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

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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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Issued patents, if applicable, are listed in the appendix.

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

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.

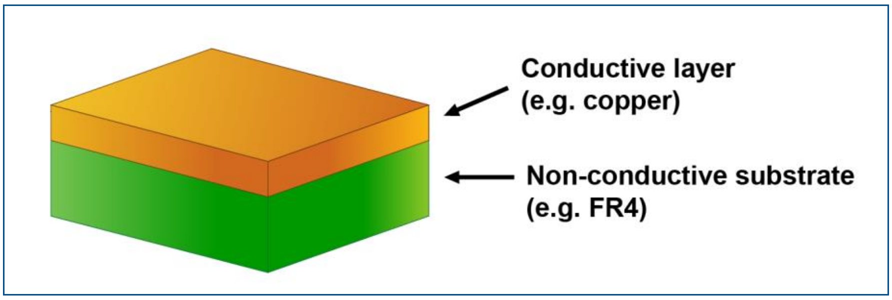
1 Basics

This chapter describes the following topics:

- Processing principle of the ProtoLaser
- 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 efficient.

PCB material consists of a conductive layer (usually copper) that is laminated onto a non-conductive substrate (usually FR4):



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

1.1 Processing principle of the ProtoLaser

This chapter describes the processing principle of the ProtoLaser systems. The basic rubout process consists of the following stages:

1. Creating the isolation channels
2. Hatching
3. Delamination

The following figure shows an example layout in the CAM view that is used for explaining the processing principle:

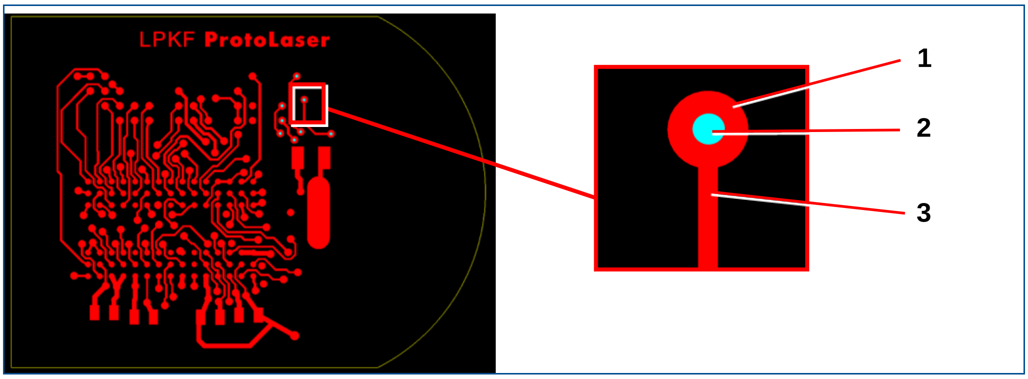


Fig. 1: PCB layout

1	Pad	**3**	Conductive track
2	Drill hole		

Creating the isolation channels

Processing starts by creating isolation channels (i.e. “contours”) on the layout’s rubout area around the objects (conductive tracks, pads, etc.). The isolation channels separate the rubout area from the conductive layer. The following figure shows the isolation channel around the conductive track in the CAM view:

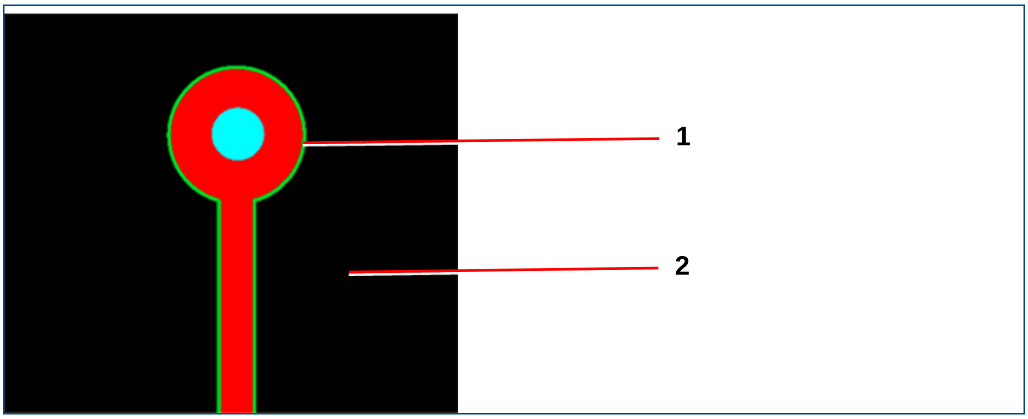


Fig. 2: PCB layout | isolation channel

1 Isolation channel

2 Rubout area

Hatching

The process is continued by hatching, i.e. cutting the rubout area “into strips”. The following figure illustrates the strips with the hatching lines in the CAM view:

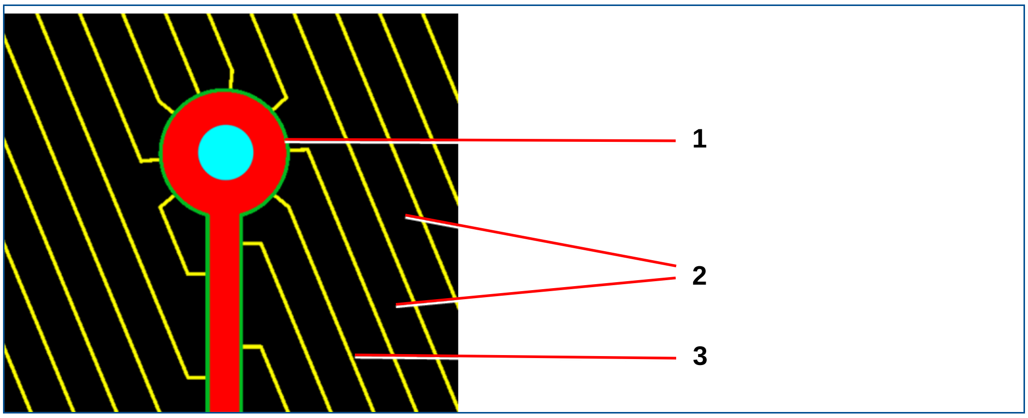


Fig. 3: PCB layout | hatching

1 Isolation channel

2 Strips of the rubout area

3 Hatching line

Delamination

The final stage of the rubout process is delamination. Each strip of the rubout area is being heated up until the copper layer is removed from the base material. The following figure shows heating lines in the CAM view that are used for removing the copper layer:

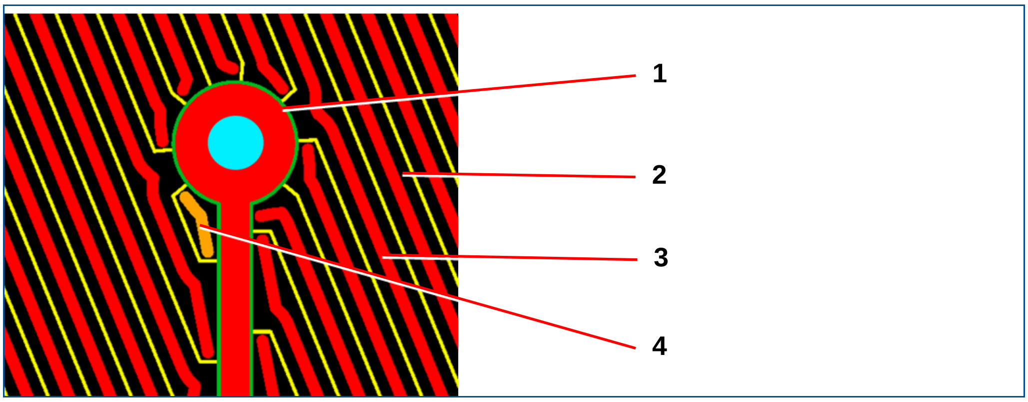


Fig. 4: PCB layout | delamination

1 Isolation channel

2 Strip of the rubout area

3 Heating line

4 Short heating line

1.2 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 this principle:

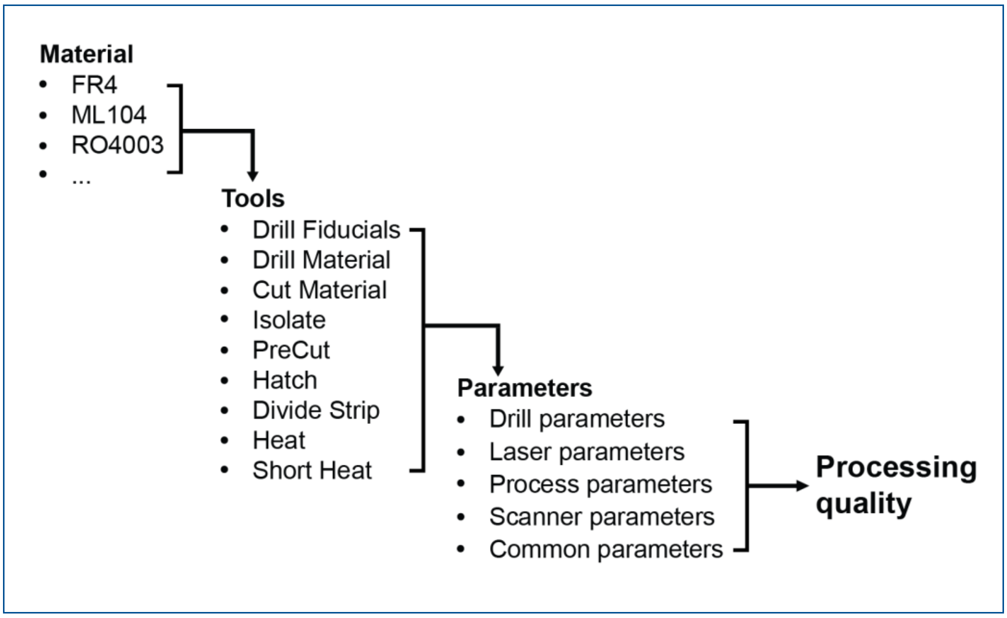


Fig. 5: Processing principle in the system software

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

- The functionality of every tool;
- The identification of a certain tool on the layout in CAM view (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	Toolpath color 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 around the objects (conductive tracks, pads etc.).	Green
PreCut	Creates additional isolation channels into 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 calculated toolpaths in the CAM view:

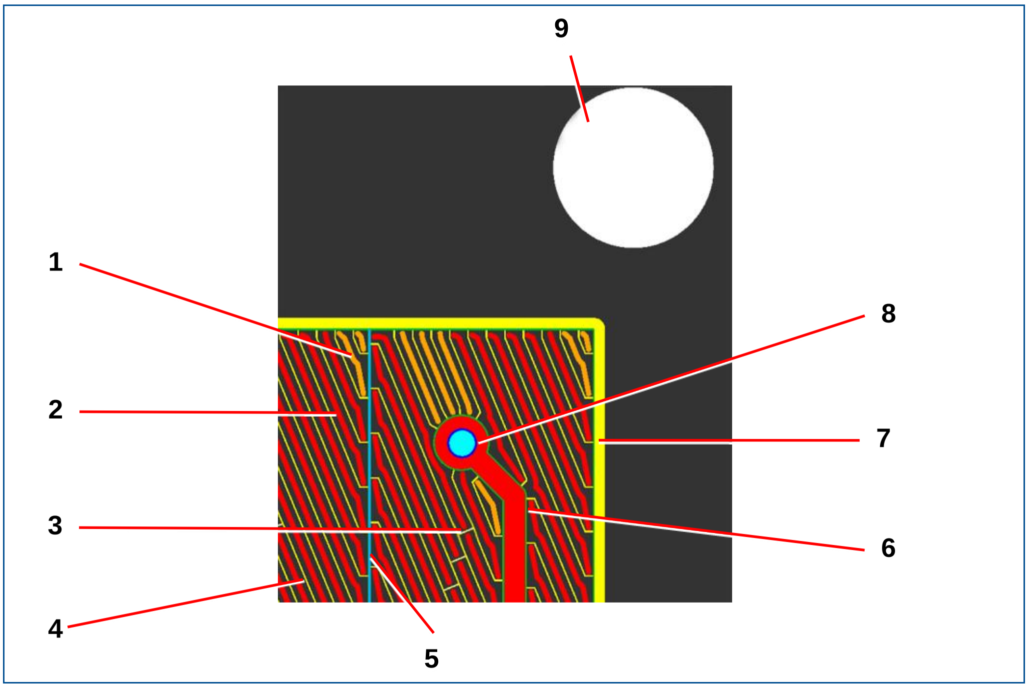


Fig. 6: Tools in CAM view

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 show a comparison between a layout in the CAM view (with calculated toolpaths) and the same layout after it has been realized on the material (without delamination):

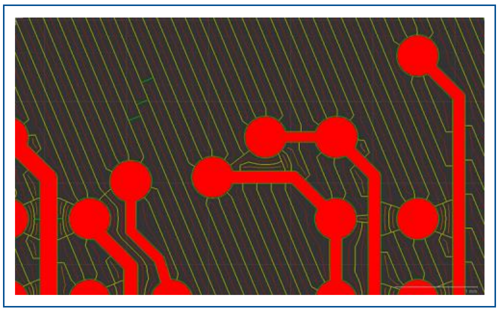


Fig. 7: CAM view of a layout with calculated toolpaths

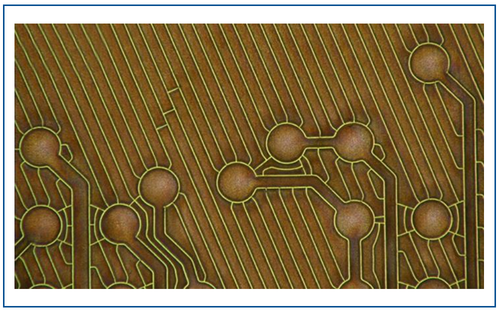


Fig. 8: Layout realized on the material (without delamination)

These figures help you to learn how to identify the use of a certain tool on the processed material.

1.3 Checking the processed material

The processed material is checked by using a microscope. For a successful identification of faults on the processed material, the following prerequisites must be fulfilled:

- Use a single-sided material;
- Set up the light source underneath the material.

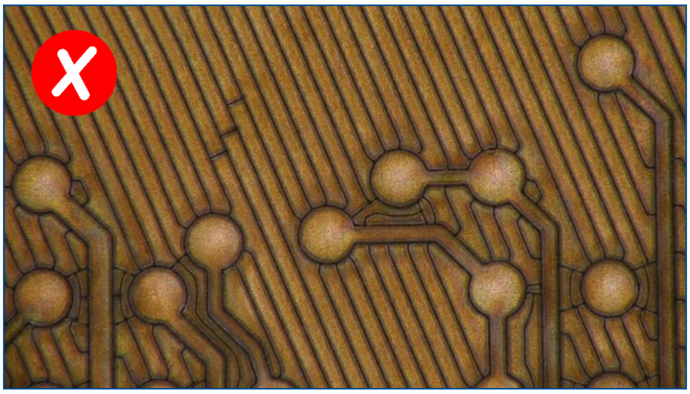


Fig. 9: Processed single-sided material under the microscope | no light source underneath the material

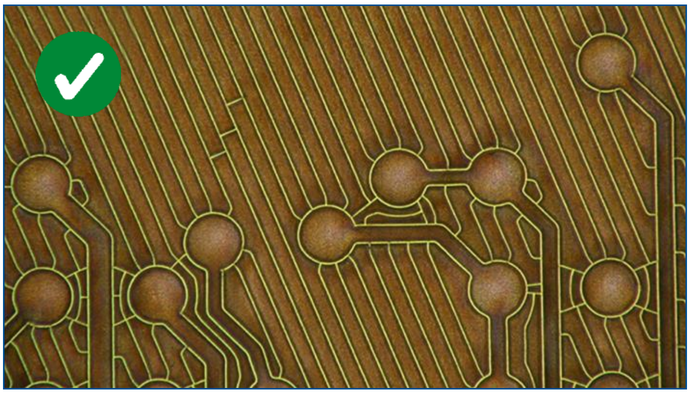


Fig. 10: Processed single-sided material under the microscope | light source underneath the material

2 Processing quality

This chapter describes the most typical faults that reduce the processing quality, as well as the remedies for them. In addition, it provides expert knowledge of the scanner parameters that have great influence on laser processing.

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

2.1 Most typical faults in processing

There are two types of typical faults in processing:

- An incompletely removed conductive layer;
- Burn-in effects on the material.

2.1.1 Incompletely removed conductive layer

The following reasons can lead to incompletely removed conductive layer:

- The conductive layer is not cut on the entire rubout area;
- Heating is too weak or too fast;
- The wrong material type is selected in the system software.

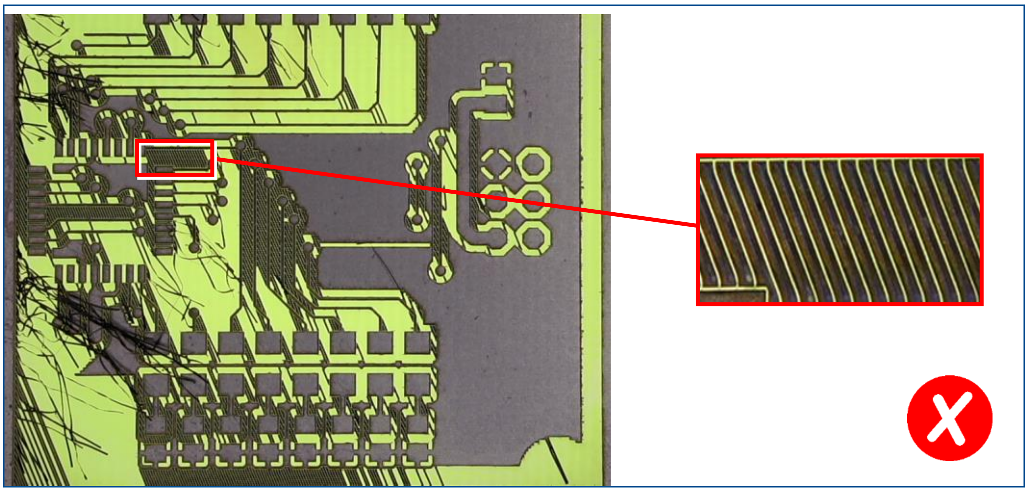


Fig. 11: Incompletely removed conductive layer

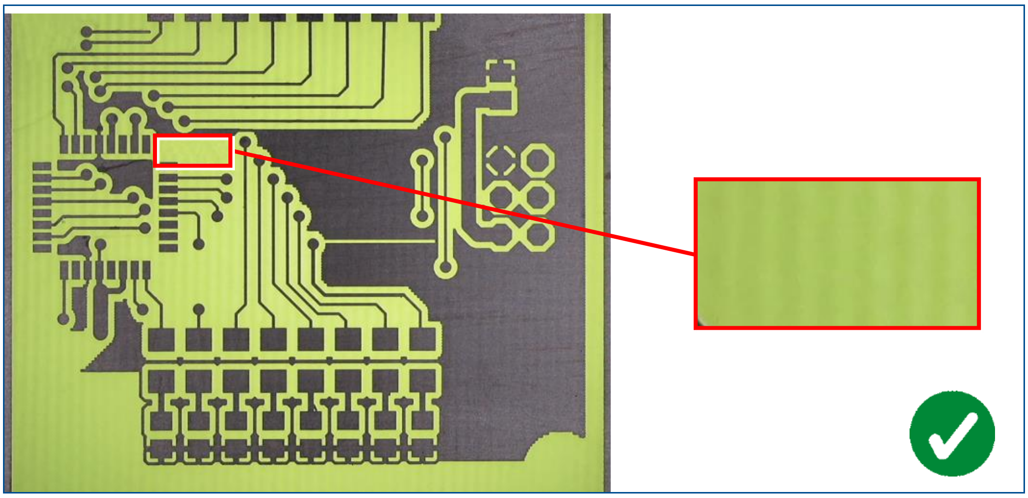


Fig. 12: Completely removed conductive layer

The following table contains the most common processing faults and the remedies for them:

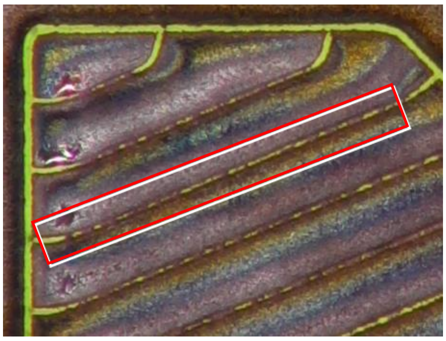
Figure	Fault	Remedy
	The isolation channel is not cut completely - consequently, the strips of the conductive layer are not delaminated.	Decrease the *Mark speed* of the tool *Isolate* in steps of 5 % to 10 %.
	The hatching line is not cut completely - consequently, the strips of the conductive layer are not delaminated.	Decrease the *Mark speed* of the tool *Hatch* in steps of 5 % to 10 %.

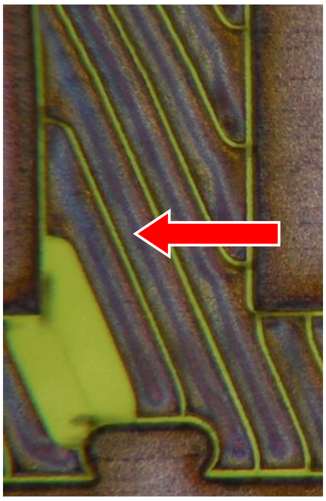
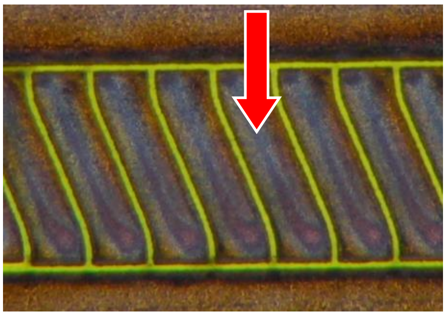
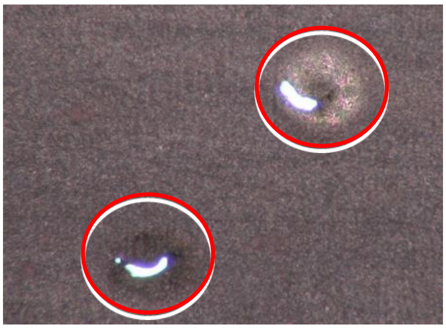
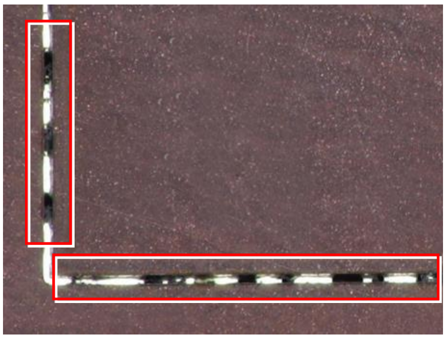
Figure	Fault	Remedy
	The isolation channel and the hatching line are cut through, but the strips of the conductive layer are not delaminated.	Decrease the *Mark speed* of the tool *Heat* in steps of 10 %.
	The isolation channel and the hatching line are cut through, but the short strips of the conductive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

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 hatching process is too slow;
- The laser power is too high;
- The wrong material type is selected in the system software.

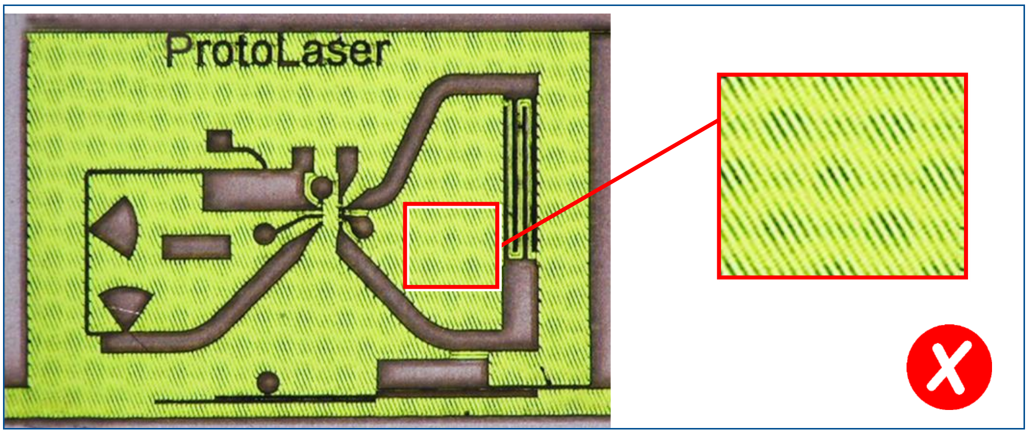


Fig. 13: Burn-in effects

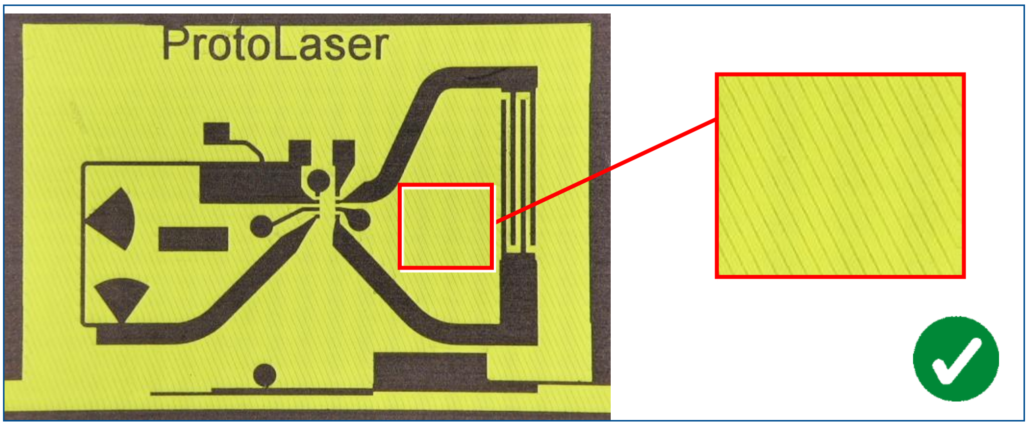


Fig. 14: No burn-in effects

The following table contains the most common processing faults and the remedies for them:

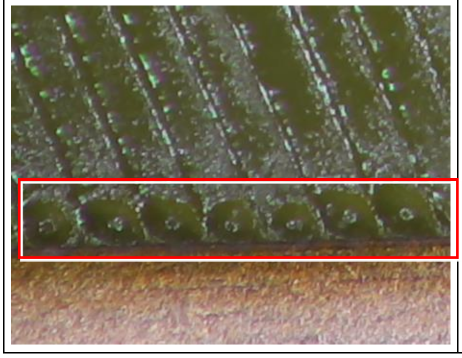
Figure	Fault	Remedy
	Burn-in effects of isolation channels and hatching lines.	Increase the *Mark speed* of the tool *Hatch* and the tool *Isolate* in steps of 10 %.
	Burn-in effects (i.e. “tick marks”) at the end of heat lines.	Decrease the *Laser off delay* of the tool *Heat* in steps of 20 µs to 50 µs (the 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 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 give the mirrors a calming period 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:

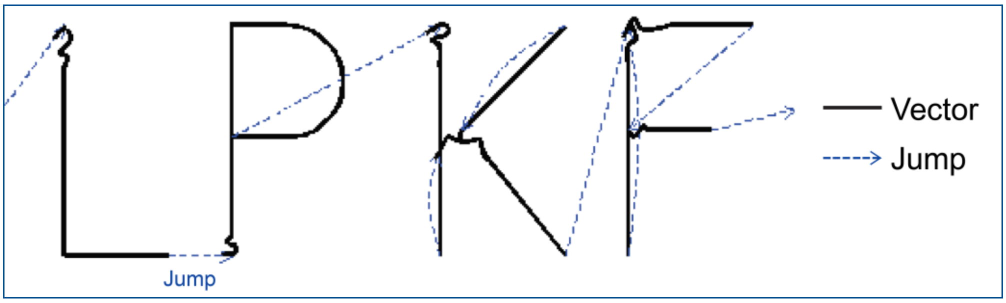


Fig. 15: Jump delay too short

The mirrors of the scanner have not yet calmed 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 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 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:

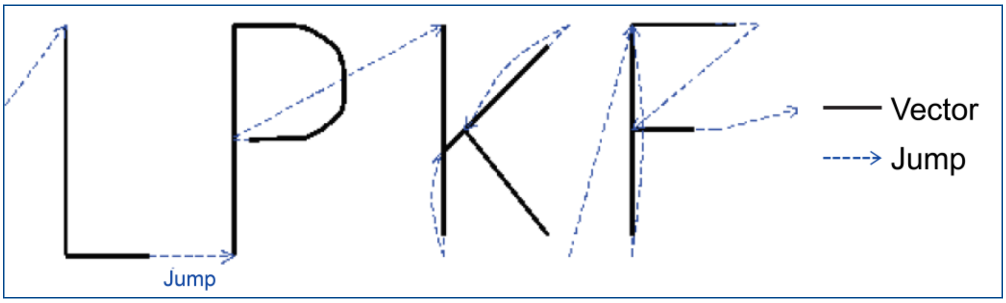


Fig. 16: Laser off delay too short

The 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 laser off delay that is too long:

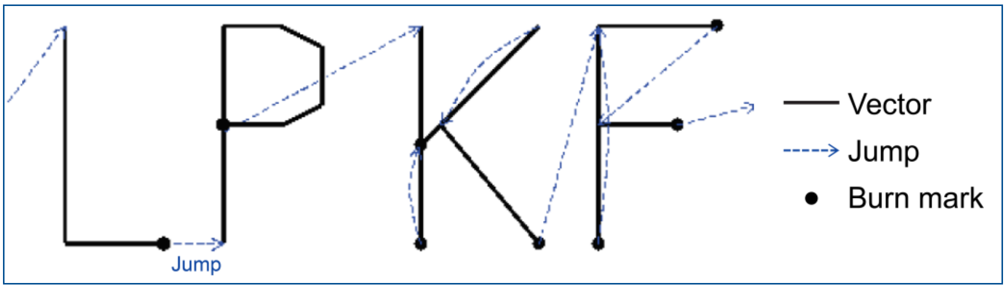


Fig. 17: Laser off delay too long

The 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 end of a vector (or a sequence of vectors) before the gate is closed for the following vector. Due to their acceleration phase, the mirrors only reach the mark speed with a delay. To prevent a hard laser beam material impact during the acceleration phase, the gate will be opened when 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:

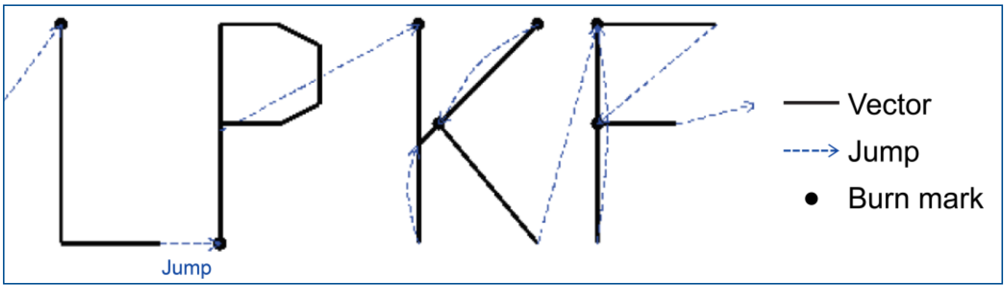


Fig. 18: Laser on delay too short

The 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:

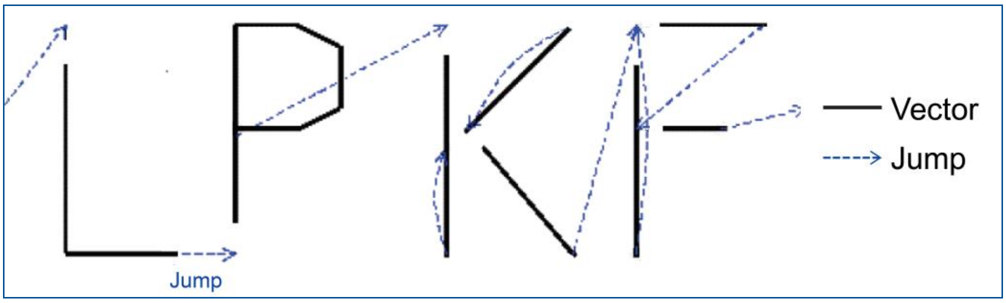


Fig. 19: Laser on delay too long

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

Mark delay

The value of this parameter represents the waiting period at the end of a vector (or a sequence of vectors). The mark delay is necessary to compensate the tracking error. If the mark delay is too long, no effect is visible. However, the processing time becomes longer.

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

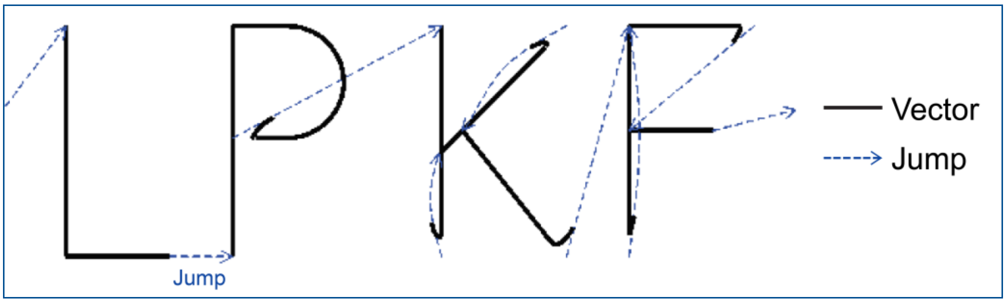


Fig. 20: Mark delay too short

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 gate. This value is, in addition to the frequency, decisive for the material processing. The slower the adjusted moving speed, the more the energy supplied to the target material per area. The overlap of the single pulses becomes larger.

The value for this parameter depends on the application.

Polygon delay

The value of this parameter represents the waiting time between the individual vectors of a vector sequence. 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 crossovers 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:

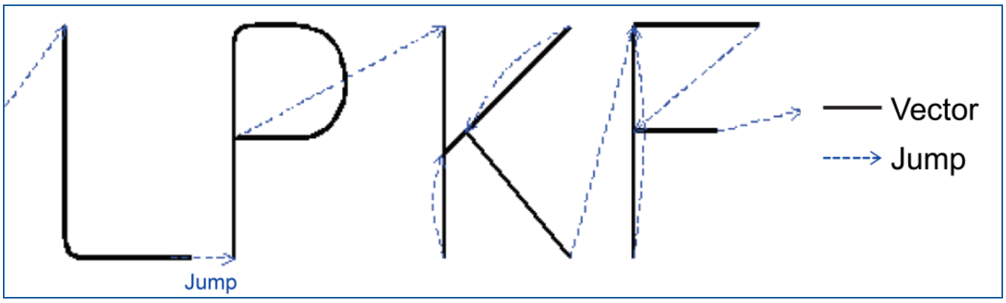


Fig. 21: Polygon delay too short

Radii are formed on the crossovers between the vectors.

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

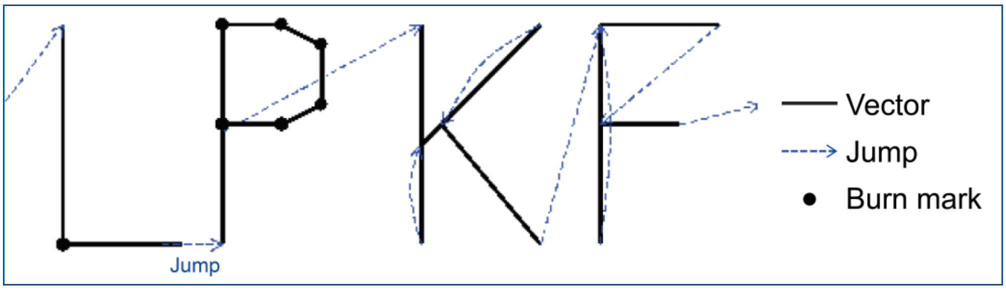


Fig. 22: Polygon delay too long

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

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

3 Appendix

This chapter contains navigation elements of the document.

3.1 List of figures

3.2 List of tables