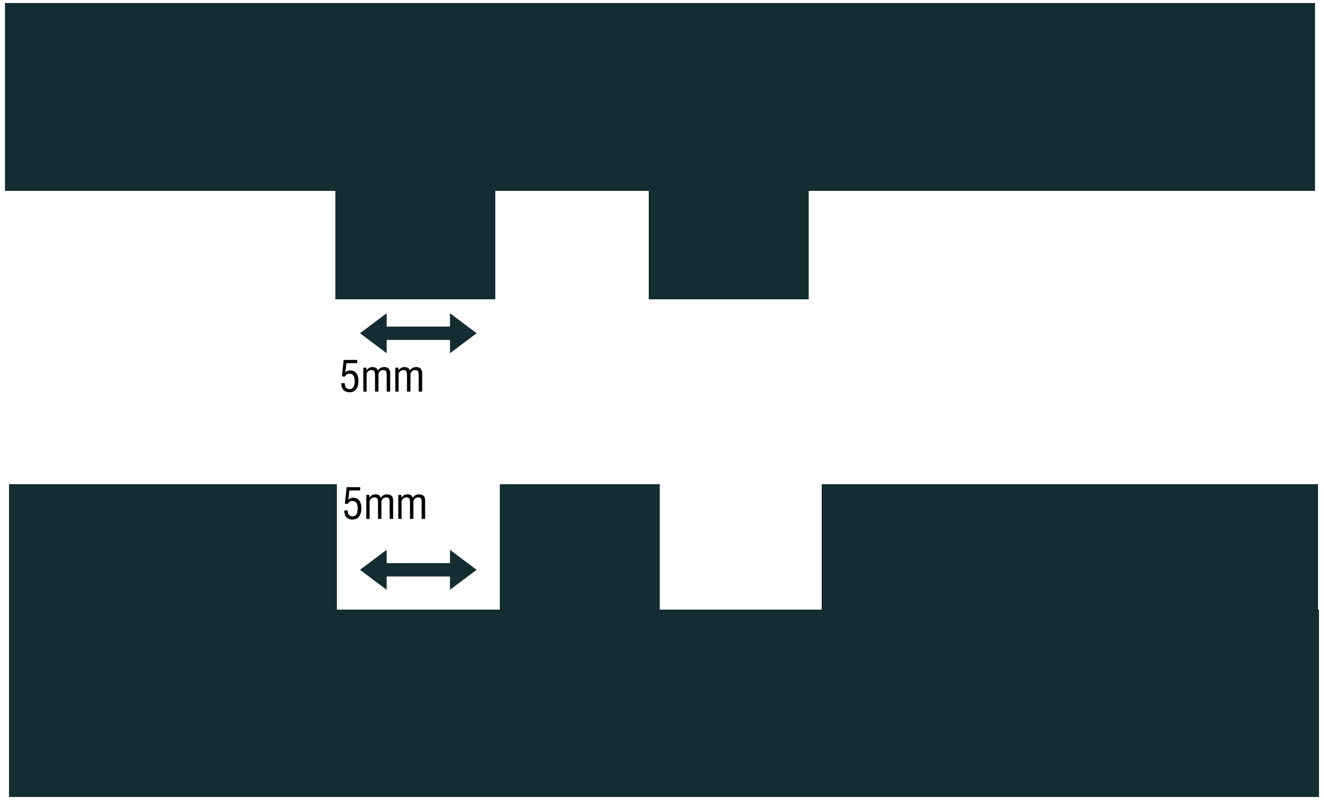
Joints - creating 3D objects

finger joints (box joints)

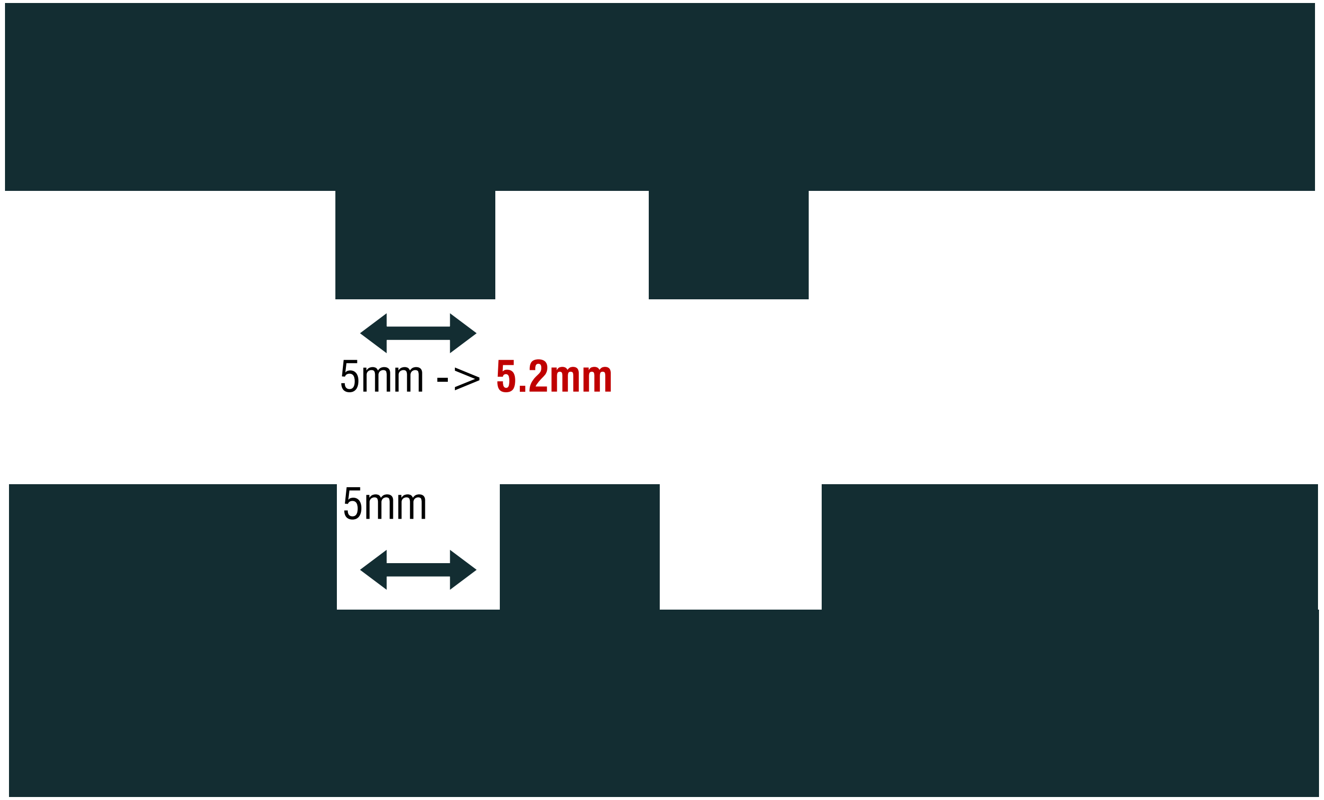






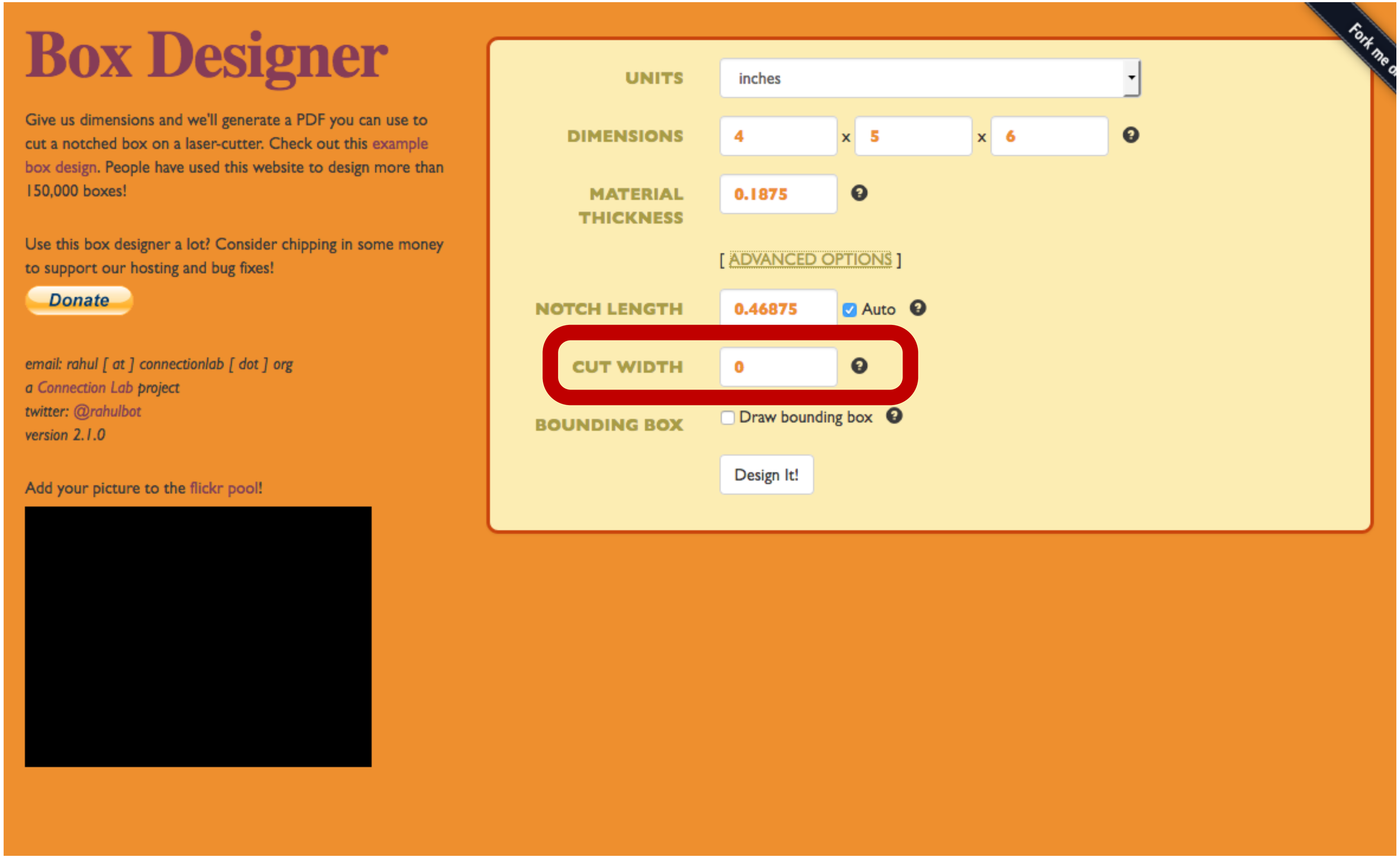


will this fit?



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

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



Box Designer

Give us dimensions and we'll generate a PDF you can use to cut a notched box on a laser-cutter. Check out this example box design. People have used this website to design more than 150,000 boxes!

Use this box designer a lot? Consider chipping in some money to support our hosting and bug fixes!

email: rahul [at] connectionlab [dot] org
a Connection Lab project
twitter: @rahulbot
version 2.1.0

Add your picture to the flickr pool!

UNITS: inches
DIMENSIONS: 4 x 5 x 6
MATERIAL THICKNESS: 0.1875
[ADVANCED OPTIONS]
NOTCH LENGTH: 0.46875 ☑ Auto
CUT WIDTH: 0
BOUNDING BOX: ☐ Draw bounding box

http://boxdesigner.connectionlab.org/

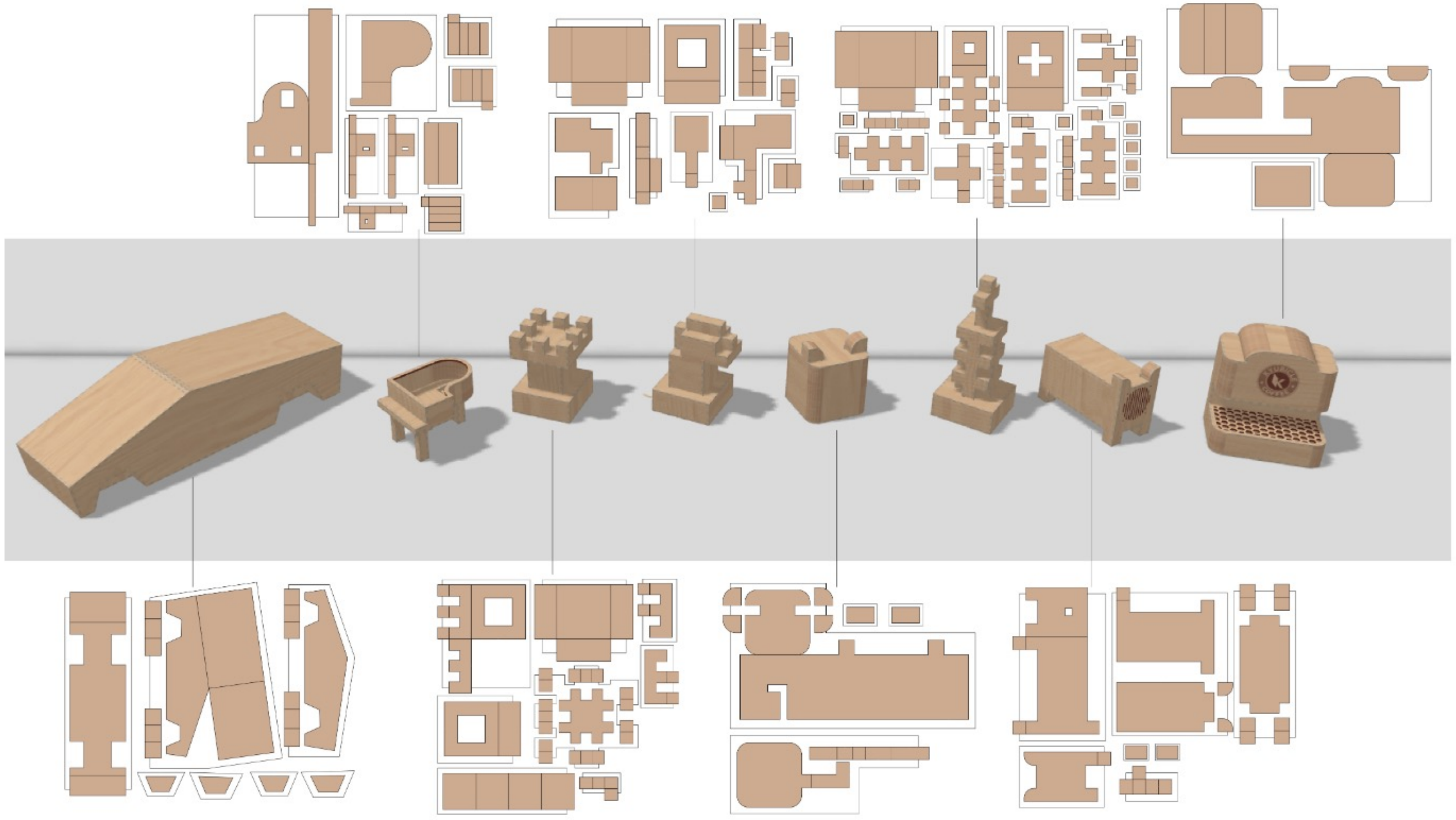
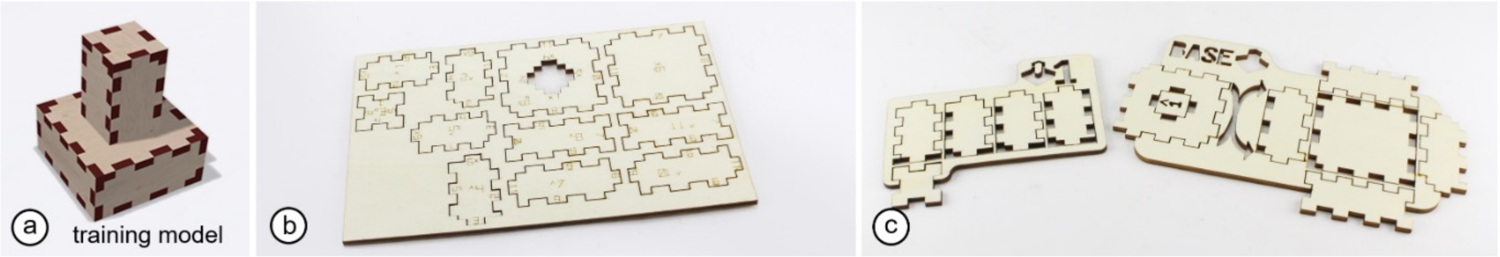


Figure 16: Roadkill layouts of some models from the Kyub repository.



Roadkill: Nesting Laser-Cut Objects for Fast Assembly

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Figure 1: Our software tool *Roadkill* converts 3D models to 2D cutting plans for laser cutting—such that the resulting layout allows for *fast assembly*. Roadkill achieves this with the help of a visual language that conveys assembly instructions directly in the generated layout and by collocating plates to be joined, thereby minimizing visual search.

ABSTRACT

We present Roadkill, a software tool that converts 3D models to 2D cutting plans for laser cutting—such that the resulting layouts allow for *fast assembly*. Roadkill achieves this by putting all relevant information into the cutting plan: (1) *Thumbnails* indicate which area of the model a set of parts belongs to. (2) *Parts with exposed finger joints* are easy to access, thereby suggesting to start assembly here. (3) Openings in the sheet act as *jigs*, affording assembly *within* the sheet. (4) Users continue assembly by inserting what has already been assembled into parts that are immediately *adjacent* or are pointed to by *arrows*. Roadkill maximizes the number of joints rendered in immediate *adjacency* by breaking down models into "subassemblies." Within a subassembly, Roadkill holds the parts together using *break-away tabs*. (5) Users complete subassemblies according to their labels 1, 2, 3. . ., following 1 -> 1 links to insert subassemblies into other subassemblies, until all parts come together. In our user study, Roadkill allowed participants to assemble layouts *2.4 times faster* than layouts generated by a traditional pair-wise labeling of plates.

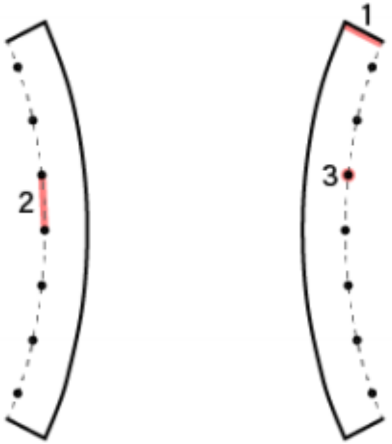
UIST '21, October 10–14, 2021, Virtual Event, USA

ACM ISBN 978-1-4503-8635-7/21/10.
https://doi.org/10.1145/3472749.3474799

UIST 2021

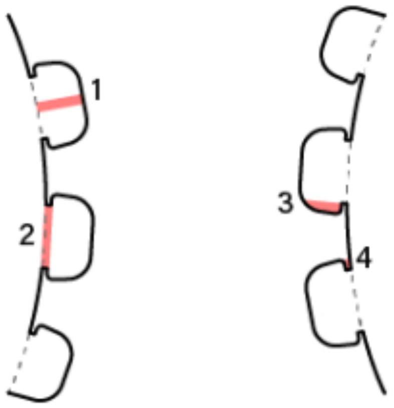
Abdullah et.al.

other connection joints



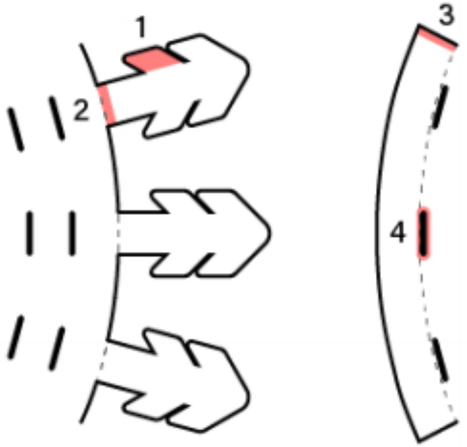
Hem

1. Hem Offset
2. Hole Spacing
3. Hole Diameter



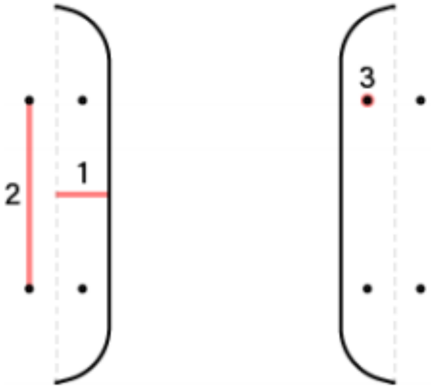
Interlocking

1. Tab Height
2. Tab Width
3. Grip
4. Material Thickness



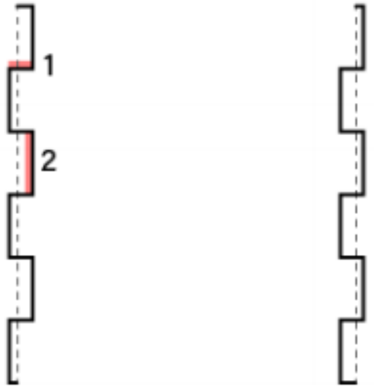
Loop Insert

1. Hook Size
2. Hook Width
3. Hem Offset
4. Material Thickness
5. Hook Count



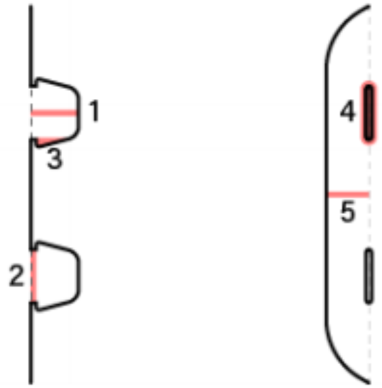
Flap

1. Flap Height
2. Hole Spacing
3. Hole Diameter



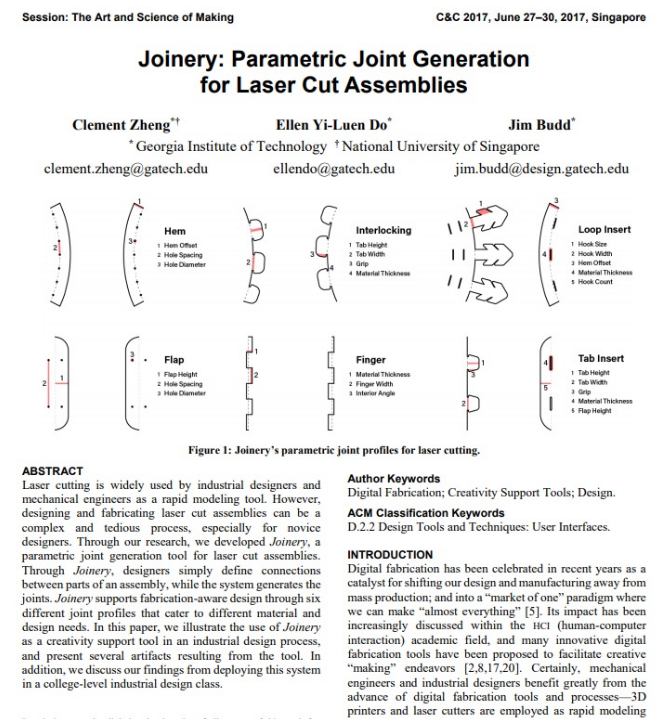
Finger

1. Material Thickness
2. Finger Width
3. Interior Angle



Tab Insert

1. Tab Height
2. Tab Width
3. Grip
4. Material Thickness
5. Flap Height



Session: The Art and Science of Making C&C 2017, June 27–30, 2017, Singapore

Joinery: Parametric Joint Generation for Laser Cut Assemblies

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Figure 1: Joinery's parametric joint profiles for laser cutting.

ABSTRACT

Laser cutting is widely used by industrial designers and mechanical engineers as a rapid modeling tool. However, designing and fabricating laser cut assemblies can be a complex and tedious process, especially for novice designers. Through our research, we developed *Joinery*, a parametric joint generation tool for laser cut assemblies. Through *Joinery*, designers simply define connections between parts of an assembly, while the system generates the joints. *Joinery* supports fabrication-aware design through six different joint profiles that cater to different material and design needs. In this paper, we illustrate the use of *Joinery* as a creativity support tool in an industrial design process, and present several artifacts resulting from the tool. In addition, we discuss our findings from deploying this system in a college-level industrial design class.

Author Keywords
Digital Fabrication; Creativity Support Tools; Design.

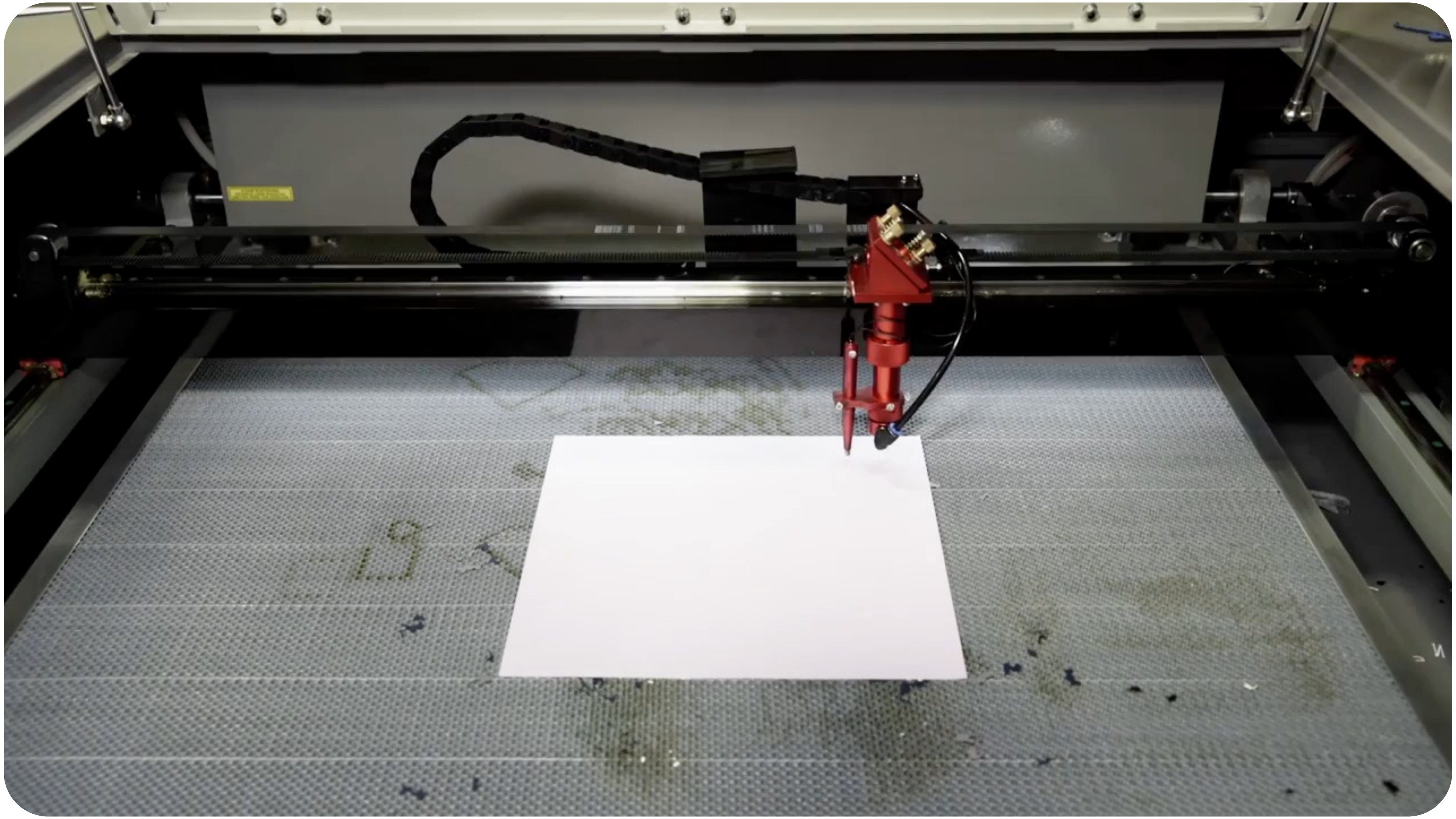
ACM Classification Keywords
D.2.2 Design Tools and Techniques: User Interfaces.

INTRODUCTION

Digital fabrication has been celebrated in recent years as a catalyst for shifting our design and manufacturing away from mass production; and into a "market of one" paradigm where we can make "almost everything" [5]. Its impact has been increasingly discussed within the HCI (human-computer interaction) academic field, and many innovative digital fabrication tools have been proposed to facilitate creative "making" endeavors [2,8,17,20]. Certainly, mechanical engineers and industrial designers benefit greatly from the advance of digital fabrication tools and processes—3D printers and laser cutters are employed as rapid modeling

C&C 2018

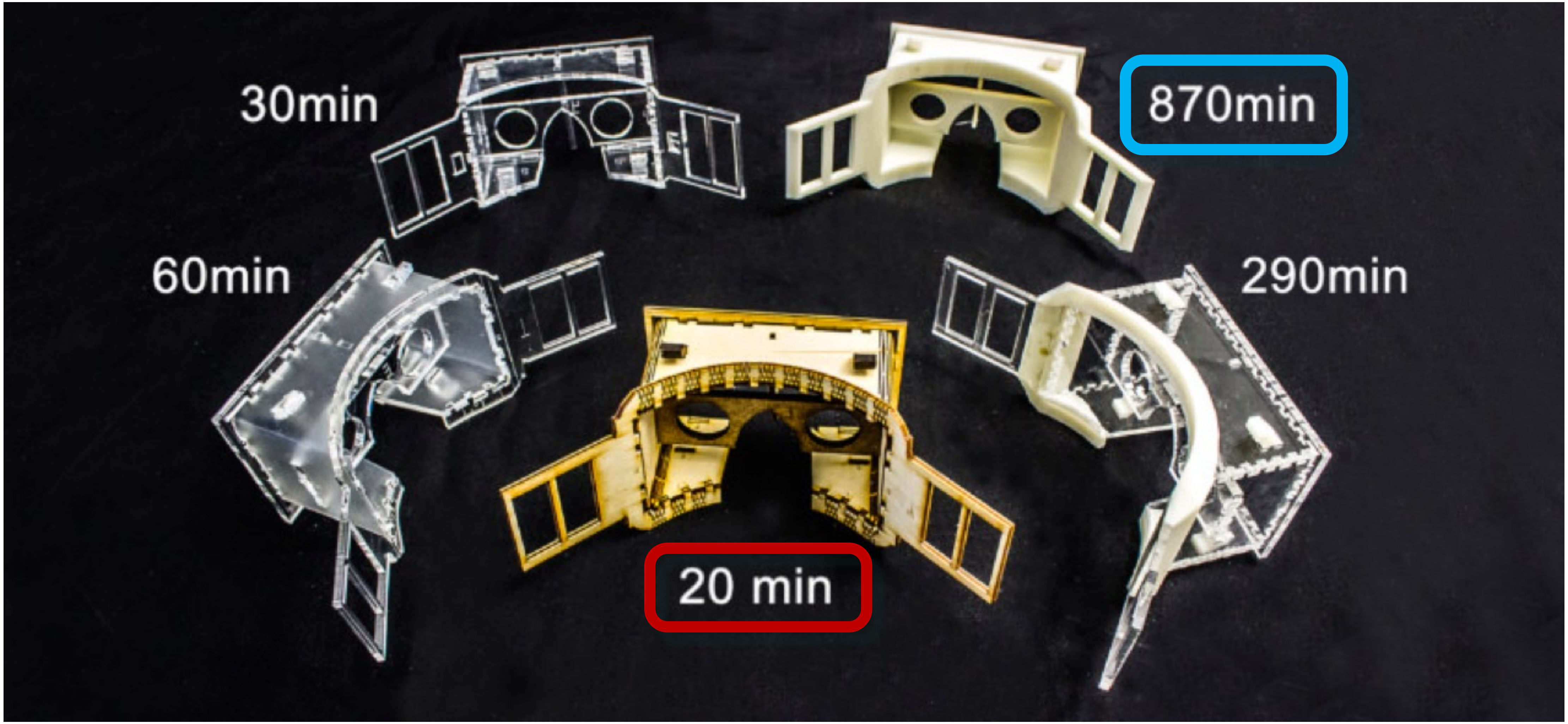
Zheng et.al.

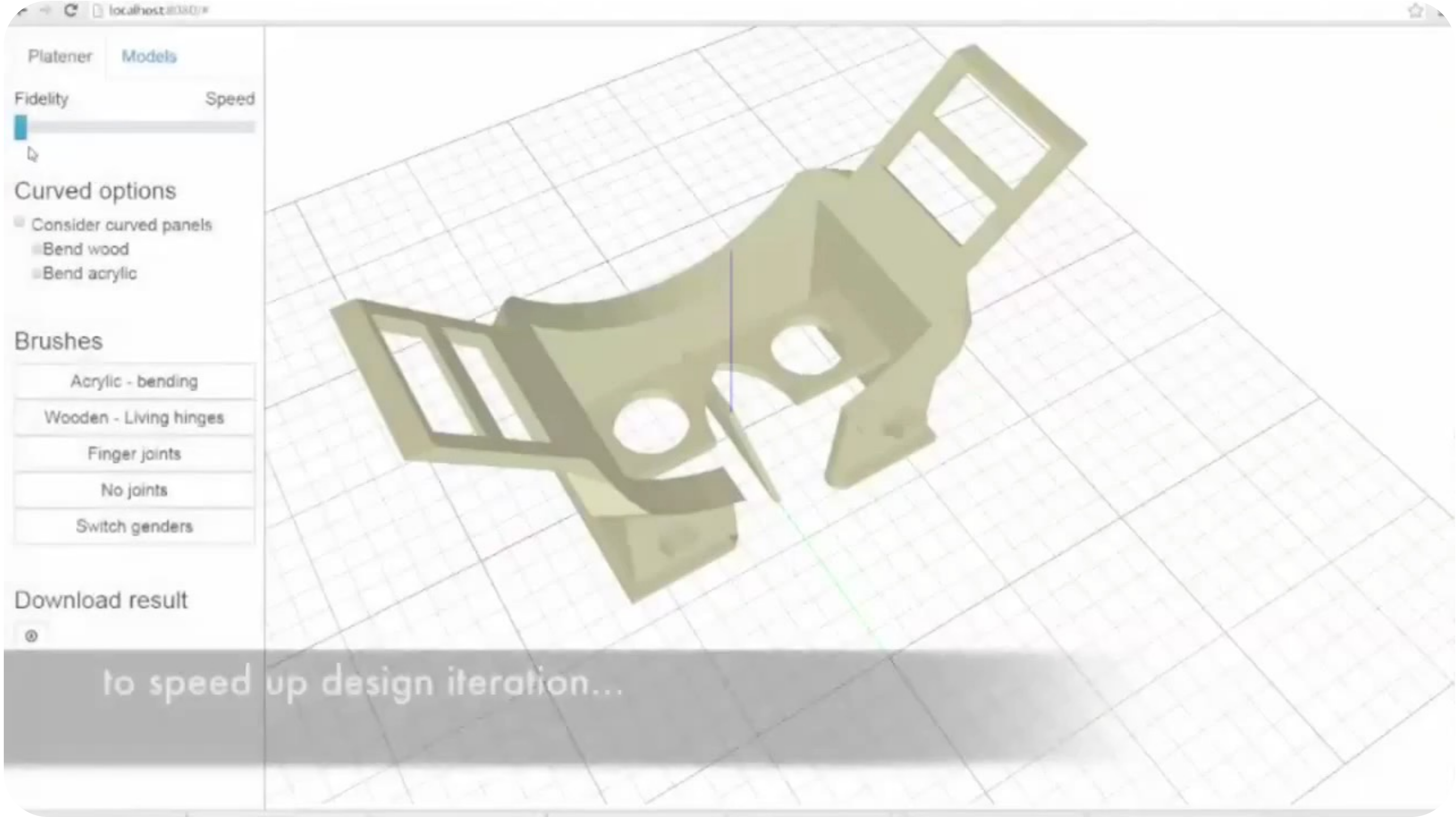


We already talked about 3D printing, why laser cutting?

Fast (Good for iteration)
Durable (because there is no layer bonding)
Simple (Similar to 2D paper printing)

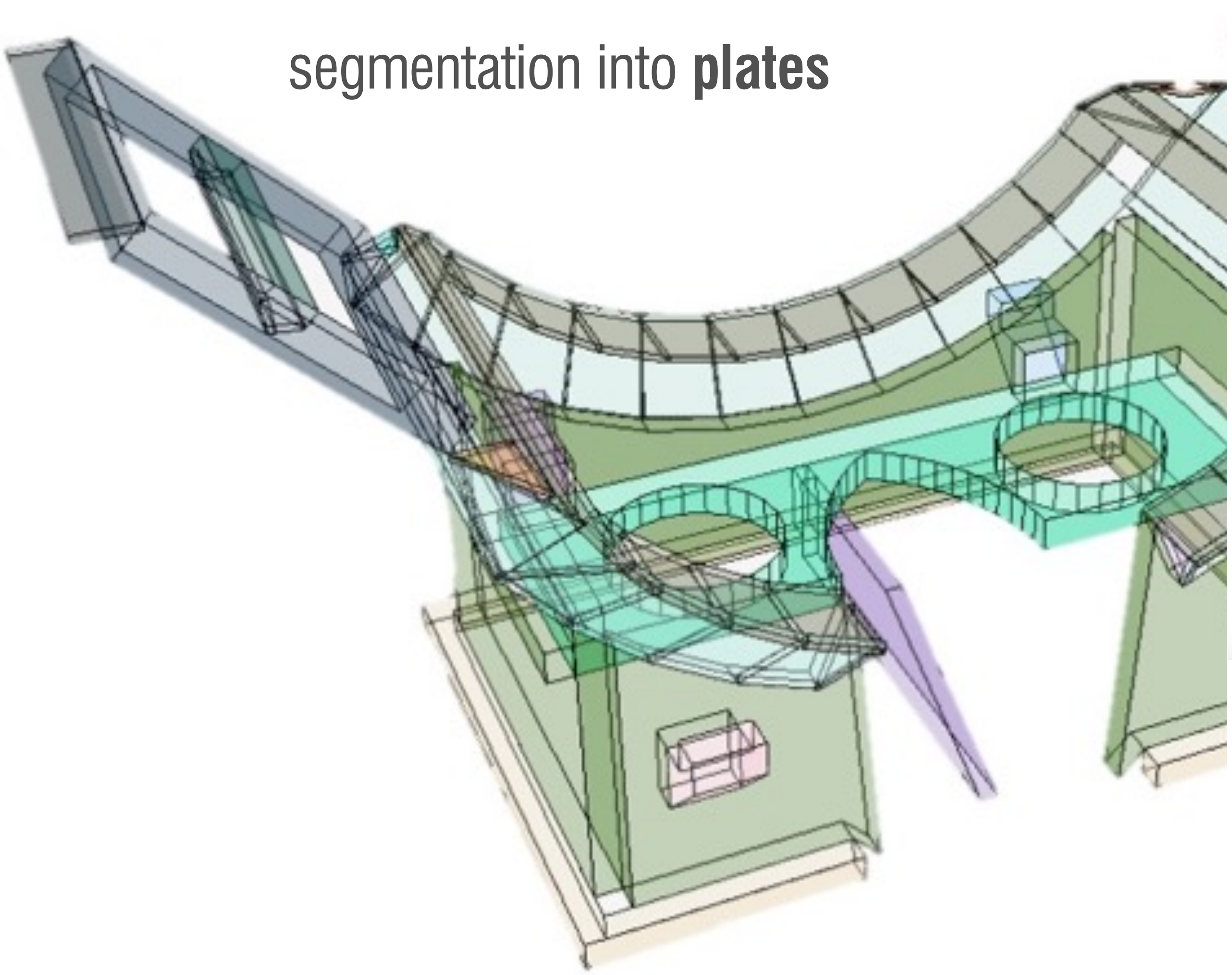
replace 3D print with laser cut 2D plates:

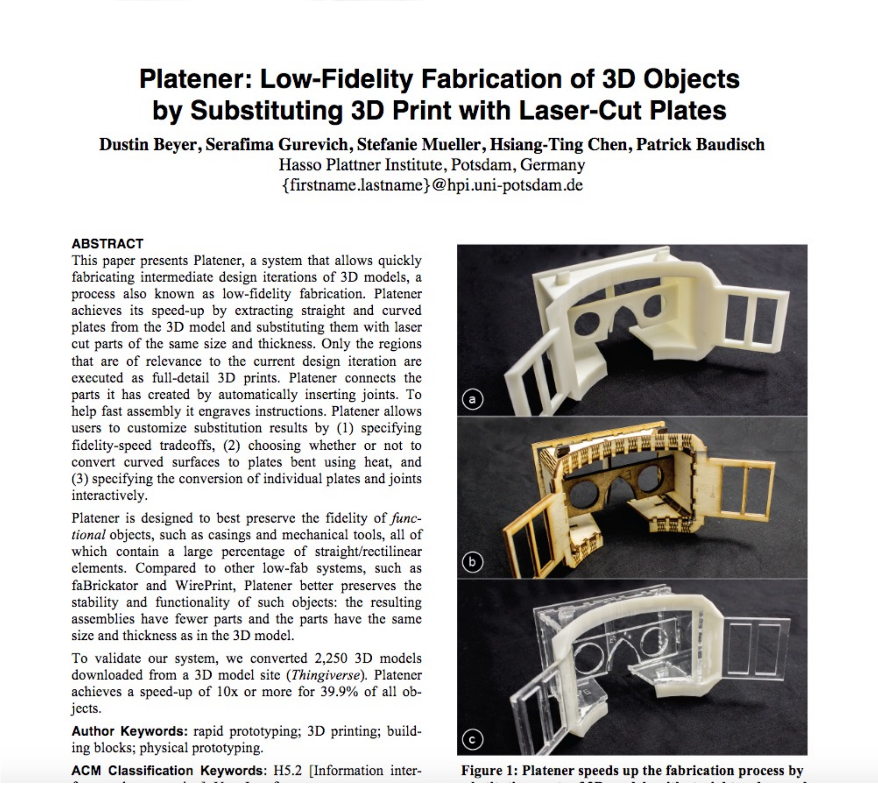




to speed up design iteration...

segmentation into **plates**





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

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{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.

ACM Classification Keywords: H5.2 [Information inter-

Figure 1: Platener speeds up the fabrication process by

UIST 2015

Beyer et.al.

Why **laser cutter** again?


CHI 2019 Paper CHI 2019, May 4–9, 2019, Glasgow, Scotland, UK

Kyub: A 3D Editor for Modeling Sturdy Laser-Cut Objects

Patrick Baudisch, Arthur Silber, Yannis Kommana, Milan Gruner, Ludwig Wall,
Kevin Reuss, Lukas Heilman, Robert Kovacs, Daniel Rechlitz, and Thijs Roumen
Hasso Plattner Institute at the University of Potsdam
Potsdam, Germany
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Figure 1: A selection of objects created using *kyub*, a software system that allows users to design 3D objects for laser cutting. By affording closed box structures, objects made using kyub are very strong. This allows users to make tables, shelves, and chairs that can hold a person. (All shown objects are assembled from 4mm plywood sheets—pressure fit, not glued).

ABSTRACT

We present an interactive editing system for laser cutting called kyub. Kyub allows users to create models efficiently in 3D, which it then unfolds into the 2D plates laser cutters expect. Unlike earlier systems, such as FlatFitFab, kyub affords construction based on closed box structures, which allows users to turn very thin material, such as 4mm plywood, into objects capable of withstanding large forces, such as chairs users can actually sit on. To afford such sturdy construction, every kyub project begins with a simple finger-joint "boxel"—a structure we found to be capable of withstanding over 500kg of load. Users then extend their model by attaching additional boxels. Boxels merge automatically, resulting in larger, yet equally strong structures. While the concept of stacking boxels allows kyub to offer the strong affordance and ease of use of a voxel-based editor, boxels are not confined to a grid and readily combine with kuyb's various geometry deformation tools. In our technical evaluation, objects built with kyub withstood hundreds of kilograms of loads. In our user study, non-engineers rated the learnability of kyub 6.1/7.

CCS CONCEPTS

- Human-centered computing~Human computer interaction

KEYWORDS

Personal fabrication; laser cutting; interactive editing.

ACM Reference format:

Patrick Baudisch, Arthur Silber, Yannis Kommana, Milan Gruner, Ludwig Wall, Kevin Reuss, Lukas Heilman, Robert Kovacs, Daniel Rechlitz, and Thijs Roumen. 2019. Kyub: a 3D Editor for Modeling Sturdy Laser-Cut Objects. In *2019 CHI Conference on Human Factors in Computing Systems Proceedings (CHI 2019), May 4–9, 2019, Glasgow, Scotland, UK*. ACM, New York, NY, USA. https://doi.org/10.1145/3290605.3300796

ACM ISBN 978-1-4503-5970-2/19/05...$15.00

https://doi.org/10.1145/3290605.3300796

Paper 566 Page 1

CHI 2019

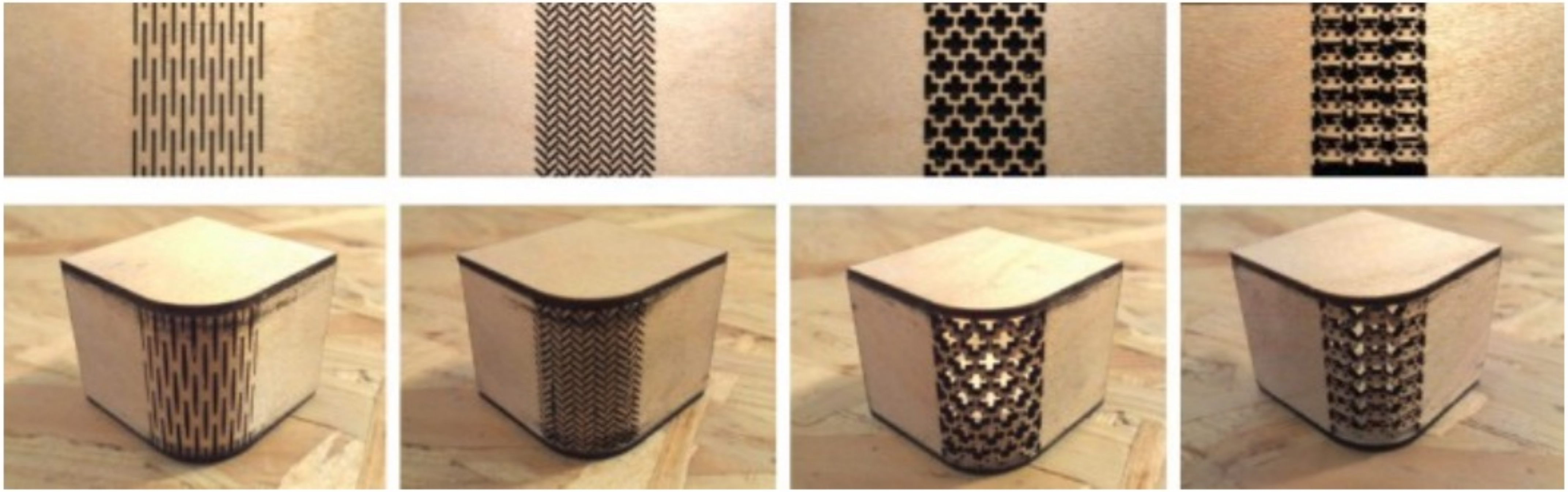
Baudisch et.al.

laser features #4

bending

living hinges

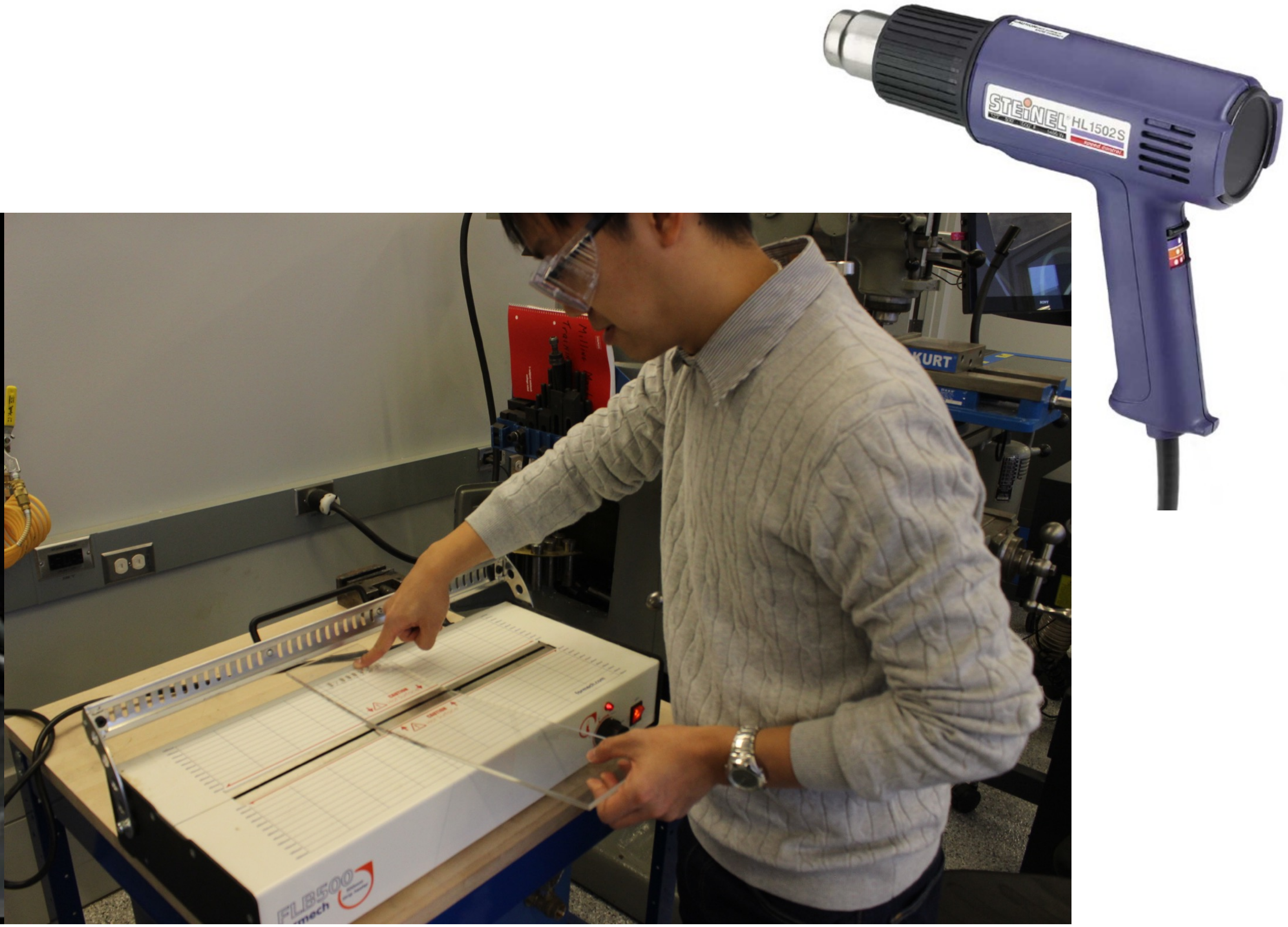
living hinges

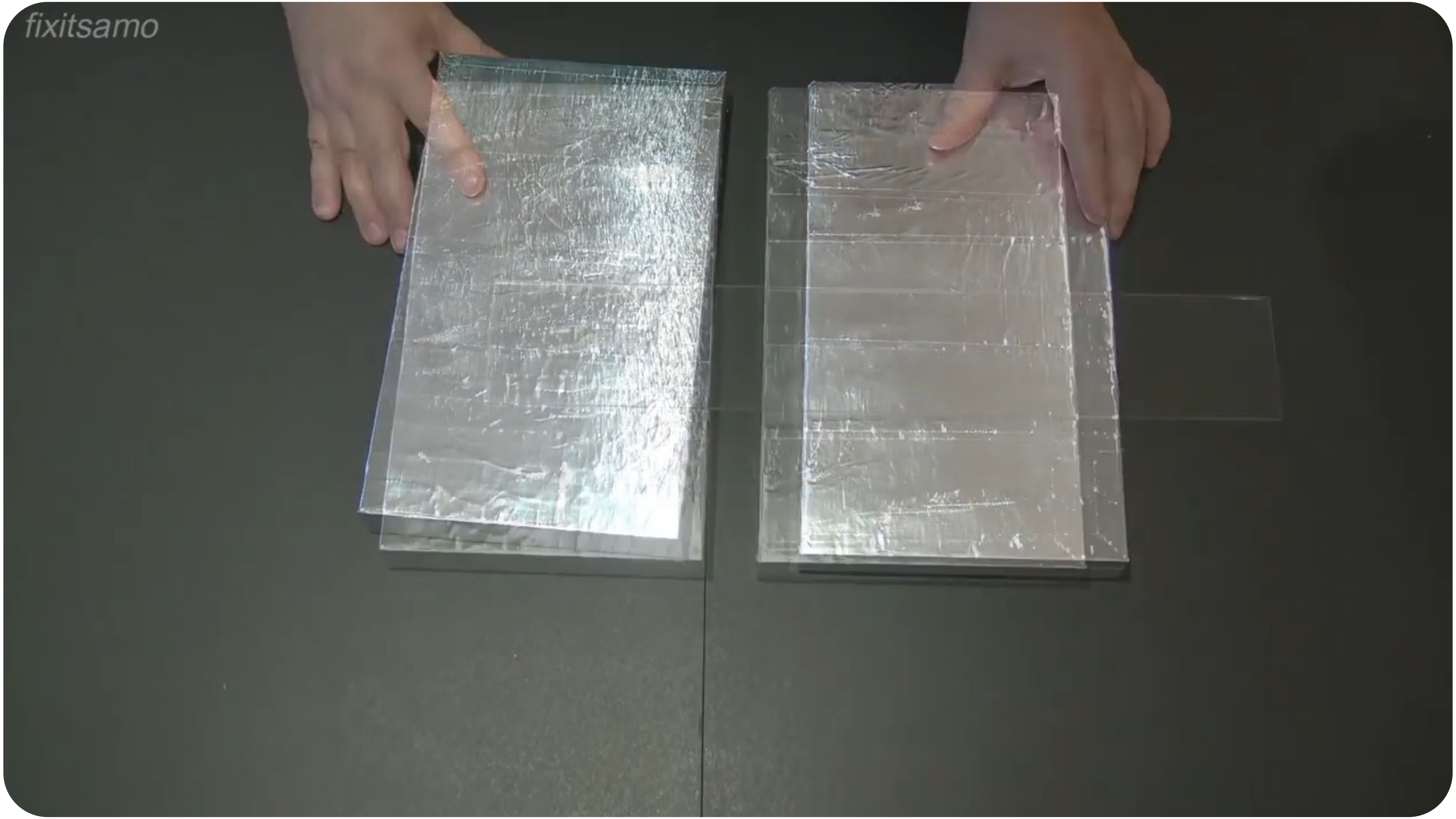


Repeated patterns with **continuous** connections
Stiff material becomes bendable (with lightweight force applied)
Only work for certain materials (i.e. **acrylics will not work**)

bend acrylic

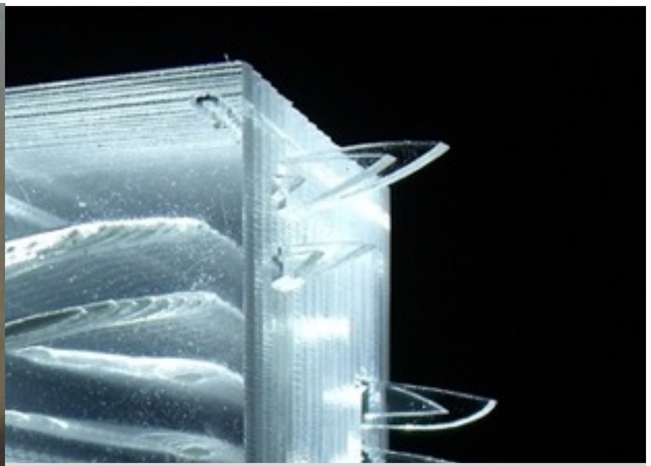
to bend acrylic use a **heat gun** or **strip heater**



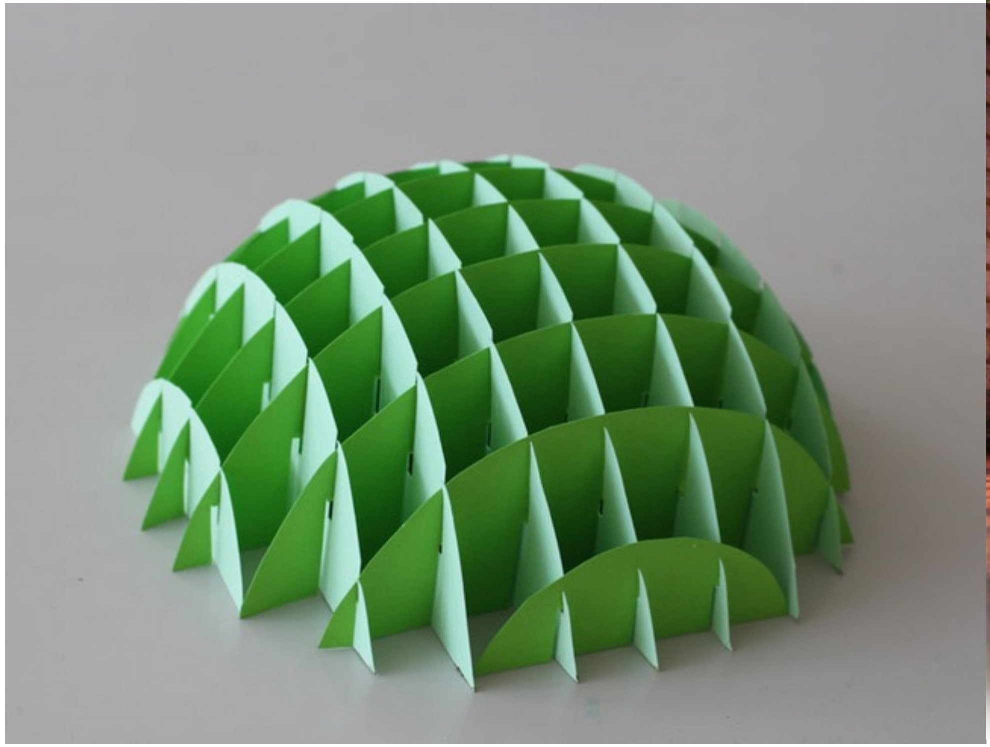

fixitsamo

other ways to make 3D

stacking

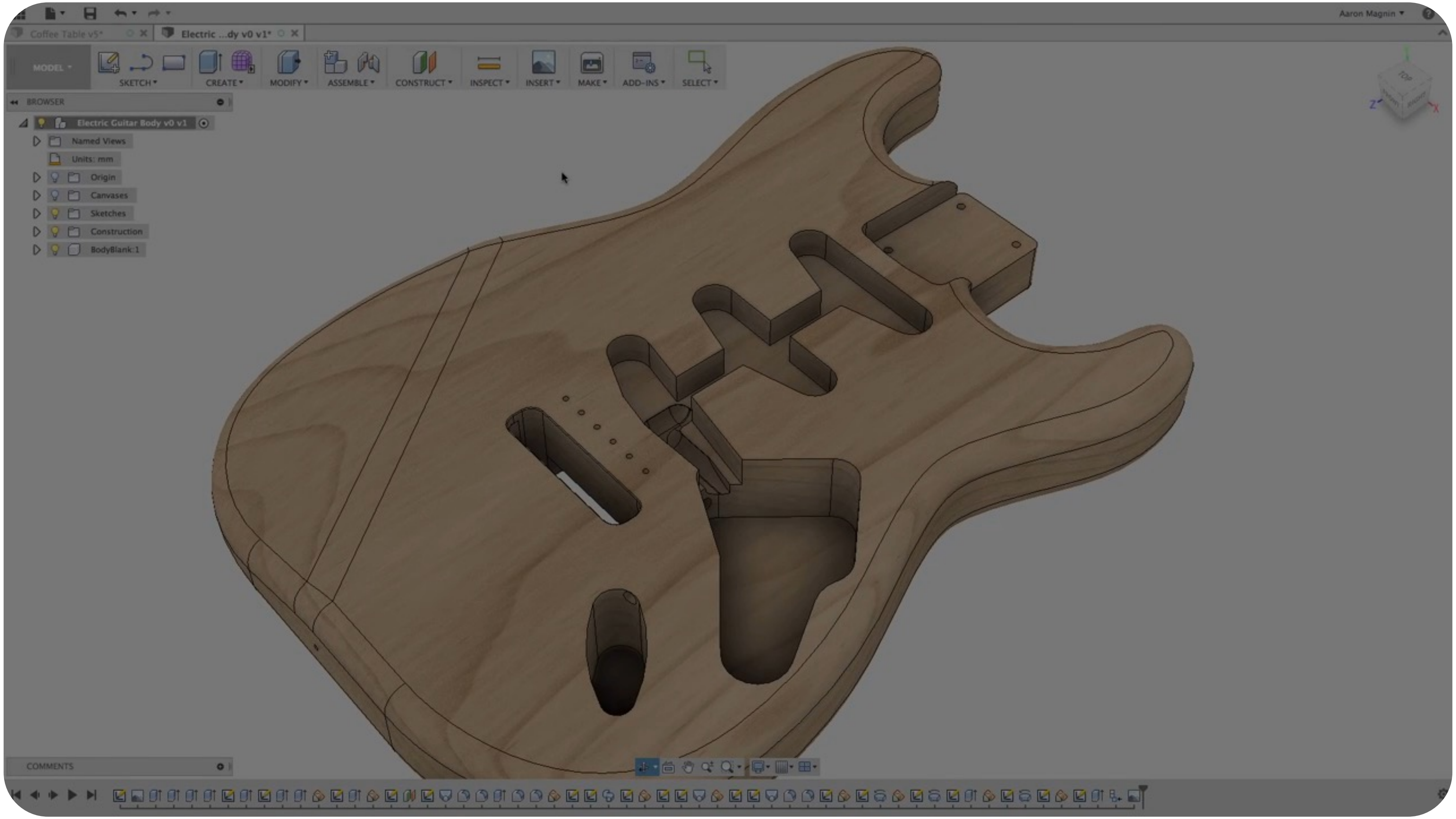


intersecting



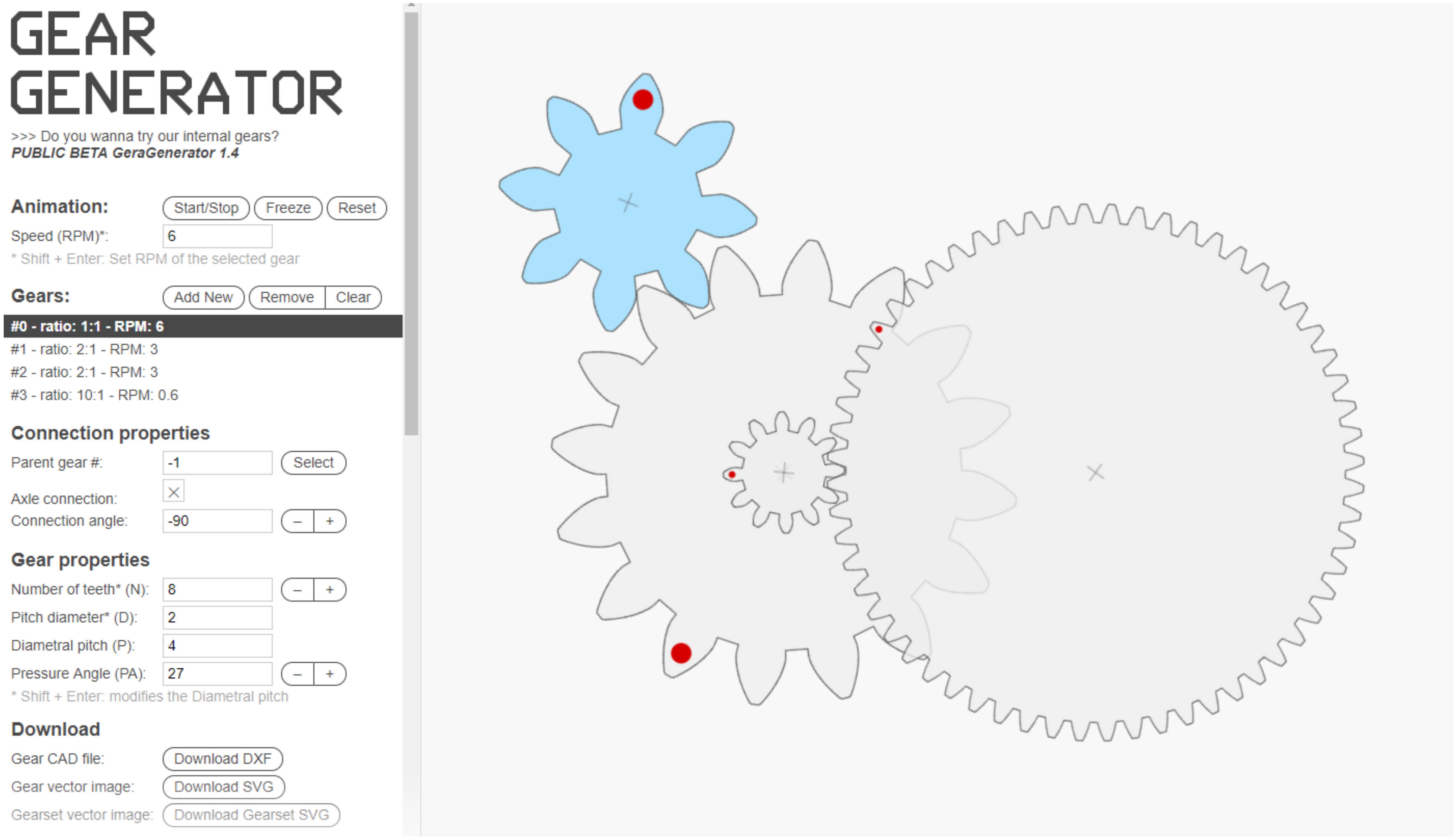
surface folding

Fusion 360 slicer



laser features #5:

moving parts



GEAR GENERATOR

>>> Do you wanna try our internal gears?
PUBLIC BETA GeraGenerator 1.4

Animation:

Speed (RPM)*: 6

* Shift + Enter: Set RPM of the selected gear

Gears:

#0 - ratio: 1:1 - RPM: 6
#1 - ratio: 2:1 - RPM: 3
#2 - ratio: 2:1 - RPM: 3
#3 - ratio: 10:1 - RPM: 0.6

Connection properties

Parent gear #: -1
Axle connection: ☒
Connection angle: -90

Gear properties

Number of teeth* (N): 8
Pitch diameter* (D): 2
Diametral pitch (P): 4
Pressure Angle (PA): 27

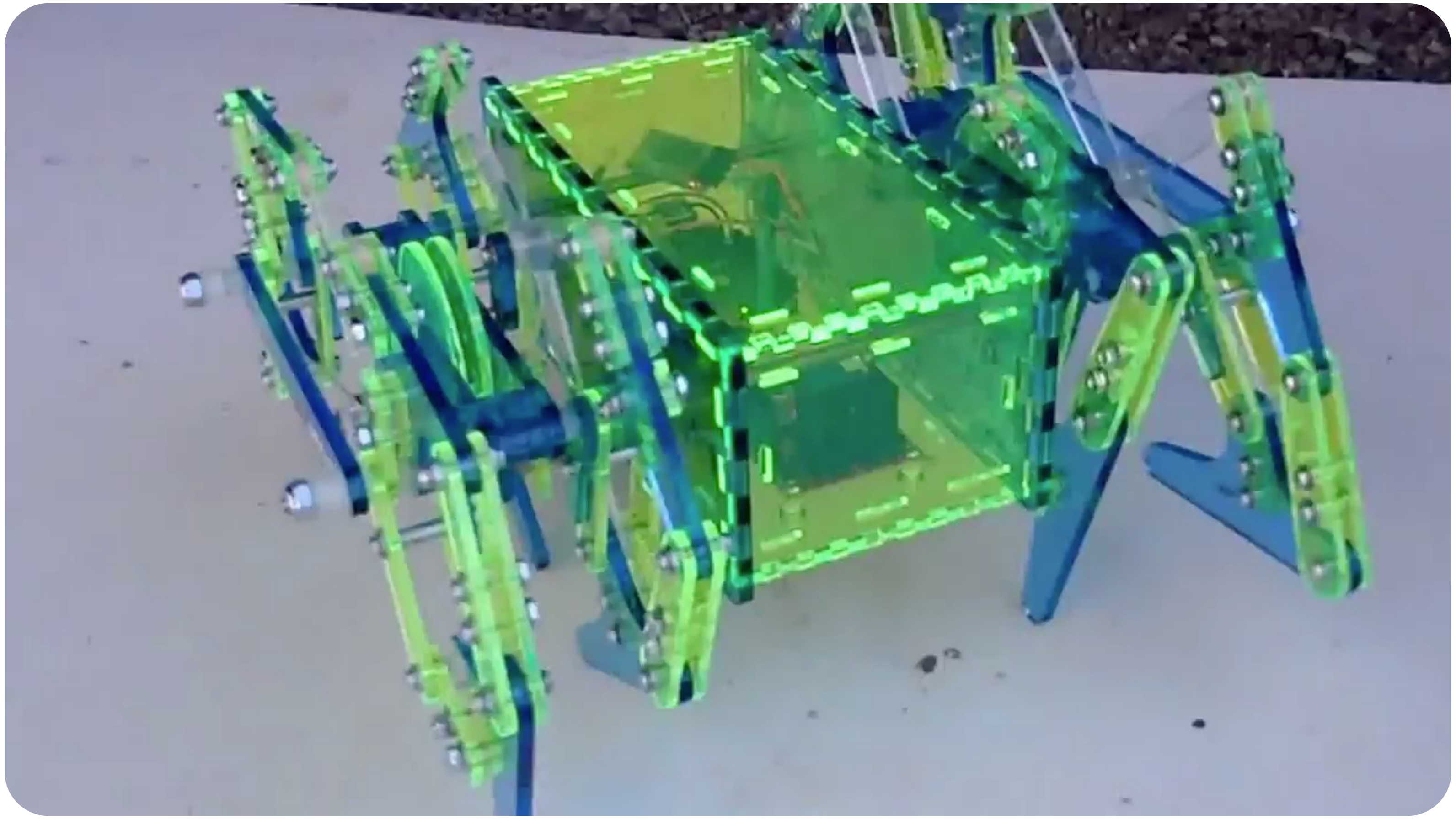
* Shift + Enter: modifies the Diametral pitch

Download

Gear CAD file:
Gear vector image:
Gearset vector image:

https://geargenerator.com

gears & linkages::



CO2 laser cutter types

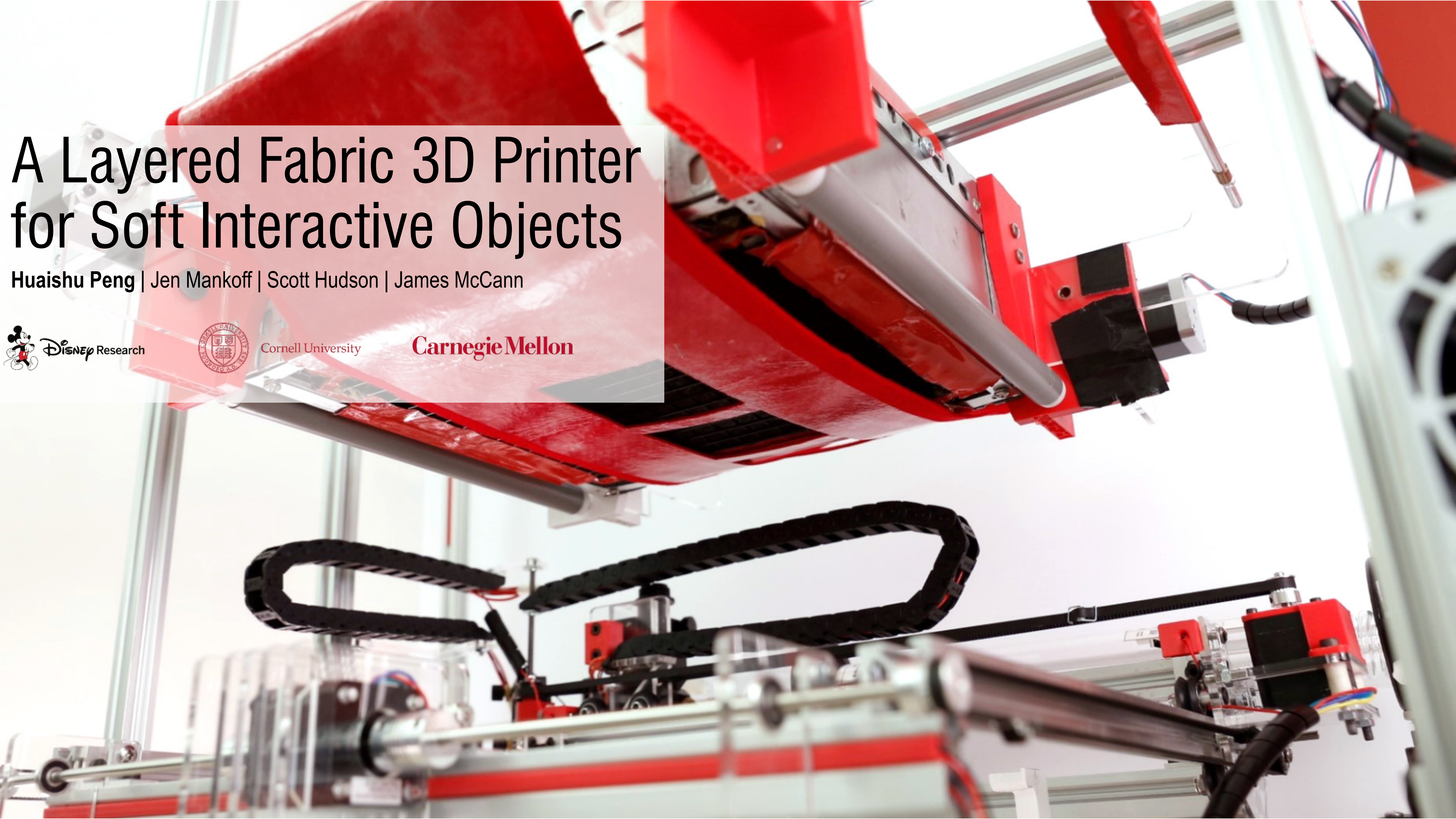
industrial laser cutter
$20k - 50k

(we have 2 in the makerspace)

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

hacker laser cutters < $1,000

water pump under the desk



A Layered Fabric 3D Printer for Soft Interactive Objects

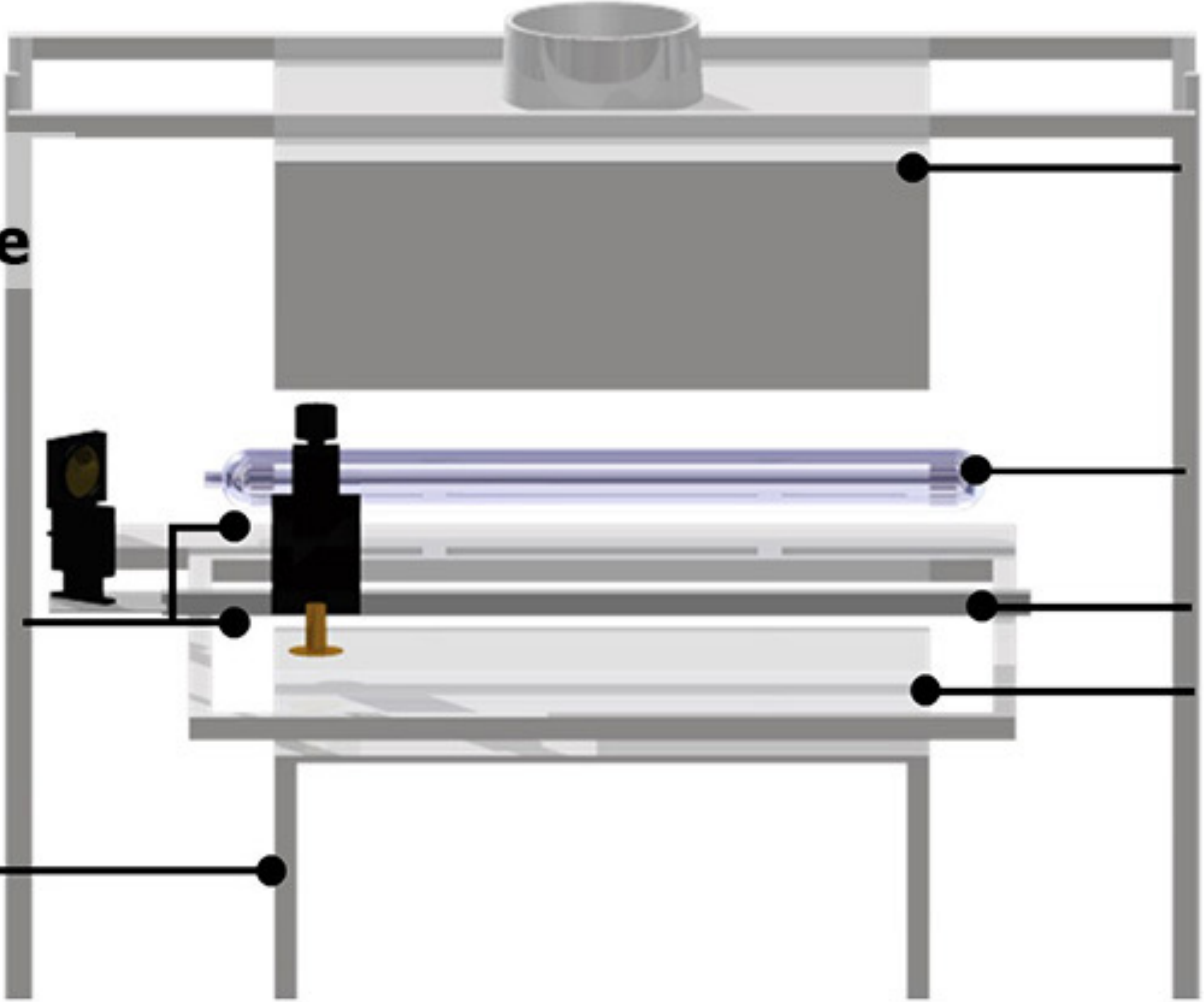
Huaishu Peng | Jen Mankoff | Scott Hudson | James McCann

Disney Research

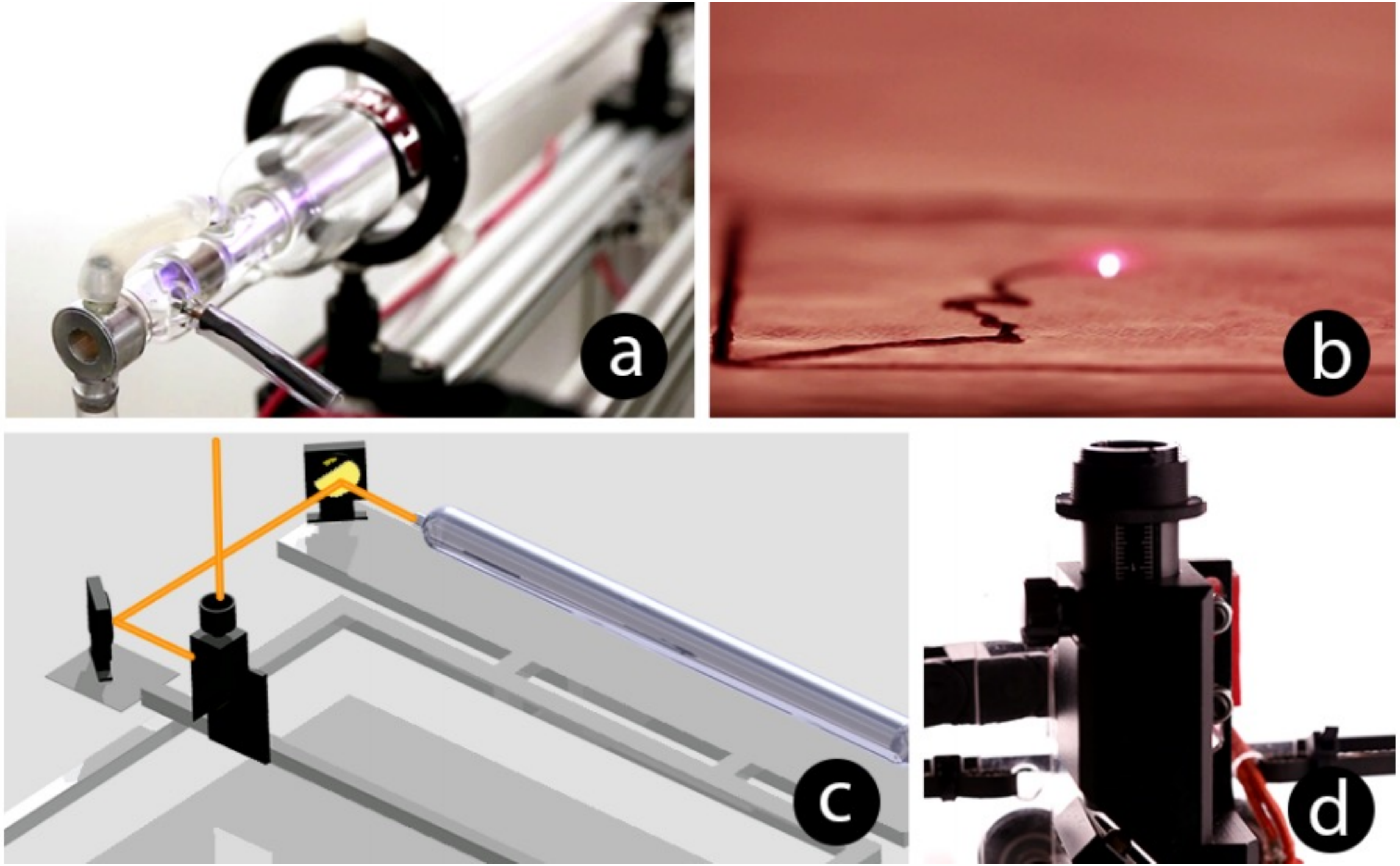
Cornell University

Carnegie Mellon

Printer Structure



Disney Research, Pittsburgh


a
b
c
d

Customize control for laser cutters

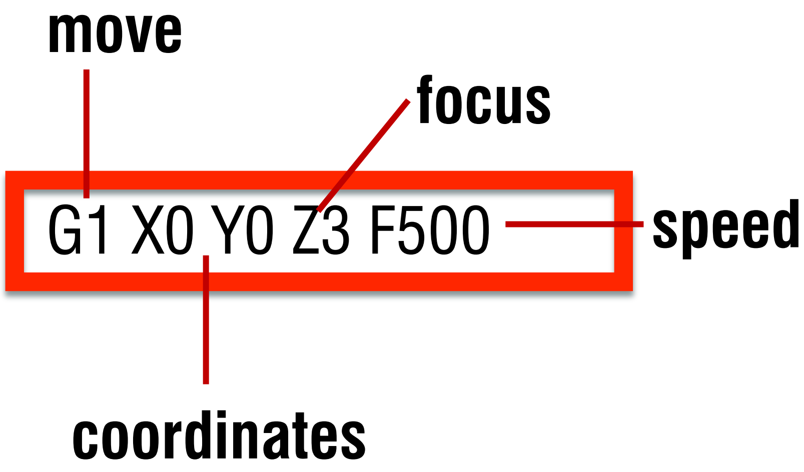
LAOS board

(open source controller board)

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

gcode::

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



move

focus

```
G1 X0 Y0 Z3 F500
```

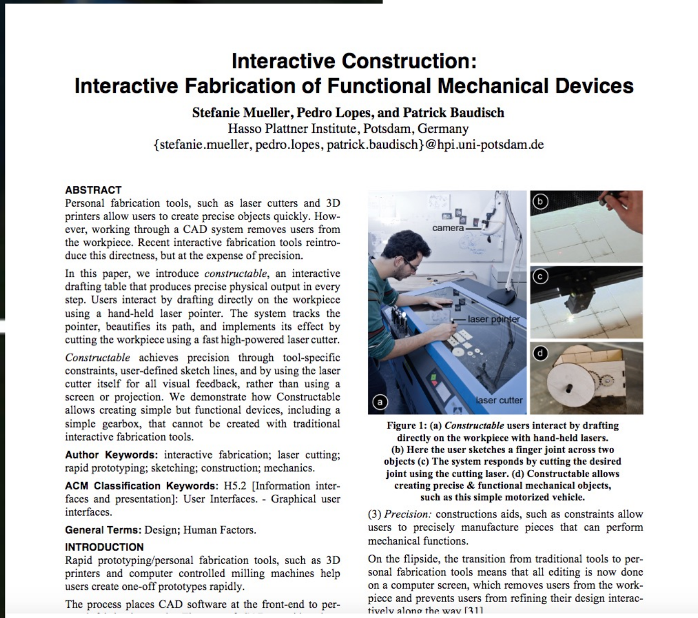
speed

coordinates

That’s also how we control 3D printers

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



Interactive Construction:
Interactive Fabrication of Functional Mechanical Devices

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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.

The process places CAD software at the front-end to per-

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.

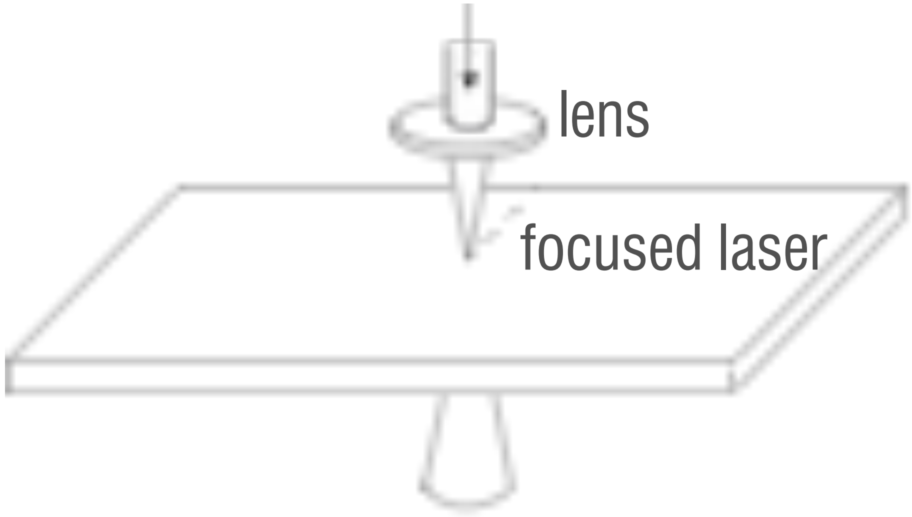
(3) *Precision:* constructions aids, such as constraints allow users to precisely manufacture pieces that can perform mechanical functions.

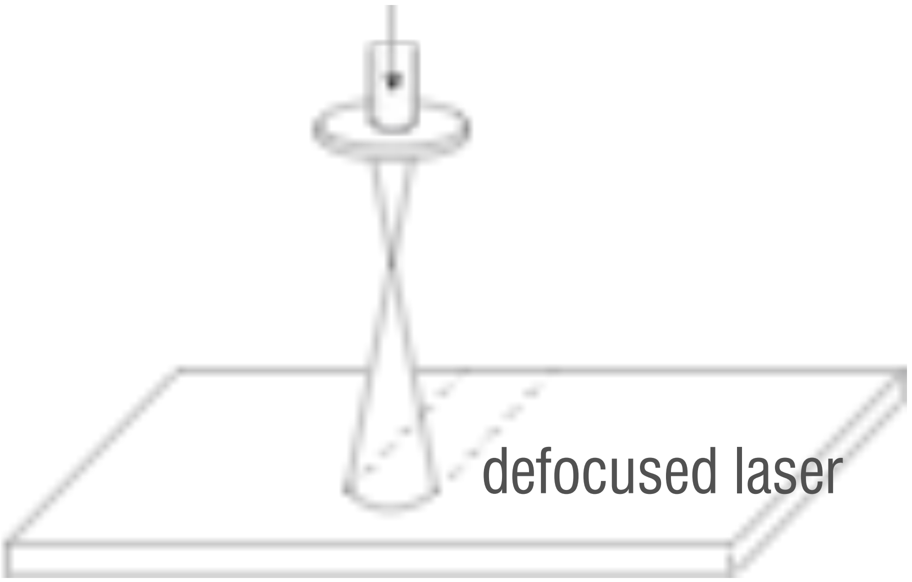
On the flipside, the transition from traditional tools to personal fabrication tools means that all editing is now done on a computer screen, which removes users from the workpiece and prevents users from refining their design interactively along the way [31].

UIST 2012

Mueller et.al.

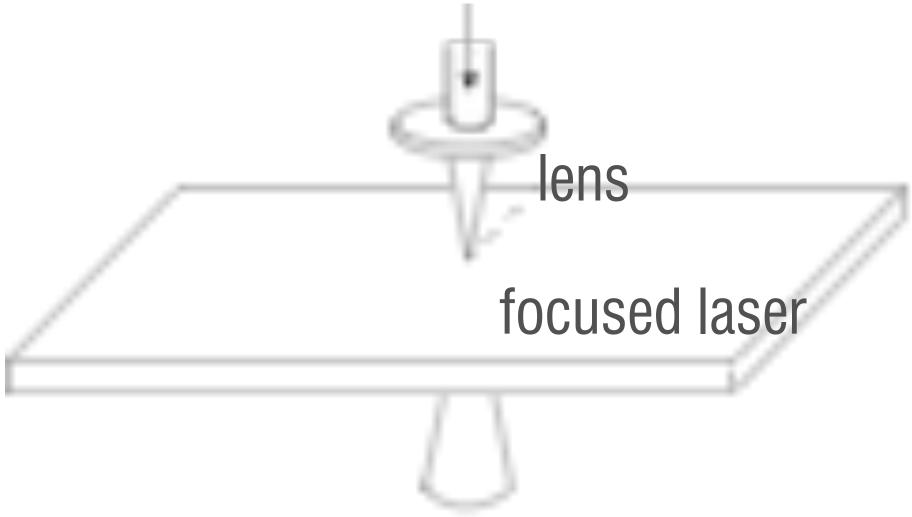
advanced tricks with defocused laser

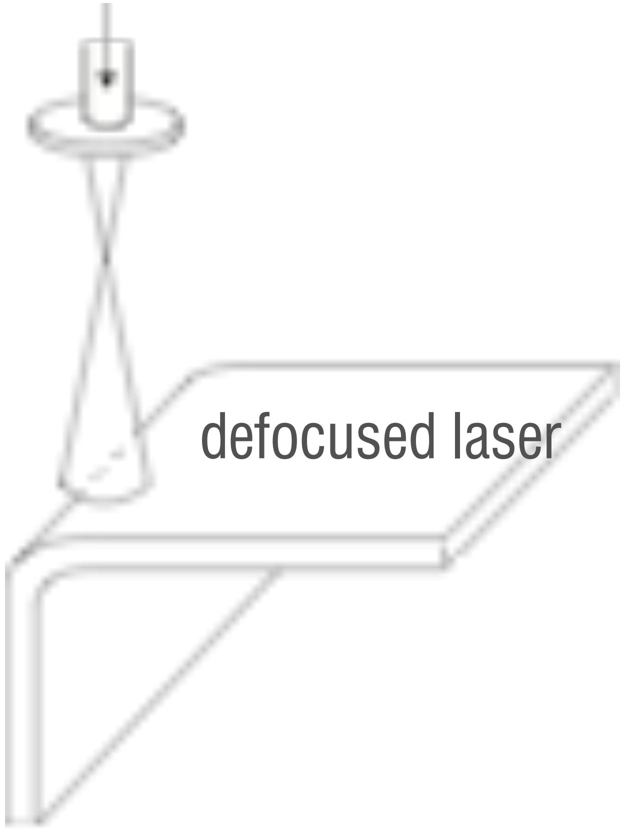




To cut-through we need to have the laser focused to the top surface of the material

Any benefit of defocusing a laser?

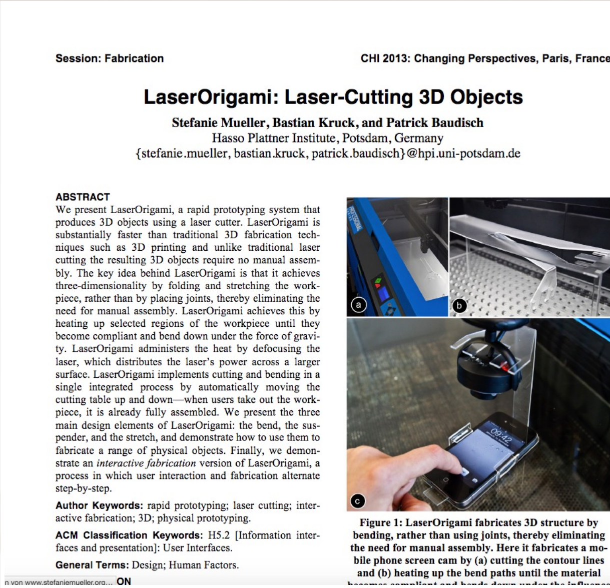




laser cutting -> laser bending


3x


SOLVE-IT
STEIGENBERGER HOTEL FRANKFURT - CITY



LaserOrigami: Laser-Cutting 3D Objects

Stefanie Mueller, Bastian Kruck, and Patrick Baudisch
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{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.

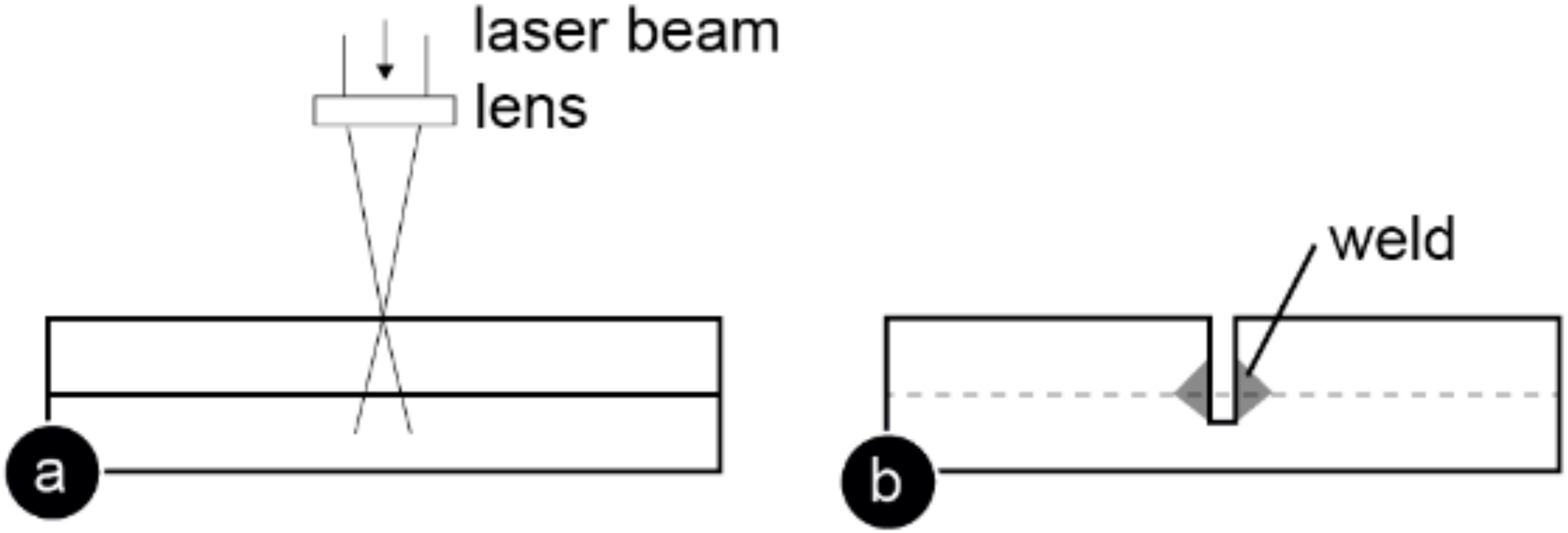
General Terms: Design; Human Factors.

n von www.stefaniemueller.org... **ON**

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 and (b) heating up the bend paths until the material

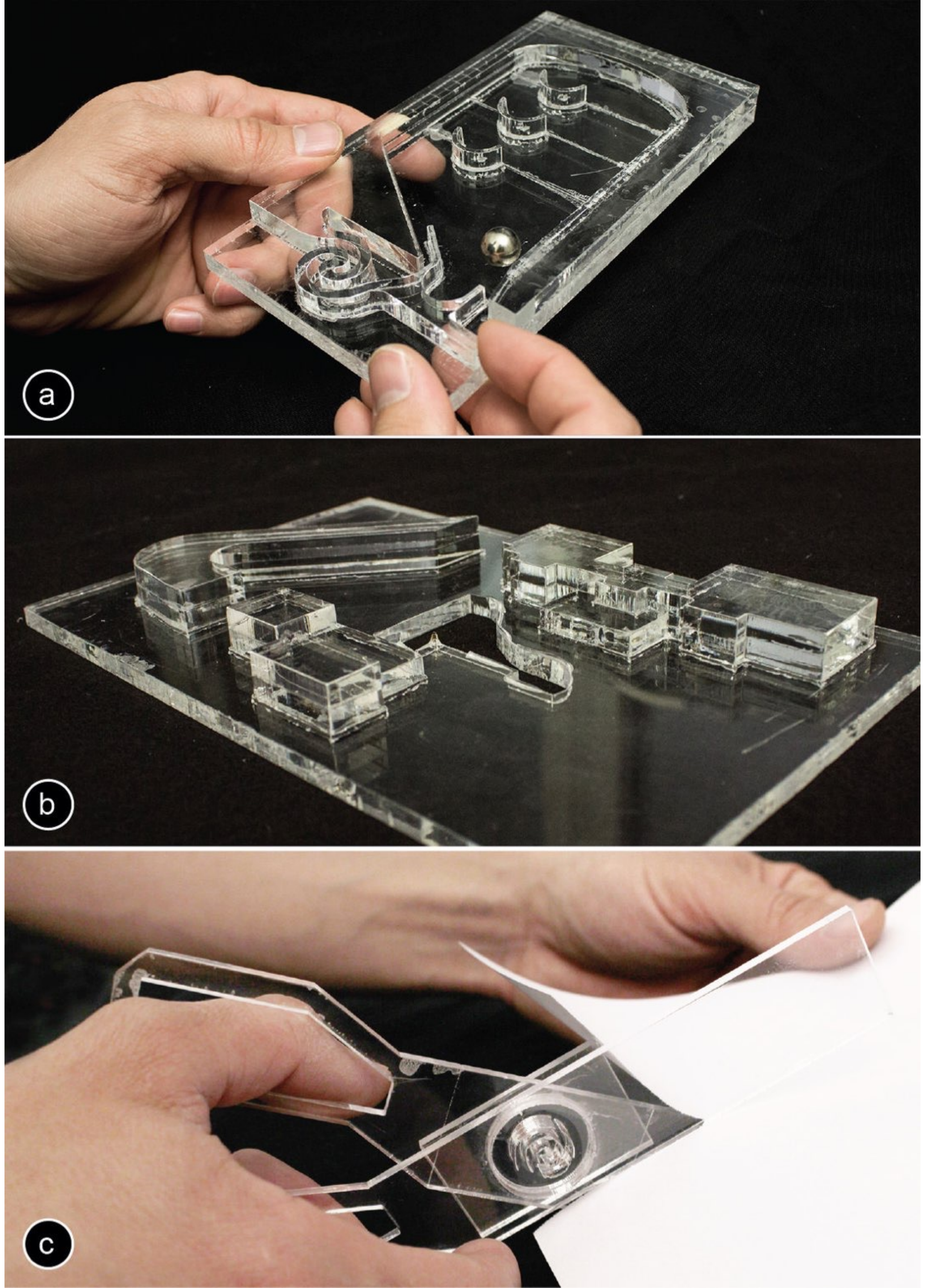
CHI 201

Mueller et



Using defocused laser to bond layers of acrylics for prototyping

Auto-stacking


a
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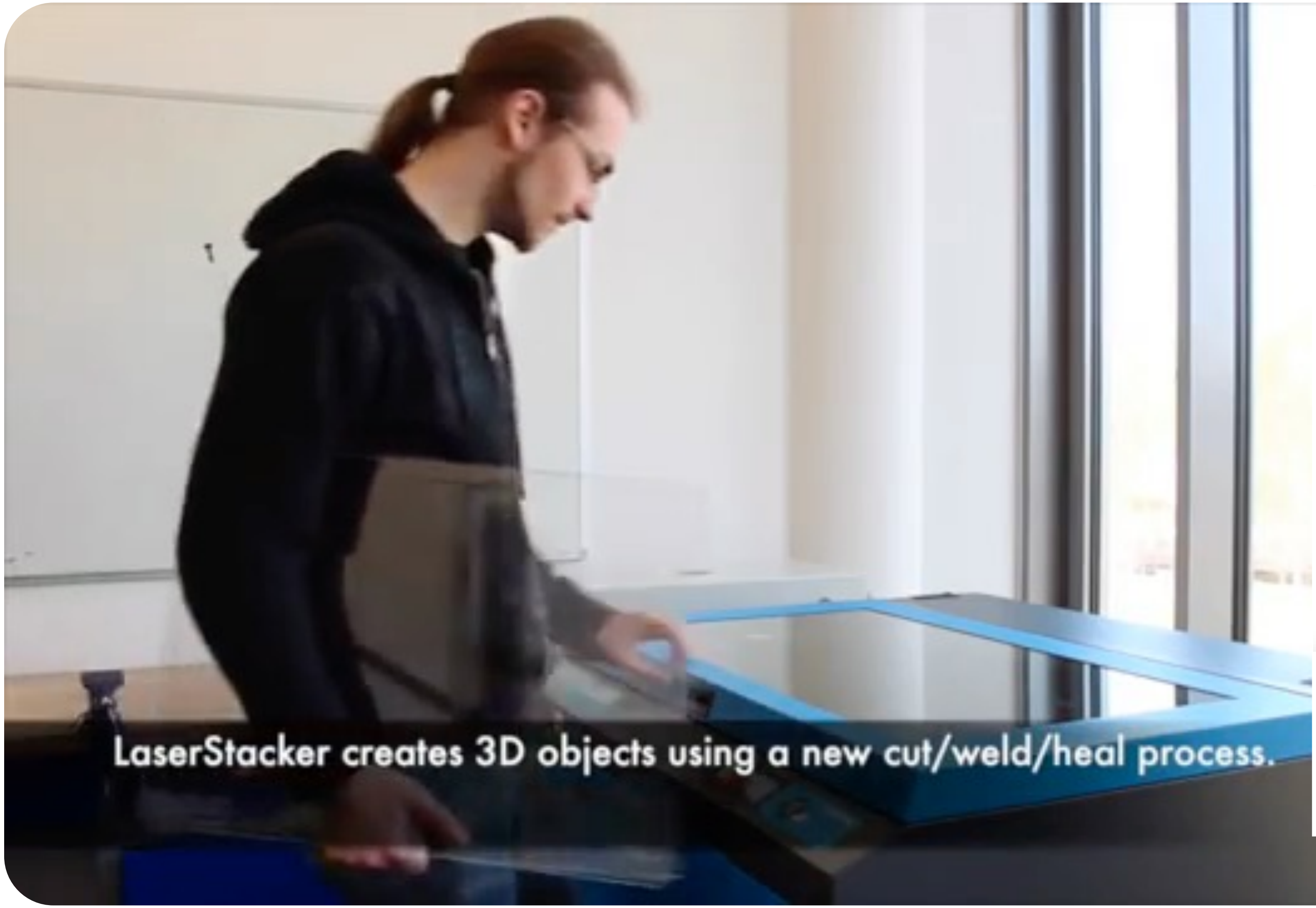

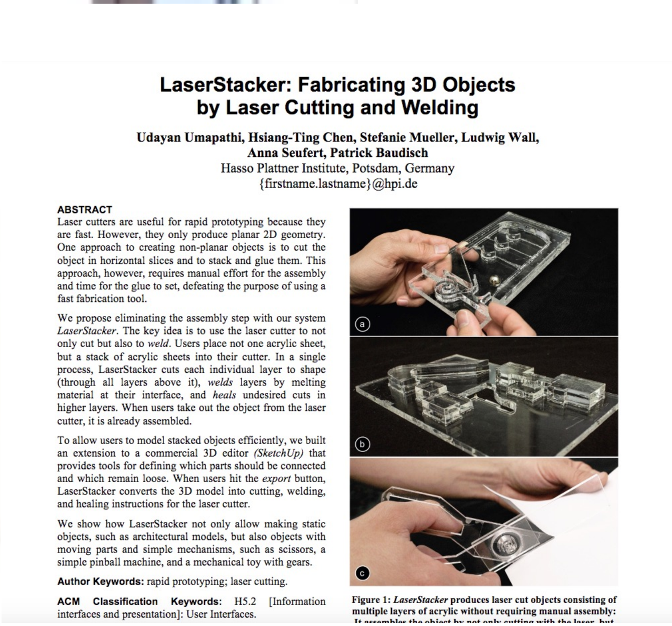

LaserStacker: Fabricating 3D Objects by Laser Cutting and Welding

Udayan Umapathi, Hsiang-Ting Chen, Stefanie Mueller, Ludwig Wall,
Anna Seufert, Patrick Baudisch
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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.

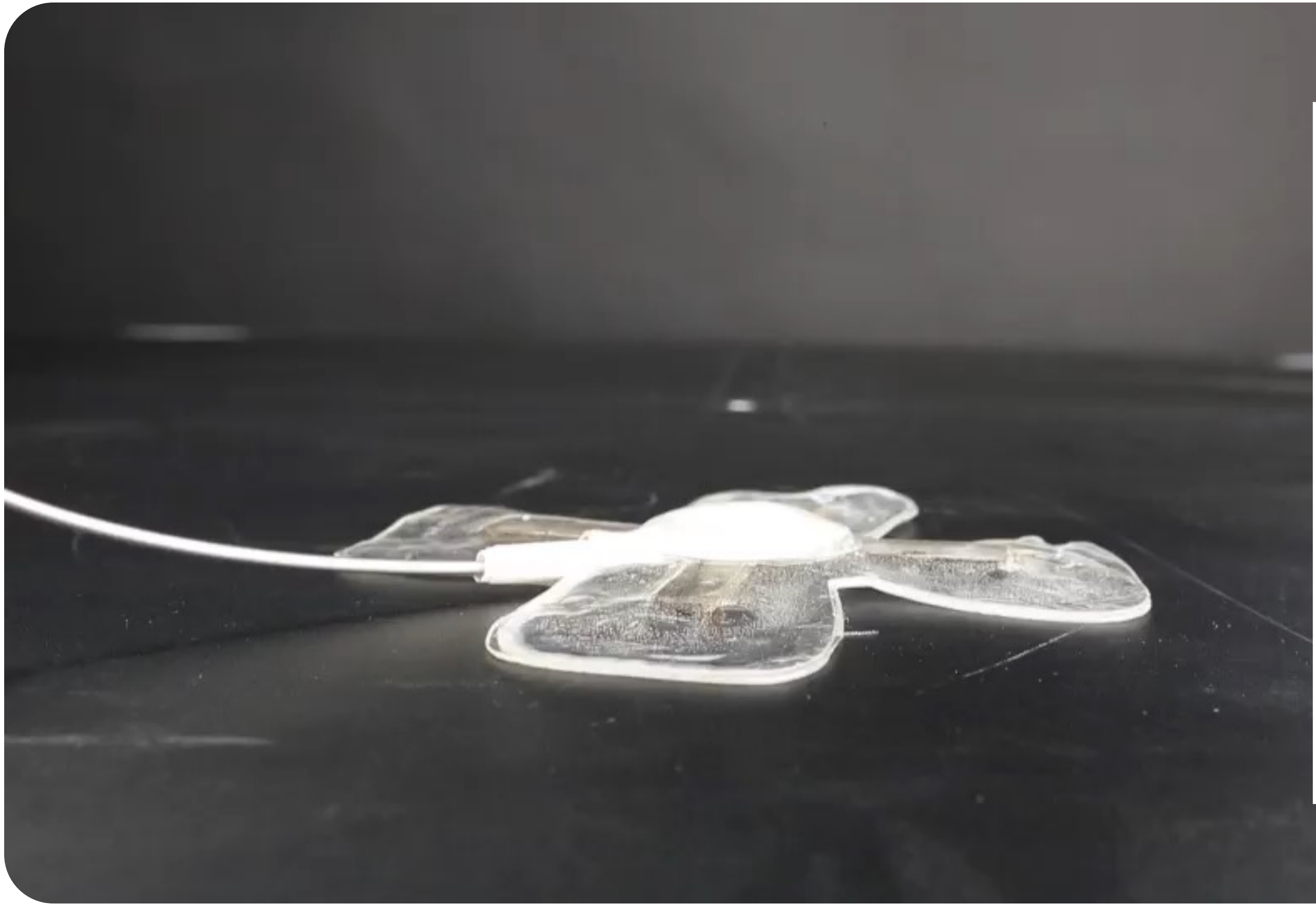
ACM Classification Keywords: H5.2 [Information interfaces and presentation]: User Interfaces.

Figure 1: ***LaserStacker*** **produces laser cut objects consisting of multiple layers of acrylic without requiring manual assembly:**

UIST 2015

Umapathi et.al.

Other methods to create 3(2.5)D shape with laser cutter?



BlowFab: Rapid Prototyping for Rigid and Reusable Objects using Inflation of Laser-cut Surfaces

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ABSTRACT

This study proposes BlowFab, a prototyping method used to create a 2.5-dimensional prototype in a short time by combining laser cutting and blow molding techniques. The user creates adhesive areas and inflatable areas by engraving and cutting multilayered plastic sheets using a laser cutter. These adhesive areas are fused automatically by overlapping two crafted sheets and softening them with a heater. The user can then create hard prototypes by injecting air into the sheets.

Objects can be bent in any direction by cutting incisions or engraving a resistant resin. The user can create uneven textures by engraving a pattern with a heat-resistant film. These techniques can be used for prototyping various strong inflatable objects. The finished prototype is strong and can be collapsed readily for storage when not required.

In this study, the design process is described using the proposed method. The study also evaluates possible bending mechanisms and texture expression methods along with various usage scenarios and discusses the resolution, strength, and reusability of the prototype developed.

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation; User Interfaces.

Author Keywords

Fabrication; Prototyping/Implementation; Creativity Support; Smart materials.

INTRODUCTION

Inflatable membrane structures such as temporary buildings and portable kayaks are widely used owing to their light weight and portability. These structures derive their strength from the internal pressure of air against their membranes. In the recent past, several studies of soft robotics and shape changing interfaces of human-computer interaction (HCI) have proposed techniques for creating inflatable three-dimensional (3D) objects using soft materials such as silicone rubber [21, 13]. These techniques can be used to create programmable shapes, such as soft actuators and temporary furniture, by injecting air into flat objects. Large objects such as temporary houses are flattened or made compact after use. Because these products are made of soft elastic materials such as rubber, it is necessary to continue to pump air into the products to maintain their shape. In addition, there is a risk of air escaping from even a small hole, making the structure unusable. Detecting these tiny holes can be challenging. This risk also reduces their potential usage in even slightly tough environments and terrains.

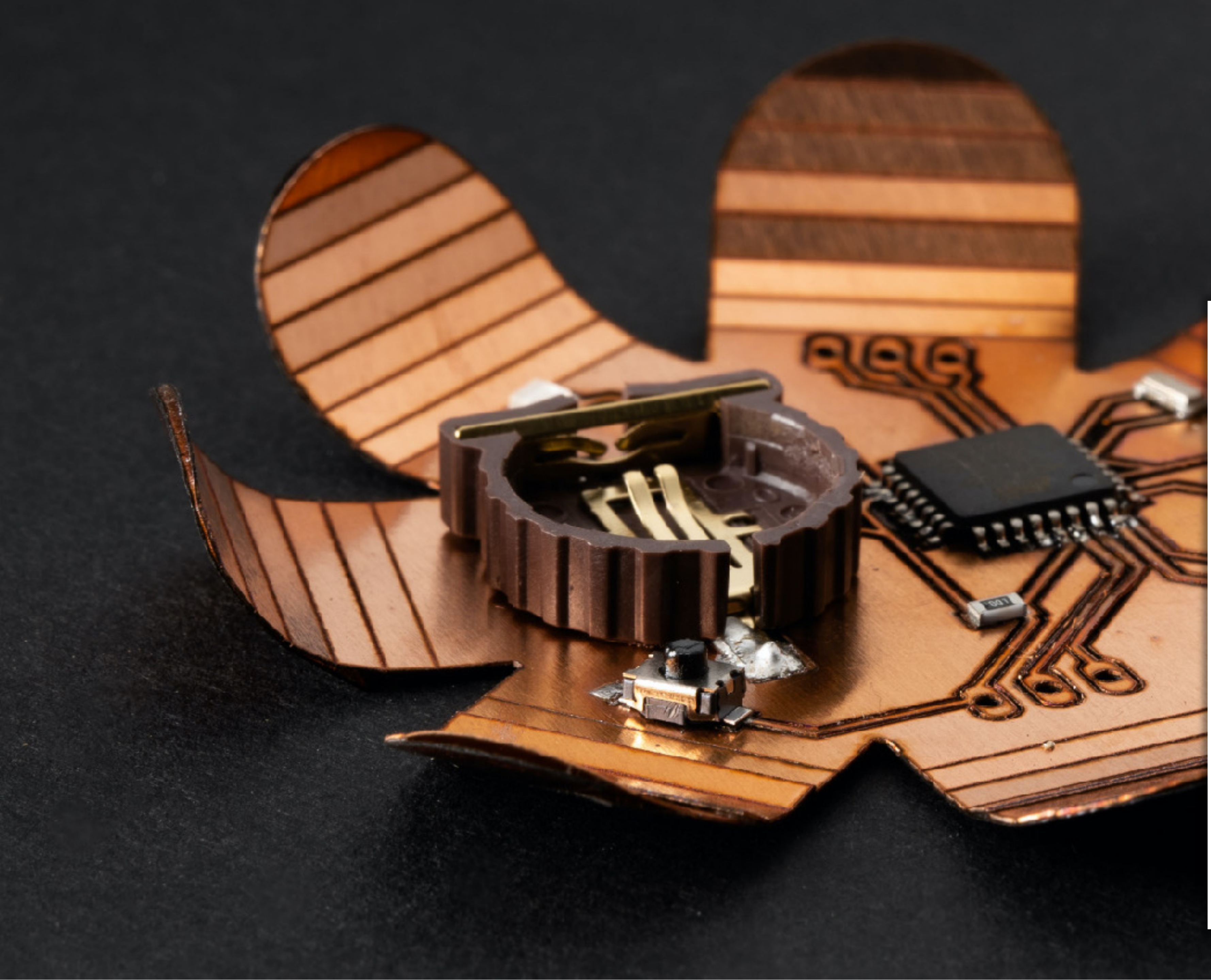
Blow molding, which is a manufacturing method used to make plastic bottles, can be used to produce a hard product by injecting air into a thermo-reversible resin capsule. This method is flexible and the shape of the object can be changed freely when the material is heated and softened. However, a mold is necessary when making an object using blow molding.

Therefore, we propose BlowFab, which combines the blow molding technology using a thermo-reversible resin, the technology used for making inflatable products, and rapid digital fabrication technology to create hard inflatable products. BlowFab can be used to create a 3D prototype in a short time by combining laser cutting and blow molding techniques. The user begins by creating adhesive and inflatable areas by engraving and cutting multilayered plastic sheets using a laser cutter. Two such cutout sheets are softened using a heater (or a heat gun) and placed together. The adhesive areas are fused automatically, leaving the space for inflation. The user can create hard prototypes by injecting air into the sheets. The objects can be bent in any direction by making a specially designed cutting pattern or engraving a resistant resin. The user can even create uneven textures by engraving a pattern with a heat-resistant film. These techniques can be used for prototyping various strong inflatable and reusable objects (Figure 1).

UIST 2018

Yamaoka et.al.

Remember the **fiber laser** I mentioned earlier?



Fibercuit: Prototyping High-Resolution Flexible and Kirigami Circuits with a Fiber Laser Engraver

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Department of Computer Science,
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College Park, MD, USA

Figure 1: Fibercuit overview. a) Our fiber laser engraver setup with a custom rotary table. b) Cutting the conductive layer on our custom composite using the fiber laser. c) A kirigami flower circuit that can function as an Arduino. d) A custom stretchable flex cable. e) A kirigami crane with a battery holder and 2 LEDs.

ABSTRACT

Prototyping compact devices with unique form factors often requires the PCB manufacturing process to be outsourced, which can be expensive and time-consuming. In this paper, we present Fibercuit, a set of rapid prototyping techniques to fabricate high-resolution, flexible circuits on-demand using a fiber laser engraver. We showcase techniques that can laser cut copper-based composites to form fine-pitch conductive traces, laser fold copper substrates that can form kirigami structures, and laser solder surface-mount electrical components using off-the-shelf soldering pastes. Combined with our software pipeline, an end user can design and fabricate flexible circuits which are dual-layer and three-dimensional, thereby exhibiting a wide range of form factors. We demonstrate Fibercuit by showcasing a set of examples, including a custom dice, flex cables, custom end-stop switches, electromagnetic coils, LED earrings and a circuit in the form of kirigami crane.

CCS CONCEPTS

• **Human-centered computing** → **Interactive systems and tools**; **Interaction devices**; • **Hardware** → *Printed circuit boards.*

KEYWORDS

fiber laser, laser cut, PCB, circuit board, kirigami, flexible PCB

ACM Reference Format:
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1 INTRODUCTION

In the ongoing effort to weave computing into our daily lives [49], designing smart devices has been a major research focus in HCI. As these devices aim to discreetly recede into the environment or onto the user's body, they usually possess small and unconventional form factors. Building and prototyping such devices requires multiple rounds of iterative design to successfully integrate the function into the form. While the consumerization of 3D printers and laser cutters has shortened the iteration cycle, this advancement has been largely withheld from the PCB design and manufacturing process. Due to their flexibility and convenience, breadboards are still the most popular method to quickly prototype circuits. Apart from requiring bulky breakout boards for all surface-mounted components (SMD),

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[*] Both authors contributed equally to this research.

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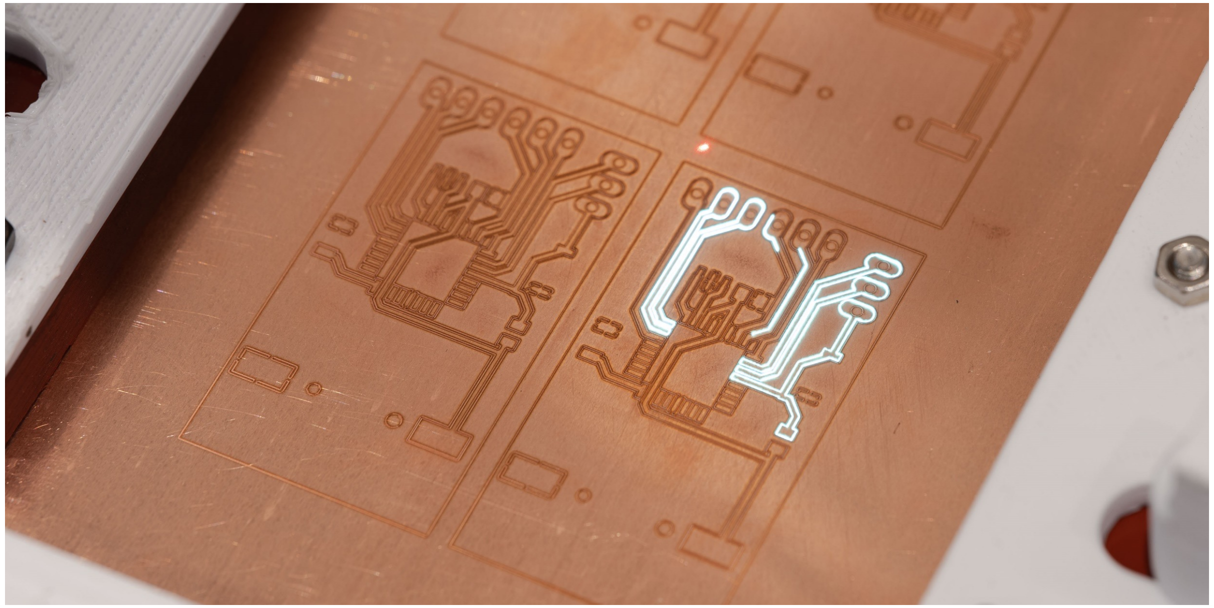
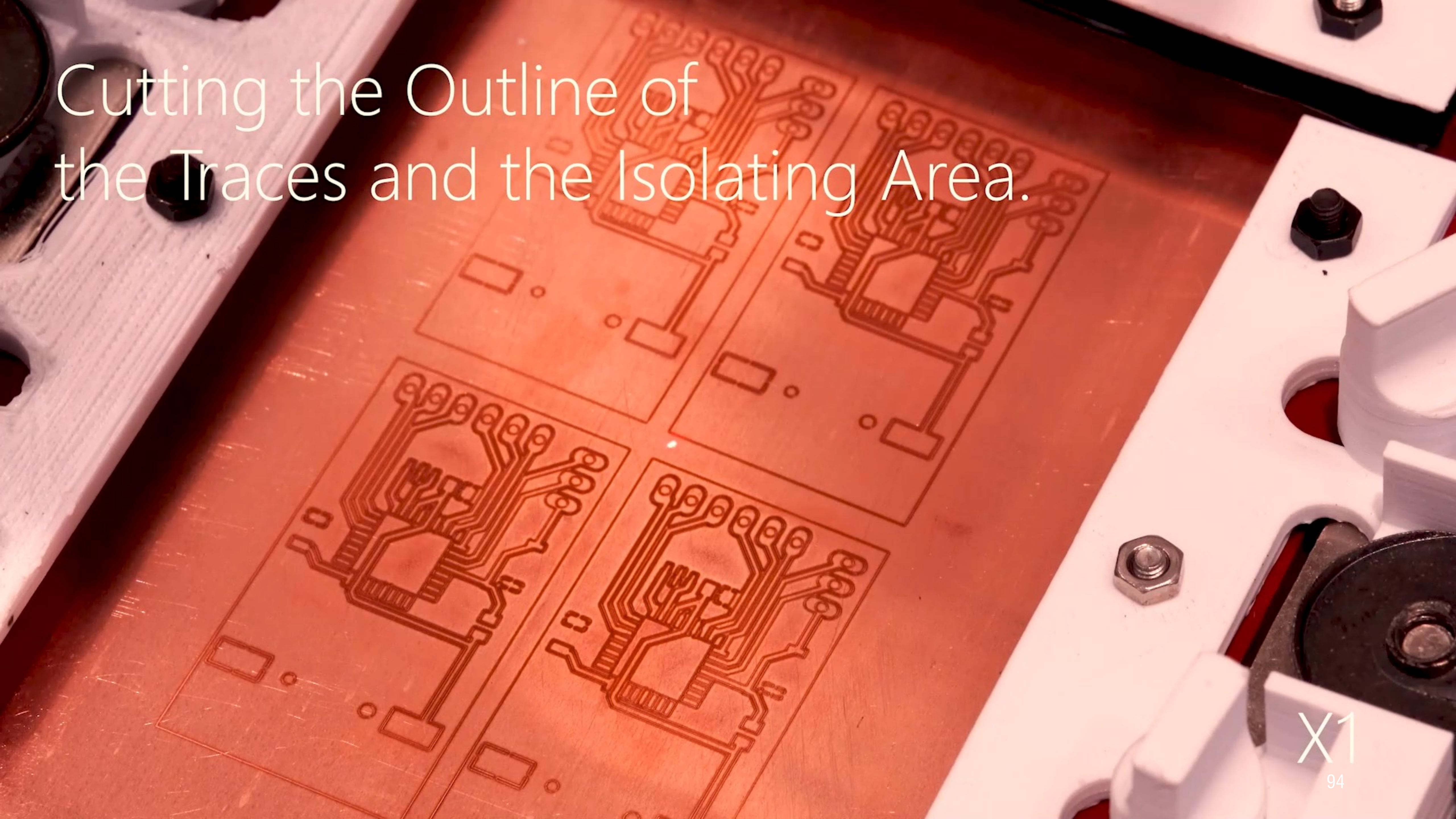
CO_2 laser

10600 nm

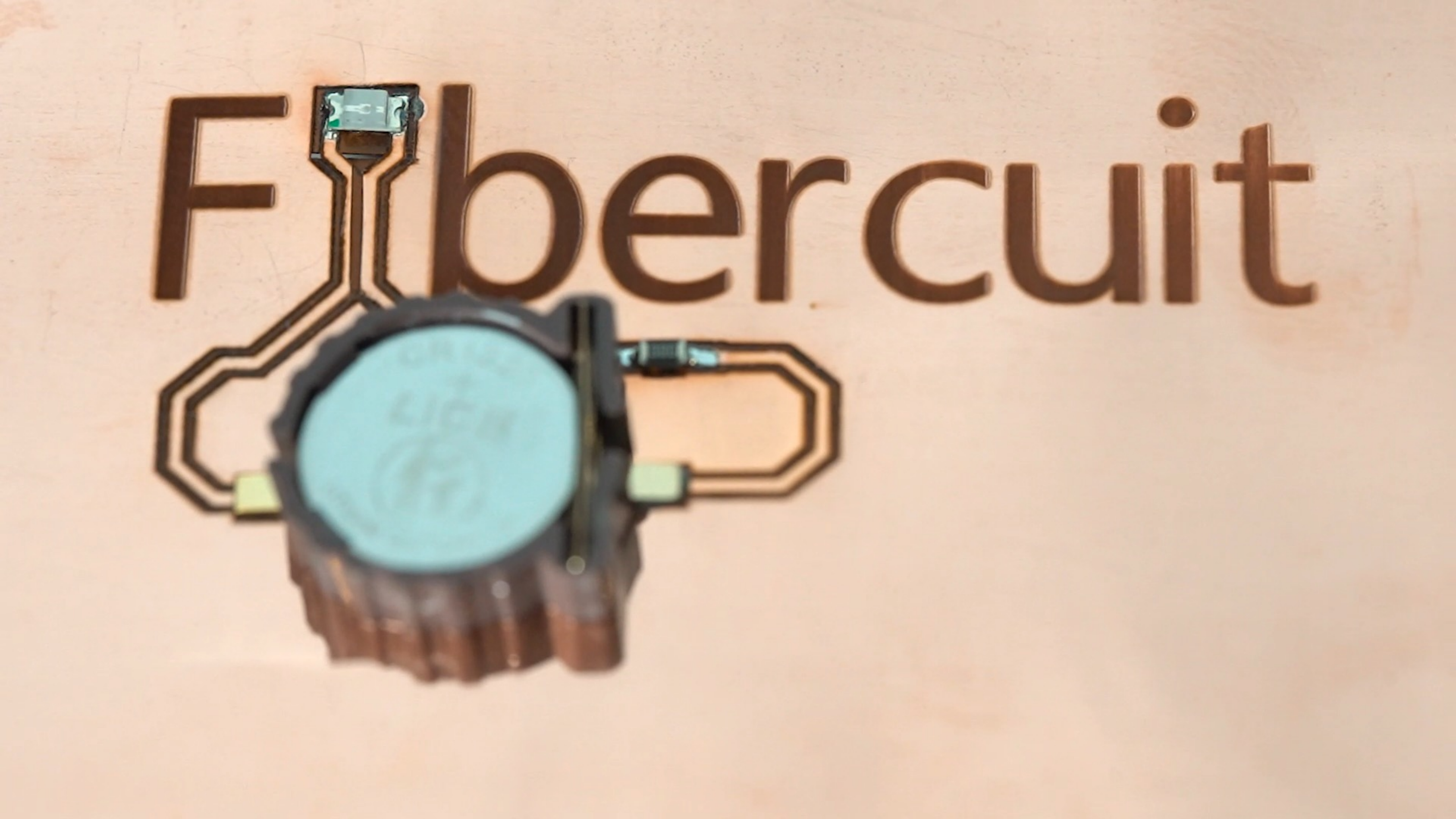
fiber laser

1064 nm

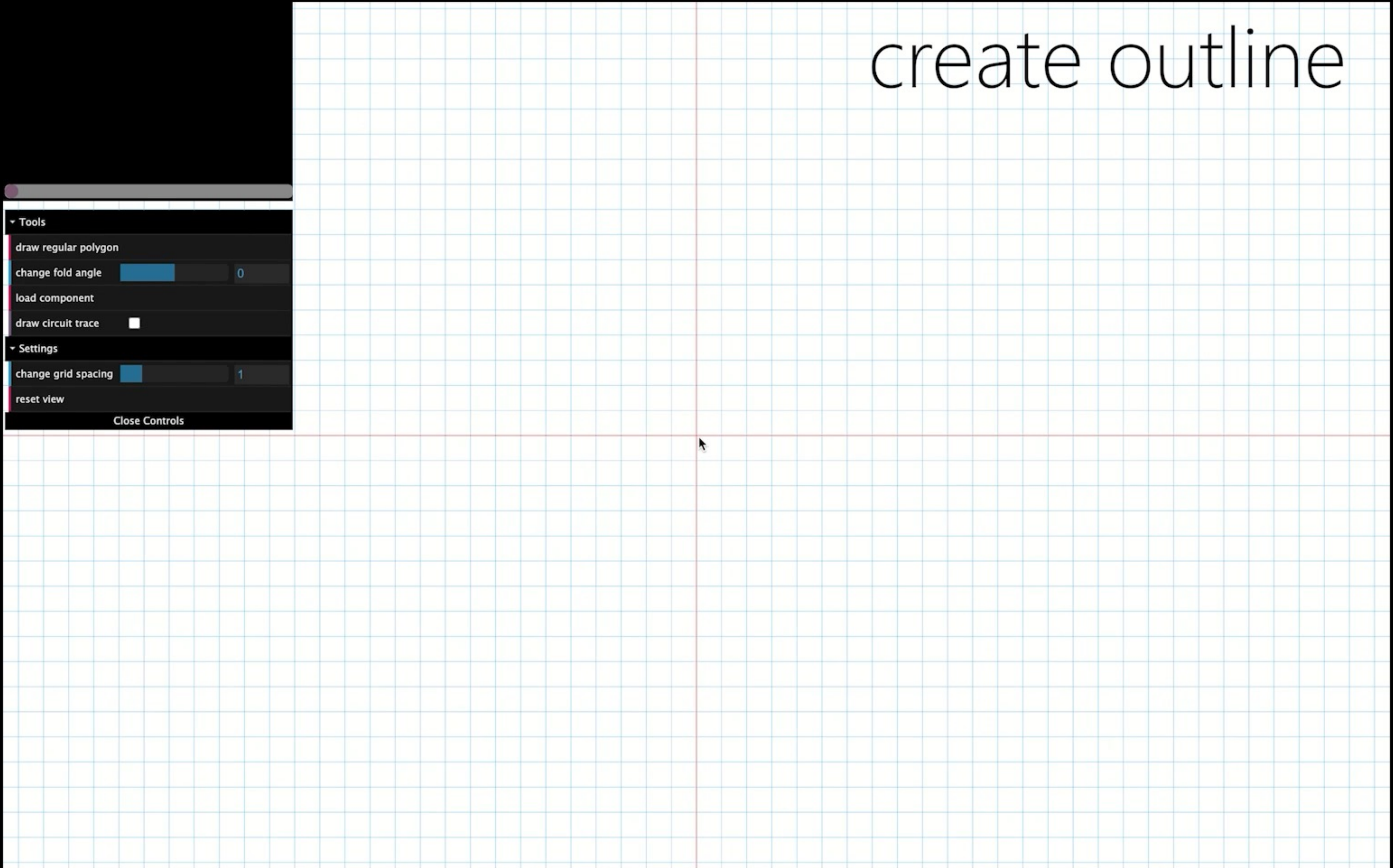




Cutting the Outline of the Traces and the Isolating Area.


Fibercuit

create outline

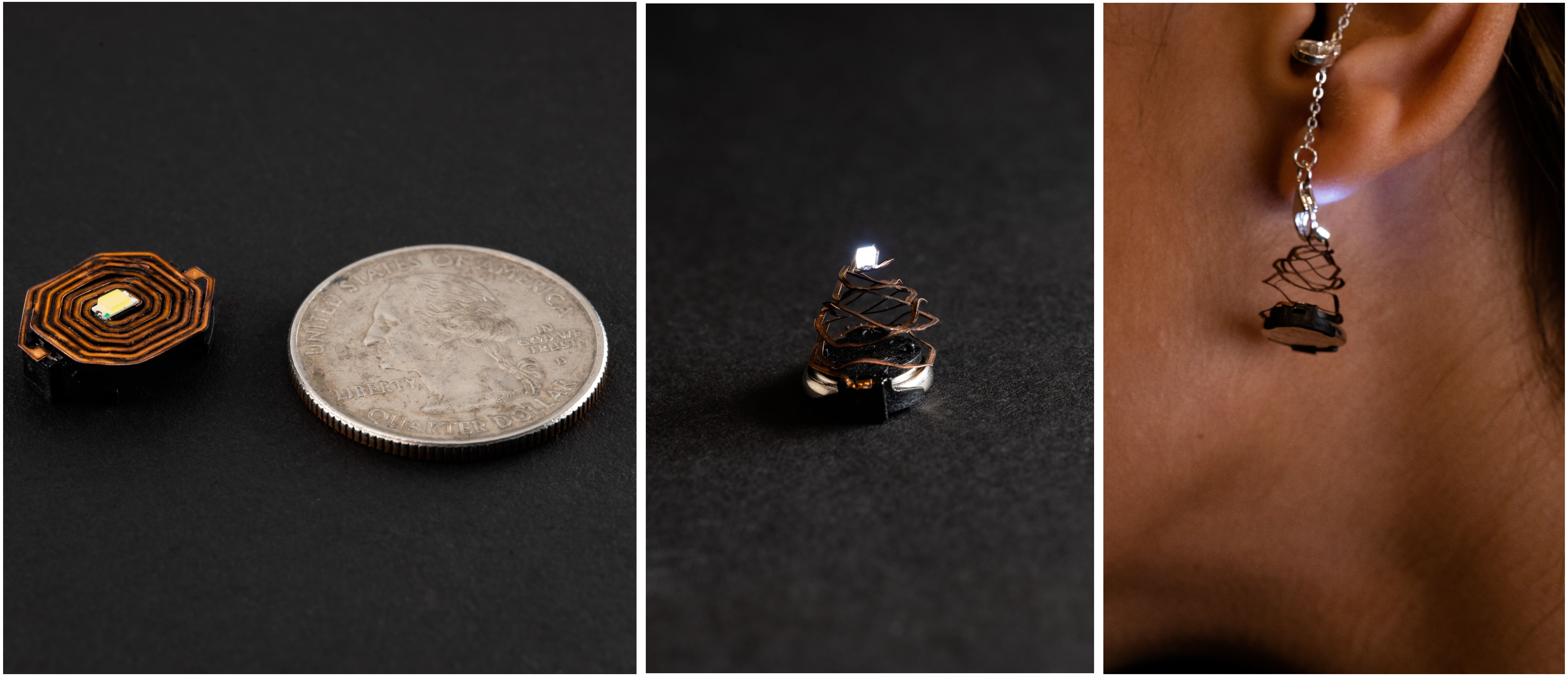


change fold angle 0

draw circuit trace ☐

change grid spacing 1

Examples


UNITED STATES OF AMERICA
IN GOD WE TRUST
LIBERTY
D
QUARTER DOLLAR

laser features #1

Raster engraving

laser features #2

Vector engraving/cutting

laser features #3

Joints - creating 3D objects

laser features #4

bending

laser features #5

moving parts

Based on Stefanie Mueller’s slides

Optional readings

Fibercuit: Prototyping High-Resolution Flexible and Kirigami Circuits with a Fiber Laser Engraver

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Figure 1: Fibercuit overview. a) Our fiber laser engraver setup with a custom rotary table. b) Cutting the conductive layer on our custom composite using the fiber laser. c) A kirigami flower circuit that can function as an Arduino. d) A custom stretchable flex cable. e) A kirigami crane with a battery holder and 2 LEDs.

ABSTRACT

Prototyping compact devices with unique form factors often requires the PCB manufacturing process to be outsourced, which can be expensive and time-consuming. In this paper, we present Fibercuit, a set of rapid prototyping techniques to fabricate high-resolution, flexible circuits on-demand using a fiber laser engraver. We showcase techniques that can laser cut copper-based composites to form fine-pitch conductive traces, laser fold copper substrates that can form kirigami structures, and laser solder surface-mount electrical components using off-the-shelf soldering pastes. Combined with our software pipeline, an end user can design and fabricate flexible circuits which are dual-layer and three-dimensional, thereby exhibiting a wide range of form factors. We demonstrate Fibercuit by showcasing a set of examples, including a custom dice, flex cables, custom end-stop switches, electromagnetic coils, LED earrings and a circuit in the form of kirigami crane.

CCS CONCEPTS

• **Human-centered computing** → **Interactive systems and tools**; **Interaction devices**; • **Hardware** → *Printed circuit boards.*

KEYWORDS

fiber laser, laser cut, PCB, circuit board, kirigami, flexible PCB

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1 INTRODUCTION

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Yan et.al.

LaserFactory: A Laser Cutter-based Electromechanical Assembly and Fabrication Platform to Make Functional Devices & Robots

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Figure 1: LaserFactory is an integrated fabrication process that creates fully functional devices. (a) Our hardware add-on to an existing laser cutter consists of a silver dispenser and pick-and-place mechanism and allows the machine to not only cut geometry, but also create circuit traces and assemble electronic components. Our accelerometer-based motion classifier enables the add-on to interface with the laser cutter without the need to change the underlying firmware. (b) To cure the deposited silver traces, we developed a laser soldering method that uses the heat of the defocused laser to make the traces conductive. (c) After laser soldering, the fabricated device is fully functional.

ABSTRACT

LaserFactory is an integrated fabrication process that augments a commercially available fabrication machine to support the manufacture of fully functioning devices without human intervention. In addition to creating 2D and 3D mechanical structures, LaserFactory creates conductive circuit traces with arbitrary geometries, picks-and-places electronic and electromechanical components, and solders them in place. To enable this functionality, we make four contributions. First, we build a hardware add-on to the laser cutter head that can deposit silver circuit traces and assemble components. Second, we develop a new method to cure dispensed silver using a CO_2 laser. Third, we build a motion-based signaling method that allows our system to be readily integrated with commercial laser cutters. Finally, we provide a design and visualization tool for making functional devices with LaserFactory. Having described the LaserFactory system, we demonstrate how it is used to fabricate devices such as a fully functioning quadcopter and a sensor-equipped wristband. Our evaluation shows that LaserFactory can assemble a variety of differently sized components (up to 65g), that these can be connected by narrow traces (down to 0.75mm) that become highly conductive after laser soldering (3.2Ω/m), and that our acceleration-based sensing scheme works reliably (to 99.5% accuracy).

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI).**

KEYWORDS

Human-computer interaction, rapid prototyping, personal fabrication, printed electronics, robotics

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