# Base models in YieldStar optics

Ang Chen[1]

[1] *MZ optoelectronics, Shanghai, China*[*]

In this note, we review the thesis [1], which systematically introduces the theories and methods of diffraction-based overlay (DBO) used in semiconductor manufacturing.

## I. Introduction

### I.1. Test

## A. Fourier transformation of an image

When computing the two-dimensional (2D) Fourier transform (FT) of an image, the output represents the frequency components of the in the spatial frequency domain. Now let's determine the frequency range associated with the Fourier transform, based on the dimension of the image with both pixel pixels ($N_x$ pixels$\times N_y$ pixels) and actual physical sizes ($L_x$ nm$\times L_y$ nm). Here, the unit can be any length unit, and we just make nm as an example: If using nm, the unit of spatial frequency domain would be nm$^{-1}$.

The pixel spacing in each dimension given by the ratio of the physical size to the numbers of pixels:

$$\Delta_x = \frac{L_x}{N_x},\ \Delta_y = \frac{L_y}{N_y}. \tag{A1}$$

When an image is applied with FT, its spatial frequency range is determined by the *Nyquist sampling theorem*, which states that the sampling frequency should be no less than the maximum frequency times by 2, leading to

$$f_{x,\max} = \frac{f_{x,\mathrm{samp}}}{2} = \frac{1}{2\Delta_x} = \frac{N_x}{2L_x}, \tag{A2a}$$

$$f_{y,\max} = \frac{f_{y,\mathrm{samp}}}{2} = \frac{1}{2\Delta_y} = \frac{N_y}{2L_y}. \tag{A2b}$$

The frequency bins (in cycles per nanometer) in $x$ and $y$ directions are spaced by:

$$\Delta f_x = \frac{1}{L_x},\ \Delta f_y = \frac{1}{L_y}, \tag{A3}$$

and thus the frequency components in the Fourier transform will range from $[-\frac{N_x}{2L_x}, \frac{N_x}{2L_x}]$ and $[-\frac{N_y}{2L_y}, \frac{N_y}{2L_y}]$.

We give an example with FFT in MATLAB, as shown in Fig.

[1] Daan Swinkels. *Spectral shaping for the next-generation overlay metrology.* Student thesis: Master, 2021.

* chenang@outlook.com

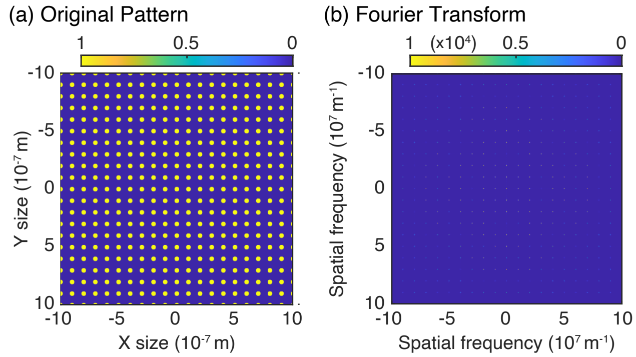
(a) Original Pattern
1
0.5
0
-10
-5
0
5
10
Y size (10-7 m)
-10
-5
0
5
10
X size (10-7 m)
(b) Fourier Transform
1
(x10⁴)
0.5
0
-10
-5
0
5
10
Spatial frequency (10⁷ m-1)
-10
-5
0
5
10
Spatial frequency (10⁷ m-1)

FIG. 1.