Bitmap Generator for Focused Ion Beam Instruction Manual

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Introduction

We present a graphical user interface developed in python that facilitates the generation of bitmap files for the fabrication of patterns and arrays of different geometries with a Focused Ion Beam (FIB), taking into account different milling parameters. For 3D structures, a suitable grayscale can be generated depending on the profile function defined. A second window will show the cross-section view of the structure. The patterns generated with the interface can be saved as a 24-bit bitmap file and then imported into the FIB system.

1. Overview of the window

The main window (Figure 1) consists of 4 sections:

1. Canvas: The canvas widget is the workspace where patterns and geometries will be generated and saved as bitmap files.
2. Cross-Section View: This widget shows the profile function for 3D structures.
3. Milling parameters: This widget allows the user to calculate the pitch value. It also displays information about some milling parameters for the Helios G4 system.
4. Toolbar: The toolbar contains the necessary functions to generate patterns and geometries on the canvas widget.

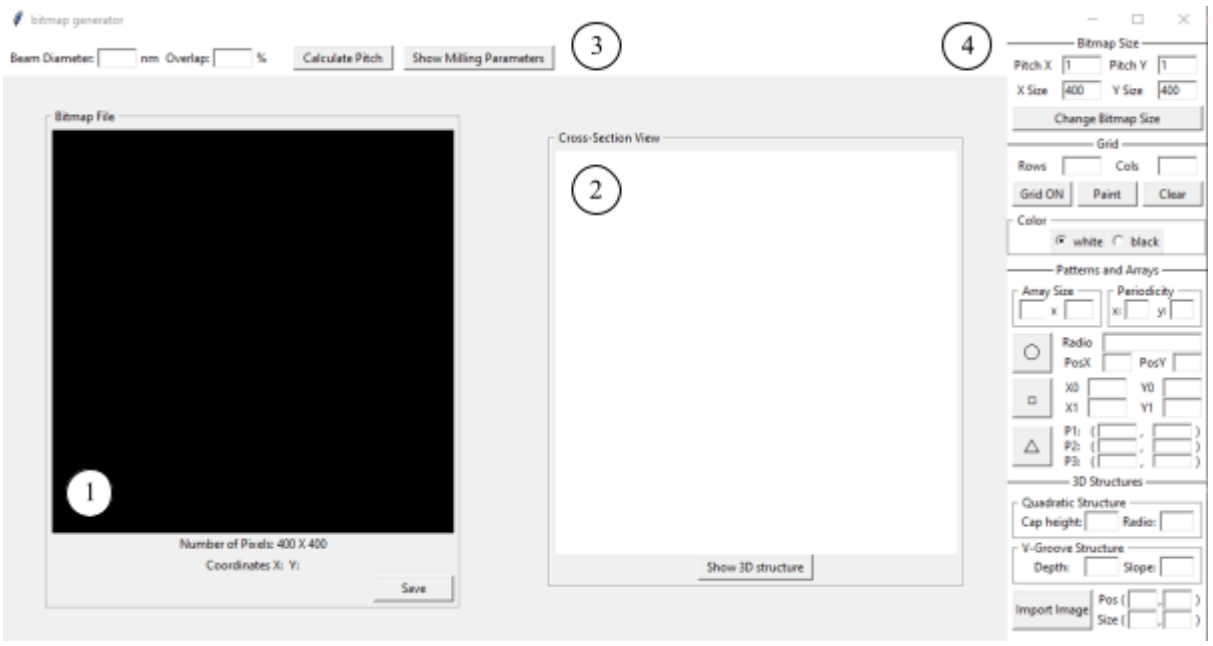

Fig. 1. Main window of the Graphical User Interface

2. Defining the size of the bitmap

The number of pixels in the bitmap will depend on the beam diameter, the pitch value and the overlap ratio. For example, if you have a beam diameter of 400 nm and a pitch value of 200 nm in the x and y direction, the overlap is 50% and 50 pixels would be needed to cover a 10 um x 10 um milling area (Figure 2).

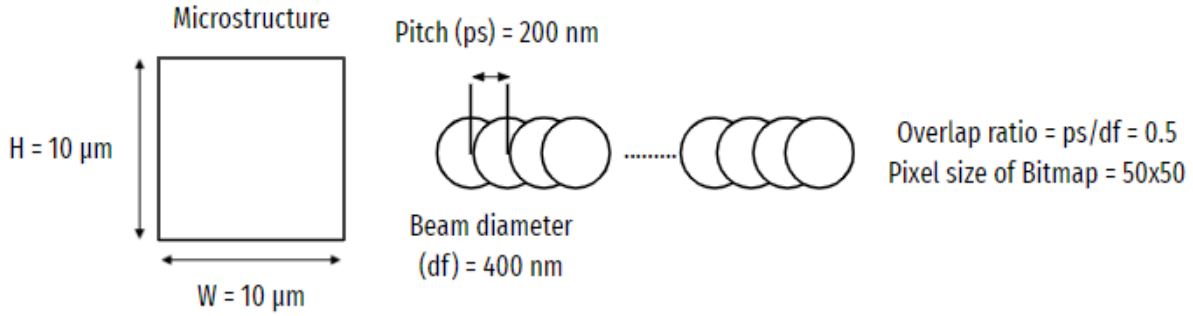

Figure 2. How the milling area dimensions, beam diameter and pitch value define the size of the bitmap.

Therefore, a bitmap of size MxN is defined as:

$$M = \frac{W}{p_x} \qquad N = \frac{H}{p_y}$$

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Where W and H are the width and height of the milling area, respectively. Px and Py are the pitch values in the x and y direction.

To define the bitmap size in the interface, the user can set the value for the beam diameter and the overlap to calculate the pitch value (Figure 3). The user can also enter the pitch value manually. The "Show Milling Parameters" button opens a new window containing information about the beam diameter values for different beam current values at 30 kV (Figure 4). These values only apply for the Helios G4 system. The new window will also show information about the volume per dose values for different materials at 30 kV (Figure 5).

After defining the pitch value, the user can enter the dimensions of the milling area. By clicking on the "Change Bitmap Size" button, the size of the canvas will change and the number of pixels will be displayed at the bottom of the canvas (Figure 6). The dimensions of the milling area must have the same units as the pitch, usually in nm.

Figure 3. Milling Parameters widget

Beam Diameter at 30 kV | Material Volume per Dose Rates at 30 kV

Beam Current	Beam Diameter (nm)
90 pA	20.4
41 pA	15
26 pA	12.5
7 pA	9.5
1 pA	5.3
0.26 nA	36.6
0.44 nA	50.4
0.75 nA	66.2
1.2 nA	86.1
2.4 nA	131
9.1 nA	267
20 nA	445
47 nA	960
65 nA	1500

Figure 4. Beam diameter values for different Beam currents at 30 kV.

Beam Diameter at 30 kV | Material Volume per Dose Rates at 30 kV

Material	Volume per Dose (µm3/nC)	Material	Volume per Dose (µm3/nC)
C	0.18	Au	1.50
Si	0.27	MgO	0.27
Al	0.30	SiO2	0.24
Ti	0.37	Al2O3	0.08
Cr	0.10	TiO	0.15
Fe	0.29	SiN4	0.20
Ni	0.14	TiN	0.15
Cu	0.25	Fe2O3	0.25
Mo	0.12	GaAs	0.61
Ta	0.32	Pt	0.23
W	0.12	PMMA	0.4

Figure 5. Volume per Dose Rates for different Materials at 30 kV. The information was extracted from the Helios G4 System User Operation Manual.

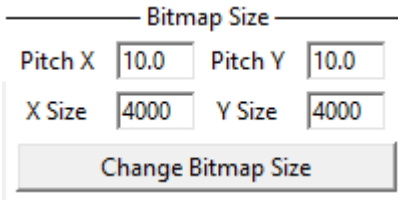

Figure 6. "Change Bitmap Size" Button.

2. Generating patterns and arrays for different geometries

The interface has a box painting system that generates simple patterns and drawings. A grid system can be generated by defining the number of rows and columns and clicking on the "Grid ON" button (Figure 7). By clicking on the "Paint" button, the grid can change from black to white or from white to black by clicking and moving the mouse around. The grid system can be deleted by clicking on the "Grid OFF" button. (Figure 8). The color can be defined with the option "Color" in the toolbar (Figure 9).

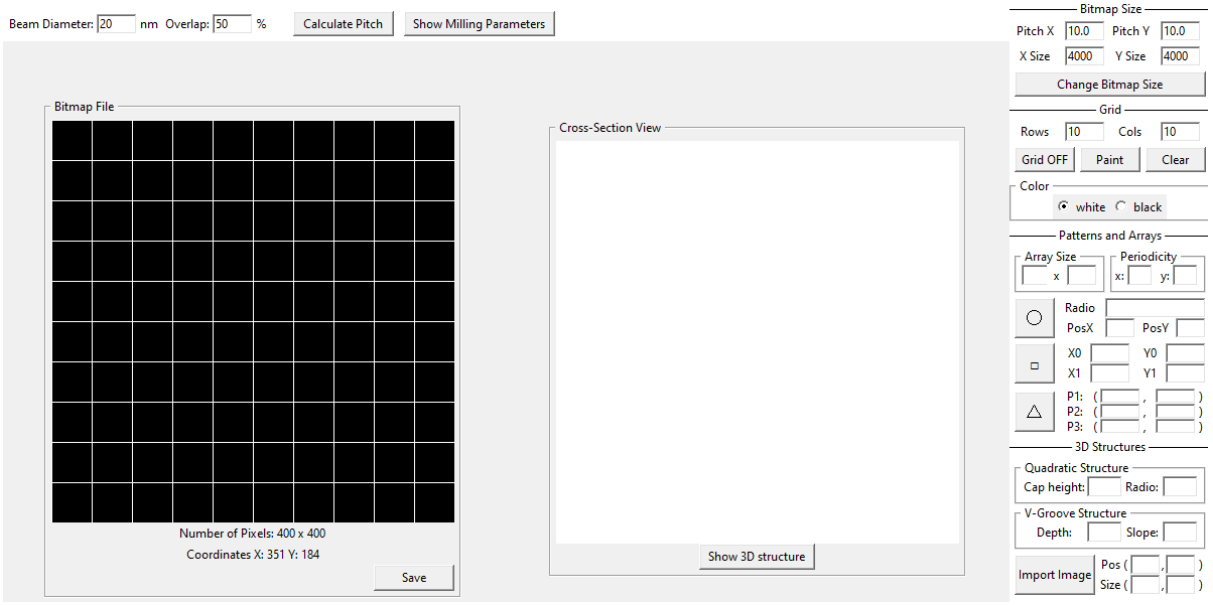

Figure 7. A grid of 10 rows and 10 columns generated on the canvas.

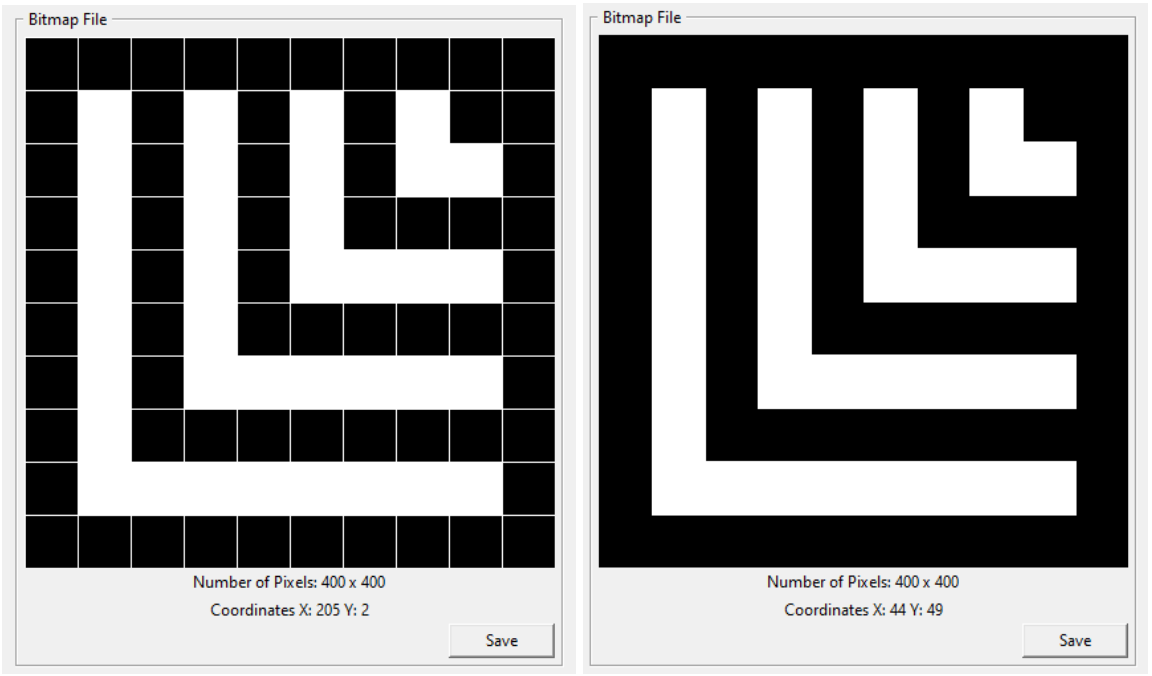

Figure 8. Pattern generated with the grid system.

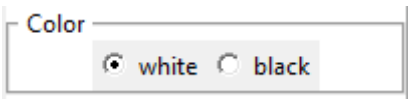

Figure 9. Change color from white to black.

The interface also allows generating arrays for different geometries. In the section patterns and arrays, the user can set the size of the array and the spacing between the different elements in the x and y direction (Figure 10). The user only has to define the position of the first object and click on the geometry icon to generate the array (Figure 10).

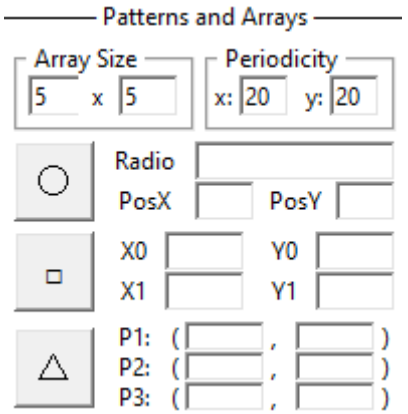

Figure 10. Change color from white to black.

For the circle object, we define the radius and the X and Y position of the center of the first object that will form the array. For the square object, the coordinate (X0, Y0) defines the position of the upper left corner of the square and the coordinate (X1, Y1) defines the position of the lower right corner. For the triangle object, P1, P2 and P3 are the three points of the triangle. Figure 11 shows an example. If the user moves the mouse over the canvas, the pixel positions are displayed at the bottom.

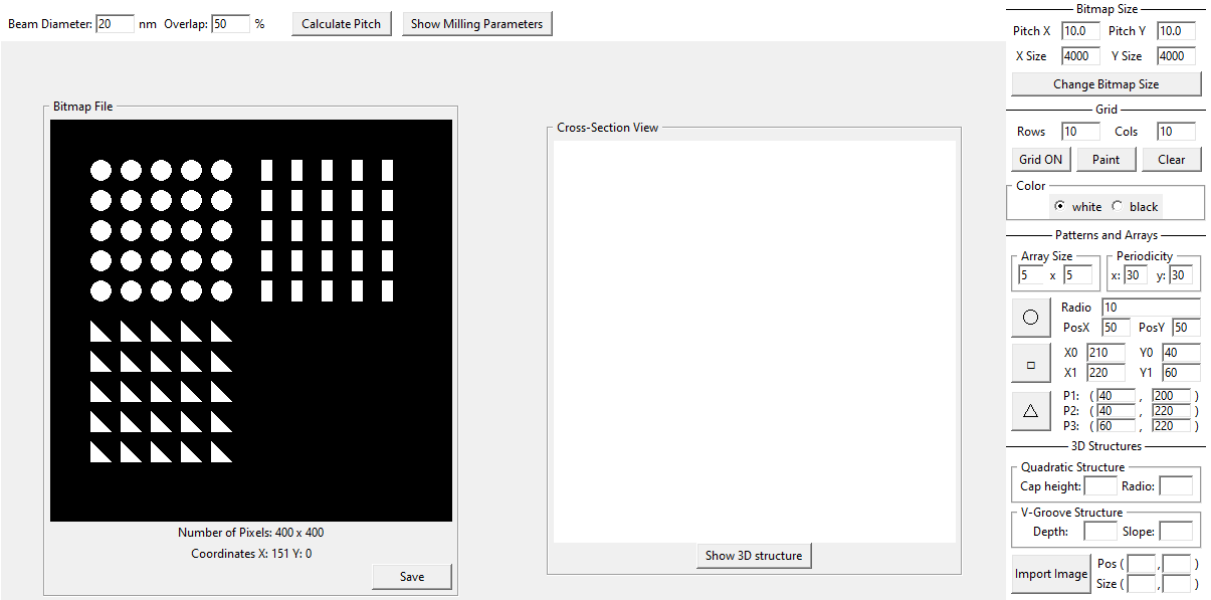

Figure 11. Array of circles, rectangles and triangles generated with the interface.

Finally, for more complex structures, the user can import an image on the canvas by defining the position and size of the image and clicking on the “Import Image Button” (Figure 12).

Figure 12. Image imported to canvas.

All objects and elements created on the canvas can be deleted by clicking on the "Clear" button.

3. Generating a grayscale for 3D structures

For 3D structures, the interface will generate a suitable grayscale according to the profile function of the structure. Two types of structures can be created: quadratic and v-groove. For the quadratic structure, the user only has to define the value for the cap height and the radio. For the v-groove structure, the deepest point of the profile and the radio should be defined. By clicking on the "Show 3D Structure" button, the interface will display the bitmap on the canvas and the profile function on the Cross-Section View widget (Figures 13-14).

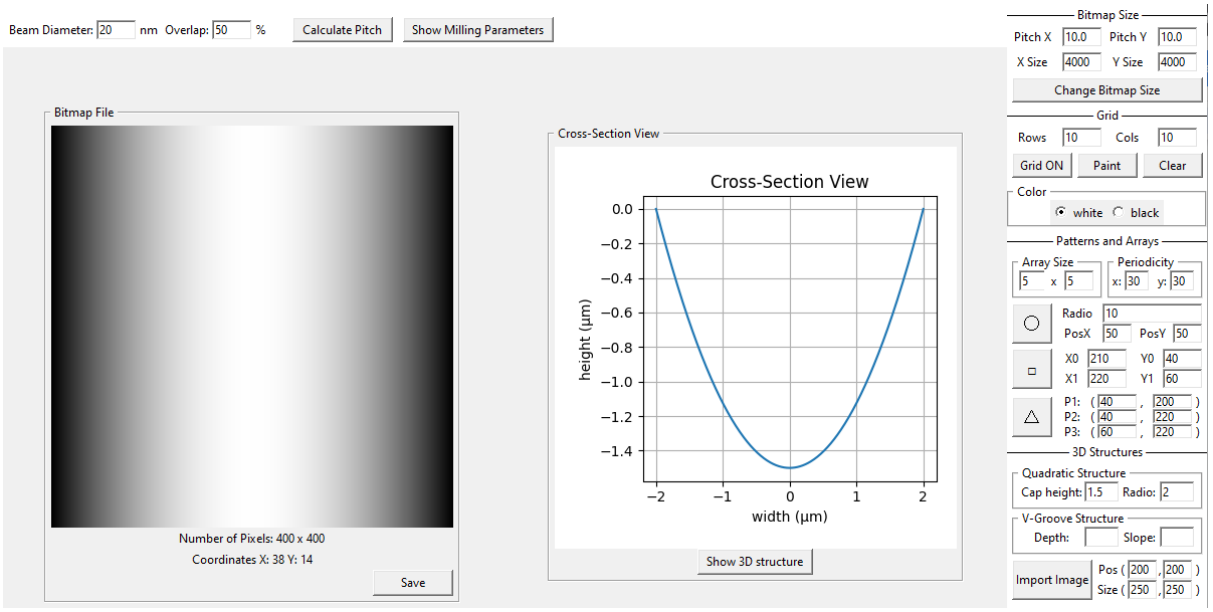

Figure 13. Bitmap generated for a Quadratic profile

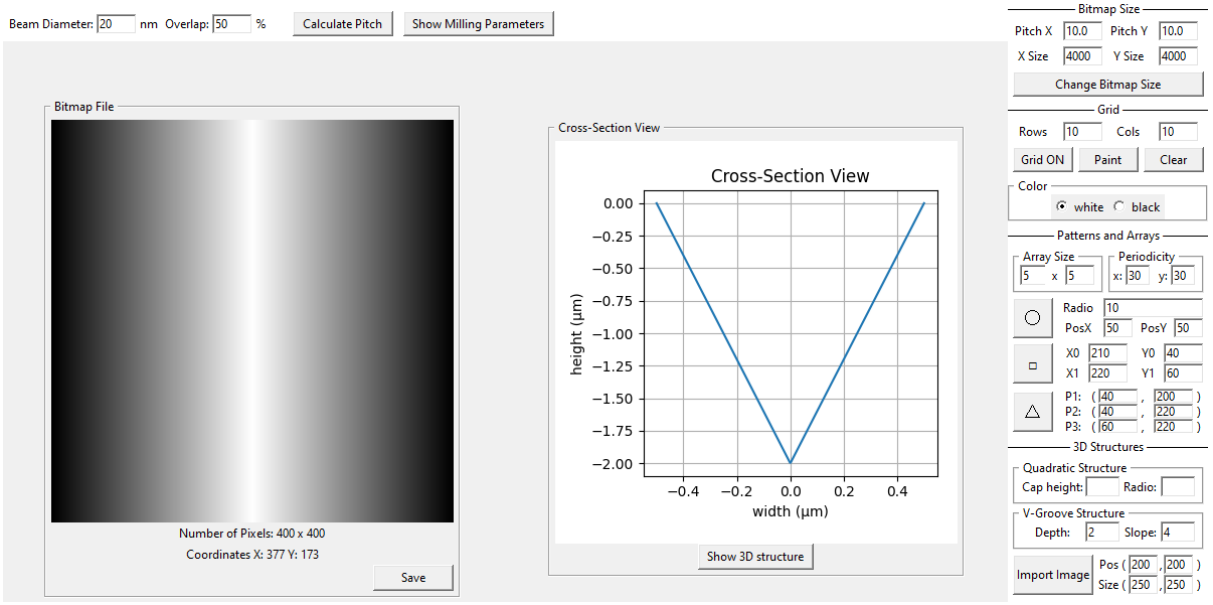

Figure 14. Bitmap generated for a v-groove profile

4. Saving the bitmap file

The bitmap can be saved by clicking on the "Save" button located below the canvas widget. The image is saved as a 24-bit .bmp file, the only format accepted by the Helios G4 system (Figure 15-16).

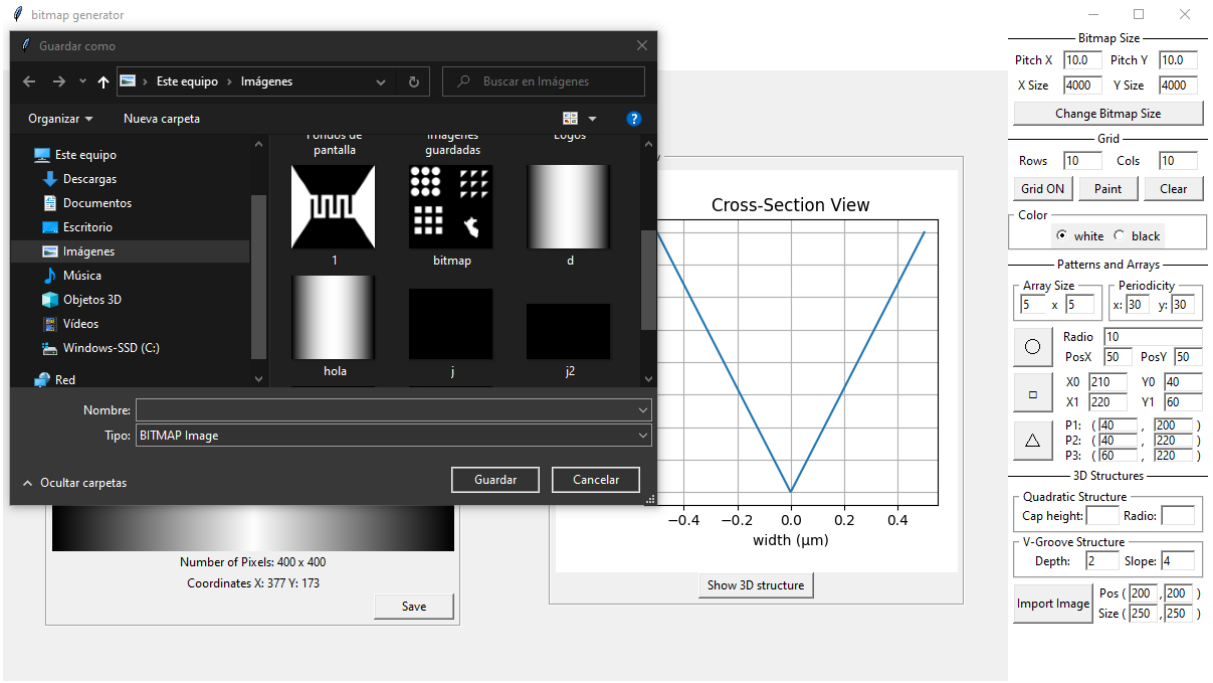

Figure 15. The interface will ask to save the file in a specific directory.

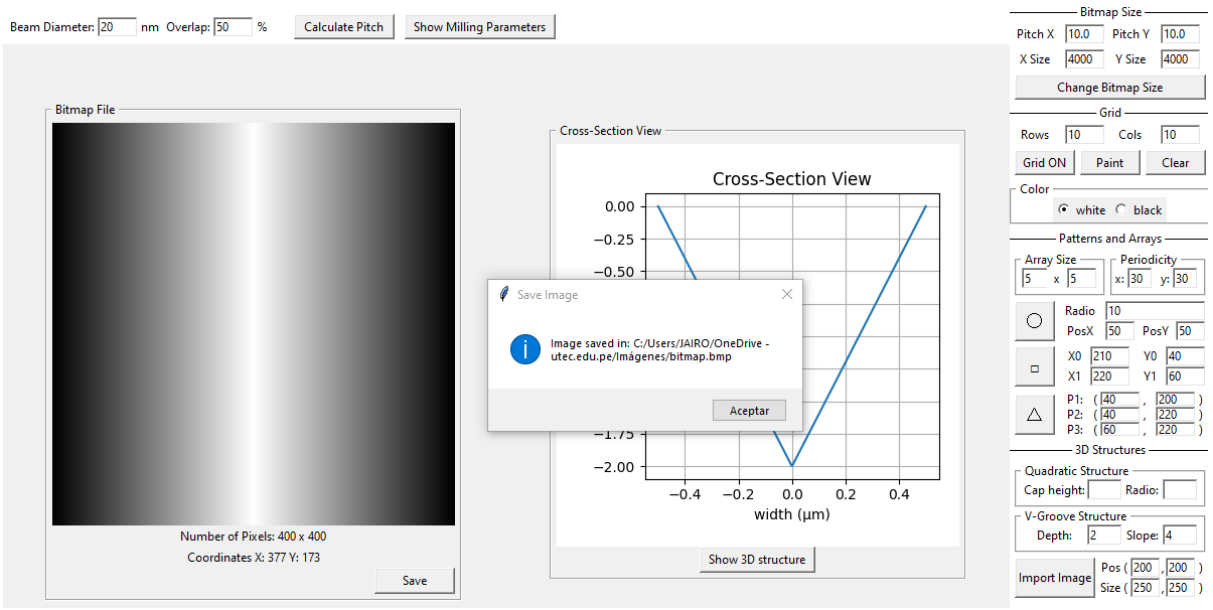

Figure 16. A message window will appear indicating that the bitmap file has been saved correctly.