

# CCD Camera Calibration for POF Measurements

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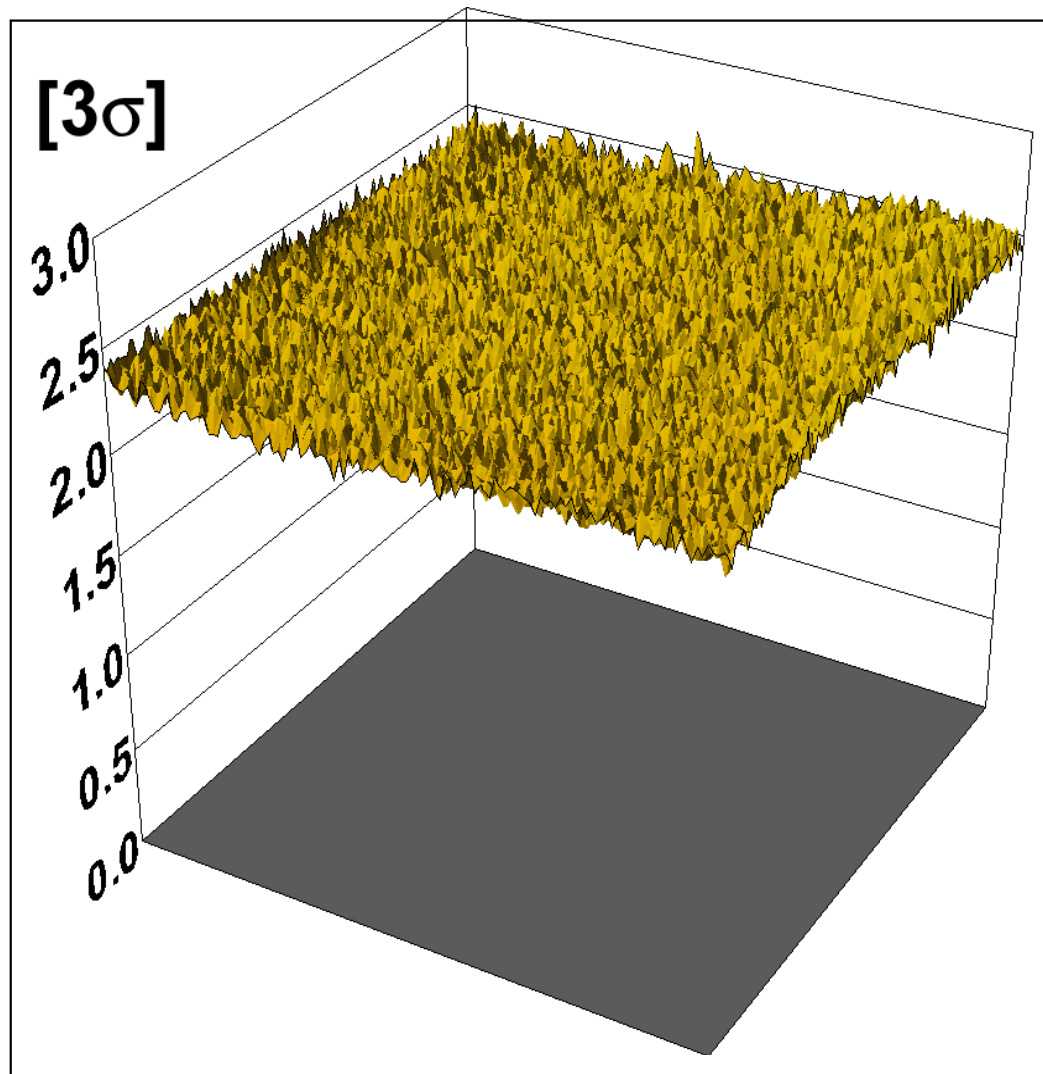
# CCD Camera Measurement Problems

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- **Random noise**
- **Dark current**
- **Non-uniform sensitivity**
- **Damaged CCD cells**
- **Too small dynamic range**

# Random Noise

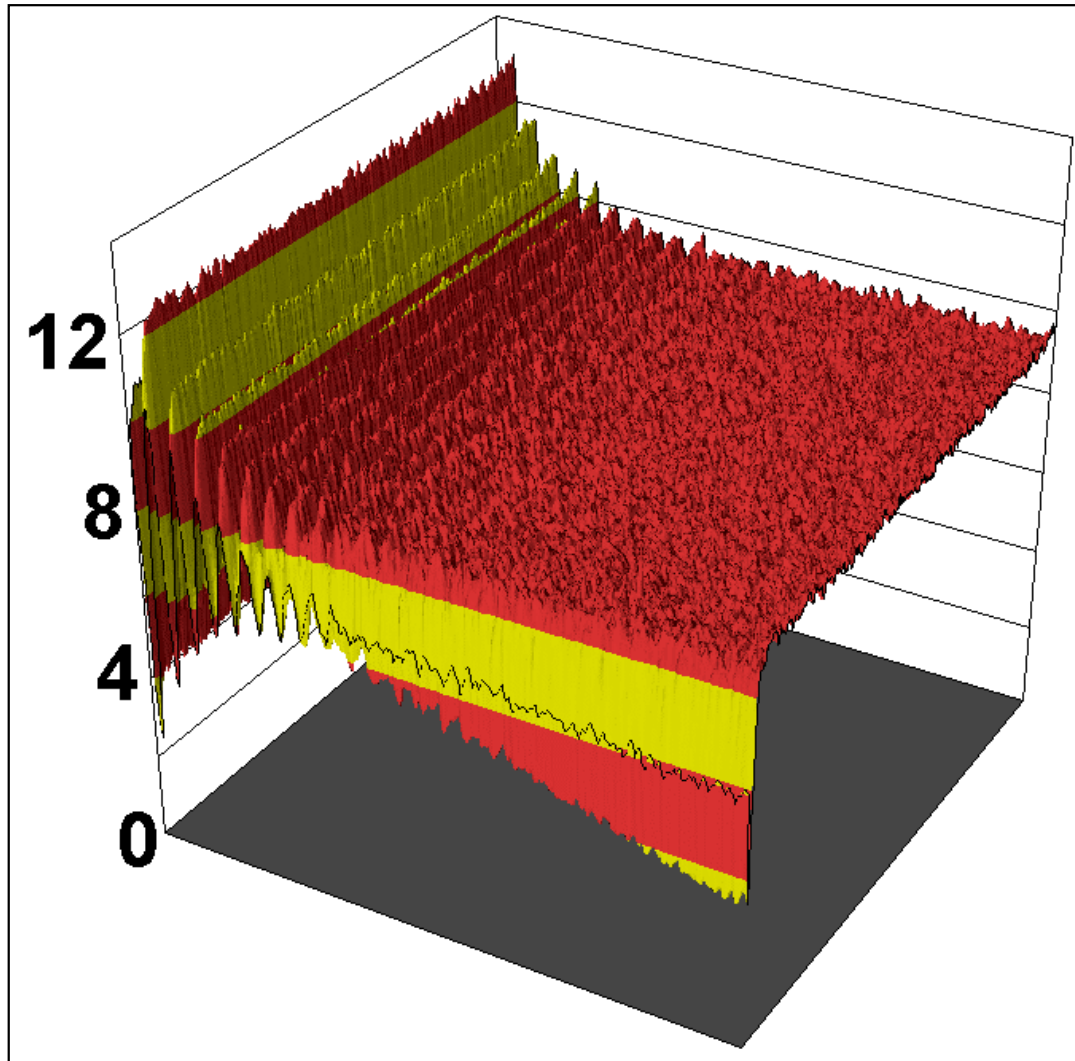
99.7% certainty level ( $3\sigma$ ) of the CCD camera's random noise.



## Notes:

- Random noise takes few further bits from camera's bit depth.
- Taking averages instead of single measurements reduces its effect.

# Black Profile

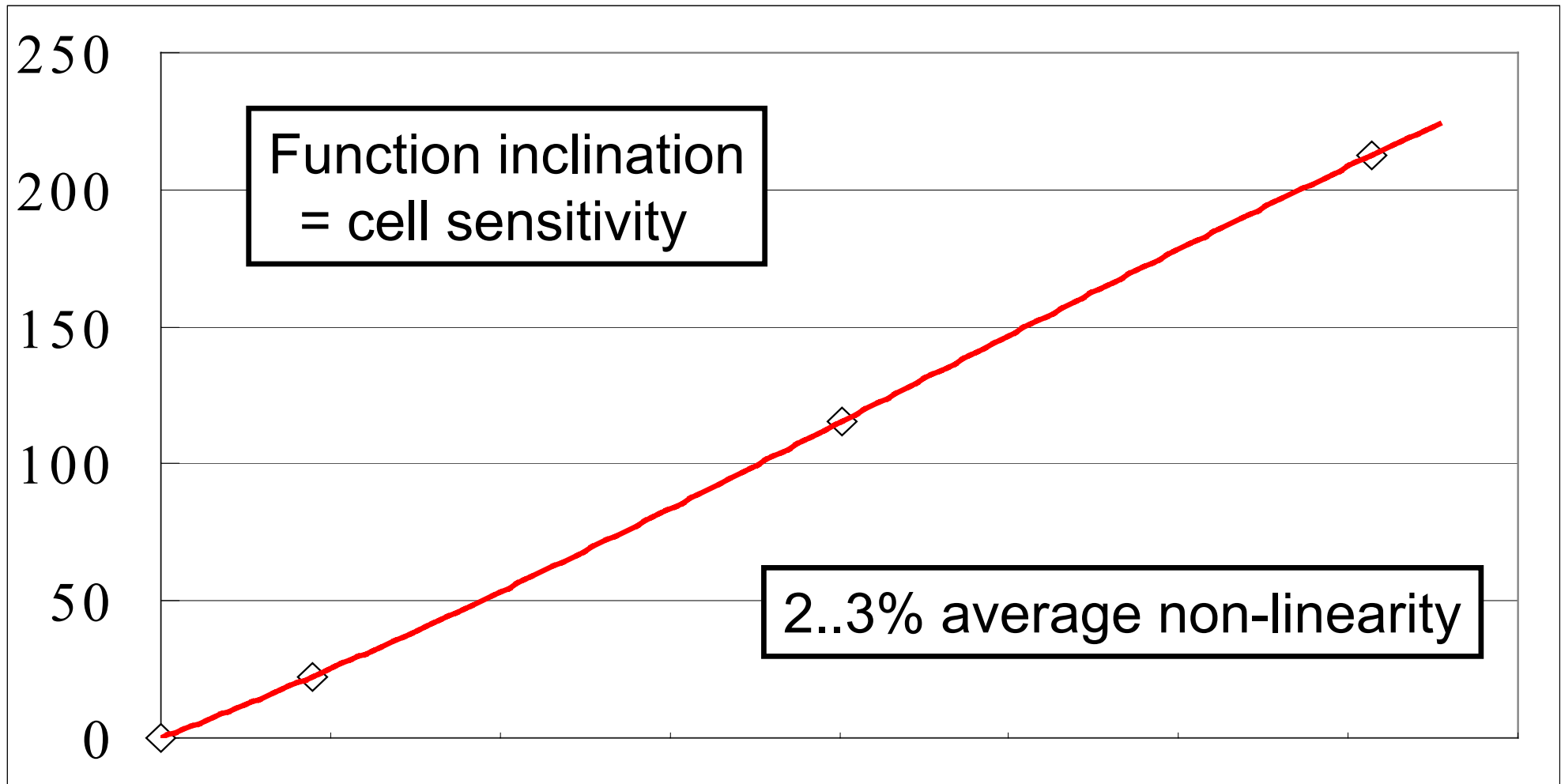


## Effects:

- CCD cells row-arrangement.
- Drop at sensor side.

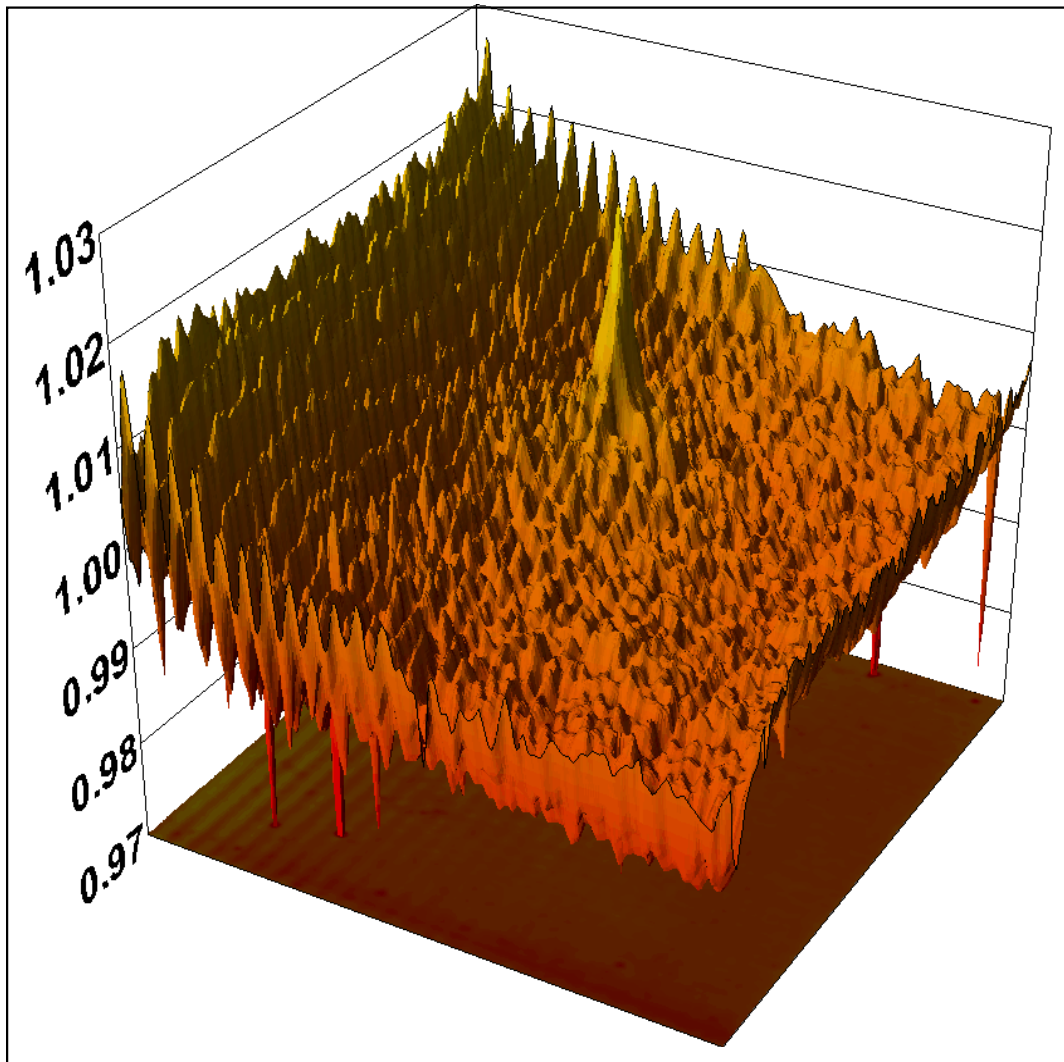
# CCD Cell Response Function

Response function of a sample CCD cell (arbitrary units).



# Non-uniform Sensitivity

Interpolated sensor sensitivity at zero lighting intensity.



Differences between cells' response functions lead to:

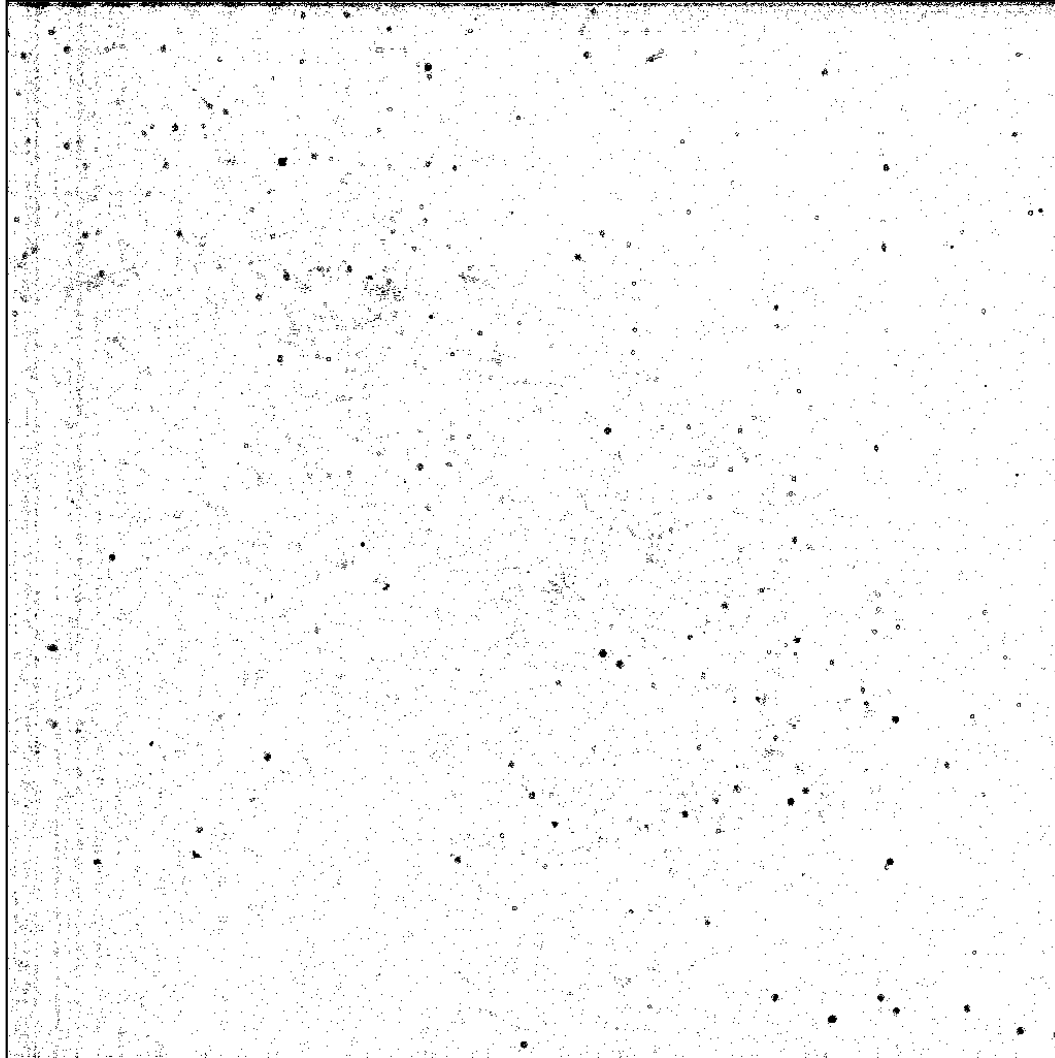
- Non-uniform sensitivity.

Non-linearity of cells' response functions lead to:

- Different sensitivity profiles at different illumination levels.

# Irregular Cells

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## Effects:

- Worse quality of sensor sides.
- CCD cells row-arrangement.
- Dust and scratches.

# Dynamic Range

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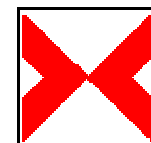
Dynamic range of most of low-end scientific cameras is 8 bit, for many of POF-measurement applications it is not enough.

## Solution:

- Make several calibrated measurements with different exposure times.
- Merge them using the least-square-error method.

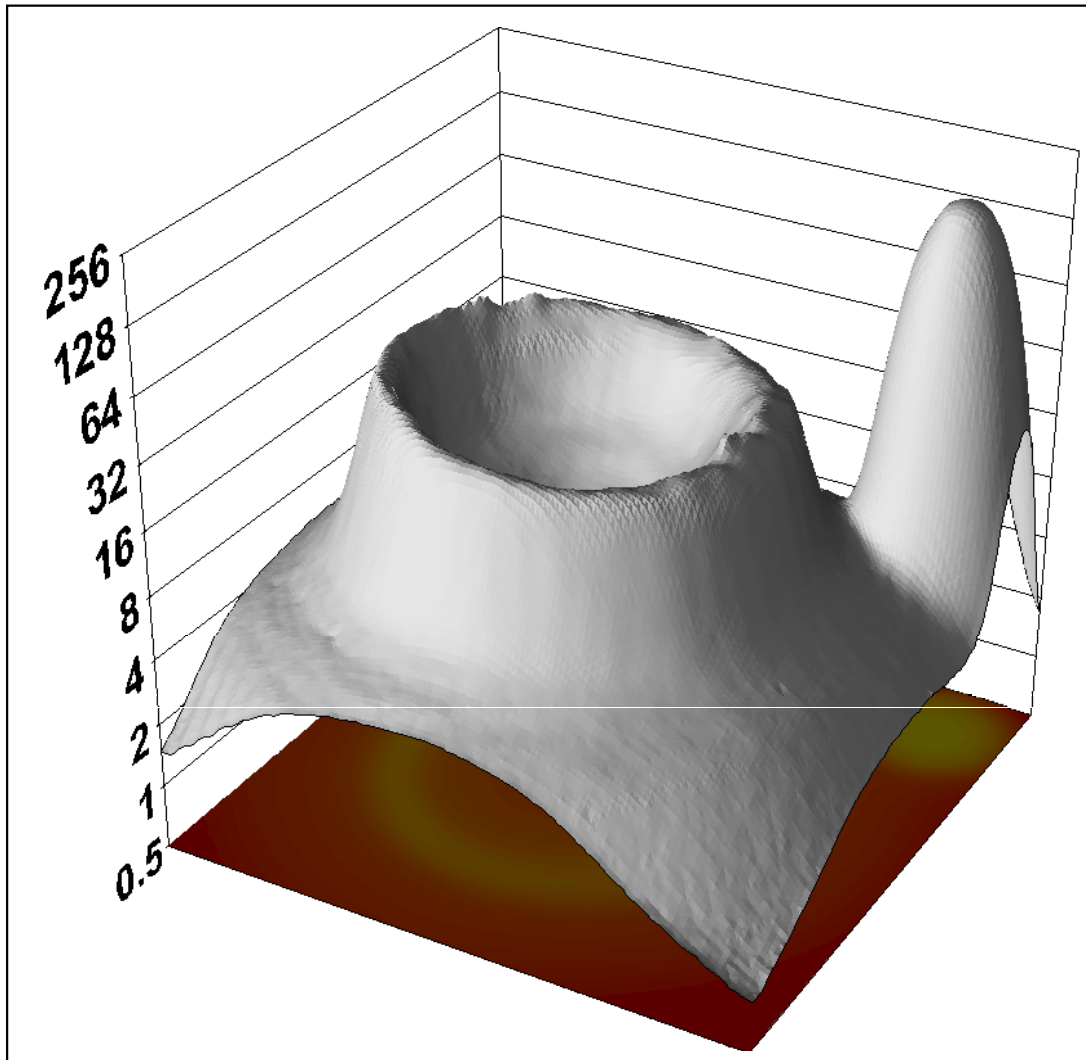
## Problems:

- Less resolution in high measurement areas.
- Blooming effect may occur.



# Sample Measurement

Two fibers' output measurement after calibration.



## Notes:

- Five exposure times (50, 100, 200, 400, 800ms).
- Each measurement = average of four snaps.

# Thank you !

