# Fringe Projection Simulator Manual

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## Part I
# Introduction

Scanning three-dimensional objects has become a commonly used quality control procedure in the industry, but the techniques can still be improved. To enhance the overall quality of the scans, scientists are looking for different measurement setups and more accurate algorithms. Because building and aligning these setups is incredibly time-consuming, we developed software that simulates this method accurately. The software is capable of simulating the projection of fringes on complex models of over 400.000 vertices. The user can load the desired model as an stl-file, which is a supported file format in most regularly used CAD programs. The software can handle a projector with a diverging or telecentric lens. The calculated illumination pattern from the virtual projector is simulated on the complex object and all the gray values are calculated on a fragment base. The user can easily modify the frequency and the phase of the projection pattern so that spatial and temporal profilometry techniques can be simulated. To simulate Moir measurements, a second grid can be oriented freely in space, for which the user can set the frequency and phase shift as well. The virtual camera can also be operated with a diverging or telecentric lens. The above-mentioned options allow the operator to simulate both collimated and non-collimated projection and observation, with either parallel or crossed lens axes. The software is available for 32-bit and 64-bit Windows operating systems and can be downloaded for free from our dedicated website: http://www.fringesimulator.com (Now available at Github, licensed under the GPL license).

## Part II
# The Fringe Projection Simulator Screen

The program will start up after double-clicking the executable file : 'Fringe Projection Simulator 2012a.exe'. The start up screen will look as shown in Figure 2. The screen is divided into several areas, with each area having their own function. Next Figure 3 shows these different areas.

## 1 Title Bar

The title bar displays the title of the program that is running at the moment.

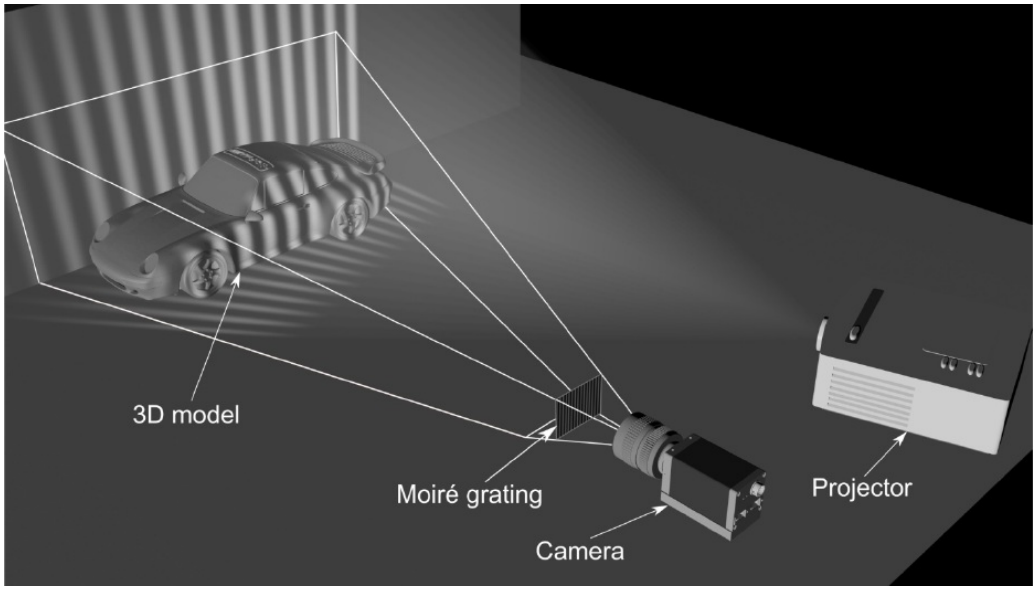


Figure 1: Virtual projection Moiré profilometry setup (Moiré grating is multiplied with the camera image)

## 2 The Menu Bar

The menu bar is used to navigate through the different controls within the program. These different controls will be further explained in the next parts.

## 3 Controls

The 3 controls buttons which are found in the top right corner, are used to hide or exit the program. Maximalising or minimalising the program is not possible.

## 4 Button Frame

This frame consists of several buttons, which are actually shortcuts to controls that can be found in the menu bar. Except for the read settings, this option is only available in the button frame.

## 5 Display Screen

This screen will display our objects with the used shaders and gratings.

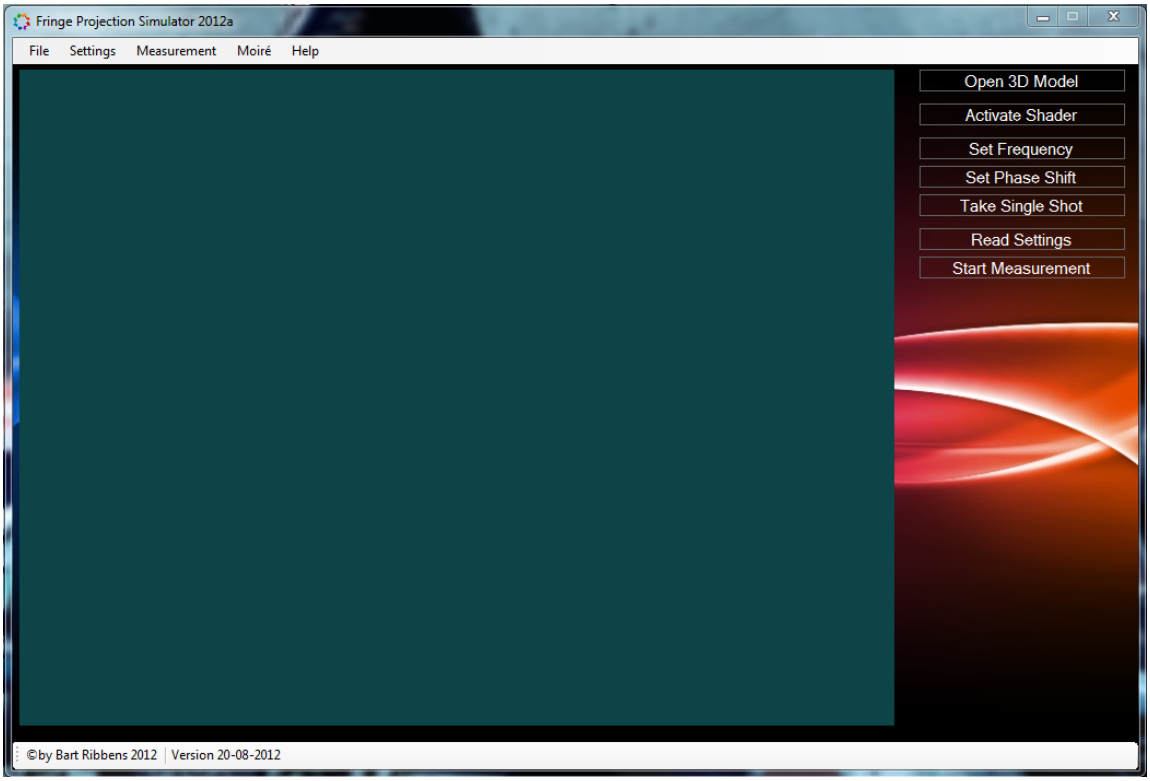


Figure 2: Fringe Projection Simulator screen


Figure 3: Startup screen

## 6 About

This bar shows the creator of this program and the current version.

# Part III
# The Fringe Simulation Controls

In this part we will explain all of the functions that are made possible with this program. First, we have the buttons in the menu bar. These buttons are again divided into different buttons with different controls.

## 7 File

When we click the file button in the menu bar, there will appear a pop up screen as shown in Figure 4. This means we have two controls we can execute within this menu.

### 7.1 Open 3-D Model

With this button, we can load a 3D Model within our program. The file has to be of the .STL extension, which means it consists of solely edges. The 3D model contains no volume. Note that it

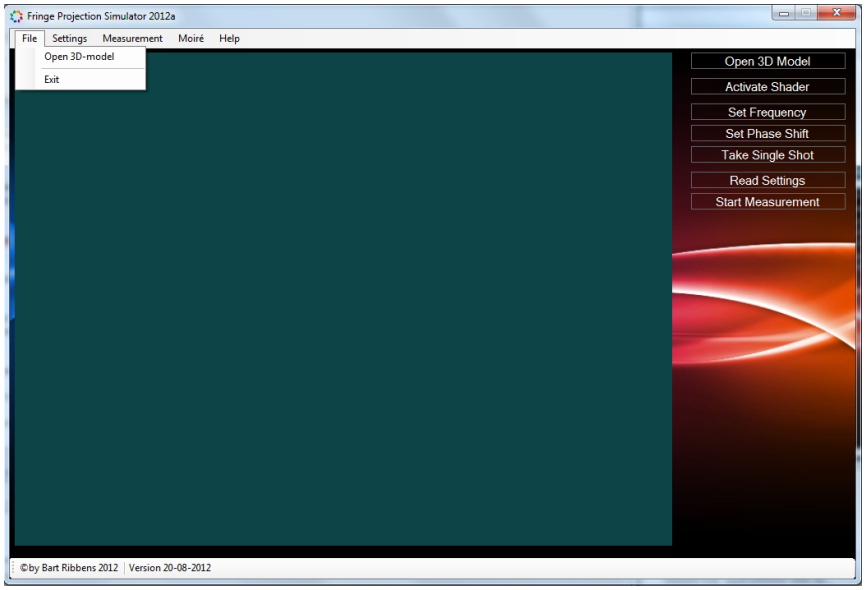


Figure 4: File

is possible to create your own 3D Model with inventor and save it as an .STL file, this 3D model can be used in this program.

### 7.2 Exit

When you click this button, the program will close.

## 8 Settings

The next button in the menu bar, is the settings button. Figure 5 shows us which controls are accessible through this button. With these controls we can choose between different settings to change the setup of the simulation and manage the shaders.

### 8.1 Resolution

Using the resolution button, we can change the display of our program. Standard we have a resolution of 800x600 pixels, this means that our program screen is 800 pixels in width and 600 pixels in height. It is possible to change the resolution to other standard resolutions, such as : 640x480 or 1024x768. Resolution 640x480 gives a smaller screen where the 1024x768 resolution results in a bigger screen.

### 8.2 Beamer settings

This button allows us to change several properties of the beamer within the simulation.

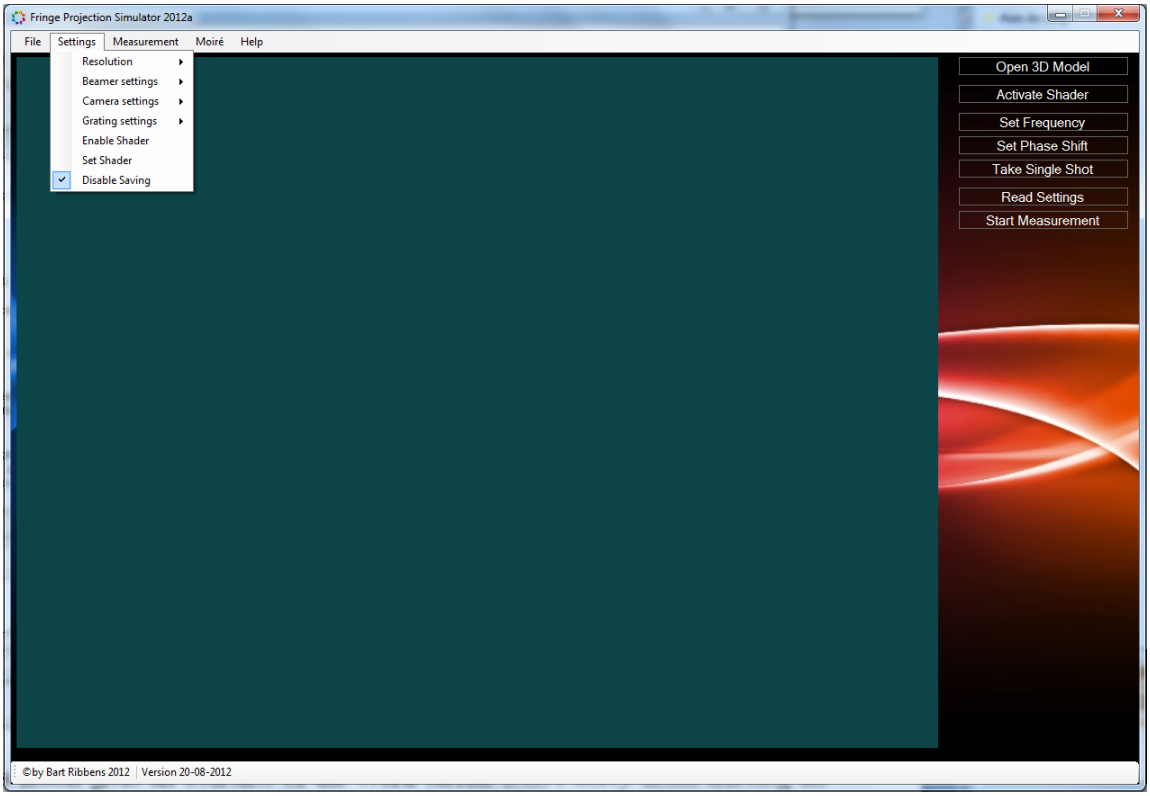


Figure 5: Settings

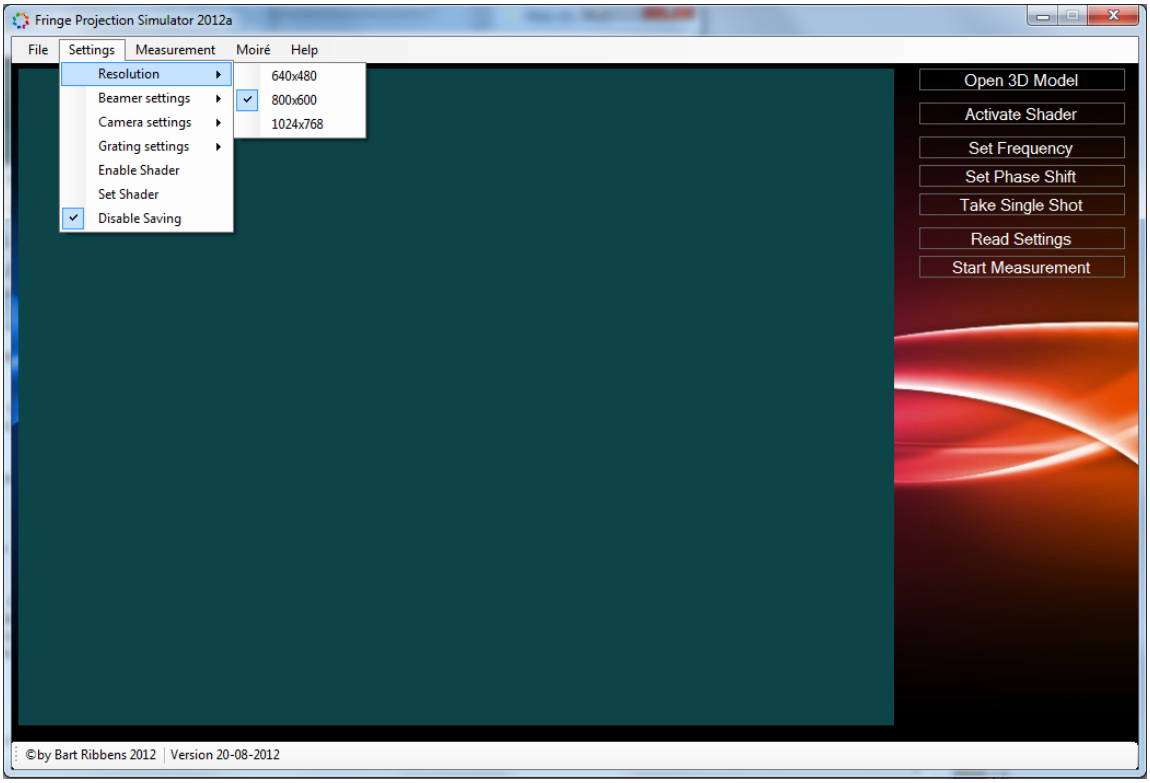


Figure 6: Resolution

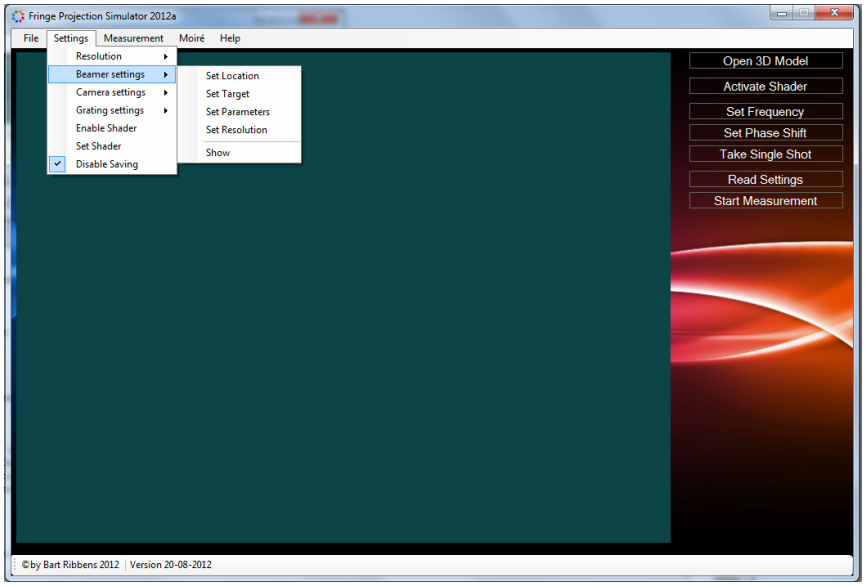


Figure 7: Beamer settings

### 8.2.1 Set Location Beamer

Using the Set Location control, we can choose at which location our beamer is placed. First, we have to enter an X value. Next, is the Y value of the beamer. Lastly, we have to fill in a Z value. When this is done, we have given a location in space to the beamer.

### 8.2.2 Set Target Beamer

With the Set Target control, we can choose at which position in space the beamer will be focused. For example when the target has the coordinates (x = 10; y = 4; z = 2), the beamer will focus directly at that point.

### 8.2.3 Set Parameters Beamer

We are able to adjust the parameters of the beamer with this control. The parameters consist of the beamer angle and the width/height ratio.

**FOV (Field Of View)** First we enter the angle of the beamer, this is the same as the field of view. The FOV (field of view) tells us how big the angle of our sight is. A FOV of 90 degrees gives us a larger sight than a FOV of 50 degrees. The FOV gives us more information about how big our horizontal view is. In 11 we can easily see the difference between a FOV of 60 degrees on top and below a FOV of 90 degrees.

**Aspect Ratio** Next, we are able to adjust the width/height ratio which we can use to determine the vertical view. If we know the width of our beamer, we can easily determine the value of the

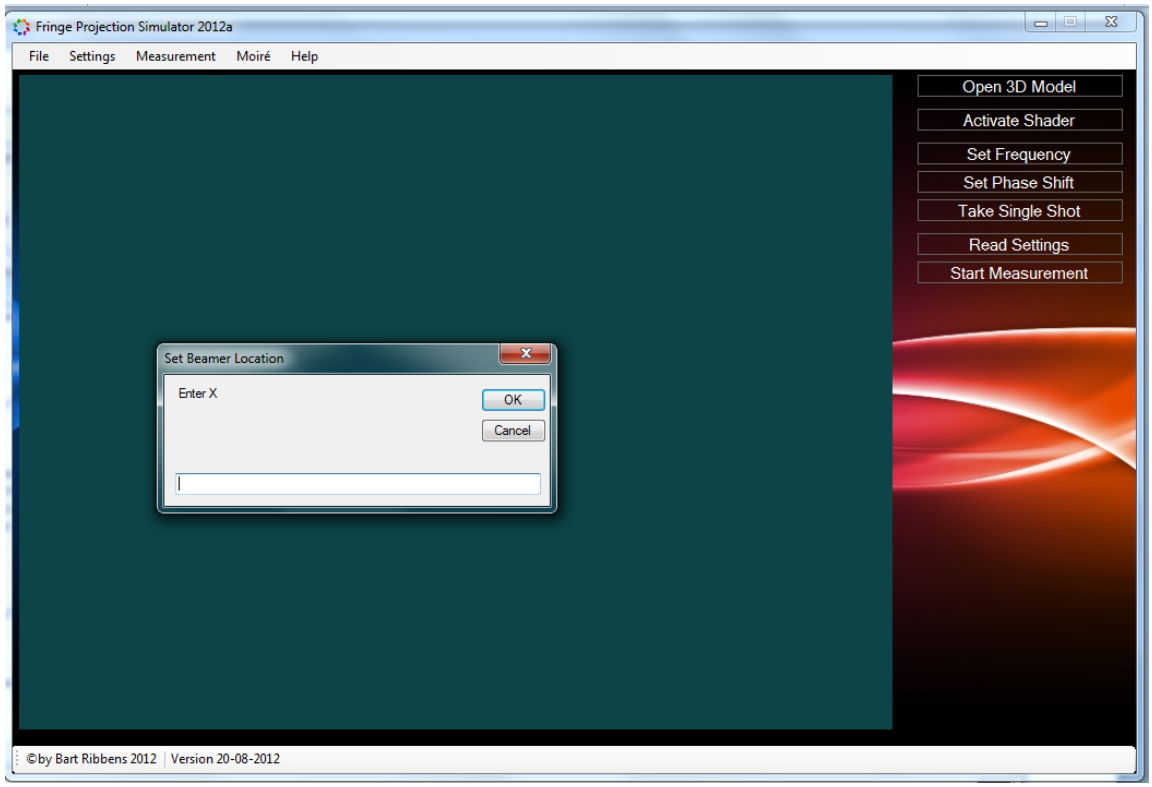


Figure 8: X Beamer

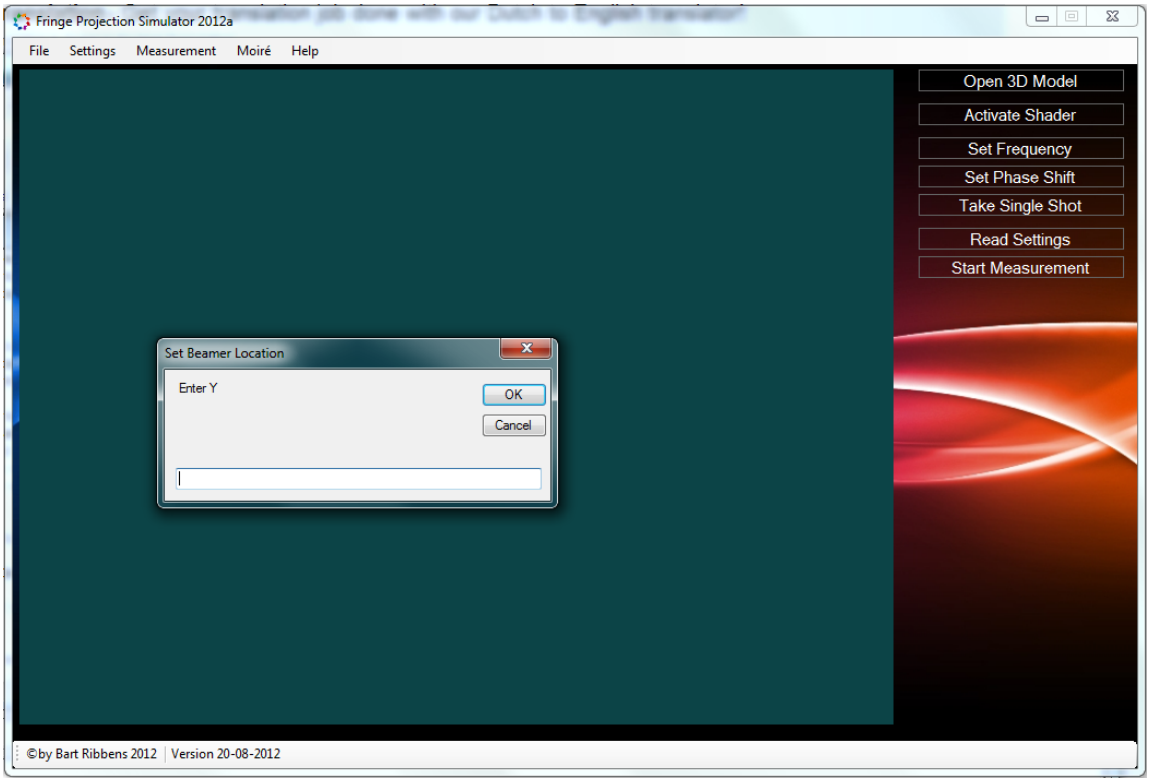


Figure 9: Y Beamer

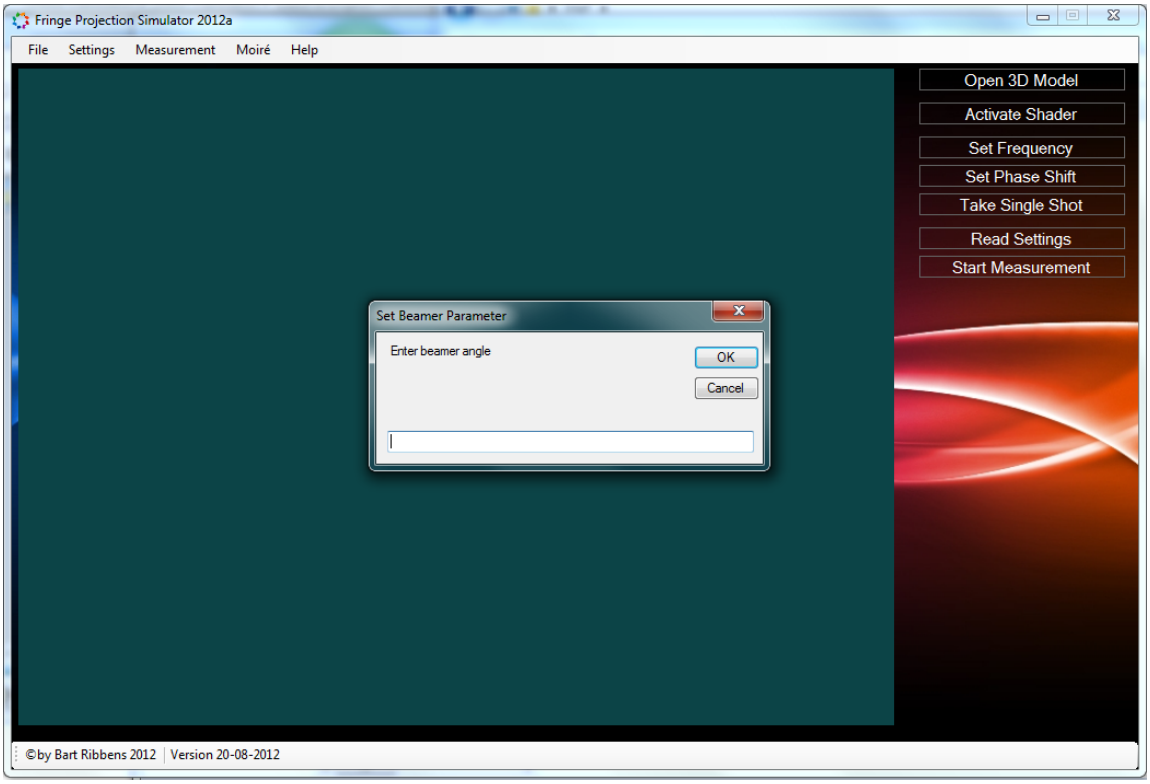


Figure 10: Beamer Angle


Figure 11: Field of view


Figure 12: Ratio

height. First we insert the aspect ratio, then we enter the width. The standard used aspect ratio is 1,33. Figure 12 shows us an example of a 2/1 aspect ratio.

#### 8.2.4 Set Resolution

We can set the resolution to a value which we prefer. It is advisable to choose a resolution, where there are no pixellations and other optic imperfections due to a low resolution. An example of these imperfections is shown in Figure 13. If you change the resolution to 1200x1200, there are clearly imperfections within the model. That is the reason why the resolution is standard set on 20000x20000, so that we certainly have a clear image.

#### 8.2.5 Show

By clicking the show option, a pop up screen will appear which contains all the information about the beamer.

### 8.3 Camera settings

This control is used to change all the properties of the camera used in the simulation.

#### 8.3.1 Set Location Camera

Using the Set Location control, we can choose at which location our camera is placed. First, we have to enter an X value. Next, is the Y value of the camera. Lastly, we have to fill in a Z value. When this is done, we have given a location in space to the camera.

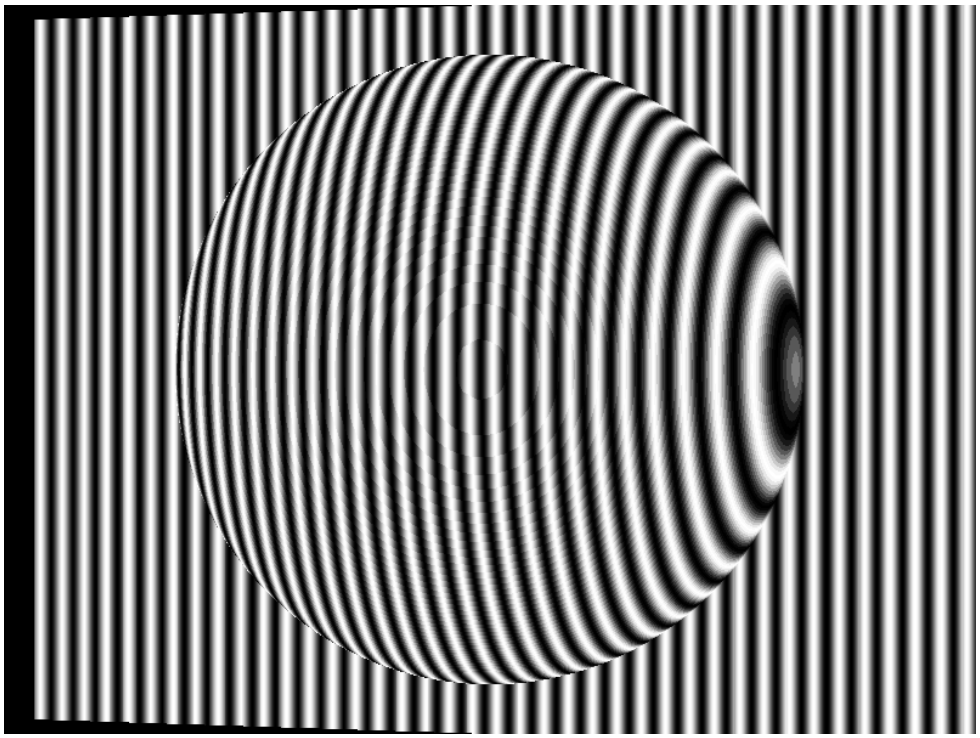

Figure 13: Imperfections in image

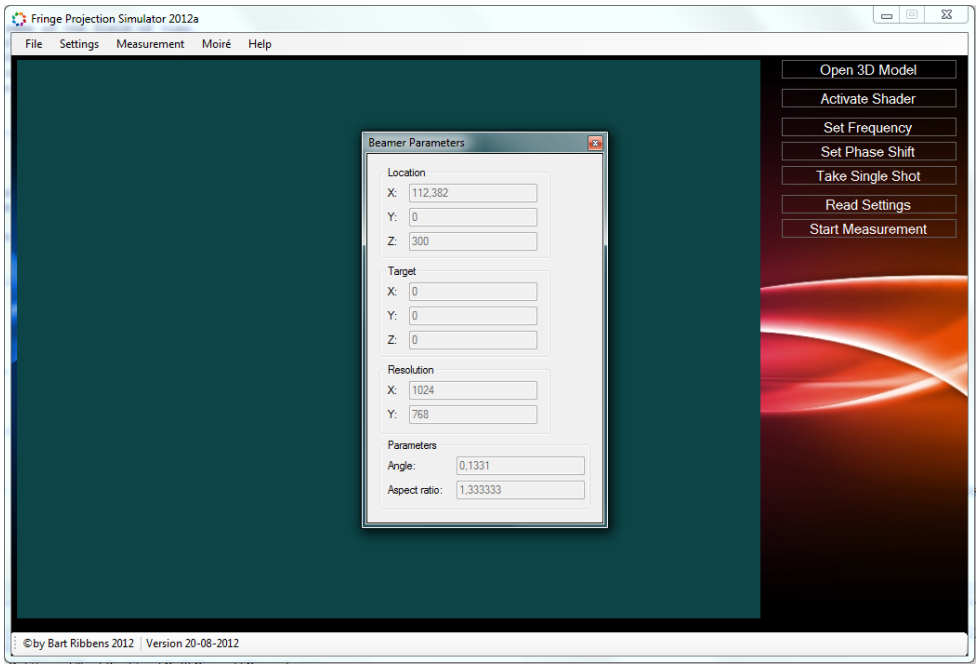


Figure 14: Show beamer settings

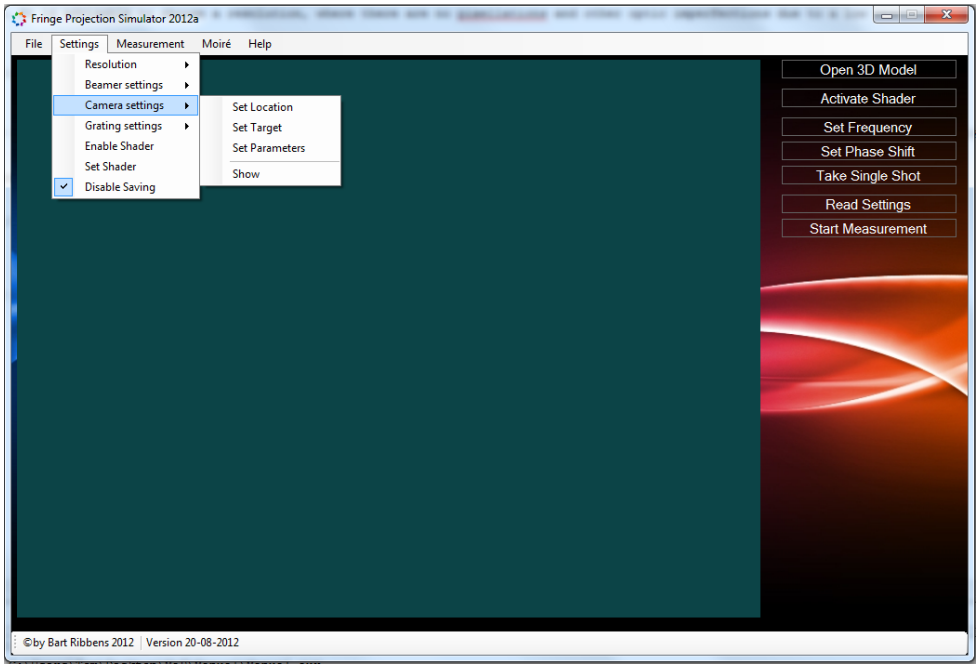


Figure 15: Camera settings

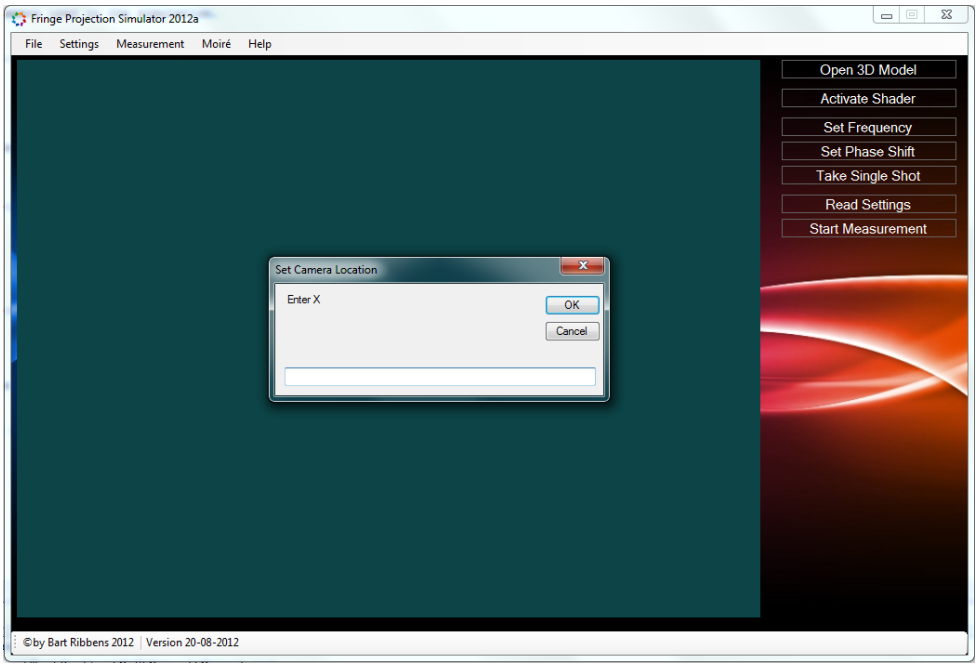


Figure 16: X Beamer

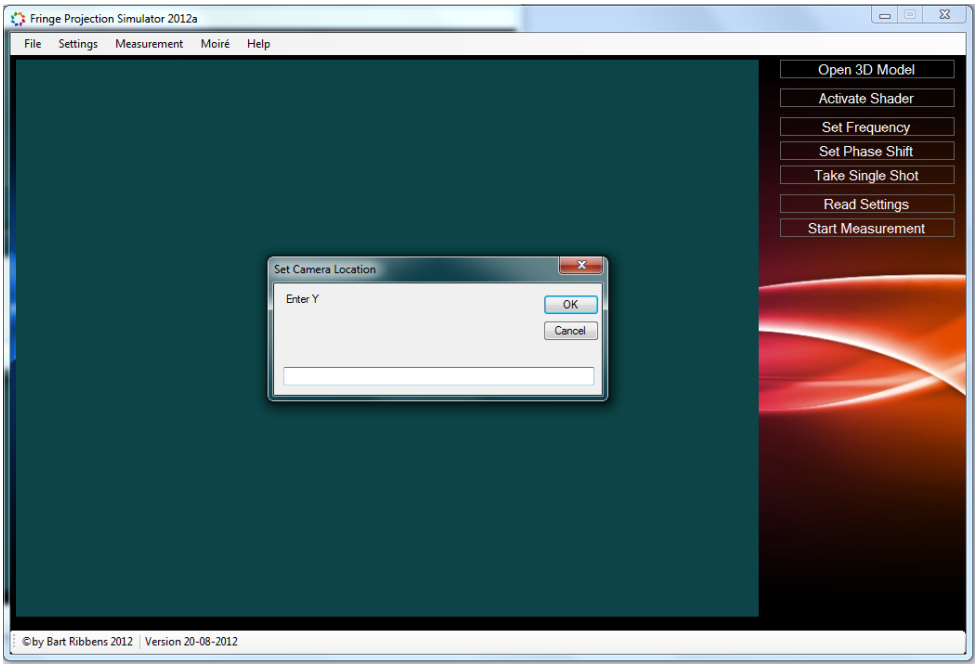


Figure 17: Y Beamer

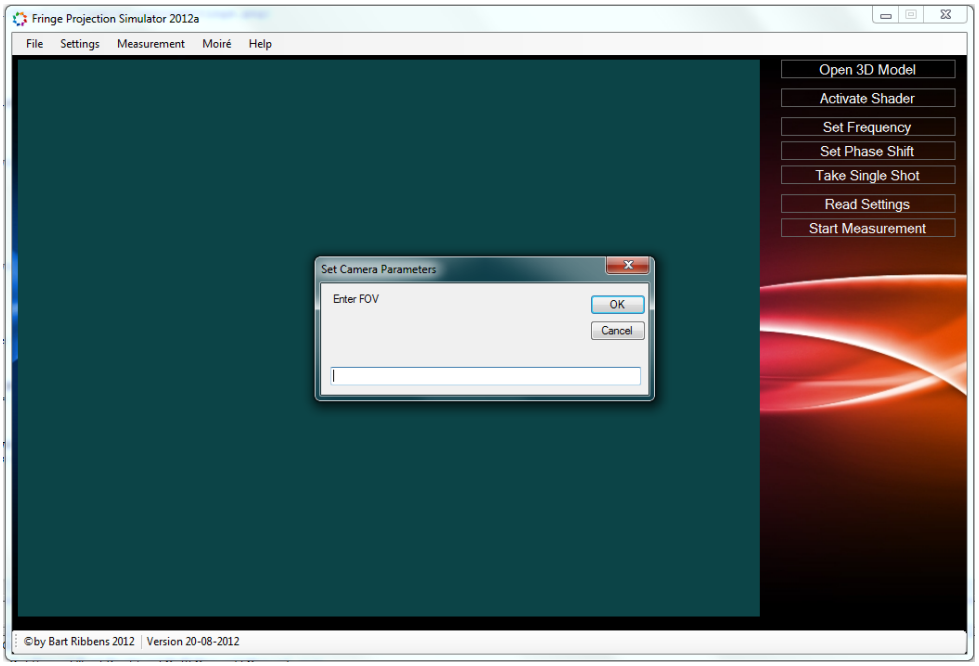


Figure 18: Camera FOV

### 8.3.2 Set Target Camera

With the Set Target control, we can choose at which position in space the camera will be focused. For example when the target has the coordinates (x = 10; y = 4; z = 2), the camera will focus directly at that point.

### 8.3.3 Set Parameters Camera

We are able to adjust the parameters of the camera with this control.

**FOV** First, we can choose the FOV of the camera (which is explained in section 8.2.3. The FOV has to be within range 0-3,1.

**Aspect Ratio Camera** Next we are able to adjust the width/height ratio. The standard used aspect ratio is 1,33.

**Near Plane** The near plane is a distance from the camera, in which objects in front of this point, are not seen.

**Far Plane** This is the opposite of near plane, objects in front of this point are seen (except if they are also in front of the near plane). Objects further then the far plane point, are not seen by the camera because they are too far away.

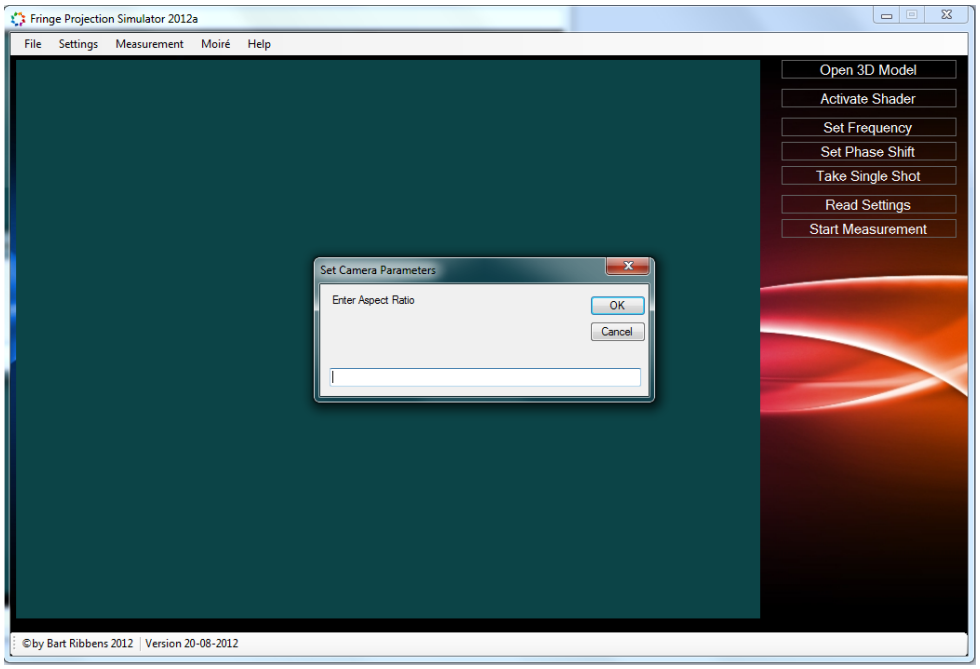


Figure 19: Aspect Ratio Camera

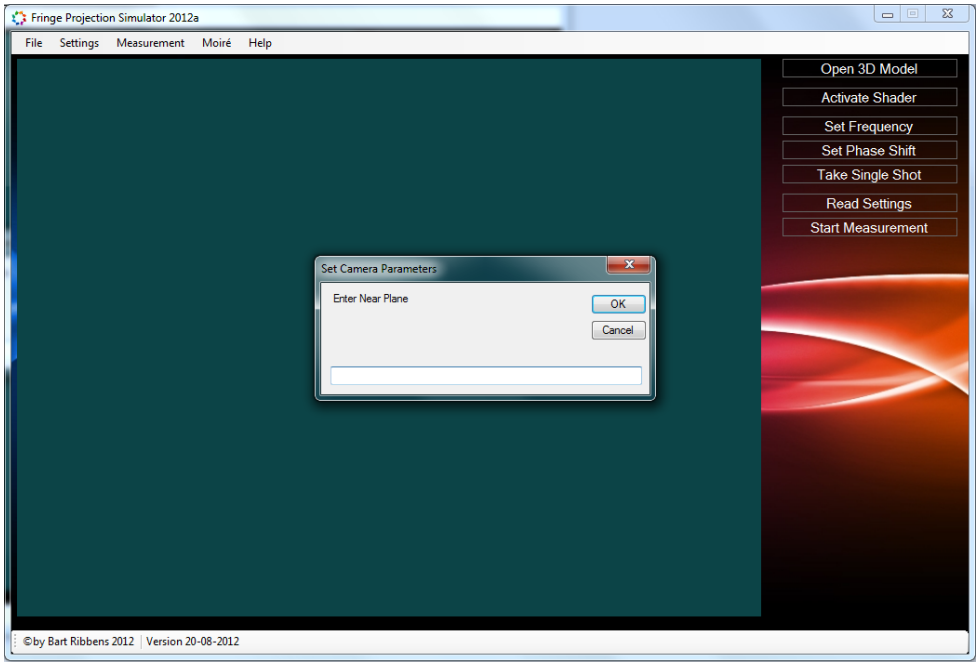


Figure 20: Near Plane

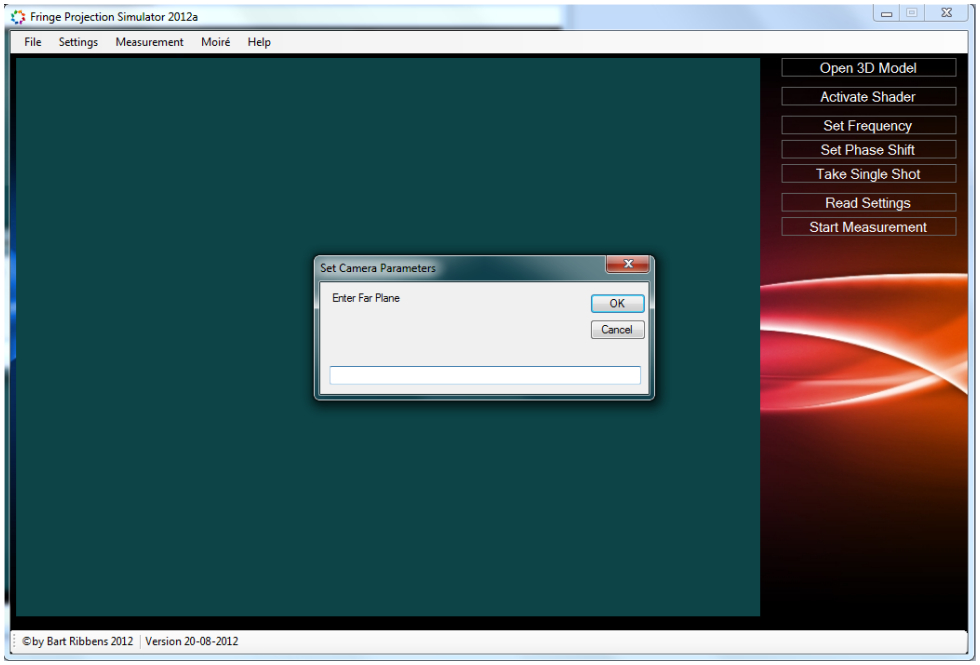


Figure 21: Far Plane

#### 8.3.4 Show

This control shows us all the properties of our camera.

### 8.4 Grating Settings

This button contains the settings of the grating used within the simulation.

#### 8.4.1 Show

Clicking this button shows us all the properties of the grating.

## 9 Enable Shader

By clicking the enable shader button, we can activate the beamer. After we have enabled the shader, our display will look like Figure 26. We see a pattern that is projected onto our reference. If we want to disable the shader, simply press on disable shader. The pattern will disappear because we inactivated the shader.

### 9.1 Set Shader

The shaders used within this simulation are already loaded when the program is started. If the user wants to load them manually, it can be done using this button.

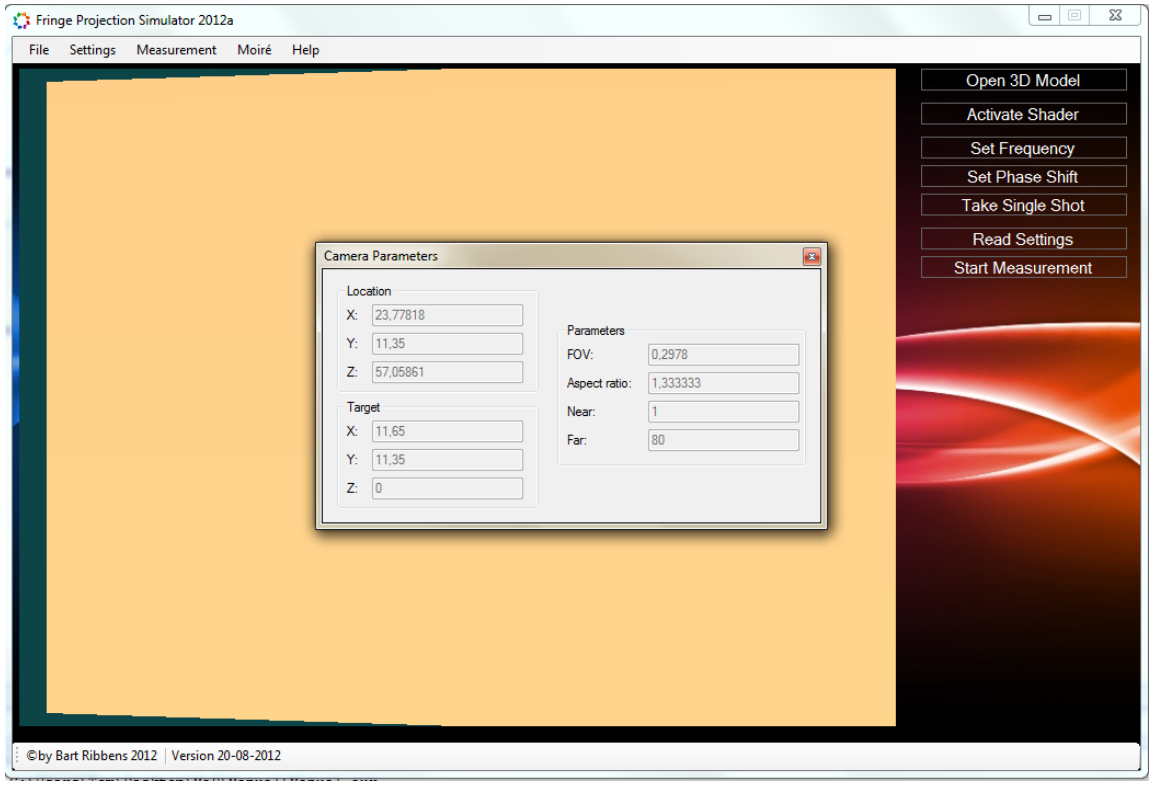


Figure 22: Settings Camera

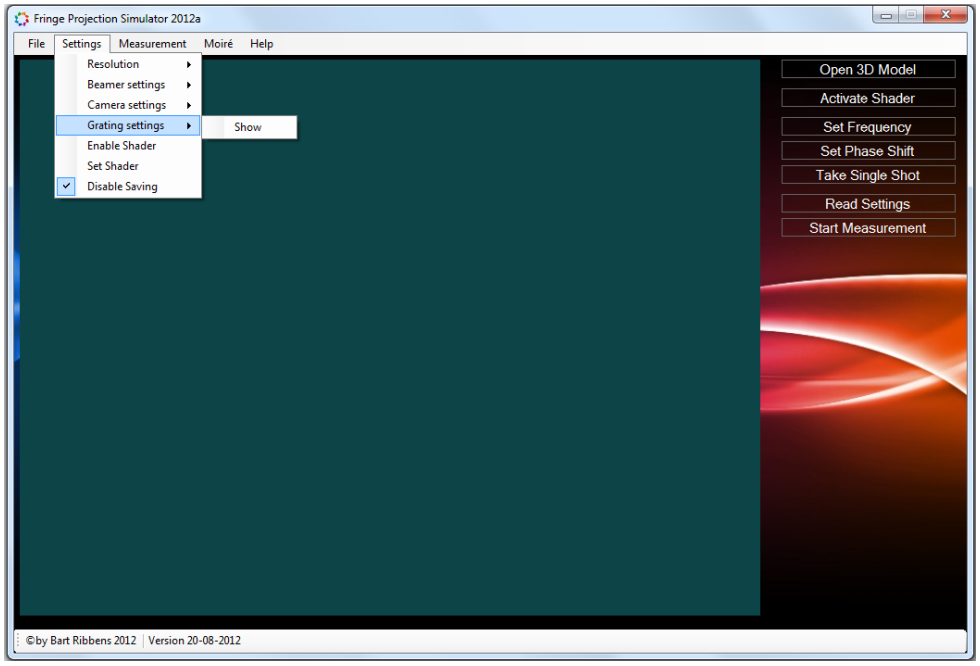


Figure 23: Grating Settings

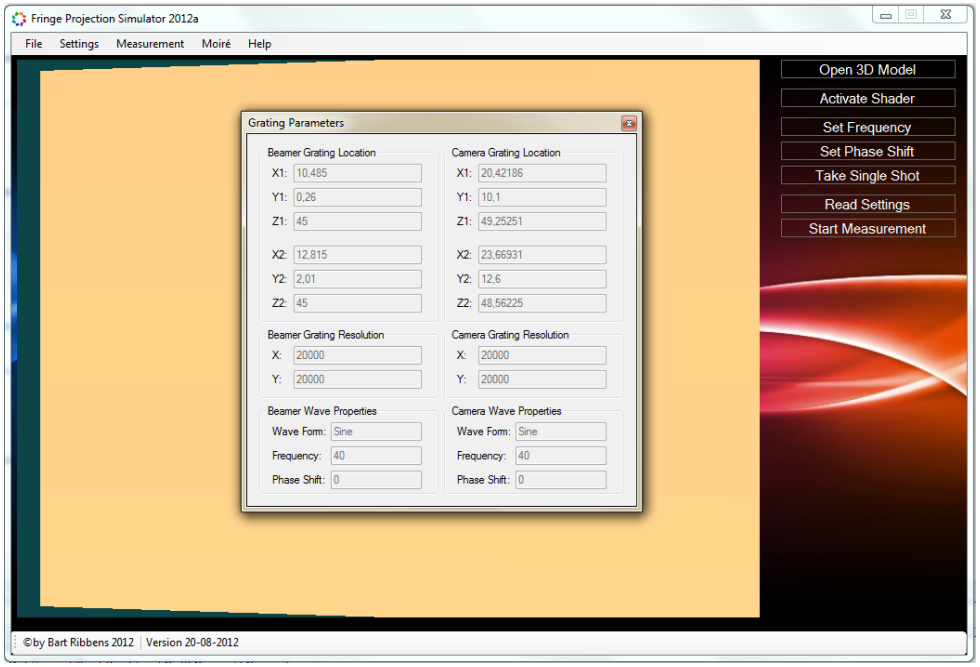


Figure 24: Show Grating Settings

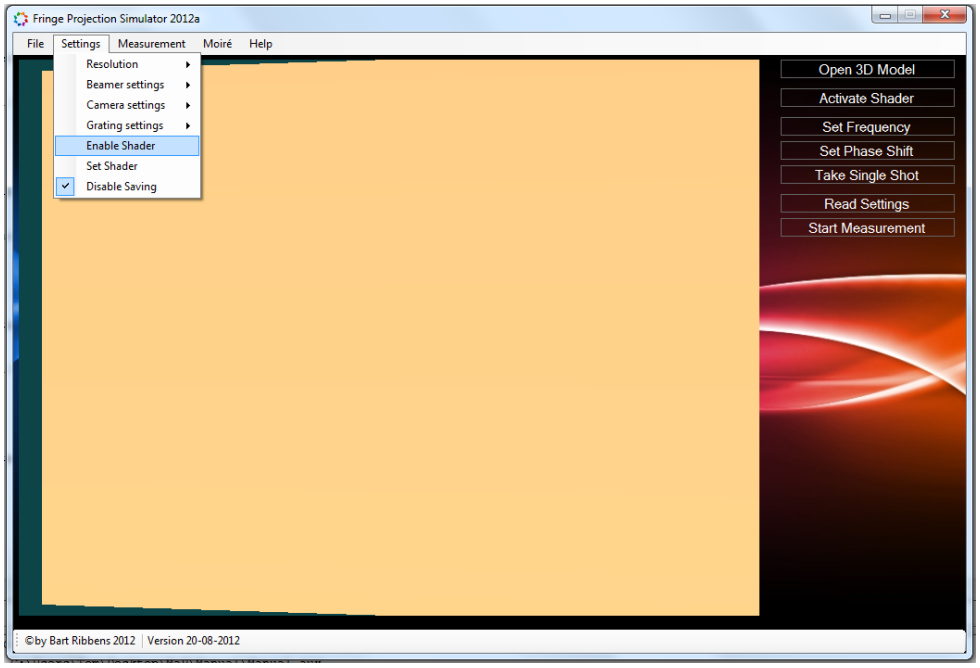


Figure 25: Enable Shader

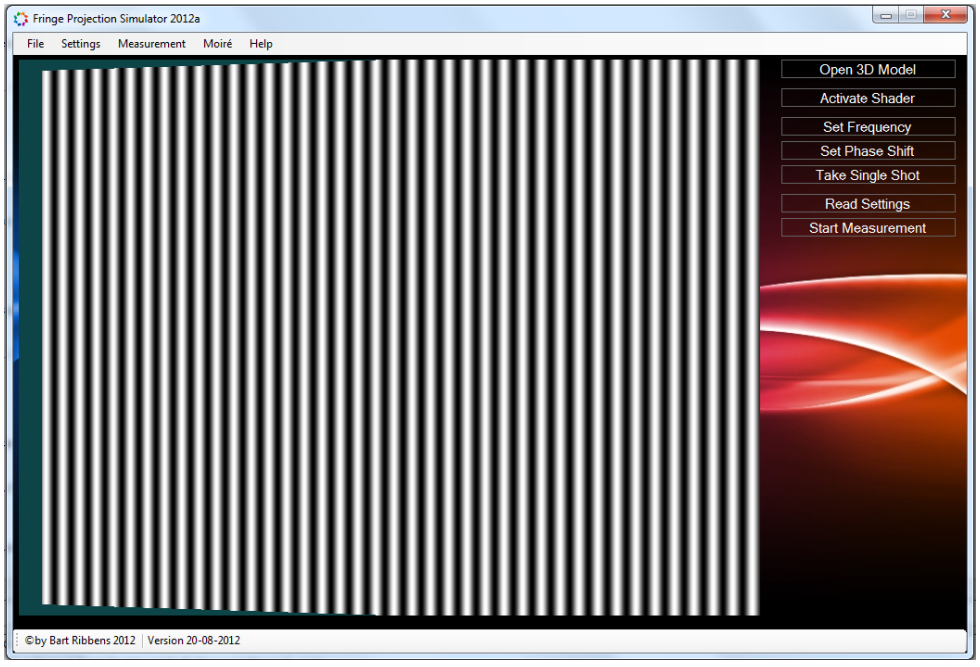


Figure 26: Shader Enabled

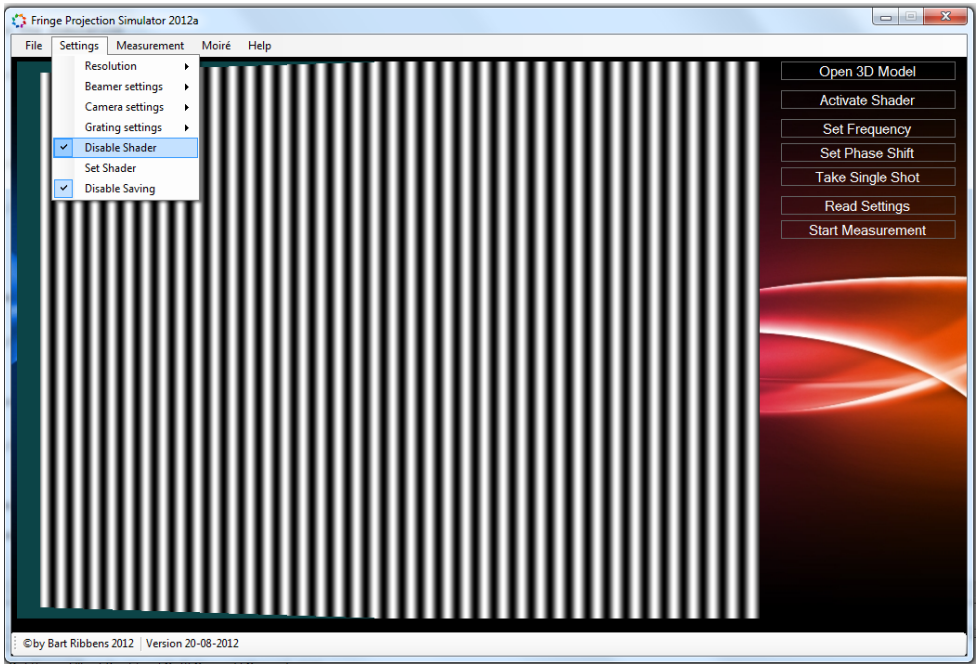


Figure 27: Disable Shader

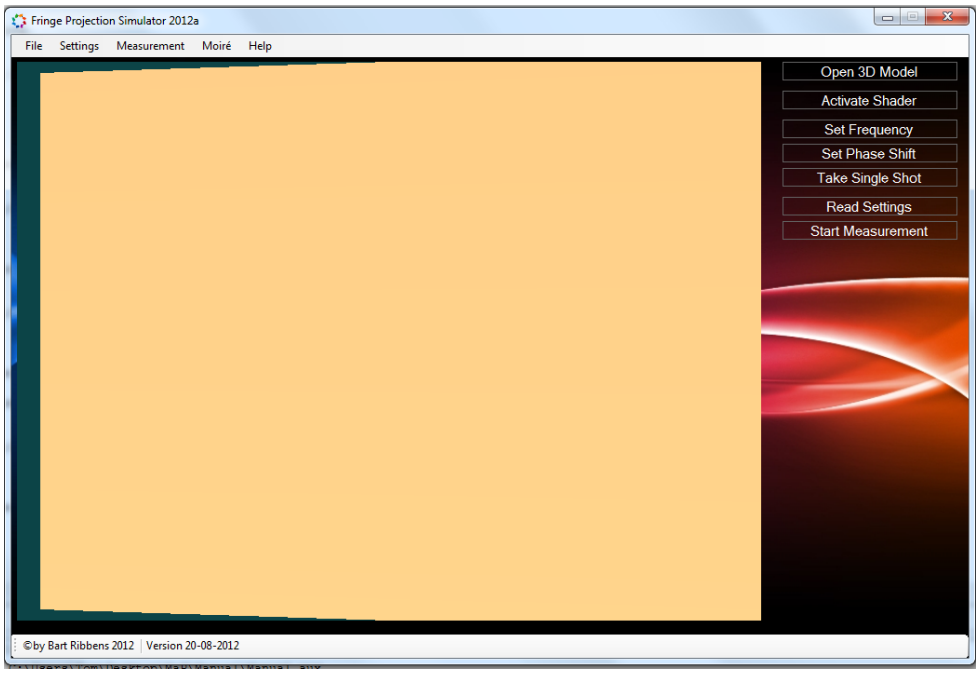


Figure 28: Shader Inactive

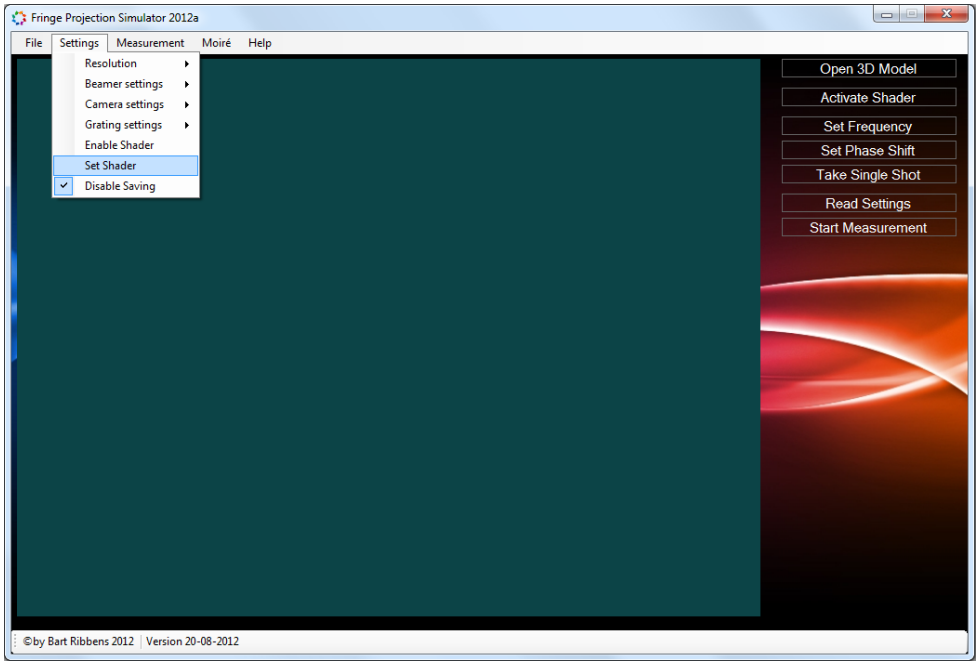


Figure 29: Set Shader

### 9.1.1 Vertex Shader

First we choose the vertex shader, which we will be using in this simulation.

Next, we can choose the fragment shader.

# 10 Enable/Disable Saving

When starting up the program, saving is enabled. By clicking this button, you will be unable to save a picture. If you want to save a picture, simply press the enable save button.

# 11 Measurement

With the measurement control, we can change the settings of the pattern that is projected by our beamer.

## 11.1 Set Frequency

With this control, we can alternate the frequency of the projected pattern. In Figure 35, we can see 20 white lines projected upon the model. Frequency: 50 When we look at Figure 36, we see 50 white lines projected onto the model.

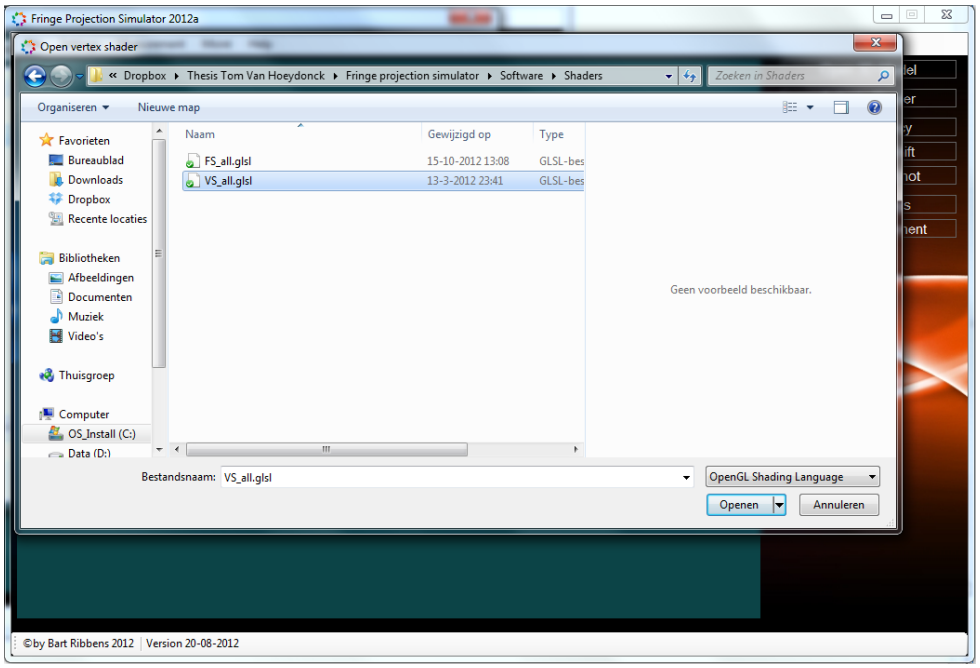


Figure 30: Vertex Shader

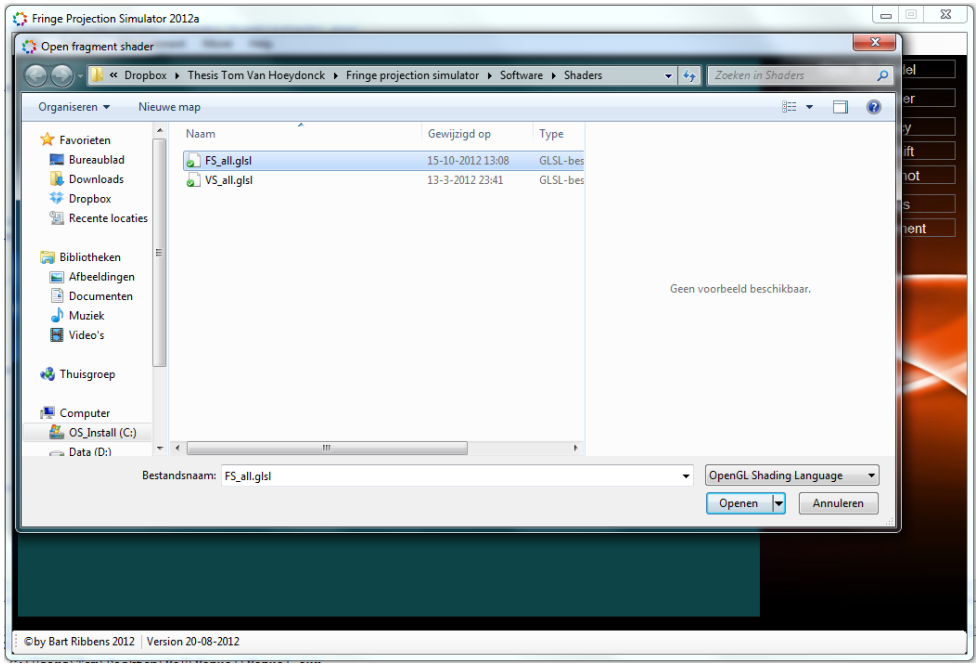


Figure 31: Fragment Shader

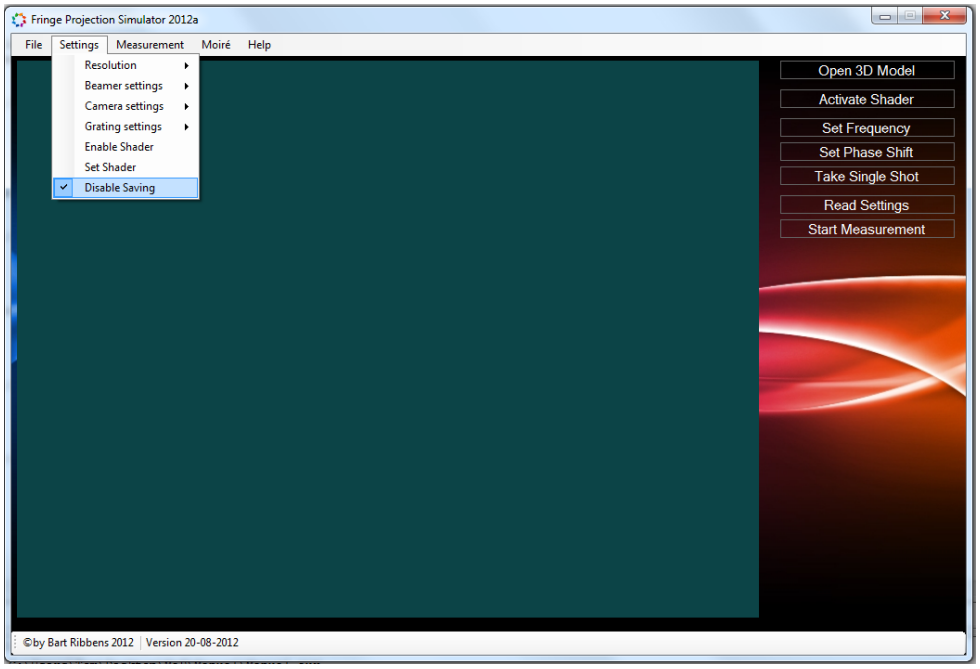


Figure 32: Saving

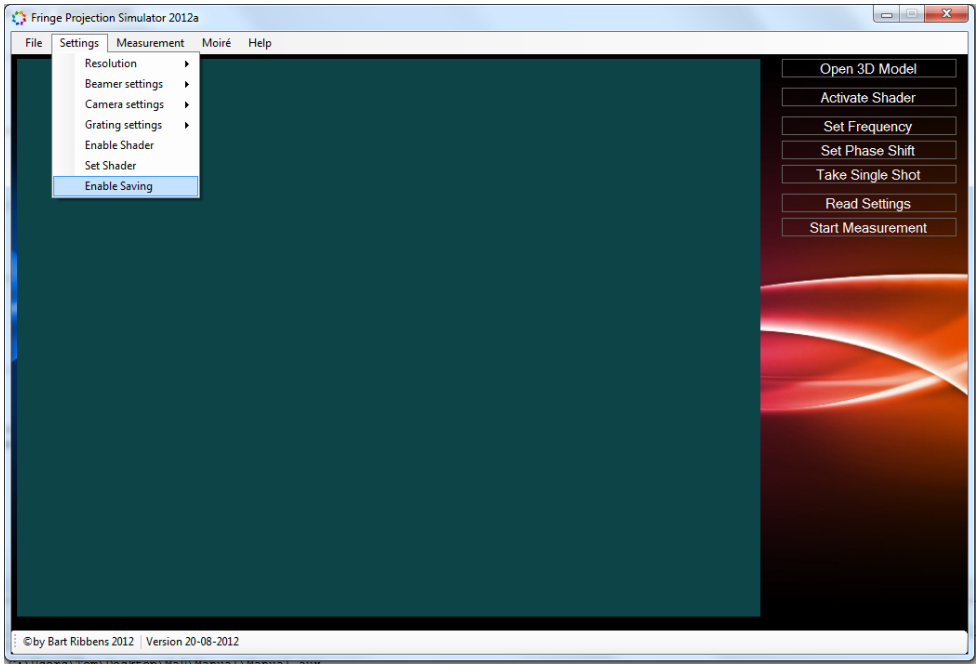


Figure 33: Enable Saving

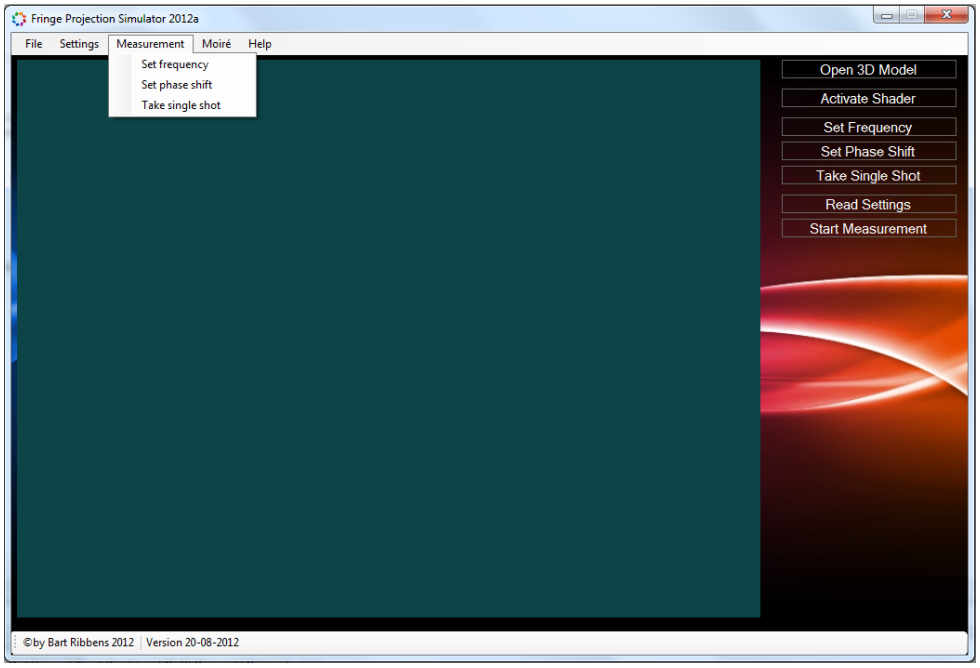


Figure 34: Measurement Settings

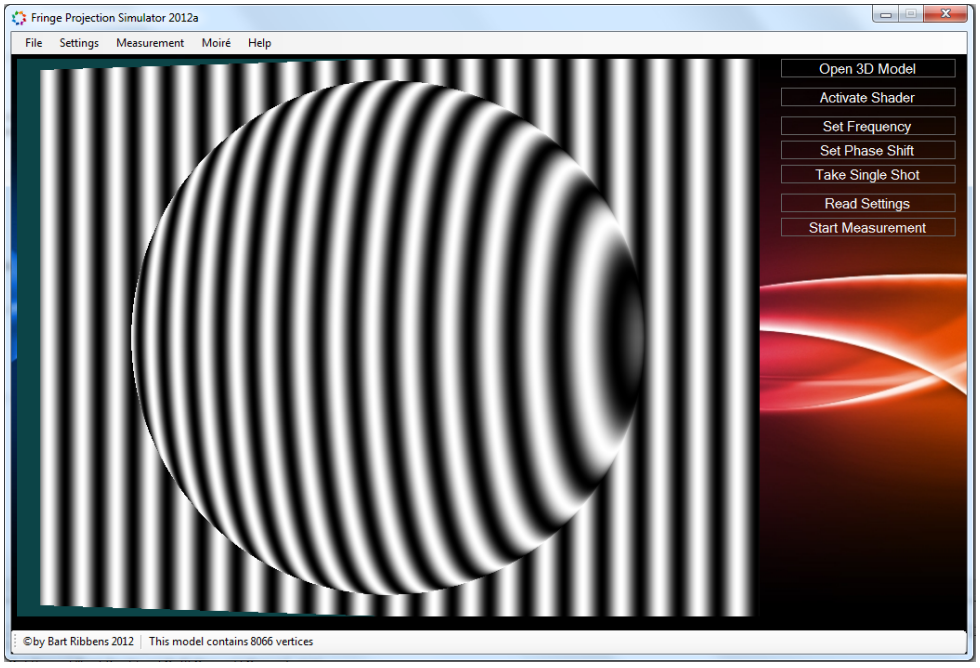


Figure 35: Frequency of 20

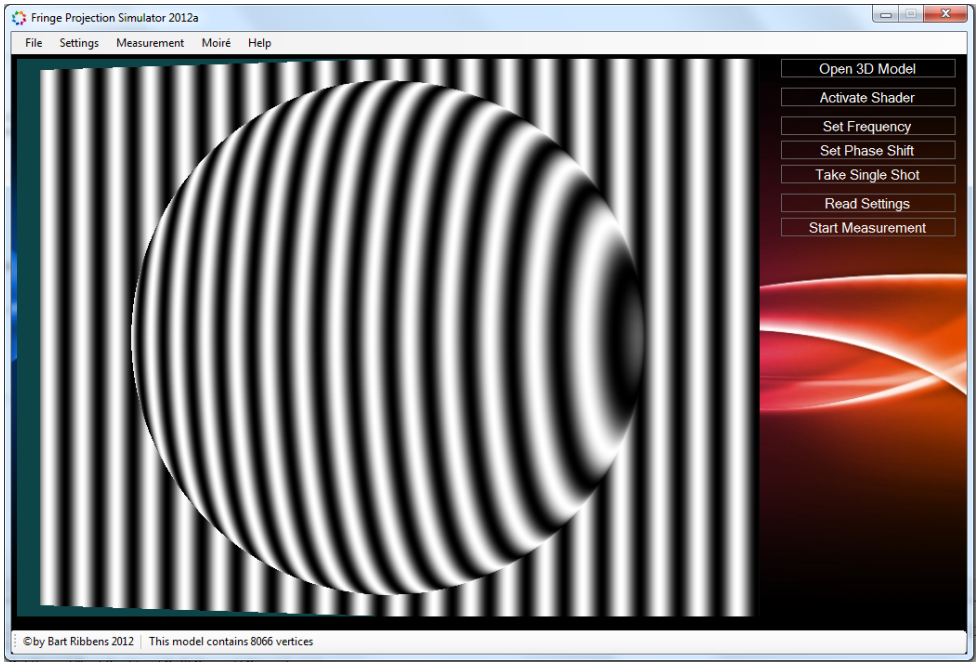


Figure 36: Frequency of 50

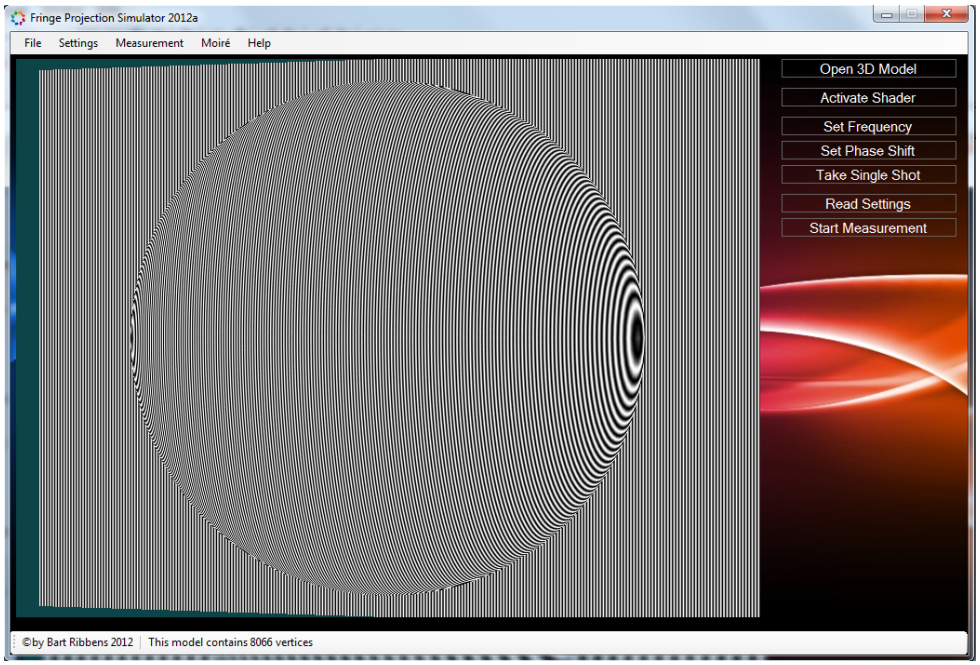


Figure 37: Aliasing

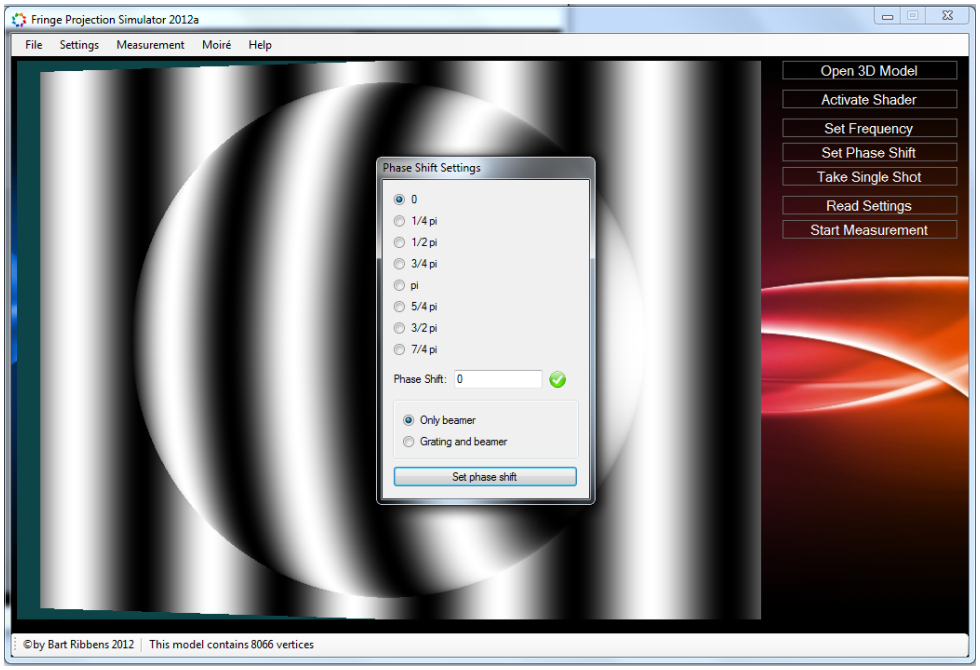


Figure 38: Phaseshift

**Aliasing**

## 11.2 Set Phaseshift

Phaseshifting is also possible in this simulation. When clicking this button, a pop up screen will appear. Standard the phaseshift is set at 0. The phaseshift is expressed in radians. A period is equal to 2PI (360 degrees), this contains one white line and one black line. When we set the phaseshift at PI/2 radian, we can see that only half the length of the first white line is visible. This is because the whole pattern is shifted PI/2 radians (90 degrees), 1/4th of a period. It is also possible to insert a phaseshift manually. Instead of only changing the phaseshift of the beamer, we can also set the phaseshift of the beamer and grating together.

## 11.3 Take Single Shot

By taking a single shot, we can save the file as a .PNG file.

# 12 Moiré

In this menu, we can change every aspect of the moiré grating.

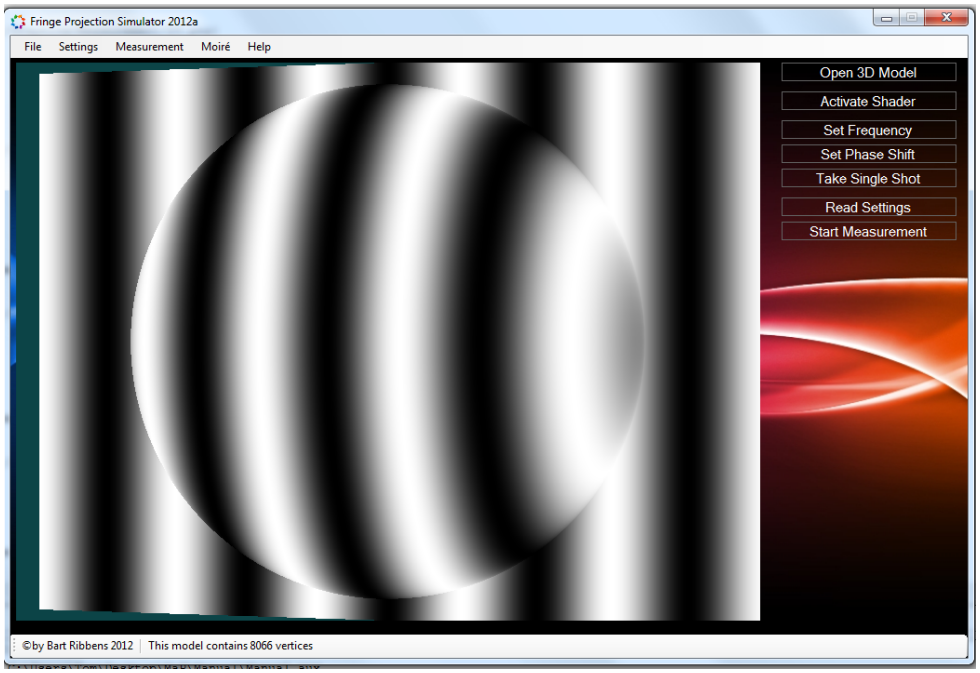


Figure 39: Phaseshift PI/2

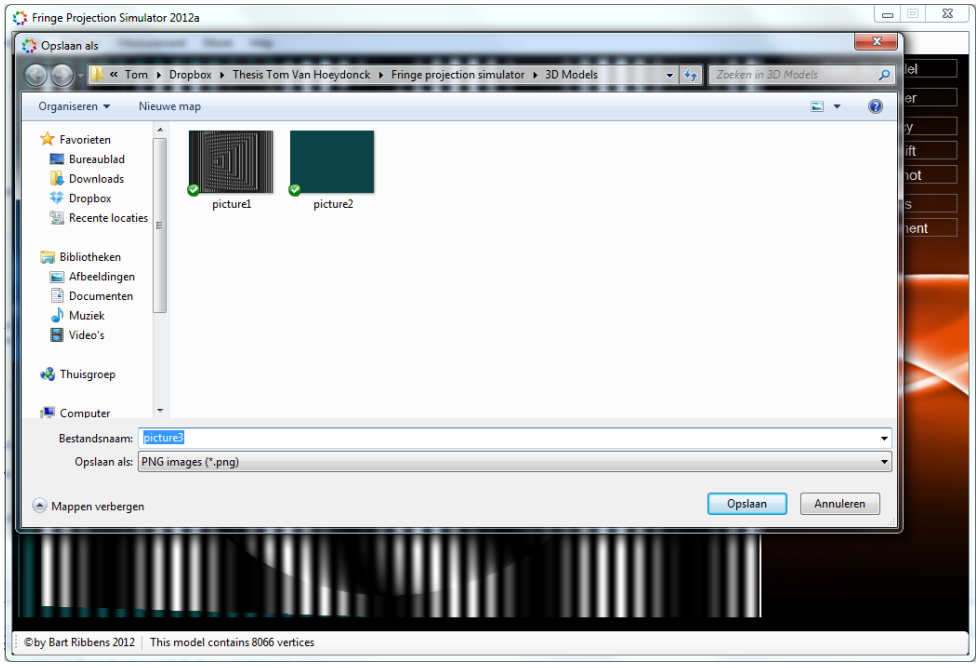


Figure 40: Save File

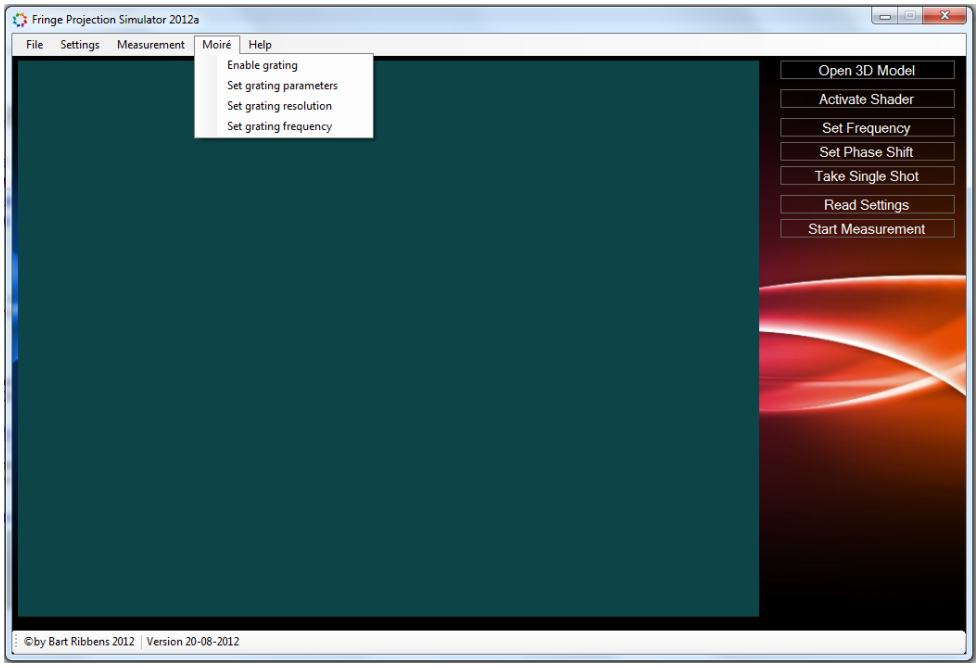


Figure 41: Moiré

## 12.1 Enable grating

Using the enable grating button, allows us to activate the moiré grating. When we start the program and enable the moiré grating, it will look like Figure 42. We only see a square, but no pattern. This is because we haven't enabled the shader yet. When we active the shader, we will have a pattern looking like Figure 43. In order to get a meaningful output, we still have to adjust the parameters to get a working setup as we will see in our example.

**Set Grating Parameter** We can choose the position of the grating using this button. First, we have to insert the X position of our first point. Then we have to enter the Y position and the Z position. After we inserted our first point, we have to insert the second point. The first and second point are in order, the bottom left and upper right corners of the grating. This is visualized in Figure 46.

**Set Resolution** By setting the resolution of the grating, we can determine the quality of the display. When we enter a resolution that is high enough, the quality will be high. Notice that the lines are all smooth. If we lower the resolution to 500x500, we will notice that the quality is significantly lower than the previous resolution. This effect will occur more when the resolution is lower. In Figure 48 we notice that there is more fringe in the lines and less smoothness.

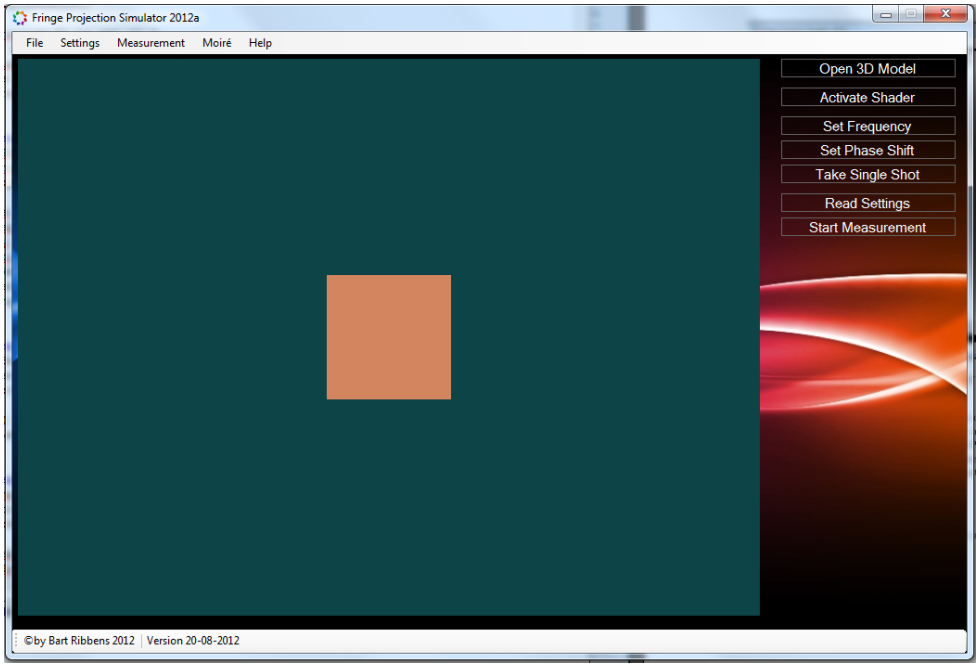


Figure 42: Moiré enabled

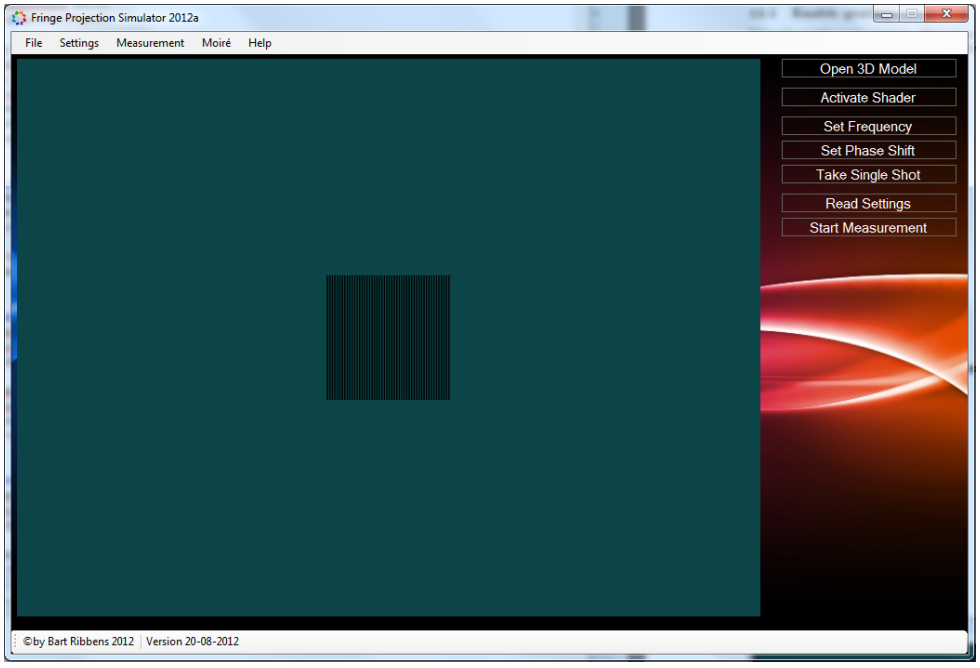


Figure 43: Moiré and shader enabled

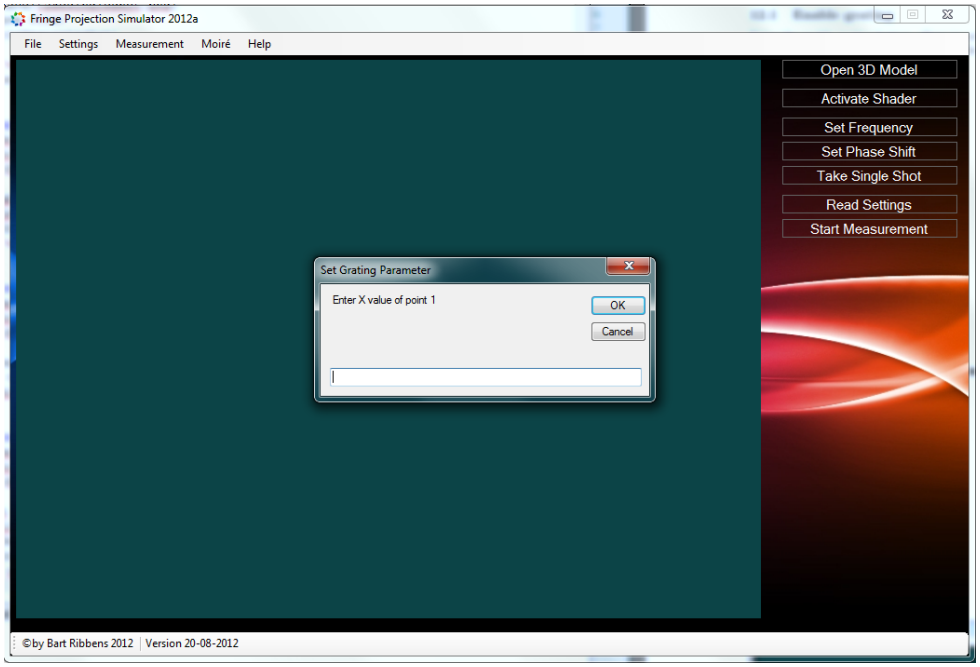


Figure 44: X position grating

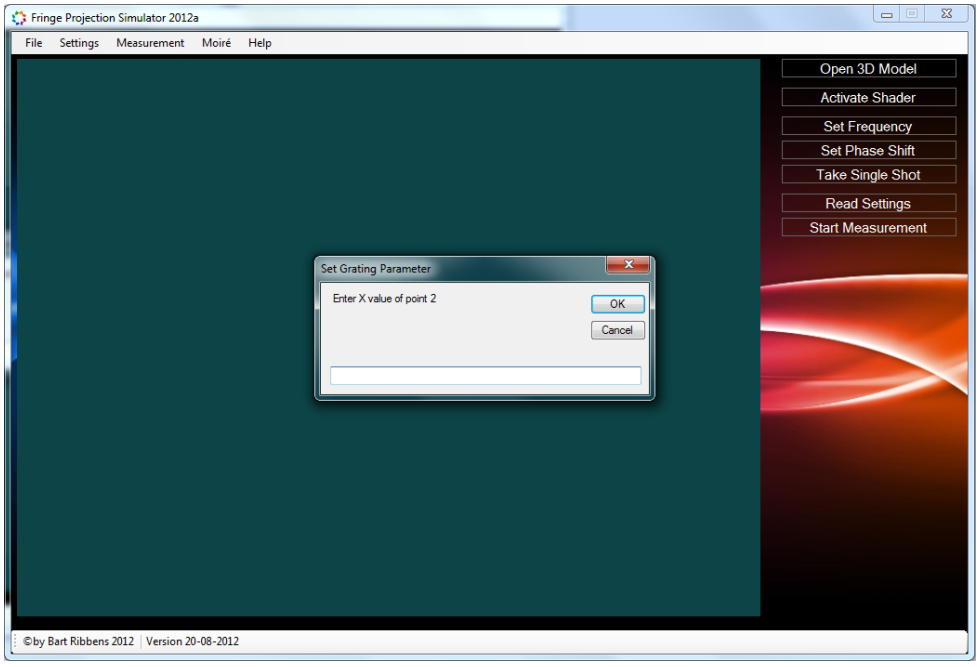


Figure 45: X position 2 grating

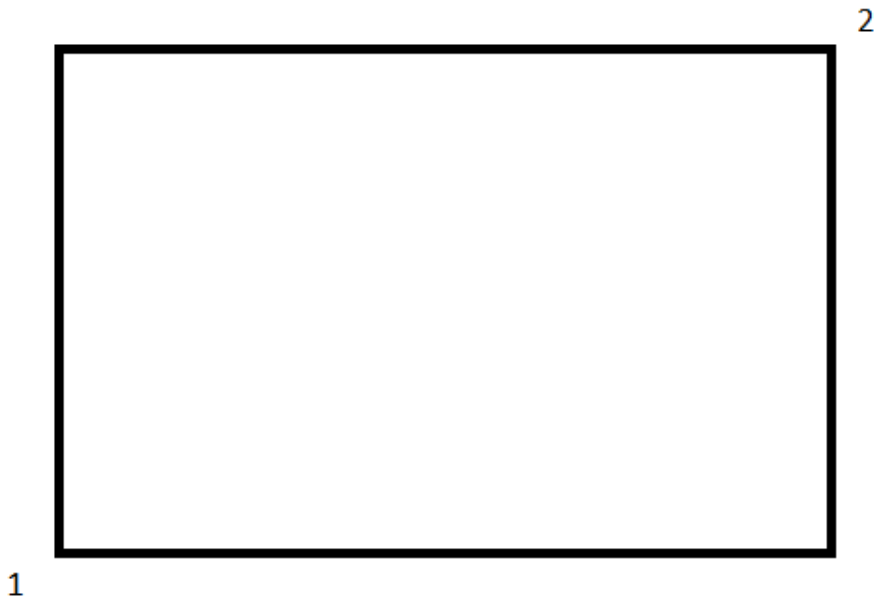


Figure 46: Grating points

### 12.2 Set Frequency

Changing the frequency and phaseshift of the grating can be done with this button. First we have to enter the frequency of the grating. Next, we can insert the phaseshift of our grating.

## 13 Help

When there are any questions or remarks, they can be sent using this menu.

### 13.1 View Help

The "View Help" button will sent you to an online contact form as seen in Figure 51.

### 13.2 About

More information about the program which is shown in Figure 52.

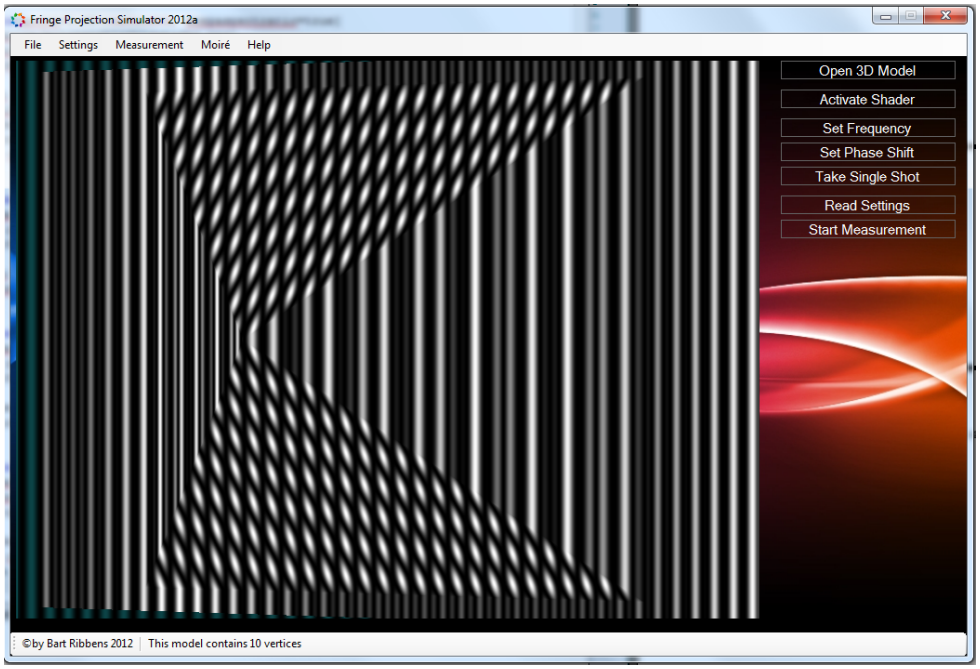


Figure 47: Grating resolution of 20000x20000

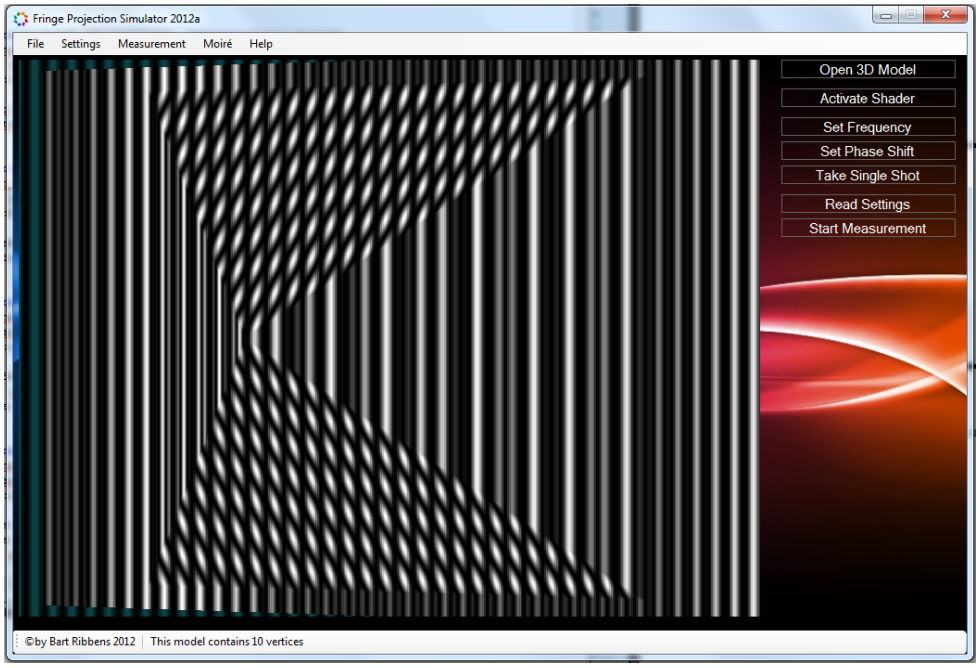


Figure 48: Grating resolution of 500x500

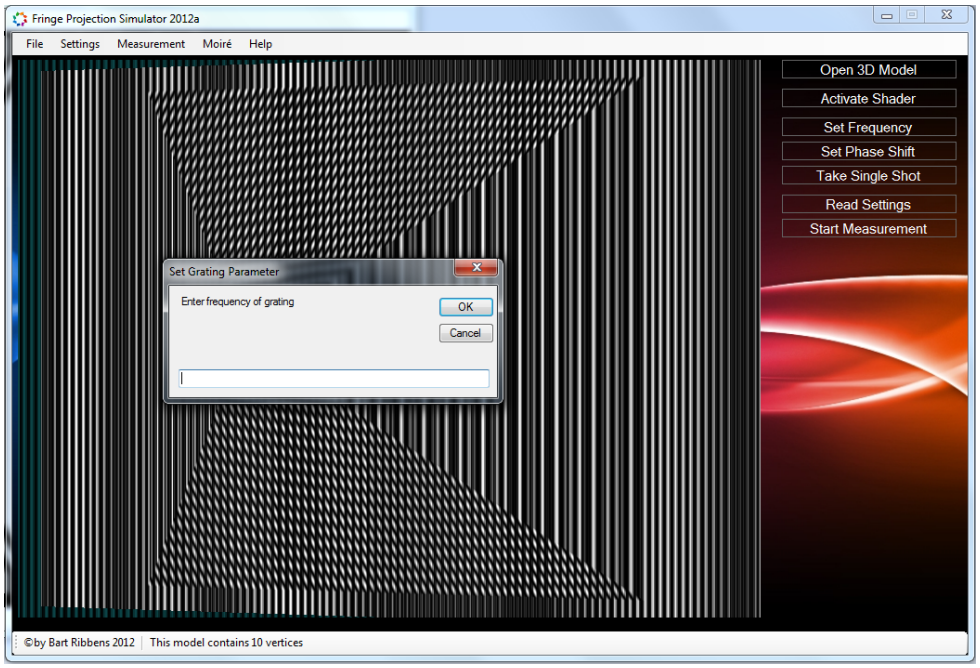


Figure 49: Grating Frequency

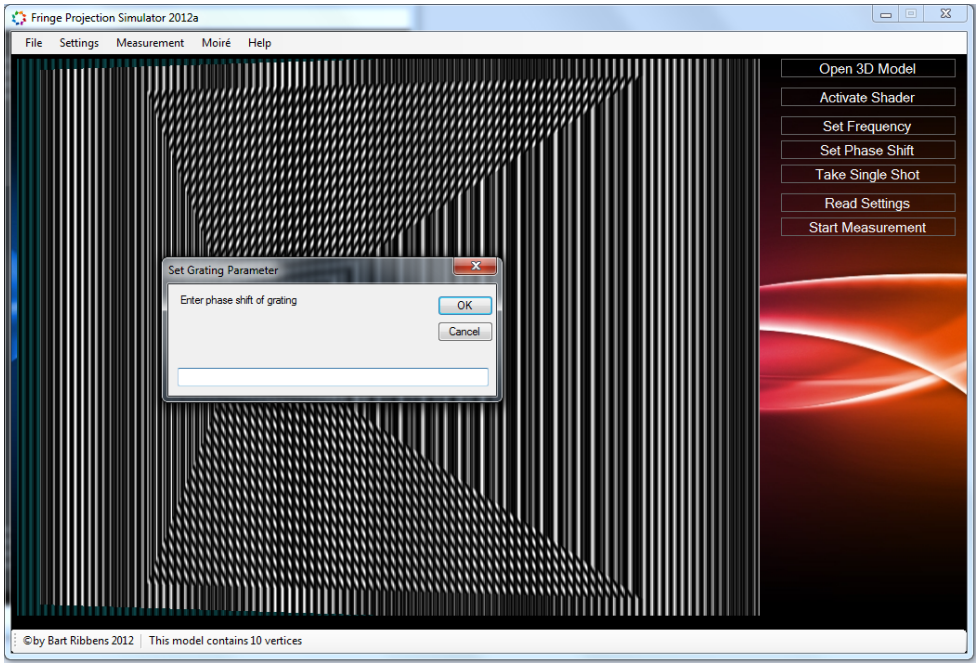


Figure 50: Grating Phaseshift

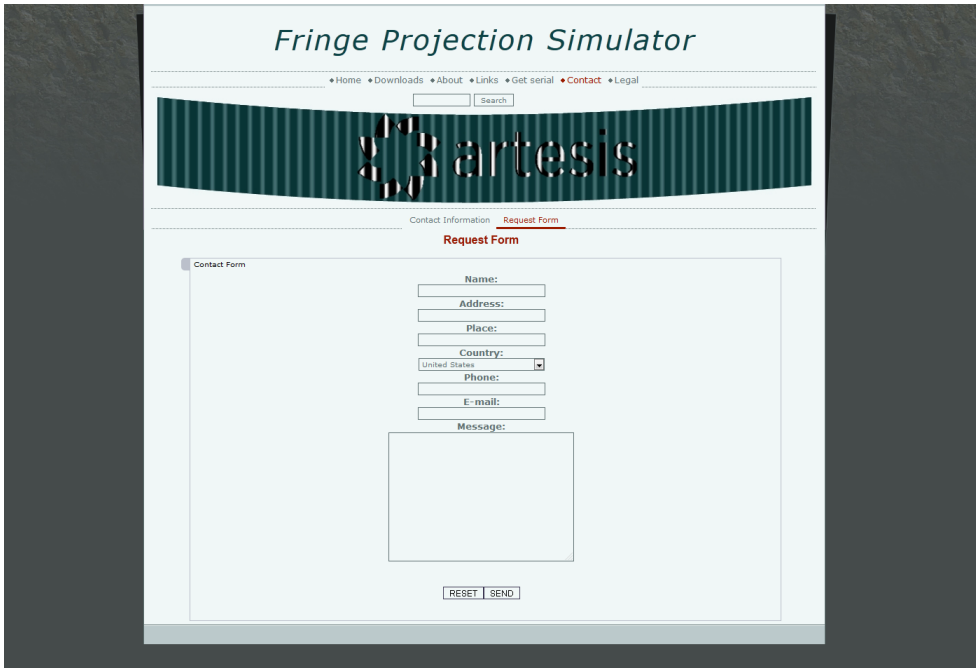


Figure 51: Request Form

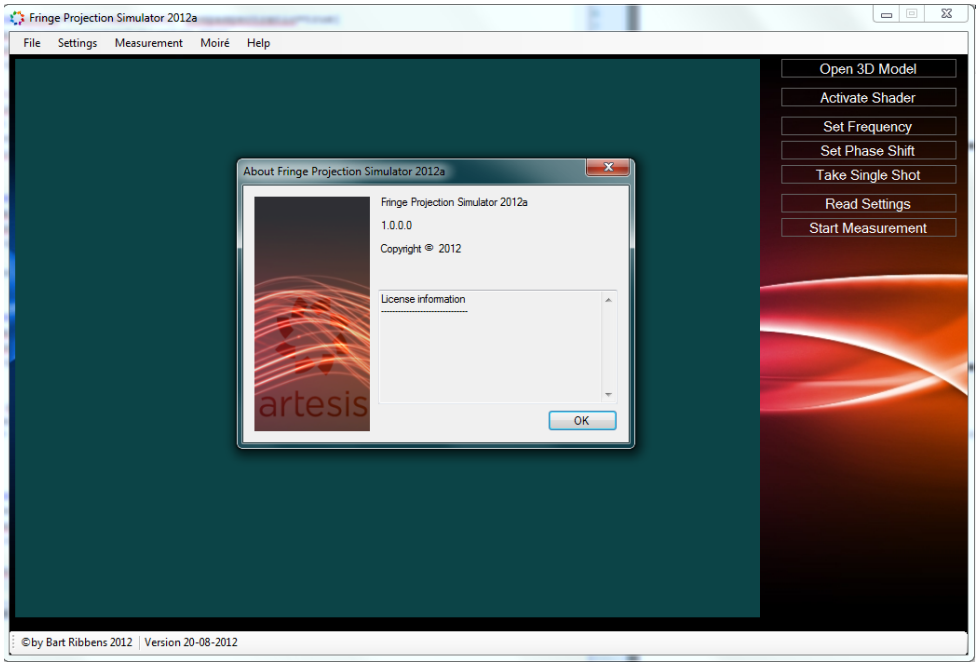


Figure 52: About

# Part IV
# Button Frame

These are several buttons which are easily to use for adjusting different parameters.

## 14 Open 3D Model

With this button, we can load a 3D Model within our program. The file has to be of the .STL extension, which means it consists of solely edges. The 3D model contains no volume. Note that it is possible to create your own 3D Model with inventor and save it as an .STL file, this 3D model can be used in this program.

## 15 Activate Shader

By clicking the activate shader button, we can activate the beamer.

## 16 Set Frequency

Using the Set Frequency button, we can change the frequency of the beamer.

## 17 Set Phaseshift

Changing the phaseshift of the beamer and/or the grating is possible with this button.

## 18 Take Single Shot

When we take a single shot, the image will be saved in a destination path we can choose.

## 19 Read Settings

To make a setup, we can just load the settings containing information about all the parameters into the simulation. This is much faster than manually inserting the parameters every time. These files can be made and edited with notepad.

## 20 Start Measurement

When we want to perform a measurement, we use this button. The parameters of the measurement are also found in the settings file. As we can see in Figure 54, the settings of our measurement are present.

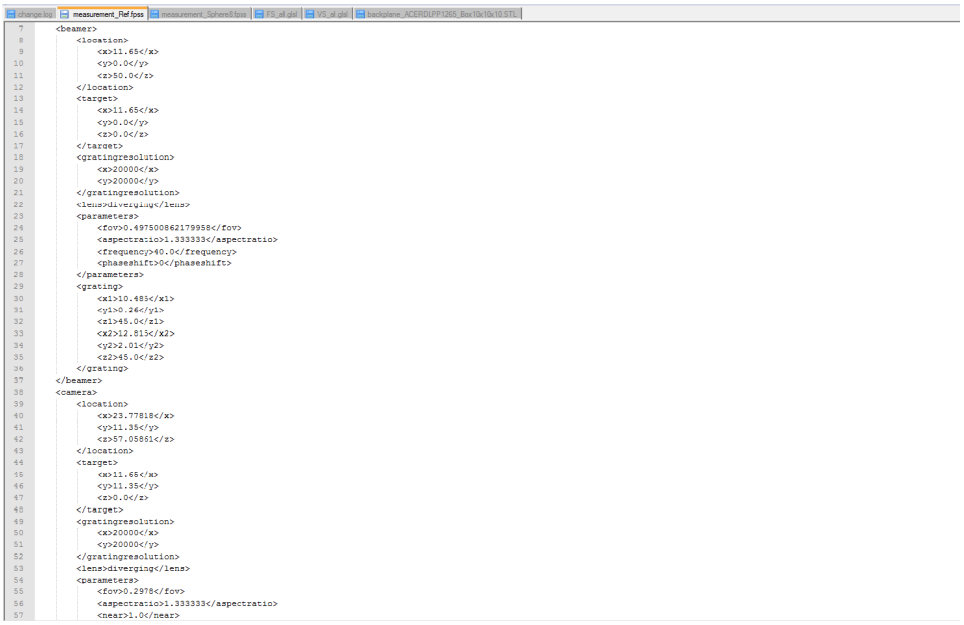


Figure 53: Example of read settings file

```
    <measurement>
        <type>fringe</type>
        <mappath>C:\Users\Tom\Desktop\MaP\Measurements\CIPT\5-30_150_Reference\</mappath>
        <filename>M001_</filename>
        <beamer>
            <blackout>3</blackout>
            <steps>150</steps>
            <grating>
                <frequency>
                    <start>5</start>
                    <stop>30</stop>
                </frequency>
                <phase>
                    <start>0</start>
                    <stop>10</stop>
                </phase>
            </grating>
        </beamer>
    </measurement>
</fringesettings>
```

Figure 54: Measurement settings

### 20.1 Mappath

The destination to which the files will be saved.

### 20.2 Filename

The filename will start with M001, followed by numbers that add up.

### 20.3 Blackout

The number of black screens saved before and after every measurement.

### 20.4 Grating Beamer

The controls "beamer" and "grating" are used to change the parameters of the grating from the beamer.

### 20.5 Frequency

We have a start and a stop frequency, at the beginning of the measurement we will have a frequency of 5. At the end, the frequency will be 30.

### 20.6 Phaseshift

Initially, the phaseshift will be 0. At the end of our measurement, the phaseshift will be 10.

### 20.7 Steps

This control determines in how many steps the change of frequency and phaseshift will occur. In this example, it will be done in 150 steps.

# Part V
# Example of a measurement

In this part, we will show an example of how a measurement is done and which steps are followed.

## 21 Read Settings

First of all, we have to adjust the parameters of our camera, grating and beamer. For this example, we will be using the "measurementRef.fpss" file so that all the parameters are already set. Remember that it is possible to edit this file so you don't have to adjust the parameters everytime you restart the program. After clicking the "Open" button, the display will look as shown in Figure 56. We will have a plane reference that we can use for our measurement.

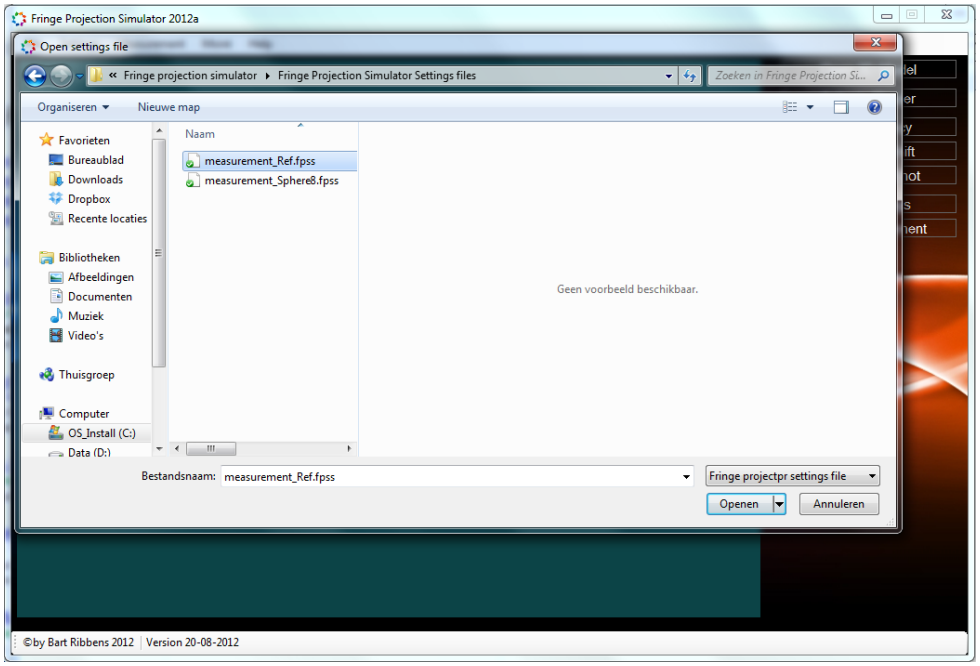


Figure 55: Read parameter settings

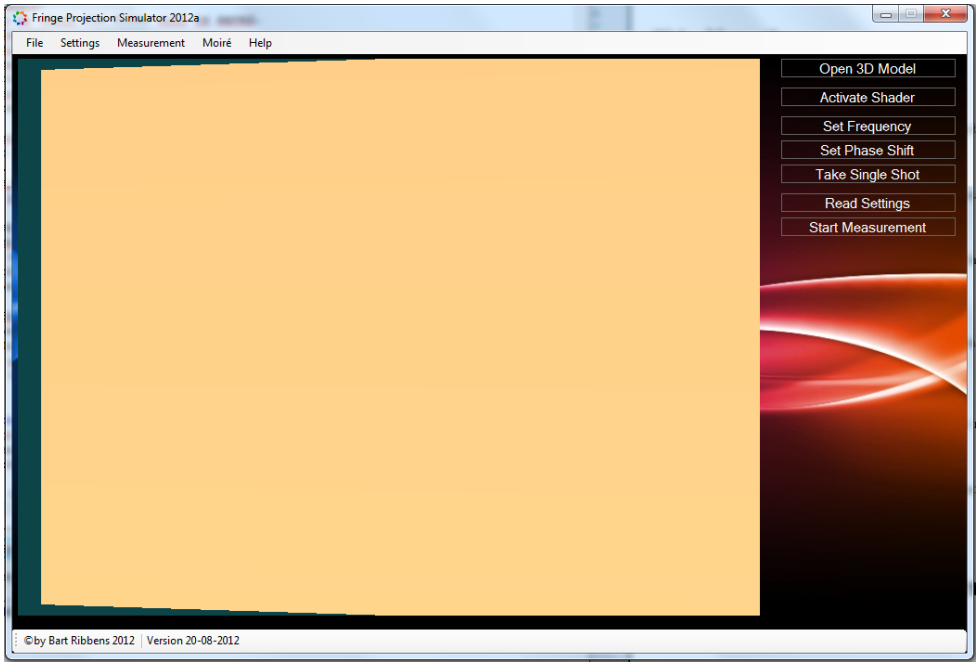


Figure 56: Plane reference

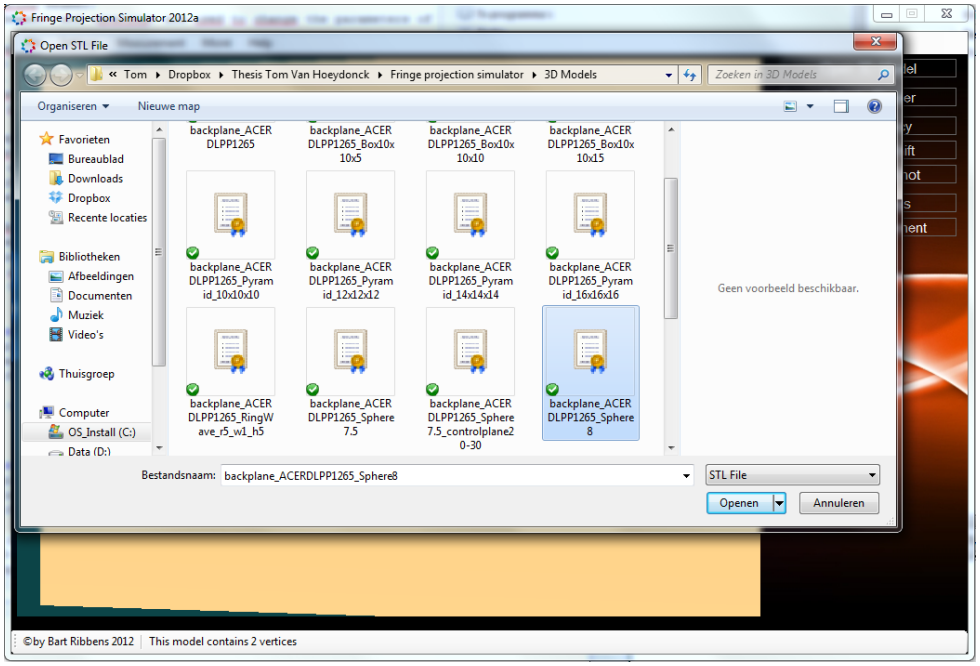


Figure 57: Open 3-D model

## 22 Open 3-D Model

Next, we will open our 3-D model which we are going to work with. As you can see in Figure 57, we will be working with a sphere. Figure 58 is what your display should look like after loading the 3-D model.

## 23 Set and activate shader

We can set the shaders by going to the settings menu, next click on set shader and select the shaders as explained in section 9.1. The shaders used in this tutorial are already loaded when starting the program. By clicking on activate shader in the button frame, the beamer will be activated. We will now have a display of our object with the pattern projected onto it as in Figure 59. Note that you can adjust the frequency and phaseshift in the measurement menu, but this will have no effect on the measurement that is performed. The only way to adjust the measurement is by changing these settings in the settings file that we opened earlier.

## 24 Measurement settings

You can edit the measurement settings using notepad. After opening the file, you will see all the information that is loaded into the simulation when it is read. In Figure 60 we see all the information

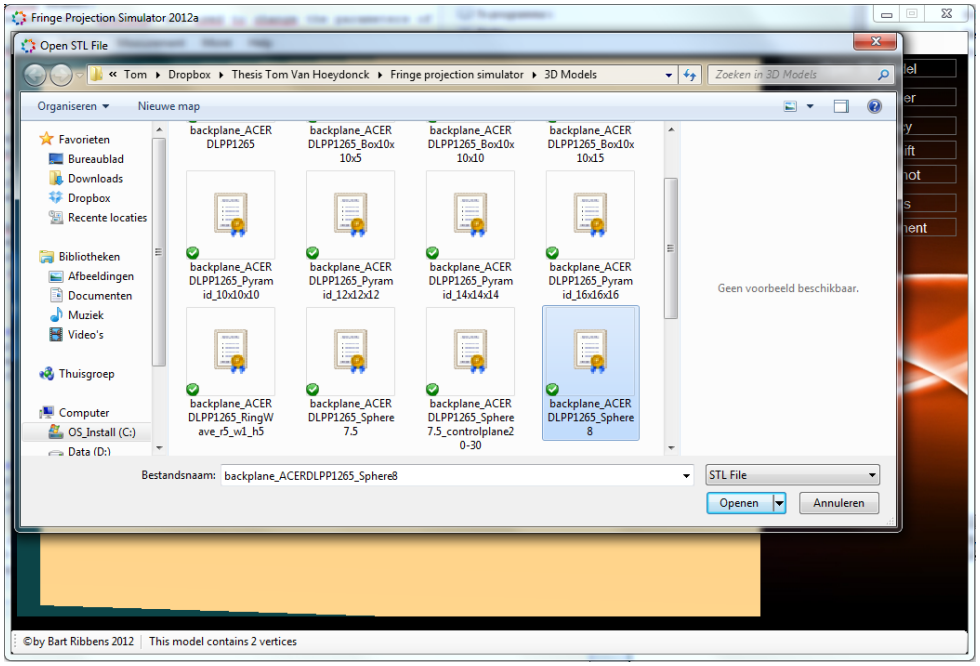


Figure 58: Display with sphere

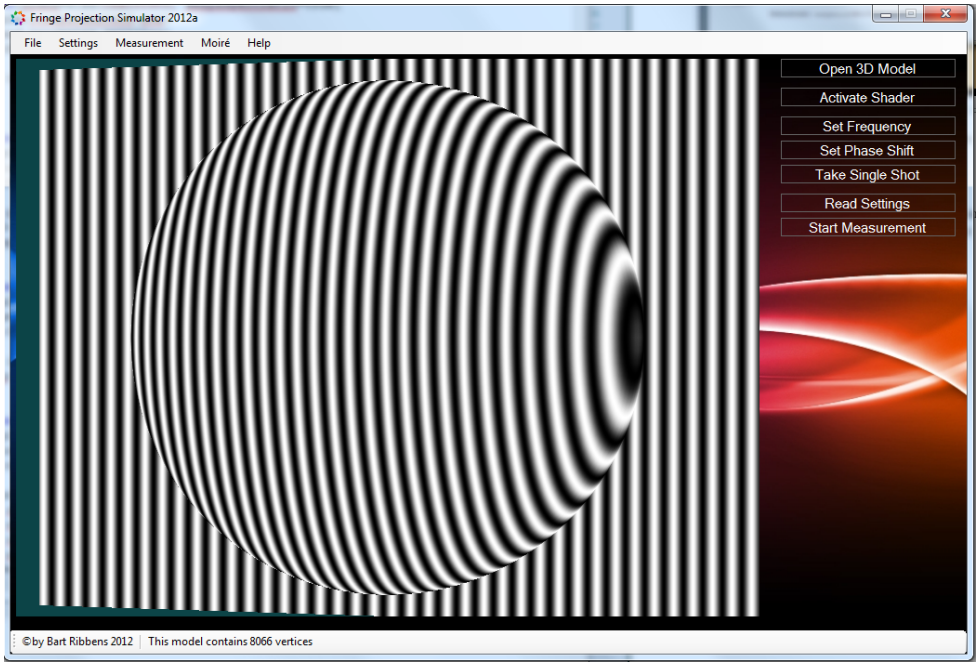


Figure 59: Display with sphere and pattern

```
    <measurement>
        <type>fringe</type>
        <mappath>C:\Users\Tom\Desktop\MaP\Measurements\CIPT\5-30_150_Reference\</mappath>
        <filename>M001_</filename>
        <beamer>
            <blackout>3</blackout>
            <steps>150</steps>
            <grating>
                <frequency>
                    <start>5</start>
                    <stop>30</stop>
                </frequency>
                <phase>
                    <start>0</start>
                    <stop>10</stop>
                </phase>
            </grating>
        </beamer>
    </measurement>
</fringesettings>
```

Figure 60: Measurement settings

to adjust the measurement. For more information about these settings, go to section 20. These settings are standard and can be manually adjusted:

1. The phaseshift begins at 0 radians and ends at 10 radians.
2. The frequency of our pattern begins at 5 and ends at 30.
3. The measurement will be executed in 150 steps.
4. Before each measurement, there will be 3 black images saved to identify each measurement.

For this example, we will keep the initial value.

# 25 Start Measurement

After clicking the start measurement button, a pop up screen, as shown in Figure 61, will appear indicating that saving is enabled. This is necessary to perform the measurement. Otherwise, the pictures won't be saved. During the measurement, you will see the change in frequency and phaseshift. After the measurement is done, go to the mappath where you saved the file. The measurement started with 3 black images and ended with 3 black images. In between there are 150 images because the measurement took 150 steps. If everything went well, it should look like Figure Figure 62. Congratulations, you have succesfully performed a measurement with the Fringe Projection Simulator!

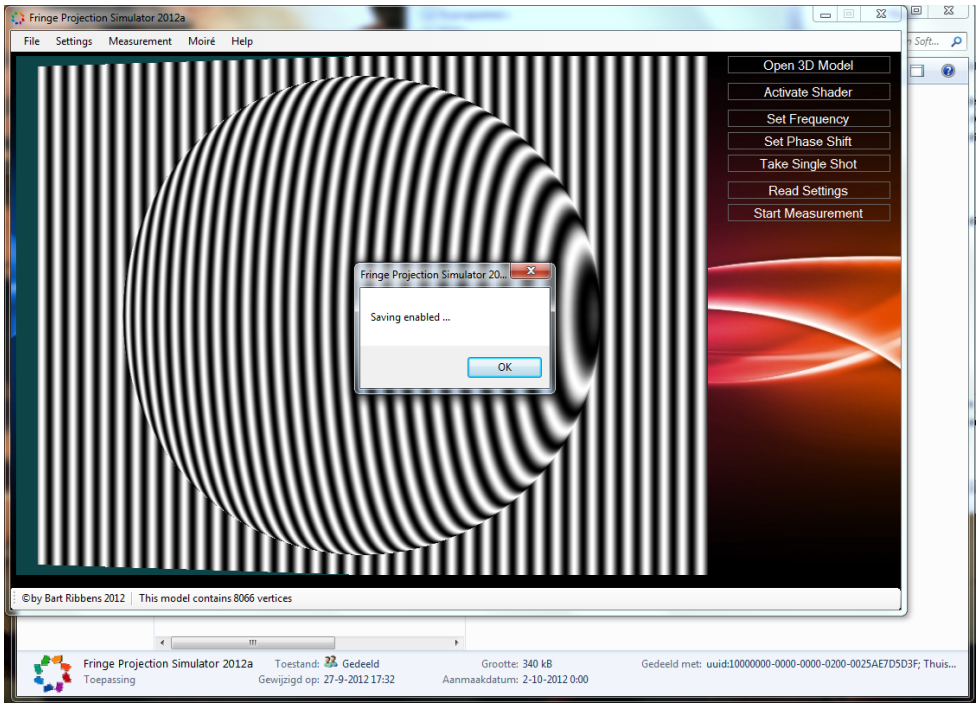


Figure 61: Saving enabled

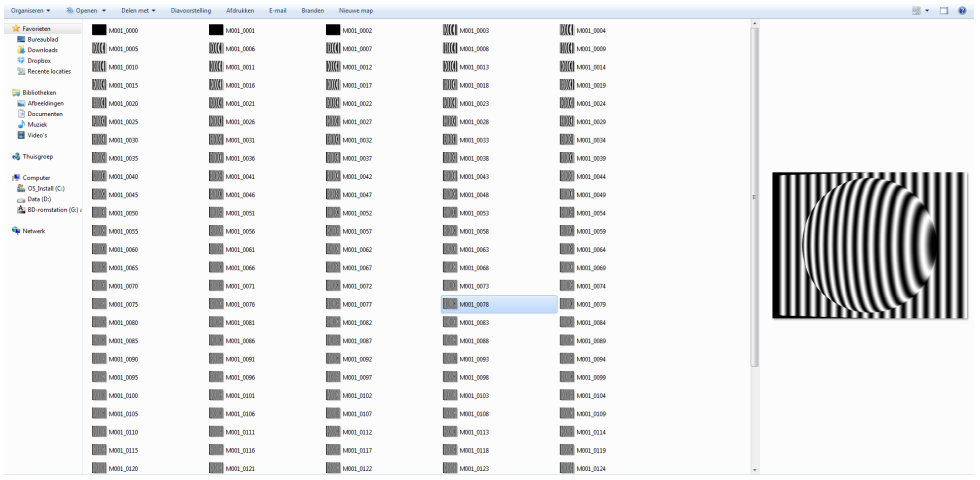

Figure 62: Images saved within the map