Research Progress on
Development of an Absolute Coordinate Calibration Device for Beam Profile Monitor

Friday, 11 April 2025

윤 주 환

1. Review of the Concept

- Scintillating Screen based BPRM
- Perspective Calibration

2. Experiment Setup

- BPRM Stage scheme
- Device Order & Setting
- Device Performance Test

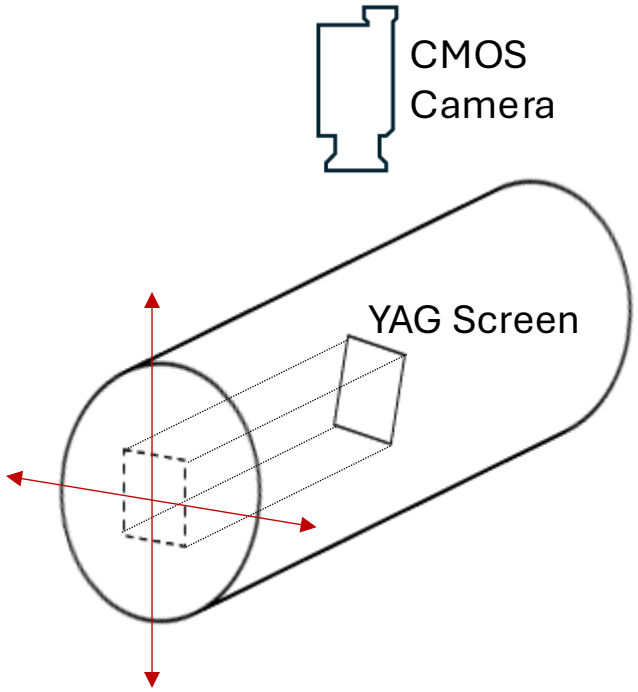
3. Experiment

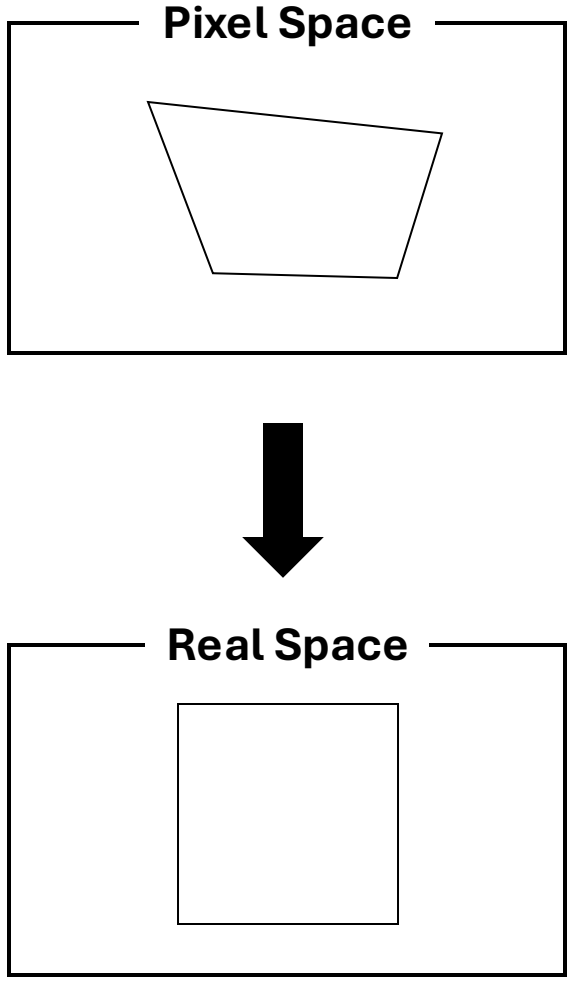
- Distorted Image Measurement
- Image Transformation into 2D Plane

4. Result Analysis

- Comparison of Original & Measured
- 1D (x, y axis) Intensity Graph Fitting
- Fitting Error

Review of the Concept





Defects of the existing BPRM

- Inclined scintillating screen
- Inaccurate position coordinates
- Resulting in distorted beam profile

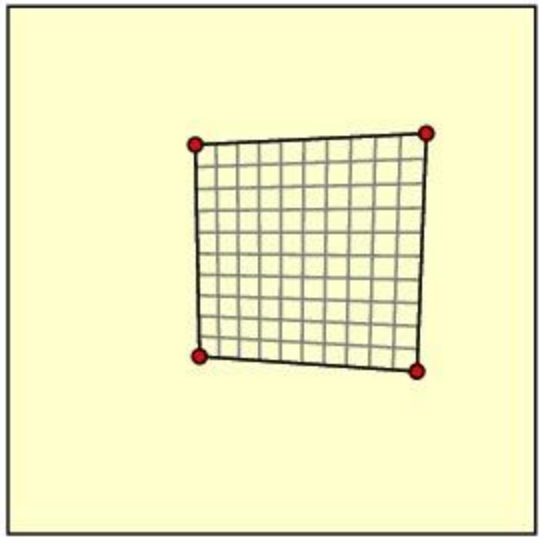
Goal of the research

- Restoring original screen space
- Identifying real beam profile

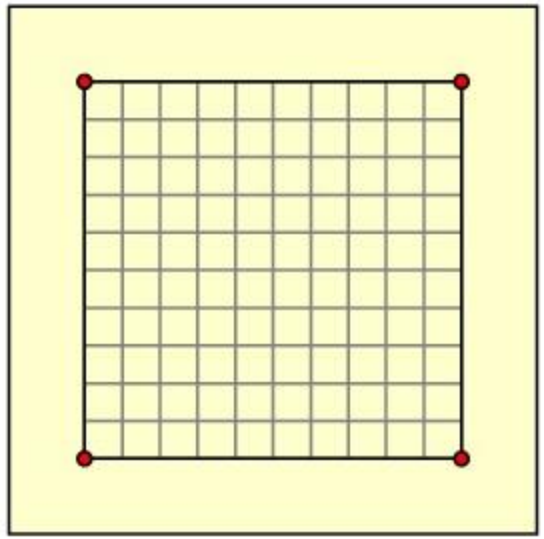
Method of image calibration

- Obtain the relationship between pixel space and real space
- Transform all coordinates

Perspective Calibration



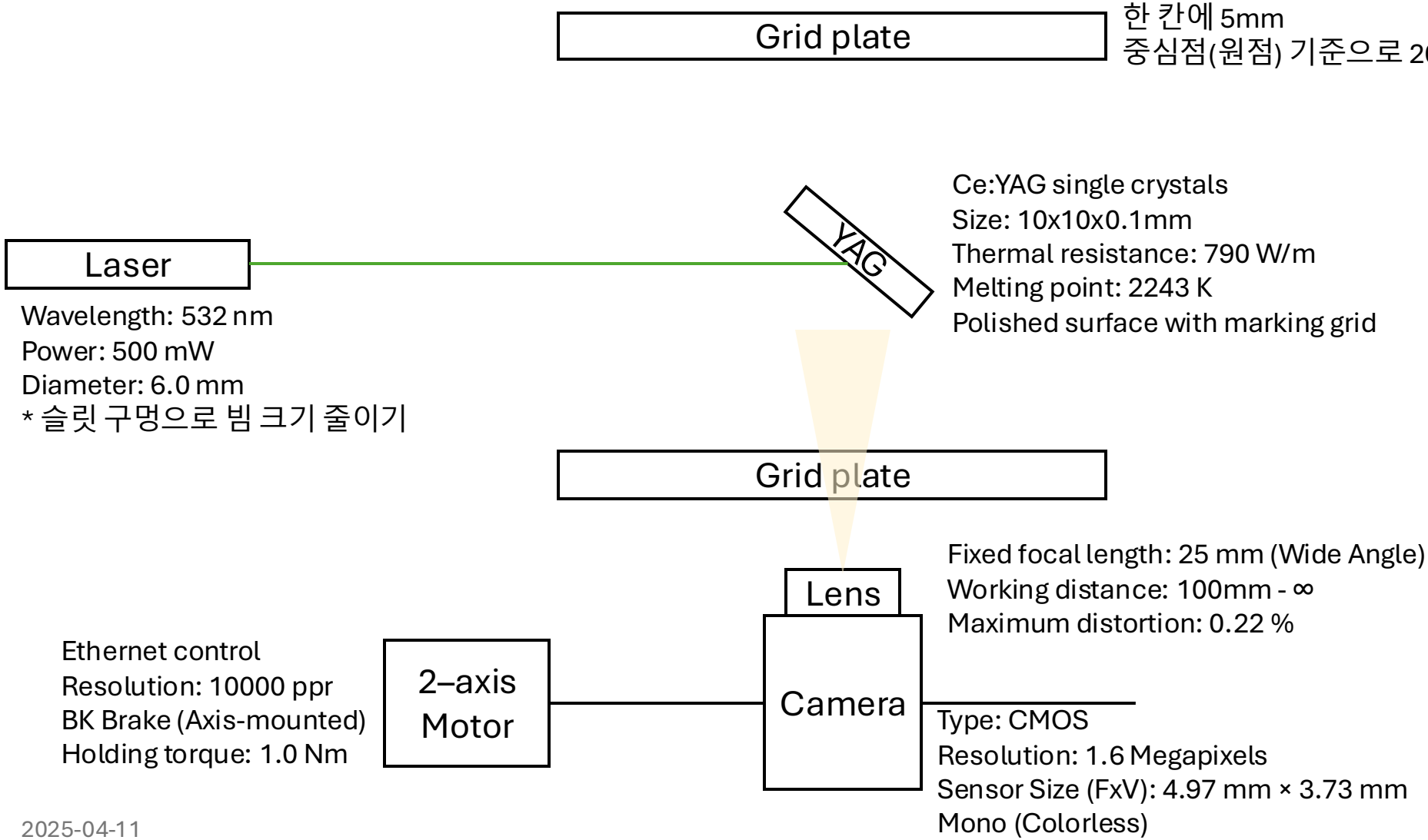
$$w_0 \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & j \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$



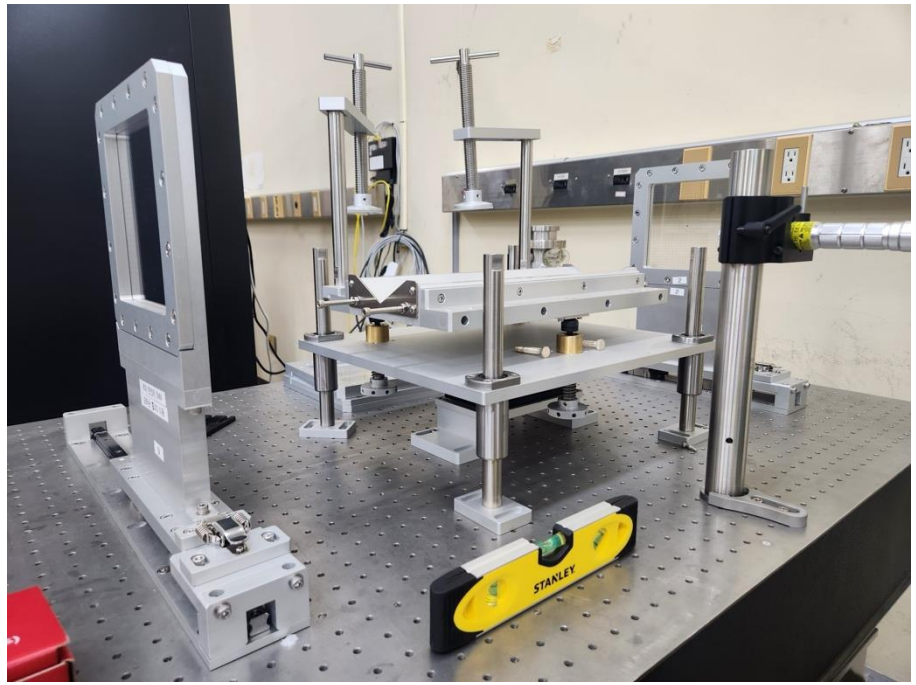
$$\begin{bmatrix} x_i & y_i & 1 & 0 & 0 & 0 & -x_i u_i & -y_i u_i & -u_i \\ 0 & 0 & 0 & x_i & y_i & 1 & -x_i v_i & -y_i v_i & -v_i \end{bmatrix} \begin{bmatrix} a \\ b \\ c \\ d \\ e \\ f \\ g \\ h \\ j \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}.$$

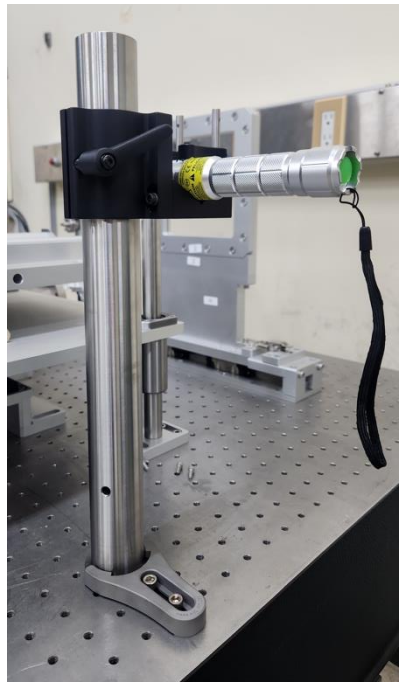
- Flattening the 3D distorted image into 2D projection space.
- Nominate 4 pairs of coordinate on both planes, to solve 3x3 matrix.

Experimental Setup



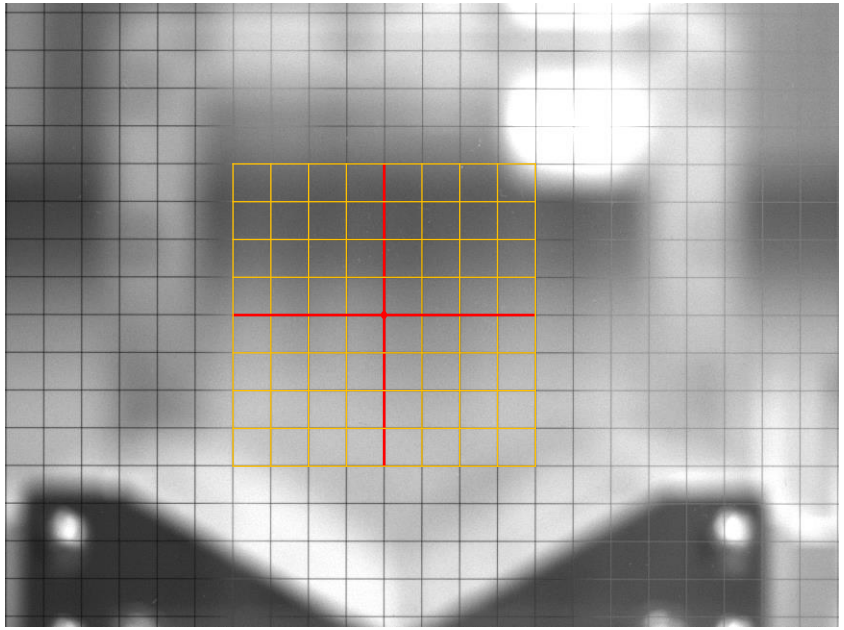
Order Laser Optics Equipment

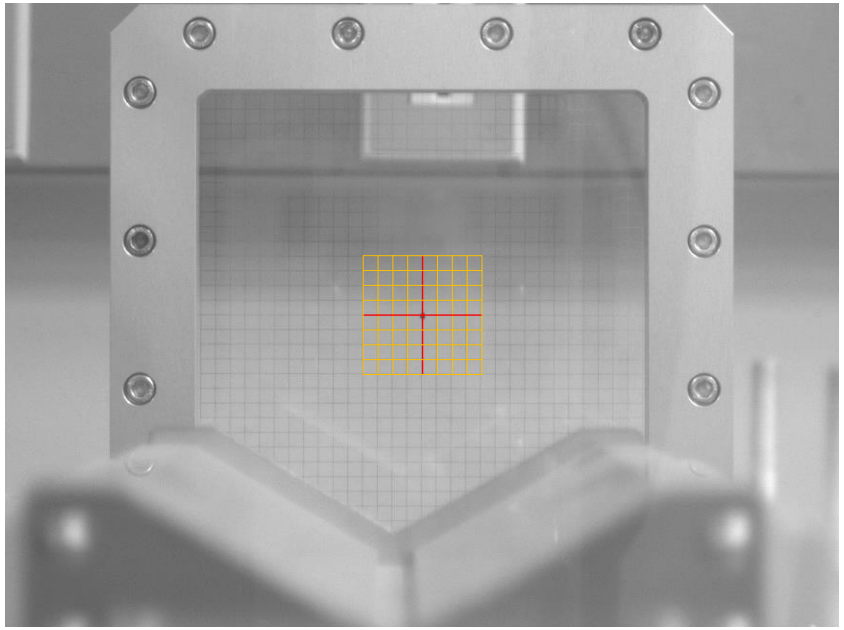




THORLABS

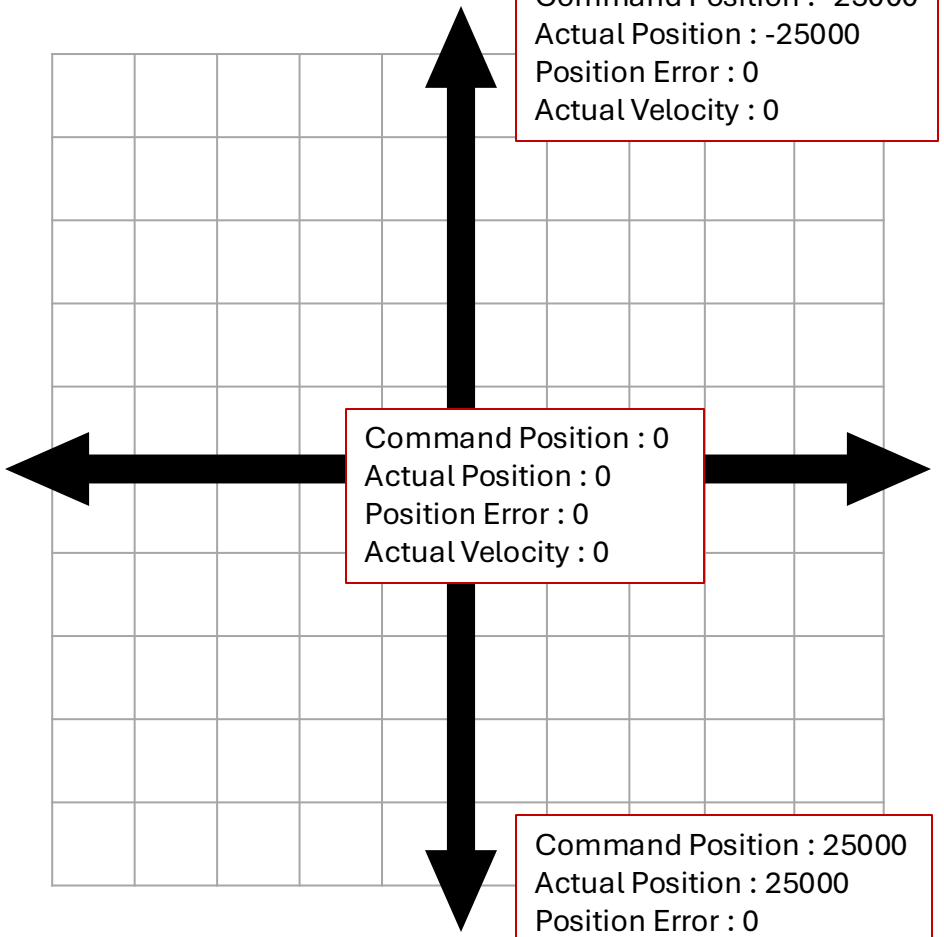
BPRM Stage Alignment





- Active area in which two glass grids are linearly parallel.
- The grid arrangement becomes more skewed towards the edge.

2-Axis Motor Repeatability



Command Position : -25000
Actual Position : -25000
Position Error : 0
Actual Velocity : 0

Command Position : 25000
Actual Position : 25000
Position Error : 0
Actual Velocity : 0

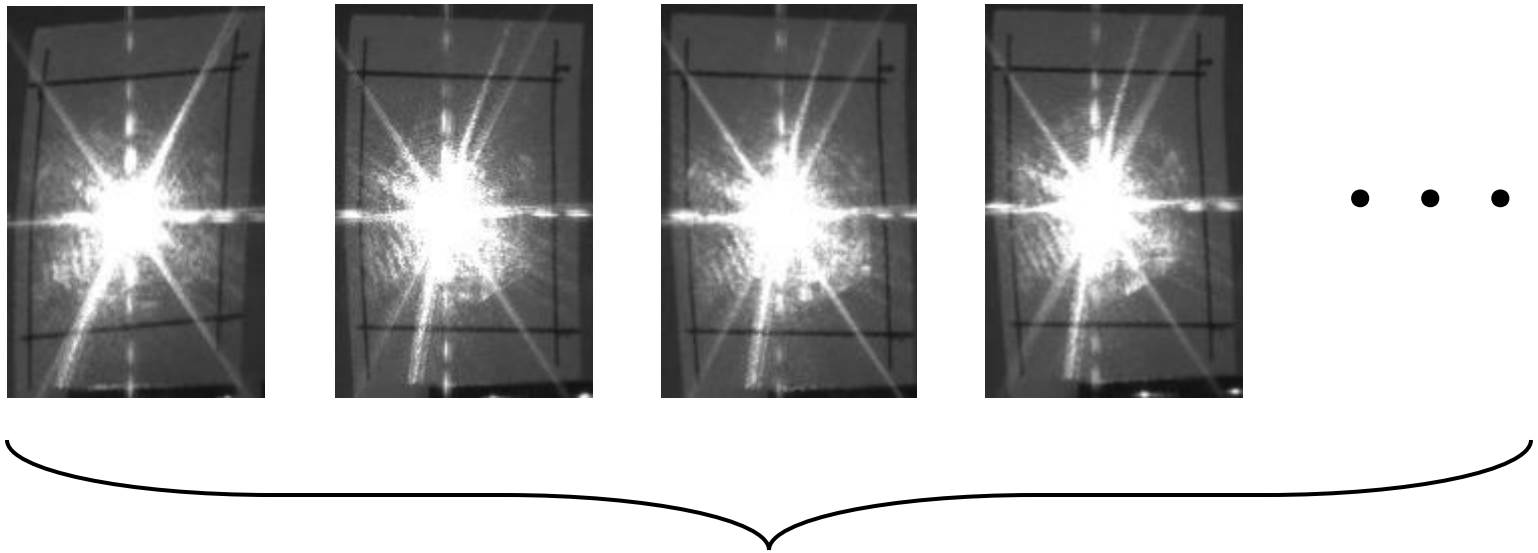
Command Position : 0
Actual Position : 0
Position Error : 0
Actual Velocity : 0

Command Position : -25000
Actual Position : -25000
Position Error : 0
Actual Velocity : 0

Command Position : 25000
Actual Position : 25000
Position Error : 0
Actual Velocity : 0

x 50 for each axis

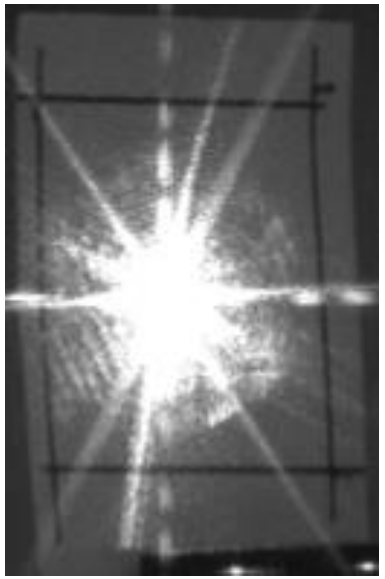
Raw Data Acquisition

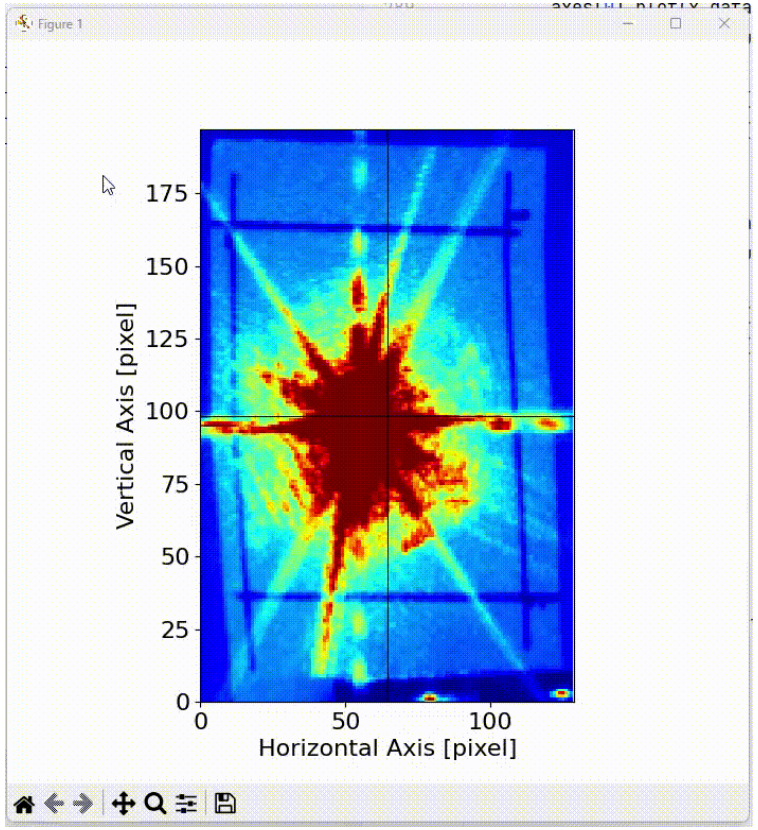


N = 10

- Collect motley samples of YAG screen images.
- Each screen has different arrangement.

Beam Profile Monitoring Method

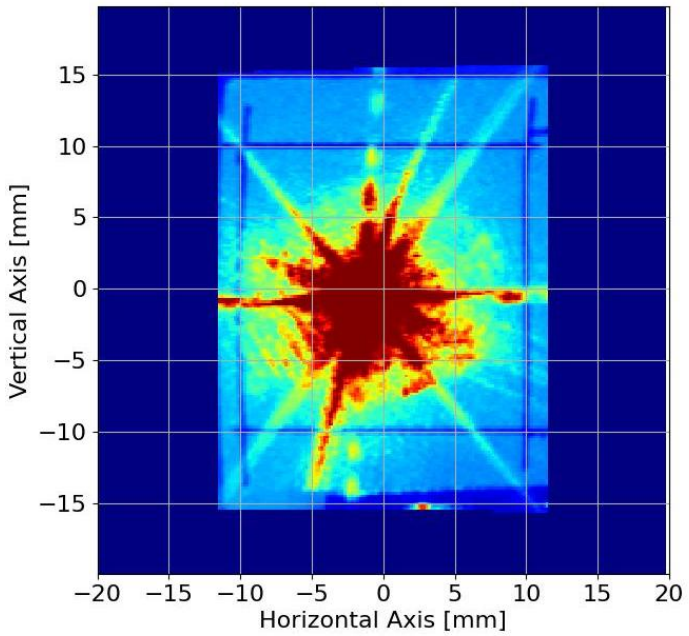


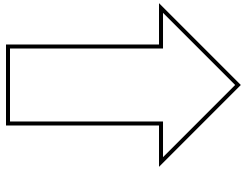


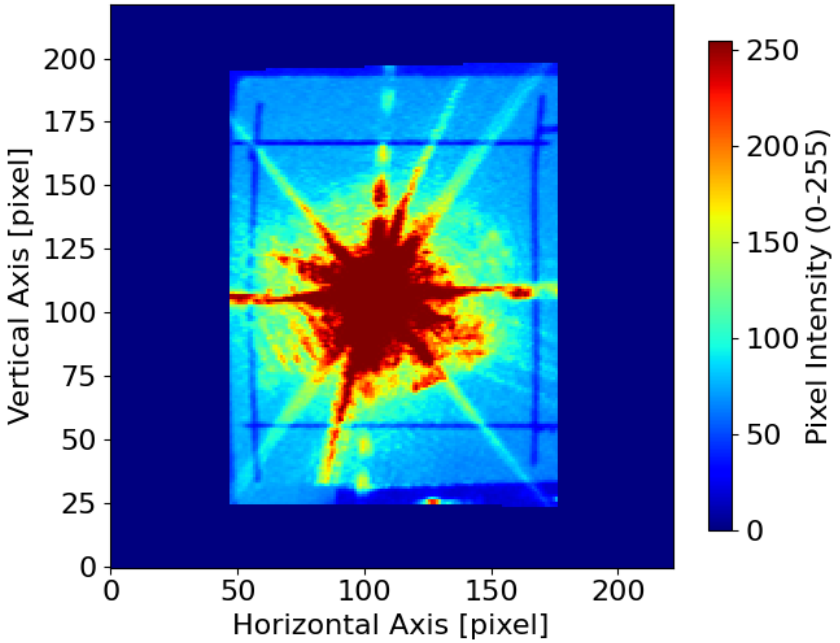

```python
# 변환 행렬 계산
def find_coeffs(pr, px):    1개의 사용 위치
    """
    pr : after transform
    px : before transform
    """
    if len(px) != 4 or len(pr) != 4:
        print('error : number of point must be 4')
        return None
    # 점이 반드시 네 개가 되어야 함

    M0 = []
    for p1, p2 in zip(pr, px):
        M0.append([p1[0], p1[1], 1.0,   0.0,   0.0, 0.0, -p2[0]*p1[0], -p2[0]*p1[1]])
        M0.append([0.0,     0.0, 0.0, p1[0], p1[1], 1.0, -p2[1]*p1[0], -p2[1]*p1[1]])

    A = np.matrix(M0, dtype=np.float64)
    B = np.array(px).reshape(8)
    res = np.dot(np.linalg.inv(A.T * A) * A.T, B)

    return np.array(res).reshape(8)
# 8개의 변환 행렬 계수
```

```python
c = Calibration( scr_pic: 'test4.JPG',  realcoord: [(-10, 10), (-10, -10), (10, -10), (10, 10)])
# 이미지 픽셀 좌표와 연결
```

Beam Profile Monitoring Method







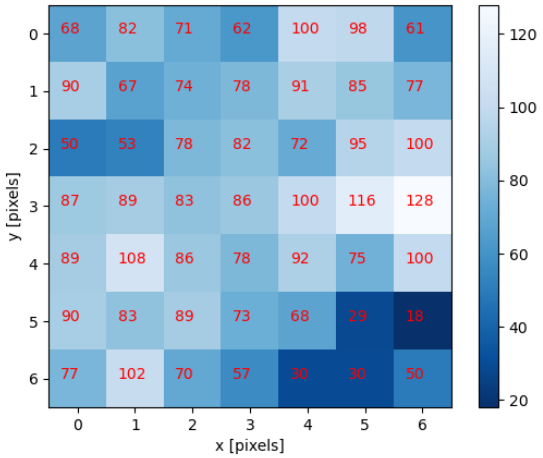
Real Space Image

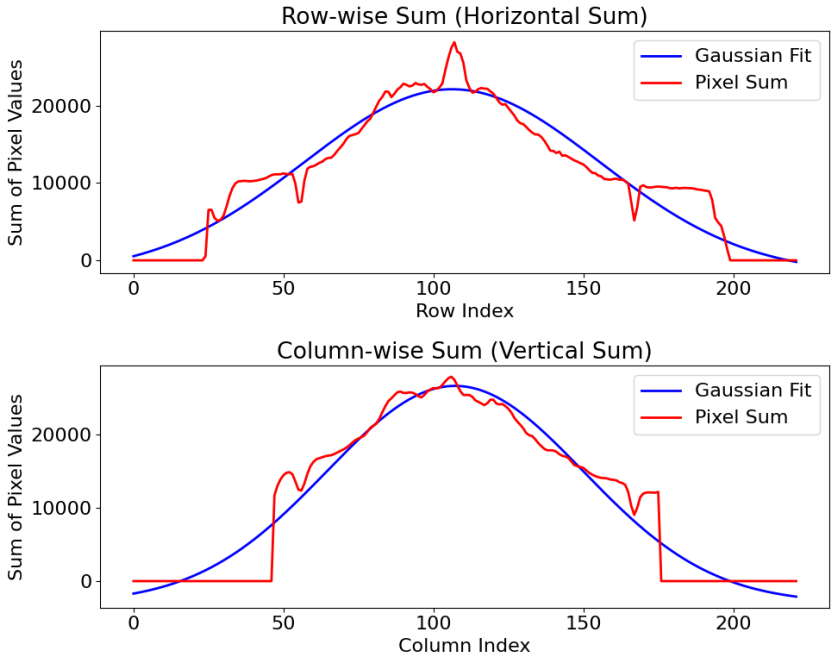
- Restored to original screen size
- Projection showing transverse beam space

Pixel Space Image

- Indicate the beam intensity
- Can be used to plot 1D graph

BPRM Measurement & Analysis





Fitting Error

- Offset (image noise)
- Blank area (Outside of the screen)

Read the raw image file

List up all pixel values of image

Sum pixel values along the axis

Plot them onto Gaussian graph

Adjust the graph fitting

Summary & Future Plan

BPRM Method

- Perspective calibration
- 2D motorized BPRM stage
- Beam profile graph fitting

Data Acquisition & Analysis

- Utilize motorized axis when collecting 4 pairs of boundary condition coordinates
- Establish the method of analyzing a set of data
- Fill out and submit the paper

THANK YOU