Workpieces and axes

Supplement of the VLM Software Description

Version 4.7

ROFIN-SINAR LASER

THE MARK OF EXCELLENCE

CONTENTS

1 VLM Model

1.1 Introduction

The VLM model of laser marking includes marking data, i.e. layout, workpiece information and a simple kinematic model of the laser. The marking data is a tree structured collection of marking objects. The workpiece represents a surface or a part of it to mark on. The kinematic model represents the kinematics of the laser installation including galvo heads of the laser, mechanical axes, conveyors belts, and turn tables to transport workpieces. The machine kinematics is described by a machine configuration either `*.CFG` or `*.XML` file.
Each VLM file contains marking data, workpiece, and kinematic information. Currently, the kinematic information determines only which mechanical axes defined in the machine configuration are to be used for executing the VLM file. Only one layout may be assigned to a workpiece.
The movement of axes and conveyor belts is controlled indirectly by marking windows and a layer attribute if a Z-axis is used. The marking windows must match the workpiece, otherwise no marking is possible.
To describe a workpiece and machine kinematics several coordinate systems are used. The most important one is the galvo head coordinate system. Its XY-plane corresponding to Z = 0 is the focal plane of the laser. The Z-axis points towards the galvo head. The directions of X- and Y-axis coincide with the X- and Y-axis of the layout. The center of the coordinate system is the center of the galvo field.
The position of the marking on a workpiece (plane or cylinder) is independent of the marking window position or size. As long as the drawing keeps its position relative to the marking area unchanged, the marking keeps its position on the workpiece. For planar marking with XY-table it was true for all the VLM versions and for cylinder marking it holds beginning with the version 4.7 (the user has to check the corresponding option – see below).

1.2 To create a new VLM file in the VLM editor

1. Select a workpiece, i.e. either plane or cylinder.
2. Check and, if necessary, type in parameters of the workpiece, e.g. diameter.
3. Uncheck axes which shall not be used.
4. Create marking objects.
5. Check and, if necessary, adjust **Z-axis [mm]** attribute of the layers in VLM's **Layer list** dialog box.
6. Create marking windows by clicking menu item **Create shadows** or using the shortcut key combination [**Ctrl+F**] while in the Marking Area View. Another option is a semiautomatic creation of marking windows via menu item **Rows and Columns**.
7. If desired, adjust positions, size and/or the number of marking windows manually. To be able to modify the size of a marking window the option **Flexible shadows** must be selected in the VLM's **Drawing** settings dialog.

In simple cases, for instance single galvo head lasers without axes, some steps may be omitted.
Note that the automatic creation of marking windows for double head configurations is not possible. In that case you should either use **Rows and Columns** menu item or create them manually.
If a new VLM file is created from a template containing no workpiece information, the VLM editor suggests a workpiece, i.e. either plane or cylinder, based on the active machine configuration. The VLM editor also suggests using all configured axes. For instance, if no rotation axis is configured, VLM suggests a plane, of course. Default workpiece assignment based on the active machine configuration also happens if a VLM file containing no workpiece information is loaded via a VMC tool.

2 Getting started

2.1 Background

The present supplement of VLM manual describes how to arrange marking with a workpiece and mechanical axes. The user is supposed to read the VLM manual, in particular chapter *Executing a VLM drawing with the laser*, section *Marking of non planar surfaces*.
This manual assumes proper configuration settings, e.g.:

- extent of galvo field,
- height of extrapolated beam origin referred to focal plane of laser,
- direction of rotation axis (either parallel to x or y),
- position of rotation axis (only if used together with Z-axis)

  -height (h_0) referred to the bottom of the laser installation

  -offset of the rotation axis referred to the center of the galvo field, measured perpendicular to the direction of rotation axis: either Δx or Δy.

It is not recommended to modify the configuration settings. This is supposed to be done by a service personnel (a technician). Configuration settings can be viewed and modified either in **Configurator** tool in the **Laser Console** application (for RCU-based systems) or in **Machine Configuration** tool (for Mico-based systems).

2.2 To prepare cylinder marking

1. Select **Workpieces and axes** from the **Options** menu of the main window.
   The *Workpiece and axes settings* window appears.
2. Select **Cylinder** from the **Surface** list box.
3. If you want to compensate for the additional distortion caused by the cylindrical surface leave **Surface correction** checked.
4. Enter the cylinder's **Diameter** [mm].
5. Optionally enter an **Angle offset** [degrees].
   The angle offset means an additional cylinder rotation before marking.
6. Enter **Default sector** [degrees].
   It means the circular sector the marking takes place in without rotating the cylinder (if the rotation axis is used). The sector determines the width/height of the marking window.
7. Select either **Convex** or **Concave** radio button to mark the outer or inner surface of a cylinder, respectively, see Hollow cylinder (inner surface) on page 14.
8. Indicate the direction of the cylinder axis by assigning values to **Axial vector**.
   The axial vector is dimensionless. If the cylinder axis is parallel to the X-axis of the VLM coordinate system the axial vector is [1, 0, 0], and if it is parallel to the Y-axis then the axial vector is [0, 1, 0]. The axial vector with a nonzero Z coordinate describes a cylinder inclined to the focal plane. If cylinder marking is done with a rotation axis the axial vector must match the direction of the rotation axis given by the configuration otherwise marking is impossible.
9. Indicate the location of the cylinder origin by assigning values to **Reference point**.
   The origin is always located at the cylinder axis. If the cylinder axis is not centered in the galvo field then either X or Y coordinate is nonzero and represents the offset from the field center. This coordinate is automatically adjusted by the VLM when a VLM file is opened to reflect the active axes configuration.

The Z coordinate of the reference point reflects the cylinder position relative to the focal plane. If the outer cylinder surface has to be marked this coordinate is negative because the cylinder axis is then under the focal plane. For the inner surface this coordinate is positive. If **Update Z value automatically** is checked the VLM calculates a reasonable value for the Z coordinate depending on the cylinder diameter, default sector, and the kind of marking (convex/concave). For convex marking we have the following relation: $Z = \frac{1}{2}(b - d)$, where b is the bulge factor of the circular sector and d is the cylinder diameter. Usually, the user does not need to modify these values, except for a setup without axes. If the user anyway modifies the coordinates the marking may be impossible.

10. Check **Update Z value automatically** if you want the VLM to adjust the Z coordinate of the reference point and update the Z-axis position in the layers after the dialog is closed by clicking the [**OK**] button.
11. If a Z-axis and no rotation axis are used for cylinder marking and the cylinder is placed on a bearing the additional height of the bearing is entered into the field **Cylinder axis height**.
    This value is used to adjust Z-axis positions of layers. If a rotation axis is used this field is disabled and has no meaning.
12. If the cylinder is marked with a rotation axis and the axis is not centered in the galvo field check **Compensate for axis offset** to get VLM to use an additional rotation so that the marking has the same position on the cylinder surface as it were if the marking were done in the galvo field center.
13. Finally check/uncheck axes you want to be used for marking. If an axis is not available in the active configuration it is not possible to check it in the dialog. The **W-axis** denotes the rotation axis. The **Z-axis** is a linear axis allowing the cylinder to be positioned according the Z coordinate of the reference point and W-axis parameter **Distance of rotation axis center to focus plane**. If the mounting support carrying the workpiece or the laser can be moved by means of an XY-table, adjust the **X-** and/or the **Y-axis** check boxes.

If a VLM file without workpiece information is opened the VLM retrieves axes settings from the active configuration (it means, all the axes configured will be checked). The user may uncheck those axes which shall not be used. Usually, the laser is moved by means of an XY-table, whereas the mounting support carrying the workpiece is not shifted across the bottom of the laser installation.

Item	Meaning
Surface	Selects plane or cylinder
Diameter	Cylinder diameter
Angle offset	Additional rotation before marking
Default sector	Circular region of the cylinder surface to be marked without moving the axes
Convex/Concave	Selects outer or inner surface to be marked on
Surface correction	Automatic compensation for additional distortion caused by the surface
Update Z value automatically	Updates Z coordinate of the reference point and Z-axis positions of the layers
Compensate for axis offset	Additional axis rotation to compensate for axis offset from the field center
Cylinder axis height	Height of a cylinder bearing if marked without rotation axis but with Z-axis
Axial vector	Direction of the cylinder axis

Item	Meaning
Reference point	Location of the cylinder origin (see page 26)
Use axes	Selects linear (x, y, z) and/or rotation axes (w)

If you have to create a number of VLM files with similar workpiece settings it is recommended to prepare a VLM template with these settings first and then create the VLM files based on that template.

2.3 To prepare plane marking

1. Select **Workpieces and axes** from the **Options** menu of the main window.

   The *Workpiece and axes settings* window appears.

2. Select **Plane** from the **Surface** list box.

3. Indicate the direction of the plane by entering the **Normal vector**.

   It is a dimensionless vector uniquely determining the plane orthogonal to it up to a translation. Horizontal planes are most common. The normal vector of a horizontal plane is [0, 0, 1]. In addition, inclined planes, for instance the surface of a wedge, can also be represented.
   The intersection line of an inclined plane and the galvo field has to be parallel either to x- or y-axis, the respective normal vectors are (0, 1, z) and (1, 0, z), whereas the z component of the normal vector depends on the tilt angle α of the inclined plane ($\alpha \neq 0$).

4. Indicate the location of the plane origin by entering the **Reference point**.

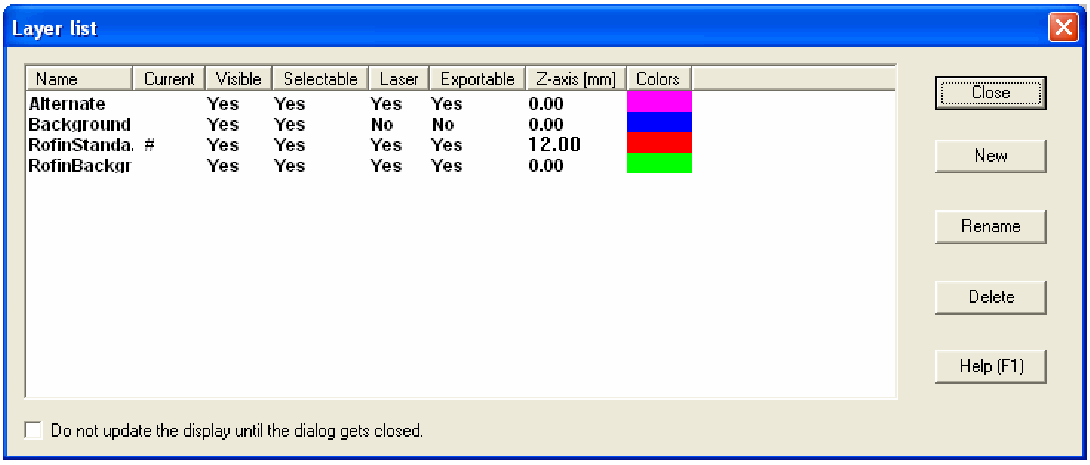
   The reference point is used to position a layout on a workpiece. For plane marking, the reasonable value for the Z coordinate of the reference point is 0, because the origin is supposed to be situated in the focal plane.

5. If you mark an inclined plane check **Surface correction** box to compensate for additional surface distortion.

6. Uncheck **Update Z value automatically** if you don't want to get Z-axis position of layers automatically adjusted.

7. Finally check/uncheck axes you want to be used for marking. The rotation axis cannot be used for planar marking.

8. If you indicated that Z-axis has to be used for marking set the **Z-axis [mm]** positions in VLM's layer attributes of the **Layer list** dialog box, by clicking on the corresponding row in the Z-axis column.



The **Z-axis [mm]** column is displayed in the layer list dialog only if it is activated in the current configuration and is to be used for this VLM file.

Although only a narrow rectangle can be marked at once due to the finite focus depth the marking windows created by the VLM doesn't reflect this.

Item	Meaning
Surface	Selects plane or cylinder
Surface correction	Automatic compensation for additional distortion caused by the surface
Update Z value automatically	Updates Z-axis positions of the layers
Normal vector	Determines whether a horizontal or an inclined plane has to be to be marked
Reference point	Location of the plane origin (see page 26)
Use axes	Selects linear (x, y, z) axes. The rotation axis w is not allowed

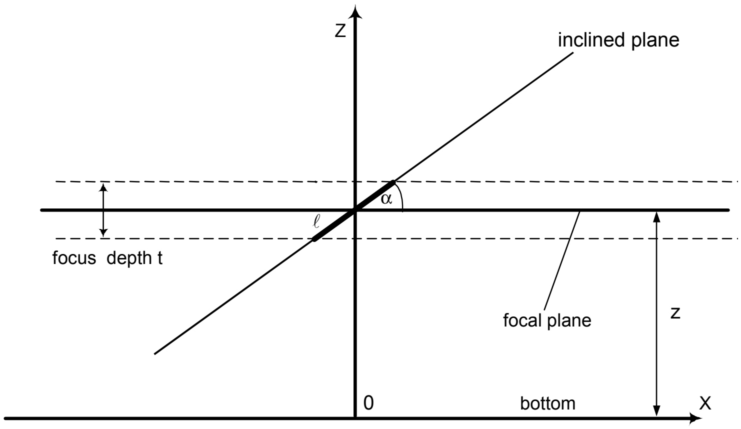
3 Examples

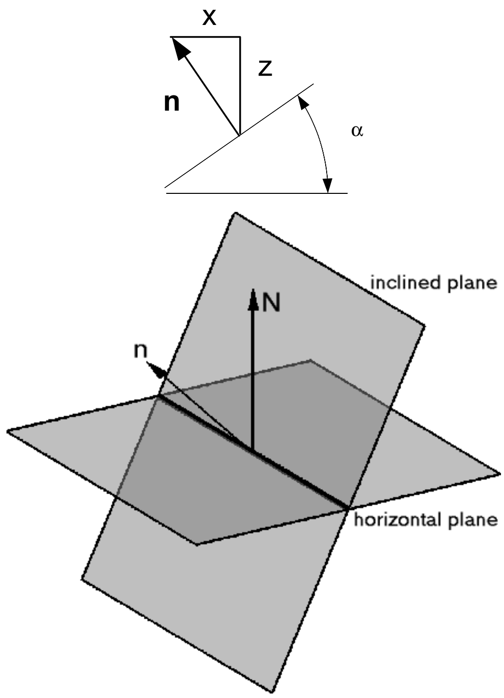
3.1 Horizontal plane (standard setup)

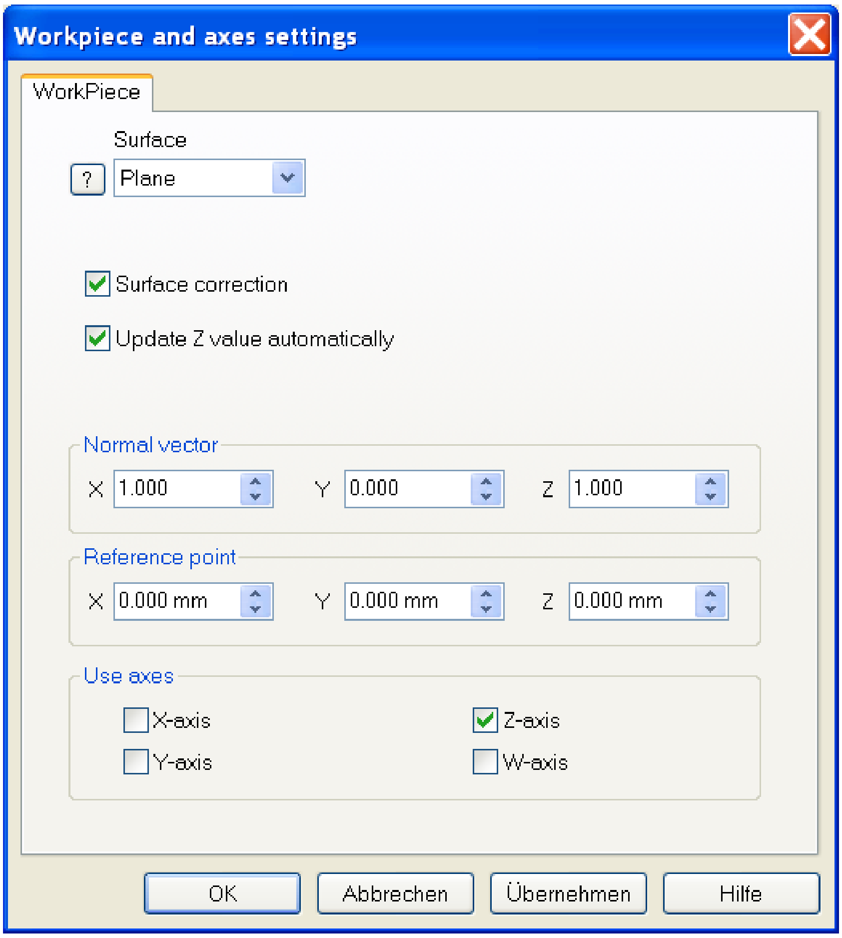
To mark horizontal planes exceeding the extent of the galvo field, see *VLM* manual, chapter *Executing a VLM drawing with the laser*, section *Marking with a double head or with axes*.
See also *To configure an XY-table* on page *24*.

3.2 Inclined plane

Depending on a tilt angle the effective marking area reduces to a rectangle compared to the whole square galvo field in the case of horizontal plane. In the example below, the intersection line of the inclined plane and the galvo field is parallel to y-axis. Consequently, its normal vector **n** amounts to [1, 0, 1]. In comparison, the normal vector **N** of a horizontal plane is [0, 0, 1].
The VLM editor actually ignores this fact and creates square marking windows for inclined planes. This is the responsibility of the user to position the marking objects so that they can be actually engraved with the laser.
If a mechanical Z-axis is used, it is possible to mark a bigger region. In that case, enter the Z coordinate in **VLM's Layer list** dialog box. The Z coordinate of the reference point is 0, because this is the most favorable position to make best use of the finite focus depth.

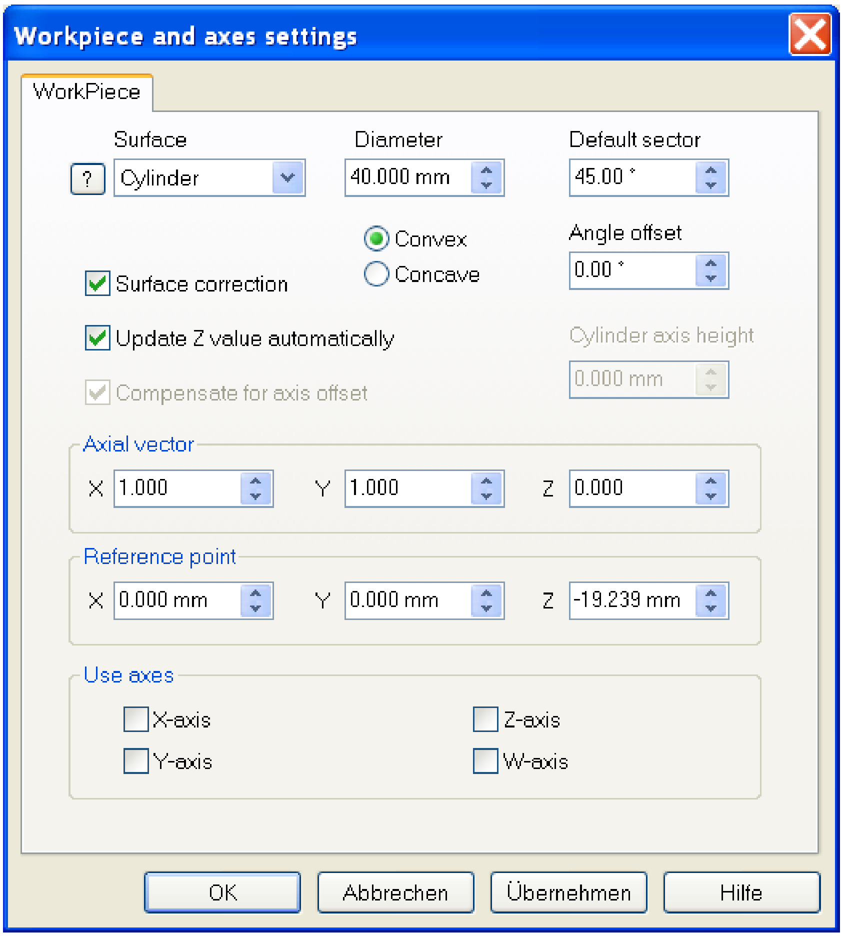





Workpiece and axes settings
WorkPiece
Surface
?
Plane
Surface correction
Update Z value automatically
Normal vector
X 1.000
Y 0.000
Z 1.000
Reference point
X 0.000 mm
Y 0.000 mm
Z 0.000 mm
Use axes
X-axis
Z-axis
Y-axis
W-axis
OK
Abbrechen
Übernehmen
Hilfe

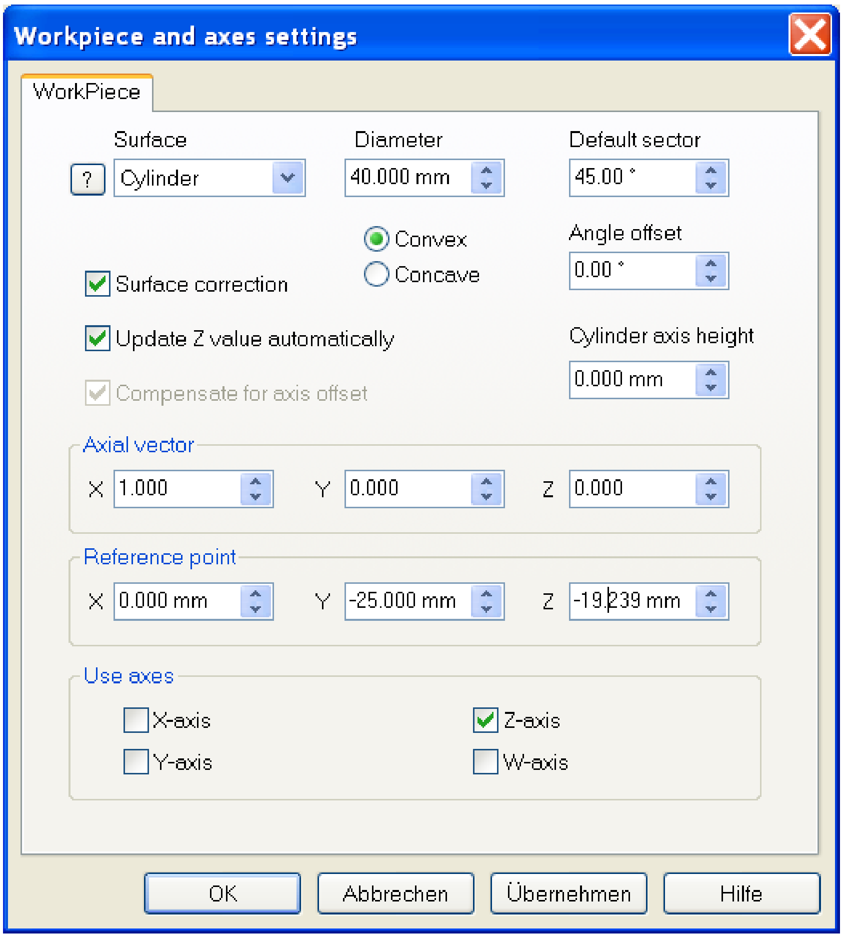
3.3 Cylinder without axes

The user has to make sure that the position of a workpiece relative to the galvo head matches the axial vector and reference point defined in the VLM file.
The size of the standard marking window (there is only one window because no mechanical axes are used) corresponds to the circular sector.
The Z coordinate of the reference point suggested by the *VLM* corresponds to the cylinder placement at half the bulge factor above the focal plane. Modifying cylinder diameter or default sector results in automatic adjustment of the Z coordinate if **Update Z value automatically** is checked. If the actual cylinder placement differs from the one described in the dialog this may result in additional distortion of the marking caused by the mismatch of the actual cylinder position and the position used for computing the surface correction.



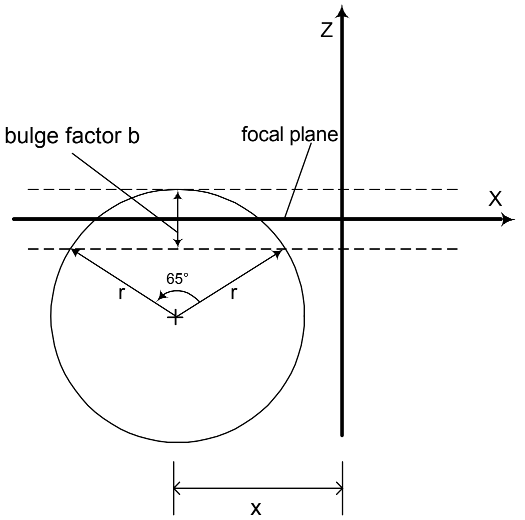
3.4 Cylinder with Z-axis

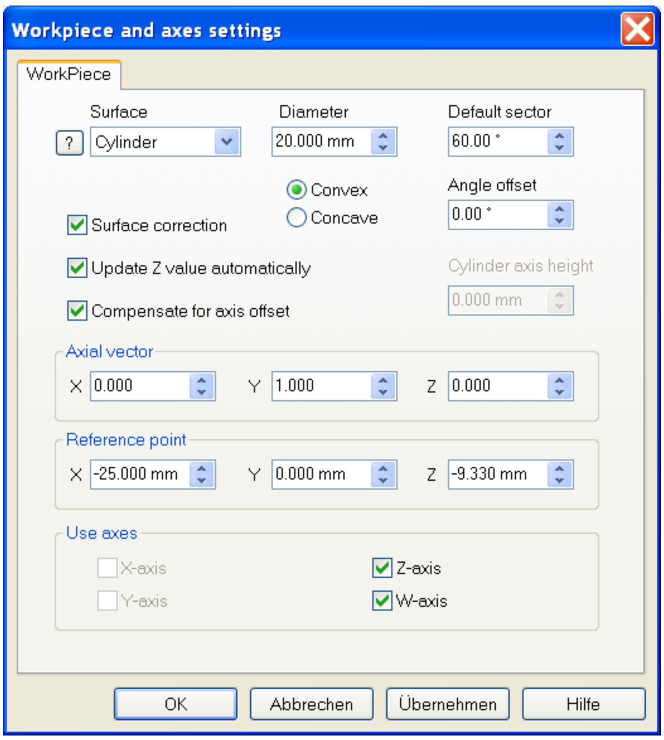
The cylinder is placed in the direction of X-axis and moved from the galvo field center. The Z coordinate of the reference point suggested by the VLM corresponds to the cylinder placement at half the bulge factor above the focal plane. There is also an additional entry field Cylinder axis height that allows for an additional Z-axis offset due to using a cylinder bearing. Modifying cylinder diameter or default sector results in automatic adjustment of the Z coordinate if **Update Z value automatically** is checked. Modifying the cylinder axis height affects the Z-axis position of layers. The Z-axis position of layers will be adjusted after closing the dialog if the flag **Update Z value automatically** is set.

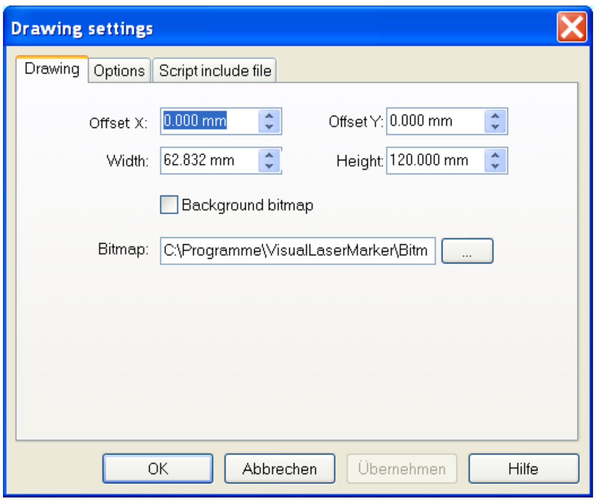


3.5 Cylinder (standard setup)

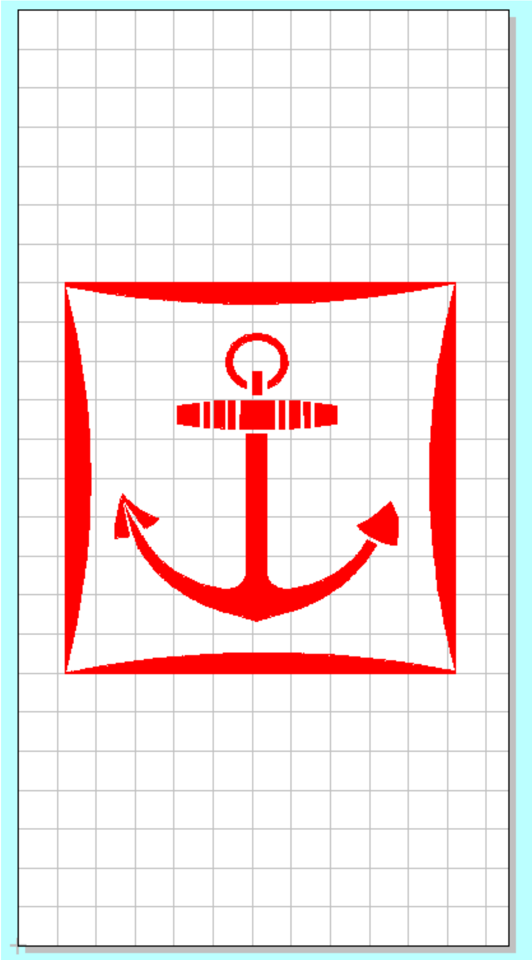
VLM calculates the Z coordinate of the reference point based on the cylinder diameter and default sector.
In the example below, the cylinder axis is moved off the center of the galvo field by -25.0 mm in x direction.
After the dialog is closed VLM calculates the corresponding circumference (2×π×r) and adjusts the drawing extension (width or height depending on the axis direction).
Although it is possible to move the whole marking along the cylinder axis by entering a nonzero value for Y coordinate of the reference point (in this particular example) it is not recommended because the offset is implemented via surface correction and this can lead to a less exact positioning. To move the drawing along the cylinder axis, move the drawing in VLM editor instead.
If the user wants to adjust the initial cylinder position, the **Angle offset** parameter is used.



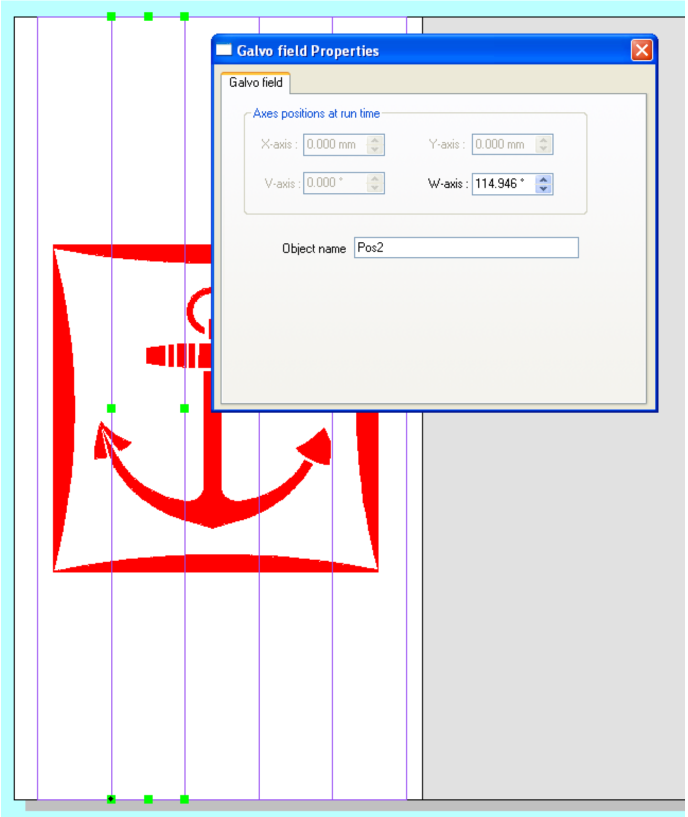




Drawing view:

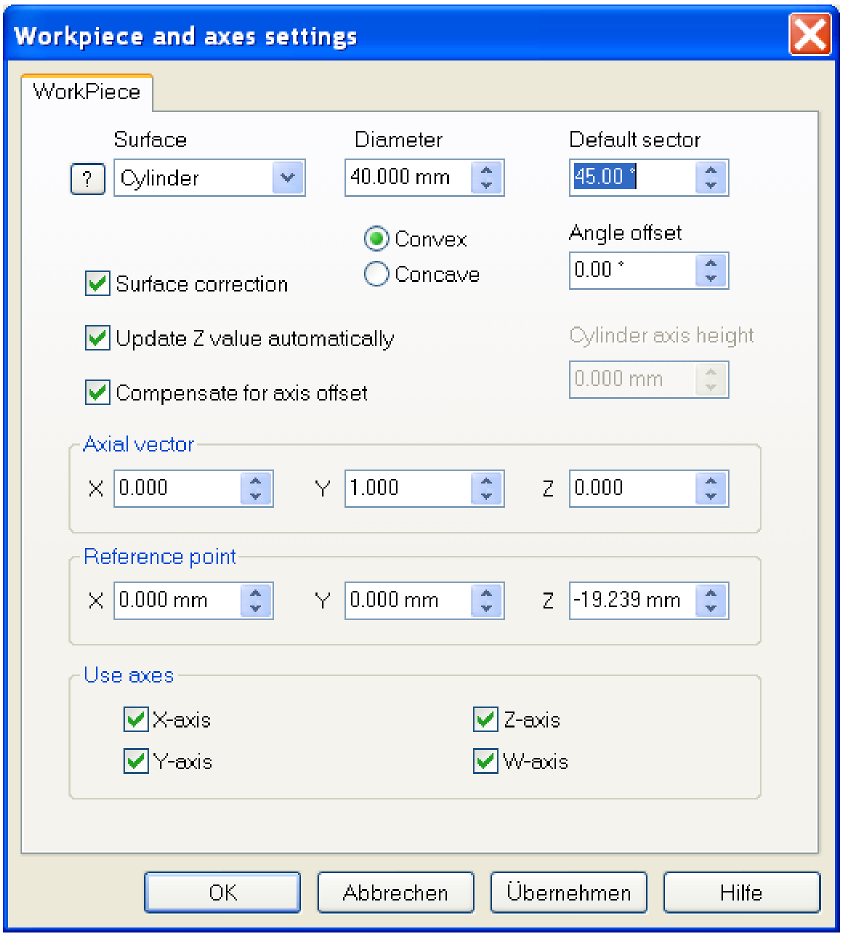


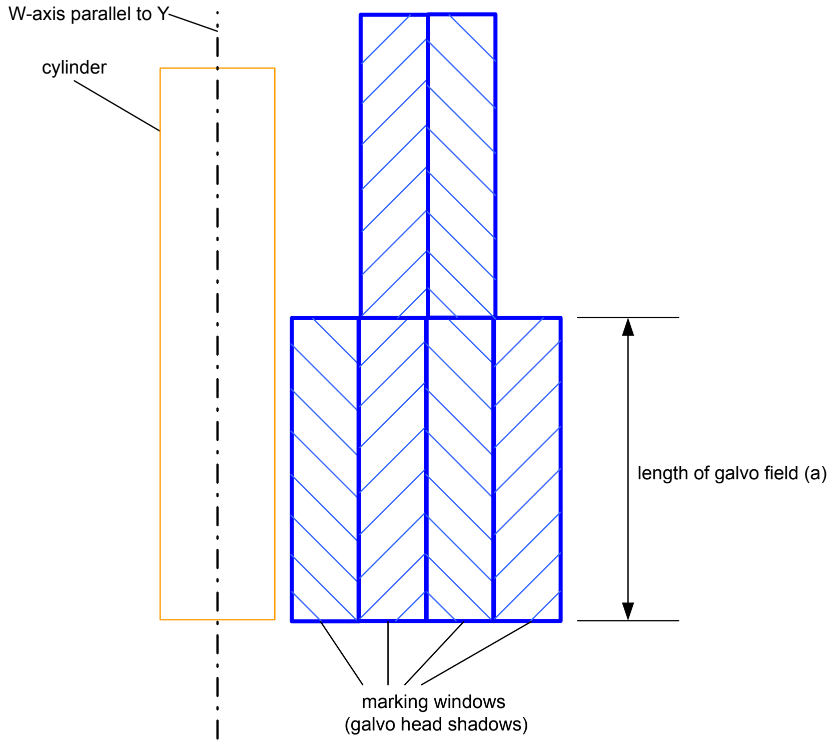
Marking view:



3.6 Cylinder (long)

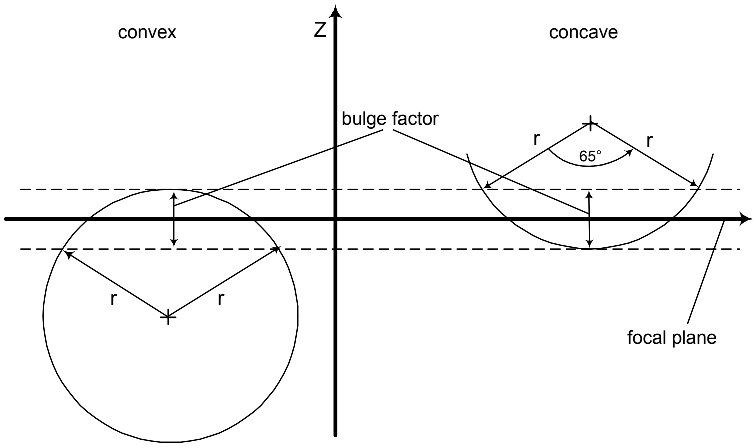
If the mounting support of the cylinder can be moved by means of an XY-table, the maximum marking area is enlarged accordingly.
In this case it is also possible to mark a cylinder moved off the center of the galvo field. The proper adjustment of the internal parameters is done by VLM automatically when a VLM file is opened.
The figure below shows two rows of marking windows covering the marking objects.



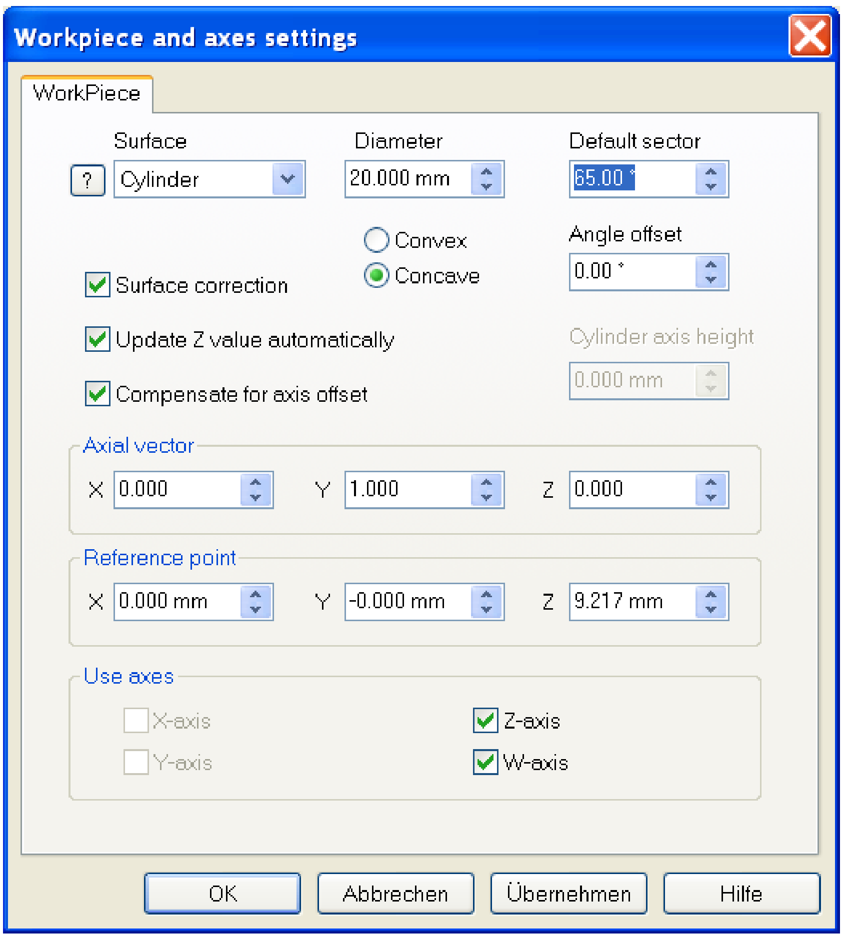

W-axis parallel to Y
cylinder
length of galvo field (a)
marking windows
(galvo head shadows)

3.7 Hollow cylinder (inner surface)

Check **Concave** radio button indicating that inner surface is to be marked. All the other settings are similar to the case of cylinder outer surface marking. The Z coordinate of the reference point computed by VLM now has a positive sign because the cylinder is placed above the focal plane. Note that there is still no automatic adjustment for the placement of marking segments on the cylinder surface. This has to be compensated by inverting the rotation direction of the W axis in the configuration (for some type of mechanical axis controller it is necessary to switch it off before inverting).

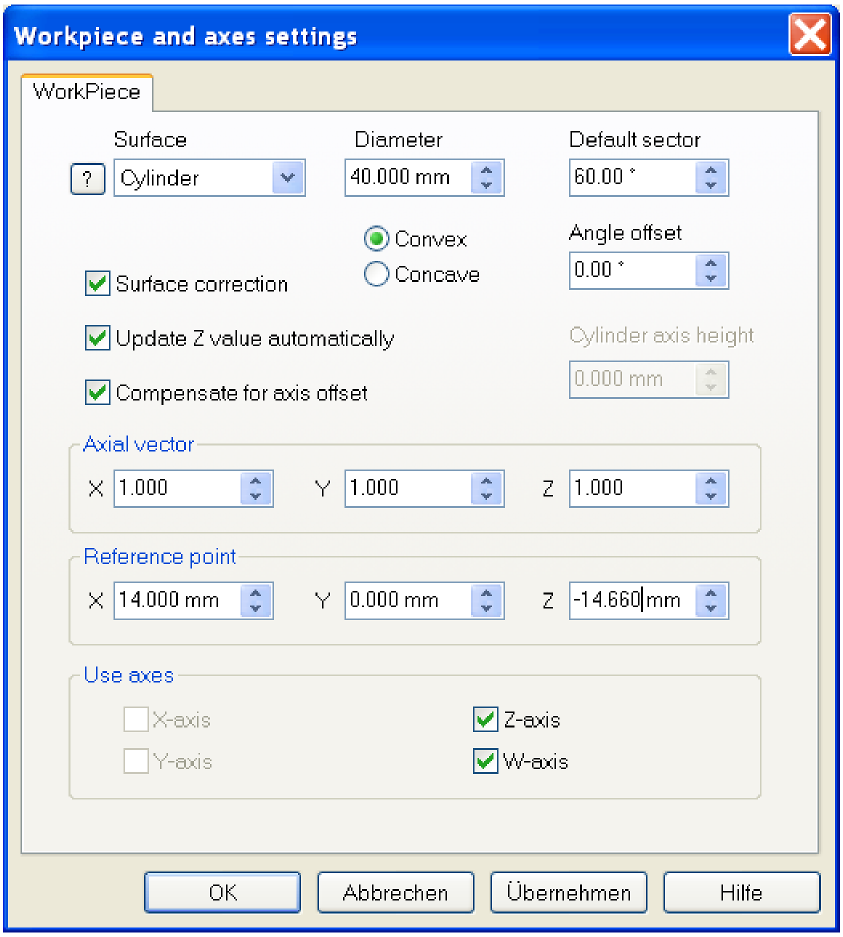


solid cylinder hollow cylinder



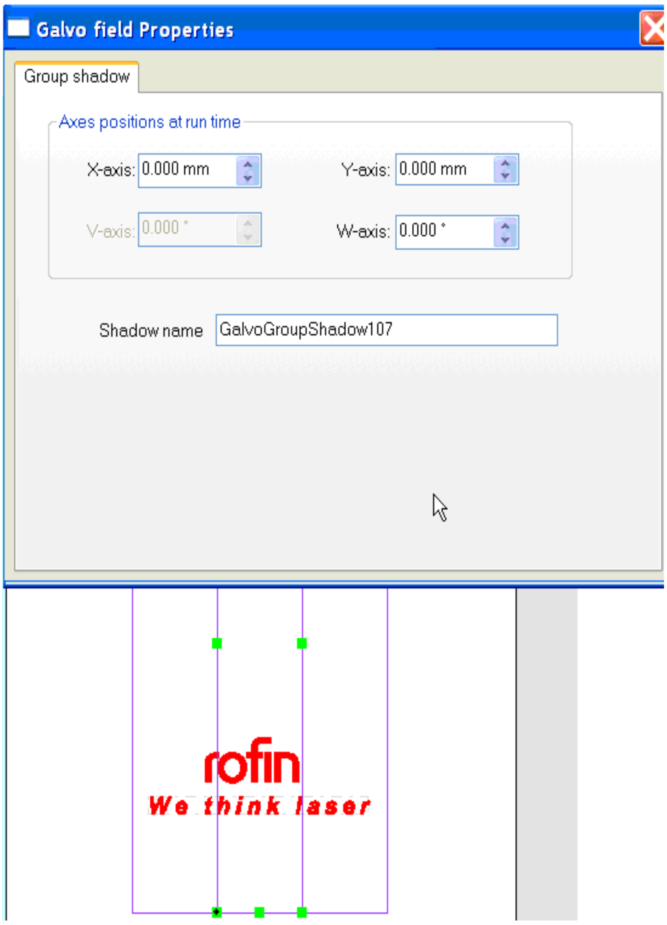
3.8 Tilted cylinder

Due to the finite focus depth, a laser can only mark a region smaller than the galvo field for each position of axes.
Enter the axial vector. Either X or Y coordinate of the axial vector has to be zero, the other coordinate depends on the tilt angle α. The tilt angle can be defined indirectly via the axial vector. It is not possible to describe a tilted mechanical axis in the configuration.
VLM suggests the X and Z coordinates of the reference point based on the diameter, default sector, and axial vetor.



4 Marking window creation

4.1 Definition

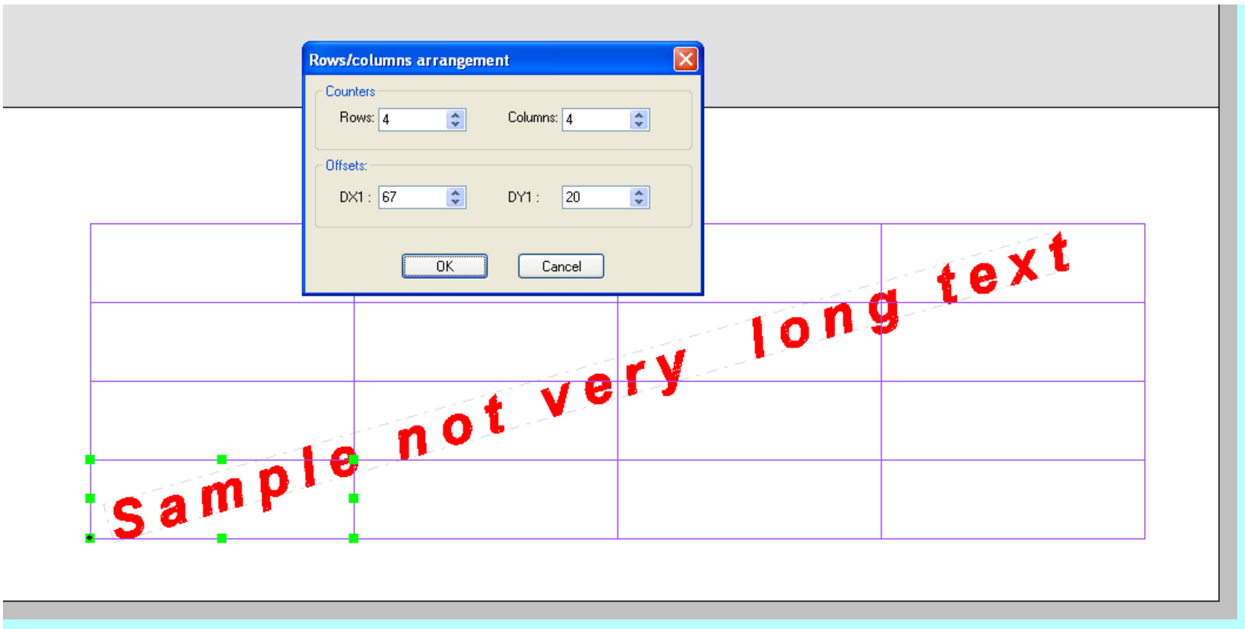


To determine a region of the drawing to be marked and associated axes positions (if there are mechanical axes installed) the VLM editor uses marking window concept. The marking windows are axes aligned rectangles.
If a workpiece is marked without mechanical axes a single marking window is created, so that not all marking objects are necessarily covered.

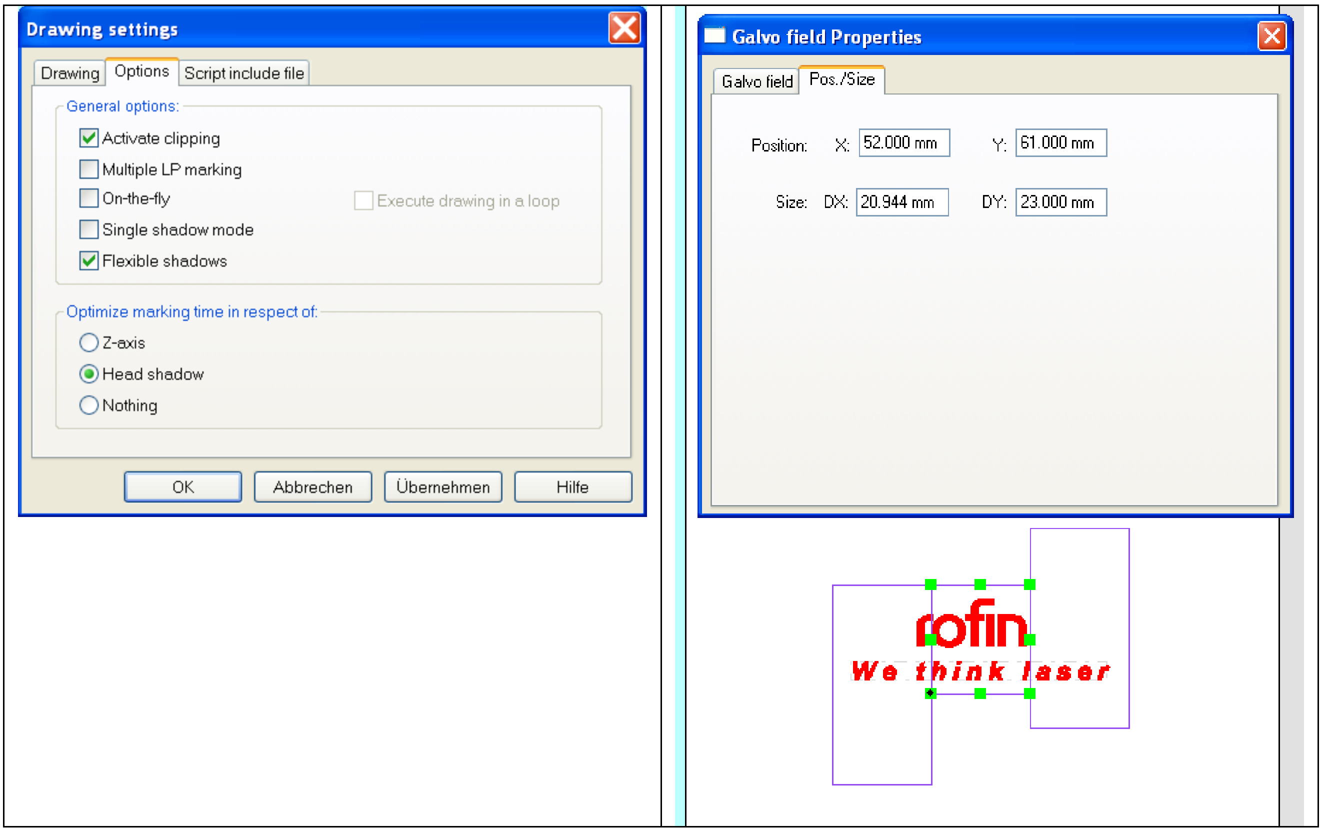
The VLM editor also provides the possibility to modify the size of a marking window individually (see the next section).

4.2 Instructions

Creating marking windows precedes laser marking. No marking is possible without marking windows.
The VLM editor can automatically create marking windows needed to mark all the objects contained in a drawing. Switch to the **Marking area view** in the Editor and select menu item **Create shadows** or use the shortcut key combination **Ctrl+F**. This works only for a single galvo head configuration. The marking windows can also be created semiautomatically. First create manually a marking window and then apply **Rows and Columns** menu item to that window.



Using menu item **Create shadows** also sets two attributes of the drawing, **Activate clipping** and **Optimize marking time in respect to head shadow**.
Since there are only two degrees of freedom for the planar representation of the marking area maximum two axes positions can be represented directly via the marking window position. Which axes are mapped directly to marking window positions depends on the configuration. For example, if three axes X, Y, and W are configured and the rotation axis W is in the direction of the Y-axis then the X coordinate of the marking window is mapped to the position of the W axis, and the Y coordinate to the position of the Y-axis. The position of the X-axis is saved as a value of the marking window properties.
The marking windows are processed in their object order defined in the VLM file if the option **Optimize marking time in respect to head shadow** is selected in the drawing settings.
In the marking area view, the user can select all marking windows by using the menu item **Select shadows** or by using a shortcut combination [**Ctrl+G**].
To be able to modify the size of a marking window check **Flexible shadows** in the **Drawing** settings. Note that changing the size of a marking window usually results in changing the axes positions associated with that window. This is because the smaller window has a fixed position in the galvo field. For linear axes, the marking window is centered in the galvo field. For a rotation axis, the marking window can be moved off the center if the corresponding offset is defined in the configuration of the rotation axis. All the marking windows in a VLM file share the same placement relative to the galvo field. It is not possible to change the window placement via the VLM editor or any programming interface (LMOSActX or LMOSAuto). This option should be used with care since it is easy to get the "Galvo overrun" error (if the marking window is bigger than the galvo field) or "Axis reached software limit" error (if the marking window position is wrong). The second problem can be alleviated by manually inspecting the axes positions of all the shadows in the shadow property dialog.


Drawing settings
Drawing
Options
Script include file
General options:
Activate clipping
Multiple LP marking
On-the-fly
Execute drawing in a loop
Single shadow mode
Flexible shadows
Optimize marking time in respect of:
Z-axis
Head shadow
Nothing
OK
Abbrechen
Übernehmen
Hilfe
Galvo field Properties
Galvo field
Pos./Size
Position: X: 52.000 mm
Y: 61.000 mm
Size: DX: 20.944 mm
DY: 23.000 mm
rofin
We think laser

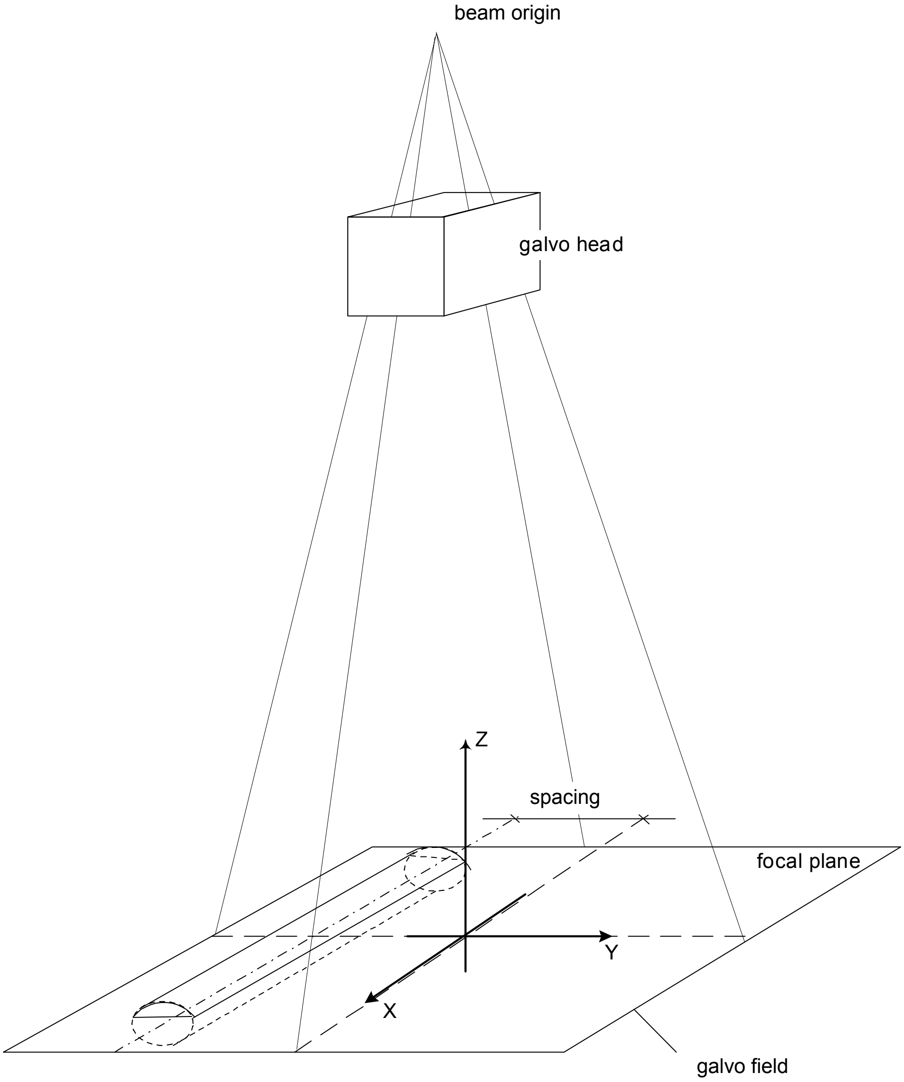
5 Positioning help

When working with smaller marking windows it is sometimes very helpful to be able to see the real position of the window on a workpiece. For this purpose, **Positioning help** of the VLM can be used. Switch to the marking area view in the VLM editor, select a marking window (shadow) and start the positioning help. All the mechanical axes available in the configuration and used by the current VLM file will move to their positions indicated in the property dialog of the selected shadow and then the rectangle of the shadow will permanently displayed with the pilot beam. There is one exception to this rule: if Z-axis is configured to be used for marking it is NOT moved. This is because all the shadows reference the same VLM layer that cannot be edited and that layer always has Z position set to zero. Note also that the positioning help displays a shadow rectangle only if a single shadow is selected. For a selection containing more than one shadow or a mixed selection (a shadow and the drawing) nothing is displayed.

6 Configuration settings

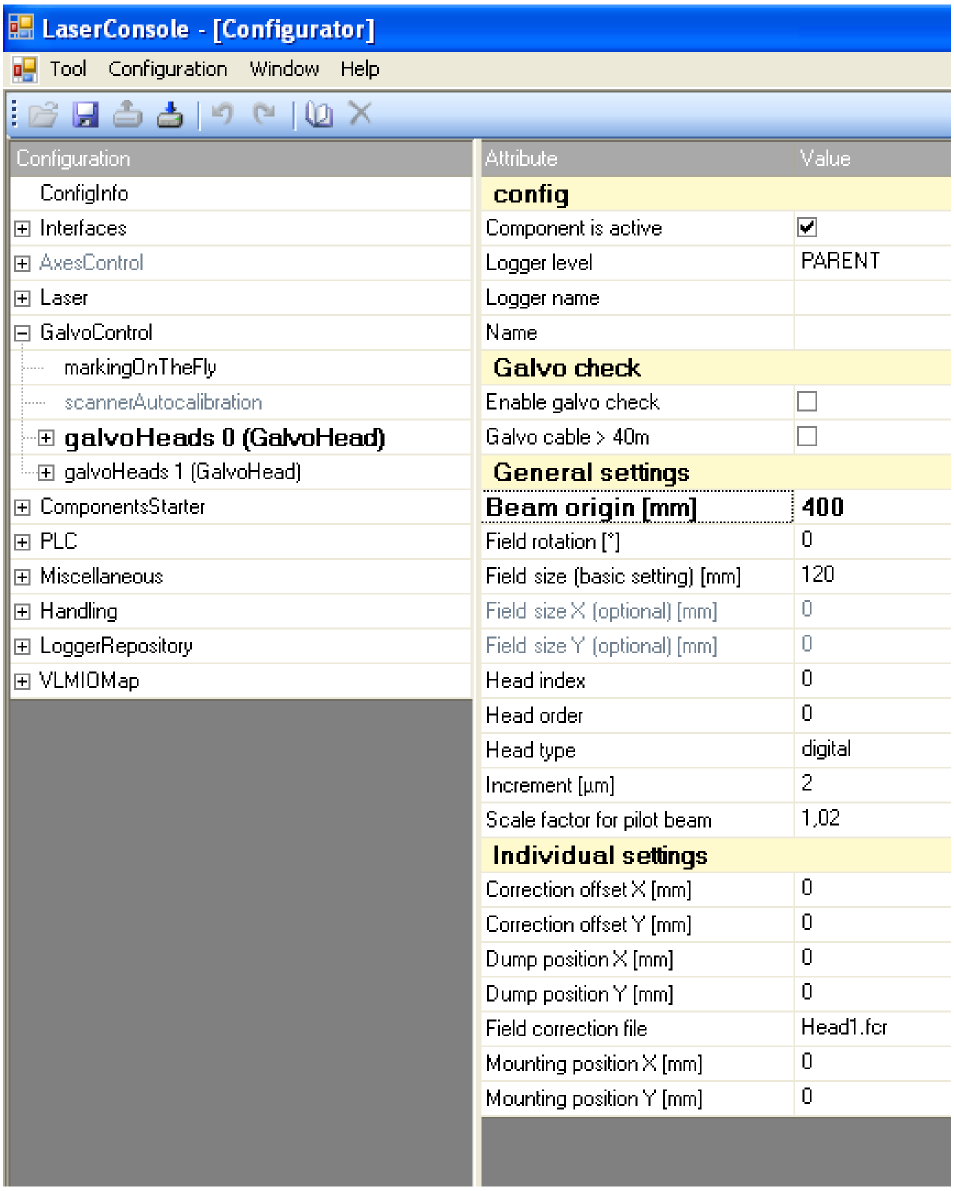
6.1 Beam origin

Only service personnel should edit the settings described in this chapter. Using an additional surface correction VLM compensates all optical distortions, thus ensuring correct engraving on a workpiece surface. To compute the surface correction a parameter **Beam origin** is needed. This is the height (Z coordinate) of the imaginable point the laser beam originates at. Basically the beam origin depends on the galvo field size. The table below gives value of beam origin for standard field sizes. For field sizes not in this table, the beam origin can be calculated by linear interpolation. In the configuration, the beam origin value is a property of a galvo head. The *Configurator tool* saves these data in the file `Config-win32.xml`.



Beam origin [mm] is proportional to galvo field size a [mm]:

galvo field size [mm]	60	120	180	240	300
beam origin [mm]	157	314	471	628	785


LaserConsole - [Configurator]
Tool
Configuration
Window
Help
Configuration
ConfigInfo
Interfaces
AxesControl
Laser
GalvoControl
markingOnTheFly
scannerAutocalibration
galvoHeads 0 (GalvoHead)
galvoHeads 1 (GalvoHead)
ComponentsStarter
PLC
Miscellaneous
Handling
LoggerRepository
VLMIOMap
Attribute
Value
config
Component is active
Logger level
PARENT
Logger name
Name
Galvo check
Enable galvo check
Galvo cable > 40m
General settings
Beam origin [mm]
400
Field rotation [°]
0
Field size (basic setting) [mm]
120
Field size X (optional) [mm]
0
Field size Y (optional) [mm]
0
Head index
0
Head order
0
Head type
digital
Increment [µm]
2
Scale factor for pilot beam
1,02
Individual settings
Correction offset X [mm]
0
Correction offset Y [mm]
0
Dump position X [mm]
0
Dump position Y [mm]
0
Field correction file
Head1.fcr
Mounting position X [mm]
0
Mounting position Y [mm]
0

6.2 Position of rotation axis

This section only applies to cylinder marking.
To configure a rotation axis, select the direction of the rotation axis and enter its offset from the galvo field center. If the rotation axis is used together with a Z-axis enter distance of axis center to focus plane.

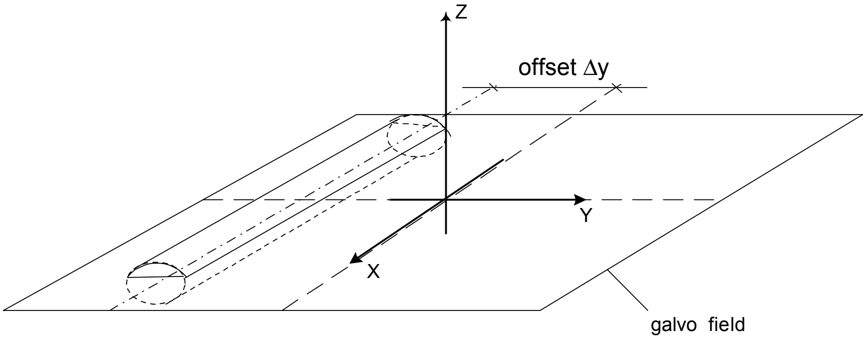
Rotation		Meaning
Direction of rotation axis	X-Axis parallel	axial vector
Distance of rotation axis center to center of galvo [mm]	17	Δx or Δy
Distance of rotation axis center to focus plane [mm]	58	h_0

☞ To configure a rotation axis (W):

1. Launch **Configurator** tool in the **Laser Console**.
2. Fetch the actual configuration from the running RCU system or open a file.
3. Open the **axis 3** component.

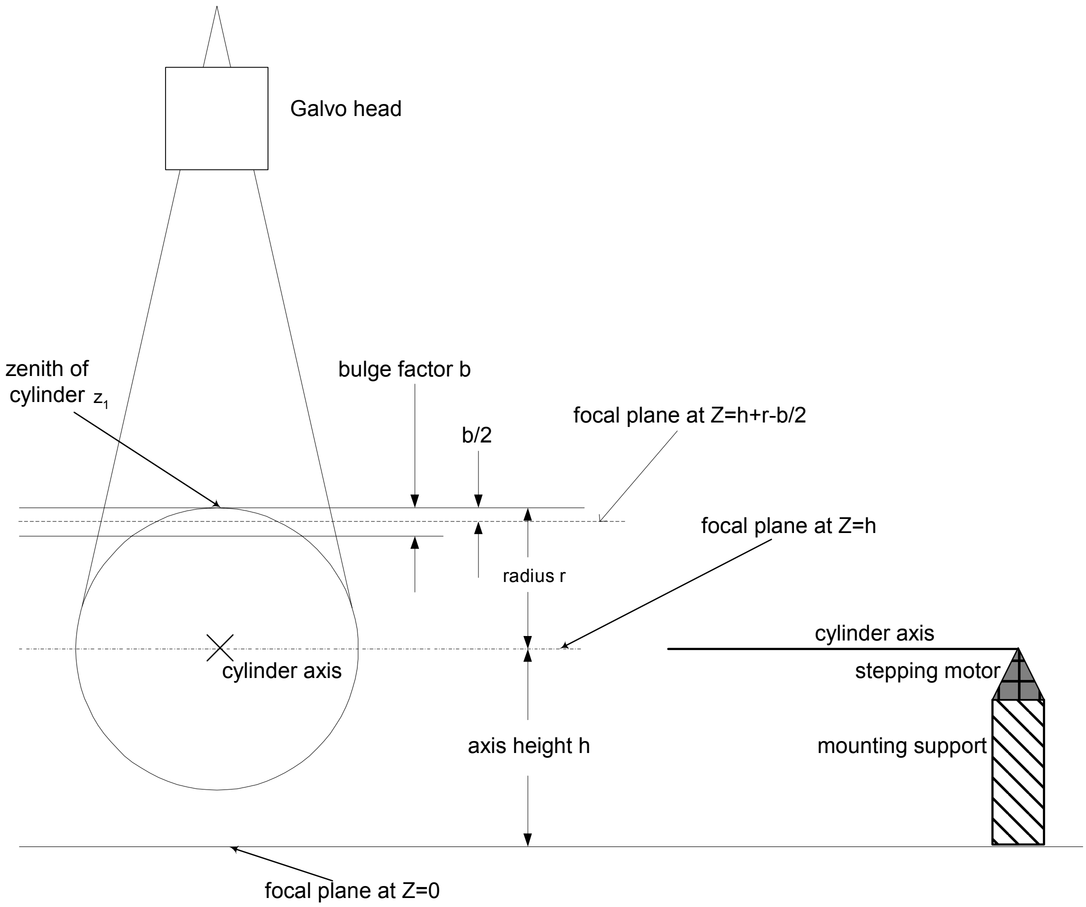
   The W-axis settings are displayed. The logging name of W axis is `AxisCan301_W_n`; n={1, 2, …}.
4. Check Component is active box.
5. Scroll to the Rotation settings.
6. Select either X- or Y-axis parallel from the **Direction of rotation** axis list box.
7. Enter the **Distance of rotation axis center to center of galvo [mm]**.

The rotation axis need not be at the center of the galvo field. The additional offset (either Δx or Δy) is represented by the parameter **Distance of rotation axis center to center of galvo** in **Configurator**. In the figure below, this offset Δy is along the Y coordinate axis. In the above configuration the offset is set to 17 mm.



8. Enter the **Distance of rotation axis center to focus plane** [mm].

It is the position of the Z-axis (axis height h_0 in the figure below) such that the geometrical rotation axis is at the focal plane. In the above configuration, this parameter is set to 58 mm.
This value can be taken from the engineering drawing of the laser installation. Alternatively this value can be found by a measurement on the laser installation. A section below describes how to do the measurement. Note that this parameter affects positioning of the mechanical Z-axis if it is used for marking.



front view side view

For a new VLM file created from a template without workpiece information VLM retrieves the above setting from configuration and suggests the corresponding workpiece parameters. If a VLM file is opened in the VLM editor or via a programming interface (LMOSActX or LMOSAuto) the axis offset form the field center and axis height are updated automatically. However the VLM doesn't update the direction of the rotation axis. If the direction defined by the workpiece doesn't match the direction from the configuration marking will not start. Usually the service personnel should configure a rotation axis.

6.3 To configure an XY-table

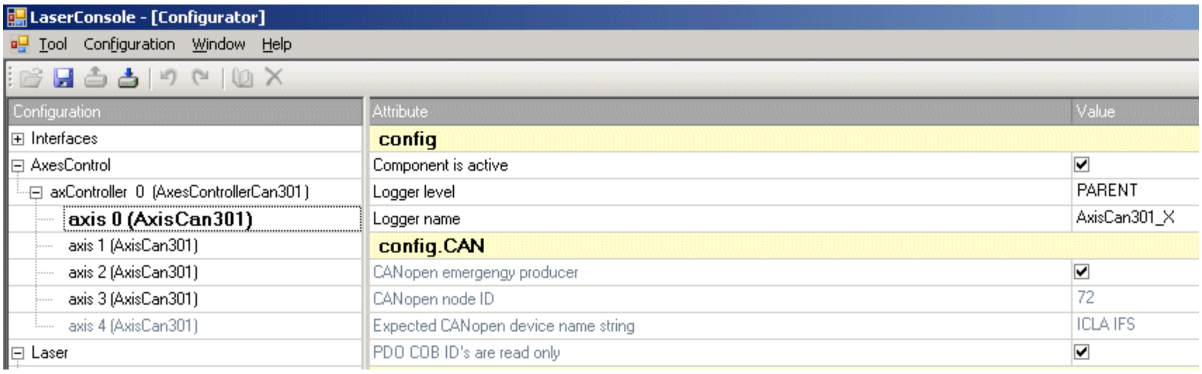
This section applies to both horizontal cylinder and horizontal plane marking.
The X-axis will be configured first.

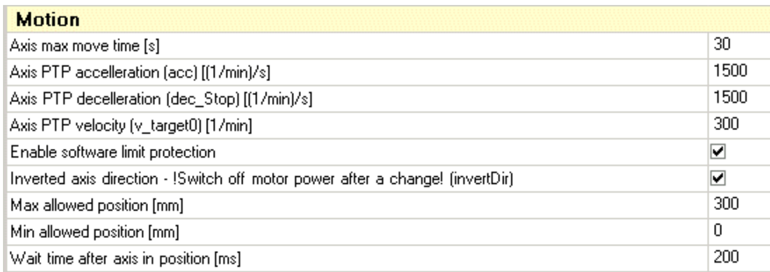
1. Launch **Configurator** tool in the **Laser Console**.
2. Fetch the actual configuration from the running RCU system or open a file.
3. Open the **axis 0** component.

   The X-axis settings are displayed. The logging name of X-axis is `AxisCan301_X`.
4. Check **Component is active** box.
5. Scroll to the **Motion** settings.
6. Enter **Min allowed position** [mm].
7. Enter **Max allowed position** [mm].

   The maximum linear axis movement in X direction Δx_{max} is given by the difference of these two numerical values.
8. Repeat this procedure for Y-axis, i.e. `axis 1` component, whose logging name is `AxisCan301_Y`.

Although present, **Rotation** settings has no effect here.

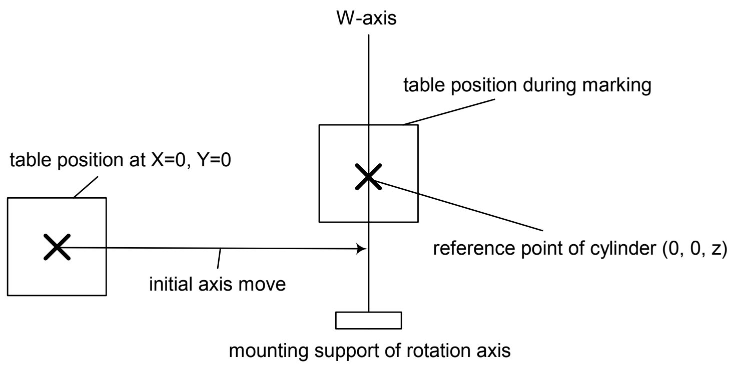




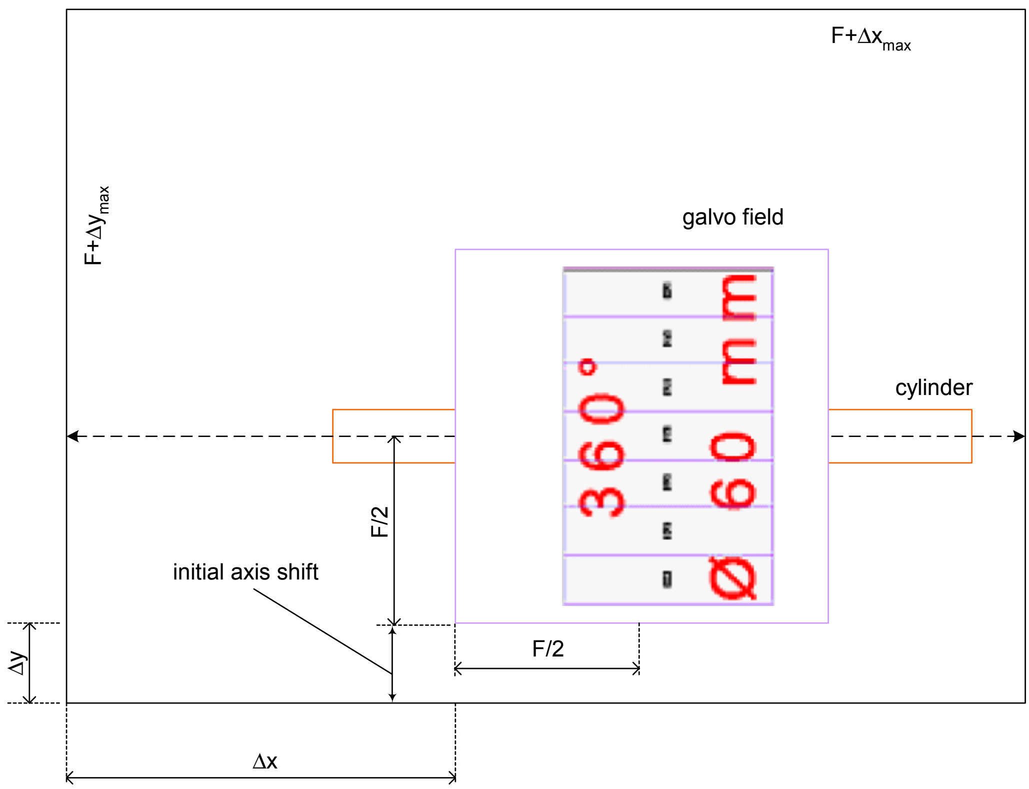
Note that the grey rectangle in the marking area view of the VLM editor represents the area where the marking is possible. The extensions of this area are Δx_{max}+F and Δy_{max}+F where F is the galvo field size. Currently the VLM editor cannot correctly visualize the marking area if **Min allowed position** of any of X and Y axes is nonzero.

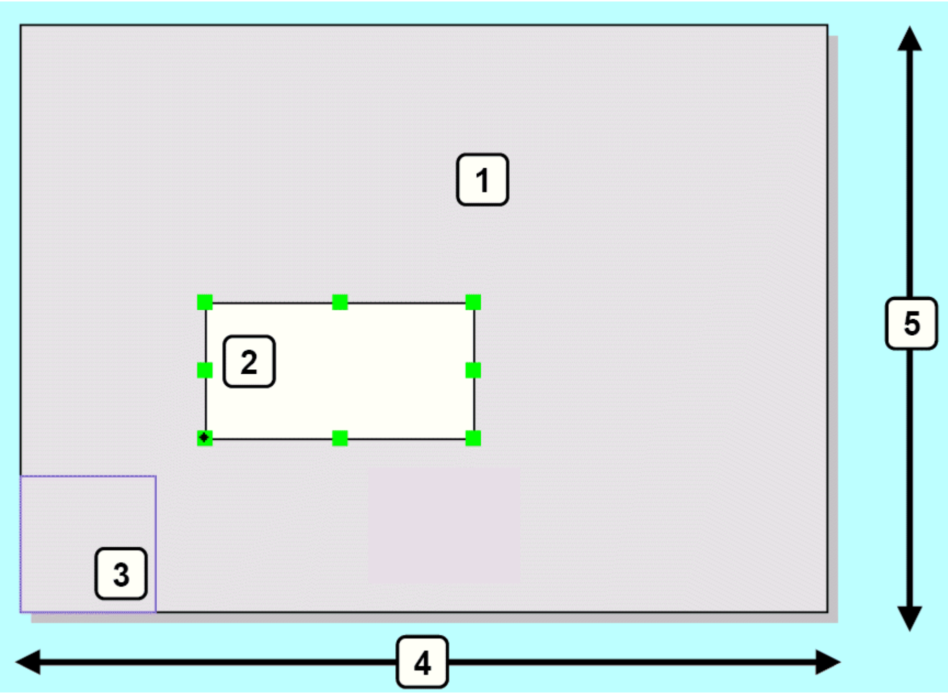
6.4 Initial linear axes positions

If the laser installation provides linear mechanical axes, X and/or Y, and also a rotation axis W it is then necessary to tell the VLM what move of one of the linear axis is needed in order to bring the rotation axis into a predefined position relative to the galvo head.



This position of the linear axis is represented by one of the parameters **Position of rotation axis in X direction** or **Position of rotation axis in Y direction** depending on the rotation axis direction. Both parameters are to be found at the rotation axis settings. If both are set to nonzero values the VLM uses only one corresponding to the direction of the rotation axis.





The meanings of the reference signs are the following:

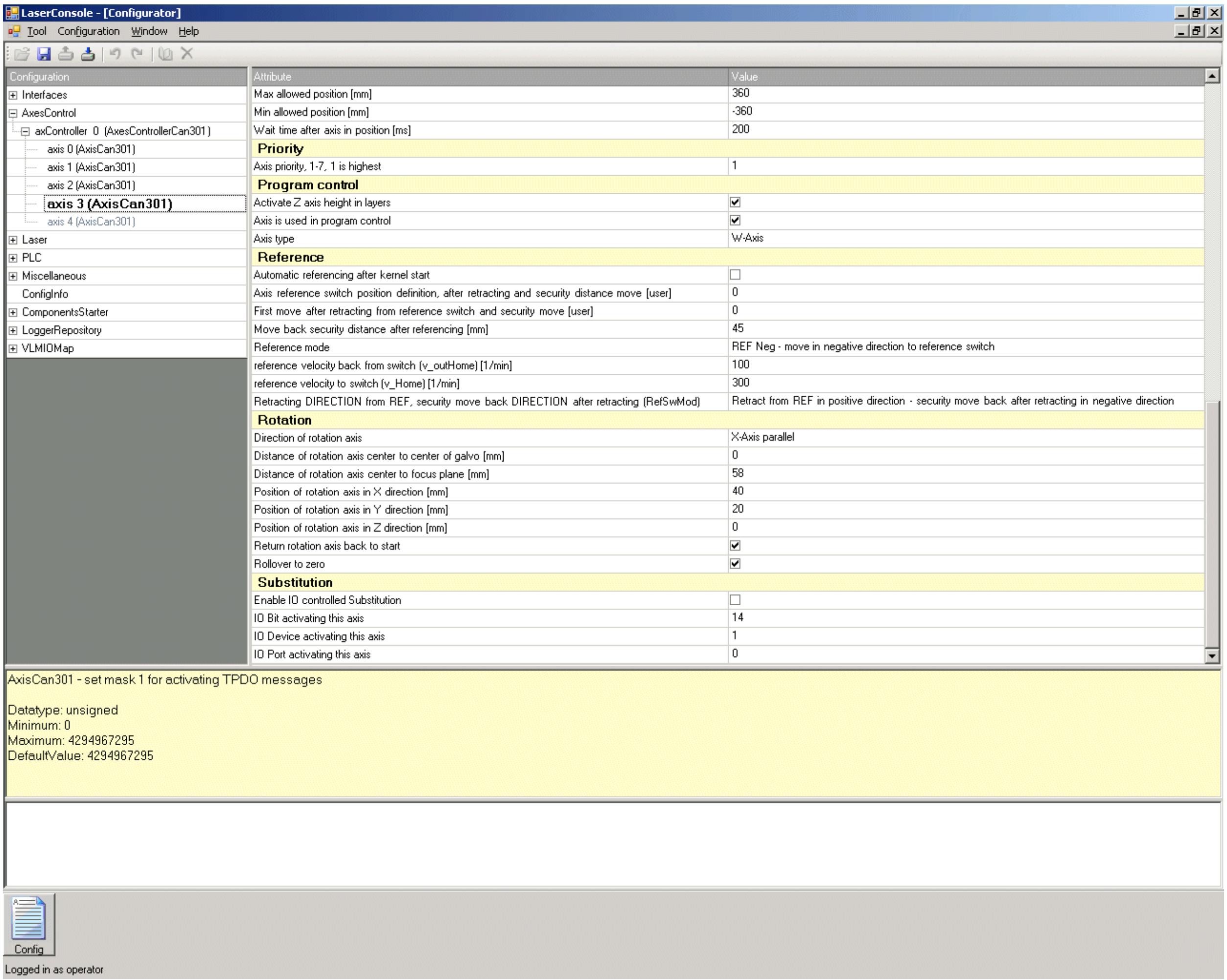
1 Marking area	4 F+Δx_{max}
2 Drawing area	5 F+Δy_{max}
3 Galvo field, area=F×F	

To determine the initial axis position (either Δx or Δy):

1. Mark (at least) lower left corner plotted in blue in the above figure on a steel plate at the bottom.
2. Move the galvo head to the desired reference point and mark a cross at center of galvo field.
3. Measure the spacing of between cross and corner mark in X and Y direction.
4. Subtracting ½F in both directions (i.e. X and Y coordinates) yields Δx and Δy.

The screen shot of **Configurator** below displays settings for initial axis positions in two directions of the XY-table carrying the rotation axis, which amounts to Δx = 40 mm and Δy = 20 mm.
To enter initial axis positions open **axis 3** (W-axis) component and scroll to **rotation** settings.

When the user clicks **Start marking** , VLM will move the XY-table accordingly before marking takes place. The cylinder needs not be centered in the galvo field. In that case enter **Distance of rotation axis center to center of galvo**.



Rotation	
Direction of rotation axis	X-Axis parallel
Distance of rotation axis center to center of galvo [mm]	0
Distance of rotation axis center to focus plane [mm]	58
Position of rotation axis in X direction [mm]	40
Position of rotation axis in Y direction [mm]	20
Position of rotation axis in Z direction [mm]	0
Return rotation axis back to start	☑
Rollover to zero	☑

6.5 Reference points: measuring coordinates for cylinders

To measure the reference point of a cylinder:

1. Launch VLM.
2. Select **Plane** from the **Surface** list box of the **Workpiece and axis settings** window.
3. Clear all **Use axes:** check boxes.
4. Measure the cylinder's diameter (2×r) using a caliper rule.
5. Place the cylinder in the mounting support.
6. Measure the spacing between bottom (z_0) and the cylinder position facing the bottom or the opposite position (z_1) by means of a caliper rule, i.e. either (h_0-r) or (h_0+r) is metered, respectively.

   Adding or subtracting the radius (r) as appropriate yields the axis height (h_0) to be entered in **Configurator**.
   Measuring horizontal coordinates requires two steps, a coarse and a precise measurement. The latter one uses the marking laser.
7. Set **Z** component of **Reference point** of the **Workpiece and axis settings** window to 0.00.
8. Mark a line parallel to the cylinder axis passing the center of the galvo field.
9. Measure distance of cylinder from the marked line using a right triangle as a ruler and then add the radius (r).

   A right triangle is supposed to replace a plummet.
   This coarse result is used then again as an initial numerical value for a precise measurement, i.e. an alignment procedure is applied. This procedure yields the spacing to be entered in *Configurator*, either Δx or Δy.
10. Set **Z** component of **Reference point** to the numerical value of -r+½t.
11. Mark three parallel lines whose spacing is 1 mm approx. at the initial spacing from the center of the galvo field.
    If these three lines are symmetric, as seen from top view, then the estimated spacing is correct within reasonable accuracy, else rotate the cylinder and try again.
12. Select **Cylinder** from the **Surface** list box.
13. Close VLM.

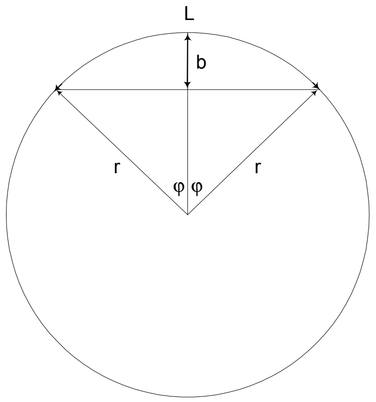
7 Definitions

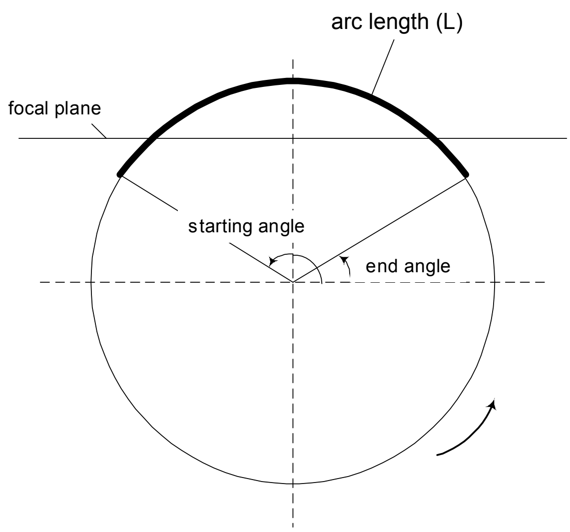
7.1 Reference point

In general, a reference point defines the position of a body. For cylinder marking, the reference point is situated on its axis.
Service personnel only has to input one coordinate, x or y, this is sufficient to determine the spacing between cylinder axis and origin of the laser head coordinate system, because the spacing is measured perpendicular to the cylinder axis. Corresponding **Configurator** settings are described in section Position of rotation axis on page 22. *VLM* retrieves these settings from **Configurator** and displays them in the **Workpiece and axes settings** window.

7.2 Marking window

A part of a drawing which can be marked without rotating a cylinder is called a marking window. Due to the finite focus depth of the laser, marking outside certain region would become blurred, hence, a cylinder has to be turned several times during laser marking. *VLM* suggests the laser focus at a distance b/2 below the surface of a cylinder to be marked. To do marking the drawing must be split into a series of marking windows whose width is the arc length (L), which depends on default circular sector and diameter. For instance, the arc length (L) of a cylinder whose diameter (d) is 60 mm equals 31.42 mm assuming default sector of 60°.
Without using a rotation axis only a narrow rectangle whose width corresponds to the arc length (L), can be marked on a cylinder.





7.3 Marking area

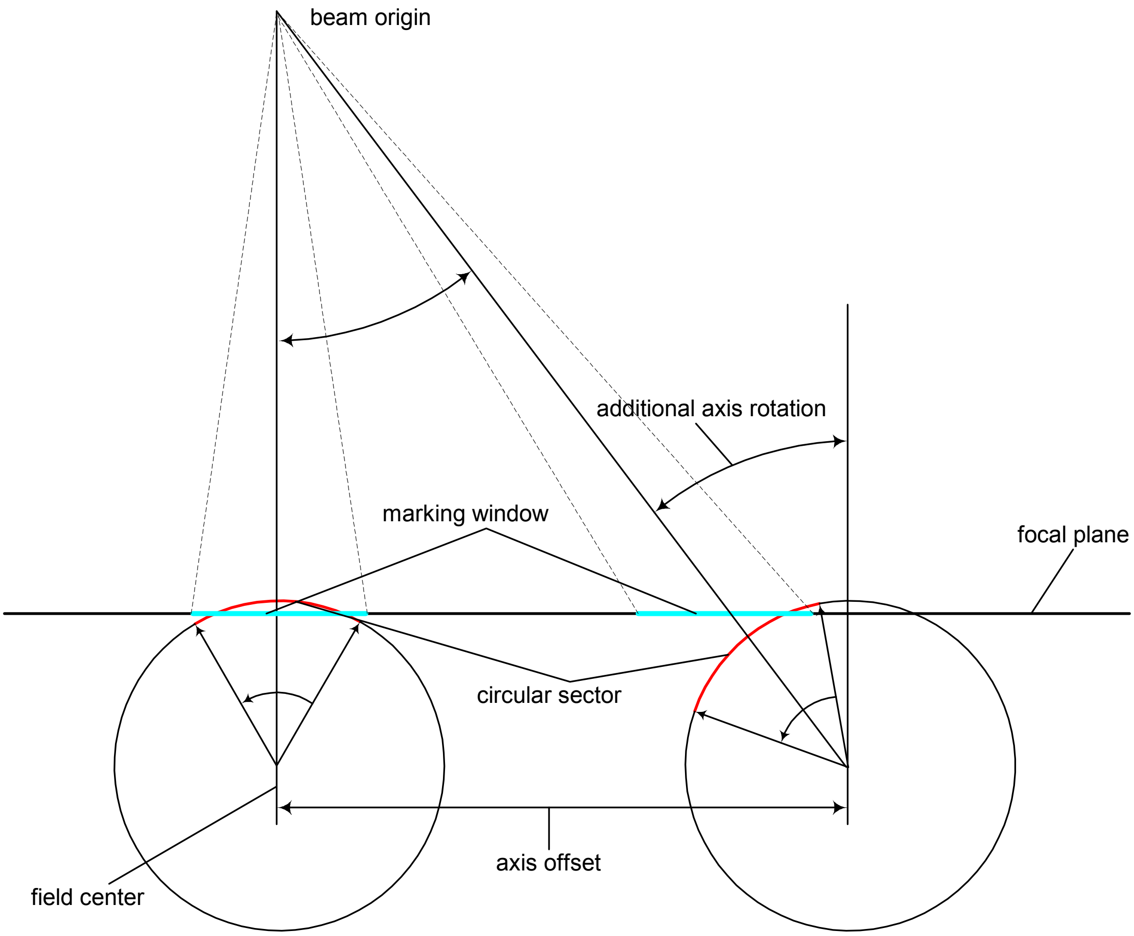
The galvo field is a square (F×F). An XY-table carrying the mounting support of a workpiece enlarges the accessible area of the laser beam, i.e. the marking area. The marking area is given by the extent of the galvo field plus the maximum linear axis move (Δx_{max}, Δy_{max}) in X and/or Y direction. Consequently, the marking area is enlarged to $(F+\Delta x_{max})\times(F+\Delta y_{max})$.

7.4 Maximum marking cylinder surface

Without linear axes the maximum marking cylinder surface is given by circumference times width of galvo field: $2\times\pi\times r\times F$.
An XY-table is required for marking a long cylinder whose height (h) exceeds the width (F) of the galvo field. Consequently, the maximum marking cylinder surface amounts to circumference times width of the galvo field plus the axis movement: $2\times\pi\times r\times(F+\Delta x_{max})$, where Δx_{max} denotes the maximum linear axis movement in X direction.
The width of a drawing might exceed the circumference of a cylinder. In that case *VLM* will continue marking at an angle beyond 360°, thus wrapping the drawing around the cylinder. For instance, to mark a helix, the width of a drawing may be many times over the circumference.

7.5 Position of the marking on the cylinder surface

Here we address the question of where the marking appears on the cylinder surface. The common rule is the follows: the circular sector is placed at the circumference symmetric to the line connecting the cylinder axis with the beam origin. If the cylinder is placed at the galvo field center (in the figure below, the cylinder on the left) then the sector is placed symmetric to the cylinder zenith. If the cylinder is placed certain distance off the field center the sector rotates about its center in the direction of the origin. If the option **Compensate for axis offset** in the **Workpiece and axes** dialog is checked the cylinder is rotated by additional angle (see the figure) so that the marking doesn't move relative to the cylinder surface. Note that the surface correction is responsible for transforming the planar marking windows into circular segments without distortion.


beam origin
additional axis rotation
marking window
focal plane
circular sector
axis offset
field center

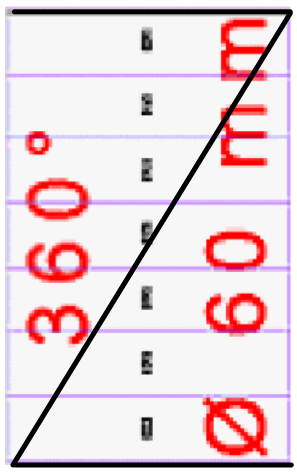
8 Troubleshooting

8.1 Zigzag lines

The user draws a straight line across a cylinder, yet VLM marks a series of parallel straight lines following a zigzag line.
Reversing the cylinder's rotational direction will solve the problem: To switch from counterclockwise to clockwise or vice versa, either check or clear the **Inverted axis direction** box.

8.2 Stepping motor does not run within reasonable accuracy

The user wants the stepping motor to revolve a cylinder by 360° during marking a whole cylindrical shell, yet an angle deviation occurs.
If the height of a drawing equals the circumference of a cylinder, the upper and the lower straight line of the drawn character Z should merge into one another.



Adjusting the **mm per inc scale factor [user/inc]** parameter in the configuration of the rotation axis, which applies to angles [deg.] as well, should solve the problem. Increase or decrease this numerical value and try again.

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