KLOE SA

GRAYSCALE STRUCTURES

TUTORIAL 3

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Tutorial 3 – Grayscale structures

The purpose of this document is to describe the typical recommended method to create grayscale structures with KLOE's Dilase technology.

Introduction

The photo-lithographic approach to work in “grayscale” with KLOE-DILASE technology consists in irradiating a photoresist with a gradual energy dose.

The main topic presented in this document concerns the “slope” structures (also called “ramp” or blazed gratings”) used to make diffractive surfaces.

Grayscale realization: Slope

A typical process to create a slope in grayscale resist is to generate a laser trajectory with KloeDesign (element “line” generates in Fast synchronized laser trigger) which will be added several times in DilaseSoft file list. The number of loaded files (n) and the distance between each line (step Δn) will determine the slope dimensions.

In DilaseSoft each file *{1, 2, 3..n} will be associated with and XY position* (to do not overwrite each line) and an energy *(m_i - i= {1, 2, 3..n})* (to create a thick gray scale) of their own.

The energies must follow a linear law of variation or not (defined by the user) to create a slope with the following principle: Areas where the energy is high will be thick after development and those where the energy is low will leave a small thickness of resin after development.

The principle of creation is presented by Fig 1 :

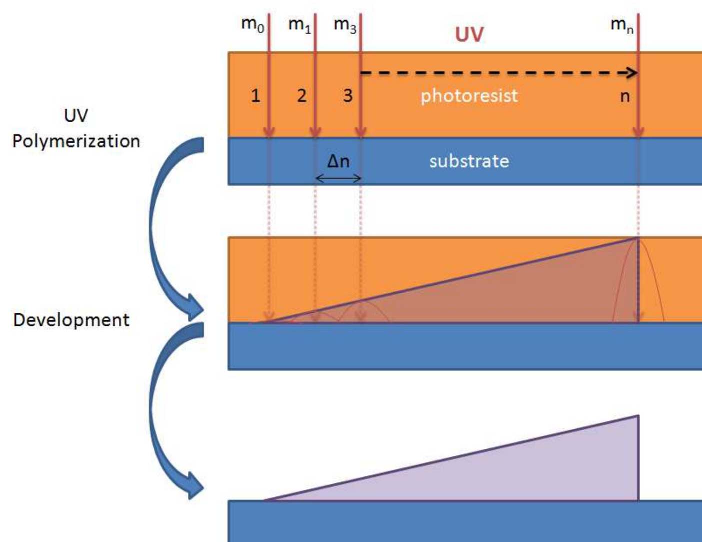

Fig 1 : Writing principle

{1, 2, 3..n} represents the laser paths

Note : An increasing or decreasing modulation will define the direction of the slope.

Example design of a 100µm slopes network over a 10mm² surface.

Generating the basic path

The base file for the creation of the slope is realized by the software KLOEDESIGN.

Generating steps are described below.

1. Generation of a line length of 10mm.
   - Click on the library tab and select the object Line.
   - Click on the line and enter a length of 10mm in the lower right window of the property.
   - Confirm with "Enter".

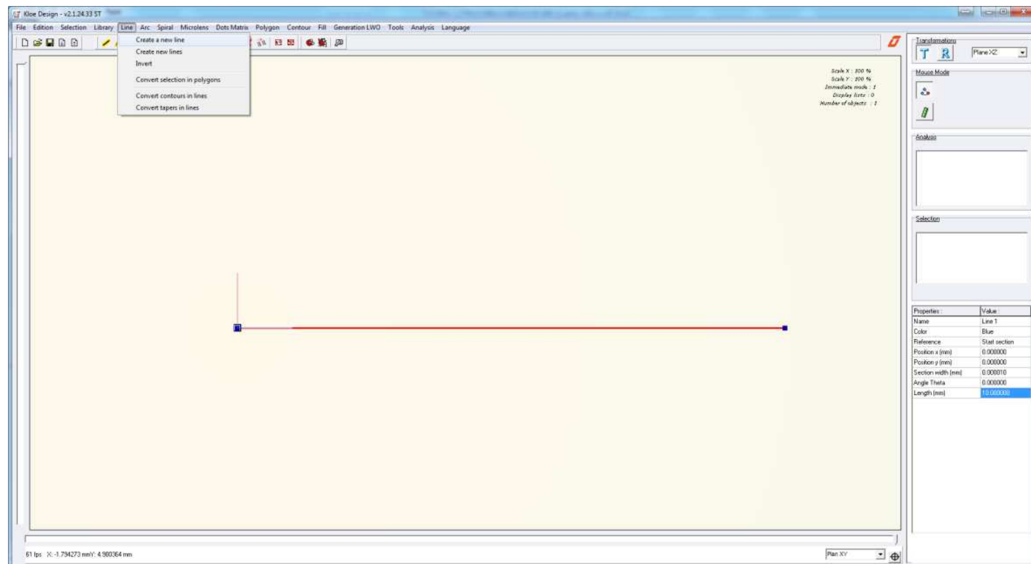

Fig 2 : Creating a line

2. Define the stabilization length (see Fig 3).
   - Click on Generation LWO > Generation Options...>Trajectories Tab.
   - Enter 5mm value in the "Stabilization lengths before / after laser synchronization" and confirm.

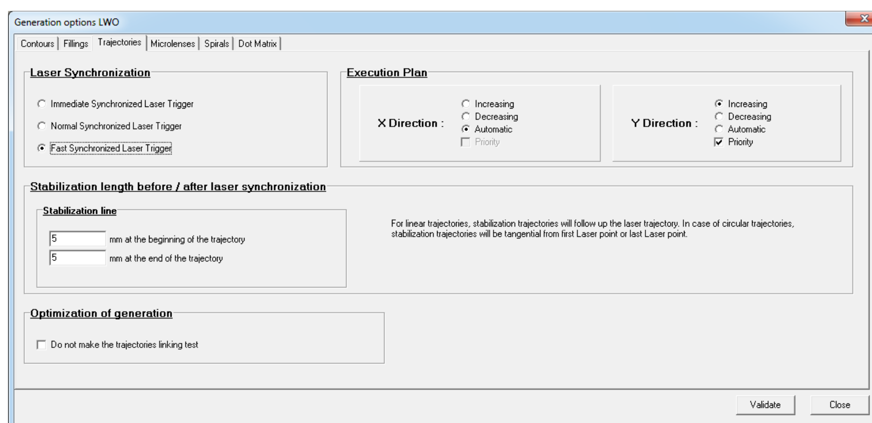

Fig 3 : Setting stabilization lengths

Note : Stabilization length allows during a write to stabilize the positioning of the motors in the axis of their trajectory

3. Generation of the trajectory
    - Click on Generation LWO > Generate the current pattern.. (see Fig 4)

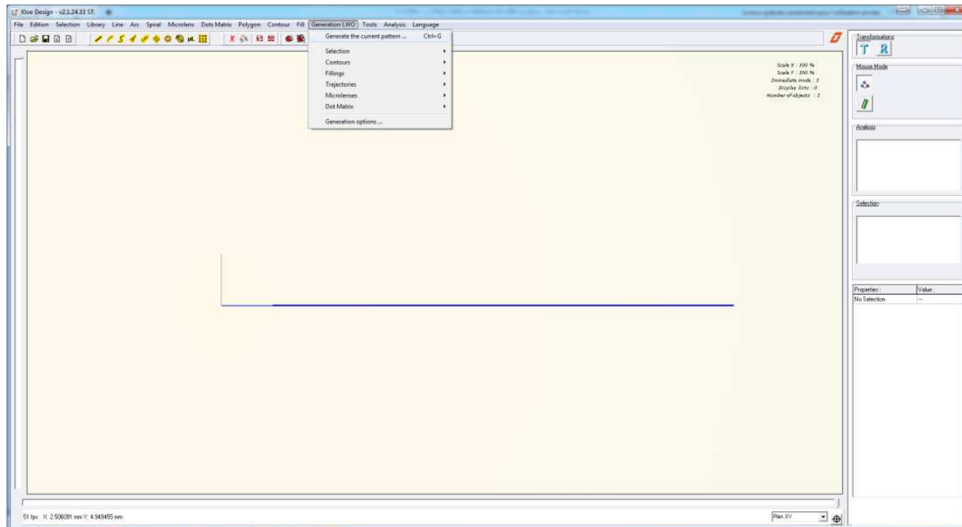

Fig 4 : Generation of the trajectory

- Save the file in a folder under the name “1LINE-A.lwo”. An information window informs that the line has been exported to LWO (see Fig 5).

Fig 5 : Validating the generation of the trajectory

Generating a slope

The previously exported trajectory must be duplicated to form a single slope. Generating steps are described below.

Using the “DFL Creator” software tool.

This software that can be accessed from the menu “Applications” of DilaseSoft is dedicated to creating file list, with the possibility to make changes to the parameters of position, energy and speed.

- Settings of DFLcreator

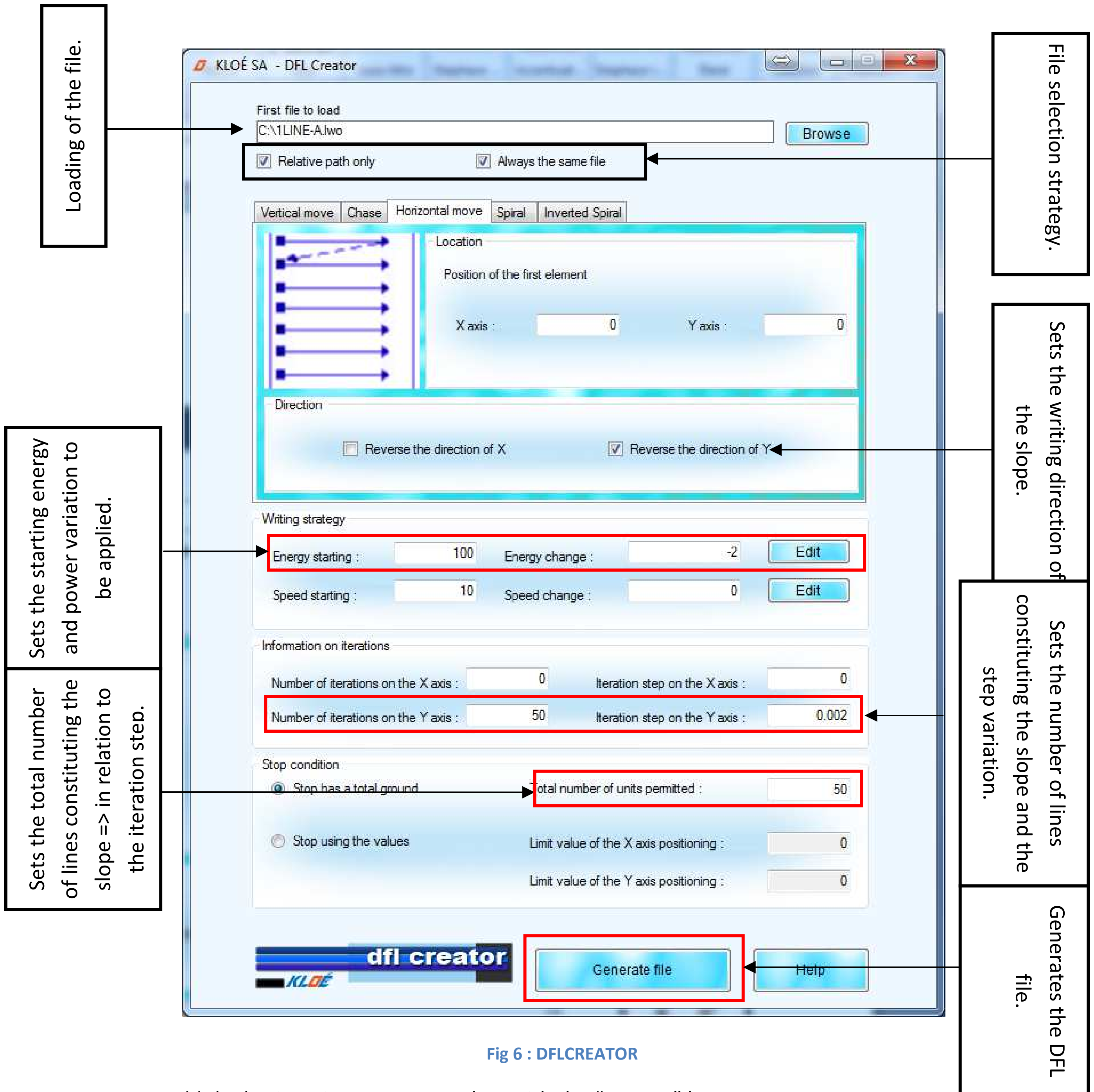

Fig 6 : DFLCREATOR

- Add the basic trajectory 1LINE-A.lwo with the "Browse" button.
- Enter the parameters of the slope :

Energy starting:	100	Value defined according to lithographic parameters
Energy variation:	-2	Value defined according to lithographic parameters
Speed variation:	10	Value defined according to lithographic parameters

Number of iterations on the Y axis: 50

Iteration step on the Y axis: 0.002

Total number of units authorized: 50

"Relative path only" is checked as well as "Always the same file" and "Invert the direction in Y"

- Generate DFL file representative of a slope under the name "Pente1.dfl".

If the generation is correct, the following message will appear :

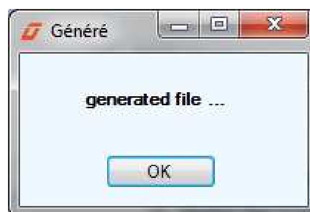

Fig 7 : Generation indication

At this point, the file list describing the dimensional and energetic profile of a slope was performed.

Note : A LWO file is a file trajectory that can be loaded and configured in speed, modulation, and position on DilaseSoft. A DFL file represents a series of LWO files already containing the modulation parameters, speed and position, loadable or exportable. The DFL files can be created either by DFLCreator or by DilaseSoft (the "Export" button in the "lithography zone"), and may be reedited or corrected in a text editor.

Creating a slope network

The created slope will now be duplicated to cover a surface 10mm². The software used is always DFLCreator..

- Load the « pente1.dfl » file.
- Enter the number of iterations on the Y axis to 100 and the iteration step on the Y axis 0.1. The total number of authorized units is set at 100.

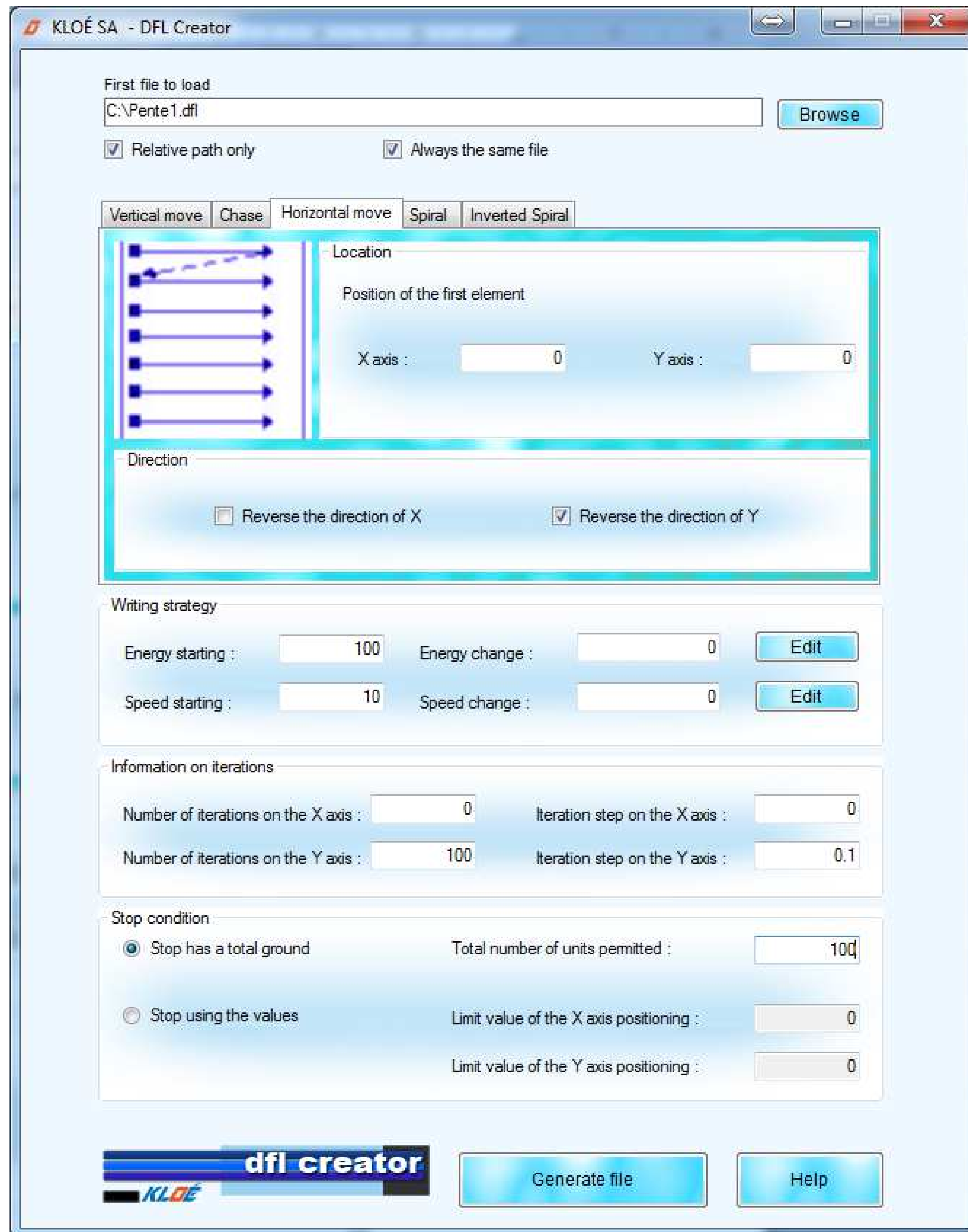

Fig 8 : Duplication slope pattern

- Generate the file as "100pentes1.dfl".

Note : The "100pentes1.dfl" file created can be loaded by DilaseSoft.

Simulation of trajectories using KloeDesign

To view the newly pattern created before starting the writing with DilaseSoft, you can load it into KLOEDESIGN.

- Click on tab "File>Import>Importation DFL>"100pente1.dfl"

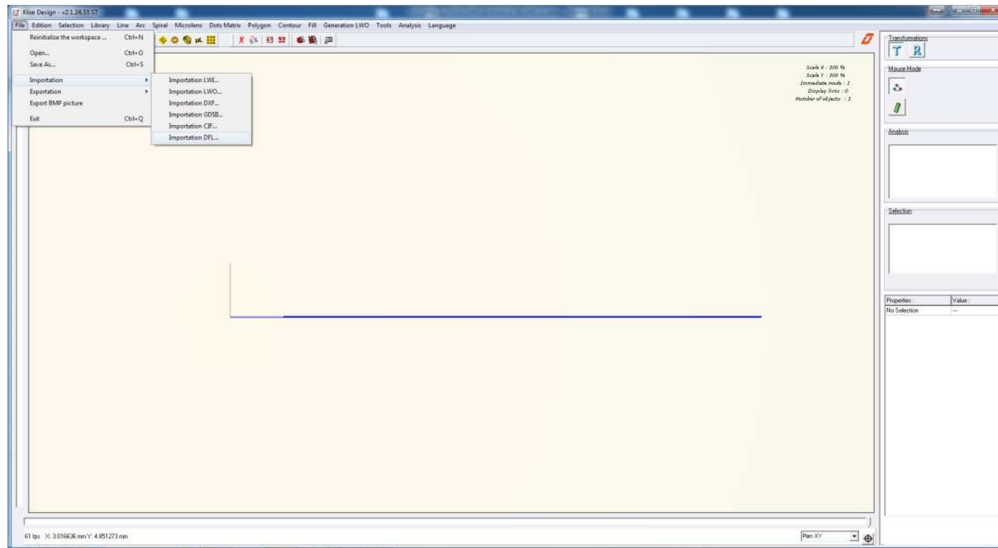

Fig 9 : Importing pattern

Answer "yes" to the following two windows that appear, to reset the KloeDesign workspace, and keep in the calculation of write times the established speed when entering with DFLCréator and included in the file .dfl .

The opening of a .dlf file in KloeDesign immediately launches the simulation of all the LWO files simultaneously (see Fig 10).

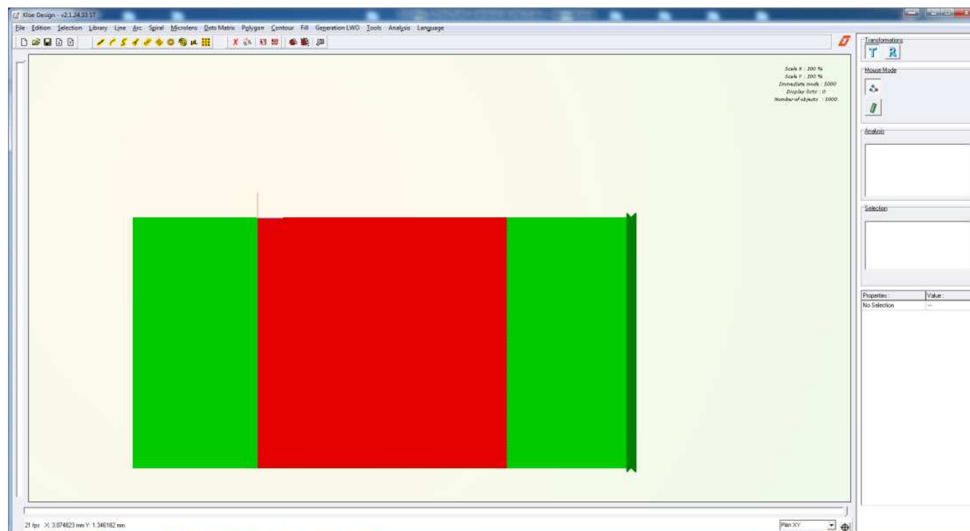

Fig 10 : Loading DFL

Note : The estimate of the writing time will not be available for the entire dlf file but only for a .lwo. Add up the time of all .lwo included dlf for the total time.

Loading in DilaseSoft

The created pattern will now be loaded into the Dilase interface. The software used is DilaseSoft.

- Click "Add" to load the pattern to be lithograph.
- Select the type of the file: type "dlf"
- Select the file you want and confirm (Fig 11).

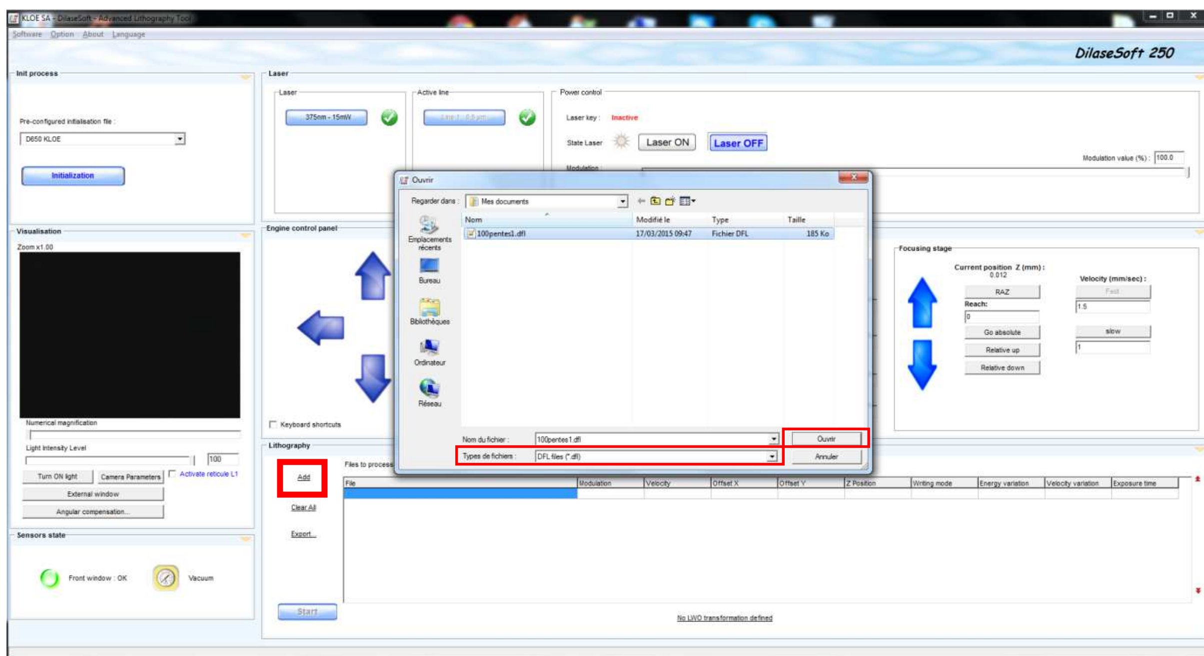

Fig 11 : Importation du motif sous DilaseSoft

After loading the file, click "start" to begin the lithography (Fig 12).

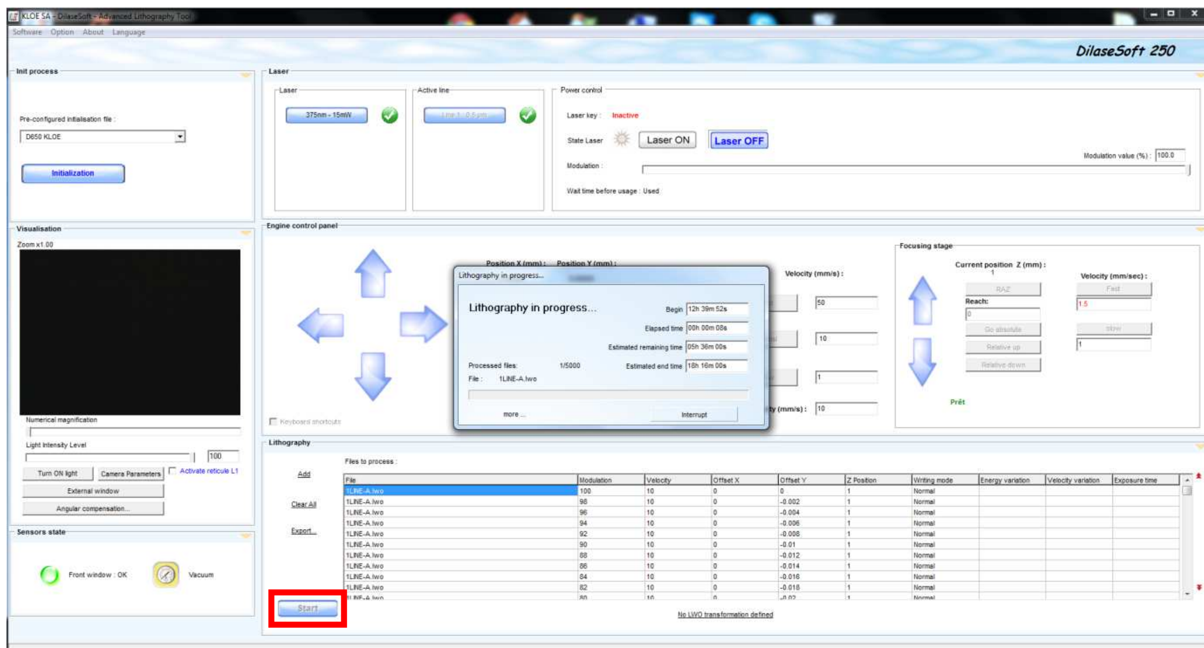

Fig 12 : Starting lithography

Grayscale realization: Microlens

The microlens element in KloeDesign allows after some settings to realize a microlens in grayscale resist (Resist from KLOE called K-NG) with a DILASE equipment.

The principle of creation is presented by Fig 13.

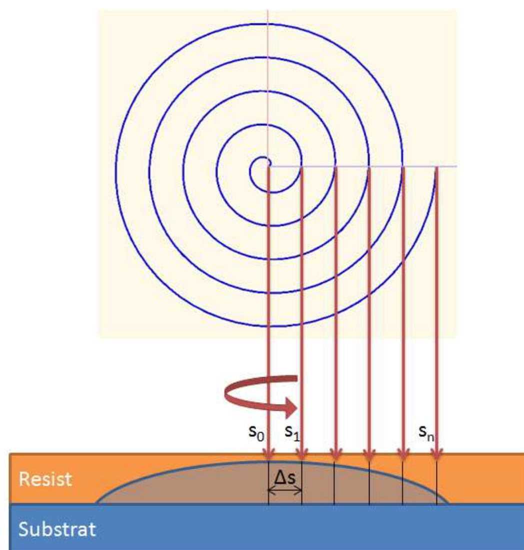

Fig 13 : Writing strategy for a microlens.

The microlens is made of spires. The number of spires "Sn" and their spacing "Δn" define the size of the microlens and its curvature. The writing of the microlens will start from its center towards the outside, while considering a starting energy "E_{start}" and an ending energy "E_{end}". For each written spire, the write speed increases and the laser power decreases so that it will describe the curvature of the microlens.

We will take as an example in this tutorial, a 20x20 microlens array with 200µm diameter and focal length 20mm +/-1mm at 633nm made on a 0.5mm glass substrate. The equipment used is a Dilase 650 embedding a 10µm laser spot size.

Microlens settings

The first step of this realization is to determine the sagittal height of the lens, which is a function of the diameter of it and the desired focal length.

Note : The sagittal height of the lens determines the thickness of the resist to be coated.

The principle used to determine the sagittal height of the lens as a function of its focal length is presented by the Fig 14.

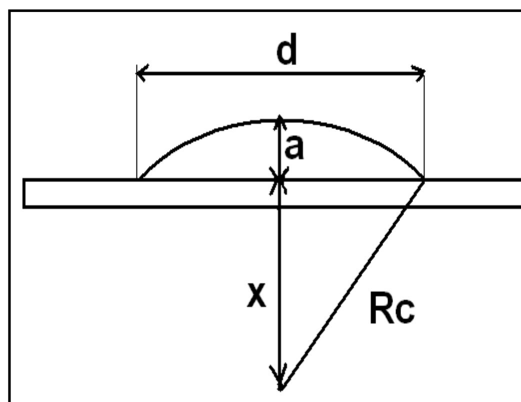

Fig 14 : Graphical representation of a lens on a glass substrate

The focus length « f » of the lens is function of its radius of curvature "Rc" and the index "n" of the material (Resin K-NG : n = 1.57 à 633nm).

$$f = \frac{Rc}{n-1} \quad \text{and} \quad Rc = f.(n-1)$$

The sagittal height "a" is obtained by the following formula:

$$a = Rc - x \quad \text{with} \quad x = \sqrt{Rc^2 - (\frac{d}{2})^2}$$

The theoretical sagittal height in function of the focal length is presented by the following tab :

Focal length (mm)	Sagittal height (µm)
19	9.6
20	9.12
21	8.69

Table 1 : Sagittal height depending on the focal length

Note : The photo-resist thickness required to achieve a 9.12µm sagittal height lens must be at least 10µm.

Software creation of the microlens

Click on the icon "µL" in the shortcut bar (see Fig 15) or from the menu "microlens" > "create a new microlens" to create a new microlens.

Fig 15 : Creation of the microlens

Once the microlens created (see Fig 16), then you can change its properties.

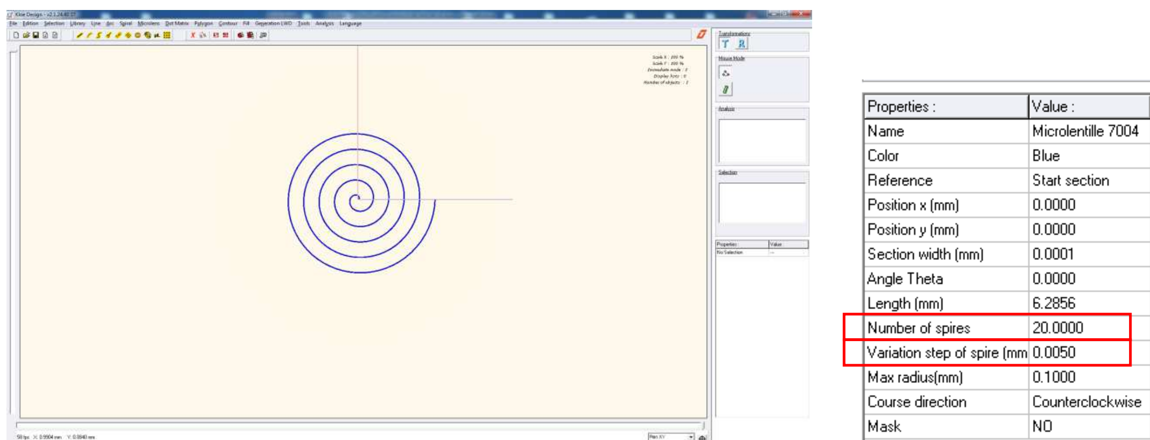

Fig 16 : microlens component // Properties of a microlens

We will change the settings in order to have a maximum radius of 0.1 mm and a pitch variation of spire about 0.005mm, so that it will be the half spot size, defining a 50% overlap.

The number of spires obtained is 20.

Generation of the microlens

To generate the microlens :

- Click on "LWO Generation" > "Generate the current pattern...".
- Save the microlens as "microlens.lwo".

An information window appears informing that a microlens has been generated (Fig 17).

Fig 17 : Exportation of the microlens

Loading in DilaseSoft

The microlens made will now be loaded in Dilase's piloting interface. The software used is DilaseSoft.

- Click on « Add » to add the pattern to imprint.
- Select the type of file to load: type ".lwo"
- Select the file "microlens.lwo", and then validate.

We now have access to the settings associated with the microlens element (see Fig 18) :

- Energy variation: This parameter defines the pitch of energy variation to apply to each spire.

- Speed variation: This parameter defines the pitch of speed variation to apply to each spire.

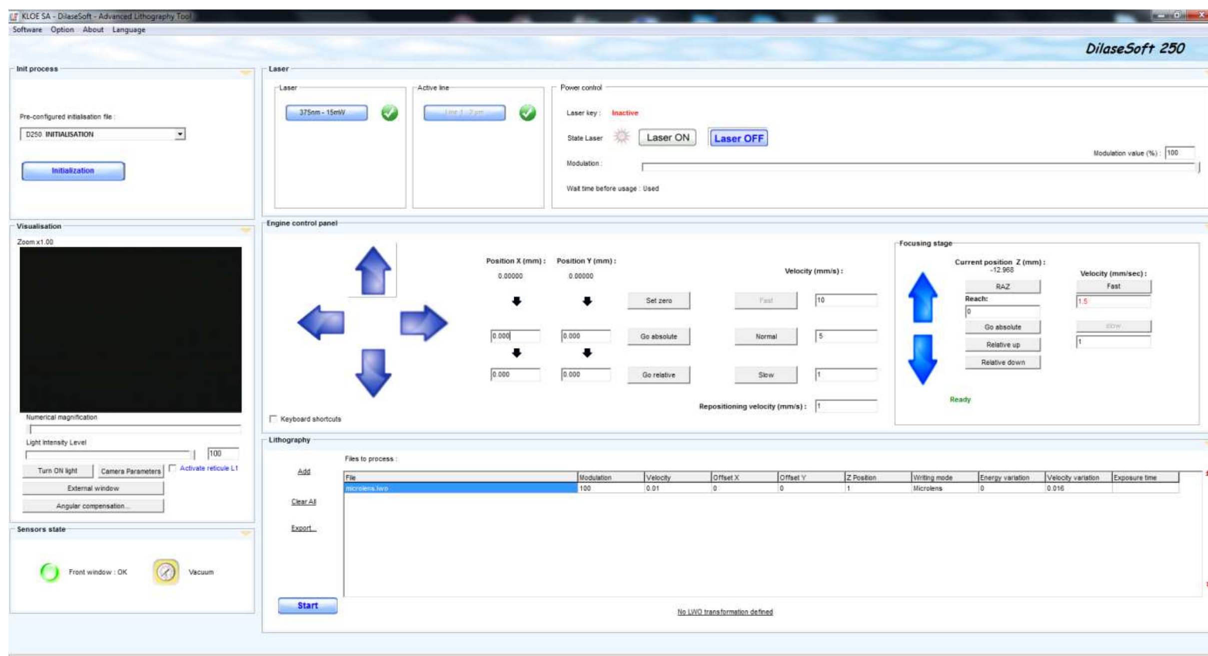

Fig 18 : Adding the microlens element in the DilaseSoft interface.

Note : By default the writing speed of the microlens is 0.01 mm/s and its speed variation is 0.016 mm/s. These default values are perfectly suited to write a microlens, so they do not need to be changed unless others specifications.

The parameters of "modulation" and "pitch variation" must be modified empirically by the resist process.

The parameter of energy variation "ΔE" is set according to the initial energy to be applied "E_{start}", the end energy "E_{end}" and the number of spires N_{SPIRES}.

$$\Delta E = \frac{E_{END} - E_{START}}{N_{SPIRES}}$$

This parameter must be empirically modified to find the ideal curvature that provides the expected focal length.

The following table shows the "variation pitch" determined according to the number of spire.

Edit the starting energy value in the field « Modulation » from DilaseSoft interface, and edit the pitch variation value found with the help of the table 2 given in exemple in the field « Energy variation».

ENERGY				Nb of spires 20																
START \\ END	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
100	0.000000	0.250000	0.500000	0.750000	1.000000	1.250000	1.500000	1.750000	2.000000	2.250000	2.500000	2.750000	3.000000	3.250000	3.500000	3.750000	4.000000	4.250000	4.500000	4.750000	5.000000
90			0.000000	0.250000	0.500000	0.750000	1.000000	1.250000	1.500000	1.750000	2.000000	2.250000	2.500000	2.750000	3.000000	3.250000	3.500000	3.750000	4.000000	4.250000	4.500000
80					0.000000	0.250000	0.500000	0.750000	1.000000	1.250000	1.500000	1.750000	2.000000	2.250000	2.500000	2.750000	3.000000	3.250000	3.500000	3.750000	4.000000
70							0.000000	0.250000	0.500000	0.750000	1.000000	1.250000	1.500000	1.750000	2.000000	2.250000	2.500000	2.750000	3.000000	3.250000	3.500000
60									0.000000	0.250000	0.500000	0.750000	1.000000	1.250000	1.500000	1.750000	2.000000	2.250000	2.500000	2.750000	3.000000
50											0.000000	0.250000	0.500000	0.750000	1.000000	1.250000	1.500000	1.750000	2.000000	2.250000	2.500000
40													0.000000	0.250000	0.500000	0.750000	1.000000	1.250000	1.500000	1.750000	2.000000
30															0.000000	0.250000	0.500000	0.750000	1.000000	1.250000	1.500000
20																	0.000000	0.250000	0.500000	0.750000	1.000000
15																		0.000000	0.250000	0.500000	0.750000
10																			0.000000	0.250000	0.500000
0																					0.000000

Table 2 : Example table showing the pitch of energy variation according to the number of spires.

Once the parameters found, the microlens array can be realized using the software DFLCREATOR.

- Load the file « microlens.lwo ».
- Select the spiral duplication mode.
- Enter the total number of authorized element and the pitch of iterations on the X axis and Y to 0.2.
- Click on "generate file" and save it as "20x20-microlens.dfl".

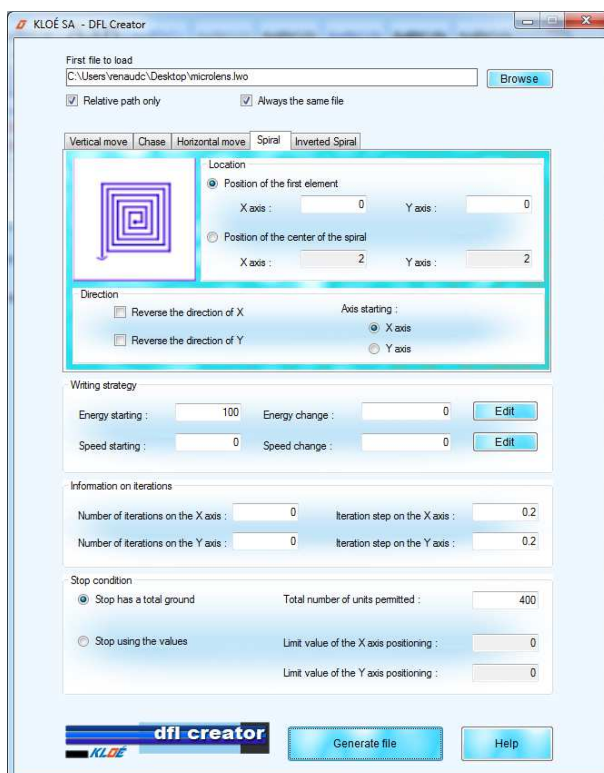

Fig 19 : Duplication with DFLCREATOR

The created file can be loaded and executed on DilaseSoft after entering the lithographic parameters.

APPENDIX

WORKING ON SLOPE

Case study

- 5µm K-NG (KLOE) Photo resist on glass substrate.
- Equipment Dilase 650 –100mm travel – Optical line 5µm @375nm or @405nm.
- File pente1.dfl – Speed 10mm/sec – Energy de 50% to 2% - no change on X - Y change all 0.002mm.
- Development Butanol – No rinsing – drying compressed Air - No PEB or HB.

Interpretation of results

- After lithography and development, it is possible that the profile of Fig 20 is seen in cross section. This means that the high energy values are too high.

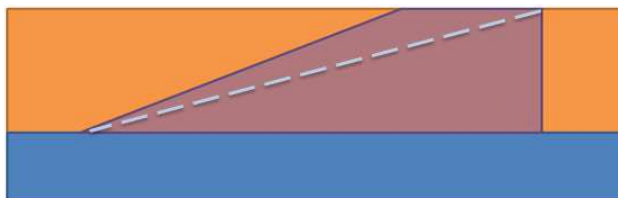

Fig 20 : Upper part of the slope excessively insolated = excessively high values.

- => It is necessary to readjust the energy levels of most of lines used in the higher part of the slope.
- After lithography and development, it is possible that the profile of Fig 21 is seen in cross section. This means that low energy values are too low.

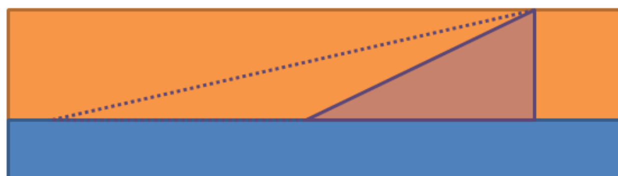

Fig 21 : Not enough power on the low energies.

- => It is necessary to readjust the energy levels of most of lines used in the lower part of the slope.
- If there is a curved profile in cross section view, this means that we have to strong accumulation of energy in the middle of the slope.

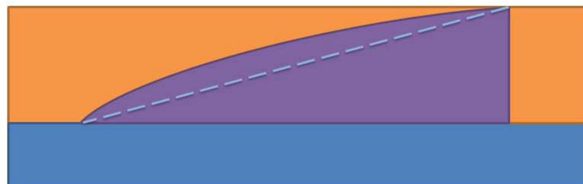

Fig 22 : Strong accumulated energy in the center of the slope

=> Should not bring a linear energy profile, but adapt the profile of the slope to a polynomial equation.

WORKING ON A MICROLENS

Case study

- 10µm K-NG (KLOE) Photo resist on glass substrate.
- Equipment Dilase 650 –100mm travel – Optical line 10µm @375nm or @405nm.
- File microlens.lwo – Speed 0.01mm/sec – Start energy 80% Energy variation 3%.
- Development Butanol – No rinsing – drying compressed Air - No PEB or HB.

Interpretation of results

Figure 23 presents the ideal profile after lithography.

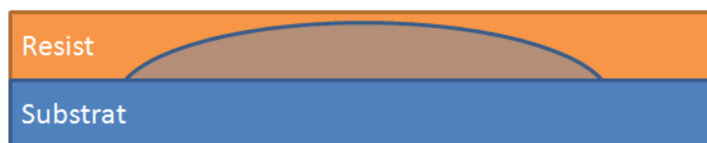

Figure 23 : ideal profile

- After lithography and development, it is possible that the profile of Fig 20 is seen in cross section. This means that the start value is too low.

Figure 24 : Upper part of the microlens too weakly insulated = too low value.

=> We must adapt the starting energy by increasing it.

- After lithography and development, it is possible that the profile of Fig 21 is seen in cross section. This means that the starting energy value is too high or that the energy variation is too low.

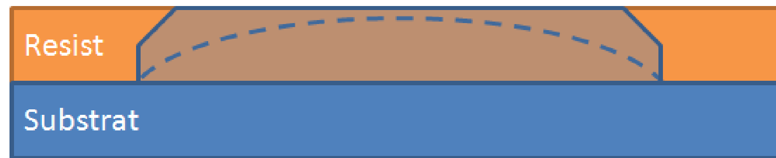

Figure 25 : Starting energy is too high or the pitch of energy is too low.

=> We must adapt the energy of departure or decreasing energy steps.