

1. Mathematical Supplementals

Raytracing Approach:

The intersection calculation of the individual rays with the DMD can be described as follows. To get the point of diffraction on the DMD \vec{f}_k must equal \vec{d} , this leads to:

$$\begin{pmatrix} m & 0 & \frac{1}{2}(1 - \cos \gamma + \cos \gamma) & \frac{1}{2}(1 - \cos \gamma) & -ax \\ 0 & m & \frac{1}{2}(1 - \cos \gamma) & \frac{1}{2}(1 - \cos \gamma + \cos \gamma) & -ay \\ 0 & 0 & -\frac{1}{\sqrt{2}}\sin \gamma & \frac{1}{\sqrt{2}}\sin \gamma & -az \end{pmatrix} \begin{pmatrix} m_x \\ m_y \\ s \\ t \\ u \end{pmatrix} = \begin{pmatrix} h_x \\ h_y \\ h_z \end{pmatrix}$$

This equation system is under determined. To solve this, we need to check every mirror (m_x, m_y) , which leads to:

$$\begin{pmatrix} \frac{1}{2}(1 - \cos \gamma + \cos \gamma) & \frac{1}{2}(1 - \cos \gamma) & -ax \\ \frac{1}{2}(1 - \cos \gamma) & \frac{1}{2}(1 - \cos \gamma + \cos \gamma) & -ay \\ -\frac{1}{\sqrt{2}}\sin \gamma & \frac{1}{\sqrt{2}}\sin \gamma & -az \end{pmatrix} \begin{pmatrix} s \\ t \\ u \end{pmatrix} = \begin{pmatrix} h_x \\ h_y \\ h_z \end{pmatrix} - m \begin{pmatrix} m_x \\ m_y \\ 0 \end{pmatrix}$$

This has an analytic solution for each single mirror (see ray-dmd-intersection.nb in the attached repository). But there is only one valid Solution, which can be determined by checking the range of s and t . If there are still more than one solution then the solution with the smallest u is the valid one, because that is the position on the DMD which gets hit first.

Analytic Phase Shifting Approach:

The field of a single mirror can be written down as follows. The integral can be solved analytically. (see dmd.nb in the attached repository)

$$E^{single\ mirror}(\vec{a}, \vec{b}, \gamma_{m_x, m_y}^{\pm}, w, \lambda) = \iint_0^w \exp\left(\frac{2\pi i}{\lambda} \left(R(\gamma_{m_x, m_y}^{\pm}) \cdot (s, t, 0)\right) \cdot (\vec{a} - \vec{b})\right) ds dt$$

The field generated by the phase shift between the single mirrors can be written down as follows.

$$E_{m_x, m_y}^{shift}(\vec{a}, \vec{b}, m, \lambda) = \exp\left(\frac{2\pi i}{\lambda} \vec{m}(m_x, m_y) \cdot (\vec{a} - \vec{b})\right)$$

Grating Approach:

The sum over the phase shifts of the single mirrors corresponds to the field of the native DMD grating. The sum can furthermore be simplified as follows.

$$\begin{aligned}
E_{grating}(\vec{a}, \vec{b}, m, N_x, N_y, \lambda) &= \sum_{m_x=0, m_y=0}^{N_x-1, N_y-1} E_{m_x, m_y}^{shift}(\vec{a}, \vec{b}, m, \lambda) \\
&= \sum_{m_x=0, m_y=0}^{N_x-1, N_y-1} \exp\left(\frac{2\pi m i}{\lambda} ((a_x - b_x)m_x + (a_y - b_y)m_y)\right) \\
&= \frac{\left(-1 + \exp\left(\frac{2\pi m i}{\lambda} (a_x - b_x)N_x\right)\right)\left(-1 + \exp\left(\frac{2\pi m i}{\lambda} (a_y - b_y)N_y\right)\right)}{\left(-1 + \exp\left(\frac{2\pi m i}{\lambda} (a_x - b_x)\right)\right)\left(-1 + \exp\left(\frac{2\pi m i}{\lambda} (a_y - b_y)\right)\right)}
\end{aligned}$$

2. Quick guide though the Coherent DMD Simulator Fiji-Plugin

After copying the file "coherent_dmd_sim_simulator.jar" into the ".../Fiji.app/plugins" directory, you can access our algorithms in Fiji under "Plugins>Coherent DMD Simulator>..." (Figure 1). The default settings of the plugin are chosen to reproduce the results in our article. Currently the plugin has no CUDA GPU support. If you want to use the GPU support, you must customize the .java files and start them from the command line or a development environment of your choice.

Figure 2 to Figure 5 show the input masks for the approaches presented in our article. Depending on the approach, you can specify various system constraints. The ray tracing approach Figure 2 and the analytic phase shifting approach Figure 3 each simulate one single diffraction pattern. The ability to simulate different patterns is currently not yet implemented in the ray tracing approach but will be available soon.

The grating approach simulates many diffraction images depending on the incidence parameters. For these the distance between the brightest diffraction order and the center of the envelope in pixels is determined. Additionally, the x and y position of the brightest diffraction order is determined. These data are stored e.g. at a simulation wavelength of 488 nm in the files "488_false-eveope-peak-distance.tif", "488_false-intensity-max-x.tif" and "488_false-intensity-max-y.tif". Before starting the grating approach, you will be asked whether the diffraction images should also be stored, which requires a lot of RAM. The results of the grating approach can be further processed using the diffraction space analysis (Figure 6) to find out under which diffraction angles a blaze condition is fulfilled.

All saved .tif files contain meta information about the system constraints set for the simulation. These can be displayed via "Image>Show Info" (Figure 7)

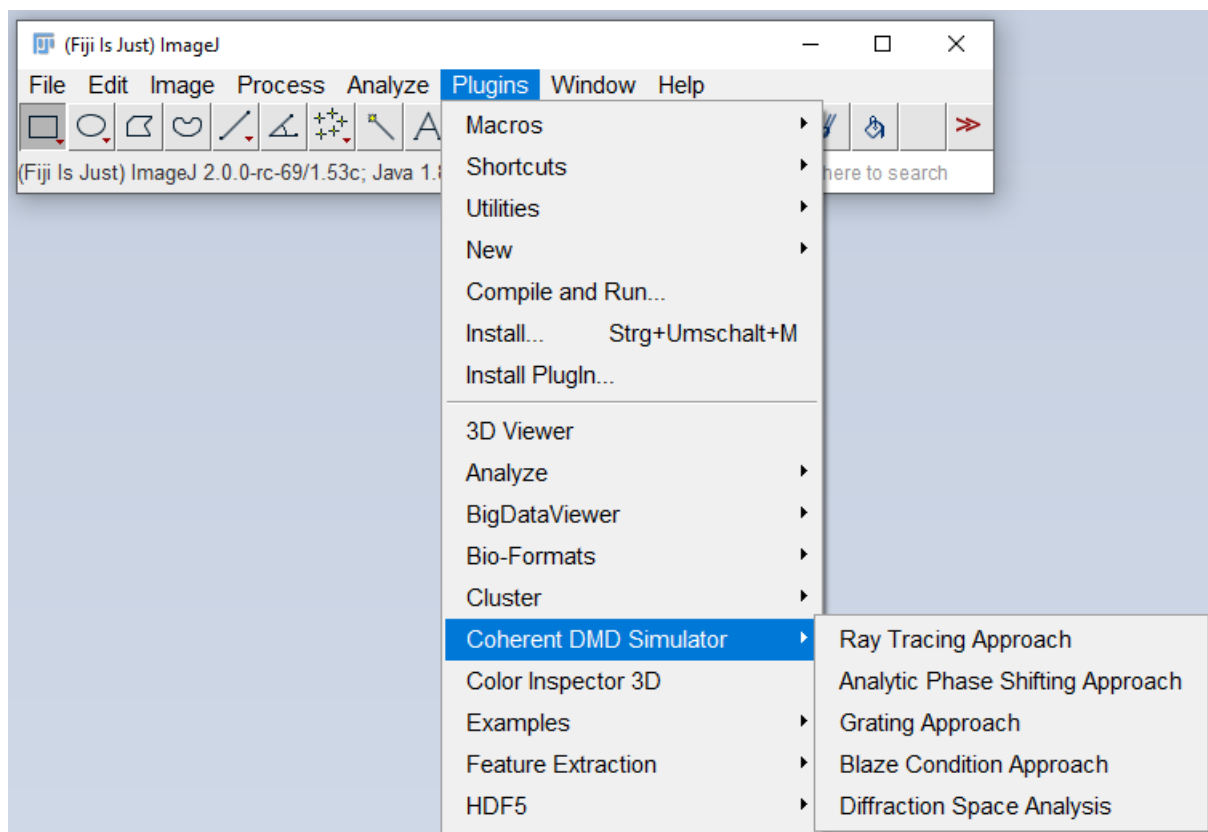


Figure 1

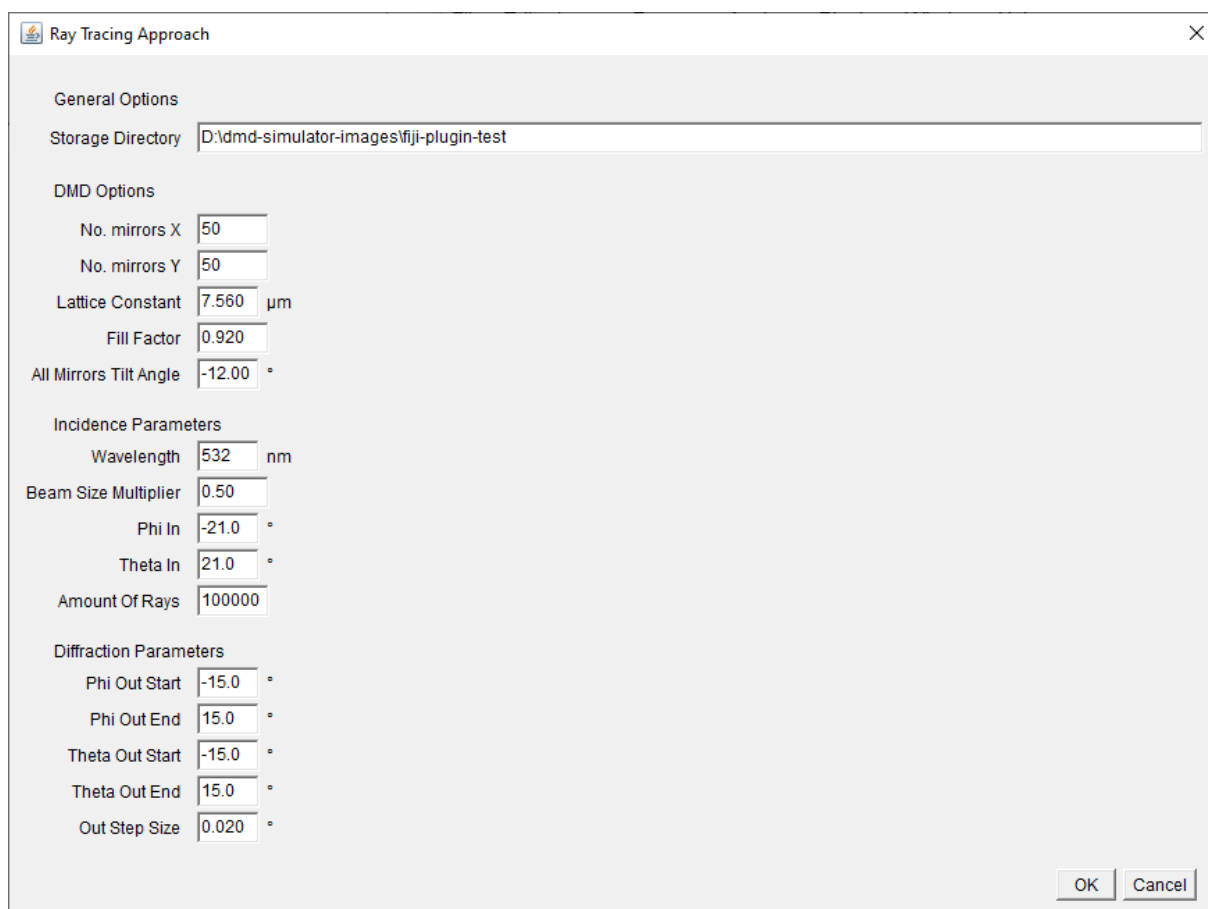


Figure 2

Analytic Phase Shifting Approach

General Options

Storage Directory

DMD Options

No. mirrors X

No. mirrors Y

Lattice Constant μm

Fill Factor

Mirror Tilt Angle $^\circ$

Tilt State Image (*.bmp)

Incidence Parameters

Wavelength nm

Beam Size Multiplier

Phi In $^\circ$

Theta In $^\circ$

Diffraction Parameters

Phi Out Start $^\circ$

Phi Out End $^\circ$

Theta Out Start $^\circ$

Theta Out End $^\circ$

Out Step Size $^\circ$

OK Cancel

Figure 3

Grating Approach [X]

General Options

Storage Directory: D:\dmd-simulator-images\ffji-plugin-test

DMD Options

No. mirrors X: 50

No. mirrors Y: 50

Lattice Constant: 7.560 μm

Fill Factor: 0.920

All Mirrors Tilt Angle: -12.00 °

Incidence Parameters

Wavelength: 532 nm

Beam Size Multiplier: 0.50

Phi In Start: -60.0 °

Phi In End: 60.0 °

Theta In Start: -60.0 °

Theta In End: 60.0 °

In Step Size: 0.2 °

Diffraction Parameters

Phi Out Start: -80.0 °

Phi Out End: 80.0 °

Theta Out Start: -80.0 °

Theta Out End: 80.0 °

Out Step Size: 0.100 °

OK Cancel

Figure 4

Blaze Condition Approach [X]

General Options

Storage Directory: D:\dmd-simulator-images\ffji-plugin-test

DMD Options

Lattice Constant: 7.560 μm

All Mirrors Tilt Angle: -12.00 °

Incidence Parameters

Wavelength Start: 400 nm

Wavelength End: 700 nm

Alpha In Start: -90.0 °

Alpha In End: 90.0 °

In Step Size: 0.2 °

OK Cancel

Figure 5

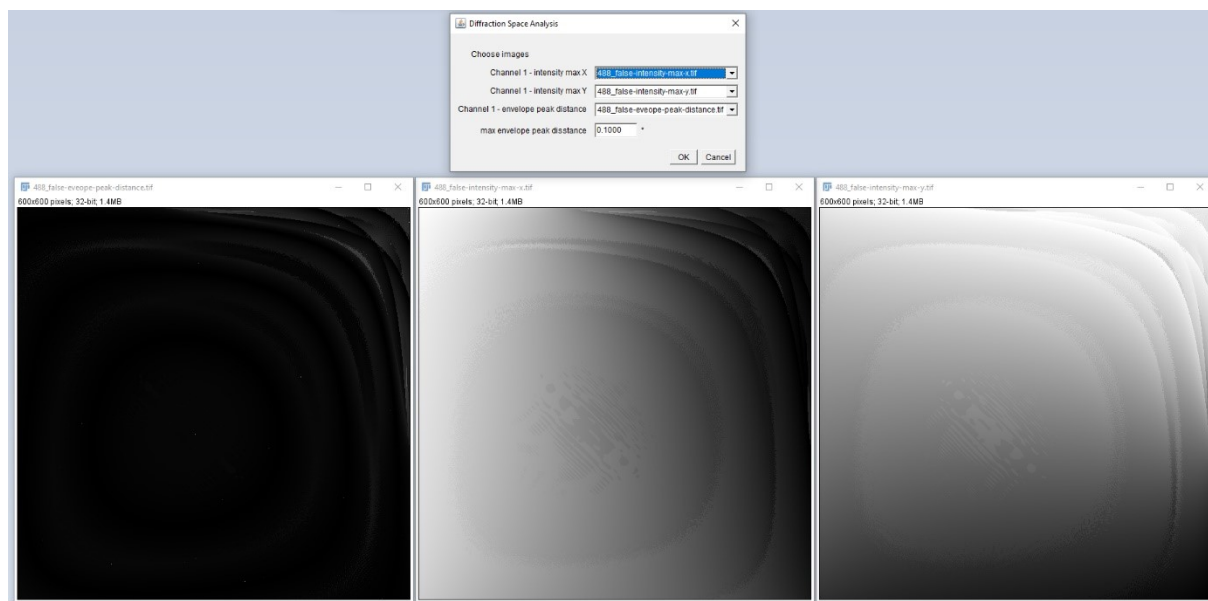


Figure 6

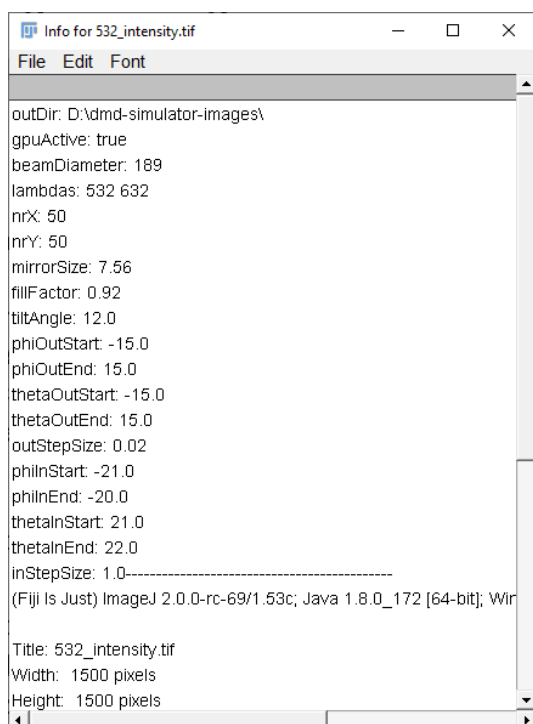


Figure 7