

# Margin Allocation for 500GB Holographic Memory System using Monocular Architecture

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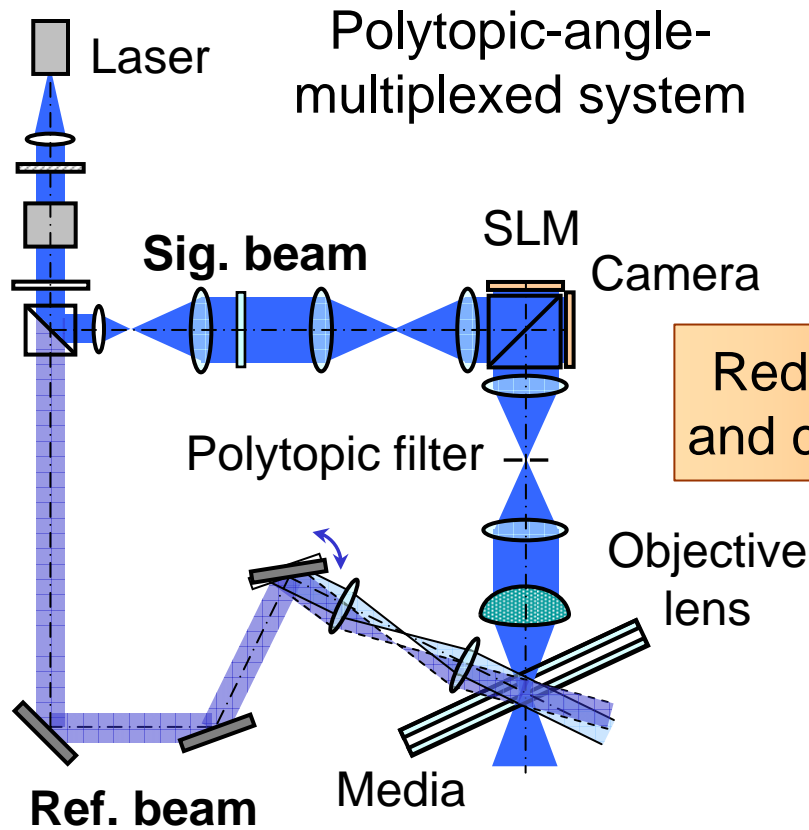
**HITACHI**  
Inspire the Next

1. Introduction
2. Requirements to signal metric
3. Experimental setup
4. Results
5. Conclusion

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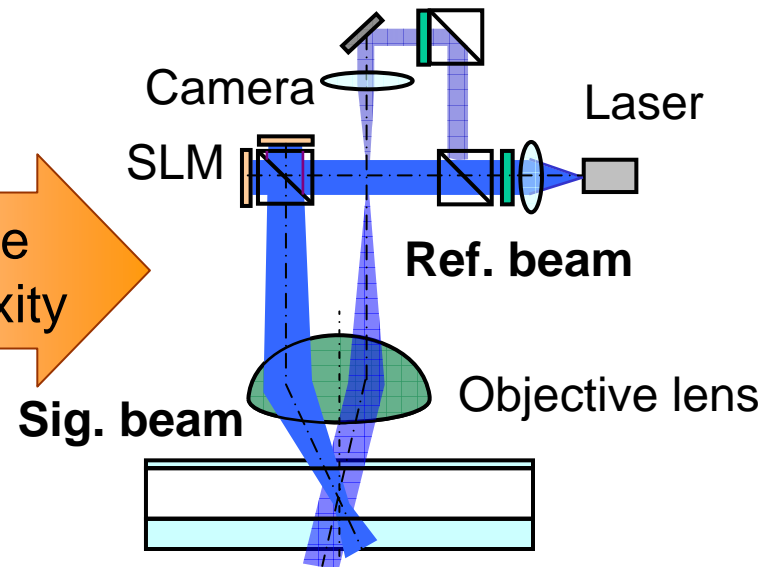
# 1.1 Monocular Architecture

(a) Professional system



(b) Consumer system

## Monocular architecture<sup>[1]</sup>



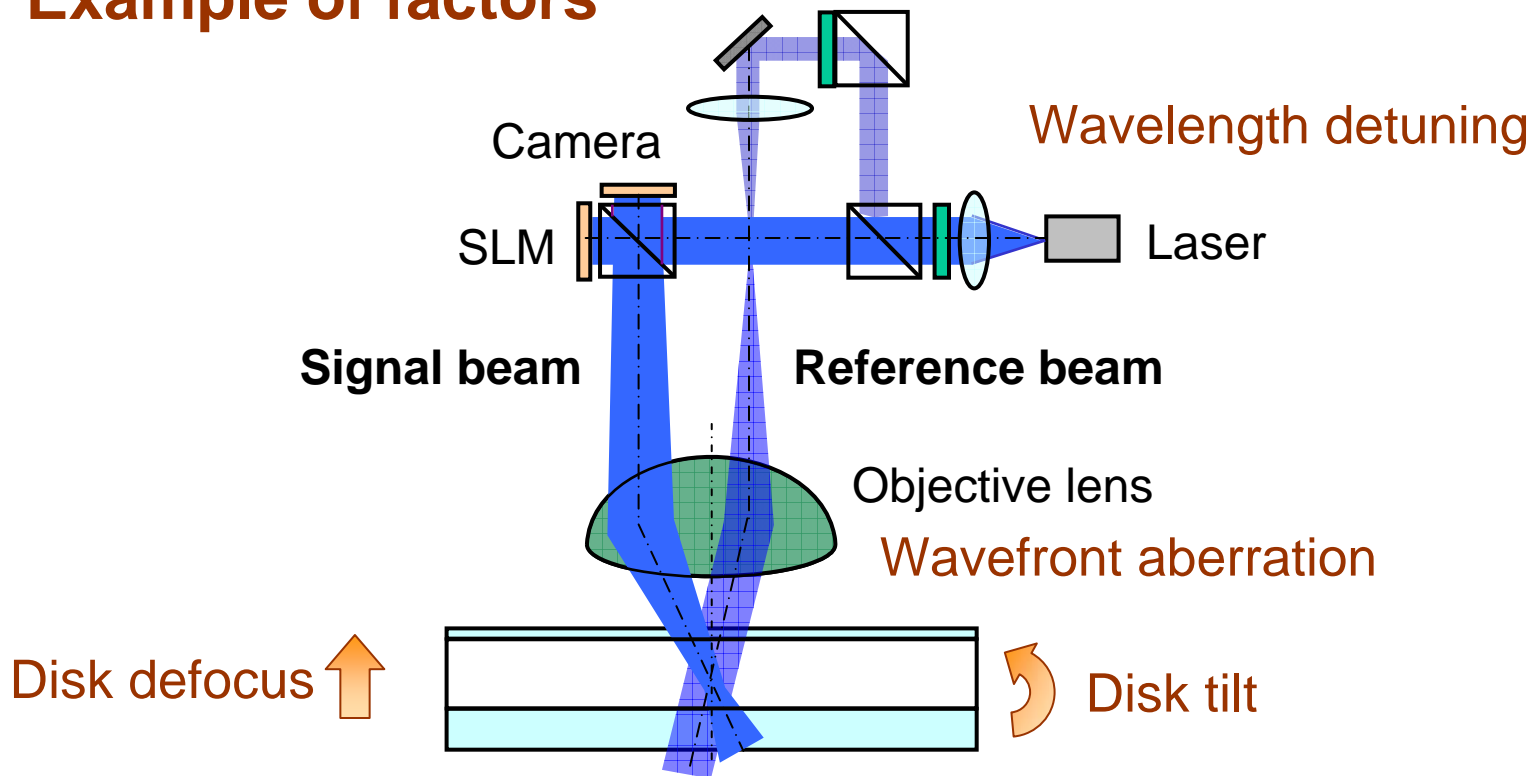
Reduce size  
and complexity

[1] TuC2 "High density recording using Monocular architecture for 500GB consumer system"

# 1.2 Necessity of Margin Allocation

Many factors which affect signal quality

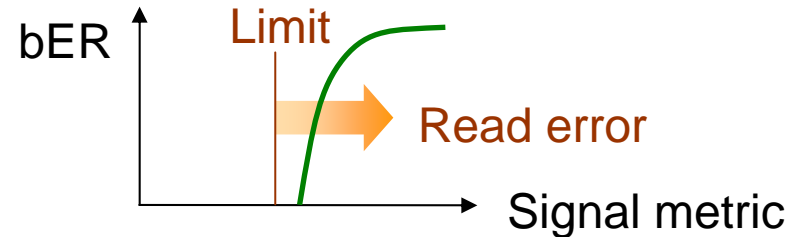
## Example of factors



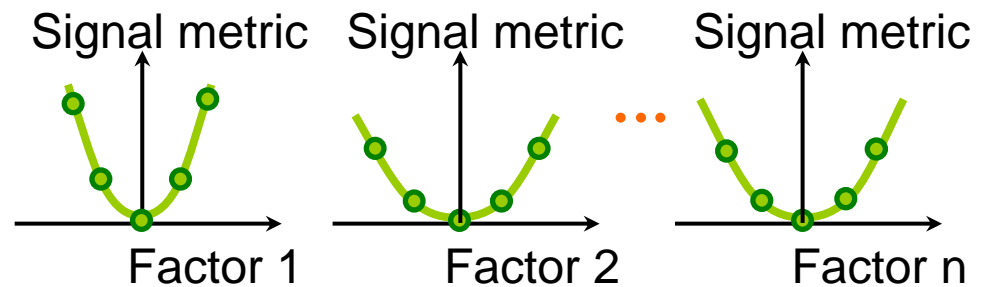
**Margin allocation is necessary to figure out the technical difficulty for product design**

# 1.3 Flow of Margin Allocation

(a **Determine the limit**  
)



(b **Measure tolerance**  
)



(c **Allocate margin**

considering multiple stresses are applied simultaneously

Factor	Margin	Signal metric
Factor 1 ( Wavelength )	. . .	. . .
Factor 2 ( Defocus )	. . .	. . .
Factor 3 ( Tilt )	. . .	. . .
. . .	. . .	. . .
<b>Total signal quality</b>		. . . <b>Within the limit</b>

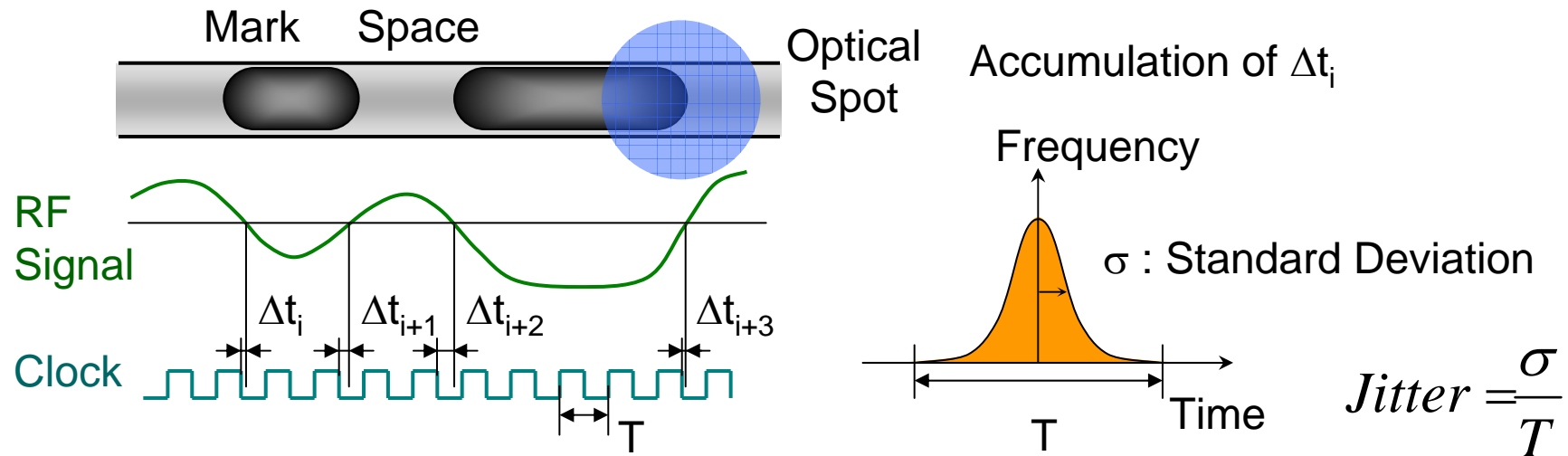
# 1.4 Purpose

**To allocate margin for 500GB holographic memory system using Monocular architecture**

**To establish new metric and margin allocation technique for page based holographic memory system**

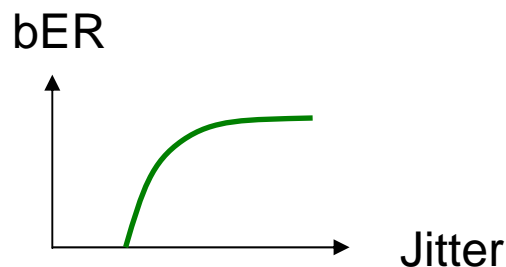
1. Introduction
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# 2.1 Jitter - Metric of Traditional ODD



## Requirements to metric for margin allocation

1) High relationship with signal quality



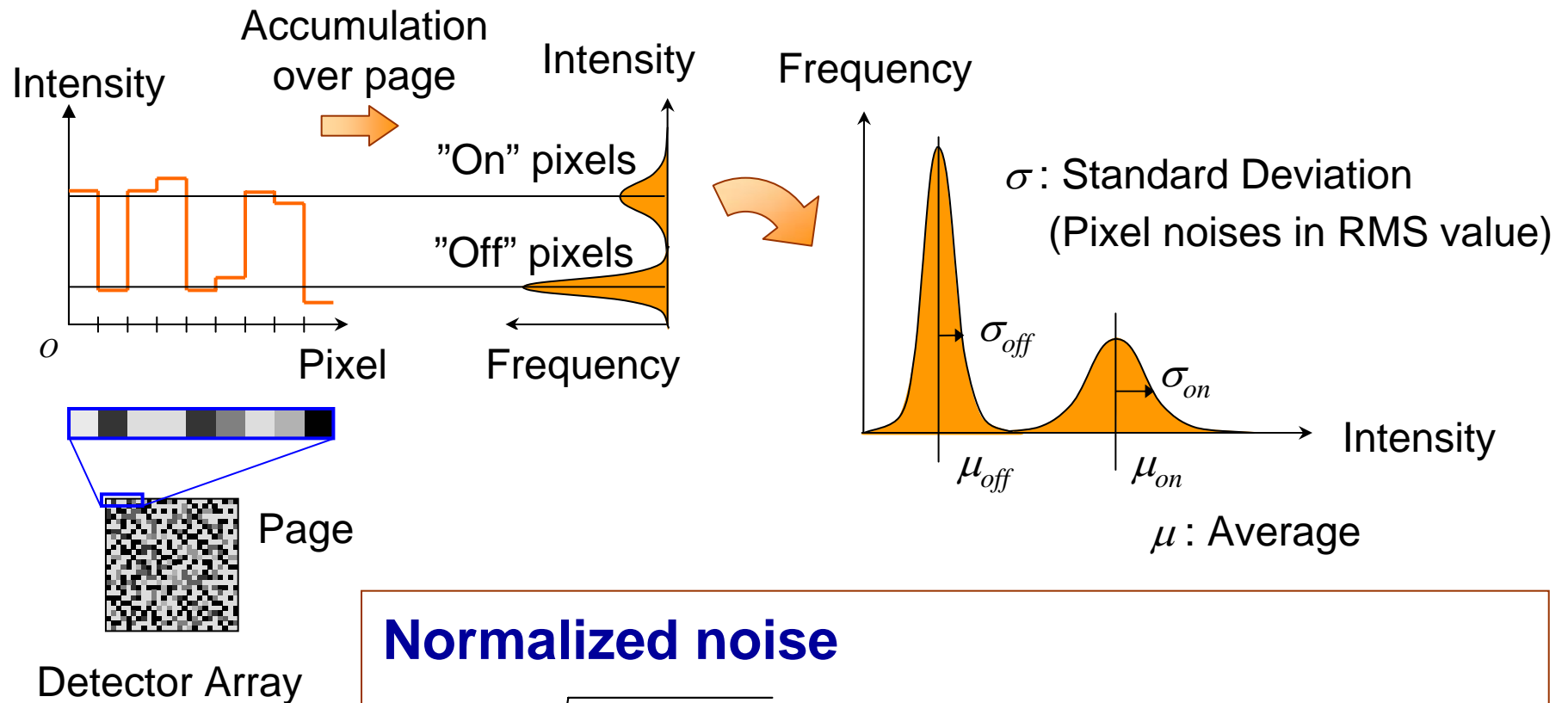
2) Additivity of metrics

$$\sigma = \sqrt{\sigma_0^2 + \sum_{i=1}^n \sigma_i^2}$$

$\sigma_0$  : DC jitter  
 $\sigma_i$  : Individual jitter

Total jitter      RSS of individual jitters  
(RSS : Root Sum Square)

# 2.2 Normalized Noise - New Metric



## Normalized noise

$$\sigma' = \frac{\sqrt{\sigma_{on}^2 + \sigma_{off}^2}}{\mu_{on} - \mu_{off}}$$

..... Pixel noise (RSS of  $\sigma_{on}$  and  $\sigma_{off}$ )

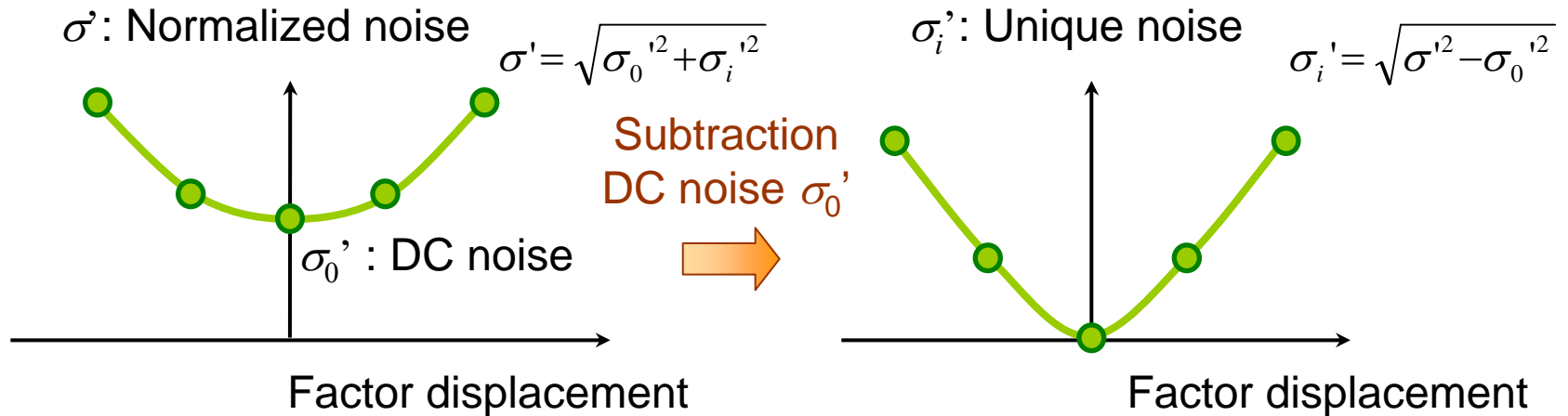
..... Signal amplitude

Same concept as the jitter

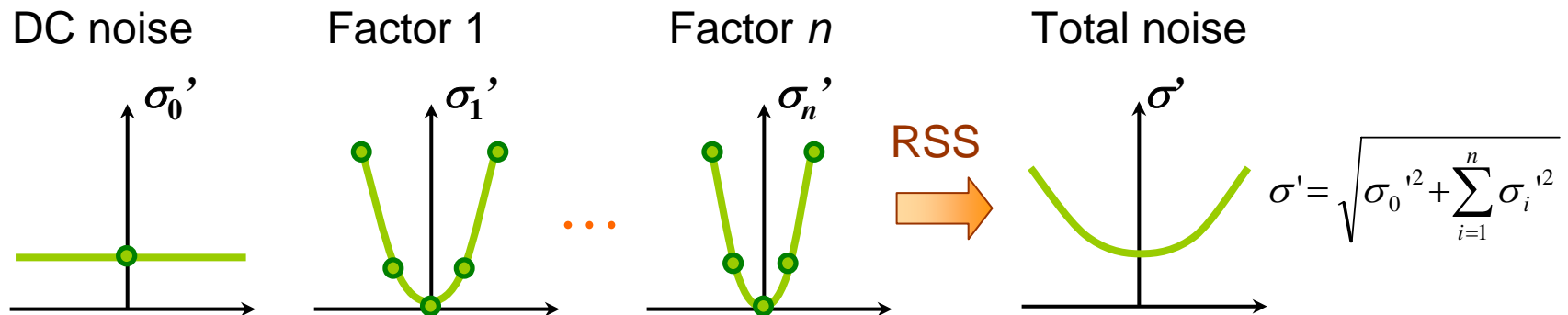
**Satisfy requirements for margin allocation**

# 2.3 Unique Noise and Total Noise

Subtraction DC noise by RSS  $\Rightarrow$  **Unique Noise**

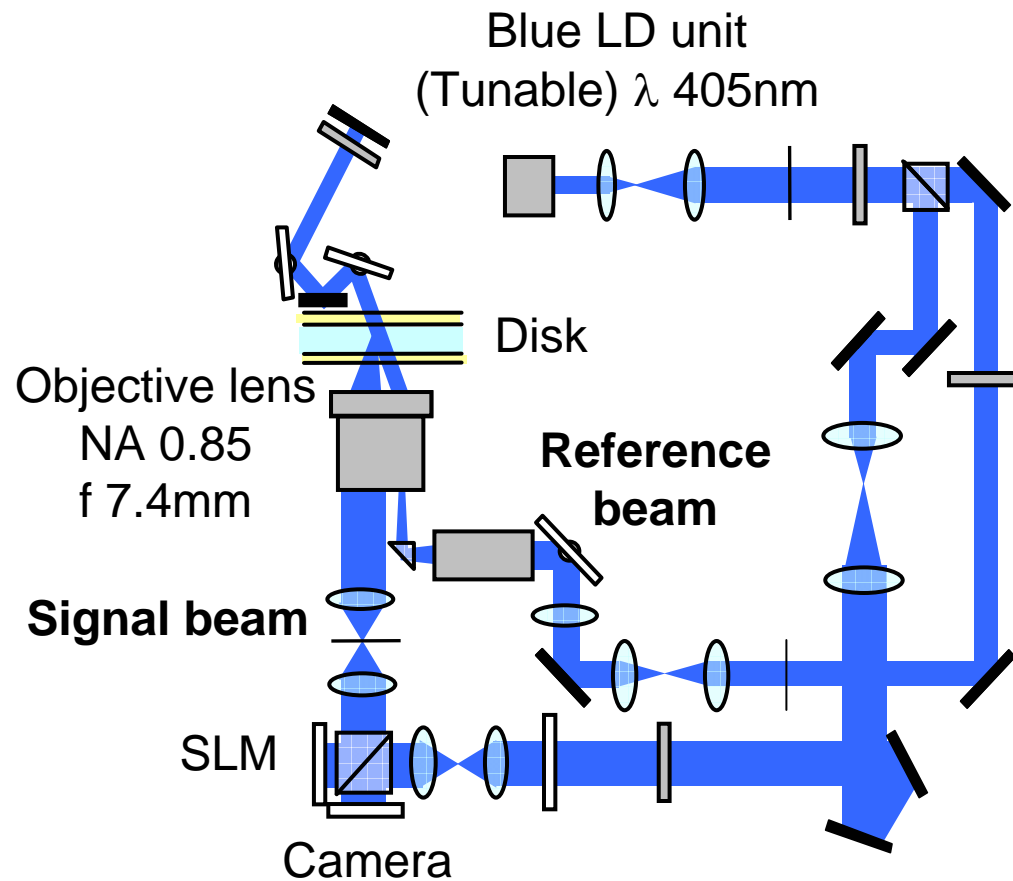


Addition unique noises by RSS  $\Rightarrow$  **Total Noise**



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# 3.1 Experimental Setup



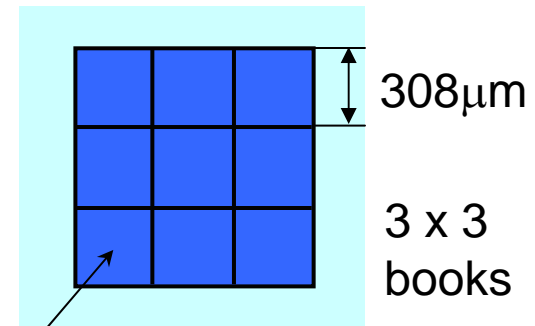
## Monocular architecture

### Recording condition

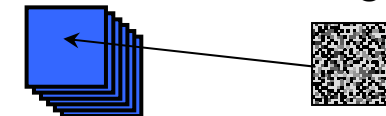
**500GB/disk**

( Coding rate : 0.488 )  
12cm disk

610Gbits/inch<sup>2</sup>



Book Page



112 pages 100,676 bytes (raw)

## 3.2 Main Tolerance

### Selected main factors which significantly affect signal quality

Reference beam angle displacement

Disk tilt ( Bragg direction, Radial )

Detrack ( Tangential, Radial )

Defocus ( Disk, Camera )

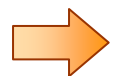
Wavelength detuning

Temperature

Wavefront aberration

### Tolerance measurement

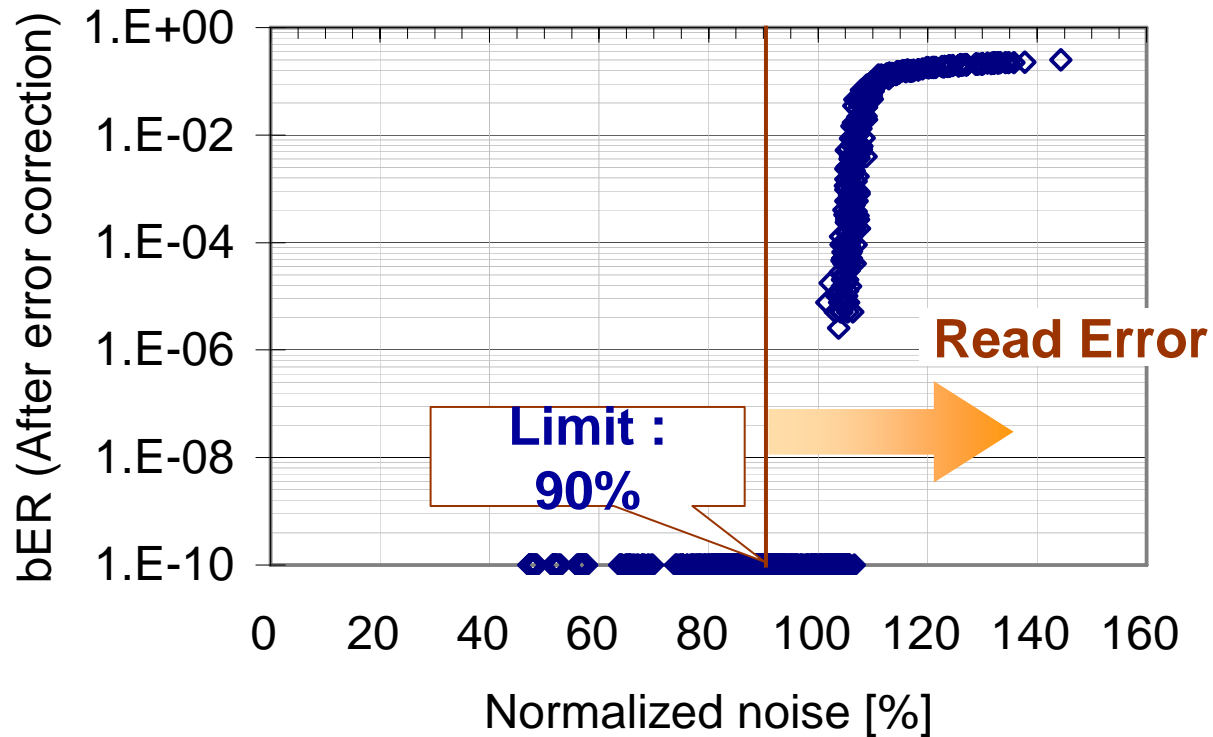
Recorded in the optimum condition



Reproduced with each stress applied

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  - 4.1 Limit of Normalized Noise
  - 4.2 Tolerances
  - 4.3 Margin Allocation
5. Conclusion

# 4.1 Limit of Normalized Noise



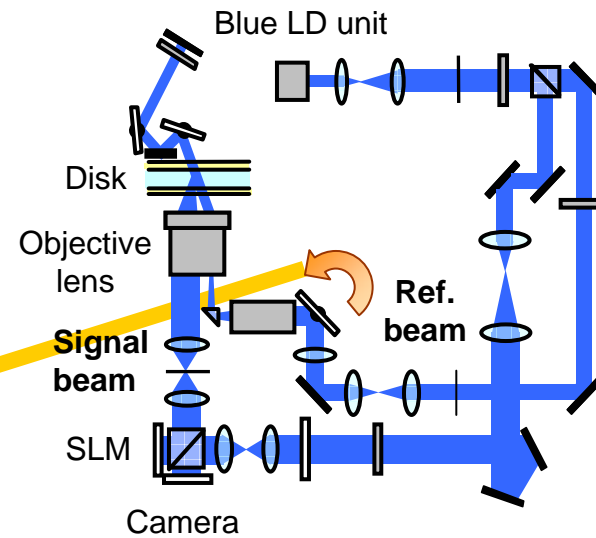
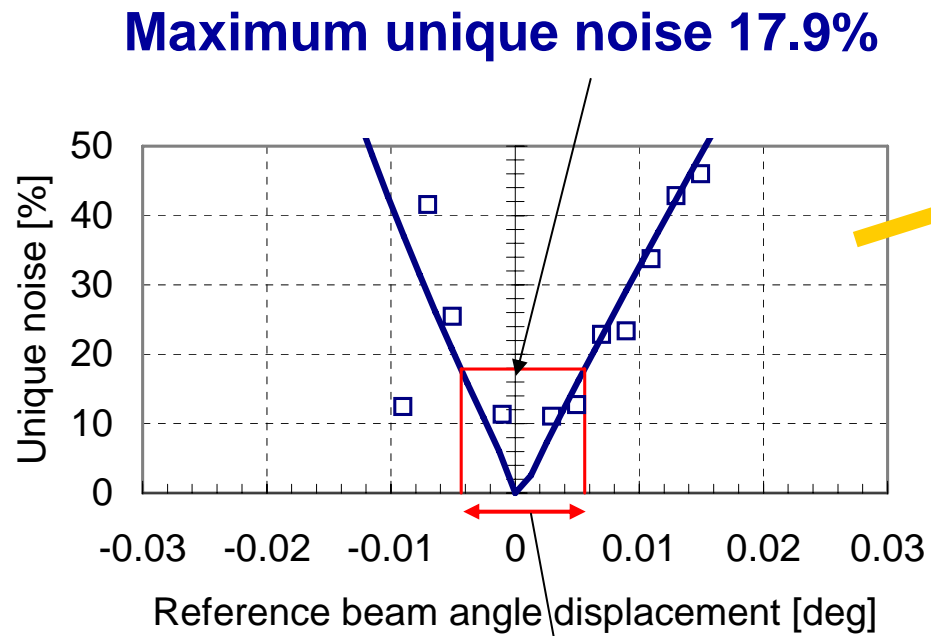
**Limit of the normalized noise was determined as 90%**

## 4.2 Tolerance

	Margin	Unique noise
Under optimum condition (DC noise)	-	
Reference beam angle displacement	[deg]	
Disk tilt in Bragg direction	[deg]	
Disk tilt in radial direction	[deg]	
Tangential detrack	[ $\mu\text{m}$ ]	
Radial detrack	[ $\mu\text{m}$ ]	
Disk defocus	[ $\mu\text{m}$ ]	
Camera defocus	[ $\mu\text{m}$ ]	
Wavelength detuning	[nm]	
Temperature	[ $^{\circ}\text{C}$ ]	
Wavefront aberration (rms)	[ $\lambda$ ]	
Total	-	Within 90%

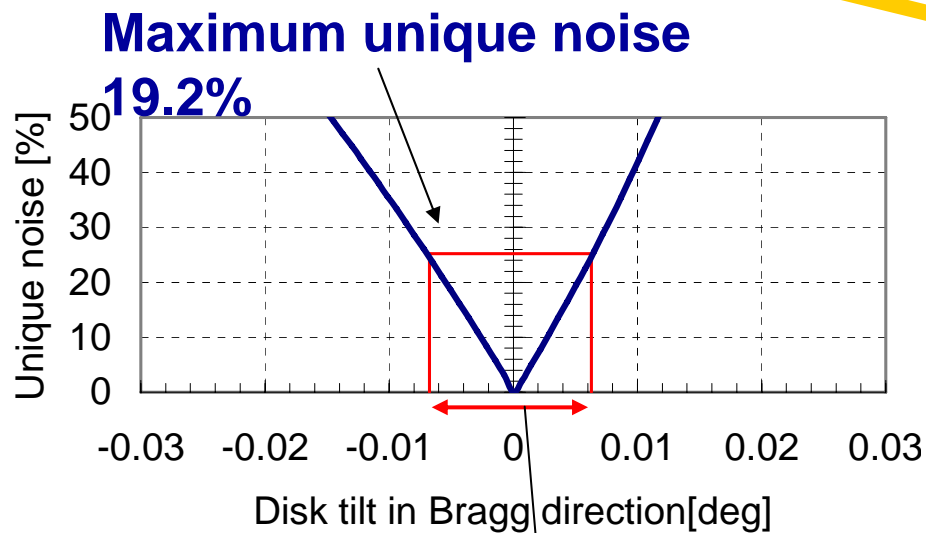
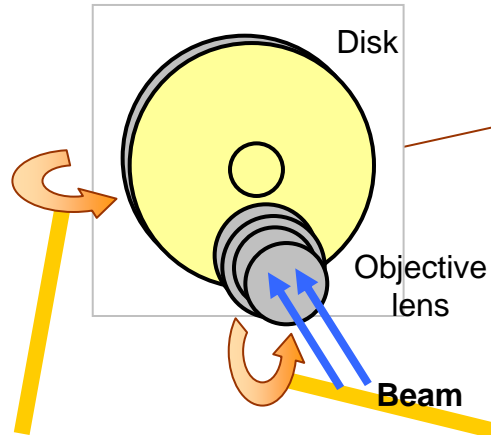
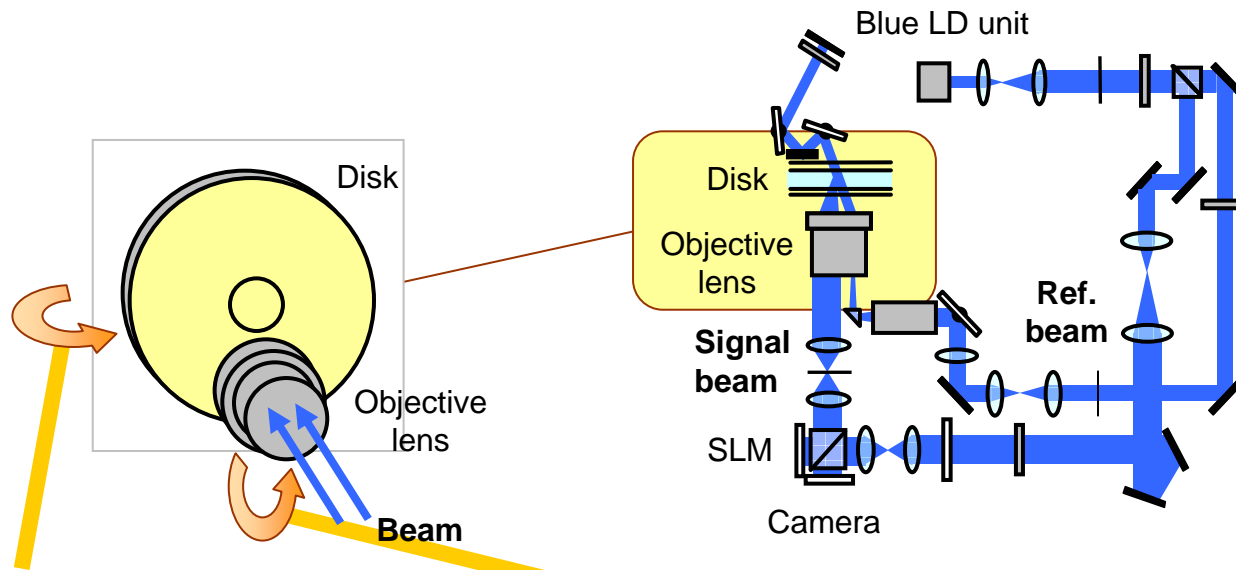
**Measure tolerance and determine the margin for each factor**

## 4.2 Tolerance -Reference beam angle displacement

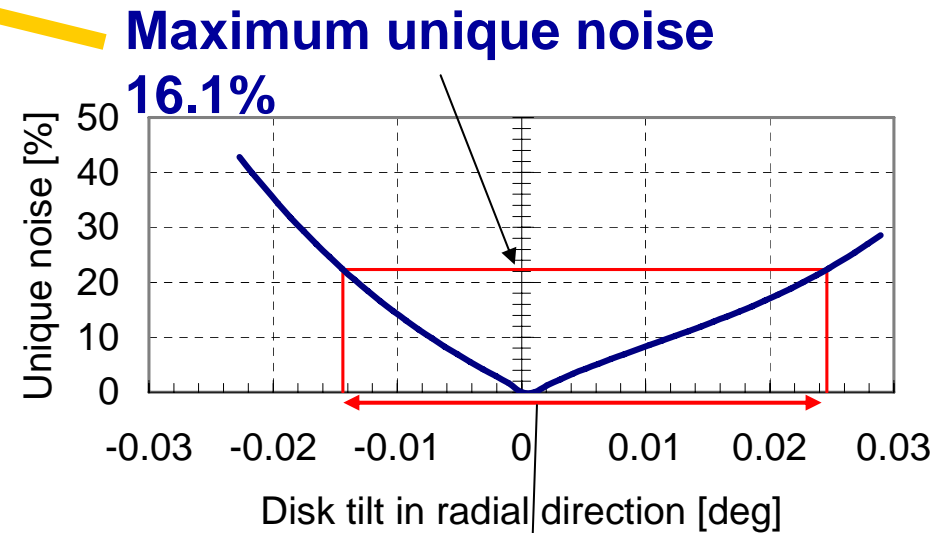


**Allocated margin  $\pm 0.0050\text{deg}$**

# 4.2 Tolerance -Disk tilt (Bragg direction, Radial)

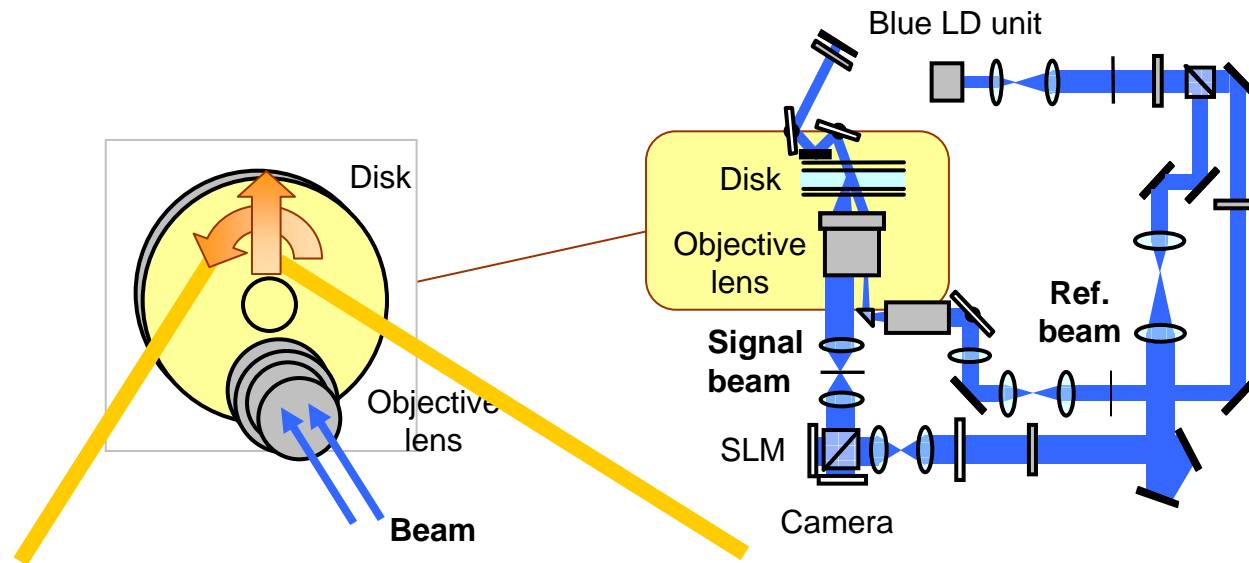


**Allocated margin**  
 **$\pm 0.0050\text{deg}$**



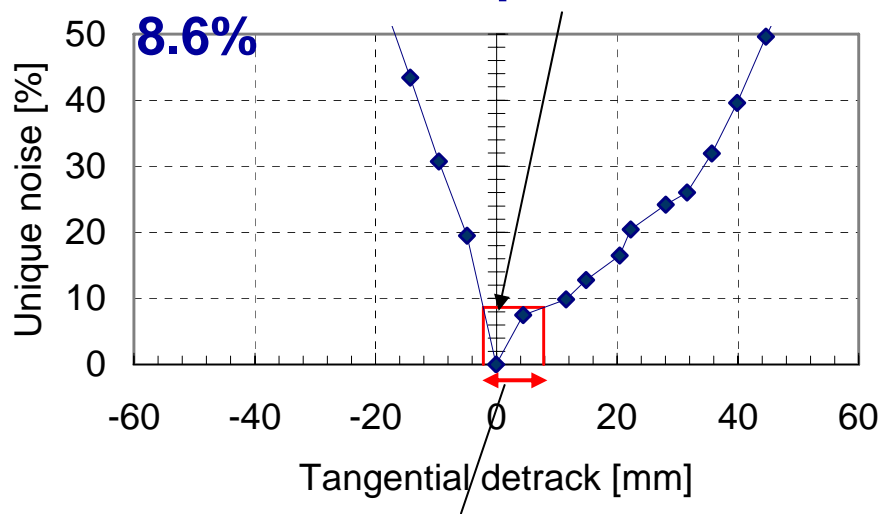
**Allocated margin**  
 **$\pm 0.0150\text{deg}$**

# 4.2 Tolerance -Detrack ( Tangential, Radial )



**Maximum unique noise**

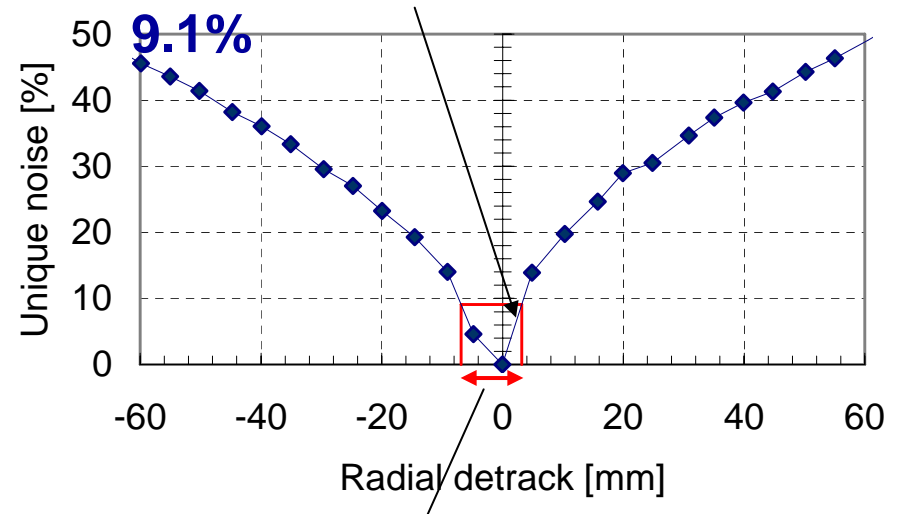
**8.6%**



**Allocated margin  $\pm 5.0\mu\text{m}$**

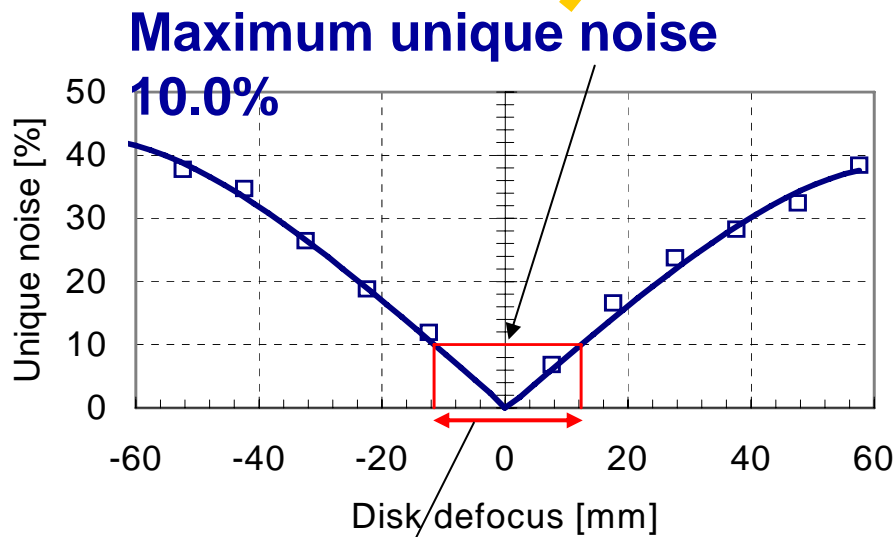
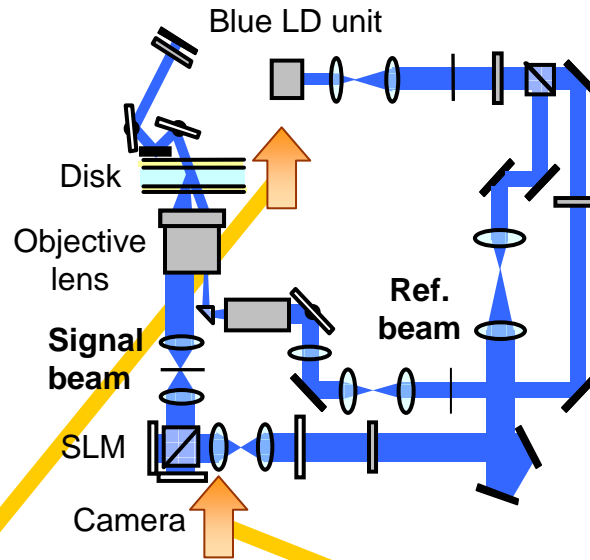
**Maximum unique noise**

**9.1%**

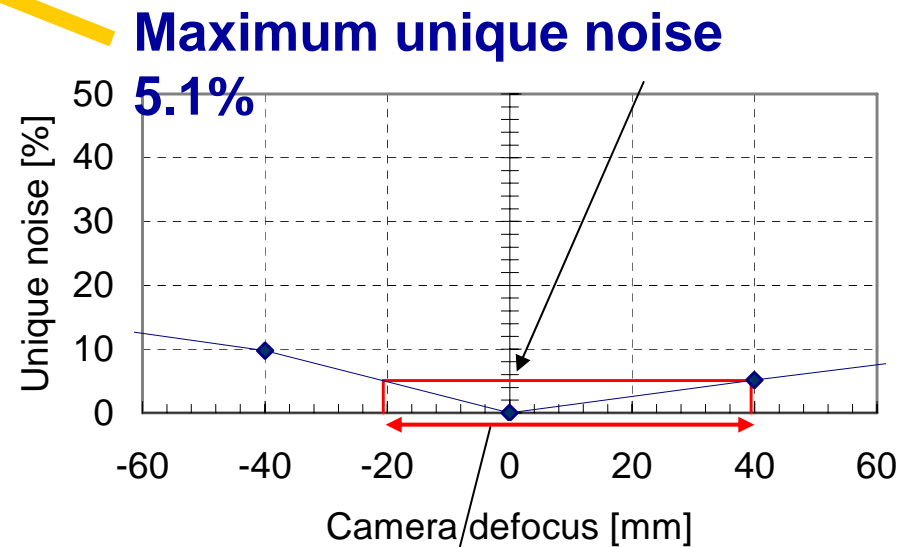


**Allocated margin  $\pm 5.0\mu\text{m}$**

# 4.2 Tolerance -Defocus ( Disk, Camera )

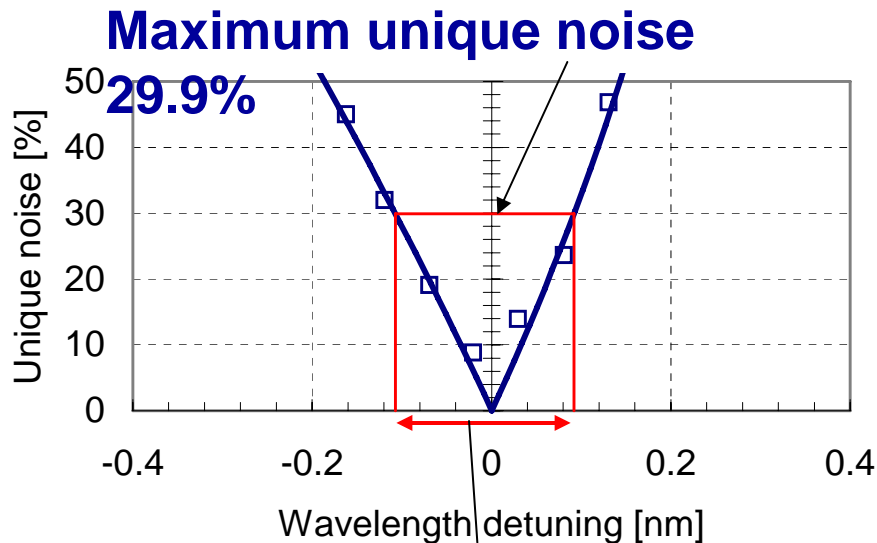
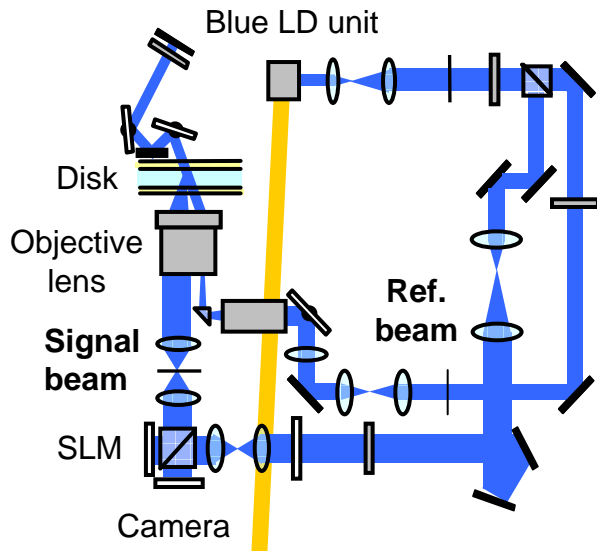


**Allocated margin  $\pm 12.0\mu\text{m}$**



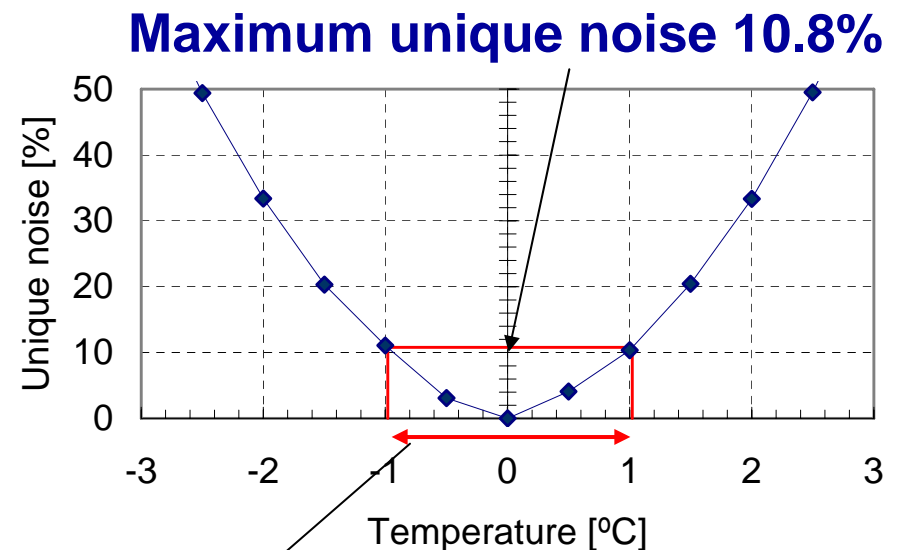
**Allocated margin  $\pm 30.0\mu\text{m}$**

# 4.2 Tolerance -Wavelength detuning and Temperature



**Allocated margin  $\pm 0.100\text{nm}$**

Exceptionally simulated result

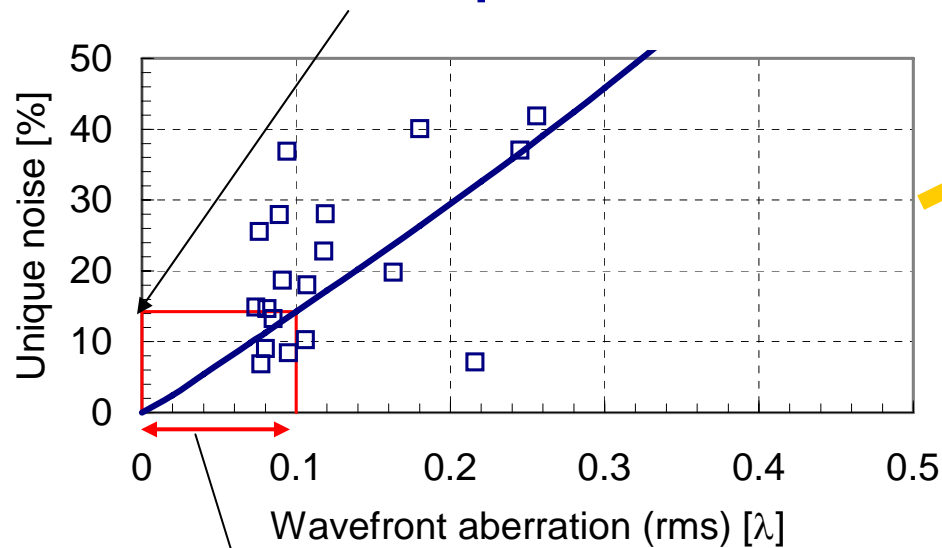


**Allocated margin  $\pm 1.0\text{ °C}$**

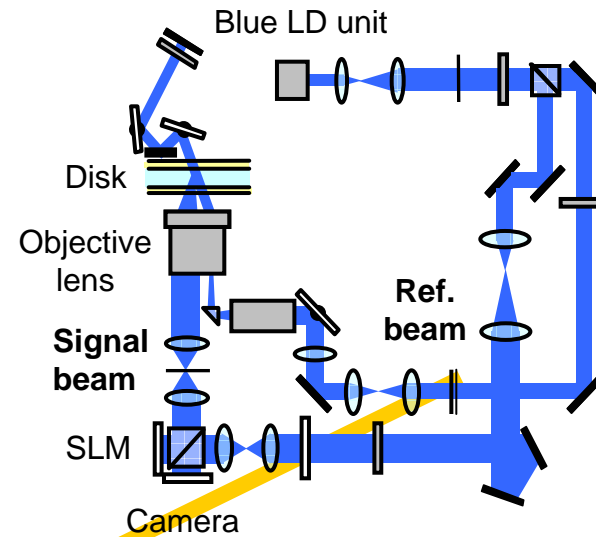
## 4.2 Tolerance -Wavefront aberration

Reproduced with phase plates  
which have various aberrations

**Maximum unique noise 14.2%**



**Allocated margin  $\pm 0.1\lambda$**



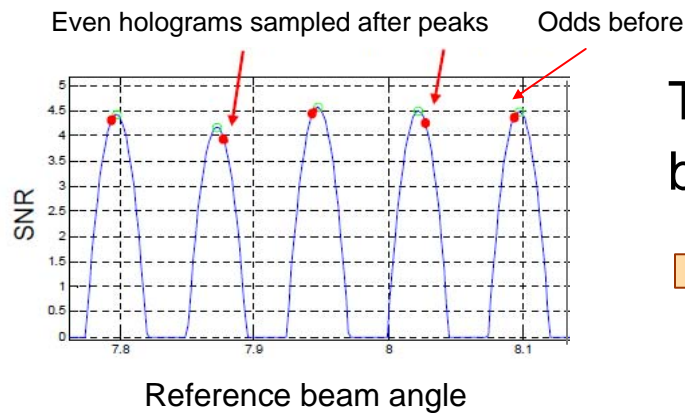
# 4.3 Margin Allocation Result

	Margin	Unique noise [%]	BD margin
Under optimum condition (DC noise)	-	$\sigma_0$ 75.0	
Reference beam angle displacement	$\pm 0.0050$ [deg]	$\sigma_1$ 17.9	
Disk tilt in Bragg direction	$\pm 0.0050$ [deg]	$\sigma_2$ 19.2	$\pm 0.2$ deg
Disk tilt in radial direction	$\pm 0.0150$ [deg]	$\sigma_3$ 16.1	$\pm 0.1$ deg
Tangential detrack	$\pm 5.0$ [ $\mu\text{m}$ ]	$\sigma_4$ 8.6	
Radial detrack	$\pm 5.0$ [ $\mu\text{m}$ ]	$\sigma_5$ 9.1	
Disk defocus	$\pm 12.0$ [ $\mu\text{m}$ ]	$\sigma_6$ 10.0	
Camera defocus	$\pm 30.0$ [ $\mu\text{m}$ ]	$\sigma_7$ 5.1	
Wavelength detuning	$\pm 0.100$ [nm]	$\sigma_8$ 29.9	
Temperature	$\pm 1.00$ [ $^{\circ}\text{C}$ ]	$\sigma_9$ 10.8	$\pm 25$ $^{\circ}\text{C}$
Wavefront aberration (rms)	0.100 [ $\lambda$ ]	$\sigma_{10}$ 14.2	
Total	-	RSS 89.8 <i>Within the limit</i>	

**Tighter than traditional ODD,  
but can be controlled with wobble servo technique**

# 4.3 Wobble Servo Technique

Mark R. Ayres, et al, "Wobble alignment for angularly multiplexed holograms,"  
Tech. Digest of ISOM/ODS'08, ThC.



Track hologram angle during read-out by introducing a small alternating angle offset

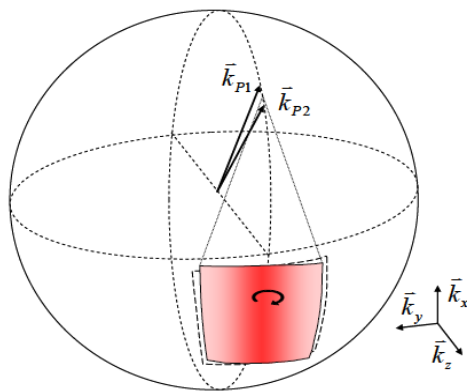
➡ **Disk tilt in Bragg control**

Disk tilt in radial (pitch) causes horizontal shift of intensity centroid

➡ **Disk tilt in radial control**

Wavelength detuning causes vertical shift of intensity centroid

➡ **Wavelength/Temperature control**



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# 5. Conclusion

A new signal quality metric called normalized noise and a novel margin allocation technique were developed.

 **Useful for product design  
in page based holographic memory system**

Margin allocation for 500GB holographic memory system using Monocular architecture was performed.

 **Each designed margin is realistic and achievable.**