Titel Image: Alexander Schidlbaur, Arctic Studio, UIBK, 2017

Digital Fabrication

Laser

Introduction lecture

Laser Cutting

Basics of digital fabrication using a laser cutter & some references.

Speaker: Marc Ihle

overview

Overview

Digital Fabrication **Laser Cut**

1.1. Digital Fabrication

Digital Modeling & Fabrication

Digital modeling and fabrication is a design and production process that combines 3D modeling or computing-aided design (CAD) with additive and subtractive manufacturing.

overview

1.1. Digital Fabrication

Additive manufacturing

Additive manufacturing uses data computer-aided-design (CAD) software and deposits material, layer upon layer, in precise geometric shapes.

As its name implies, additive manufacturing adds material to create an object.

-> 3d printing

1.1. Digital Fabrication

Fused deposition modelling (3D printing)

Fused deposition modeling, also known as fused filament fabrication, uses a 3-axis robotic system that extrudes material, typically a thermoplastic, one thin layer at a time and progressively builds up a shape.

1.1. Digital Fabrication

Stereolithography (3D printing)

Stereolithography uses a high intensity light projector, usually using DLP technology, with a photosensitive polymer resin. It will project the profile of an object to build a single layer, curing the resin into a solid shape. Then the printer will move the object out of the way by a small amount and project the profile of the next layer.

1.1. Digital Fabrication

Selective laser sintering (3D printing)

Selective laser sintering uses a laser to trace out the shape of an object in a bed of finely powdered material that can be fused together by the application of heat from the laser. After one layer has been traced by a laser, the bed and partially finished part is moved out of the way, a thin layer of the powdered material is spread, and the process is repeated. Typical materials used are alumide, steel, glass, thermoplastics (especially nylon), and certain ceramics.

1.1. Digital Fabrication

Powder printer (3D printing)

Powder printers work in a similar manner to SLS machines, and typically use powders that can be cured, hardened, or otherwise made solid by the application of a liquid binder that is delivered via an inkjet printhead. Common materials are plaster of paris, clay, powdered sugar, wood-filler bonding putty, and flour, which are typically cured with water, alcohol, vinegar, or some combination thereof. The major advantage of powder and SLS machines is their ability to continuously support all parts of their objects throughout the printing process with unprinted powder. This permits the production of geometries not easily otherwise created. However, these printers are often more complex and expensive.

1.1. Digital Fabrication

Substractive manufacturing

By contrast, when you create an object by traditional means (e.g.: wood saw), it is often necessary to <u>remove material to create an object</u> through milling, machining, carving, shaping or other means ...

-> CNC mill, laser cutter, water jet cutter, ...

1.1. Digital Fabrication

CNC milling

CNC stands for "computer numerical control". CNC mills or routers include proprietary software which interprets 2D vector drawings or 3D models and converts this information to a G-code, which represents specific CNC functions in an alphanumeric format, which the CNC mill can interpret.

1.1. Digital Fabrication

Laser cutter

The laser cutter is a machine that uses a laser to cut materials and interprets vector drawings produced by various CAD software platforms.

The laser cutter is able to modulate the speed of the laser head, as well as the intensity and resolution of the laser beam, and as such is able in both to cut and to score material, as well as approximate raster graphics.

1.1. Digital Fabrication

Digital Fabrication & Rapid Prototyping

Rapid prototyping is the fast fabrication of a physical part, model or assembly using 3D computer aided design (CAD).

1.1. Digital Fabrication

quick

fast

prompt

rapid prototyping

concept

sample

test

rapid

happening in a short time or at a great rate

prototyping

“A prototype is an early sample, model, or release of a product built to test a concept or process”
https://en.wikipedia.org/wiki/Prototype

1.1. Digital Fabrication

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1.1. Digital Fabrication

quick

fast

prompt

evolutionary

concept

sample

test

involving a gradual process of change and development

1.2. Laser cutter (basics)

Laser

Light **a**mplification by **s**timulated **e**mission of **r**adiation

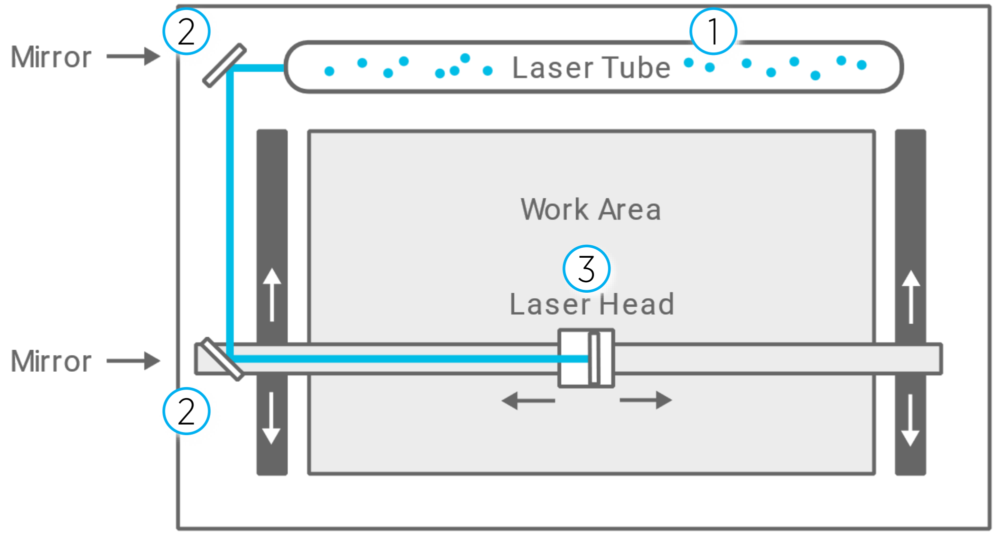
overview

1.2. Laser cutter (basics)

Laser cutting …

… is a subtractive technology that uses a **laser** to vaporize materials, resulting in a cut edge.

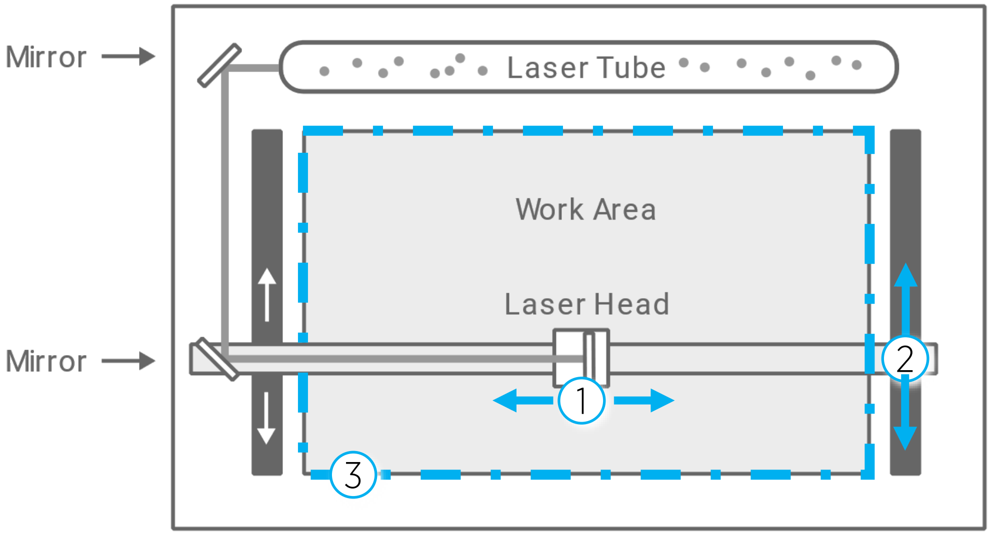
1.2. Laser cutter (basics)



The laser cutter consists of

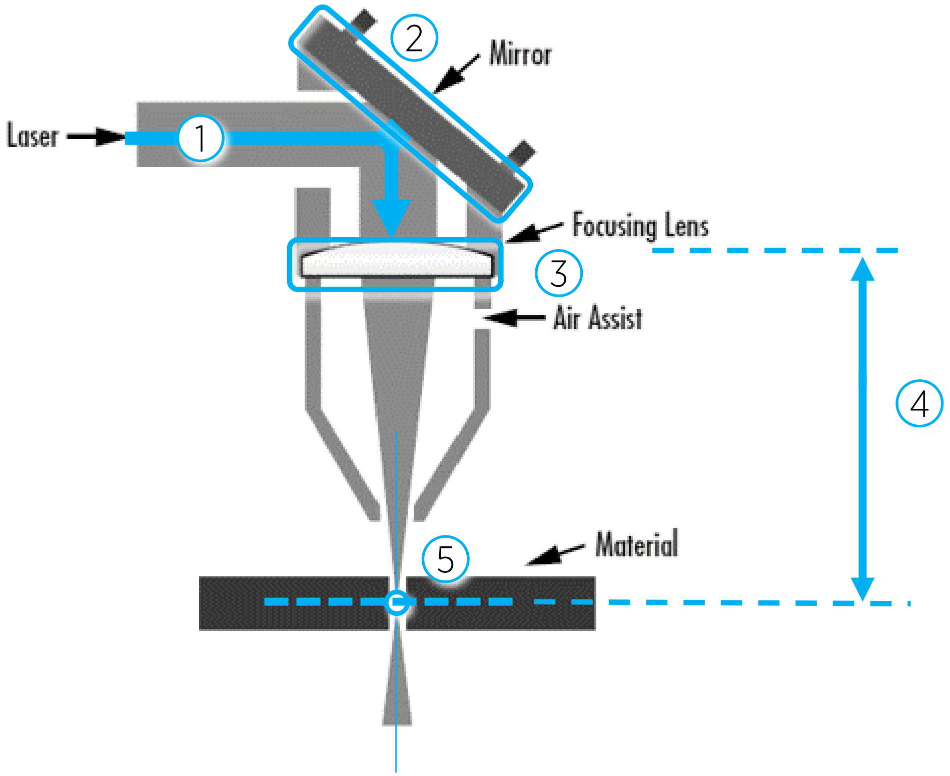
a laser tube [1] that creates a laser beam which gets reflected by mirrors [2] to the laser head [3].

1.2. Laser cutter (basics)



The **laser head** which can move in X-direction [1] and Y-direction [1] within the **work area** [3]

1.2. Laser cutter (basics)

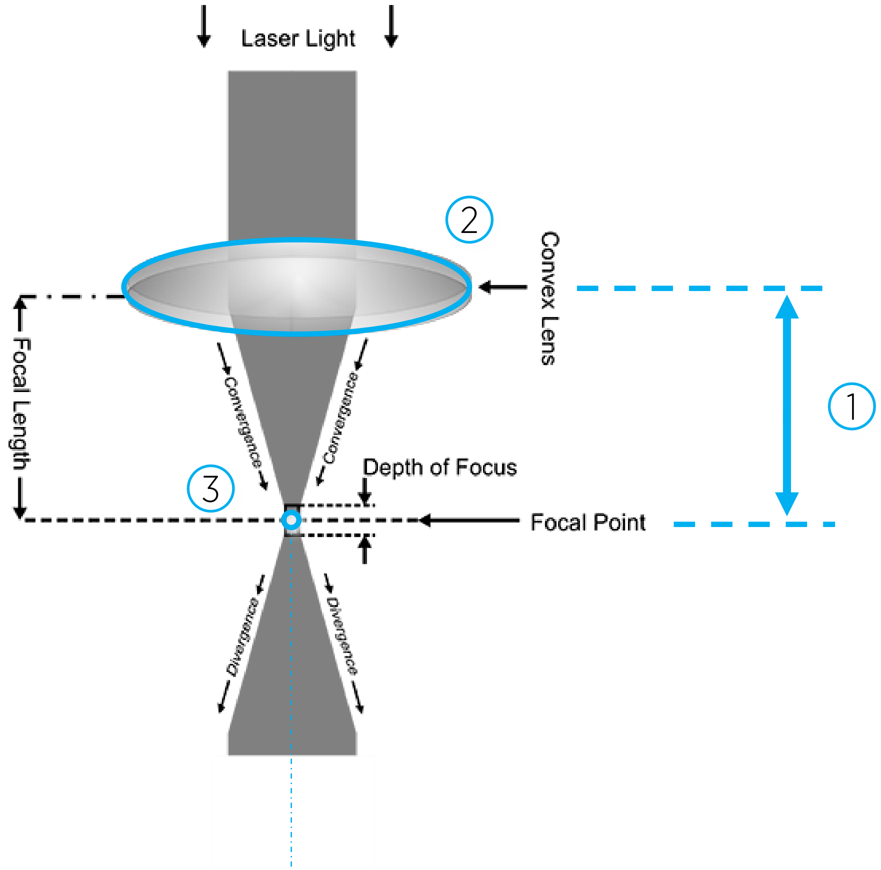


Inside of the laser head the ...

laser beam [1] gets once more reflected by a mirror [2] to the focusing lens [3].

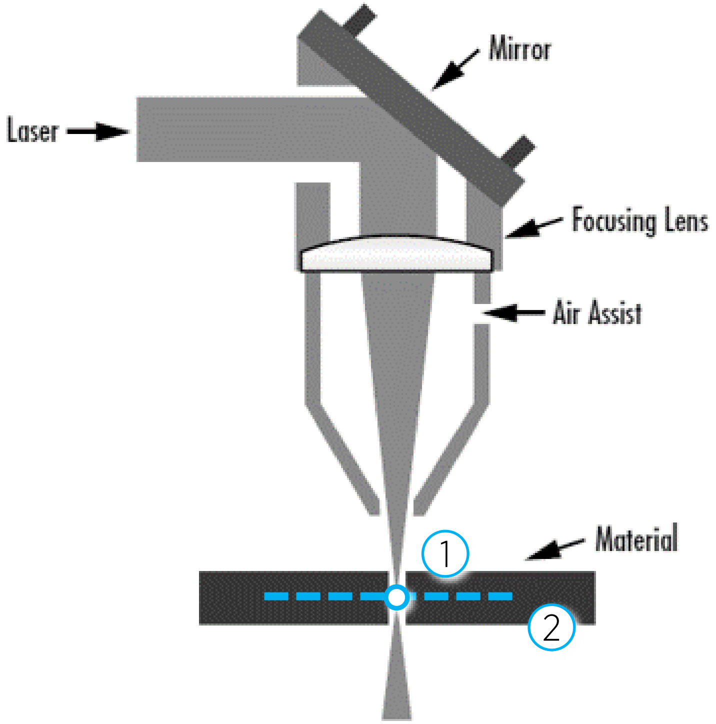
Depending on the curvature and quality of the focusing lens, the focal length [4] to the focal point [5] will vary

1.2. Laser cutter (basics)



The **focal length** [1] >>> is the distance from the center of the focusing lens [2] to the point of focus [3] (focal plane)

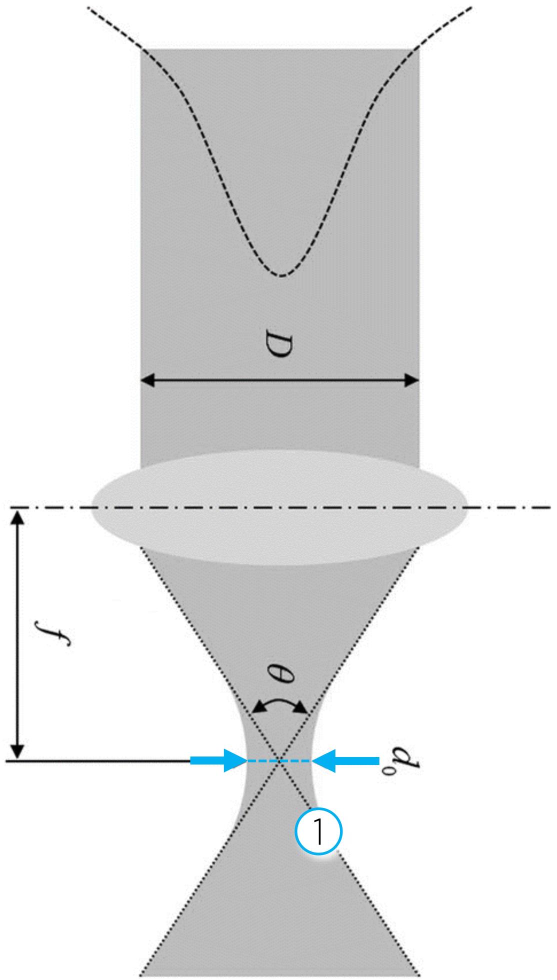
1.2. Laser cutter (basics)



the **focal point** [1] or also called **focal plane** [2] and should be at the center of the material / workpiece.

The “focal point” in reality is rather a “focal spot” with a diameter.

1.2. Laser cutter (basics)

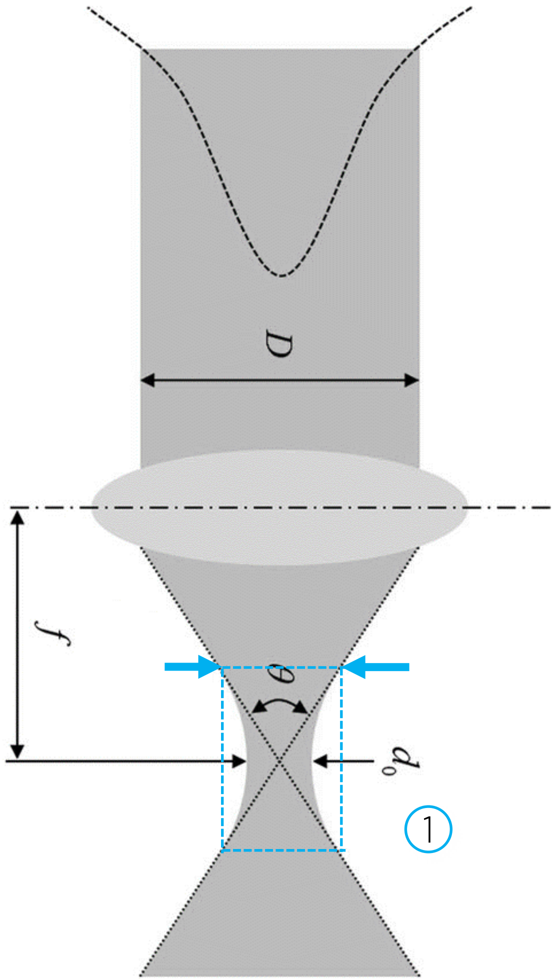


the focal **spot size** [1] is the narrowest part of the focused beam.

<u>>>> the lower the material thickness -> the lower the beam diameter / spot size ->>> the thinner and cleaner cut line</u>

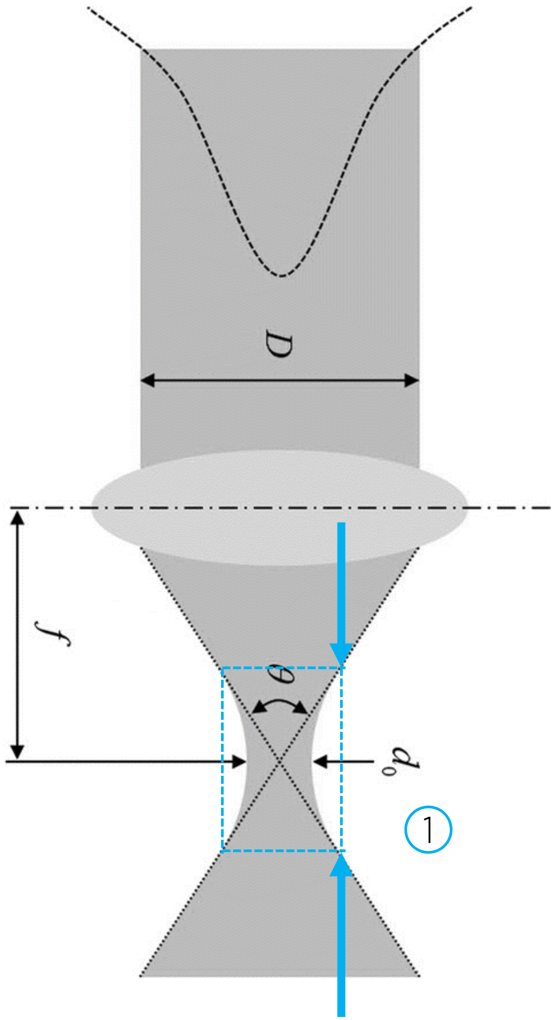
.

1.2. Laser cutter (basics)



The **beam diameter** [1] will determine the width of the cutting line.

1.2. Laser cutter (basics)

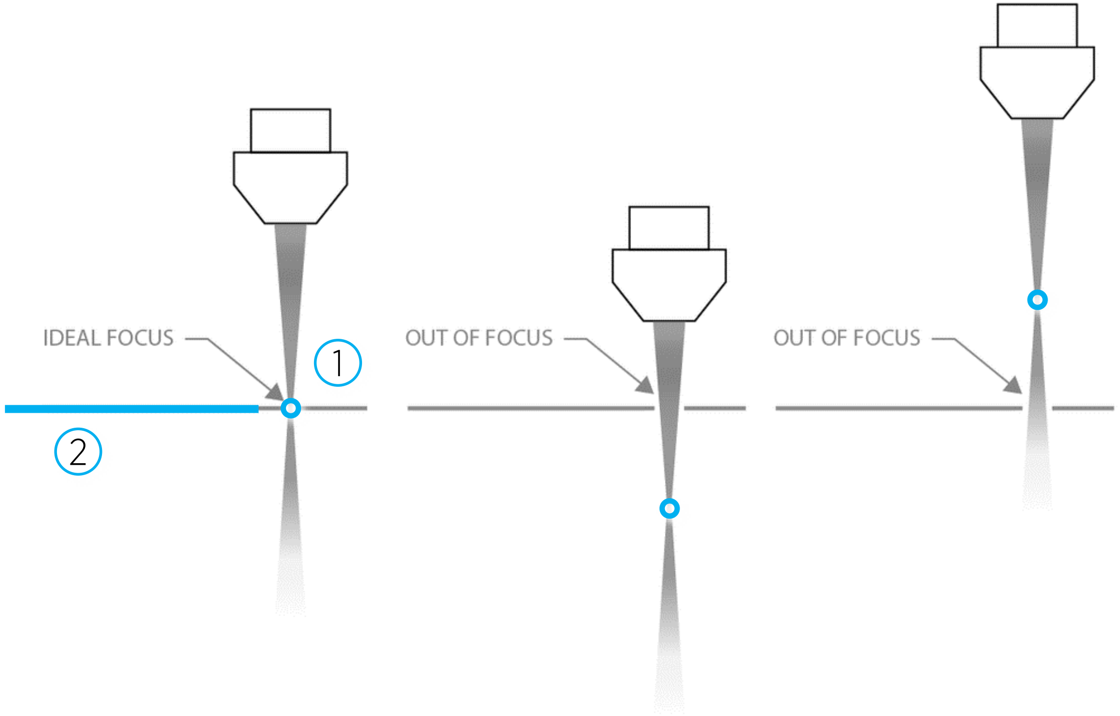


The **Focal depth** [1] is the depth the laser beam can cut while staying within the beam diameter.

>>> this will determine the thickness of materials which can be cut in one pass, or which can be cut "cleanly" without too many "burn marks" or "sprays"

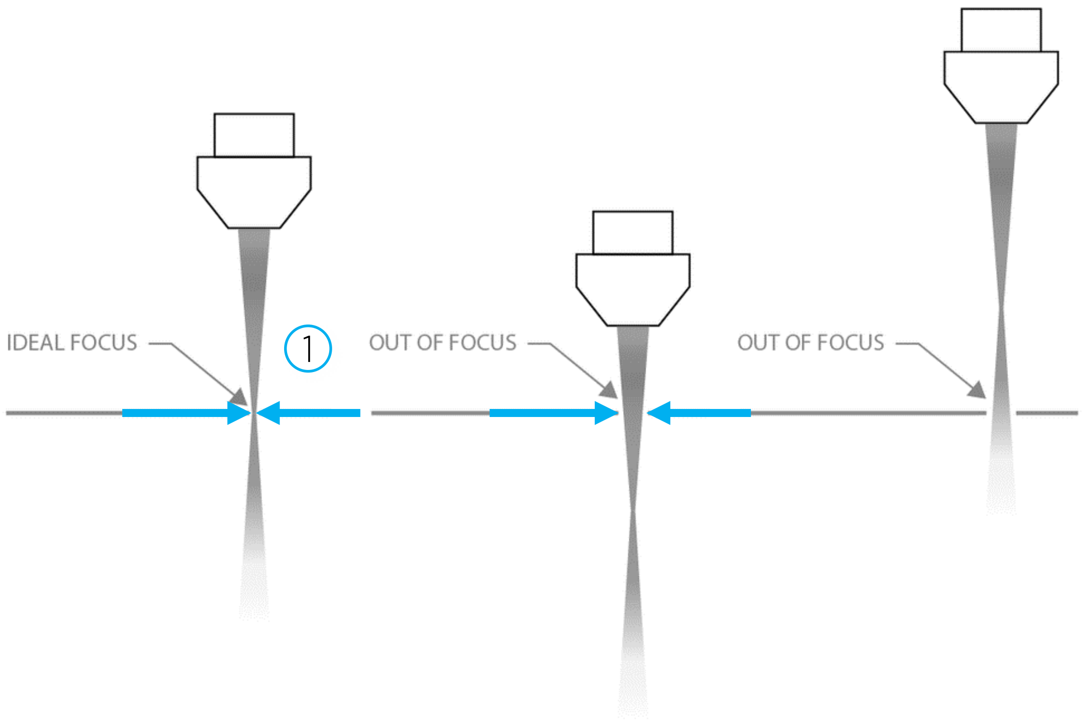
Note: thinner materials will cut cleaner

1.2. Laser cutter (basics)



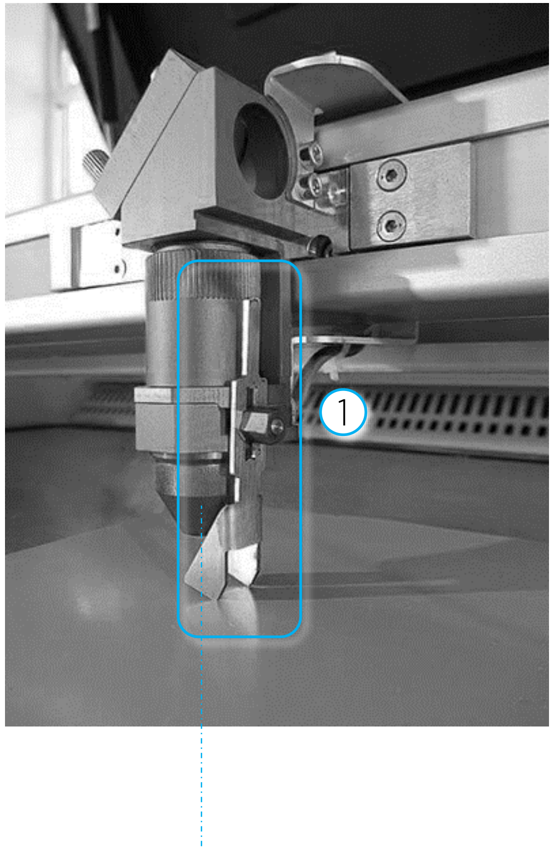
The focal point [1] / focal plane [2] ->>>
should be at the center of the material ...

1.2. Laser cutter (basics)



... if focal point is not at the center of the material -> the cutting line will be thicker, and more power will be needed to cut through the material –> this will also increase burn marks and can be dangerous since the material might catch fire!

1.2. Laser cutter (basics)

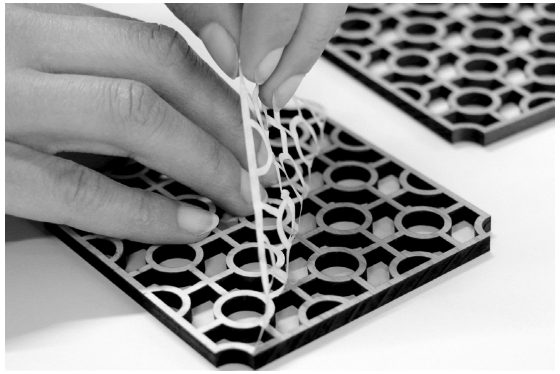


To ensure that the focus point of the beam is set correctly at the laser:

1. use the "focus tool" [1]
2. and specify the correct thickness of your material in the settings

Image: www.trotec.com

1.2. Laser cutter (basics)



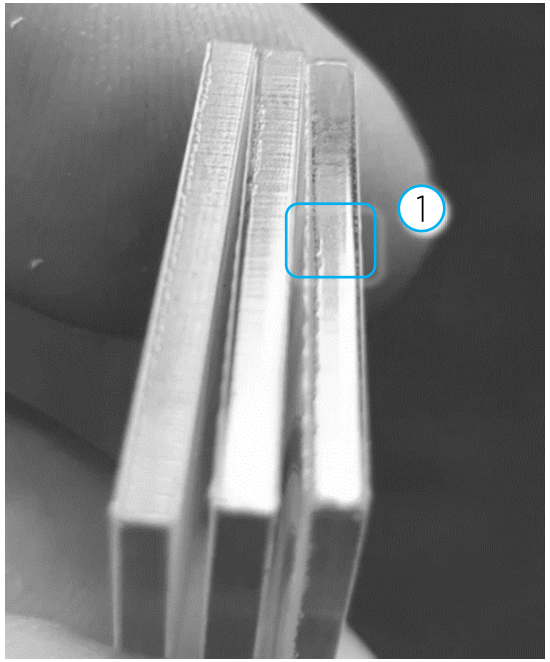
Burned edges

Wood materials will burn and also leave burned marks. These marks will be both on the top and bottom of the material.

To avoid this:

- Use a tape suited for laser cutting and which can easily be removed after
- sand the parts after cutting
- spray-paint the model after assembly

1.2. Laser cutter (basics)



melted edges

Acryl glass will not burn but rather melt … looking closer … we will see that the corners and edges are not fully sharp and clean …

for some purposes this will be ok …

… if needed the edges can be sanded.

1.5. Materials

overview

Materials at the Academy

Material	Thickness	Sheet size	Cut (P/S)	Score (P/S)
Bristol Board 246g, white	0.25 mm	1000 x 700 mm	P80 / S40*	P20 / S40*
Bristol Board 369g, white	0.40 mm	1000 x 700 mm		
Cardboard, beige	1.00 mm	1000 x 700 mm		
MDF, brown	2.10 mm	1010 x 710 mm		
Plywood, birch	3.00 mm	1222 x 666 mm		
Acrylic Glass	2.20 mm	1010 x 710 mm		

Materials

Materials you should <u>not use with a laser!</u>

- Artificial leather that contains chromium (VI)
- Carbon fibers (Carbon)
- Polyvinyl chloride (PVC)
- Polyvinyl butyrale (PVB)
- Polytetrafluoroethylenes (PTFE /Teflon)
- Beryllium oxide
- Any materials containing halogens (fluorine, chlorine, bromine, iodine and astatine), epoxy or phenolic resins

Materials

Common			
Wood		cut	engrave
Mirror			engrave
Stone			engrave
Paper (white)		cut	engrave
Paper (colored)		cut	engrave
Food		cut	engrave
Leather		cut	engrave
Fabric		cut	engrave
Glass			engrave
Ceramics			engrave
Cardboard		cut	engrave
Cork		cut	engrave

Materials

Plastic			
Acrylonitrile butadiene styrene (ABS)		cut	engrave
Acrylic/PMMA, i.e. PLEXIGLAS®		cut	engrave
Rubber		cut	engrave
Polyamide (PA)		cut	engrave
Polybutylene terephthalate (PBT)		cut	engrave
Polycarbonate (PC) up to 0.5mm		cut	engrave
Polyethylene (PE)		cut	engrave
Polyester (PES)		cut	engrave
Polyethylene terephthalate (PET)		cut	engrave
Polyimide (PI)		cut	engrave
Polyoxymethylene (POM) -i.e. Delrin®		cut	engrave
Polypropylene (PP)		cut	engrave
Polyphenylene sulfide (PPS)		cut	engrave
Polystyrene (PS)		cut	engrave
Polyurethane (PUR)		cut	engrave
Foam (PVC free)		cut	engrave

Materials

Metal			
Aluminum			engrave
Aluminum, anodized			engrave
Chromium			engrave
Precious metal			engrave
Metal foils up to 0.5mm (Aluminum, Brass, Copper)		cut	engrave
Stainless steel			engrave
Metal, painted			engrave
Brass			engrave
Copper			engrave
Titanium			engrave

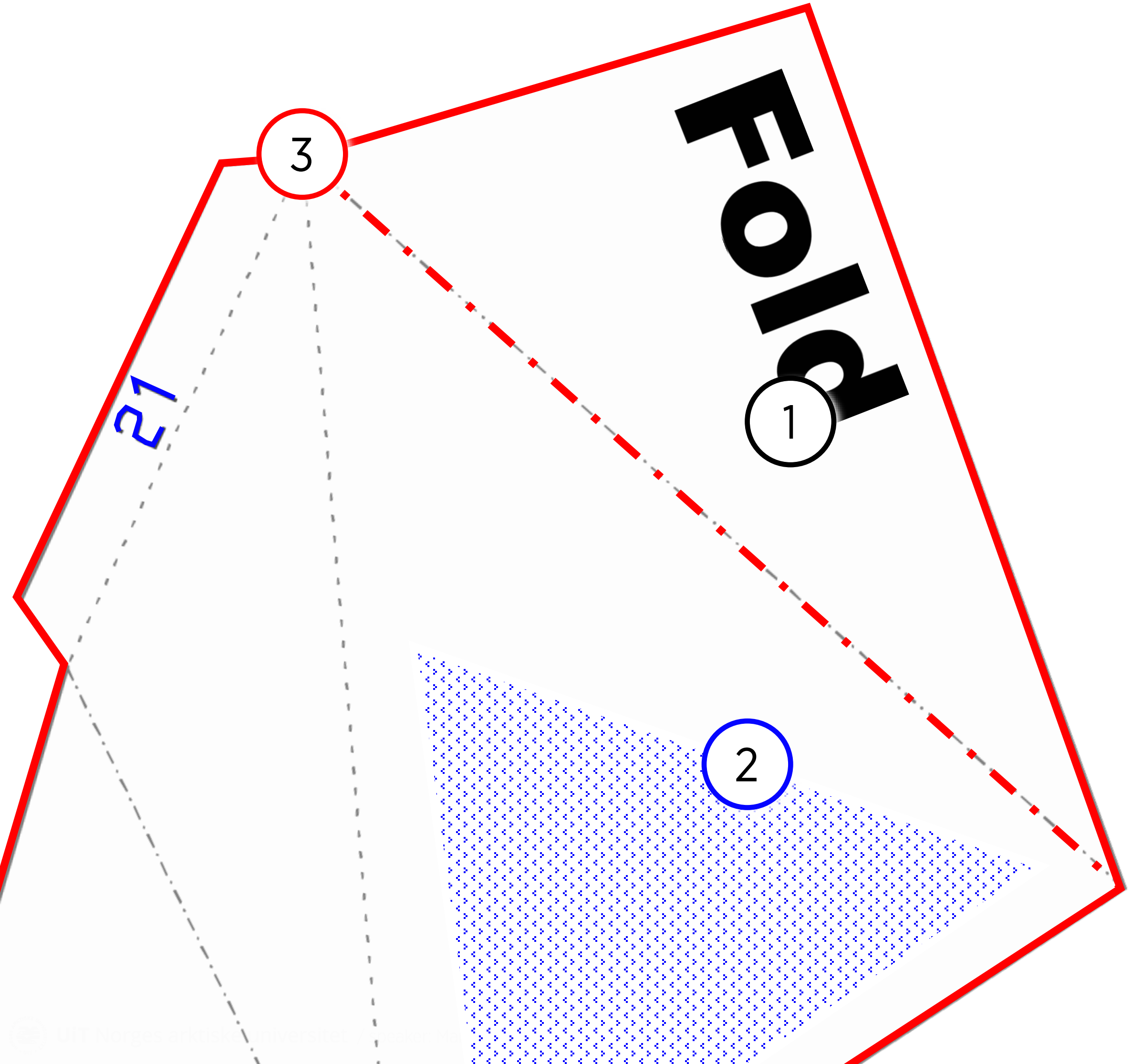
1.4. cut / score / engrave (marking)

Use different linetypes, thicknesses, hatch denities … etc.

translate the graphical appearance you are looking for into different cut-, score- and engraving passes with different power- and speed settings.

overview

1.4. cut / score / engrave (marking)



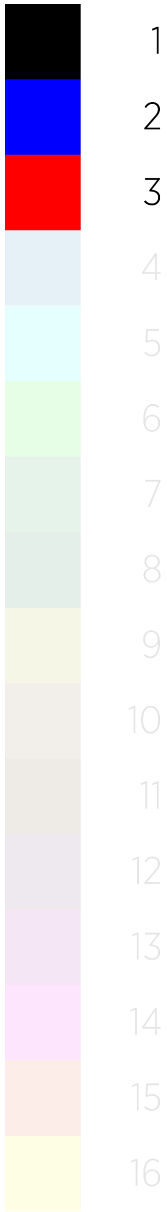
We can do 3 (4) different operations with the laser:

engrave [1]

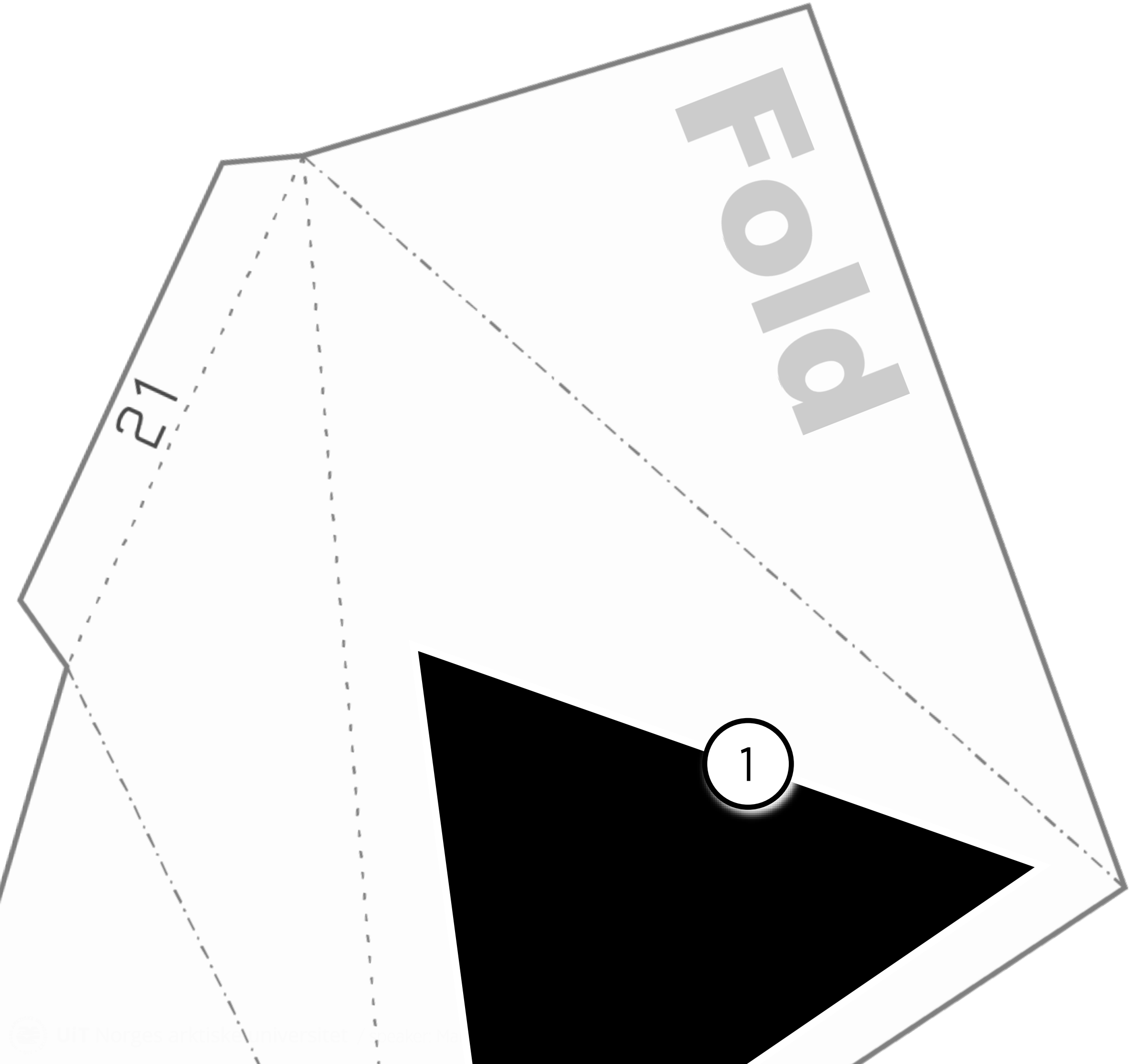
score [2]

cut [3]

(Marking)



1.4. cut / score / engrave (marking)

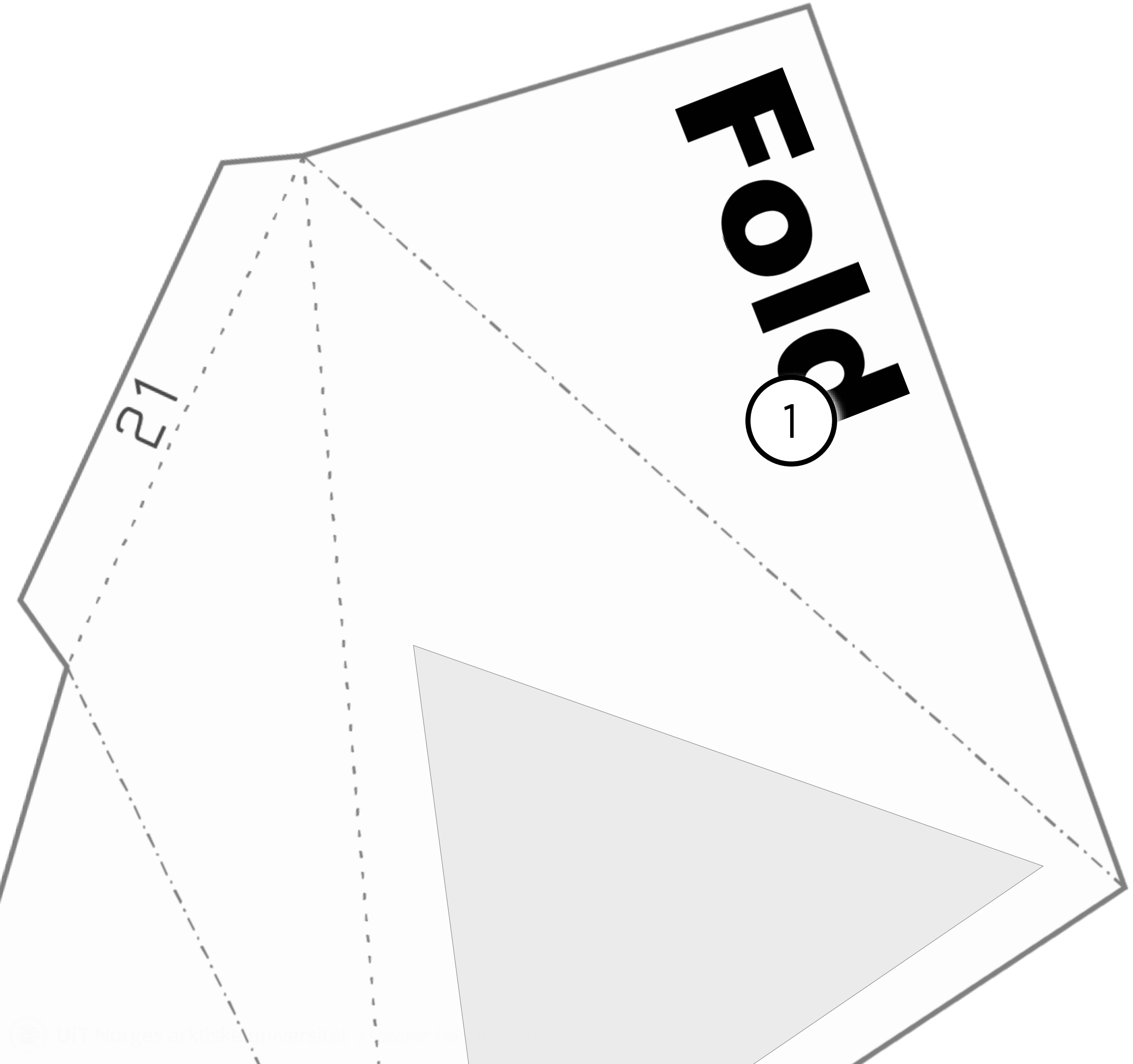


we can:

engrave [1] an area with a certain depth and resolution into the material.

Like in this example where a whole area is engraved in a specified resolution.

1.4. cut / score / engrave (marking)

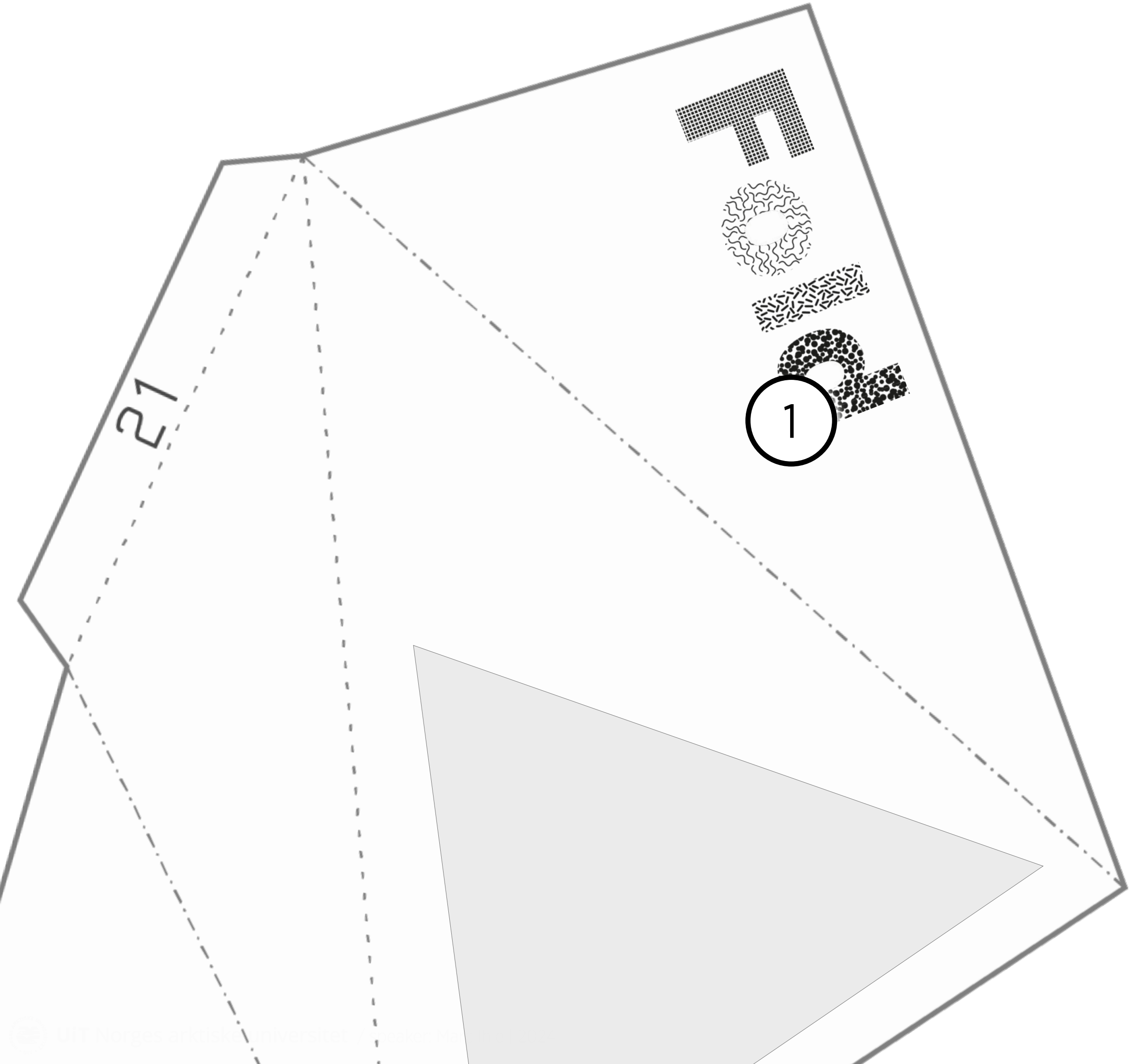


we can:

engrave [1] an area with a certain depth and resolution into the material.

Like in this example where the whole area of a text is engraved -> but note that this can be very time consuming …

1.4. cut / score / engrave (marking)

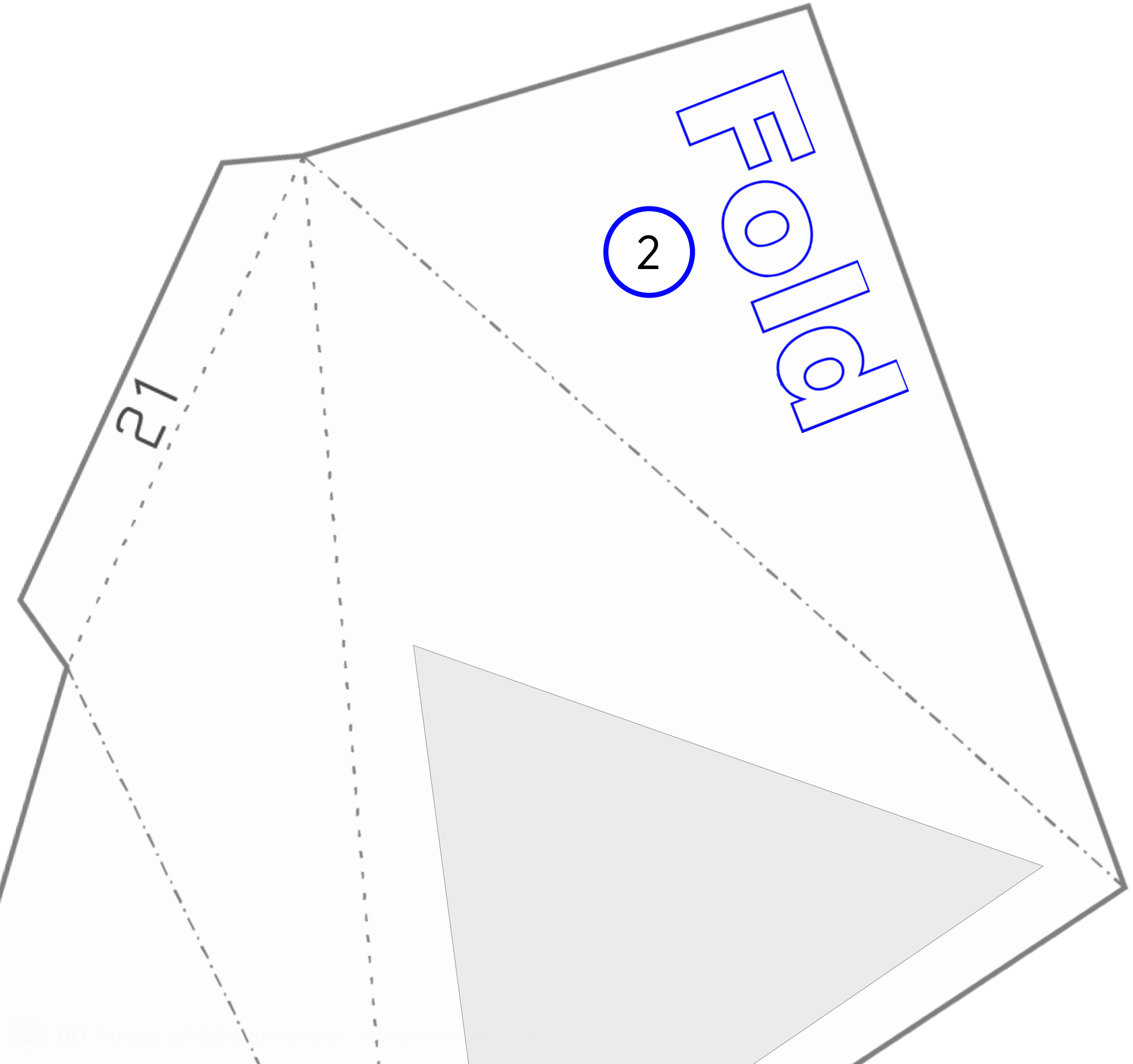


we can:

<u>engrave [1]</u> an area with a certain depth and resolution into the material.

We can also use lighter patterns than full solid hatches … To only engrave parts … this can save some time and also lead to some interesting results …

1.4. cut / score / engrave (marking)

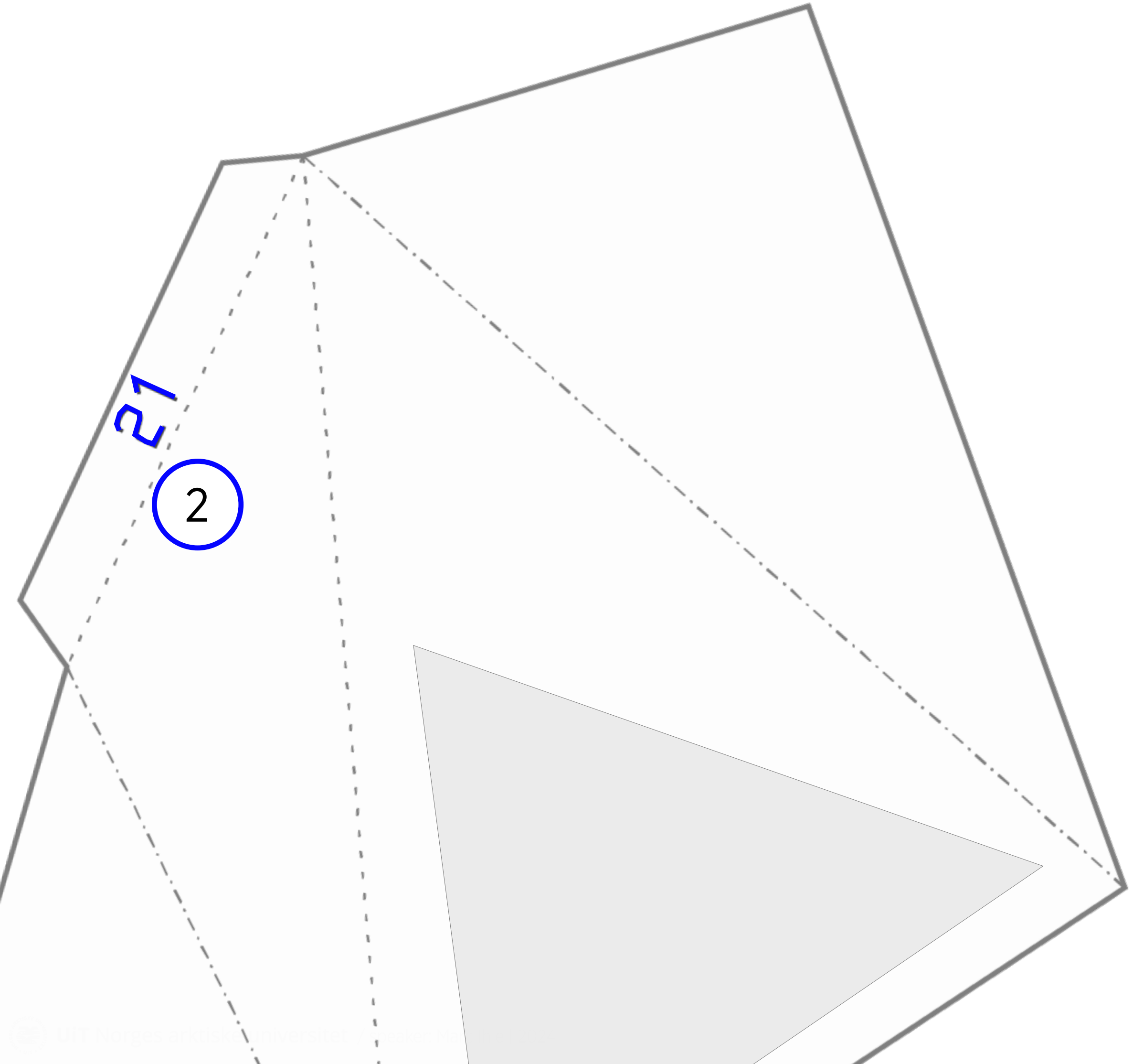


we can:

score (also called kiss-cut) [2] into the material with a certain depth … This will not cut all the way thorugh but leave a thinner line

Like in this case the outlines of a text … this will save much time compared to a full surface engraving.

1.4. cut / score / engrave (marking)

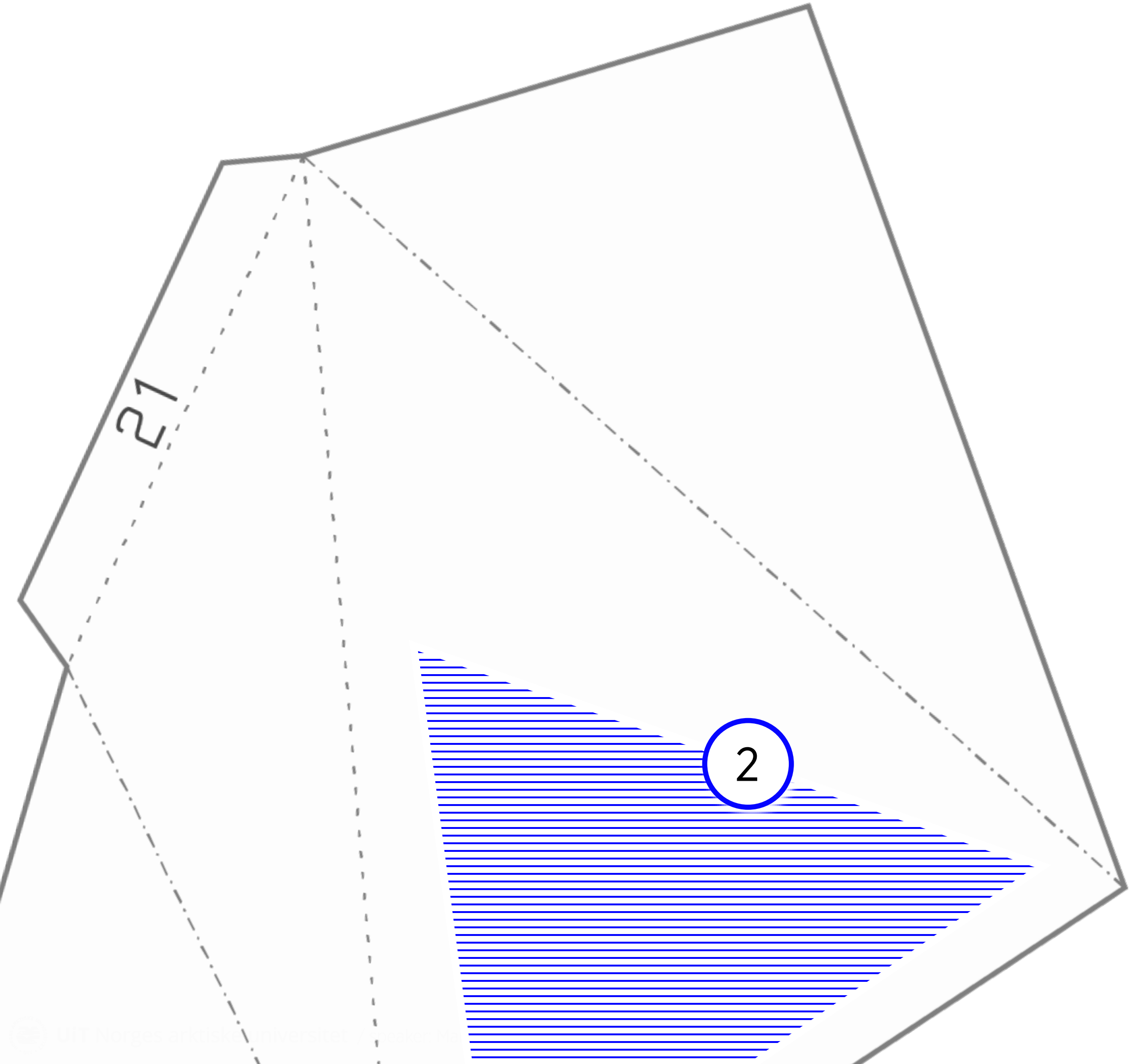


we can:

score (also called kiss-cut) [2] into the material with a certain depth … This will not cut all the way thorugh but leave a marking

Or like in this case for the text labeles where a single stroke font was used -> this will go fastest for text labels.

1.4. cut / score / engrave (marking)

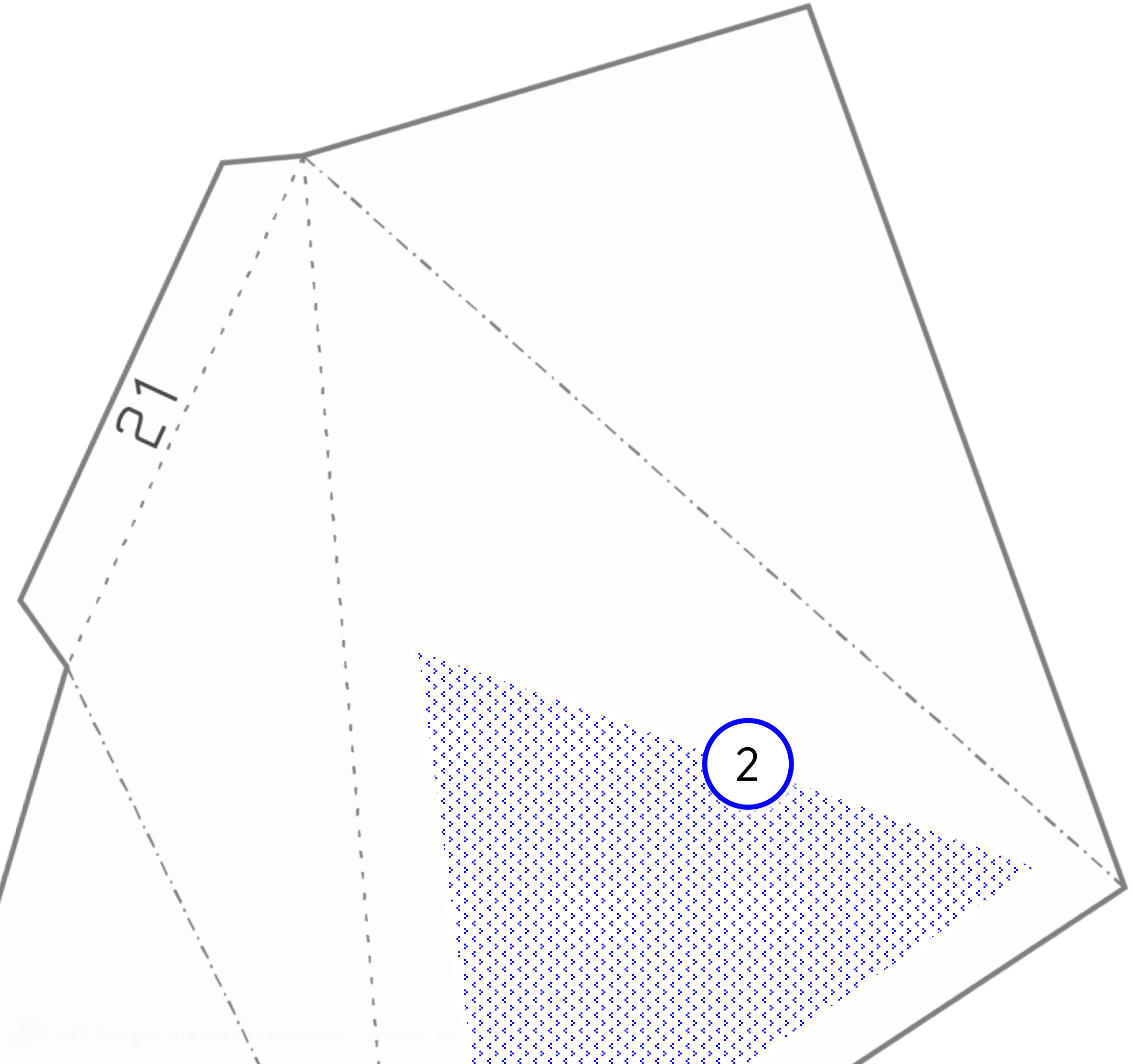


we can:

score (also called kiss-cut) [2] into the material with a certain depth … This will not cut all the way thorugh but leave a marking

Also Instead of a full surface engrave we can convert patterns to lines for scoring. -> this will go much, much faster than the full surface engrave

1.4. cut / score / engrave (marking)

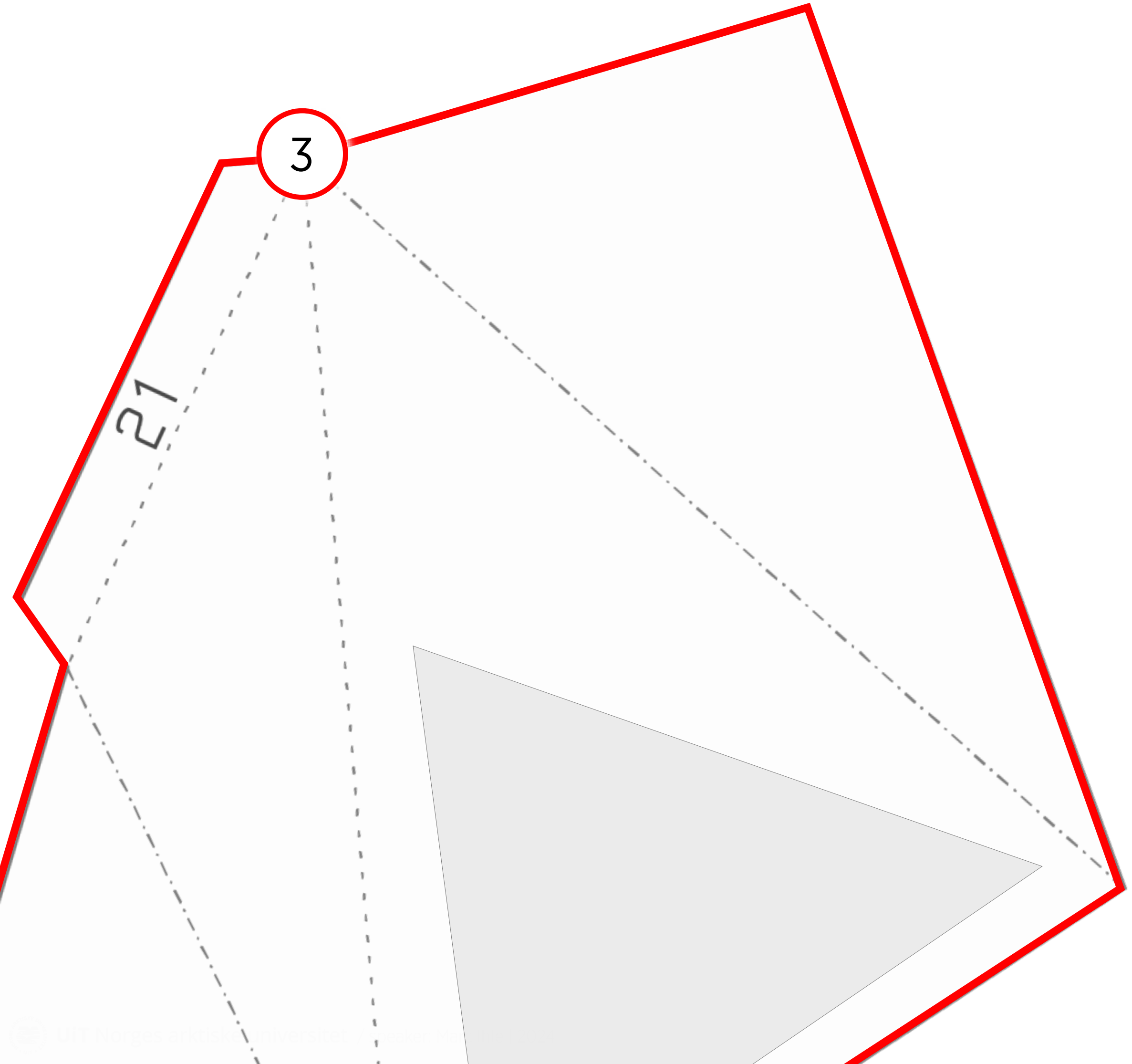


we can:

score (also called kiss-cut) [2] into the material with a certain depth … This will not cut all the way thorugh but leave a marking

There are multiple possibilities to differentiate grafices using line patterns.

1.4. cut / score / engrave (marking)

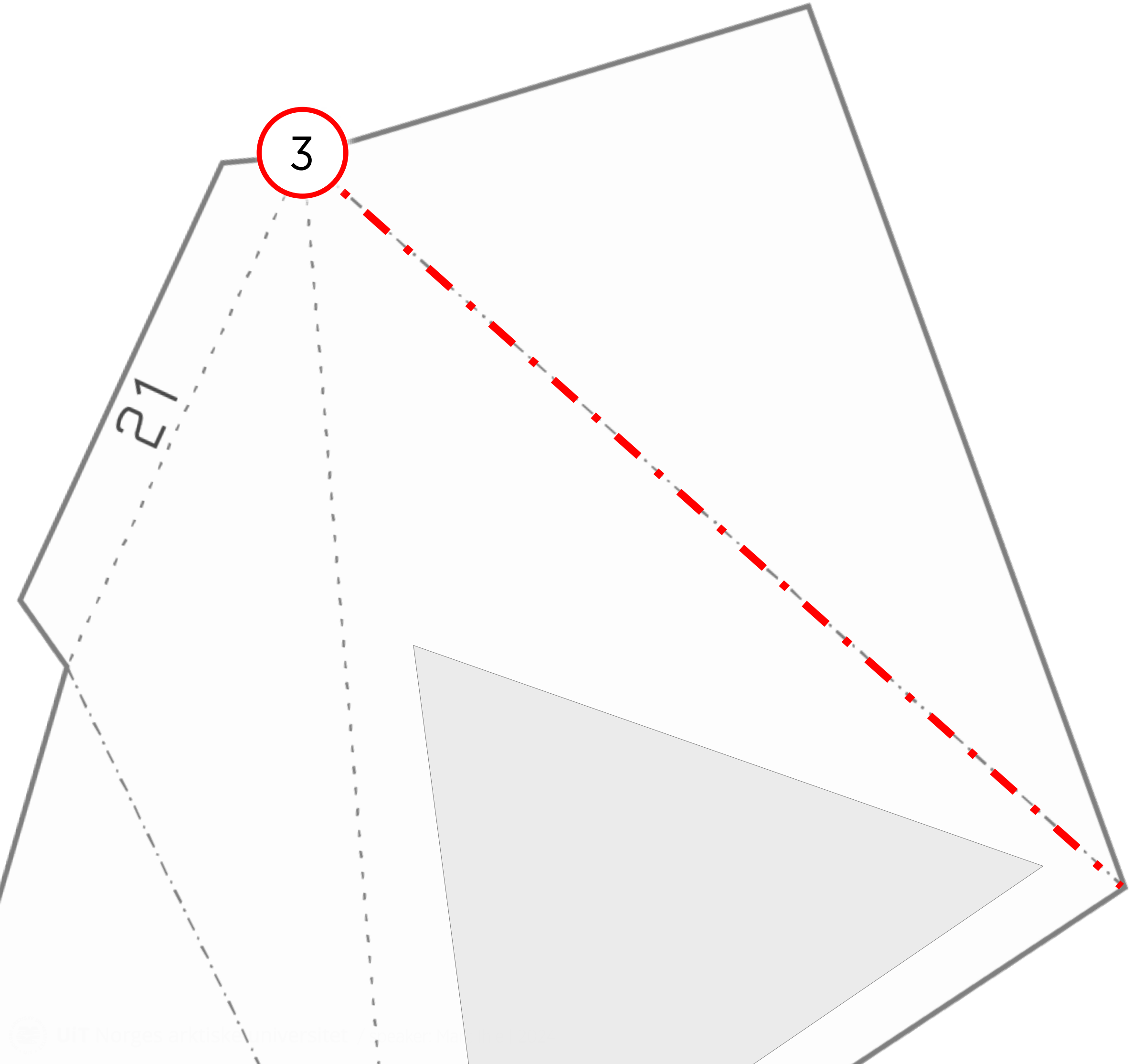


we can:

cut [3] all the way through the material.

Like in this example cutting along a continuous outline of this shape

1.4. cut / score / engrave (marking)



we can:

cut [3] all the way through the material.

Or like here cutting in a dashed / dash-doted / doted ... linetype -> converted into multiple cut lines

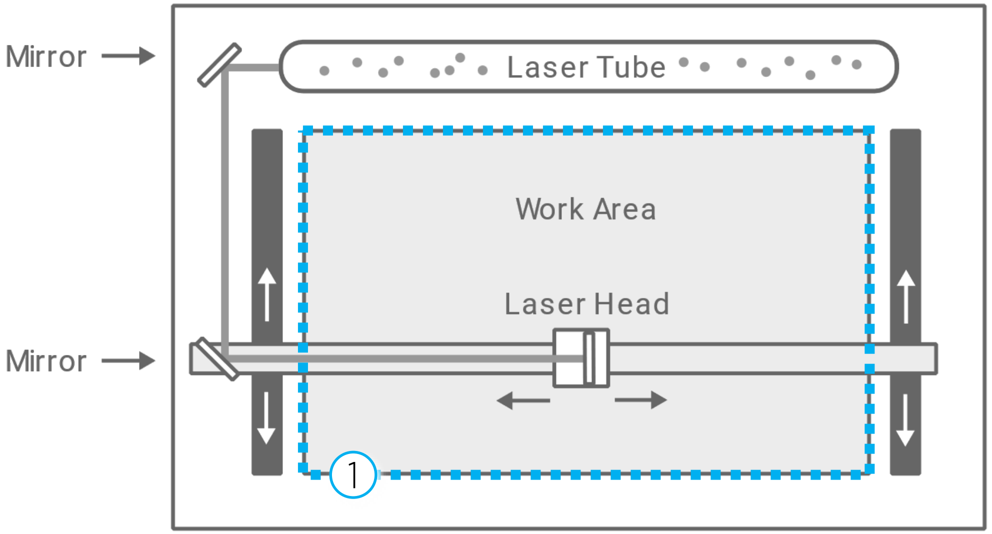
-> this will allow us to fold the material in both ways (opposed to a continous score line)

Laser cutter (Trotec)

Some basic info about the Laser at the workshop at the academy.

overview

Laser cutter (Trotec SP500 - workshop)

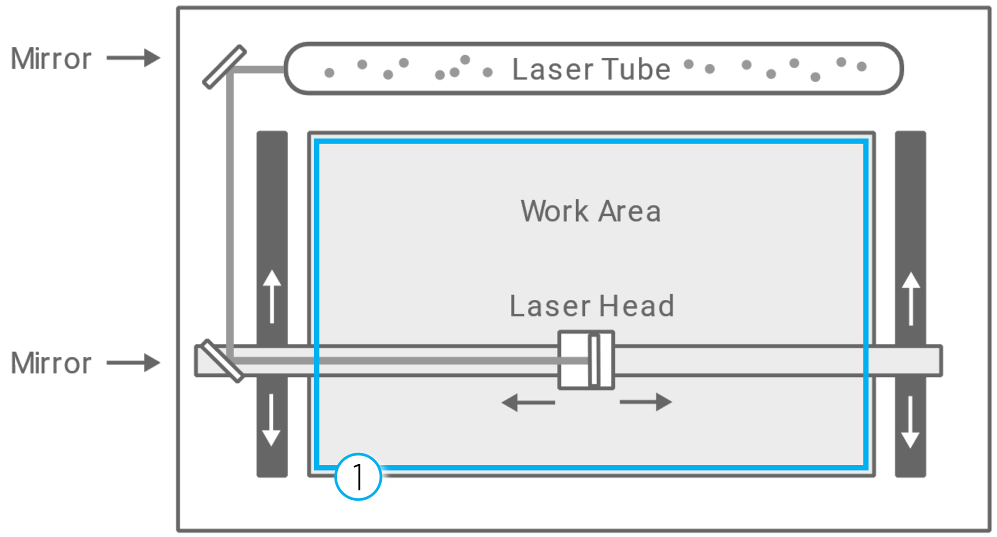


Working area

max. **working area** = 1245 x 710 mm [1]

>>> this means the maximum dimensions of the material should not be larger than: X = 1245 mm / Y = 710 mm !!!

Laser cutter (Trotec SP500 - workshop)



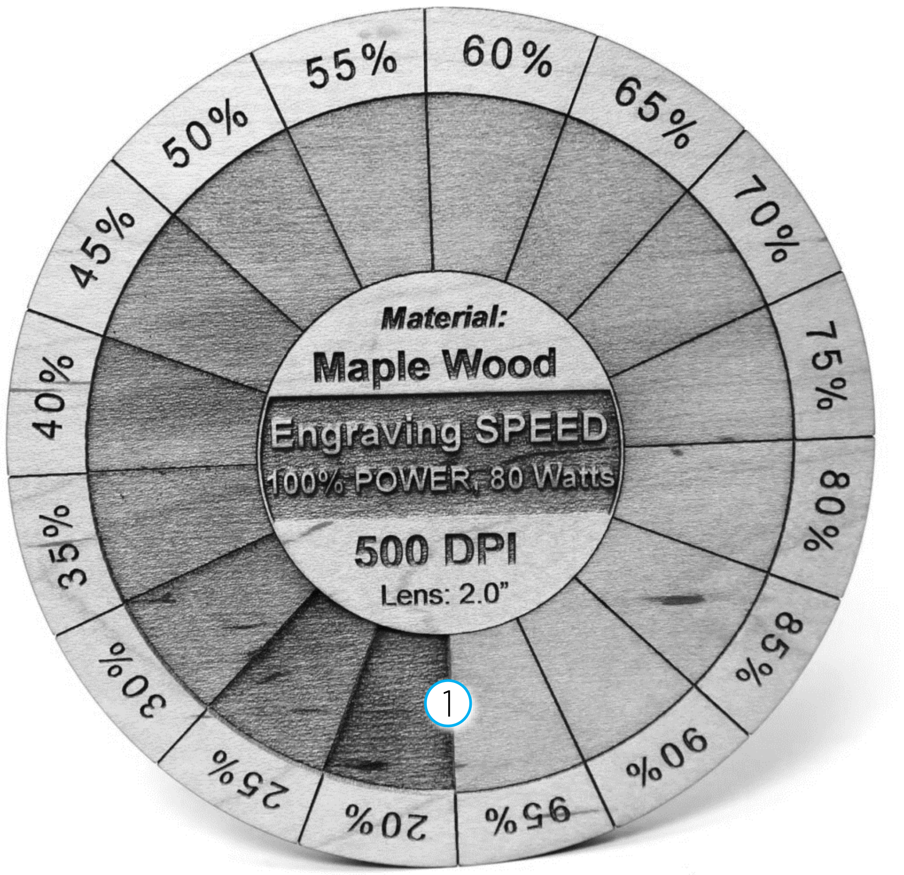
Material Dimensions

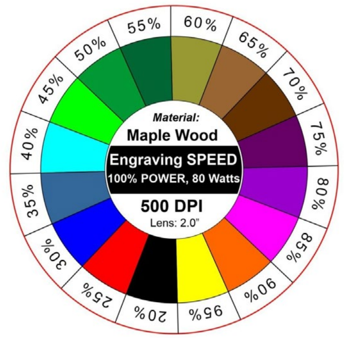
>>> better is to have a little extra space rather than to cut the material too large … +/- 1mm less in both X and Y direction should be enough

>>> this would result in maximum dimensions for the material of:

max. **material dim. = 1244 x 709 mm** [1]

Laser cutter (Trotec SP500 - workshop)





Speed settings

… the faster the laser head moves the less time the laser beam will stay on the same spot … and the less deep will be the "cut"

Compare 20% speed vs 95% speed here [1]

Laser cutter (Trotec SP500 - workshop)

Power

Speed

Speed \ Power	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
10%	250 250 250	228 228 228	202 202 202	177 177 177	151 151 151	126 126 126	100 100 100	075 075 075	049 049 049	024 024 024
20%	246 246 246	226 226 226	200 200 200	175 175 175	149 149 149	124 124 124	098 098 098	073 073 073	047 047 047	022 022 022
30%	244 244 244	224 224 224	198 198 198	173 173 173	147 147 147	122 122 122	096 096 096	071 071 071	045 045 045	020 020 020
40%	242 242 242	222 222 222	196 196 196	171 171 171	145 145 145	120 120 120	094 094 094	069 069 069	043 043 043	018 018 018
50%	240 240 240	220 220 220	194 194 194	169 169 169	143 143 143	118 118 118	092 092 092	067 067 067	041 041 041	016 016 016
60%	238 238 238	218 218 218	192 192 192	167 167 167	141 141 141	116 116 116	090 090 090	065 065 065	039 039 039	014 014 014
70%	236 236 236	216 216 216	190 190 190	165 165 165	139 139 139	114 114 114	088 088 088	063 063 063	037 037 037	012 012 012
80%	234 234 234	214 214 214	188 188 188	163 163 163	137 137 137	112 112 112	086 086 086	061 061 061	035 035 035	010 010 010
90%	232 232 232	212 212 212	186 186 186	161 161 161	135 135 135	110 110 110	084 084 084	059 059 059	033 033 033	008 008 008
100%	230 230 230	204 204 204	179 179 179	153 153 153	128 128 128	102 102 102	077 077 077	051 051 051	026 026 026	005 005 005

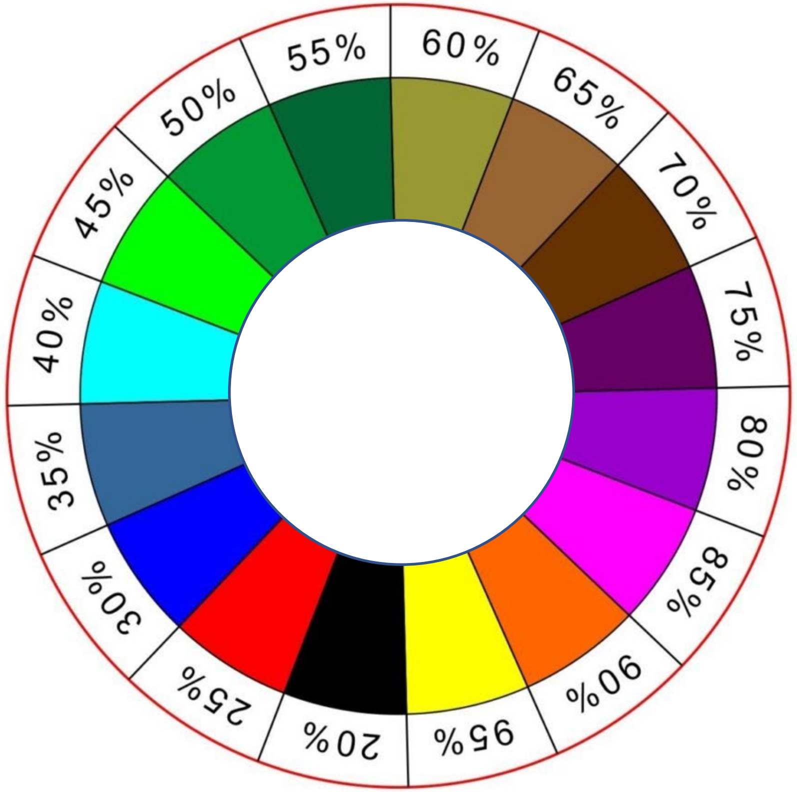
R= #
G= #
B= #

Power/Speed settings

… the more power the laser beam has the deeper will be the cut …

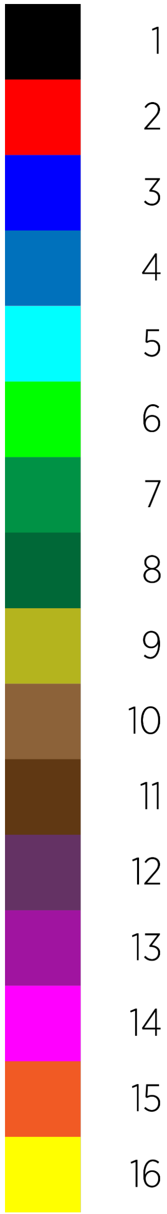
Power- and speed settings work together … 100% power and the lowest speed setting will produce the deepest cut possible

Laser cutter (Trotec SP500 - workshop)

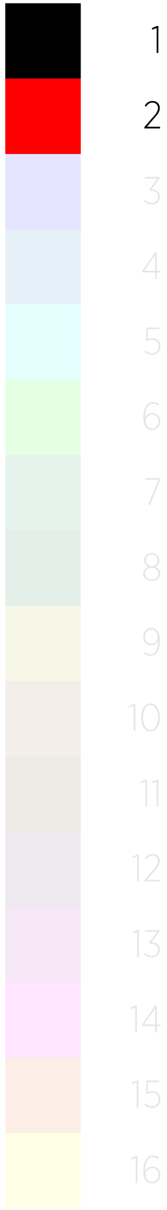


In the JobControl Software ...

we have **16 colors** which can be used to sperate individual laser passes with different power- and speed settings.



Laser cutter (Trotec SP500 - workshop)



As default:

- engraving is the first pass and set to the color black
- Cutting is the last pass and set to the color red

Laser cutter (Trotec SP500 - workshop)

But we can use multiple other colors inbetween to control different speed-and power settings and achieve more variation in appearance.

This can be either for additional engraving passes with a different depth or for scoring passes of different sets of lines with different depths.

Laser cutter (Trotec SP500 - workshop)

For example we can have in total 5 passes:

engrave

score - light

score - medium

score - deep

cut

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Laser cutter (Trotec SP500 - workshop)

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Now, since engraving can be quite time consuming, we can limit the laser passes to only scoring and cutting if applicable.

score - light

score - medium

cut

1.5. improve time consumption & reduce errors

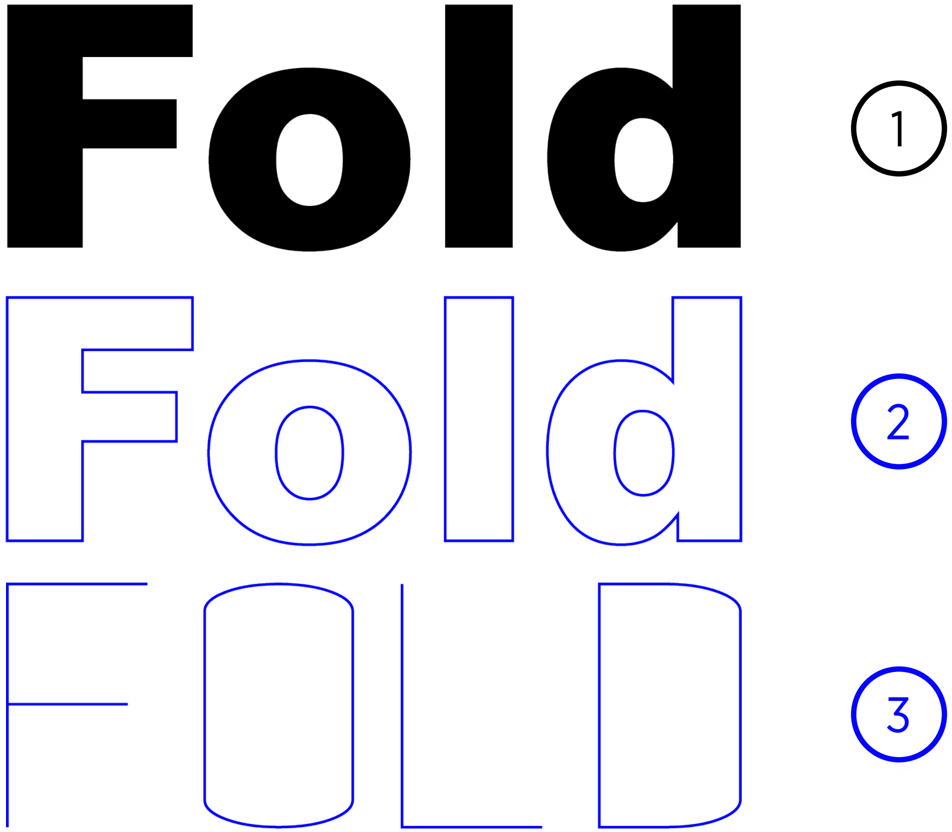
Parameters which will directly influence laser time:

- length of cutting/scoring paths
- dimensions of areas for engraving
- resolution of areas for engraving

- Material thickness -> speed settings
- Material type -> power & speed settings

overview

1.5. time consumption / errors



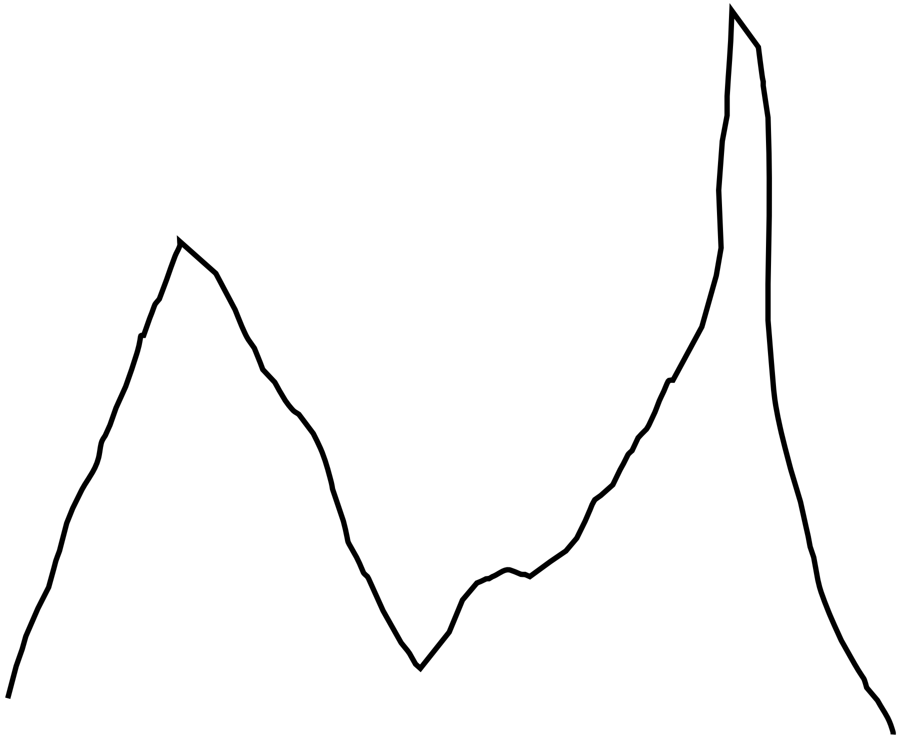
Be aware that <u>surface-engraving is very time consuming</u> -> if applicable try to use line-engraving instead of surface-engraving … rapid?

In this example **[1]** the whole area will be engraved -> this is very time consuming!

Instead you can convert the text into outlines [2] to use line-engraving

or better you use a <u>single-stroke-font</u> and convert it to lines [3] for line-engraving

1.5. time consumption / amount of detail

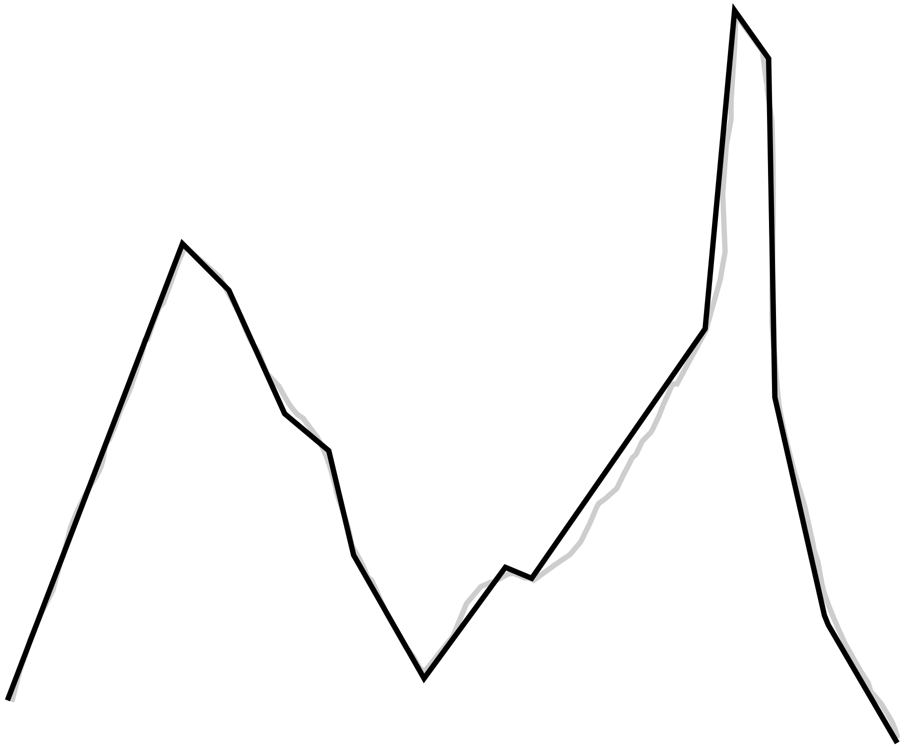


Time

Reducing the amount of geometry (path length and complexity) …

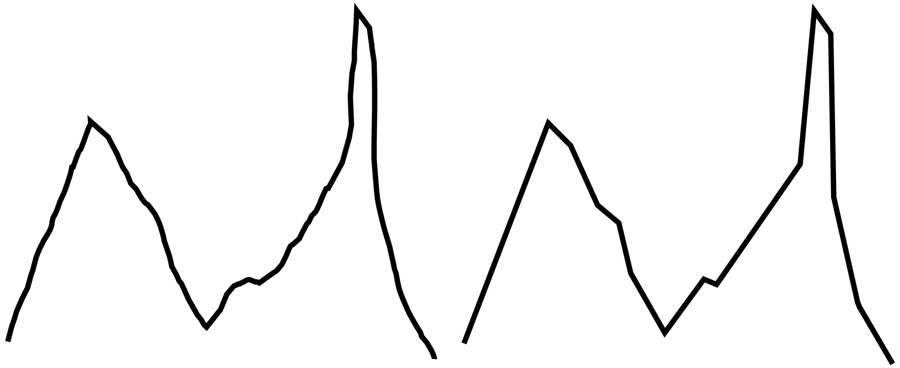
-> will reduce the time

1.5. time consumption / amount of detail



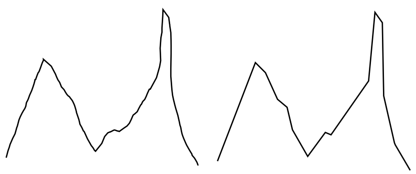
At this scale you might need the detail in the curve … and this simplification is too simple …

1.5. time consumption / amount of detail



But if we reduce the scale by 50 % ...
then the original line and the simplified line look more similar

1.5. time consumption / amount of detail



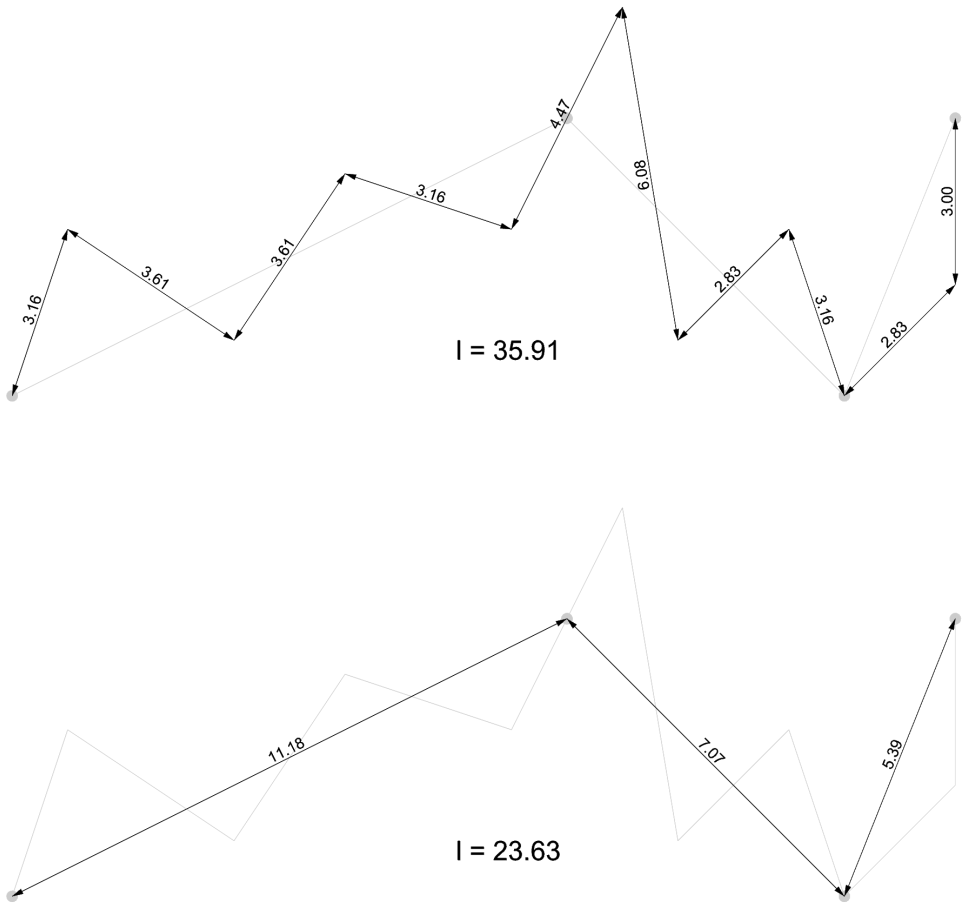
But if we reduce the scale by 25 % … then the original line and the simplified line look almost the same …

-> be aware of what detail will still be visible and which detail not.

-> Reduce detail if it will not be visible.

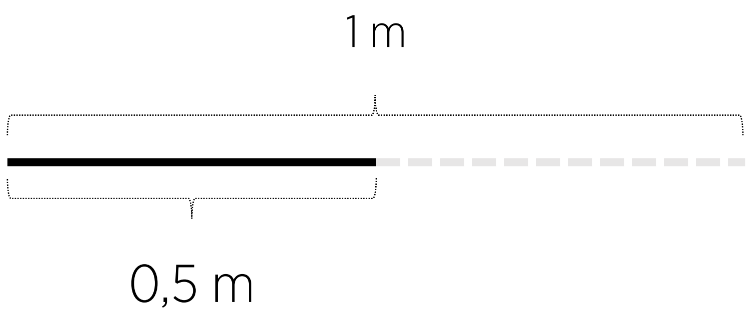
-> if line segments are very short, then this may produce errors.

1.5. time consumption / amount of detail



Decreasing the amount of control points will also shorten the length of the path and thus reduce laser time.

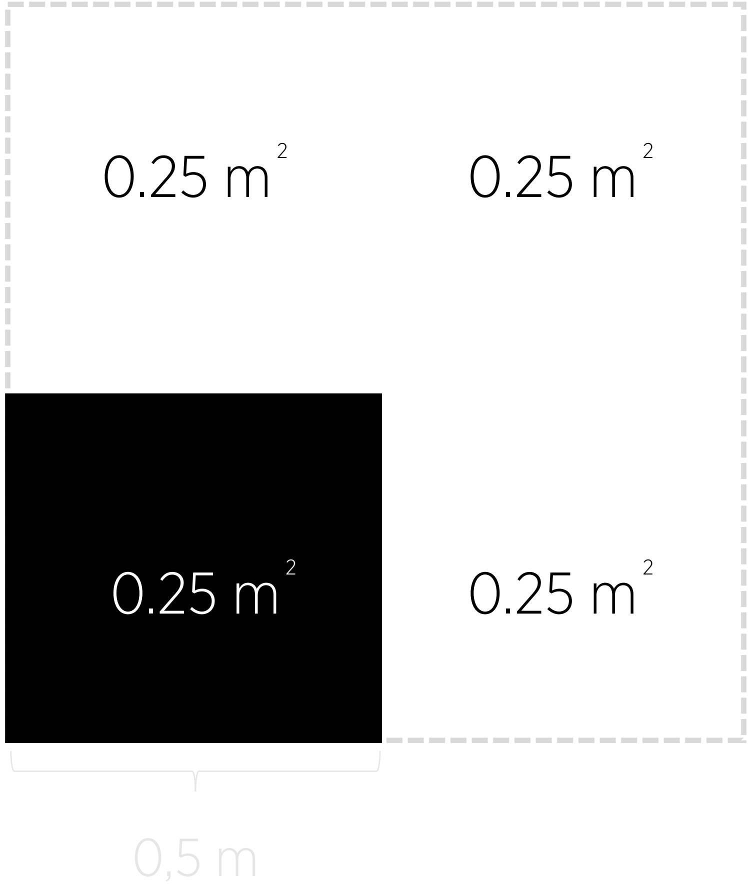
1.5. time consumption / scale 1D



<u>Scaling in 1 Dimension</u>

scaling by 0.5 will make the path 2 times shorter

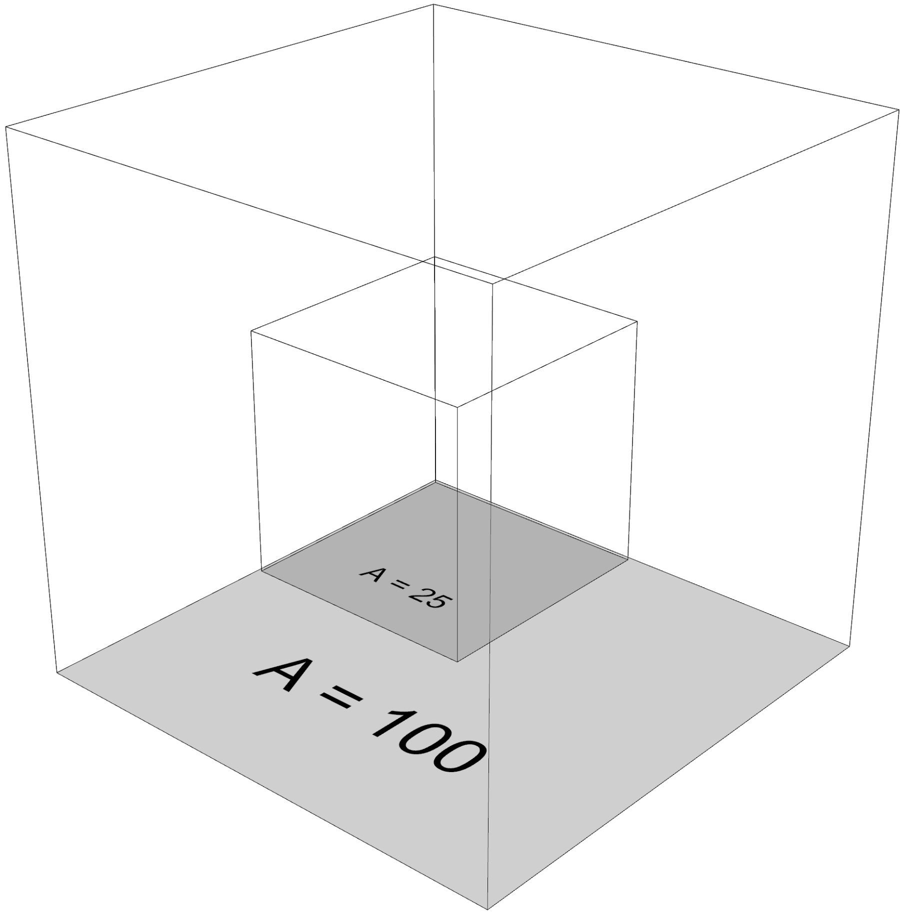
1.5. time consumption / scale 2D



<u>Scaling in 2 Dimension</u>

scaling a surface by 0.5 will make the area 4 times smaller

1.5. time consumption / scale 3D



<u>Scaling in 3 Dimension</u>

scaling a surface by 0.5 will make the volume 8 times less ...

1.6. complexity & amount of detail

Try to find <u>the right amount of detail</u>.

How much detail is necessary? – reduce as much as you can if you are still achieving a “similar” visual result that works for you.

overview

1.6. complexity & amount of detail

What can we do in 3d (before we start with 2d file production for the laser) to reduce time

- We can scale the 3d model in the z-axis. -> 2,5D Model
- We can simplify the 3d model in its complexity by decimating the point-/edge-/face-/ and/or feature count of geometry)

1.6. complexity & amount of detail

vertex count: **1.000.000**

Front view

Lets say this would be the maximum resolution of a mesh (terrain) ...

1.6. complexity & amount of detail

vertex count: **100.000**

Front view

And we reduce it to 10% of its total amount of vertices
-> it still looks very similar to our original mesh …

1.6. complexity & amount of detail

vertex count: **1.000**

Front view

If we reduce it further with 10% -> then we start seeing something different ...

1.6. complexity & amount of detail

vertex count: **500**

Front view

If we reduce it further … the appearance will totally change and this might not be what we want …

1.6. complexity & amount of detail

Front view

vertex count: **50**

… now we have abstracted the landscape quite much, which we will also do in our first tutorial later …

1.6. complexity & amount of detail

Front view

reduce the resolution as much as possible, but keep as much detail as necessary.

1.6. complexity & amount of detail

<u>What can we do in 2d to reduce time</u>

- We can rebuild the paths (curves) with a lower amount of control points
- We can use scored line patterns in instead of time-consuming full surface engraving
- We can use single-stroke fonts and use scoring instead of engraving
- We can reduce the number of single line segments by joining them to polylines …

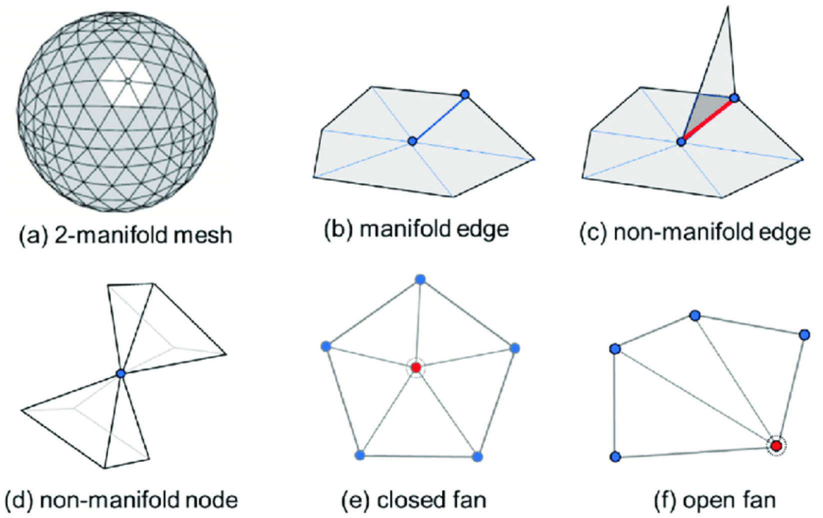
1.7. Meshes that can produce errors

-

Some things about your geometry if you are using meshes as input geometry for digital fabrication.

overview

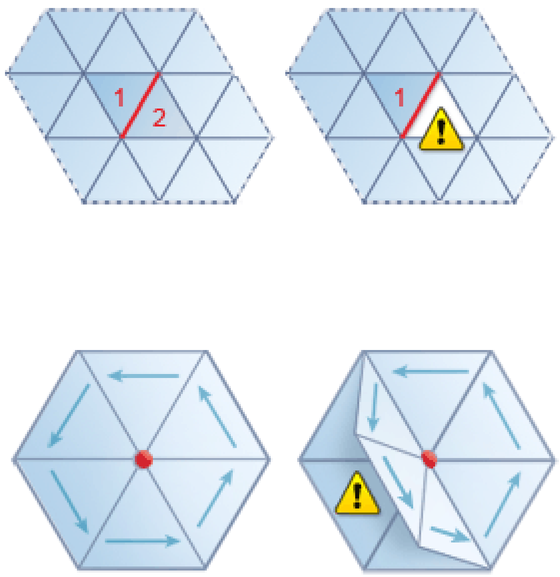
Non-manifold geometry



A mesh is <u>watertight</u> if the mesh does not have any missing triangles (i.e., surface holes). A mesh is a manifold if: (1) each edge is incident to only one or two faces and; (2) the faces incident to a vertex form a closed or an open fan

Source:
www.researchgate.net/publication/337698839_Surface_Reconstruction_for_Three-Dimensional_Rockfall_Volumetric_Analysis

Watertight 3d Models



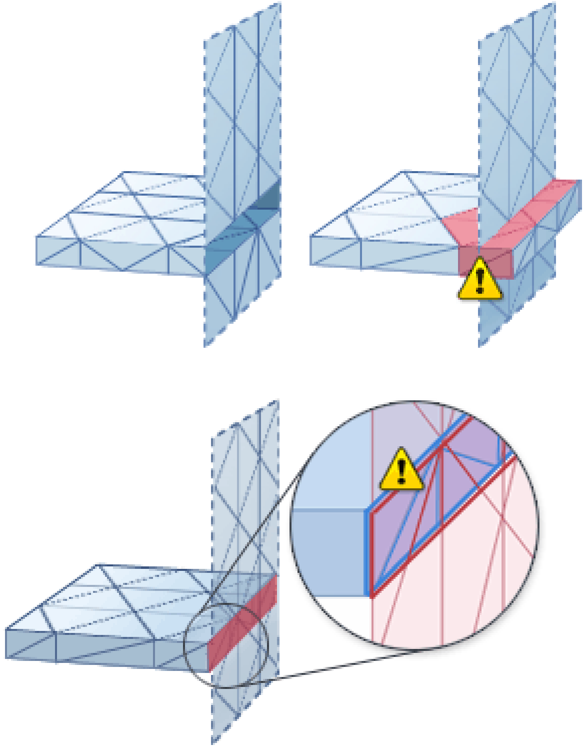
A watertight model is defined as:

1. Every triangle edge has exactly two neighbours. This implies that there are no holes or non-manifold edges.

2. Every node in the triangle is connected to only one "fan" of triangles around it. That is, for a given node, every triangle that shares that node must be accessible from any other triangle that shares the same node by moving across triangle edges. This is a further condition on the domain being a proper manifold.

Source: https://knowledge.autodesk.com

Watertight 3d Models



3. There are <u>no geometric overlaps or intersections in the model</u>. This condition is independent of definition (1) above. An STL may be properly manifold but may still have overlaps and/or intersections due to triangles intersecting or overlapping with each other geometrically.
4. There are <u>no geometric errors that produce unrealistically thin areas</u>. This is essentially similar to an overlap, but may not be severe enough to be picked up as an overlap.

Source: https://knowledge.autodesk.com

1.8. file preparation in Illustrator

Here some IMPORTANT things to consider before or during file preparation in Illustrator

overview

1.8. file preparation in Illustrator

IMPORTANT !!!

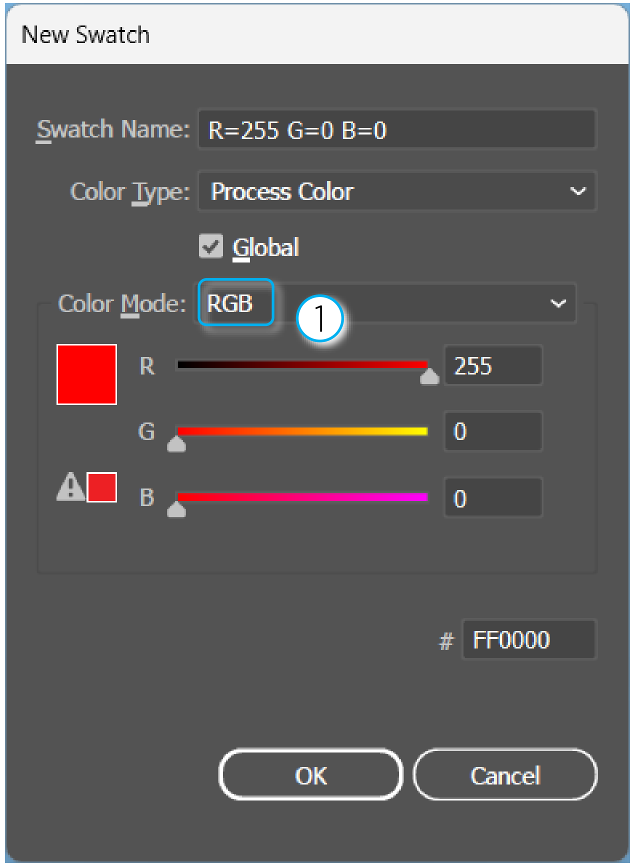
- Delete paths beyond or exactly at the edge of your artboard / file.
- Try to join single line segments into polylines if possible.
- Rebuild the lines, if necessary, before importing to Illustrator.
- Avoid line segments smaller than ~0.5mm (can cause problems)

1.8. file preparation in Illustrator

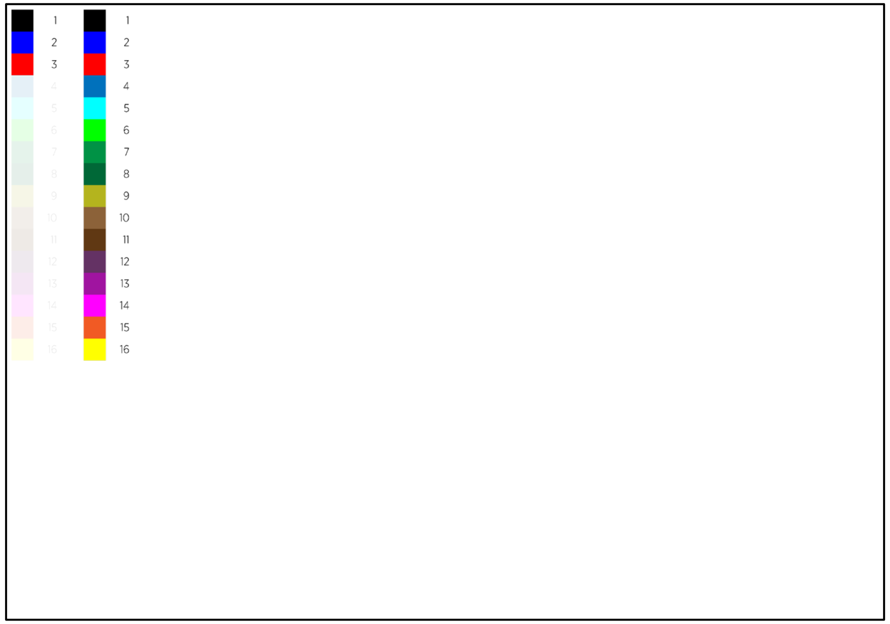
IMPORTANT !!!

- Use single stroke fonts
- Convert fonts to paths/strokes
- No groupings
- No compound paths
- No clipping masks
- No duplicate lines

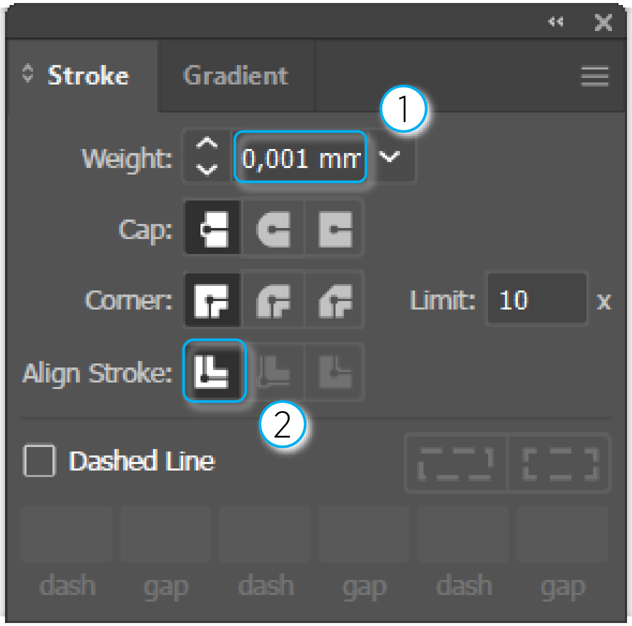
1.8. file preparation in Illustrator



- Use RGB color space for your document (the same like in the Job Control material database)
- Use RGB color swatches [1]



1.8. file preparation in Illustrator



- The stroke width for cut & score lines must be set to 0.001 mm [1] … (or 0.0001 pt … we will have to double-check the correct setting)
- The stroke must also be aligned to the center [2]

1.8. file preparation in Illustrator

More information and an example on how to prepare files in illustrator we will look at in the *paper model method*

Blender-Part-03-decimate-and-export-paper-model-method [1]

>>> Chapter 3.7. import & file preparation (Illustrator)

1.9. references & possibilities

Here some references will be shown that should inspire your ideas.

overview

Image: Hadseløya, Marc Ihle 2019

engrave

Use multiple engraving passes to achieve an appearance with different depths …

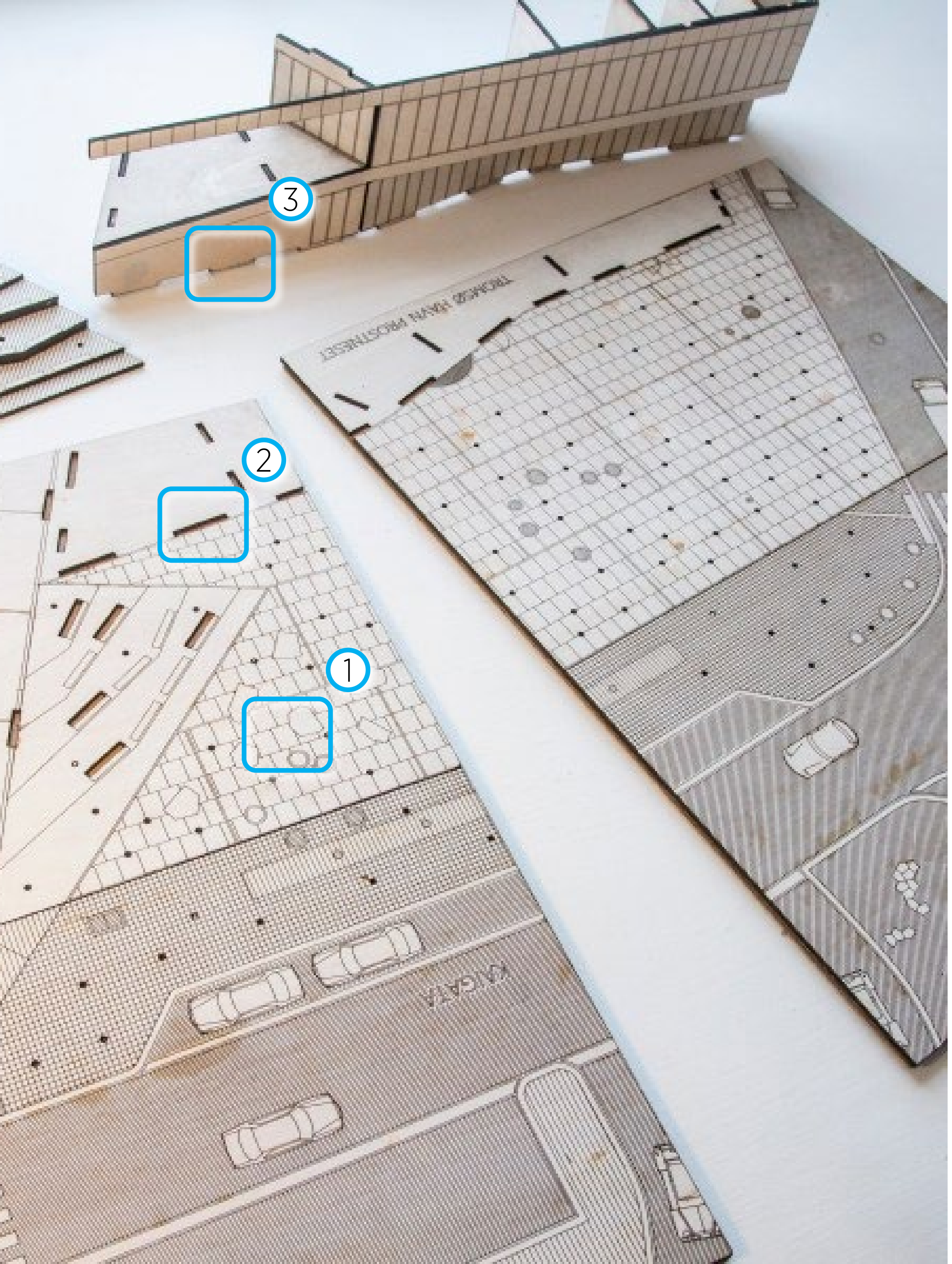


Image: Prostneset, Digital Landscapes

Score / fitting

line work was can be scored [1] to achieve very thinn lines

Cut outs [2] can be made to fit other parts [3]

Image: Basswood and Acrylic, Tina Yun

Different materials

use different materials to highlight areas or differentiate …

Image: Peter Tijhuis, berlage institute

flexible parts

making parts exchangable ... make some parts fix and some parts flexible ...

Image: Lightscapes, University of Innsbruck

Post Digital

Make parts of your model using digital fabrication and combine them with «handmade» elements …

Combine the digital with the analog

Some parts can be more defined and precise … some parts can be more loose and open …

Image: Lightscapes, University of Innsbruck

Laser & 3d print

Use different digital fabrication techniques … some parts will be better **3d-printed** some parts might be better CNC-milled … and some parts might be better **laser-cut** …

Image: Tomas Tait, Studio3, University of Innsbruck

Laser & 3d print

Use different digital fabrication techniques … some parts will be better 3d-printed some parts might be better CNC-milled … and some parts might be better laser-cut …

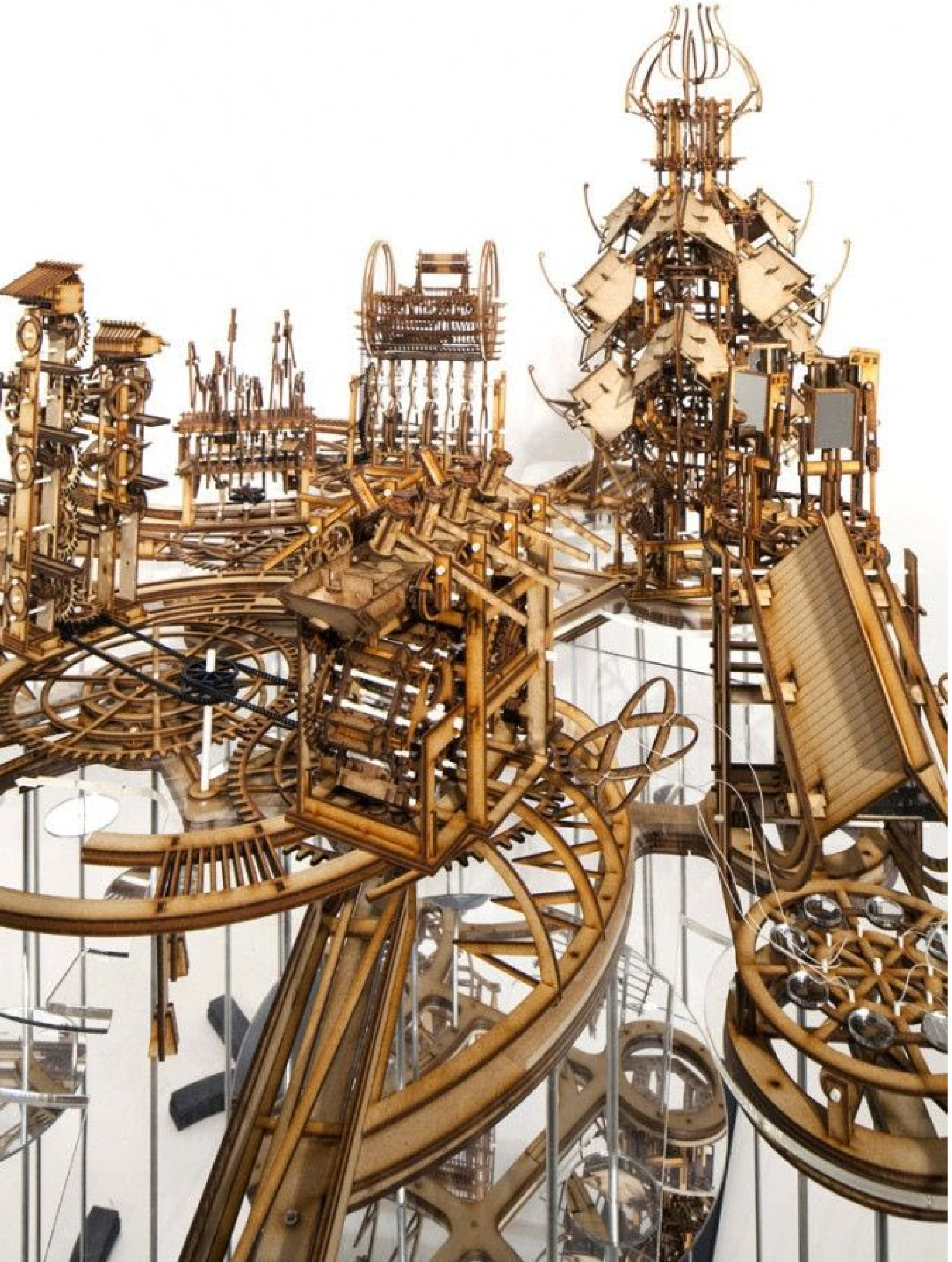


Image: Ye Hui, Unit21, bartlett UCL

Multiple parts

Create multipe parts which can work together as a whole …

Image: Sara Shafiei, Unit21, bartlett UCL

Different dimensions

Combine 2d / 3d and 2,5D ...

materials & technique

Image: Reconstructed Topographies, Studio3, UIBK

Combine different materials … use similar techniques

Image: Reconstructed Topographies, Studio3, UIBK

2 different systems

Combine 2 different systems using the similar techniques

Skip parts

Image: Reconstructed Topographies, Studio3, UIBK

Skip parts …

… reduce but keep appearance …

Image: Reconstructed Topographies, Studio3, UIBK

Add elements

Create a scaffold for your ideas and work with multiple small and simple elements … these elements can also be laser cut … or made by hand.

Image: Marc Ihle, 2012

Both in one

Embed 3d objects into the digital topography …

Image: RAW Studio, UiT 2019

Exaggerate

Adjust the z-scaling to enhance readability of your ideas.

Image: RAW Studio, UiT 2019

2 materials

shift in the use of the material …

… different parts on top of parts …

Image: University of Liechtenstein, 2010

Number & Fineness

… find aesthetics in relation to the number of elements and the «fineness» of each element …

… and the relation to its neighbouring element …

Image: RAW Studio, UiT 2019

Positive-negative

Parts on top of parts with negative engravings.

Image: RAW Studio, UiT 2019

2 materials

Parts on top of parts

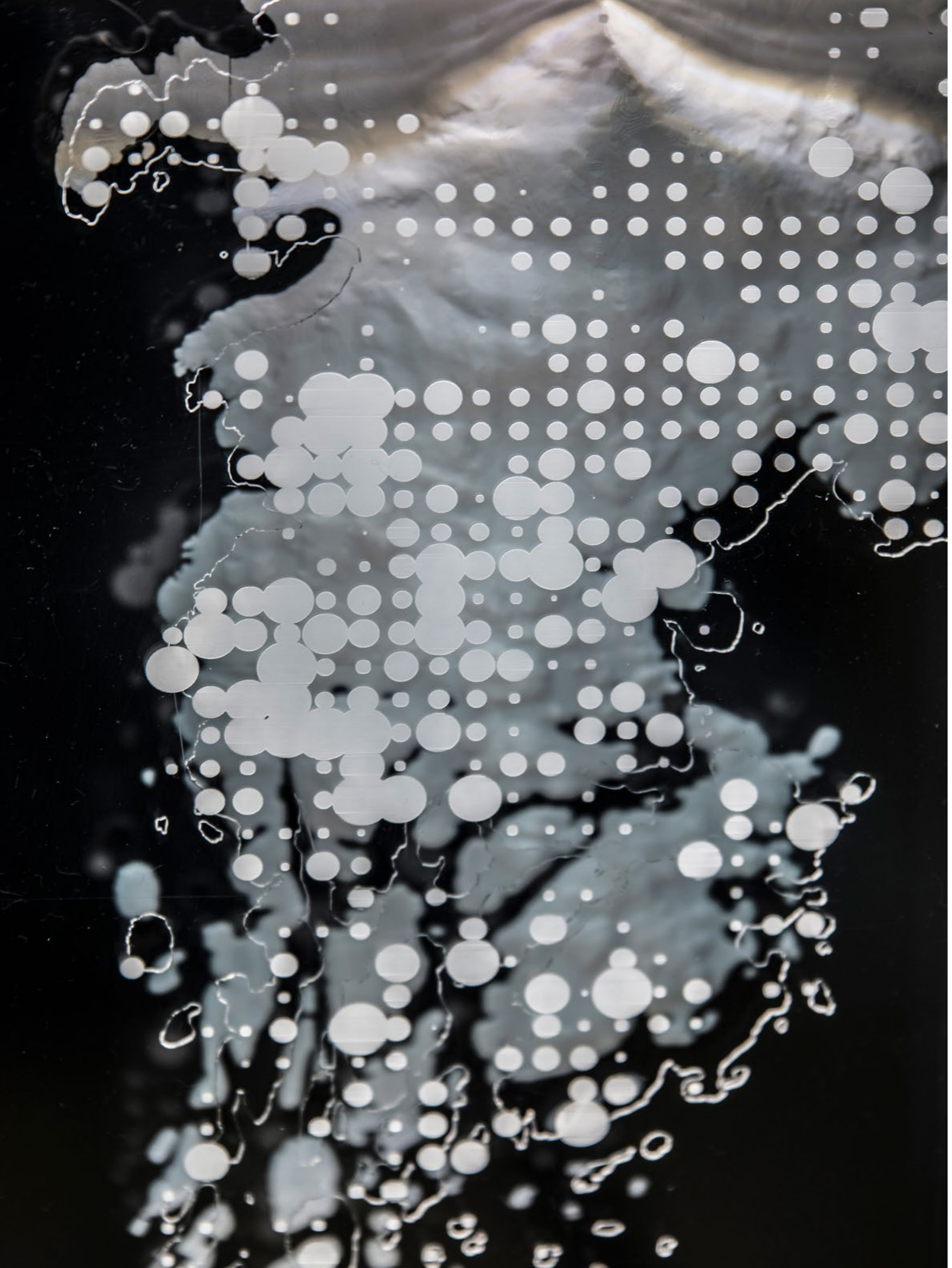


Image: Arctic Studio, UIBK, 2017

layers

Multiple layers … transparent materials and light …

Image: Arctic Studio, UIBK, 2017

layers

Multiple layers …

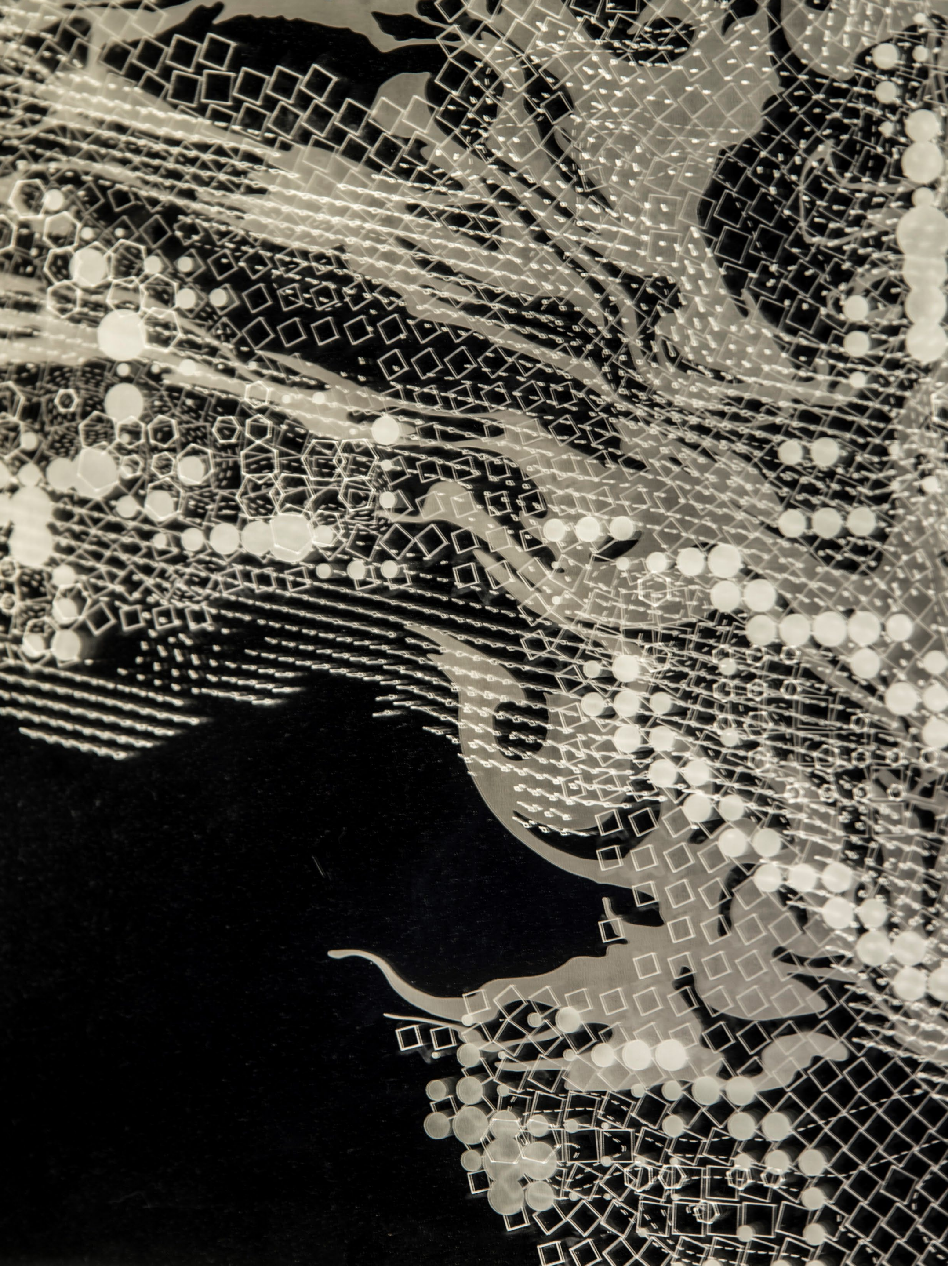


Image: Arctic Studio, UIBK, 2017

layers

Multiple layers ...

Image: Studio2: Sverre Drange, UiT, 2023

Last year …

2 grids …

Image: Studio2: Didrik Leslie Hembery, UiT, 2023

Last year …

Marking areas …

Image: Studio2: Student name missing, UiT, 2023

Last year ...

Fineness ...

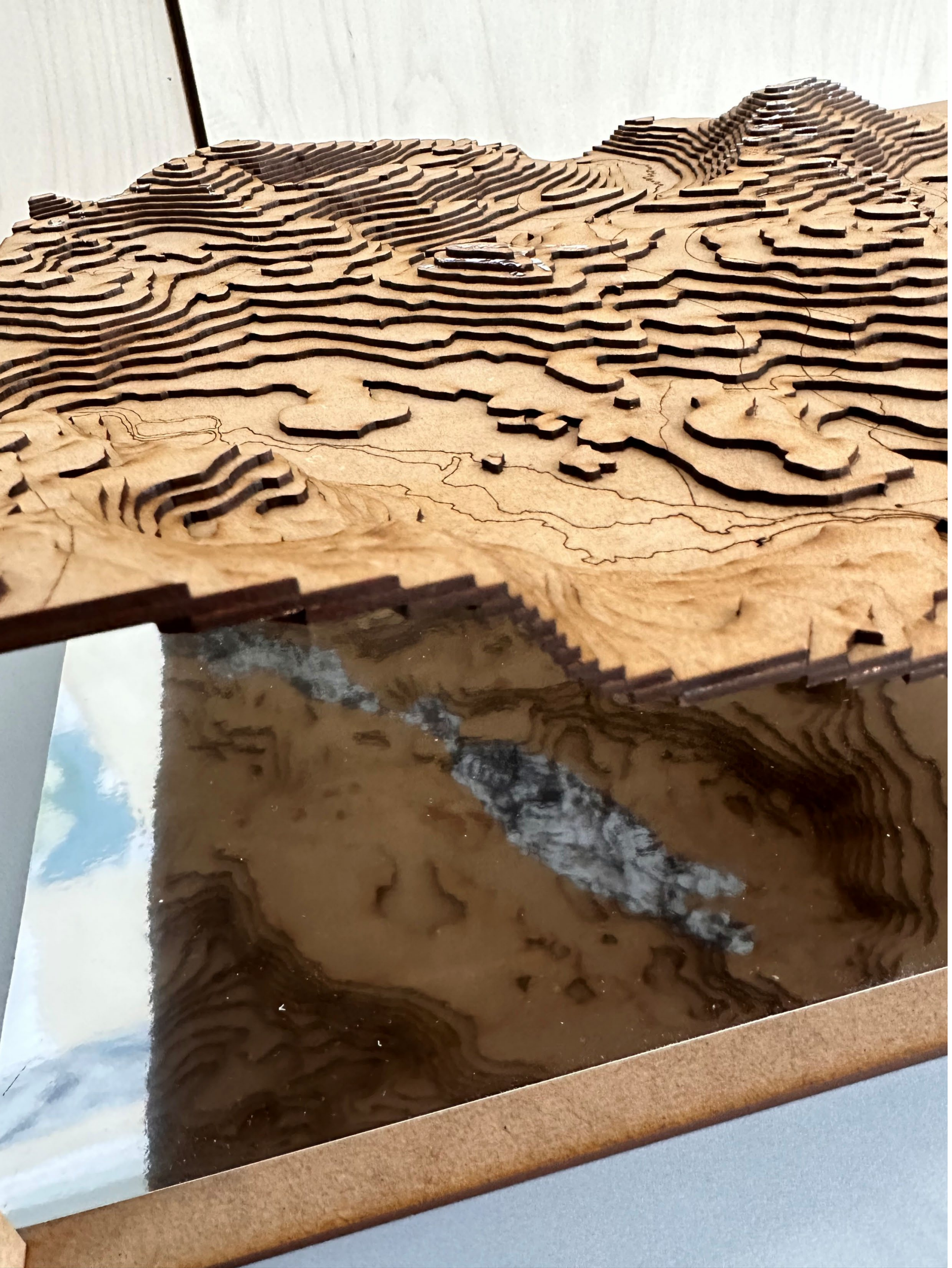


Image: Studio2: Student name missing, UiT, 2023

Last year ...

Positive / Negative ... a view below the Surface

Image: Studio2: Student name missing, UiT, 2023

Last year …

Multiple sections …