ProtoLaser: Optimizing the processing quality

TechNote

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General information

This document contains all information for the intended use of the system/product delivered. This document is intended for persons with basic knowledge of installation and operation of software-controlled systems. General knowledge of operational safety as well as basic knowledge of using PCs running Microsoft Windows® and basic knowledge of your LPKF system software are required.

When processing the how-to examples, carefully note the safety instructions from the applicable user manual of your system!

Validity

This document corresponds to the technical state at the time of publication.
LPKF Laser & Electronics AG (abbreviated to **LPKF** in the following) reserves the right to make changes in respect to the content of this document. The figures in this document serve as basic understanding and can differ from the actual state of the system.

Structure of warning messages and safety notes

The safety notes and warning messages in this document identify hazards and risks and they are created in accordance with ANSI Z535.6-2011 and the standards series ISO 3864.

The warning messages are structured as follows:

- Warning sign (only for injuries)
- Signal word indicating the hazard class
- Type and source of the hazard
- Consequences of non-observance
- Measures to avoid the hazard

⚠ + SIGNAL WORD
Type and source of the hazard! Consequences of non-observance. ▶ Measures to avoid the hazard. ▶ Further measure(s) to avoid the hazard.

Warning messages can also be embedded in the format of the surrounding text in order to avoid a *visual disruption* in a sequence. In this case, they are distinguished as follows:

Type and source of the hazard!
Consequences of non-observance.
▶ Measure(s) to avoid the hazard.

Warning messages are classified in hazard classes represented by the signal word. In the following, the warning messages are described in accordance to their hazard classes:

⚠ DANGER

Type and source of the hazard!

This warning message indicates a hazard of high risk that causes death or serious injury if not avoided.

▶ Measures to avoid the hazard.

⚠ WARNING

Type and source of the hazard!

This warning message indicates a hazard of medium risk that can cause death or serious injury if not avoided.

▶ Measures to avoid the hazard.

⚠ CAUTION

Type and source of the hazard!

This warning message indicates a hazard of low risk that can cause minor or moderate injury if not avoided.

▶ Measures to avoid the hazard.

NOTICE

Type and source of the hazard!

This warning message indicates a hazard that can lead to possible property damage.

▶ Measures to avoid the hazard.

Text styles

Various text attributes, notations, and text structures facilitate reading the document. The text attributes (highlightings) inside this document are defined as follows:

Attribute	Function
italic	highlights elements of the user interface and of control elements of the system
bold	highlights important information and keyboard input
`Courier New`	highlights file paths
[ ]	highlights elements of buttons on software user interfaces
`key`	highlights keys of the keyboard

Tasks or procedures that are described in steps are compiled to sequences in this document. A sequence consists of at least three components: objective, step, and result.

Component	Description
■	Indication of an objective. The sequence starts here.
1. 2. 3.	Indication of a sorted list of steps. The specified order must be observed.
☐	Indication of an intermediate result that is followed by further steps or the result.
☑	Indication of the result. The sequence is finished.
▶	Indication of a single step.

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The following symbols are used to indicate additional information:

This note indicates especially useful information.

Advanced information

This advanced information indicates special knowledge.

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At the moment of packaging, the system/product has been equipped with the latest software version and with the software and hardware documentation currently valid. By now, new versions of the documentation as well as new software versions might be available.

For all the latest news and updates visit the support area of our homepage: www.lpkf.com/en/support-services.

Contents

Introduction

This document describes how to optimize the processing quality of your ProtoLaser and how to avoid common faults. You will become familiar with the basic processing principles of the ProtoLaser and the corresponding software.

For all examples of processed materials that are displayed in this document, single-sided base material with a copper layer thickness of 18 µm (order no. 115968) has been used.

1 Basics

This chapter describes the following topics:

- Delamination method
- Hatching method
- Processing principle in the system software
- Checking the processed material

This information serves as a basis for successful identification of faults on your processed material. Consequently, you can find a suitable remedy faster and more efficiently.

The delamination method is used only for processing laminated PCB materials. The hatching method is used for processing laminated PCB materials and non-laminated PCB materials.

Laminated PCB materials usually consist of a conductive layer (e.g. copper) that is laminated with a bonding layer onto a non-conductive substrate (e.g. FR4):

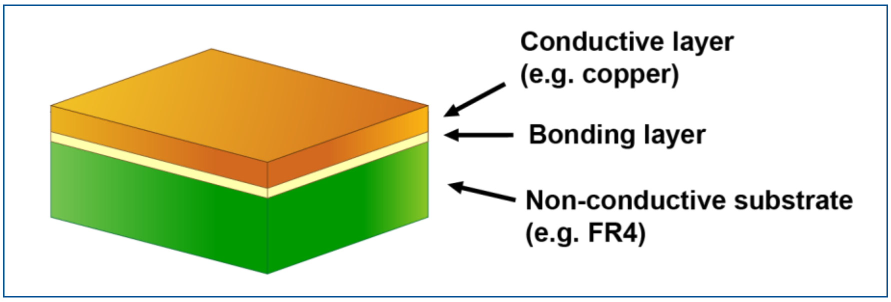


Fig. 1: Example of a laminated PCB material

Non-laminated PCB materials usually consist of a conductive layer (e.g. gold, copper) that is electrodeposited onto a non-conductive substrate (e.g. Aluminum oxide – Al_2O_3):

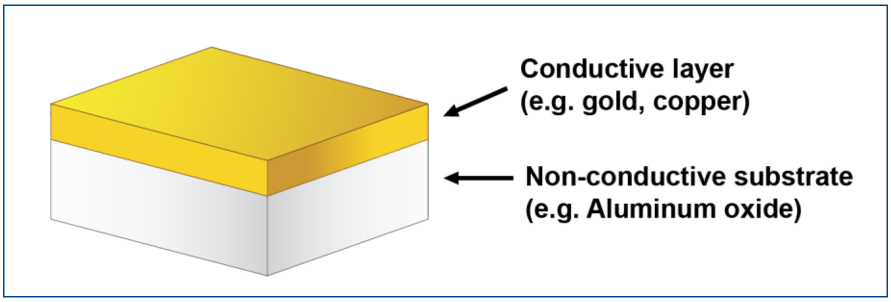


Fig. 2: Example of a non-laminated PCB material

The area to be removed from the conductive layer is called the rubout area. Both terms are used in this document.

1.1 Delamination method

The following figure shows an example layout of a PCB in the user guidance step *Toolpaths* that is used for explaining the delamination method:

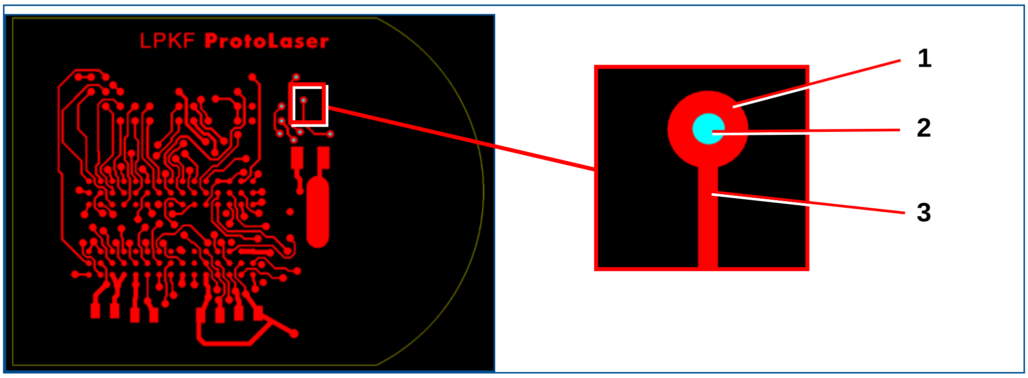


Fig. 3: **PCB layout**

1 Pad

2 Hole

3 Conductive track

The delamination method consists of the following stages:

1. Creating the isolation channels
2. Creating strips
3. Delaminating strips

Creating the isolation channels

Processing starts by creating isolation channels (i.e. contours) in the rubout area of the layer along the objects (conductive tracks, pads, etc.). The isolation channels separate the rubout area from the conductive track. The following figure shows the isolation channel along the conductive track in the user guidance step *Toolpaths*:

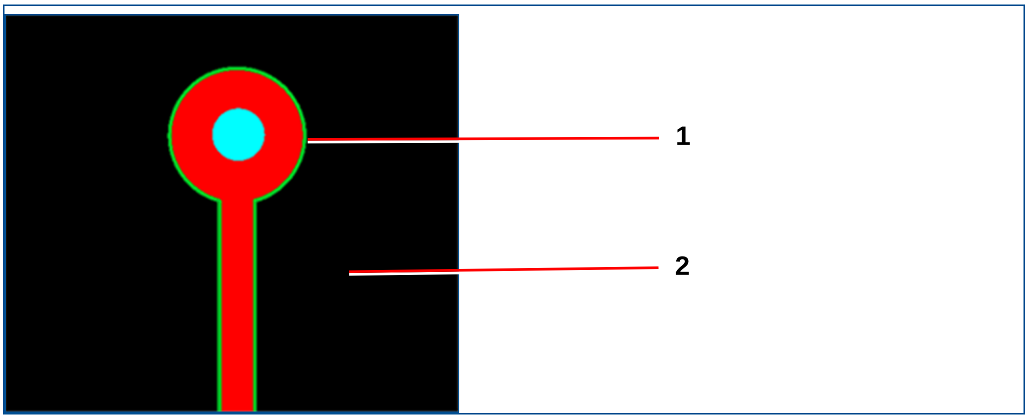


Fig. 4: **PCB layout | Isolation channel**

1 Isolation channel

2 Rubout area

Creating strips

The process is continued by cutting the rubout area into strips. The following figure shows the strips with the hatching lines in the user guidance step *Toolpaths*:

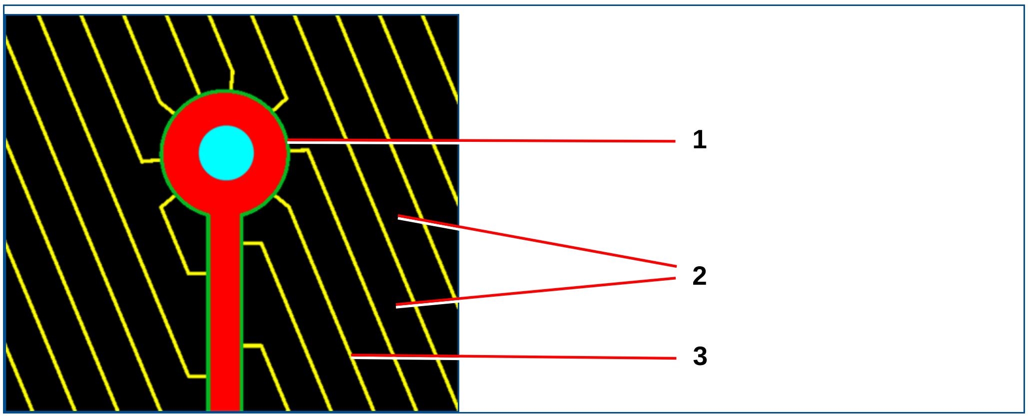


Fig. 5: **PCB layout | Structuring**

1	Isolation channel	**3**	Hatching line
2	Strips of the rubout area		

Delaminating strips

The final stage is the delamination of strips. Each strip of the rubout area is heated up until the conductive layer is removed from the substrate. The following figure shows heating lines in the user guidance step *Toolpaths* that are used for removing the strips of the conductive layer:

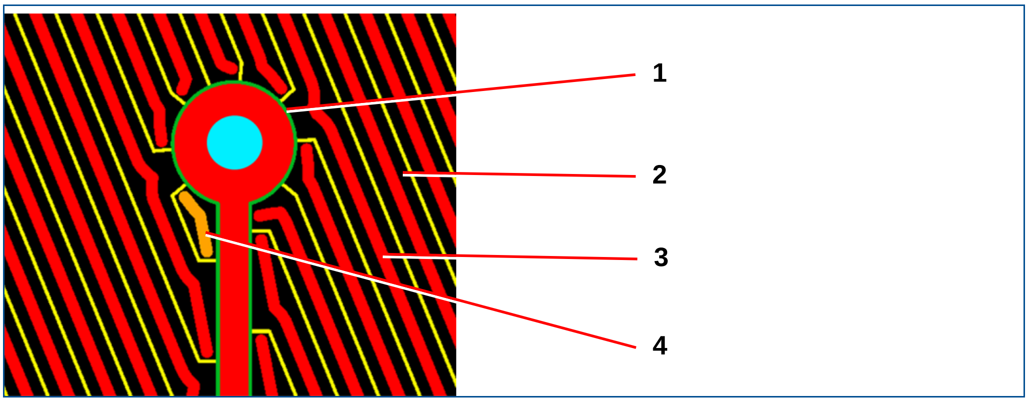


Fig. 6: **PCB layout | Delamination**

1	Isolation channel	**3**	Heating line
2	Strip of the rubout area	**4**	Short heating line

1.2 Hatching method

The following figure shows an example layout of an RF PCB in the user guidance step *Toolpaths*:

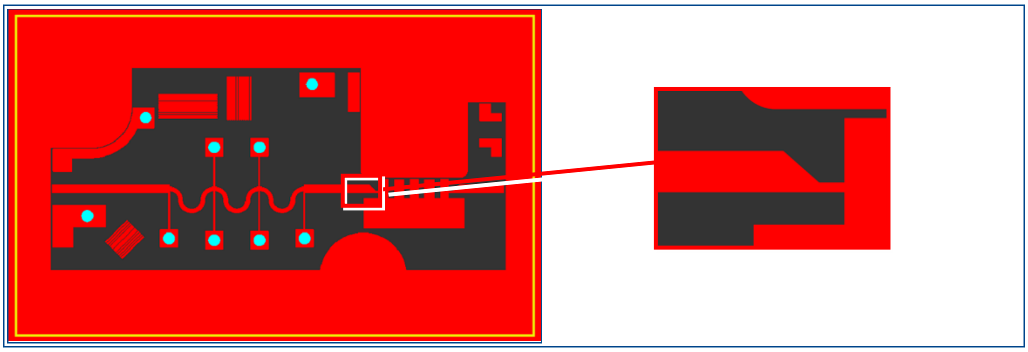


Fig. 7: RF PCB layout | RF geometry

The hatching method consists of the following stages:

1. Creating the isolation channels
2. Hatching

In comparison to the delamination method, the conductive layer is removed by ablation and not by delamination.

Creating the isolation channels

Processing starts by creating isolation channels (i.e. contours) along the objects (e.g. RF geometries). The isolation channels separate the rubout area from the PCB layout on the conductive layer. The following figure shows the isolation channel around the RF geometry in the user guidance step *Toolpaths*:

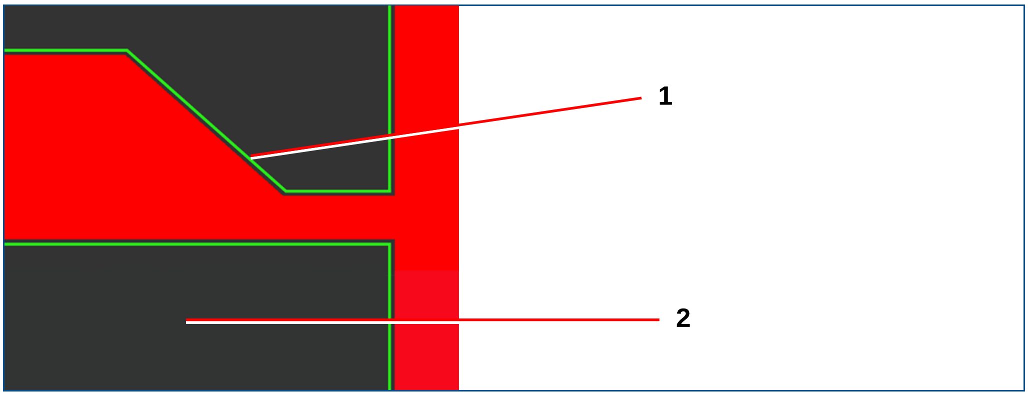


Fig. 8: PCB layout | isolation channel

1	Isolation channel	**2**	Rubout area

Hatching

Processing is continued. The rubout area is cut into lines that are very close to each other (vertically, horizontally or in both directions). The following figure shows the hatching lines (displayed as a grid) in the user guidance step *Toolpaths*:

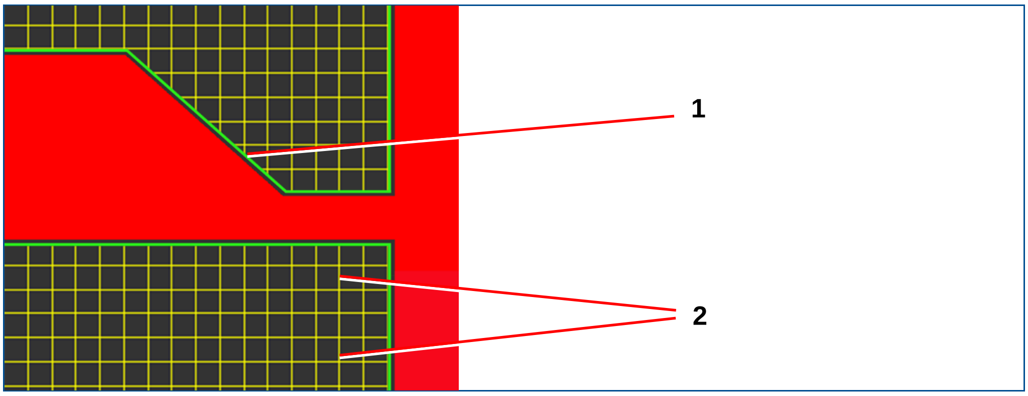


Fig. 9: **PCB layout | Structuring**

1	Isolation channel	**2**	Hatching line

The laser beam is wider than the hatching lines displayed in Figure 9 so that the structured hatching lines overlap during processing. This way all the material is removed from the rubout area.

1.3 Processing principle in the system software

This chapter describes the tools in the system software. Different tools are assigned to each material for processing. These tools consist of different parameters that have an impact on the processing quality. The parameters can be modified by the user, if necessary. The following figure shows the principle:

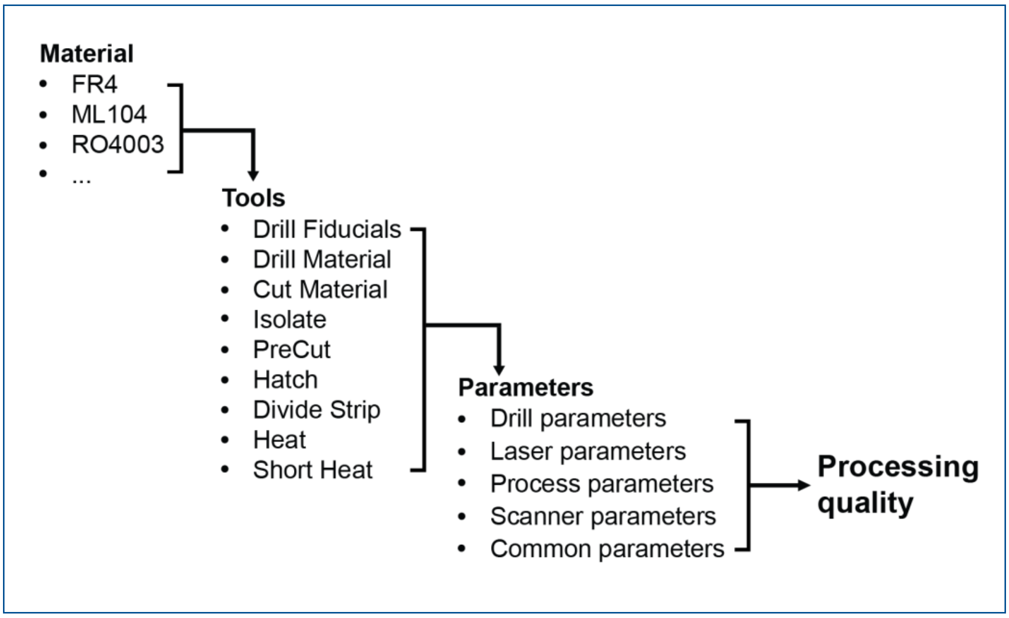


Fig. 10: **Processing principle in the system software**

To achieve a higher processing quality, it is important to understand the following:

- The functionality of every tool;
- The identification of a certain tool in the layout in the user guidance step *Toolpaths* (as calculated toolpaths in different colors);
- The identification of a certain tool on the processed material.

The following table provides an overview of the tools used by the system:

Tool	Functionality	Color of the toolpath in the layout
Drill Fiducials	Drills fiducials through the material.	White
Drill Material	Drills holes through the material.	Blue
Cut Material	Cuts through the material (e.g. for board outlines).	Yellow
Isolate	Creates isolation channels (i.e. contours) into the layout's conductive layer along the objects (conductive tracks, pads etc.).	Green
PreCut	Creates additional isolation channels in the conductive layer between scan fields (to improve stitching between scan fields).	Light blue
Hatch	Cuts the outer layer to be removed into strips.	Yellow
Divide Strip	Divides the longer strips of the outer layer to be removed to the maximum allowed length.	Light yellow
Heat	Heats the strips of the outer layer to be removed.	Red
Short Heat	Heats the short strips of the conductive layer to be removed.	Orange

Table 1: Tools in the system software

The following figure shows computed toolpaths in the user guidance step *Toolpaths*:

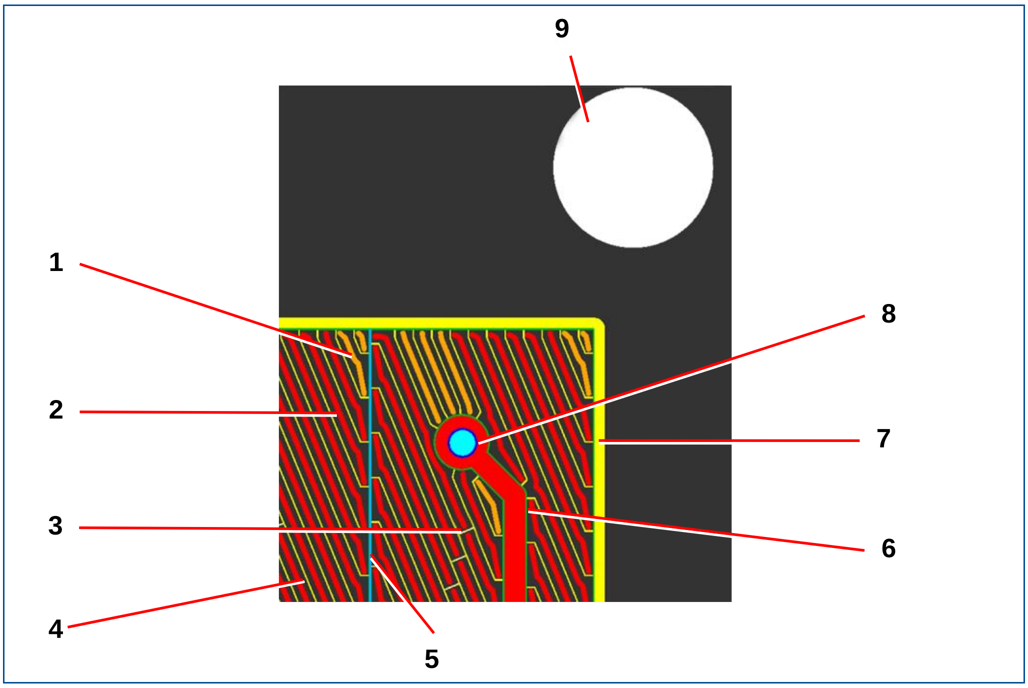


Fig. 11: Tools in the user guidance step *Toolpaths*

1 Short Heat
2 Heat
3 Divide Strip
4 Hatch
5 PreCut
6 Isolate
7 Cut Material
8 Drill Material
9 Drill Fiducials

The following figures compare a layout in the user guidance step *Toolpaths* (with computed toolpaths) with the same layout after it has been implemented on the material (without delamination):

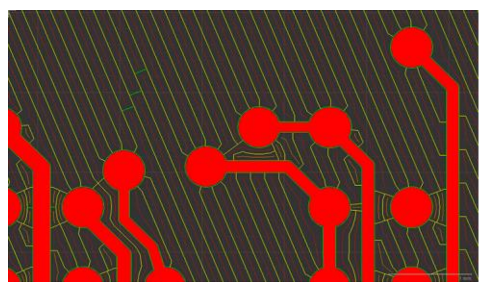


Fig. 12: Layout with computes toolpaths

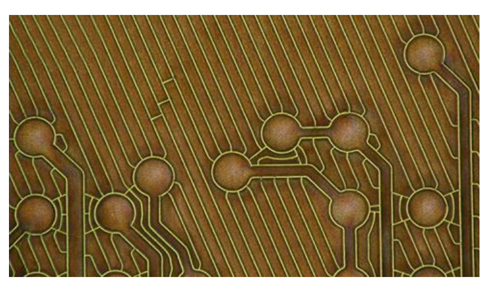


Fig. 13: Layout implemented on the material (without delamination)

1.4 Checking the processed material

The processed material is checked using a microscope. The following requirements must be met to successfully detect the defects on the processed material:

- Use single-sided material;
- Place the light source under the material;

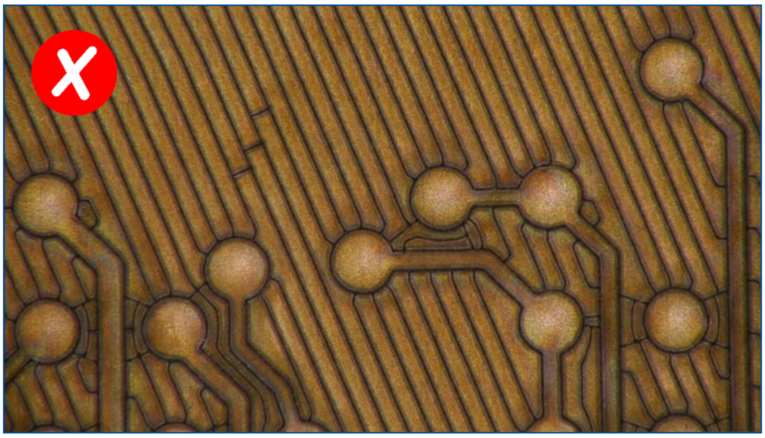


Fig. 14: Processed double-sided material under the microscope | no light source under the material

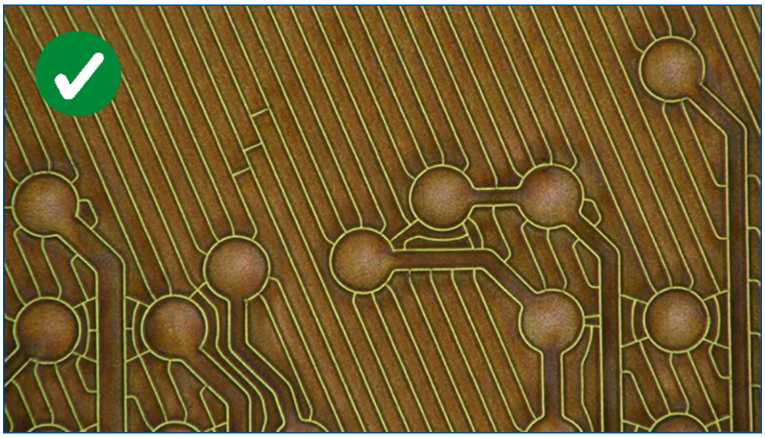


Fig. 15: Processed single-sided material under the microscope | light source under the material

2 Processing quality

This chapter describes typical faults that reduce the processing quality and the measures to eliminate them. In addition, it describes the scan field displacement and its effect on the processing quality. It also describes how to remove the copper residues after processing.

Fingerprints on the base material reduce processing quality

Fingerprints on the base material create an oxide layer on the material. This reduces the processing quality significantly. This is especially the case with IR laser systems.

Avoid fingerprints on the base material. Wear protective gloves if necessary. If fingerprints are present on the base material, clean them with LPKF Cleaner before processing.

2.1 Typical processing faults

An inappropriate material selection in the system software and associated inappropriate settings of the tool parameters are the most common reason for losses in processing quality. To counter that, the **tool parameters** have to be **adjusted**.

There are two typical processing faults:

- A conductive layer that has been removed incompletely;
- Burn-in effects on the material.

2.1.1 Incompletely removed conductive layer

The following reasons can cause a conductive layer not to be removed completely:

- The conductive layer has not been cut on the entire rubout area;
- The laser power is too low or the mark speed is too high;
- The wrong material type has been selected in the system software.

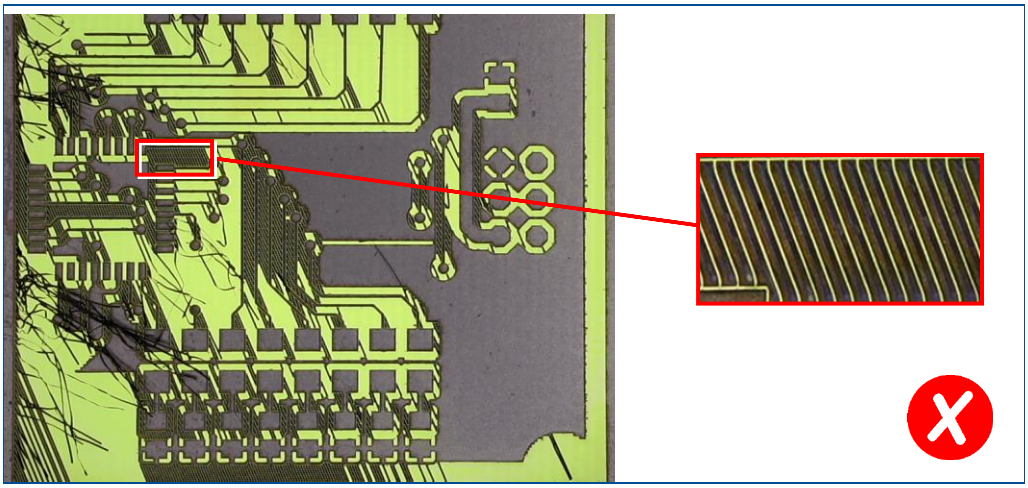


Fig. 16: **Incompletely removed conductive area**

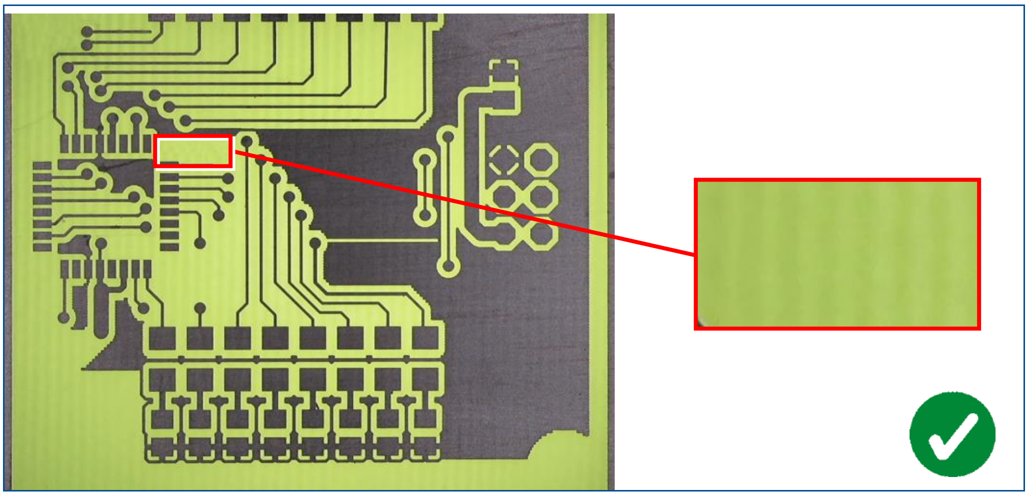


Fig. 17: **Completely removed conductive area**

The following table contains the most common processing faults and remedial measures:

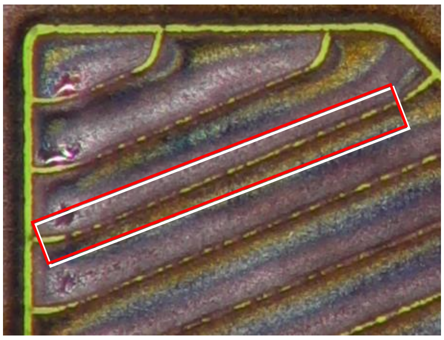
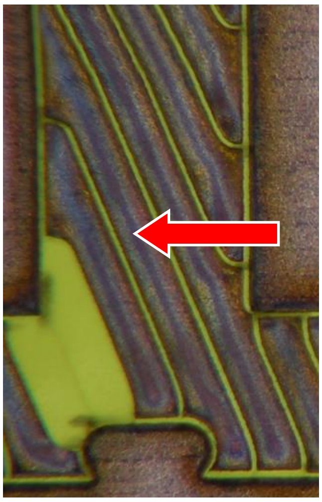
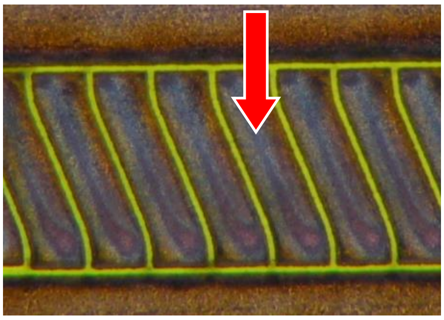
Figure	Fault	Remedy
	The isolation channel is not completely cut - thus, the strips of the conductive layer are not delaminated.	Reduce the *Mark speed* of the tool *Isolate* in steps of 5 % to 10 %.
	The hatching line is not completely cut - the strips of the conductive layer are not delaminated.	Reduce the *Mark speed* of the tool *Hatch* in steps of 5 % to 10 %.
	The isolation channel and the hatching line are completely cut but the strips of the conductive layer are not delaminated.	Reduce the *Mark speed* of the tool *Heat* in steps of 10 %.
	The isolation channel and the hatching line are completely cut but the short strips of the conductive layer are not delaminated.	Reduce the *Mark speed* of the tool *Short Heat* in steps of 10 %. (The threshold value for the short heat strip is set by default to 0.5 mm.)

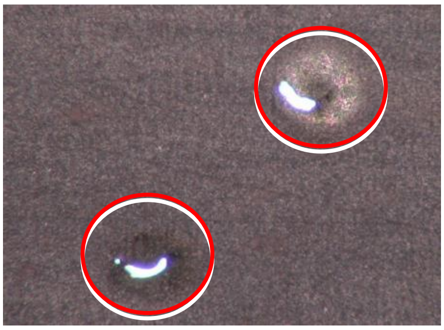
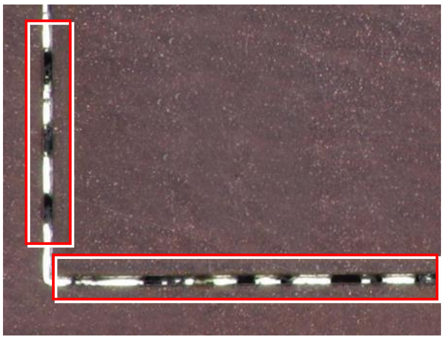
Figure	Fault	Remedy
	The holes are not completely drilled through (the figure shows the bottom view of the processed material).	Increase the *Repetitions* of the tool *Drill Material* in steps of 10 %.
	The cutouts (board outline) are not completely cut through.	Increase the *Repetitions* of the tool *Cut Material* in steps of 10 %.

Table 2: Processing quality | Incompletely removed conductive areas

For detailed information on setting the tool parameters invoke the help function by pressing `F1`.

2.1.2 Burn-in effects on the material

The following reasons can lead to burn-in effects on the material:

- The mark speed is too slow;
- The laser power is too high;
- The wrong material type has been selected in the system software.

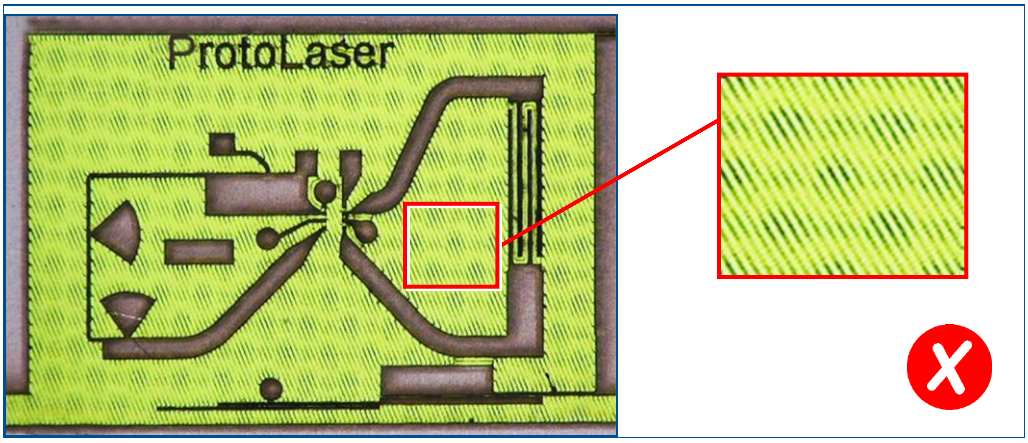


Fig. 18: **Burn-in effects**

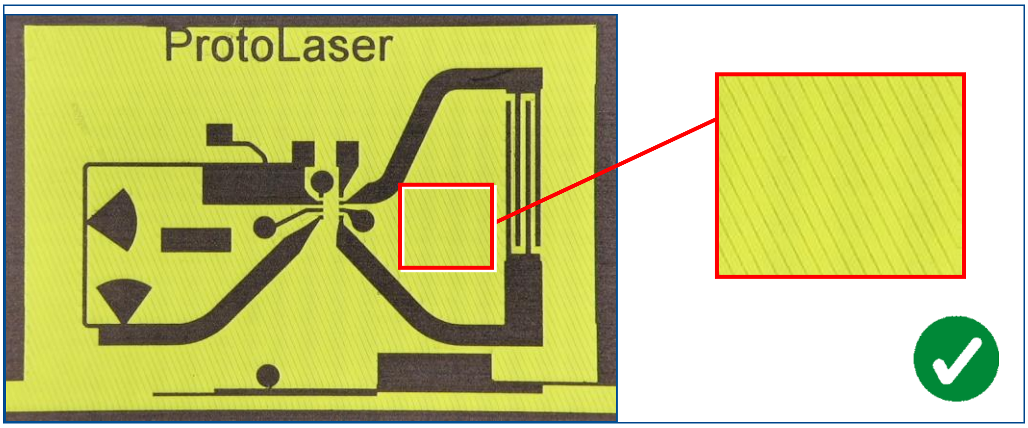


Fig. 19: **No burn-in effects**

The following table contains the most common processing faults and measures to eliminate them:

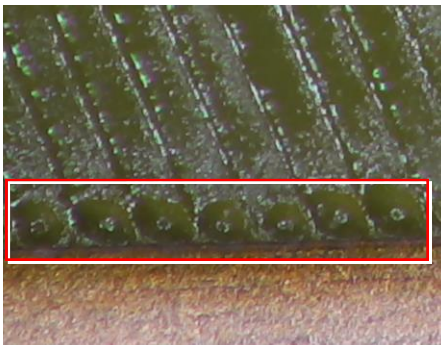
Figure	Fault	Remedy
	Burn-in effects of isolation channels and hatching lines.	Increase the *Mark speed* of the tool *Hatch* and the tool *Isolate* in 10 % steps.
	Burn-in effects (e.g. “check marks”) at the end of the heat lines.	Reduce the *Laser off delay* of the tool *Heat* in steps from 20 µs to 50 µs (this value can be negative).

Table 3: Processing quality | Burn-in effects on the material

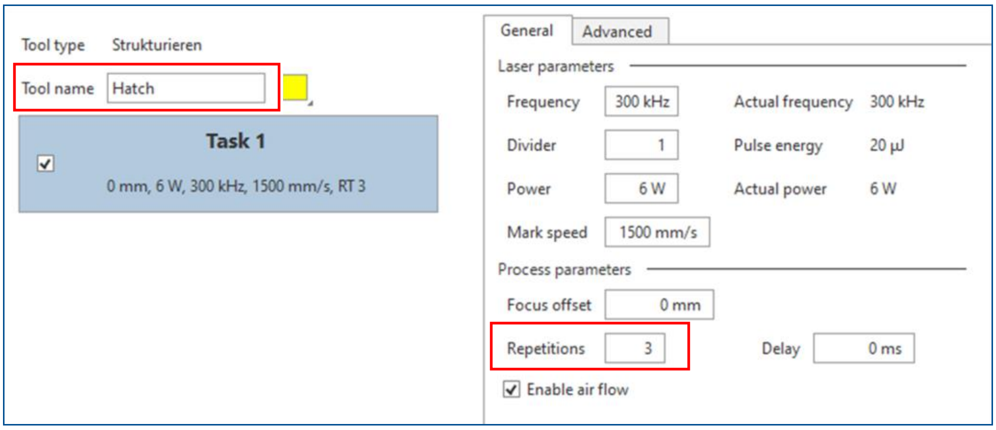
For detailed information on setting the tool parameters invoke the help function by pressing `F1`.

2.2 Improving the processing quality by scan field displacement

The scan field displacement feature can only be used with the hatching method on non-laminated materials.

For detailed information on the hatching method refer to chapter 1.

During hatching, the laser beam removes the conductive layer in multiple repetitions until it reaches the substrate. The number of *Repetitions* (in this example *3*) determines how many times a hatching toolpath is processed. The parameter *Repetitions* can be defined in the settings for the tool *Hatch*:



Tool type Strukturieren

Tool name Hatch

Task 1

☑ 0 mm, 6 W, 300 kHz, 1500 mm/s, RT 3

Laser parameters

Frequency 300 kHz

Actual frequency 300 kHz

Divider 1

Pulse energy 20 µJ

Power 6 W

Actual power 6 W

Mark speed 1500 mm/s

Process parameters

Focus offset 0 mm

Repetitions 3

Delay 0 ms

☑ Enable air flow

Fig. 20: *Repetitions* for the tool *Hatch*

The laser beam starts and ends each toolpath in the same point inside a scan field. The end point of a toolpath in one scan field and the start point of a toolpath in the next scan field meet at scan field intersections:

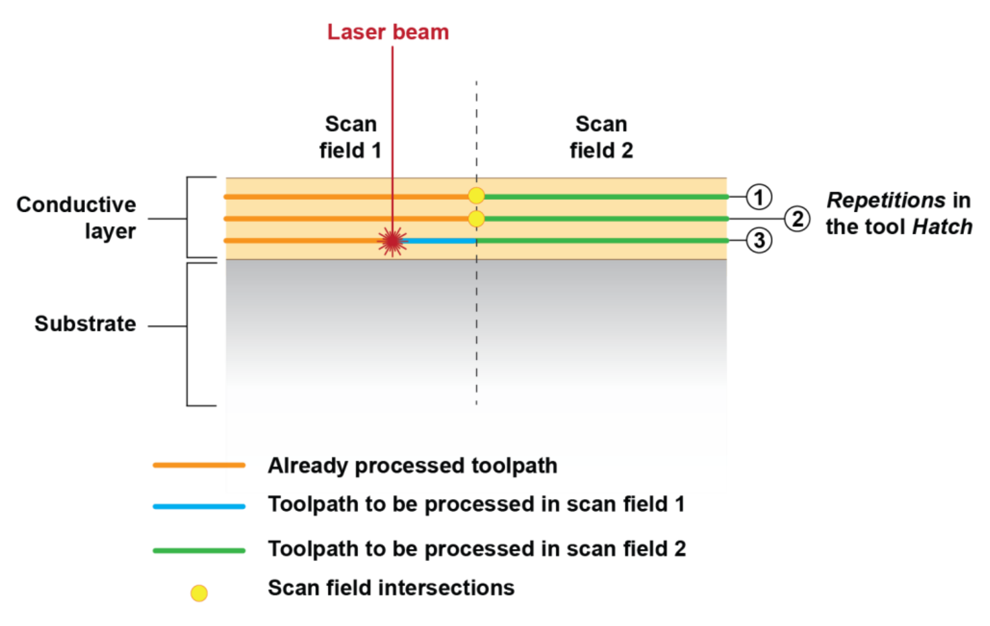


Fig. 21: Processing the toolpaths | Scan field intersections in a line

Any irregularities on scan field intersections are multiplied by each repetition. This lowers the processing quality, especially on thin flexible materials, since it causes the following:

- Perforation of the substrate;
- Lines of residual copper.

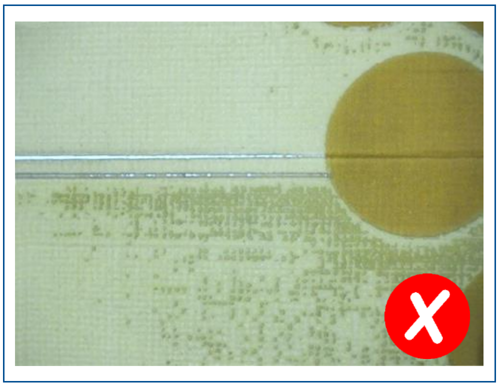
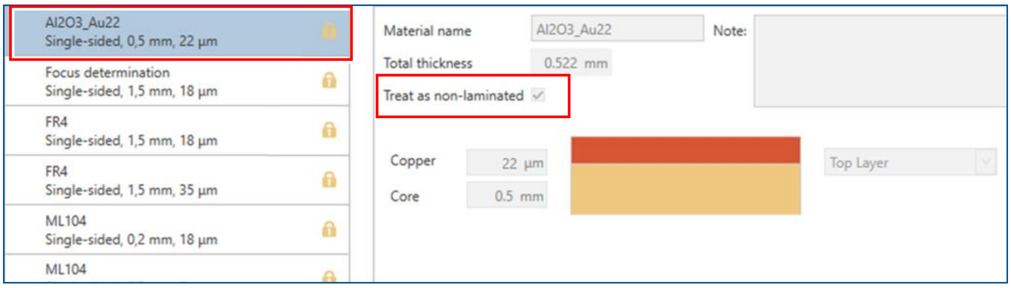


Fig. 22: Perforation of the substrate

Fig. 23: Line of residual copper

The scan field displacement feature in the system software improves the processing quality. It creates an offset between the start point (and consequently the end point) of each individual toolpath. To use the scan field displacement feature, perform the following:

1. Select a non-laminated material (in this example *Al2O3_Au22*). You can identify a non-laminated material by the activated check box *Treat as non-laminated*.



Al2O3_Au22
Single-sided, 0,5 mm, 22 µm

Focus determination
Single-sided, 1,5 mm, 18 µm

FR4
Single-sided, 1,5 mm, 18 µm

FR4
Single-sided, 1,5 mm, 35 µm

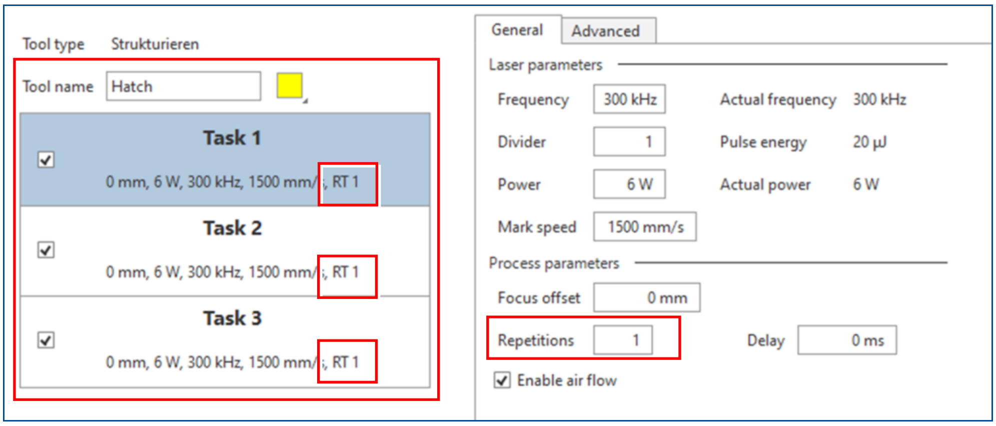
ML104
Single-sided, 0,2 mm, 18 µm

ML104

Material name Al2O3_Au22
Total thickness 0.522 mm
Treat as non-laminated ☑
Note:
Copper 22 µm
Core 0.5 mm
Top Layer

Fig. 24: Non-laminated material selected

2. Create copies of the *Task* in the tool *Hatch* (minimum two). The number of copies equals the number of *Repetitions* in the initial *Task* (see figure 20). Set **only one *Repetition*** for each *Task* (in this example 3 *Tasks* with *1 Repetition* each).



Tool type Strukturieren
Tool name Hatch

☑ Task 1
0 mm, 6 W, 300 kHz, 1500 mm/s, RT 1

☑ Task 2
0 mm, 6 W, 300 kHz, 1500 mm/s, RT 1

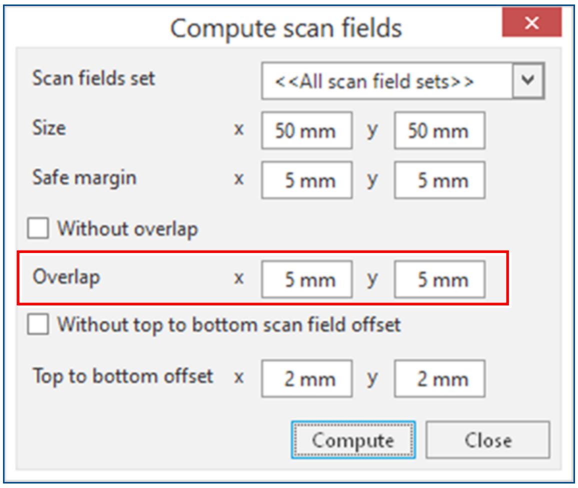
☑ Task 3
0 mm, 6 W, 300 kHz, 1500 mm/s, RT 1

Laser parameters
Frequency 300 kHz
Actual frequency 300 kHz
Divider 1
Pulse energy 20 µJ
Power 6 W
Actual power 6 W
Mark speed 1500 mm/s

Process parameters
Focus offset 0 mm
Repetitions 1
Delay 0 ms
☑ Enable air flow

Fig. 25: Multiple *Tasks* for the tool *Hatch*

3. Provide enough *Overlap* of the scan fields (in this example 5 mm).



Compute scan fields
Scan fields set <<All scan field sets>>
Size x 50 mm y 50 mm
Safe margin x 5 mm y 5 mm
☐ Without overlap
Overlap x 5 mm y 5 mm
☐ Without top to bottom scan field offset
Top to bottom offset x 2 mm y 2 mm

Fig. 26: *Overlap* of scan fields

Scan field intersections are no longer concentrated on single stitching lines only. They are dispersed across the *Overlap*:

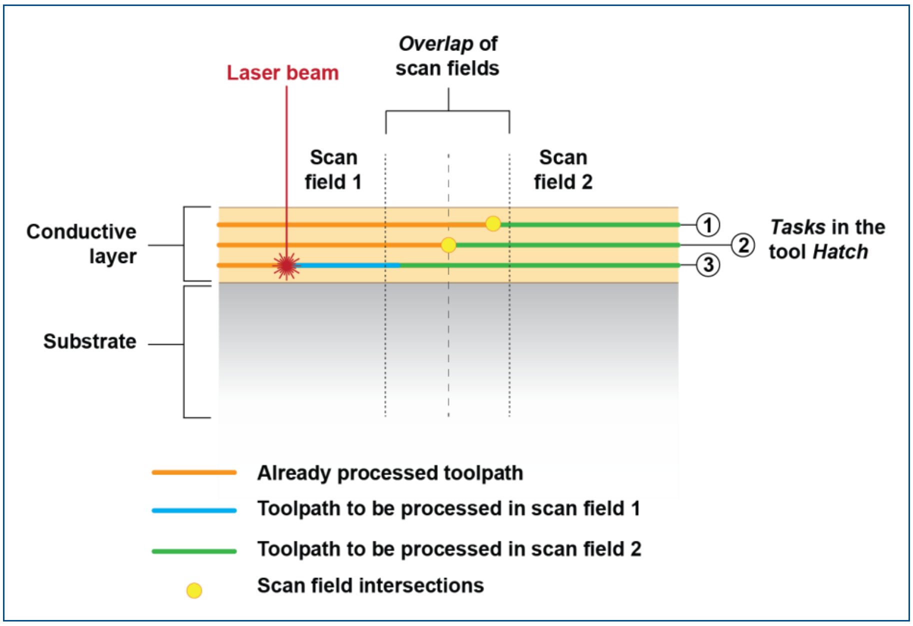
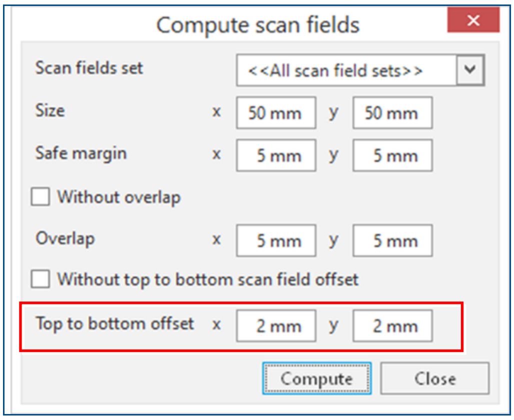


Fig. 27: Processing the toolpaths | Dispersed scan field intersections

When working with double-sided flexible materials activate the *Top to bottom offset* as well. This creates an offset between scan field positions on the top side and scan field positions on the bottom side of the PCB.



Scan fields set <<All scan field sets>>
Size x 50 mm y 50 mm
Safe margin x 5 mm y 5 mm
☐ Without overlap
Overlap x 5 mm y 5 mm
☐ Without top to bottom scan field offset
Top to bottom offset x 2 mm y 2 mm

Fig. 28: *Top to bottom offset*

The scan field displacement feature improves the processing quality. There is no perforation of the substrate, only barely visible stitching lines:

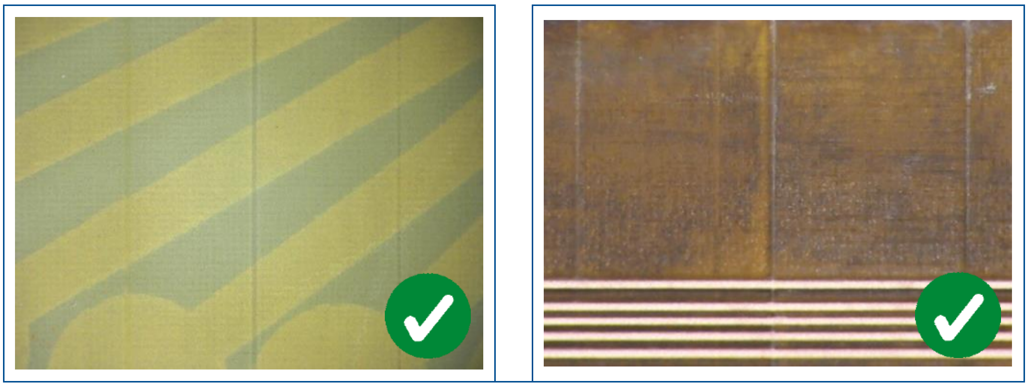


Fig. 29: Improved processing quality by scan field displacement

2.3 Removing the copper residues

When you are using the hatching processing method, it is sometimes not possible to remove all copper without damaging the substrate. This is especially important when working with delicate flexible materials.

The copper deposition on the base material during galvanic through-hole plating can be nonuniform. This especially affects the area along the through holes and is a normal effect of galvanic through-hole plating. After processing, some copper residues can remain on the PCB, particularly along the through holes.

The following figures show copper residues along the through holes:

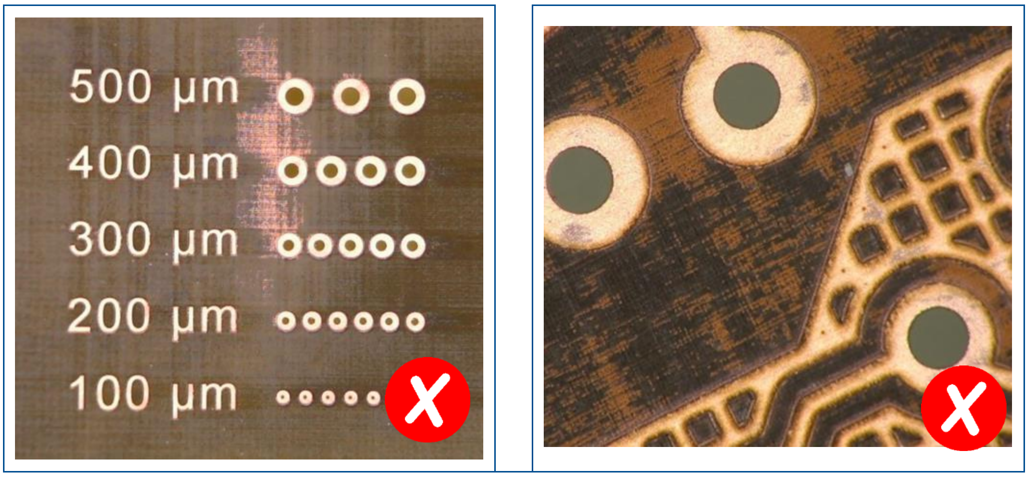


Fig. 30: Copper residues along the through holes

If you remove the copper residues by laser structuring, you risk damaging the substrate. The LPKF ViaCleaner that is used in the through-hole plating process with the Contac S4 can also be used to remove the copper residues.

Perform the following steps:

1. Insert and fasten the PCB (still attached to the base material) into the PCB holder for flexible PCBs (order code: 10067533).
2. Insert the PCB holder into the tank with the ViaCleaner solution (tank 4).
3. Start the cleaning step of Contac S4 (*phase 4*).

   The cleaning time depends on the application and on the level of depletion of the cleaning solution.
4. When *phase 4* is finished, remove the PCB holder from tank 4.
5. Check the PCB for any remaining copper residues.
6. Repeat the process until all unwanted copper residues are removed.

Prolonging the process creates a risk of removing the existing structures on the PCB. The ones affected are:

- Structures with a low overall copper thickness;
- Small structures (e.g., copper traces with a width smaller than 100 µm).

The following figures show no copper residues along the through holes:

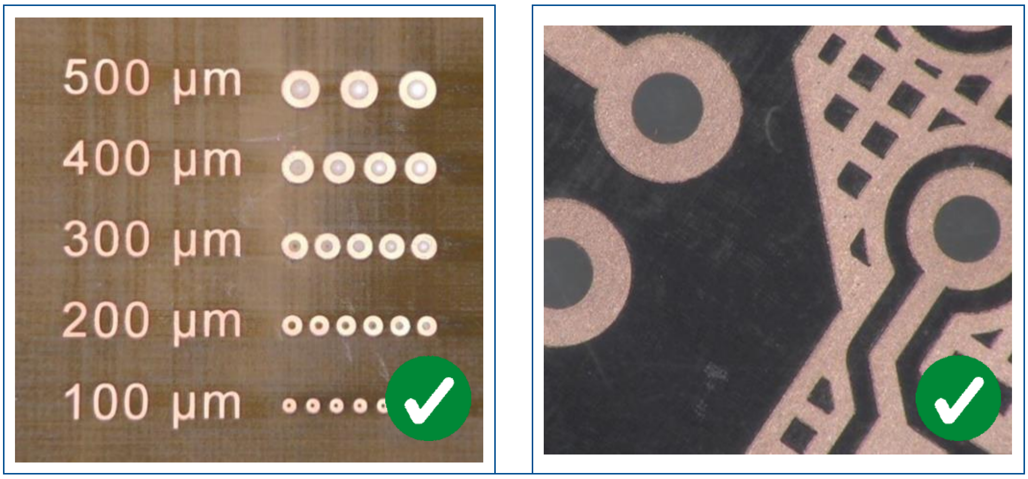


Fig. 31: **No copper residues present**

Removing copper residues on small layouts

In case of small layout sizes, you do not need to clean the entire base material. Remove the PCB from the base material and perform cleaning in a smaller container (e.g. a Petri dish).

3 Scanner parameters

This chapter describes the scanner parameters and explains their effect on processing.

The scanner parameters have an effect on the functionality of the processing head (scanning head). The processing head deflects and focuses the laser beam. The mirrors are subject to mass inertia as a result of high accelerations and speeds. The tracking error is compensated by means of delay times.

The following table shows the parameters and units that determine the movements of the scanner:

Scanner parameters	Unit
Jump delay	µs
Jump speed	mm/s
Laser on delay	µs
Laser off delay	µs
Mark delay	µs
Mark speed	mm/s
Polygon delay	µs

Table 4: Scanner parameters

Jump delay

The value of this parameter represents a waiting period at the end of a jump between two vectors. The jump delay is necessary to provide the mirrors with a settle time in order to prevent oscillations in the next vector. A jump delay that is too long generates a longer processing time but no other visible effects.

The following figure shows a distortion of the vector in case of a jump delay that is too short:

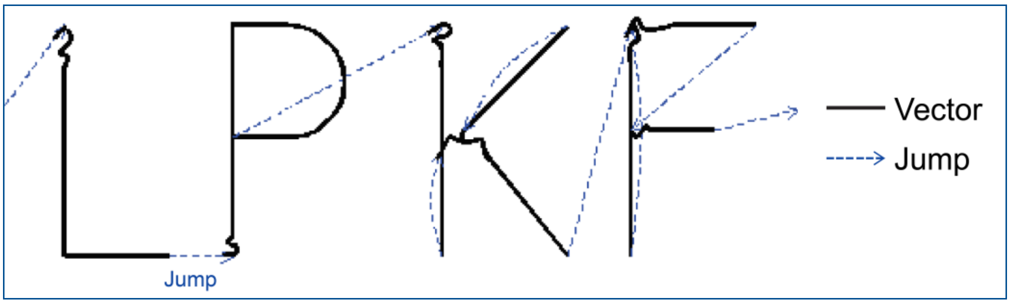


Fig. 32: Jump delay too short

The mirrors of the scanner have not yet settled down after the jump. Oscillations occur at the beginnings of the vectors.

Jump speed

The value of this parameter represents the jump speed of the mirrors between the vectors, i.e. the movement of the mirrors when the laser gate is closed.

Laser off delay

The value of this parameter represents the waiting period at the end of a vector (or a sequence of vectors) before the laser gate is closed for the following jump to the next vector. Because of the tracking error, the mirrors only reach the end of a vector (or a sequence of vectors) with a delay. To prevent parts of a vector from missing at its end, the laser gate is only closed after a waiting period.

The following figure shows a distortion of the vector in case of a laser off delay that is too short:

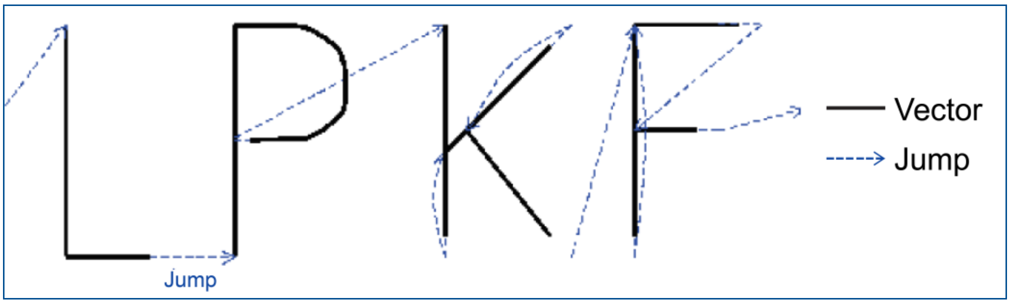


Fig. 33: Laser off delay too short

The laser gate closes before the mirrors have reached their end position. The ends of the vectors are missing.

The following figure shows a distortion of the vector in case of a jump delay that is too short:

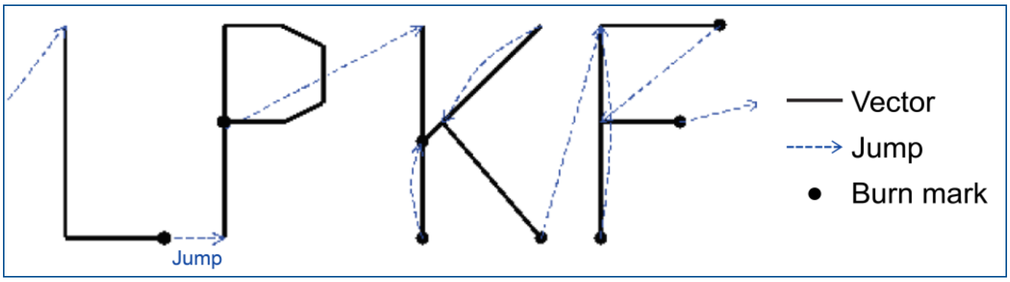


Fig. 34: Laser off delay too long

The laser gate remains open although the mirrors have already reached their final position. Burn marks are visible at the ends of the vectors.

The recommended value for this parameter is **100 µs**.

Laser on delay

The value of this parameter represents the waiting period at the start of a vector (or a sequence of vectors) before the laser gate is opened for the vector. Due to their acceleration phase, the mirrors only reach the mark speed with a delay. To prevent the laser beam from affecting the material to be processed too strongly during the acceleration phase, the laser gate is not opened until the required mark speed is reached. The result of a laser on delay that is too long are missing parts at the beginning of vectors.

The following figure shows a distortion of the vector in case of a laser on delay that is too short:

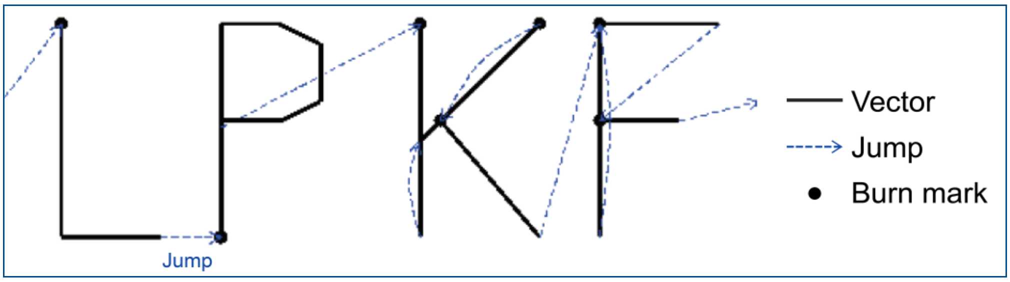


Fig. 35: **Laser on delay too short**

The laser gate opens although the mirrors have not yet reached their necessary mark speed. Burn marks are visible at the beginnings of the vectors.

The following figure shows a distortion of the vector in case of a laser on delay that is too long:

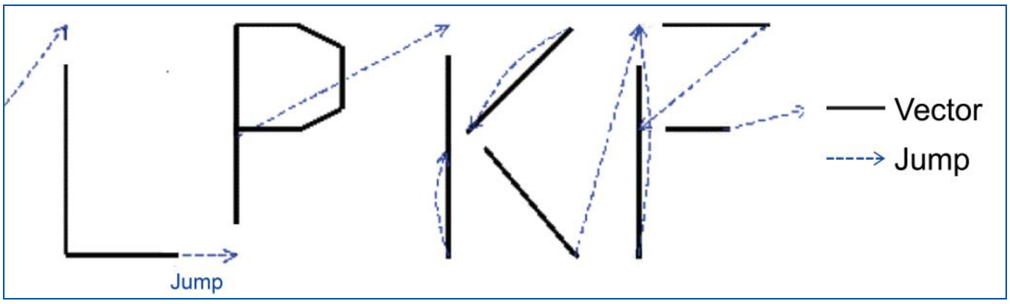


Fig. 36: **Laser on delay too long**

The laser gate opens too late so that the beginnings of the vectors are missing.

Mark delay

The value of this parameter represents a waiting period at the end of a vector (or a sequence of vectors). The mark delay is necessary to compensate the tracking error. No effect is visible if the mark delay is too long, but the processing time is increased.

The following figure shows a distortion of the vector in case of a mark delay that is too short:

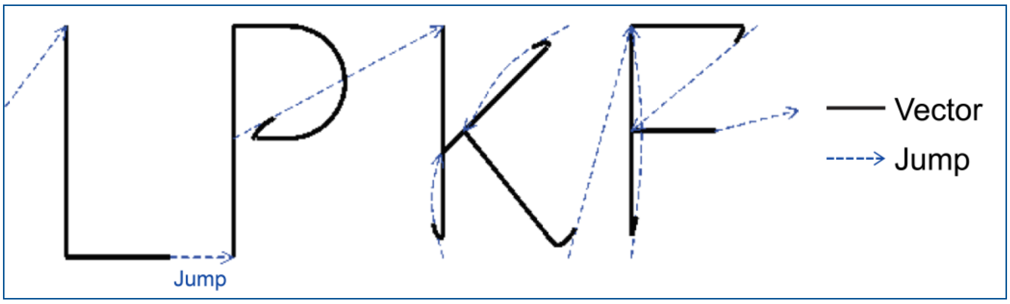


Fig. 37: **Mark delay too short**

The mirrors have not yet reached their final position at the end of a vector. The ends of the vectors are distorted.

The recommended value for this parameter is **600 µs**.

Mark speed

The value of this parameter represents the speed of the laser beam during the processing of the vectors, i.e. during the movement of the mirrors with opened laser gate. This value is, in addition to the frequency, decisive for the material processing. The slower this mark speed is set, the more the energy is applied to the target material per area. The overlap of the single pulses is increased.

The value for this parameter depends on the application.

Polygon delay

The value of this parameter represents a waiting period between the individual vectors of a sequence of vectors. A tracking error occurs as a result of the change in direction between individual vectors of a vector sequence. The polygon delay compensates this tracking error, thus preventing the formation of radii at the transitions between the individual vectors of a vector sequence.

The following figure shows a distortion of the vector in case of a polygon delay that is too short:

Radii (roundings) are formed on the transitions between the vectors.

The following figure shows a distortion of the vectors in case of a polygon delay that is too long:

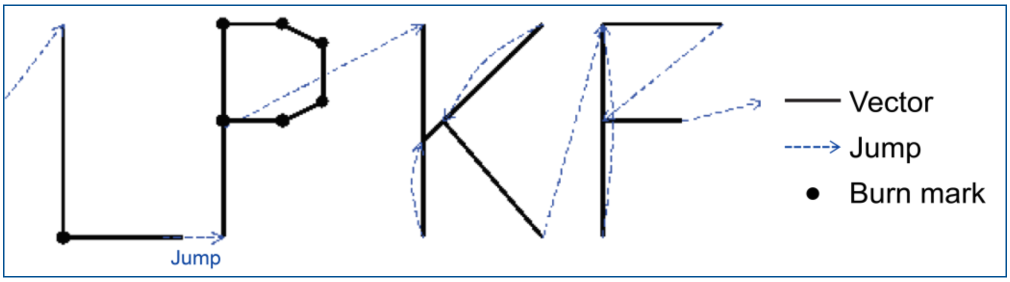
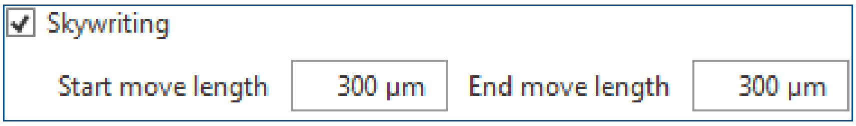


Fig. 38: Polygon delay too long

The mirrors move too slowly or even stop between the vectors. Burn marks are visible at the transitions between the vectors.

The recommended value for this parameter is **0 µs**.

Skywriting



☑ Skywriting

Start move length 300 µm

End move length 300 µm

Fig. 39: Parameter *Skywriting*

This parameter extends the scanner moves with closed laser gate at the start and end of individual vectors. The purpose of this function is to improve the accuracy of the geometry and eliminate effects on the material that are caused by acceleration and deceleration movements of the scanner. This method causes the mirrors to move already with constant speed when the laser gate is opened. The effect of the laser beam on the material is thus constant over the entire structured vector.

The values set for the parameters *start move length* and *end move length* determine the length of the extended movements of the mirrors.

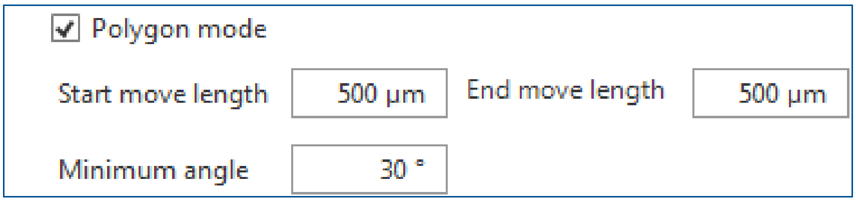
The values to set for the length of start moves and end moves depend on the mark speed.

Examples of recommended values:

300 µm *start move length*
300 µm *end move length*
500 mm/s *mark speed*

1500 µm *start move length*
1500 µm *end move length*
2500 mm/s *mark speed*

Polygon mode



☑ Polygon mode

Start move length 500 µm

End move length 500 µm

Minimum angle 30 °

Fig. 40: *Polygon mode* parameters

The *Polygon mode* is a sub-function of the parameter *Skywriting*. It is used for improving the tracking error at changes in direction between individual vectors of a vector sequence (see Polygon delay). The scanner executes a loop with closed laser gate instead of sharp turns.

The values set for the parameters *start move length* and *end move length* define the length of the extended movement of the mirrors when structuring sharp turns.

The parameter *minimum angle* defines the limit of the angle between two vectors where the *polygon mode* is used.

The following figure shows an example how skywriting enables structuring of precise and sharp turns without radii or burn marks:

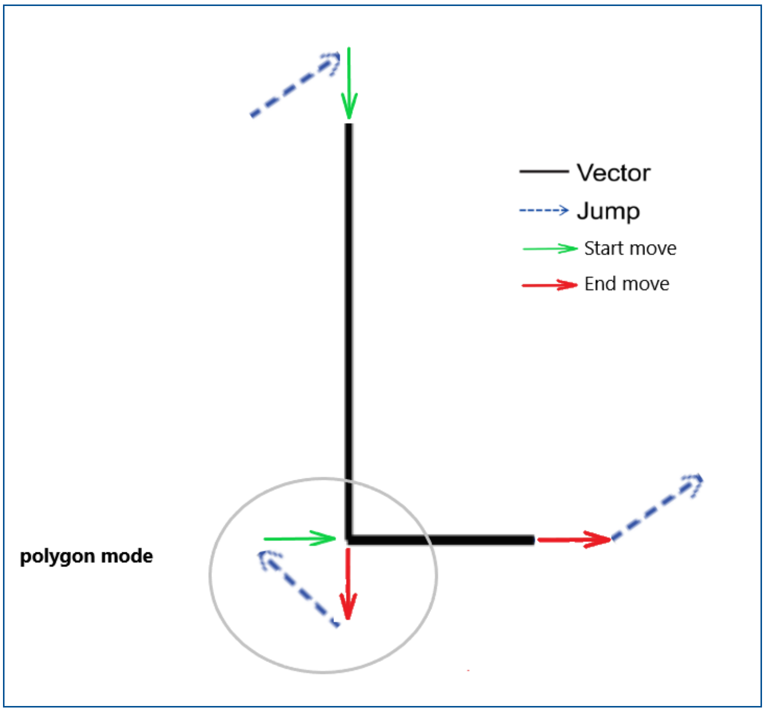


Fig. 41: ***Skywriting* example**

The values to set for the length of start moves and end moves depend on the mark speed.

Examples of recommended values:

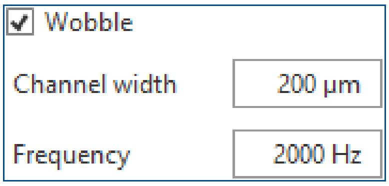
300 µm *start move length*
300 µm *end move length*
500 mm/s *mark speed*

1500 µm *start move length*
1500 µm *end move length*
2500 mm/s *mark speed*

Laser on delay and laser off delay

Use the functions Laser on delay and Laser off delay combined with skywriting to define exact positions. The laser gate is opened at these positions in order to achieve correct vector lengths and correct intersection points of the vectors. Observe that the polygon mode has to be used for this.

Wobble



☑ Wobble

Channel width 200 µm

Frequency 2000 Hz

Fig. 42: Parameter *Wobble*

This parameter adds an additional wobble scan pattern to the computed toolpaths.

This method can be useful when cutting or drilling certain materials and when structuring within narrow channels. Instead of creating several parallel lines within channels, *wobble* can be used with the desired channel width (amplitude).

The following figure shows the wobble principle:

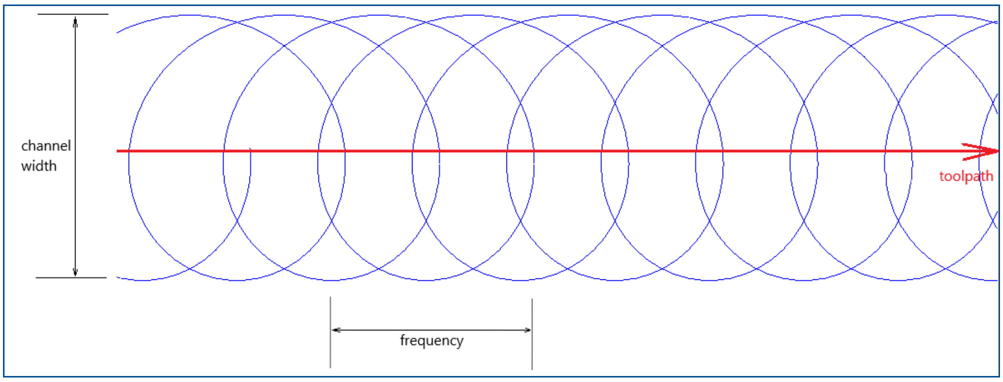


Fig. 43: Wobble principle

The parameter *Channel width* defines the wobble amplitude and thus the width of the scan pattern.

The parameter *Frequency* defines the number of oscillations per second.

Influencing factors

In order to cut through material efficiently or remove conductive material, a suitable parameter set has to be used to achieve laser beam coverage over the entire structuring area.
The mark speed, the beam diameter, and the frequency (laser) also have to be considered together with the *Channel width* and the *Frequency* (wobble).

The following parameters and figures show examples for complete overlap across the entire structuring area:

Parameter	Value	Unit
Frequency (laser)	200	kHz
Mark speed	50	mm/s
Beam diameter	15	µm
Frequency (wobble)	2500	Hz
Channel width	50	µm

Table 5: Parameters

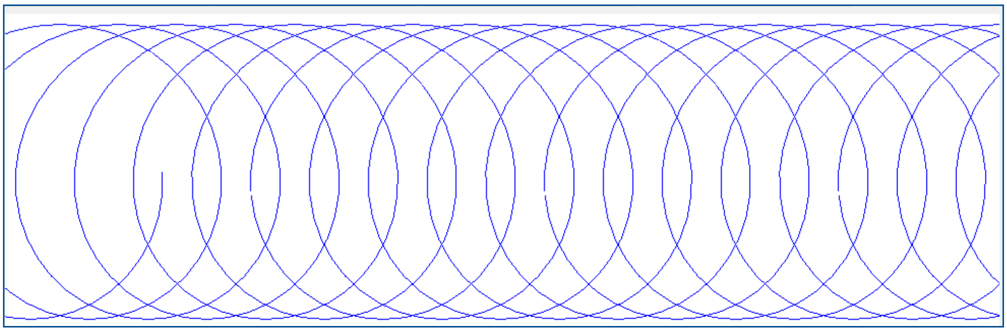


Fig. 44: Example of laser beam path with wobble function

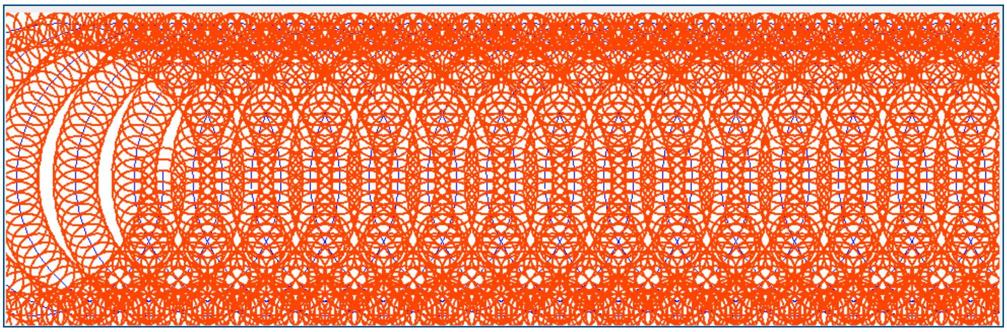
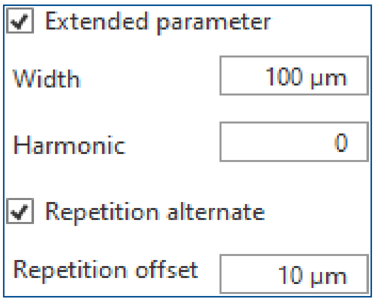


Fig. 45: Example of a laser beam path with wobble function (with laser pulses displayed)

Wobble – Extended parameters



☑ Extended parameter

Width 100 µm

Harmonic 0

☑ Repetition alternate

Repetition offset 10 µm

Fig. 46: ***Extended parameters***

The section *Extended parameters* allows to further influence the wobble scan patterns.

The parameter *width* defines the wobble amplitude in the direction of cutting. If this value differs from the *Channel width* the scan pattern can be elliptical as the following examples show:

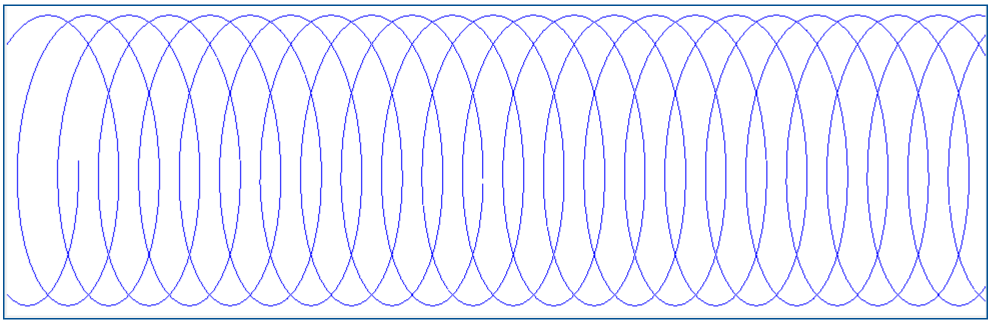


Fig. 47: **Example of a scan pattern with a *channel width* larger than the *width* in *extended parameters***

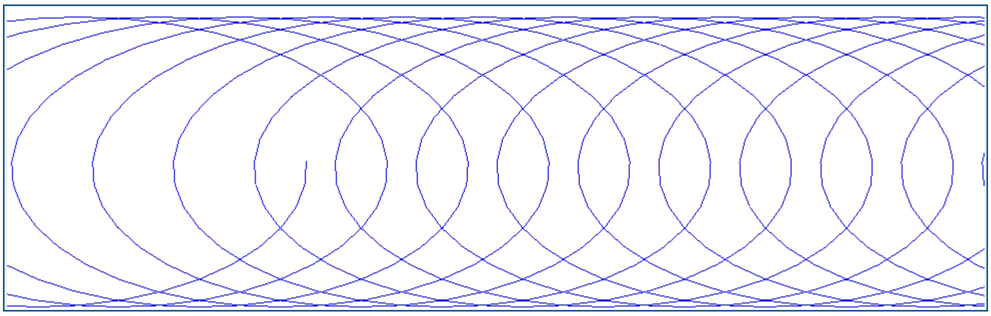


Fig. 48: **Example of a scan pattern with a channel width smaller than the *width* in *extended parameters***

The parameter *Harmonic* (0 to 4) is used for setting various wobble shapes:

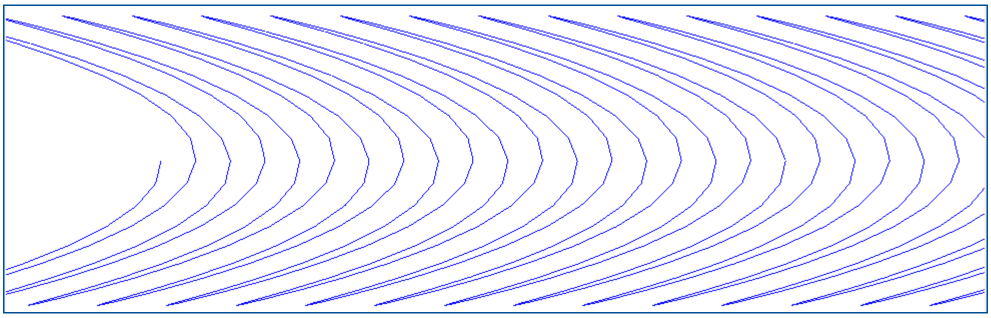


Fig. 49: **Example of scan pattern with parameter *Harmonic*=1**

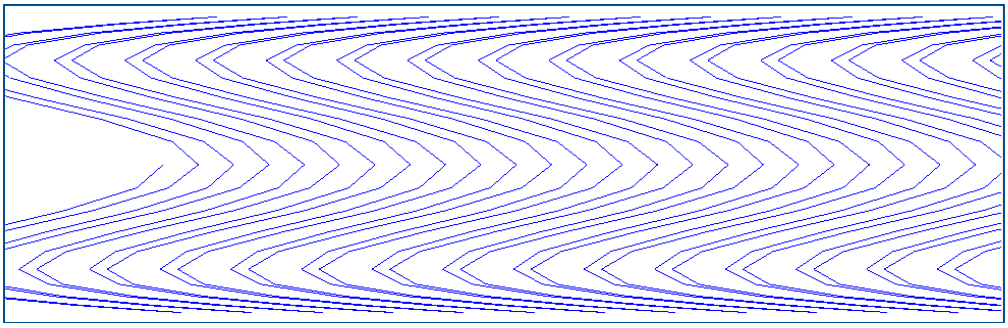


Fig. 50: Example of scan pattern with parameter *Harmonic*=2

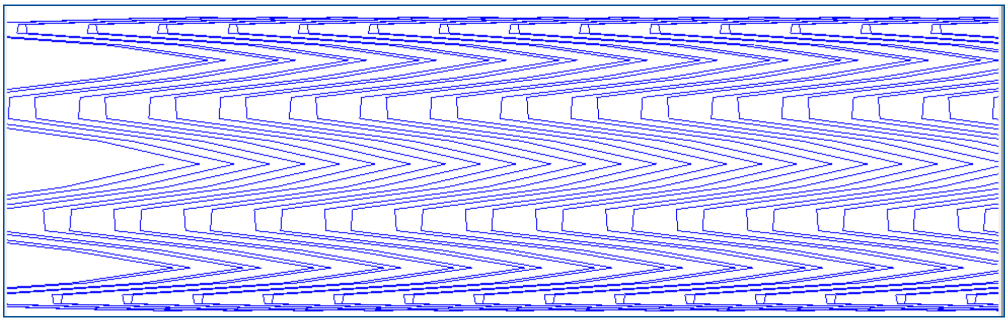


Fig. 51: Example of scan pattern with parameter *Harmonic*=3

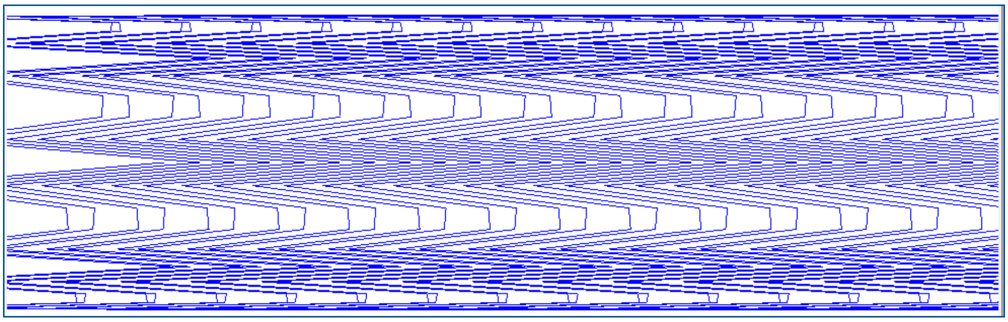


Fig. 52: Example of scan pattern with parameter *Harmonic*=4

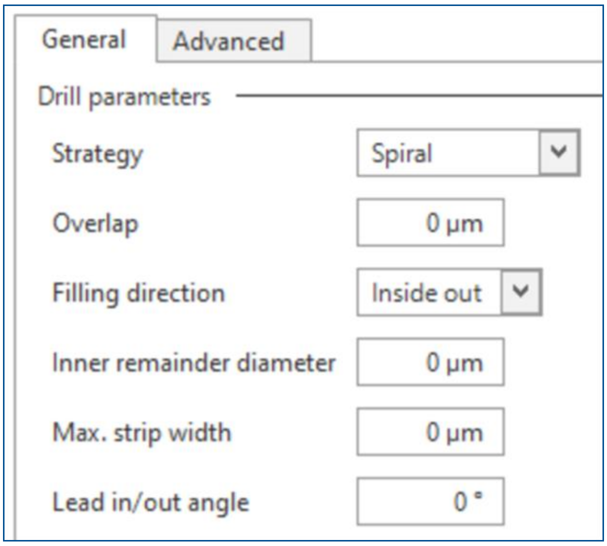
The parameter *Repetition alternate* reverses the direction of the scan pattern with each scan run/each repetition when activated. This enables producing a smoother cut edge.

The parameter *Repetition offset* creates an offset for each scan run/each repetition. This prevents marking or cutting on the same scan path in case of several repetitions and thus enables a better surface quality.

4 Drill parameters

This chapter describes the drill parameters and explains their effect on processing.

The drill parameters define the paths of the laser beam when drilling a hole. Depending on the base material and on the diameter of the hole, there are different approaches suitable to achieve optimum processing quality. The drill parameters can be defined in the settings for the tool type *Drilling*. The following figure displays the drill parameters:



Drill parameters

Strategy: Spiral
Overlap: 0 µm
Filling direction: Inside out
Inner remainder diameter: 0 µm
Max. strip width: 0 µm
Lead in/out angle: 0 °

Fig. 53: **Drill parameters**

Strategy

This parameter determines how the laser beam drills a hole.

The following options are available:

Option	Description	Figure
Outline	This option creates a single toolpath that is positioned inside the hole outline. This option disables all other drill parameters apart from *Lead in/out angle*. This option is suitable for drilling thin materials and for drilling fiducials.	

Option	Description	Figure
Concentric fill	This option creates multiple concentric toolpaths, each with a smaller radius. The outer toolpath is positioned inside the hole outline. Depending on the other drill parameters, there are two possibilities: – The toolpaths completely fill the hole. – The toolpaths fill a ring of a specific width. This option is suitable for drilling thick materials.	
Spiral	This option creates a toolpath in a form of a spiral. Depending on the other drill parameters, there are two possibilities: – The toolpath completely fills the hole. – The toolpath fills a ring of a specific width. Processing a single uninterrupted toolpath is an advantage since the laser gate is kept open. No *Laser on delays* or *Laser off delays* are needed. This option is suitable for drilling for drilling delicate materials where *Laser on delay* and *Laser off delay* could cause problems.	

Table 6: ***Strategy* options**

Overlap

This parameter determines by how much the concentric toolpaths overlap one another.

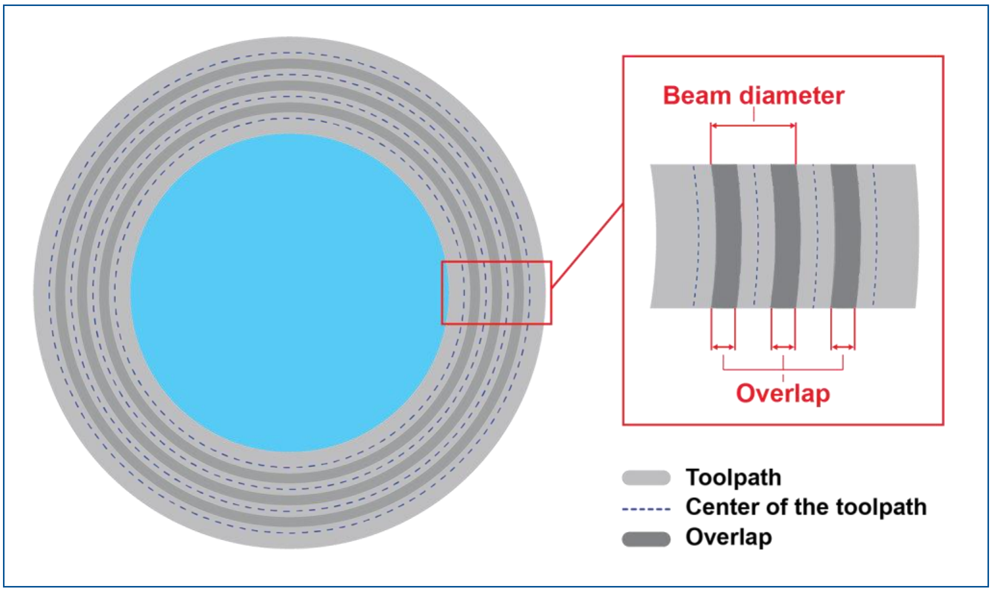
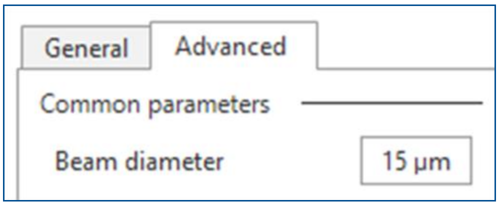


Fig. 54: **Overlap**

The toolpath width is determined by the parameter *Beam diameter* (in the tab *Advanced*):



Common parameters

Beam diameter 15 µm

Fig. 55: **Parameter *Beam diameter***

If the value of the *Overlap* is set to 0 µm, the distance between the center of the concentric toolpaths equals the *Beam diameter*. The typical setting for this parameter is 10 % to 20 % of the beam diameter.

Filling direction

This parameter determines the processing order of the toolpaths.

The following options are available:

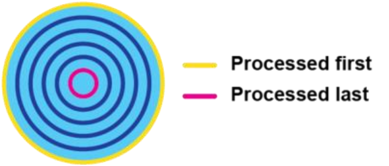
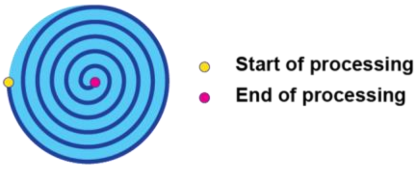
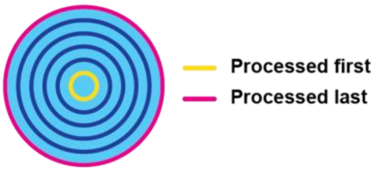
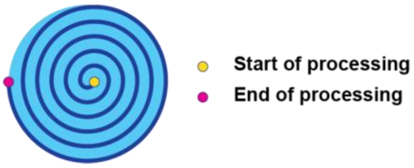
Option	Description	Figure
Outside in	The strategy *Concentric fill* processes the outermost toolpath first and the innermost toolpath last.	
	The strategy *Spiral* processes the toolpath starting at the outline of the hole and ends at the center.	
Inside out	The strategy *Concentric fill* processes the innermost toolpath first and the outermost toolpath last.	
	The strategy *Spiral* processes the toolpath starting at the center of the hole and ends at the outline.	

Table 7: *Filling direction* options

Inner remainder diameter

This parameter determines the diameter of the circle in the center of the hole that is not being processed. The following figure shows the *Inner remainder diameter*:

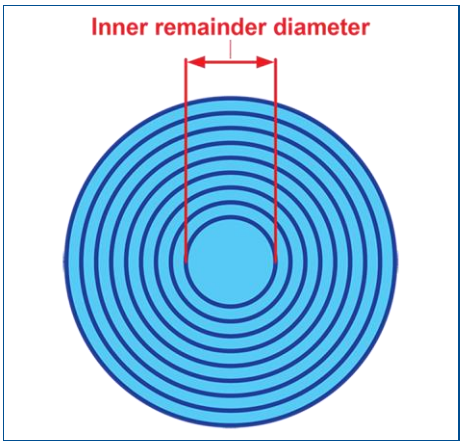


Fig. 56: Inner remainder diameter

Using this parameter avoids the center of the hole penetrate or even puncture the underlying material. The typical setting for this parameter is 20 µm to 40 µm.

Max. strip width

This parameter determines the width of the ring filled with toolpaths. Instead of filling the entire hole with toolpaths, only a sufficiently wide ring filled with toolpaths is created. This reduces the processing time.
The following figure shows the *Max. strip width*:

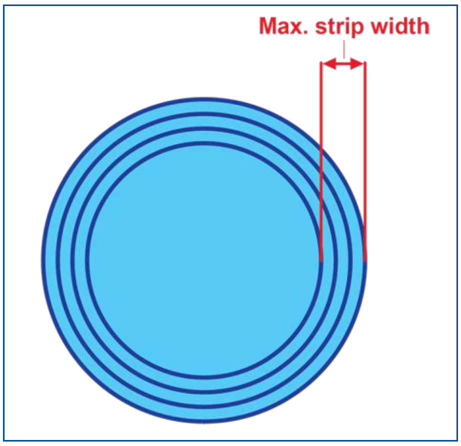


Fig. 57: **Max. strip width**

The typical setting for this parameter when using FR4, 1.5 mm material is 80 µm to 100 µm.

Lead in/out angle

In some cases, the laser beam does not process the entire toolpath. There is a gap between the start point and the end point of the toolpath:

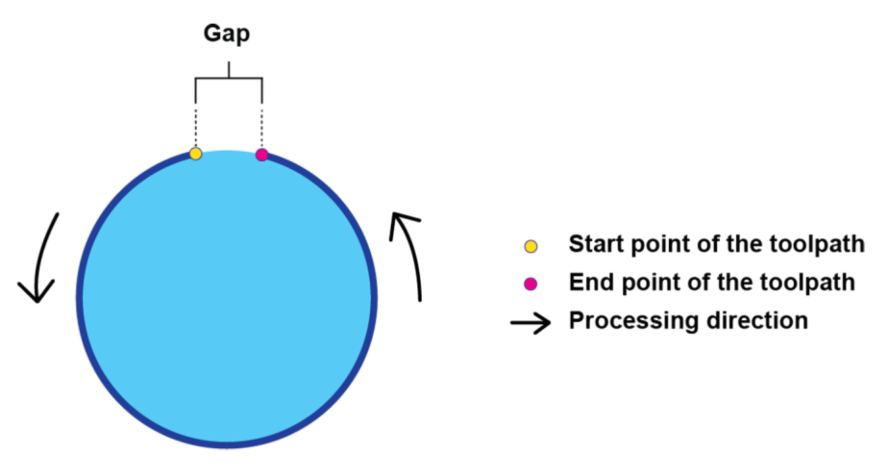


Fig. 58: **Gap between the start point and the end point**

The parameter *Lead in/out angle* extends the vector at the start of the toolpath and at the end of the toolpath. The extended vector is located on the toolpath itself. The value of this parameter determines by which angle the vector is extended. If set to 0°, no *Lead in/out angle* is used. The following figure shows the *Lead in/out angle*:

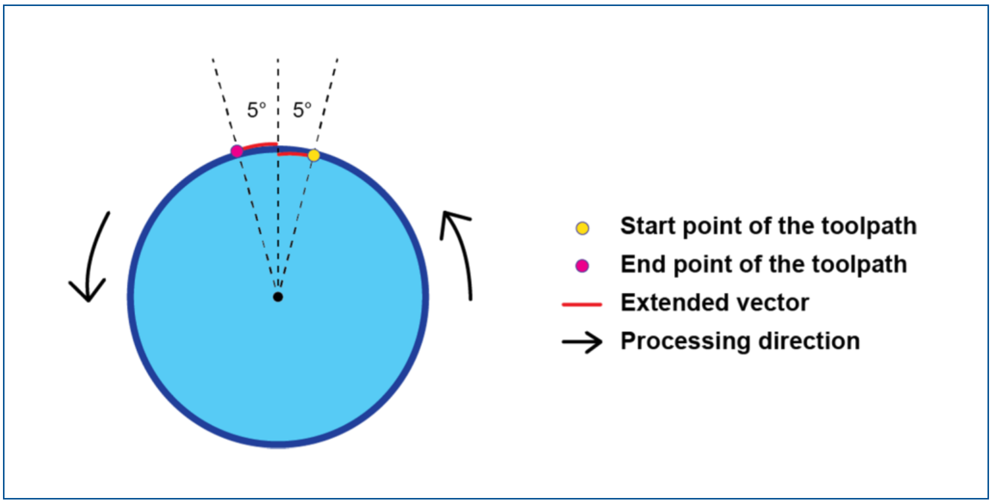
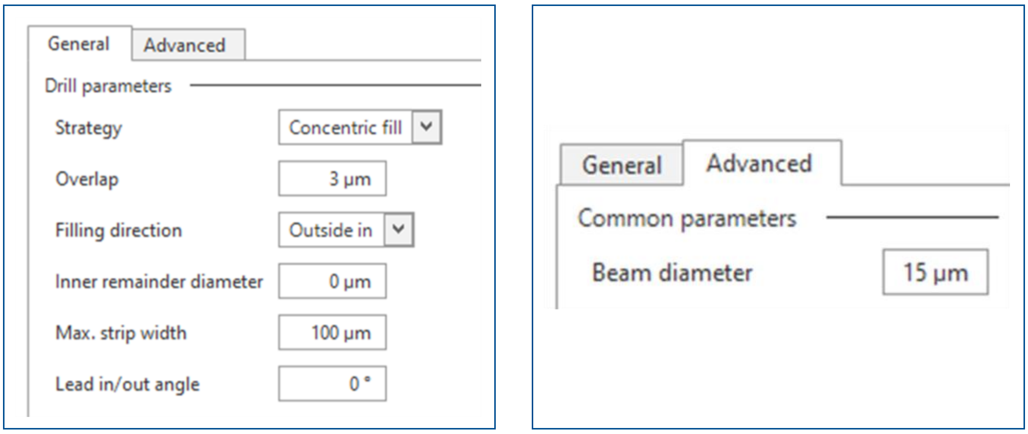


Fig. 59: **Lead in/out angle**

Example of parameter settings

The following example shows parameter settings for a hole with a 0.5 mm diameter:



Drill parameters

Strategy	Concentric fill
Overlap	3 µm
Filling direction	Outside in
Inner remainder diameter	0 µm
Max. strip width	100 µm
Lead in/out angle	0 °

Common parameters

Beam diameter	15 µm

Fig. 60: **Example parameters**

The following figure shows an example of calculated toolpaths:

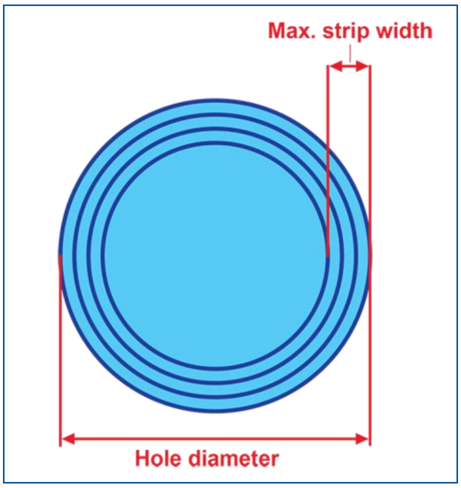


Fig. 61: **Example of calculated toolpaths**

Considering a 15 µm *Beam diameter* and a 3 µm *Overlap*, eight concentric toolpaths spaced by 12 µm are needed to create a 100 µm ring (that is determined by the value *Max. strip width*).

5 Appendix

This chapter contains navigation elements of the document.

5.1 List of figures

5.2 List of tables