How to evaluate the optical performance of spectacle lens with micro lens array

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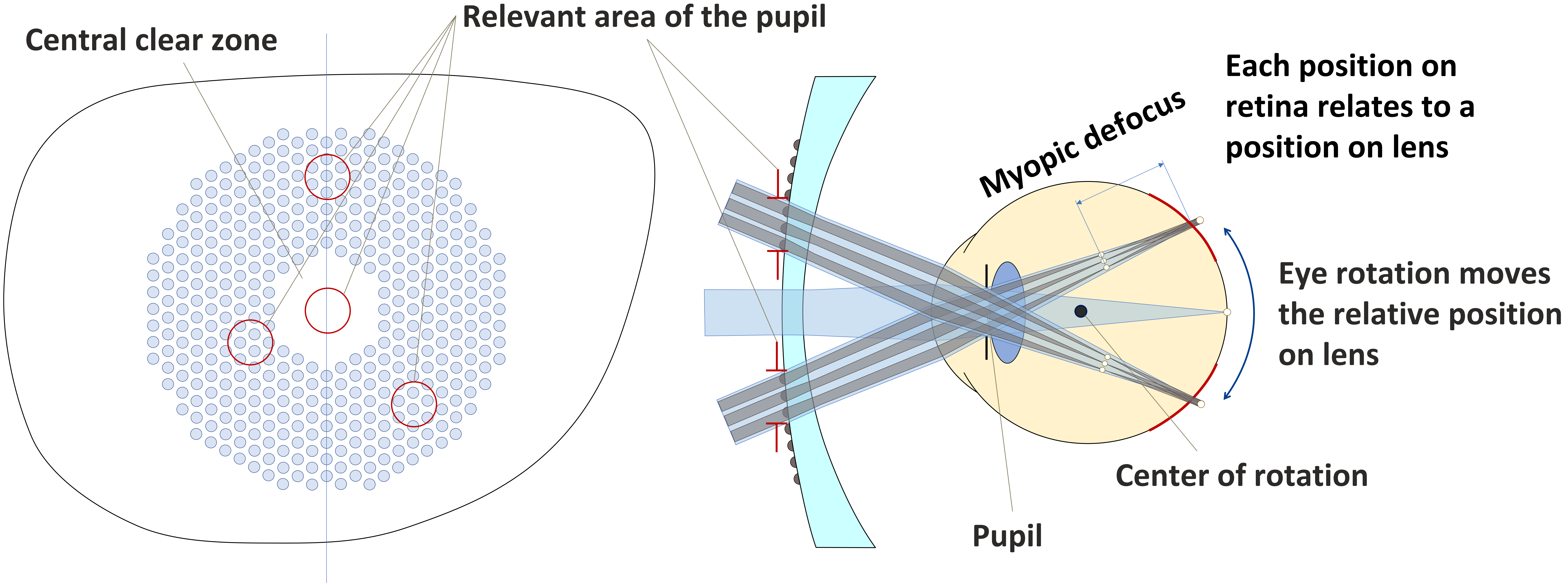
Disclosure of conflicts of interest:

Dr. Hua Qi is an employee of HOYA Corporation

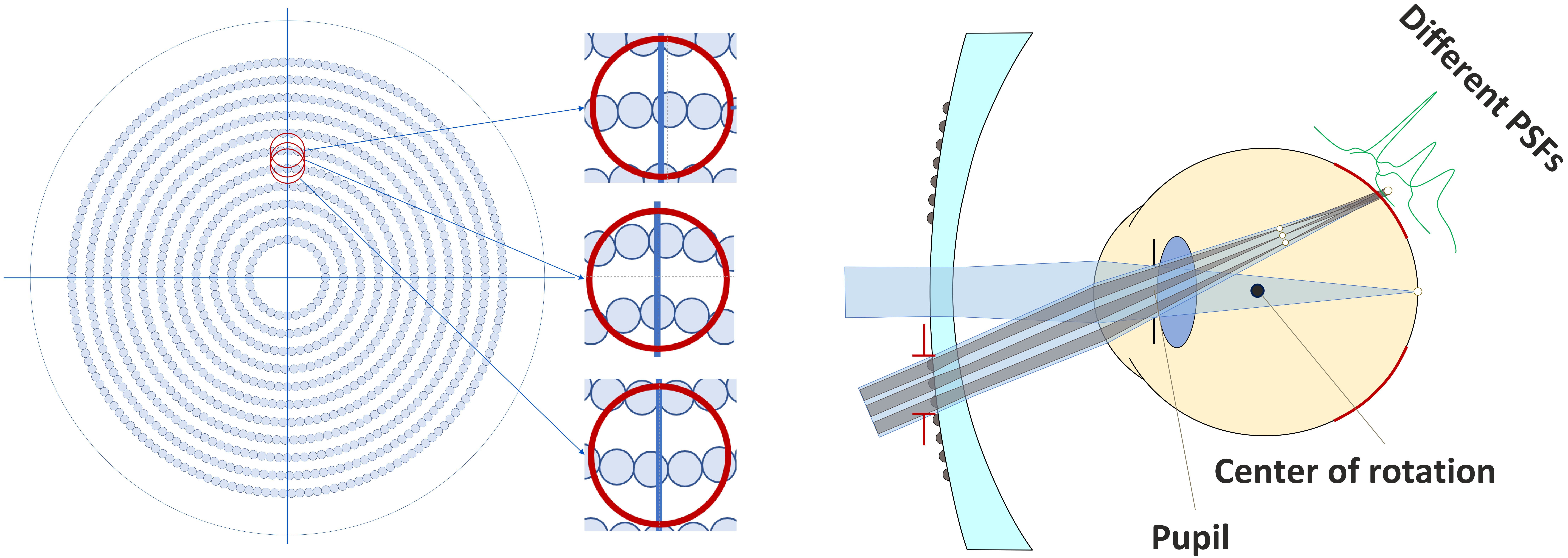
Optical system wearing a spectacle lens with micro lens array



Wearing a spectacle lens with microlens array,

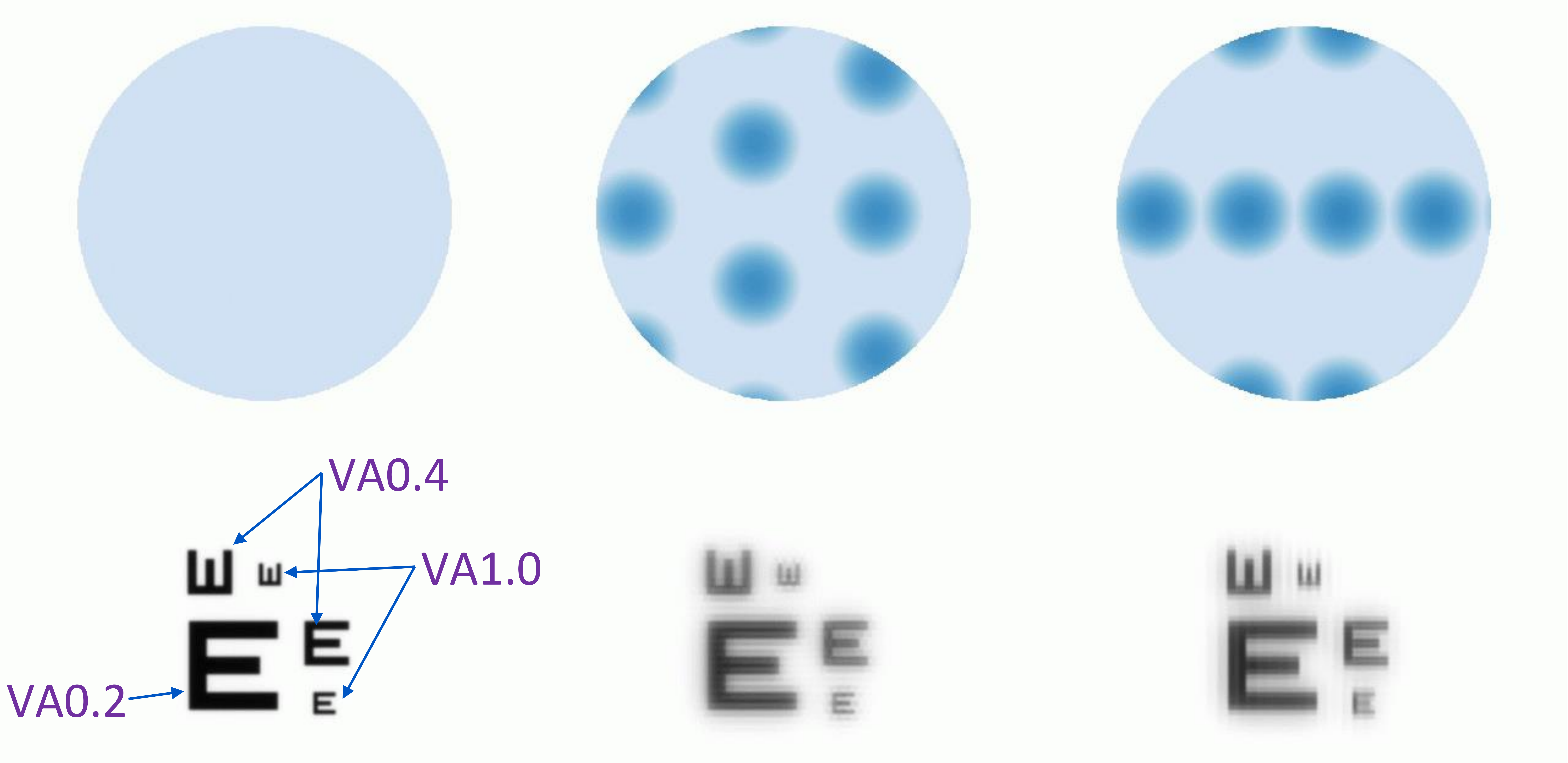
- **Possible to see things clearly**
- **All parts of retina have chance to receive myopic defocus stimuli**

Why does this spectacle have some unwanted optical effect?



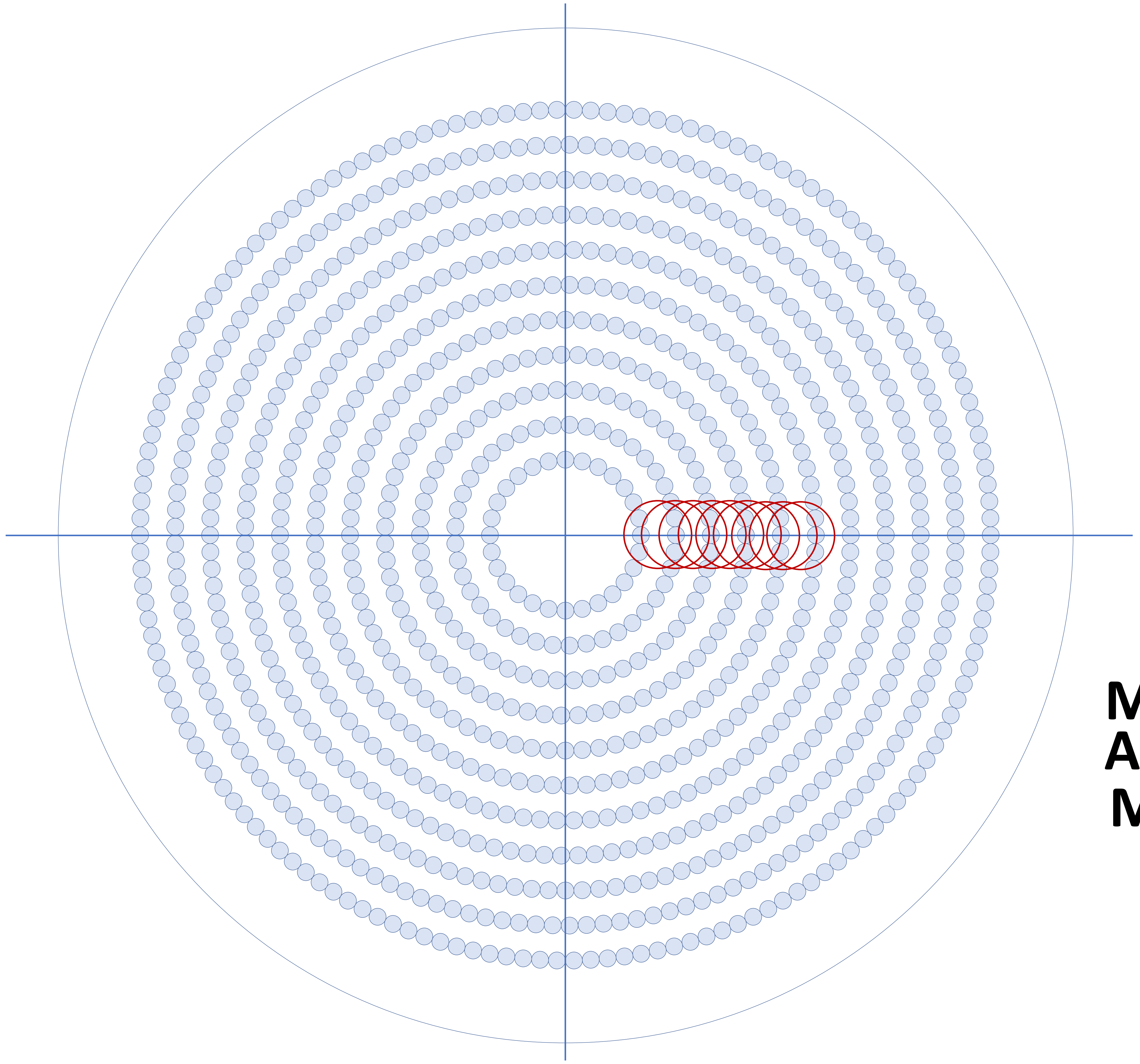
Point Spread Function (PSF) changes all over the lens

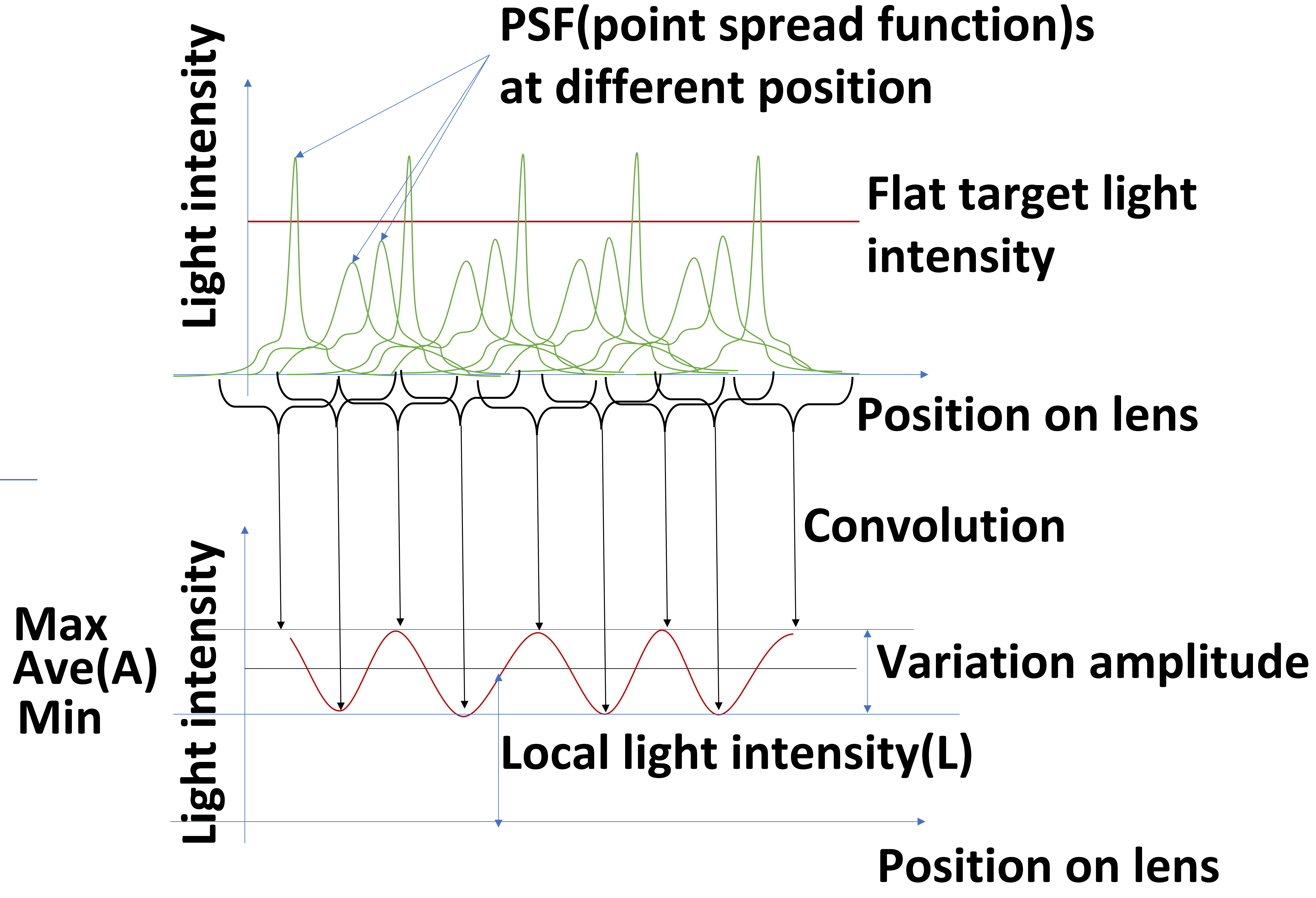
Optical property changes with position on lens



What happens?

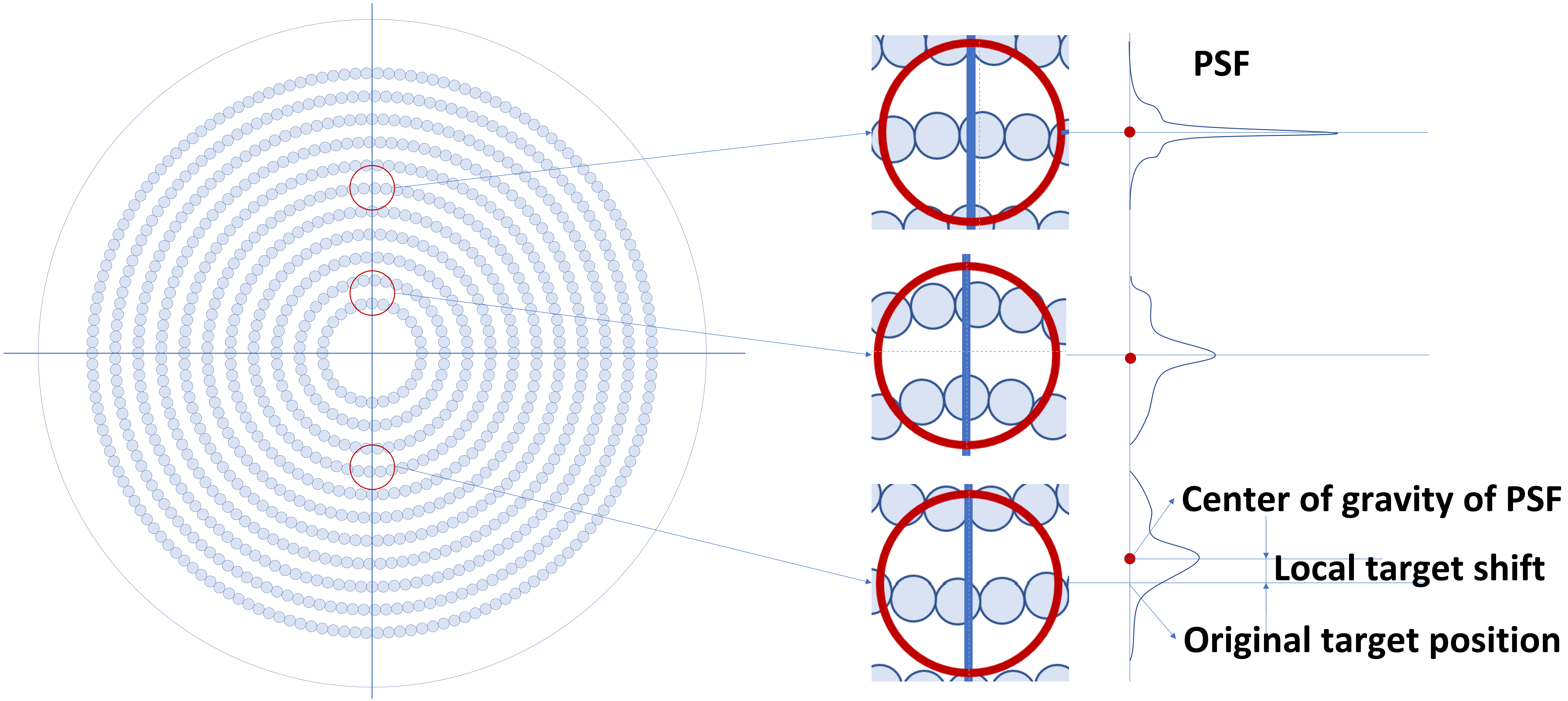
1: Light intensity changes with position





Local Light Intensity (LLI) is quantified as the ratio of to the average value: L/A. The variation amplitude is : (Max-Min)/A

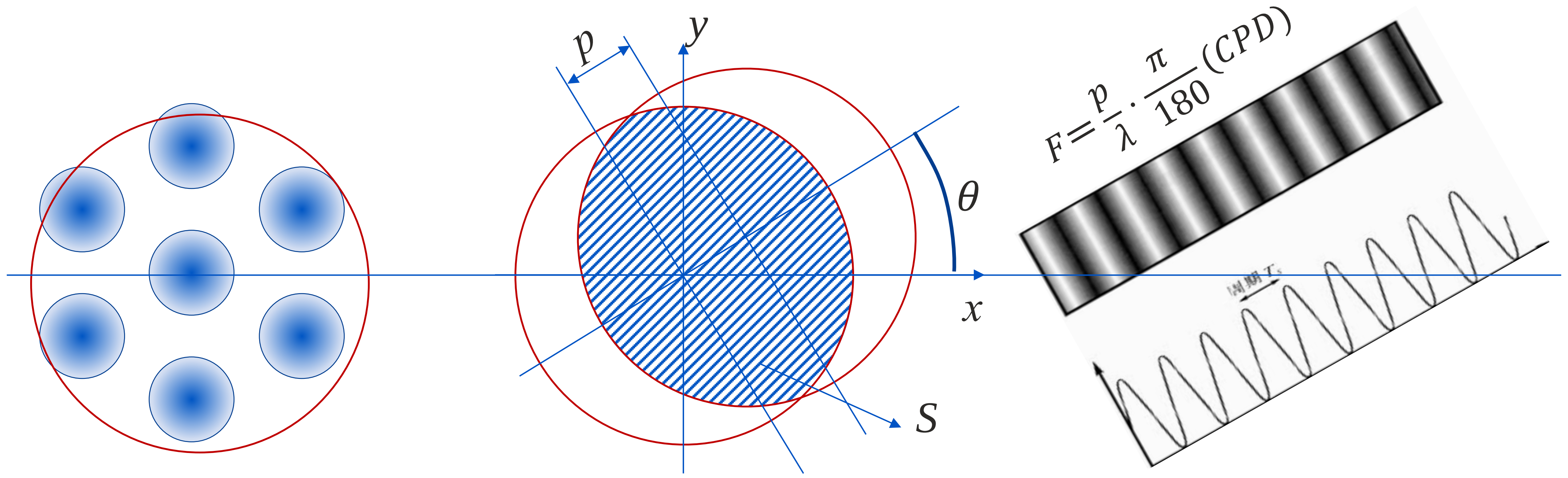
What happens?
2: Target shift changes with position



At each position, LTS (Local Target Shift) is quantified as :
100 * tan(shift angle)

What happens?
3: MTF changes with position

At each position, Modulation Transfer Function (MTF) is derived as following:



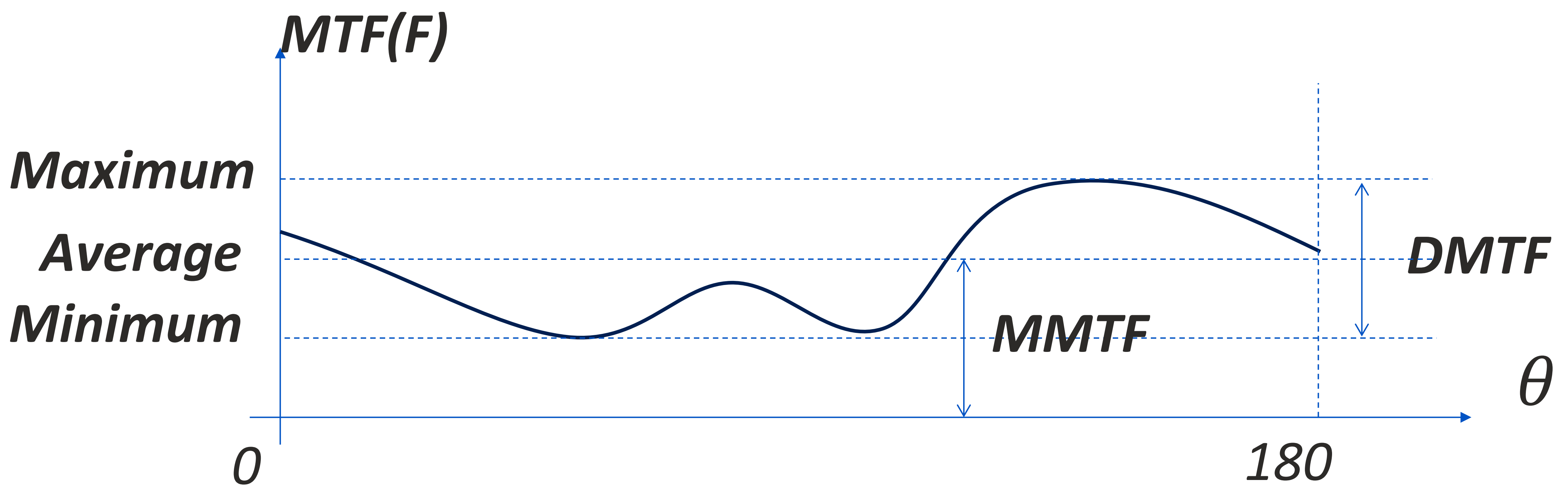
$$OTF(F,\theta) = \frac{\iint_{\sqrt{x^2+y^2}\le D/2} H(x,y)H^*(x - p\cos\theta\,, y - p\sin\theta)dxdy}{\iint_{\sqrt{x^2+y^2}\le D/2} H(x,y)H^*(x,y)dxdy}$$

$$H(x,y) = \begin{cases} exp\left(-i\frac{2\pi}{\lambda}W(x,y)\right) & ,when\ \sqrt{x^2+y^2} \le D/2 \\ 0 & ,otherwise \end{cases}$$

$$W(x,y) = \begin{cases} \frac{1}{2}P\left(r - \frac{d}{2}\right)^2 & ,when\ r < \frac{d}{2} \\ 0 & ,otherwise \end{cases}$$

$$MTF(F,\theta) = |OTF(F,\theta)|$$

At each position, MTF of a spatial frequency *F* changes with azimuth angle.



MTF of a spatial frequency *F* is quantified with two values:

1. **Local mean MTF (MMTF) and**
2. **Local maximum difference of MTF (DMTF).**

Summary of optical performance indices

At each position on lens, the following indices are defined and calculated to evaluate its optical property:

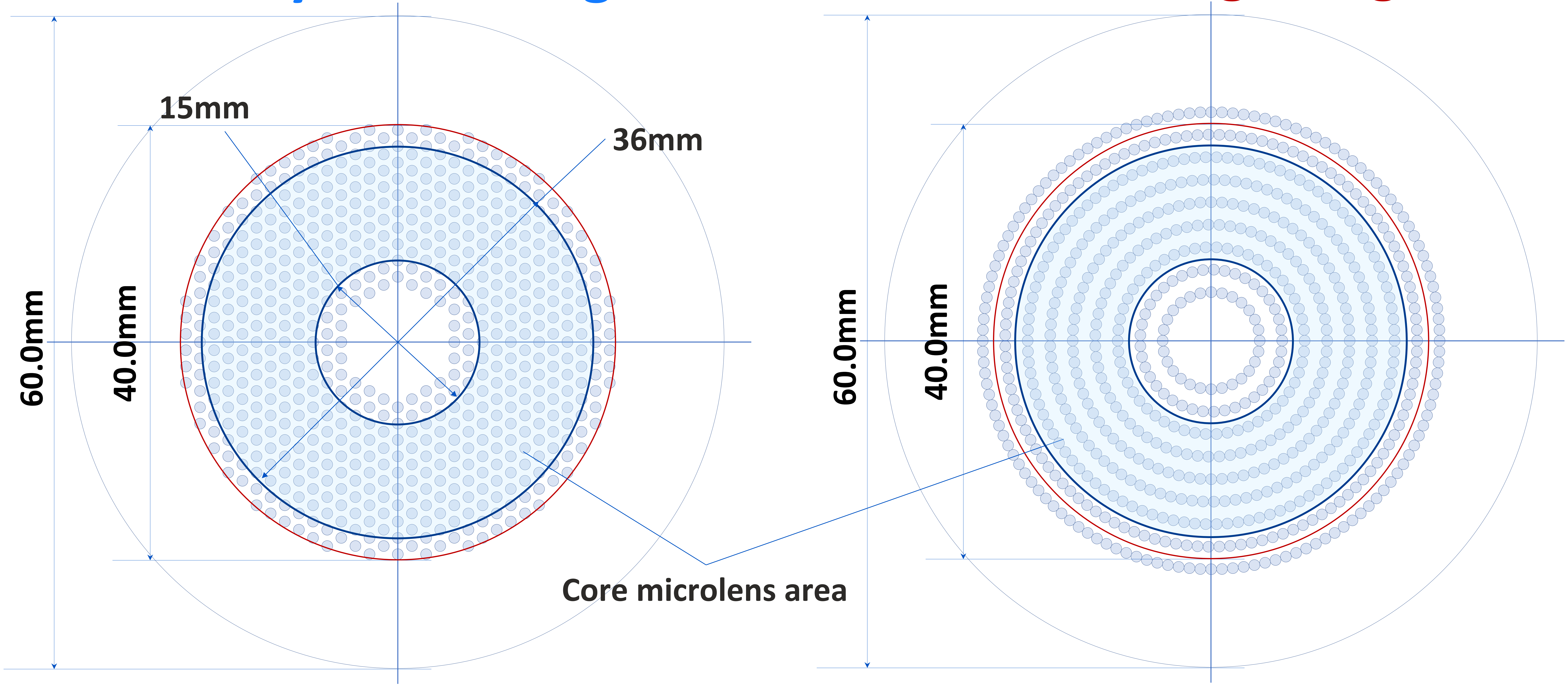
1. Local light intensity (LLI)
2. Local target shift (LTS)

For every spatial frequency *F*

3. Local mean MTF(MMTF) among all azimuth angles
4. Local maximum difference of MTF(DMTF) among all azimuth angles

Honeycomb design

Multi-ring design

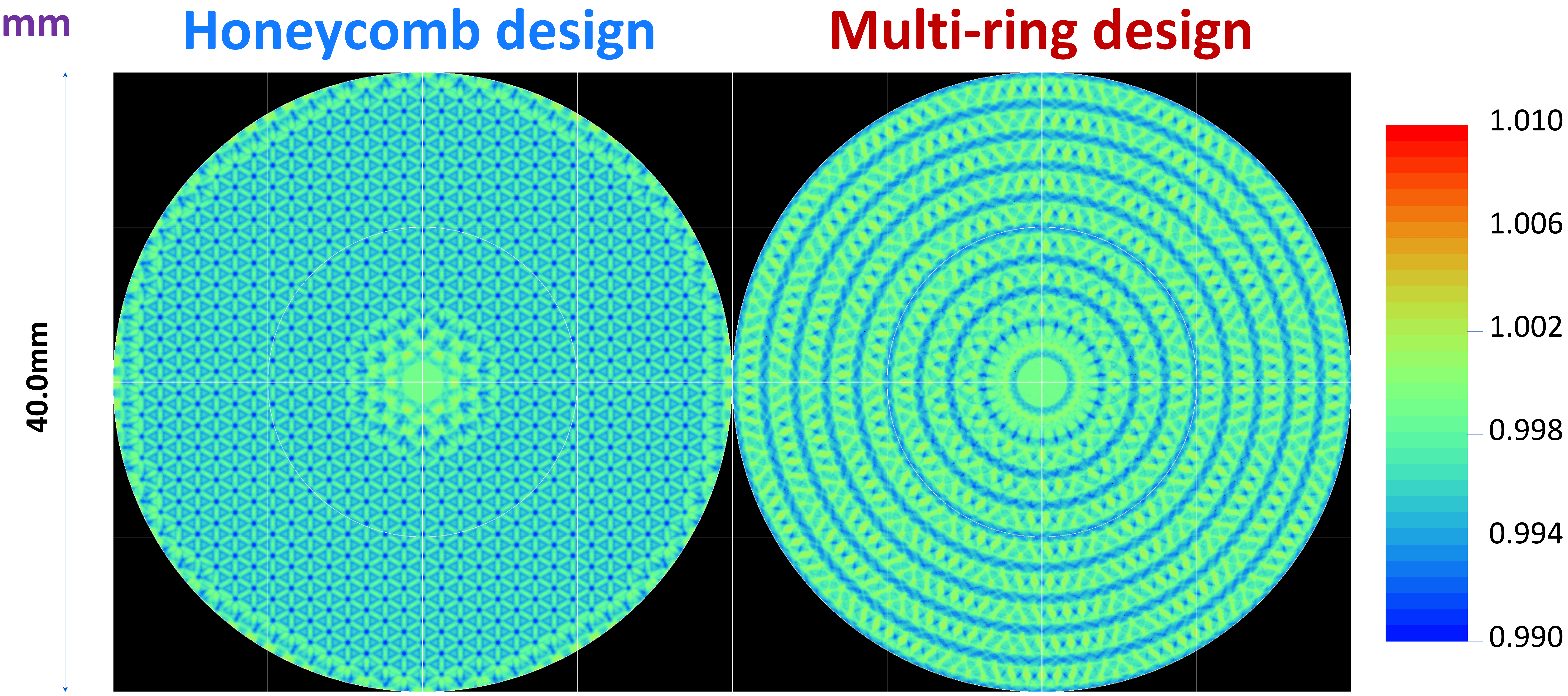


- Microlens shape : sphere
- Microlens size : 1mm
- Defocus power : 3.5D
- Interval : 1.5mm

- Microlens shape : sphere
- Microlens size : 1mm
- Defocus power : 3.5D
- Ring interval : about 2.07mm
- Number of microlenses of each ring are: 28, 41, ..., 132

Local light intensity (LLI) map

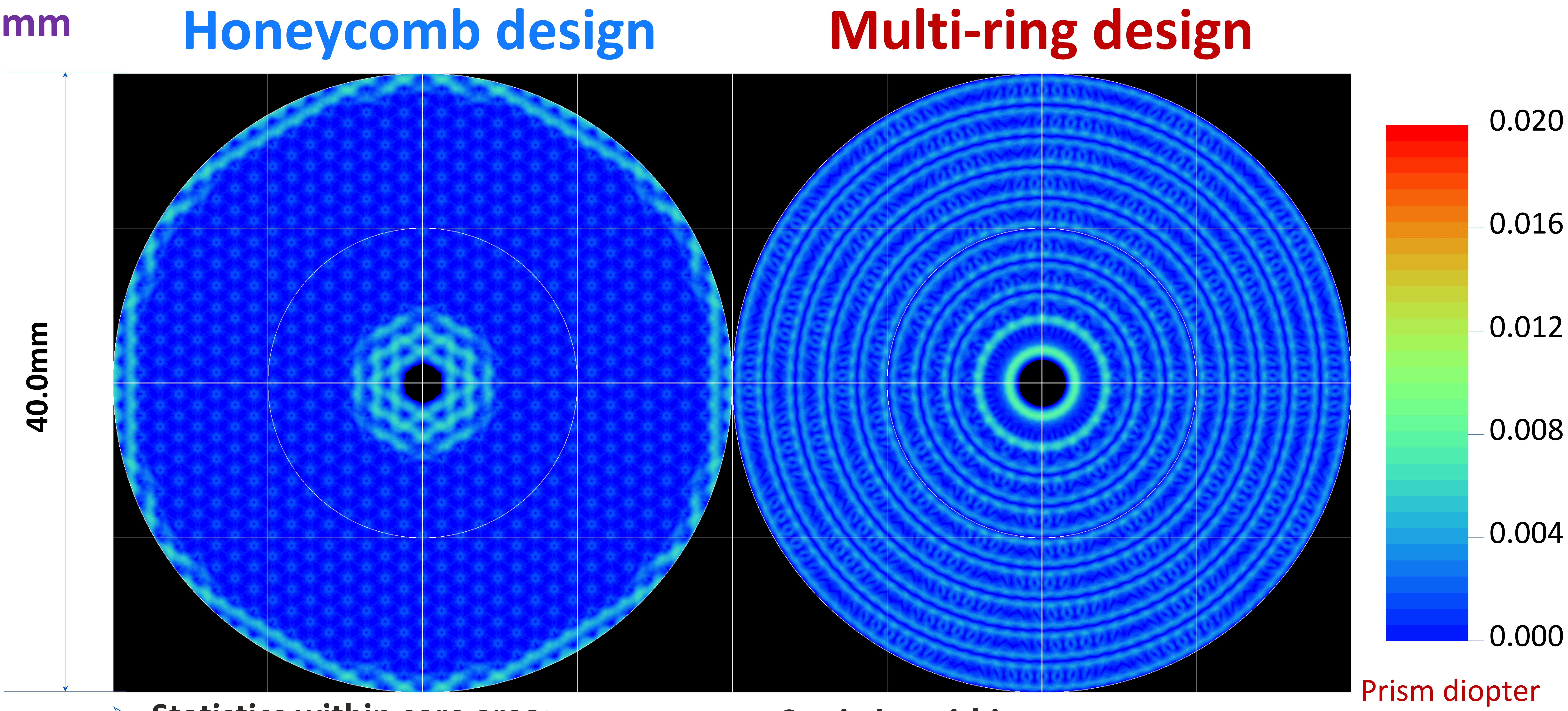
Pupil: 4mm



- Statistics within core area:
  - Maximum-minimum: 0.66%
  - Standard deviation: 0.11%
- Statistics within core area:
  - Maximum-minimum: 1.13%
  - Standard deviation: 0.21%

Local target shift (LTS) map

Pupil: 4mm



Honeycomb design

- Statistics within core area:
  - Maximum-minimum: 0.0026
  - Standard deviation: 0.0006

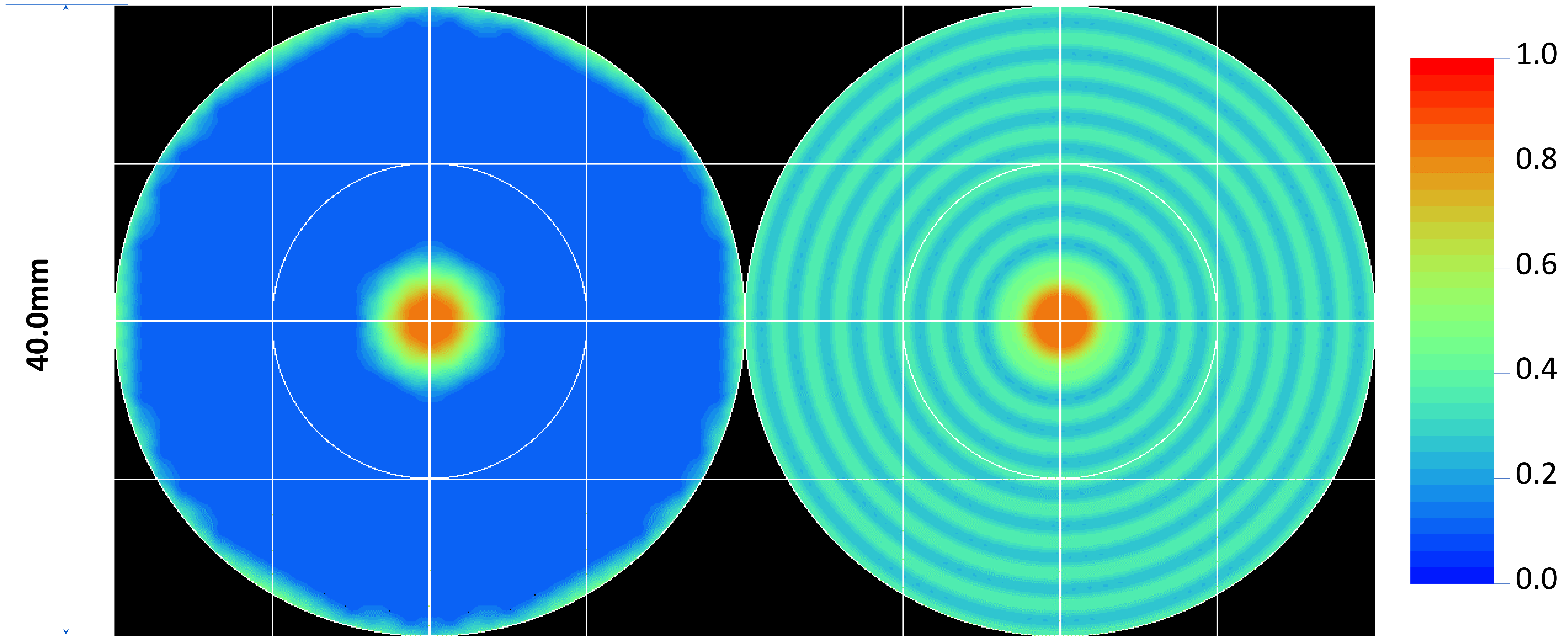
Multi-ring design

- Statistics within core area:
  - Maximum-minimum: 0.0055
  - Standard deviation: 0.0012

MMTF map at F=15CPD (visual acuity 0.5)

Pupil: 4mm

Honeycomb design **Multi-ring design**

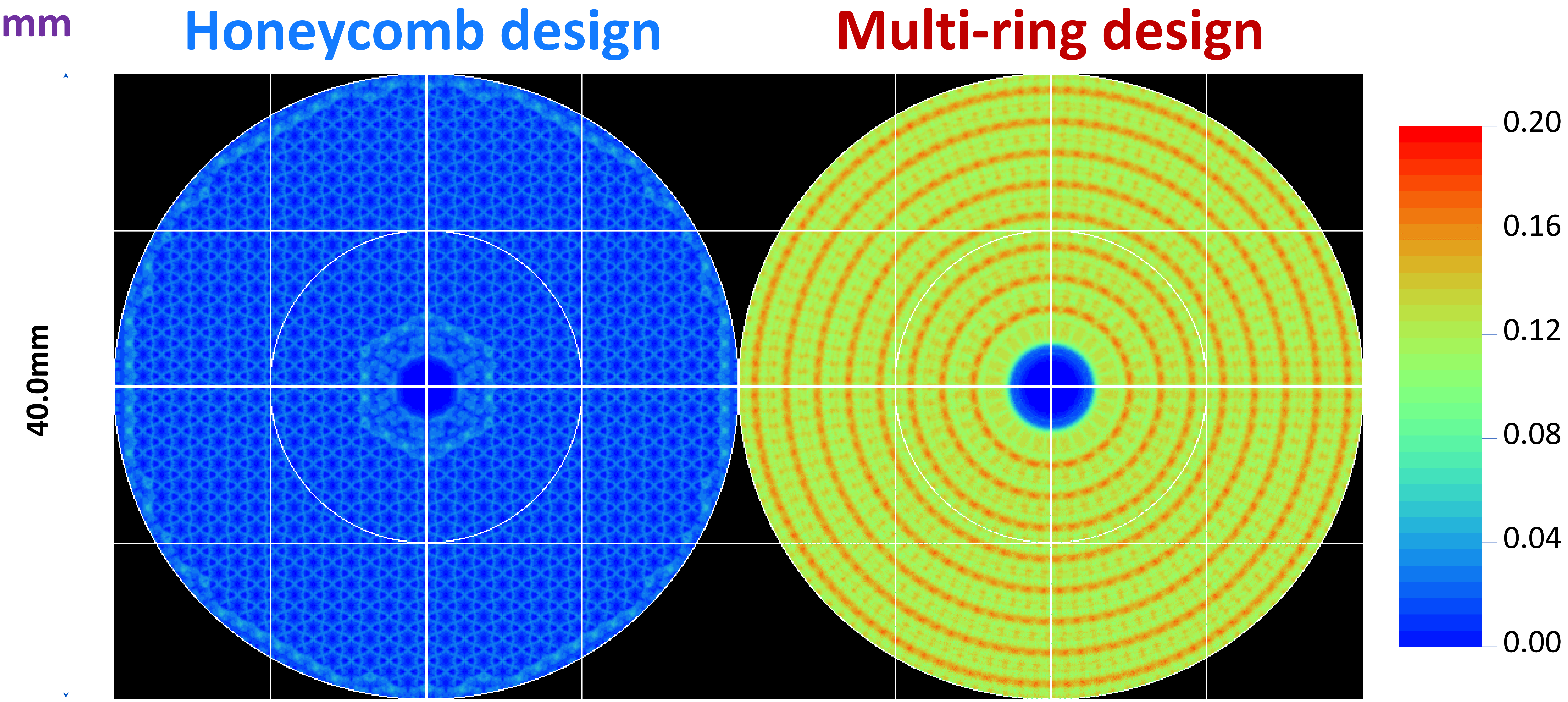


- **Statistics within core area:**
  - **Average: 0.1477**
  - **Standard deviation: 0.0033**

- **Statistics within core area:**
  - **Average: 0.3460**
  - **Standard deviation: 0.0409**

DMTF map at F=15CPD (visual acuity 0.5)

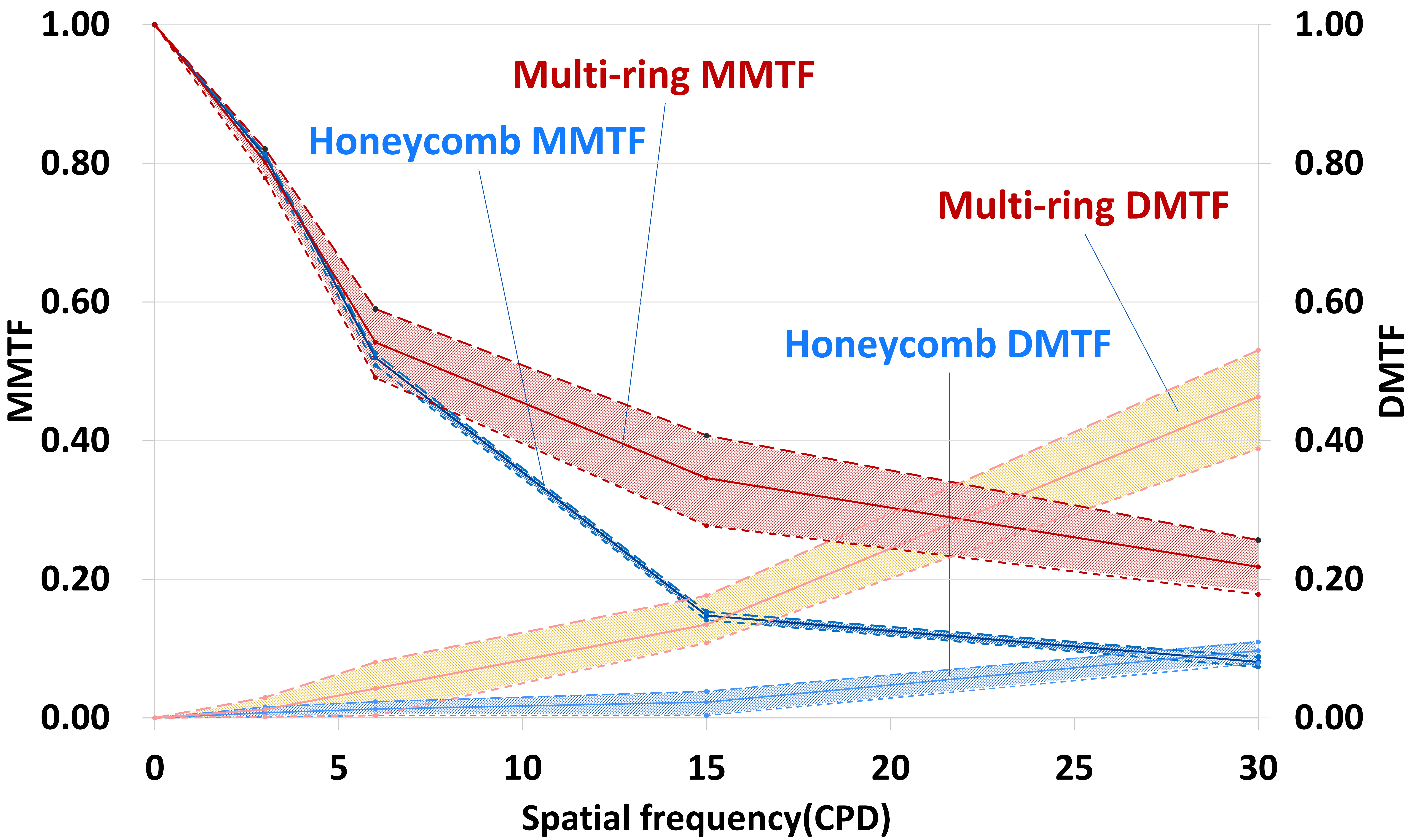
Pupil: 4mm



- Statistics within core area:
  - Average: 0.0228
  - Standard deviation: 0.0083
- Statistics within core area:
  - Average: 0.1348
  - Standard deviation: 0.0132

MTFs of both designs

Pupil: 4mm



Summary

- As the optical property varies across the spectacle lens with micro lens array, a map is necessary to describe the situation.
- At each position on the lens, following new indices are defined and calculated to access its optical property:

  1. Local light intensity(LLS),
  2. Local target shift(LTS),

  For every spatial frequency F,

  3. Local mean MTF(MMTF) among all azimuth angles
  4. Local maximum difference of MTF(DMTF) among all azimuth angles
- Two sample designs are evaluated and compared.

Thank you for your attention

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