DLIP system optical modelling using ZEMAX OpticStudio software

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General description

In the last few years there is growing interest in utilizing Direct Laser Interference Patterning (DLIP) for surface structuring with high power short pulse lasers. As Holo/Or is a major supplier of the high power diffractive optical elements (DOEs) used in many DLIP systems, we felt the need for system integration support from our customers in this field.
As a part of our unwavering commitment to our customers support, we share an in-house developed Zemax OpticStudio design file of the DLIP optical system.

Our model allows one to simulate nominal performance as well as tolerances. It can be easily customized for any optical parameters such as wavelength, beam size, splitting angles, number of orders, focal length, etc.

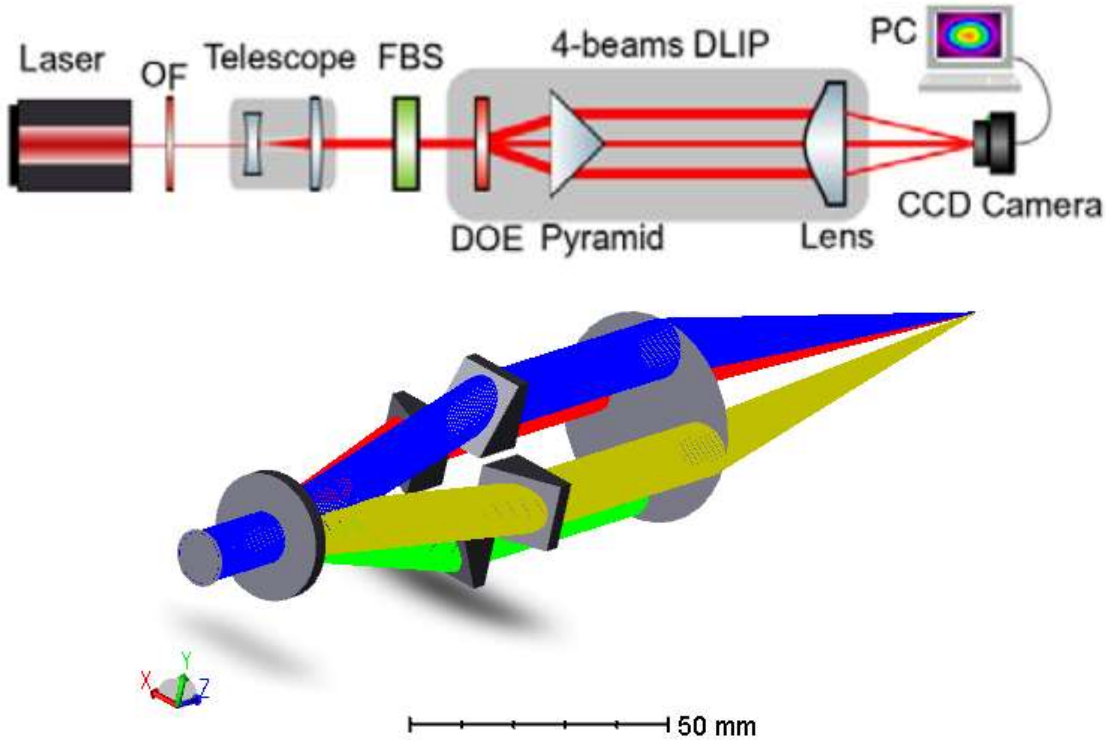
We hope that this tutorial will help professionals developing DLIP systems to better model their system and explore technical issues, including integration of our DOEs into their system.

You are welcome to download the source file from the link placed at the bottom of the document.

Detailed description of the simulation model

The file includes a four beam interference system with a Top Hat beam shaper as described in the reference[1]. In figure 1.a. the system layout from the reference is shown and in figure 1.b. a 3D layout of a similar system simulated using Zemax OpticStudio. Simulation parameters are:

- Wavelength 1053 nm
- Input beam 4mm
- Angular Diffractive square Top Hat beam shaper with an image size of 1x1mRad
- A Diffractive Beam Splitter 2x2 beams with period 4 um
- Collimating prism with four zones. The prism placed 55 mm after the beam splitter
- Ideal focusing lens with EFL 100 mm



a

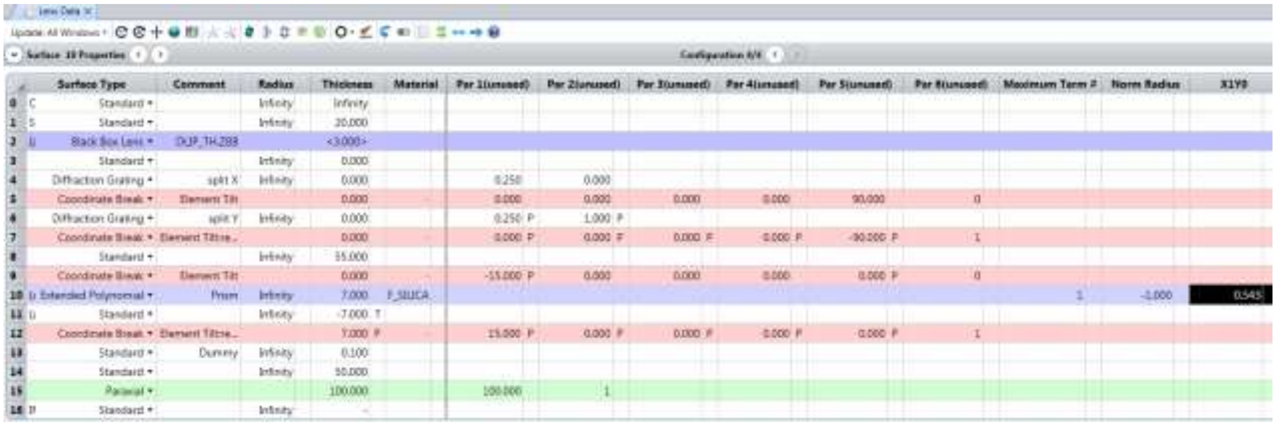
b

Figure 1. a – Layout of DLIP setup from the reference article 1. b – 3D layout from the simulation file.

The file was prepared in sequential mode, which has certain advantages in analysis methods for coherent systems.

In figure 2. we show the Lens Data window. In line 2 we placed a Top Hat beam shaper BlackBox file, followed by two orthogonal Diffraction Grating surfaces that model a 2x2 beams beam splitter. More details about modeling Diffractive Beam Splitter can be found in our tutorial[2].

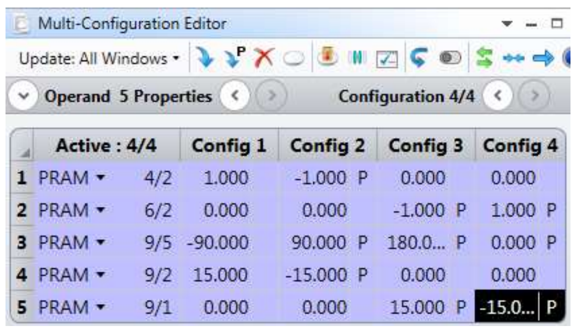
Surfaces 10 and 11 construct a single prism placed with a coordinate break to collimate the split beams. Coordinate break with Z axis rotation and shift for X and Y Axis so that the prism always collimates the rays coming out of the diffraction grating.



	Surface Type	Comment	Radius	Thickness	Material	Par 1(unused)	Par 2(unused)	Par 3(unused)	Par 4(unused)	Par 5(unused)	Par 6(unused)	Maximum Term #	Norm Radius	X1Y0
0 C	Standard ▾		Infinity	Infinity										
1 S	Standard ▾		Infinity	20.000										
2	Black Box Lens ▾	DLP_TH.ZBB		<3.000>										
3	Standard ▾		Infinity	0.000										
4	Diffraction Grating ▾	split X	Infinity	0.000		0.250	0.000							
5	Coordinate Break ▾	Element Tilt		0.000		0.000	0.000	0.000	0.000	90.000	0			
6	Diffraction Grating ▾	split Y	Infinity	0.000		0.250 P	1.000 P							
7	Coordinate Break ▾	Element Tiltre...		0.000		0.000 P	0.000 P	0.000 P	0.000 P	-90.000 P	1			
8	Standard ▾		Infinity	35.000										
9	Coordinate Break ▾	Element Tilt		0.000		-15.000 P	0.000	0.000	0.000	0.000 P	0			
10	Extended Polynomial ▾	Prism	Infinity	7.000	F_SILICA							1	-1.000	0.545
11	Standard ▾		Infinity	-7.000 T										
12	Coordinate Break ▾	Element Tiltre...		7.000 P		15.000 P	0.000 P	0.000 P	0.000 P	0.000 P	1			
13	Standard ▾	Dummy	Infinity	0.100										
14	Standard ▾		Infinity	50.000										
15	Paraxial ▾			100.000		100.000	1							
16 I	Standard ▾		Infinity	-										

Figure 2. print screen of Lens Data from the model

Each of four split beams has an individual configuration that can be seen in the Multi-configuration editor in figure 3. Diffractive order numbers, Z rotation angle and X or Y shift of prism of Coordinate Break are defined as the parameters.

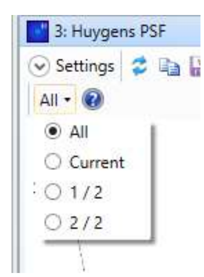


	Active : 4/4		Config 1	Config 2	Config 3	Config 4
1	PRAM ▾	4/2	1.000	-1.000 P	0.000	0.000
2	PRAM ▾	6/2	0.000	0.000	-1.000 P	1.000 P
3	PRAM ▾	9/5	-90.000	90.000 P	180.0... P	0.000 P
4	PRAM ▾	9/2	15.000	-15.000 P	0.000	0.000
5	PRAM ▾	9/1	0.000	0.000	15.000 P	-15.0... P

Figure3. Print screen of the Multi-configuration Editor.

Analysis

Huygens PSF was chosen for analysis as it is a more universal method. To see the interference, choose in the properties of the Huygens PSF the option to show all configurations together.



In figure 4 left we show the real intensity results from the reference article vs our model of a similar system.

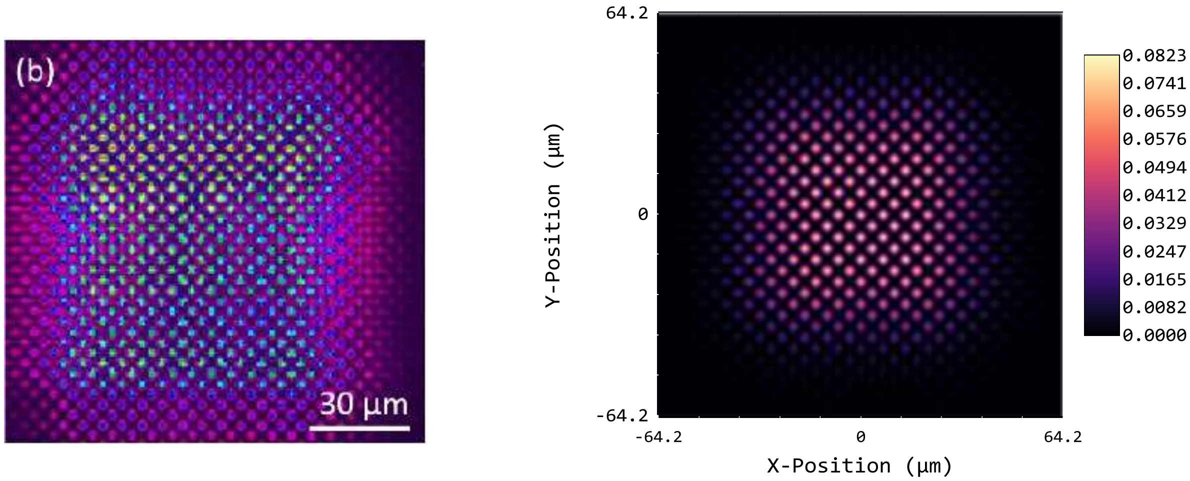


Figure 4. Left – Intensity distribution in focal plane published in the article. Right – Intensity result of our simulation model.

Summary

Holo/Or has developed an effective simulation tool for a DLIP system. You are welcome to Contact Us for more details, help in design, and an offer for the various DOE components in the DLIP setup you design.

[Download link to DLIP simulation]

References

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[1] El-Khoury, Mikhael & Voisiat, Bogdan & Kunze, Tim & Lasagni, Andrés. (2018). Utilizing Fundamental Beam-Mode Shaping Technique for Top-Hat La-ser Intensities in Direct Laser Interference Patterning. Journal of Laser Micro Nanoengineering. 13. 268-272. 10.2961/jlmn.2018.03.0021.

[2] Beam Splitter in Zemax tutorial

More articles for DLIP (you are welcome to send us your article, and we will add it to the list)

Charipar, Nicholas, et al. "Hierarchical laser patterning of indium tin oxide thin films." *Optical Materials Express* 9.7 (2019): 3035-3045.

Garliauskas, Mantas, Evaldas Stankevičius, and Gediminas Račiukaitis. "Laser intensity-based geometry control of periodic submicron polymer structures fabricated by laser interference lithography." *Optical Materials Express* 7.1 (2017): 179-184.

Stankevičius, Evaldas, Elena Daugnoraitė, and Gediminas Račiukaitis. "Mechanism of pillars formation using four-beam interference lithography." *Optics and Lasers in Engineering* 116 (2019): 41-46.

Nakata, Yoshiki, Masataka Yoshida, and Noriaki Miyanaga. "Parallel fabrication of spiral surface structures by interference pattern of circularly polarized beams." *Scientific reports* 8.1 (2018): 1-9.

Teutoburg-Weiss, Sascha, et al. "Development of a Monitoring Strategy for Laser-Textured Metallic Surfaces Using a Diffractive Approach." *Materials* 13.1 (2020): 53.

Knorr, Fabian, et al. "Large-angle programmable direct laser interference patterning with ultrafast laser using spatial light modulator." *Physics Procedia* 83 (2016): 1170-1177.

Fu, Yangxi, et al. "Picosecond Laser Interference Patterning of Periodical Micro-Architectures on Metallic Molds for Hot Embossing." *Materials* 12.20 (2019): 3409.

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Aguilar-Morales, Alfredo I., Sabri Alamri, and Andrés Fabián Lasagni. "Micro-fabrication of high aspect ratio periodic structures on stainless steel by picosecond direct laser interference patterning." *Journal of Materials Processing Technology* 252 (2018): 313-321.

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Voisiat, Bogdan, et al. "Development of an Analytical Model for Optimization of Direct Laser Interference Patterning." *Materials* 13.1 (2020): 200.

Milles, S., et al. "Influence of roughness achieved by periodic structures on the wettability of aluminum using direct laser writing and direct laser interference patterning technology." *Journal of Materials Processing Technology* 270 (2019): 142-151.

Cardoso, J. T., et al. "Superhydrophobicity on hierarchical periodic surface structures fabricated via direct laser writing and direct laser interference patterning on an aluminium alloy." *Optics and Lasers in Engineering* 111 (2018): 193-200.