

# Wave optics-based surface encoder

JPPN 2005-321241, JPPN 2006-010645

## Background

Multi-degree-of-freedom (MDOF) measurement system

Surface encoder ( 2D slope sensor + 2D angle grid )

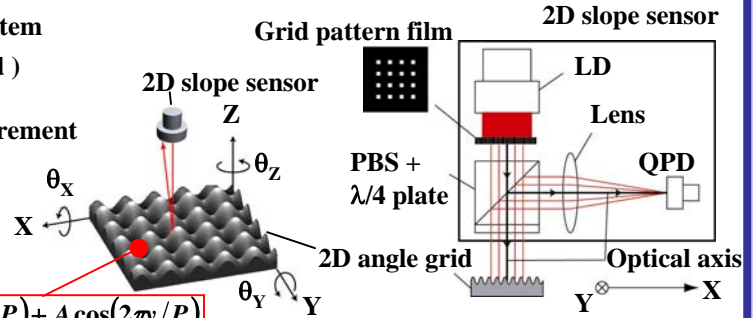
Geometric optics-based design

Advantages : Simple construction, MDOF measurement

Motivation: Wave optics-based design for improving the accuracy and resolution of encoder

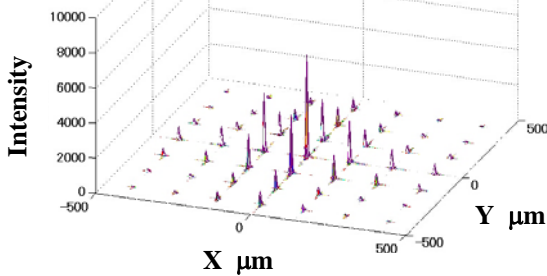
Wave optical analysis

$$h(x, y) = A \cos(2\pi x/P) + A \cos(2\pi y/P)$$



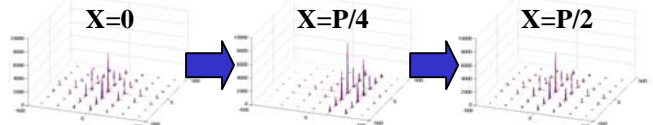
## Wave Optical Analysis

Intensity distribution of the spot on the QPD  
→ Peaks within a certain period



① X (Y) directional displacement

→ Amplitude of the peaks change in the X (Y) direction



② θ<sub>x</sub> (θ<sub>y</sub>) tilt motion

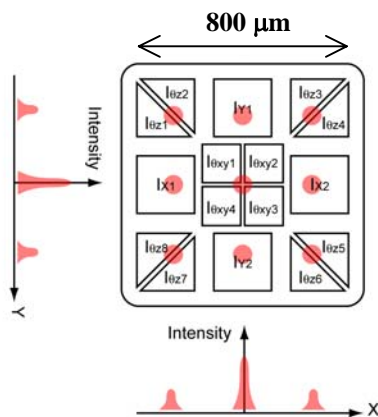
→ Spot movement in the Y (X) direction according to the autocollimation method

③ θ<sub>z</sub> rotation motion

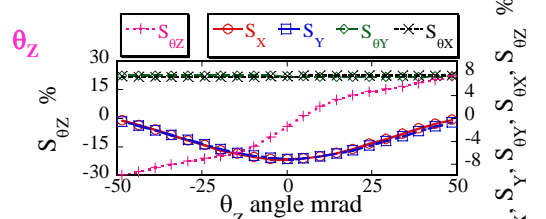
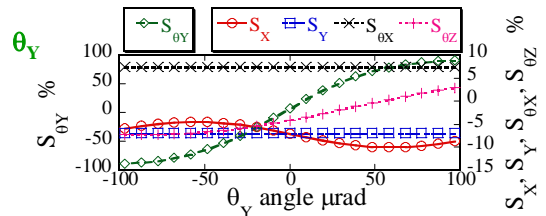
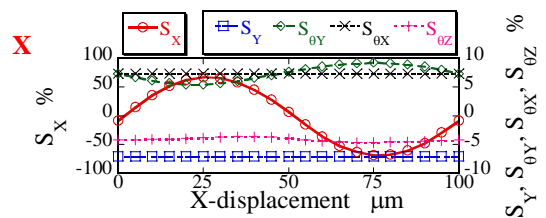
→ Spot rotation around the central peak with the same θ<sub>z</sub> angle

## 5 DOF Measurement Using a Multi-cell Photo Diode

Detecting the spot behaviors with a multi-cell photo diode instead of the QPD, 5 DOF motions are detected



< Simulation results of 5 DOF motion detection >



$$S_x = (I_{x2} - I_{x1}) / (I_{x2} + I_{x1}) \times 100\%$$

$$S_y = (I_{y2} - I_{y1}) / (I_{y2} + I_{y1}) \times 100\%$$

$$S_{\theta y} = (I_{\theta y2} + I_{\theta y3} - I_{\theta y1} - I_{\theta y4}) / (I_{\theta y1} + I_{\theta y2} + I_{\theta y3} + I_{\theta y4}) \times 100\%$$

$$S_{\theta x} = (I_{\theta x3} + I_{\theta x4} - I_{\theta x1} - I_{\theta x2}) / (I_{\theta x1} + I_{\theta x2} + I_{\theta x3} + I_{\theta x4}) \times 100\%$$

$$S_{\theta z} = \frac{(I_{\theta z2} + I_{\theta z4} + I_{\theta z6} + I_{\theta z8}) - (I_{\theta z1} + I_{\theta z3} + I_{\theta z5} + I_{\theta z7})}{(I_{\theta z1} + I_{\theta z3} + I_{\theta z5} + I_{\theta z7}) + (I_{\theta z2} + I_{\theta z4} + I_{\theta z6} + I_{\theta z8})} \times 100\%$$