Development of $XY\theta_Z$ -3DOF planar stage controller

3DOF Planar Stage

- √ **Integrative moving element**
- √ **$XY\theta_z$ -3DOF**
- √ **Planar motor**
- √ **3DOF surface encoder**

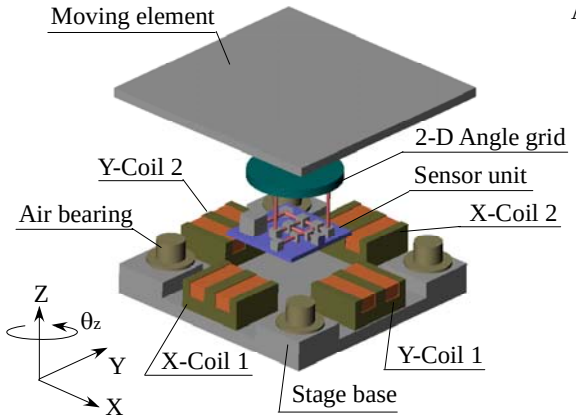

Fig.1 Schematic of stage system

Dynamics

$$M\ddot{x} = PK_f i$$

Mass $M = diag(m, m)$ Position $x = [x, y]^T$

Interrelated Array $P = \begin{bmatrix} 1 & P_x \\ P_y & 1 \end{bmatrix}$ Driven parameter s $K_f = diag(K_{f\_x}, K_{f\_y})$ Current $i = [i_x, i_y]^T$

Table1 Specifications

Item		Value	Unit
Moving element	Degree of Freedom	3 ($XY\theta_Z$)	
	Mass m	2.8	kg
	Size	260×260×8	mm
	Travel stroke	40×40	mm
Stage base	Mass	7.4	kg
	Size	250×250×15	mm
Motor amplifier	Thrust constant K_f	1.6	N/A
	Back emf constant K_{emf}	1.6	Vs/m
	Bandwidth of amplifier	1.2	kHz
Surface encoder	Measurement range (XY)	43	mm
	Resolution	20	nm
	Bandwidth	4.8	kHz

System Identification

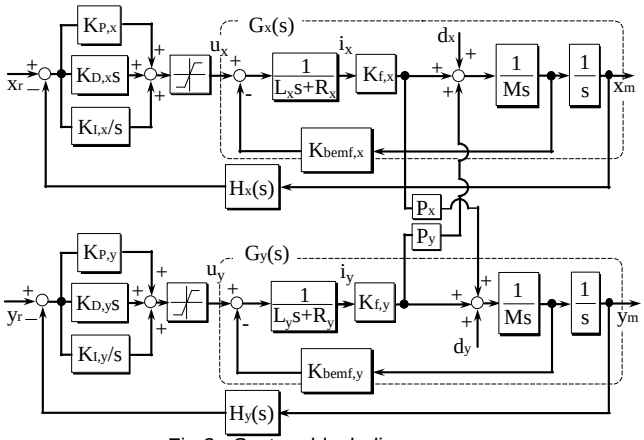

Fig.2 System block diagram

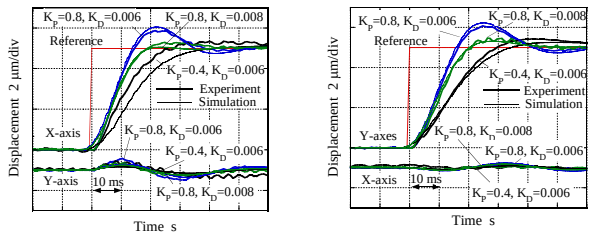

Fig.3 Step response test

Transfer function

$$G_x(s) = \frac{0.0218}{s(0.0014s^2 + 0.675s + 0.011)} \qquad G_y(s) = \frac{0.0107}{s(0.0011s^2 + 0.432s + 0.0055)}$$

Interrelated Array $P = \begin{bmatrix} 1 & 0.11 \\ 0.07 & 1 \end{bmatrix}$

Design Optimization

- ◆ PID controller design
- ◆ Noise observer
- ◆ Feedforward

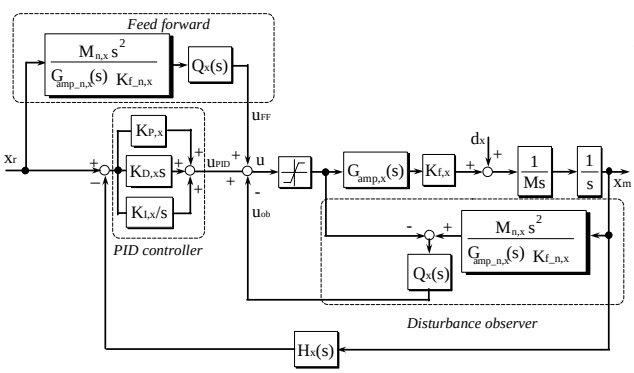

Fig. 4 Design outline of developed controller

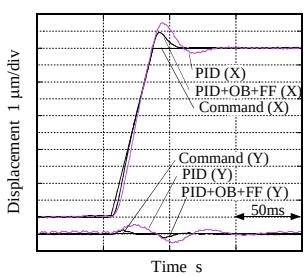

Fig.5 10 μm step responses

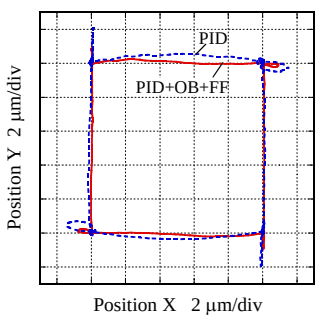

Fig.6 Square motion

- Overshoot 60% enhanced
- Influence of interference reduced
- Tracking performance of planar driven enhanced