（IDW ’17, VHF4-1 に 補足）

動画表示画質：視覚的側面、要求条件、および8K 120Hz LCDによる画質評価

Moving Image Quality: Visual Ergonomics, Requirements and Evaluation with an 8K 120 Hz LCD

栗田泰市郎

NHKメディアテクノロジー

Taiichiro Kurita, NHK Media Technology, Inc.

Ryutaro Oke*, Junichi Maruyama* and Satoshi Mima**

* Co-authors at IDW ‘17, Panasonic Liquid Crystal Display

** Co-author at IDW ‘17, Keisoku Giken

背景

- ✓ テレビ映像システムは、空間解像度、すなわち画素数を、アナログ／SDTVの525, 625から、HDTVの2K (1080), UHDTVの4K, 8Kと増加させることにより進歩してきた
- ✓ 2020年の東京オリンピックは、極めて臨場感の高い8Kスーパーハイビジョンでも放送される予定
- ✓ しかし、4K, 8Kの動画表示性能は、従来のシステムに比べてあまり改善されていない。フレーム周波数が60Hz, 50Hzにとどまっているからである
- ✓ そのようなフレーム周波数では、動画において大きな動きぼやけを生じ、UHDTVの高画素数のメリットが失われる
- ✓ UHDTVの規格であるITU-R BT.2020では、フレーム周波数として 120 Hz も規定されているが、まだあまり使われていない
- ✓ オリンピックのような動画表示性能が重要な映像コンテンツの放送においては、UHDTVの動画表示画質の改善が強く望まれる
- ✓ ここでは、映像システムの動画表示画質とその改善について述べさせていただく

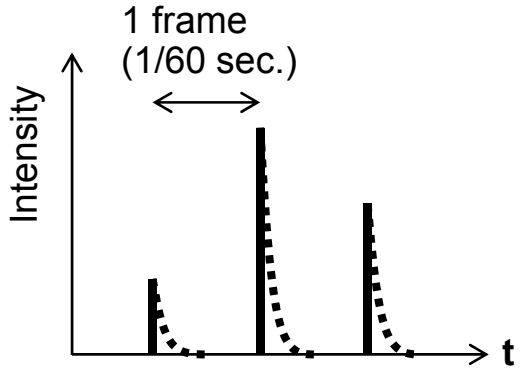
内容

1. 背景
2. ホールド型ディスプレイによる動きぼやけの視覚的側面
3. 良好な動画表示画質を得るための要求条件
4. 8K 120Hz LCDによる動画表示画質の評価
5. むすび

Visual Ergonomics of Motion Blur by Hold-type Display

- ✓ Active-matrix displays, such as AM-LCD and AM-OLED, inherently cause blur on displayed moving images, owing to their hold-type displayed light. They are also referred to as “hold-type display.”
- ✓ <u>The blur is caused by the hold-type displayed light and light integration in our eye.</u>

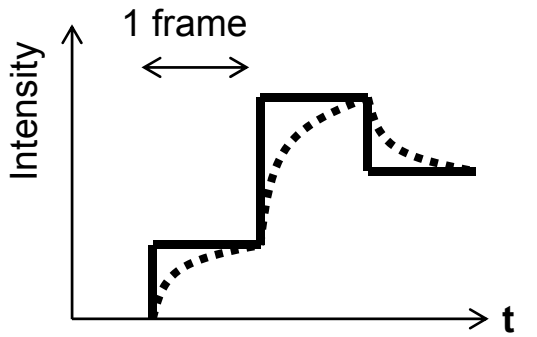
Waveforms of displayed light



CRT (impulse-type)

Displayed moving image
(without blur)

(If this picture is horizontally scrolled,)

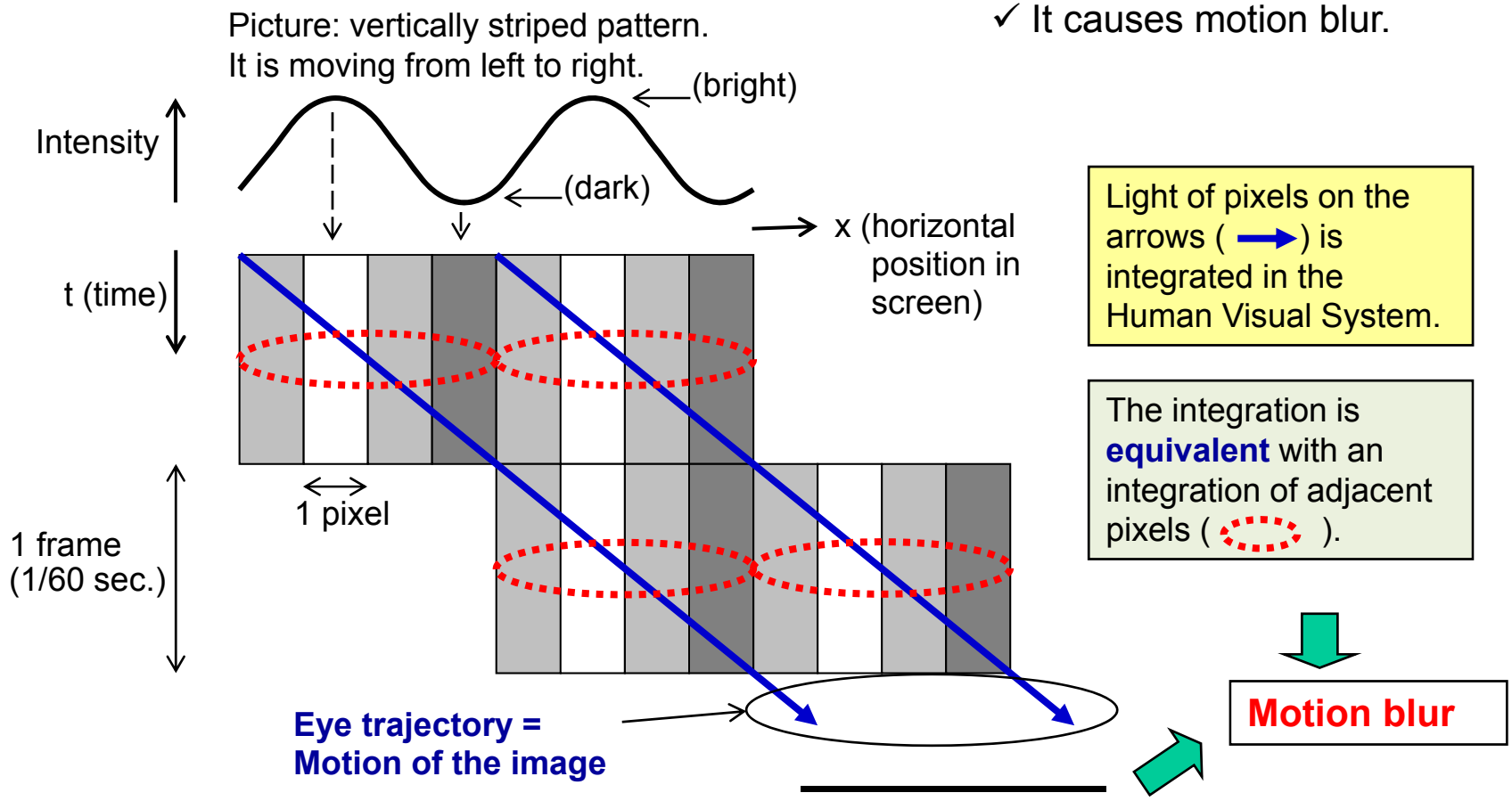


AM-LCD/OLED (**hold-type**)

Displayed moving image
with **motion blur**

Visual Integration of Hold-type Displayed Light

- ✓ Eye pursuits motion of the displayed moving image.
- ✓ Eye integrates pixels along with trajectory of the pursuit eye movement.
- ✓ It causes motion blur.



Light of pixels on the arrows (→) is integrated in the Human Visual System.

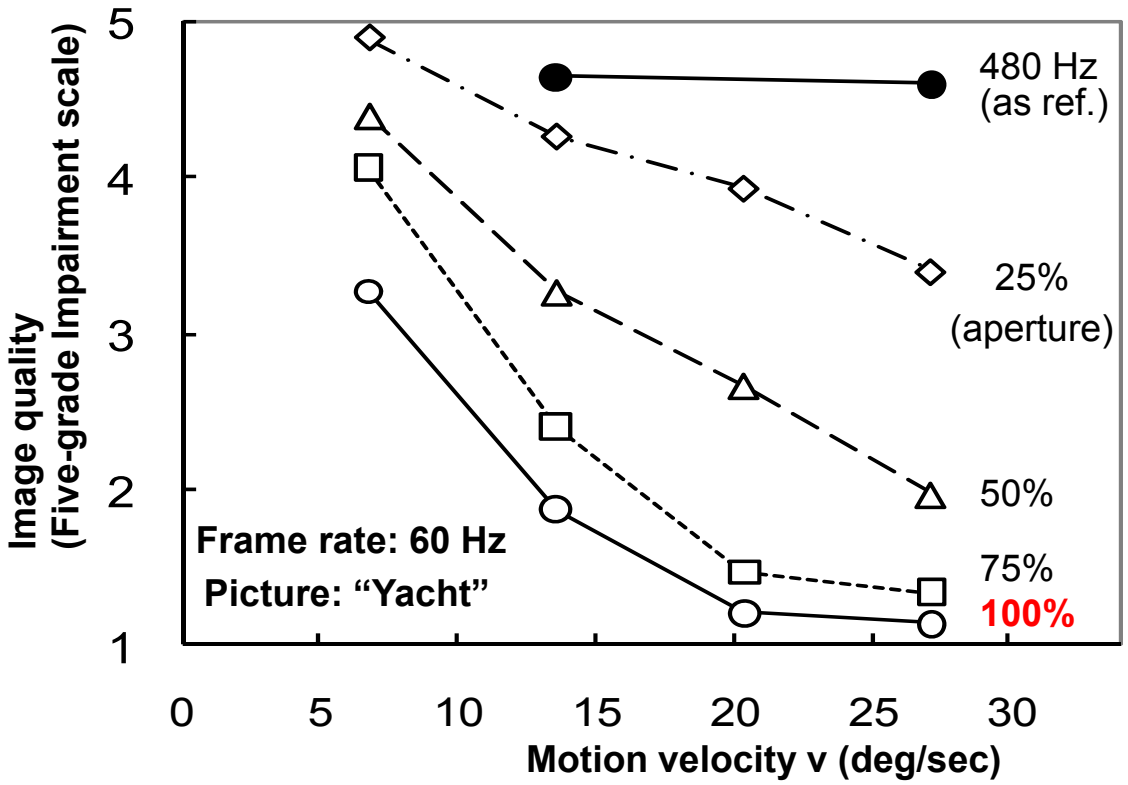
The integration is **equivalent** with an integration of adjacent pixels (⬭).

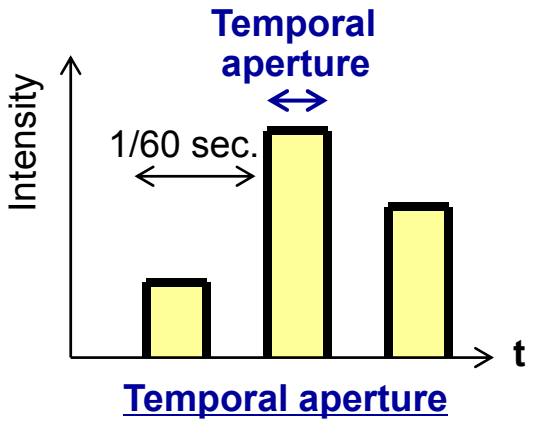
The mechanism is referred to as ***"Eye-tracing Integration"***.

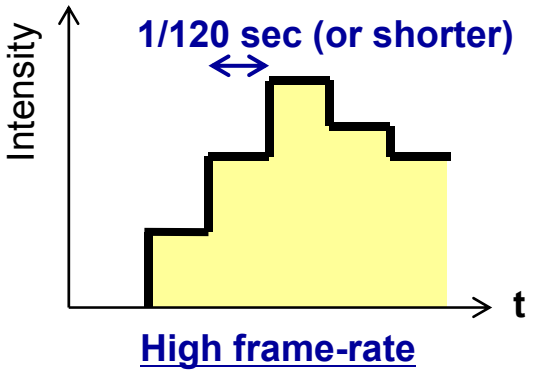
(Observed image: a constant gray)
The detailed image component is lost.

Image Quality and Improvement of Hold-type Display

- ✓ The moving image quality was confirmed with a subjective test using a 480 Hz CRT.
- ✓ **The motion blur seriously deteriorates image quality**. Its improvement is essential.
- ✓ Two fundamental methods of the improvement were proposed [6];
  1) Setting a **temporal aperture** on displayed light
  2) **High frame-rate** display

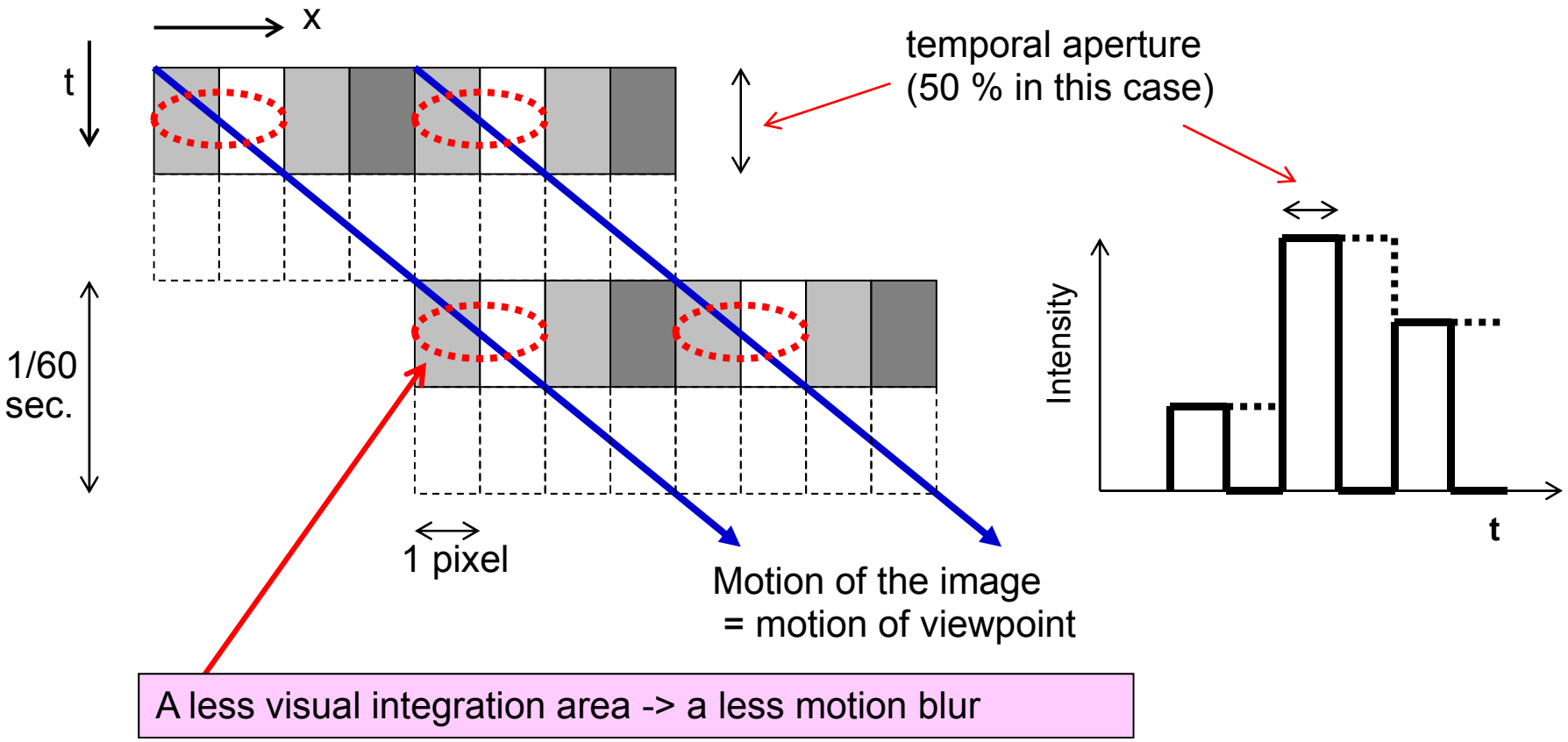






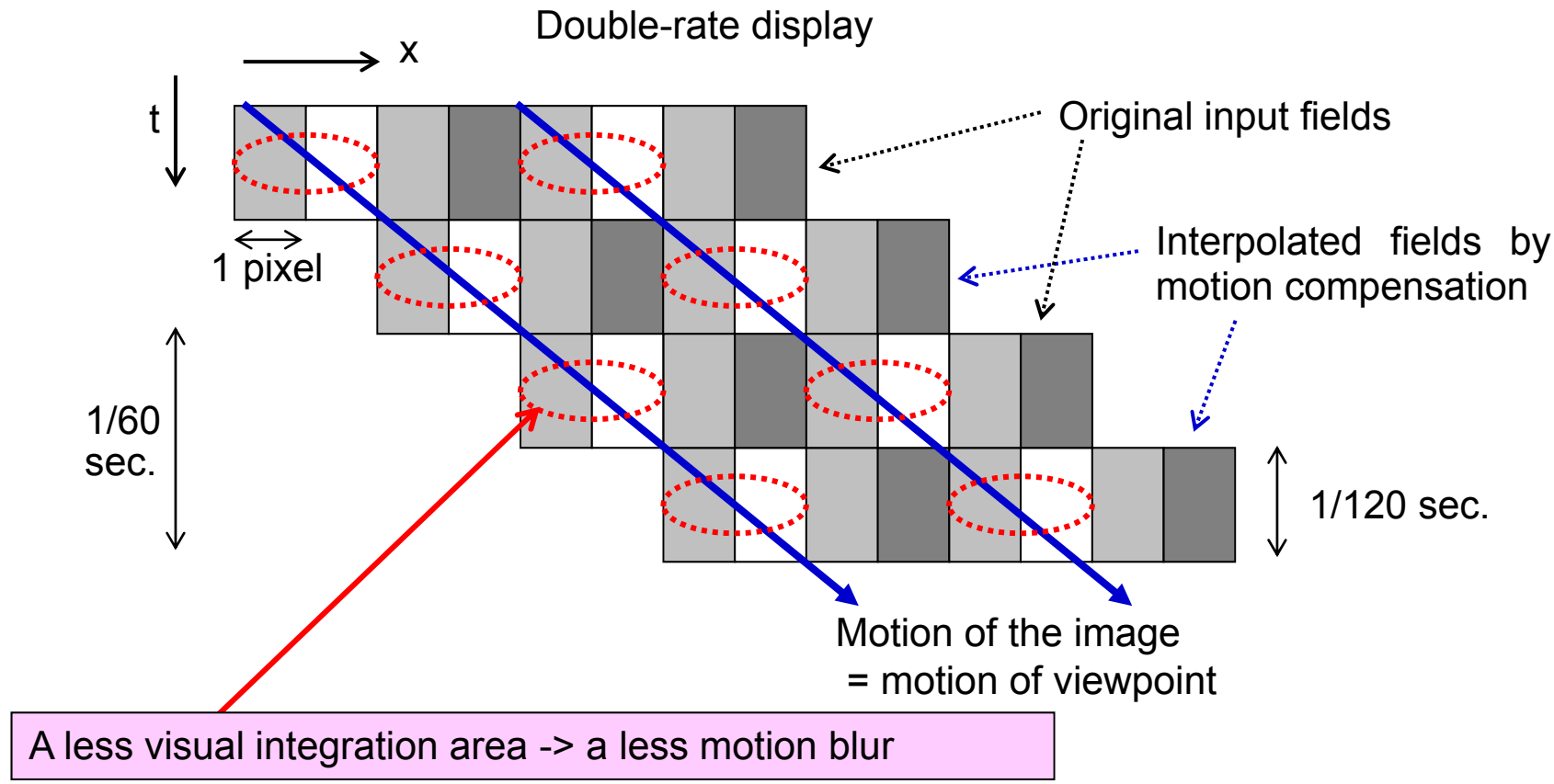
Improvement Method (1) – Temporal Aperture

◆ The integration in the visual system of the observer can be decreased by making the displayed light intermittent, or setting a temporal aperture.



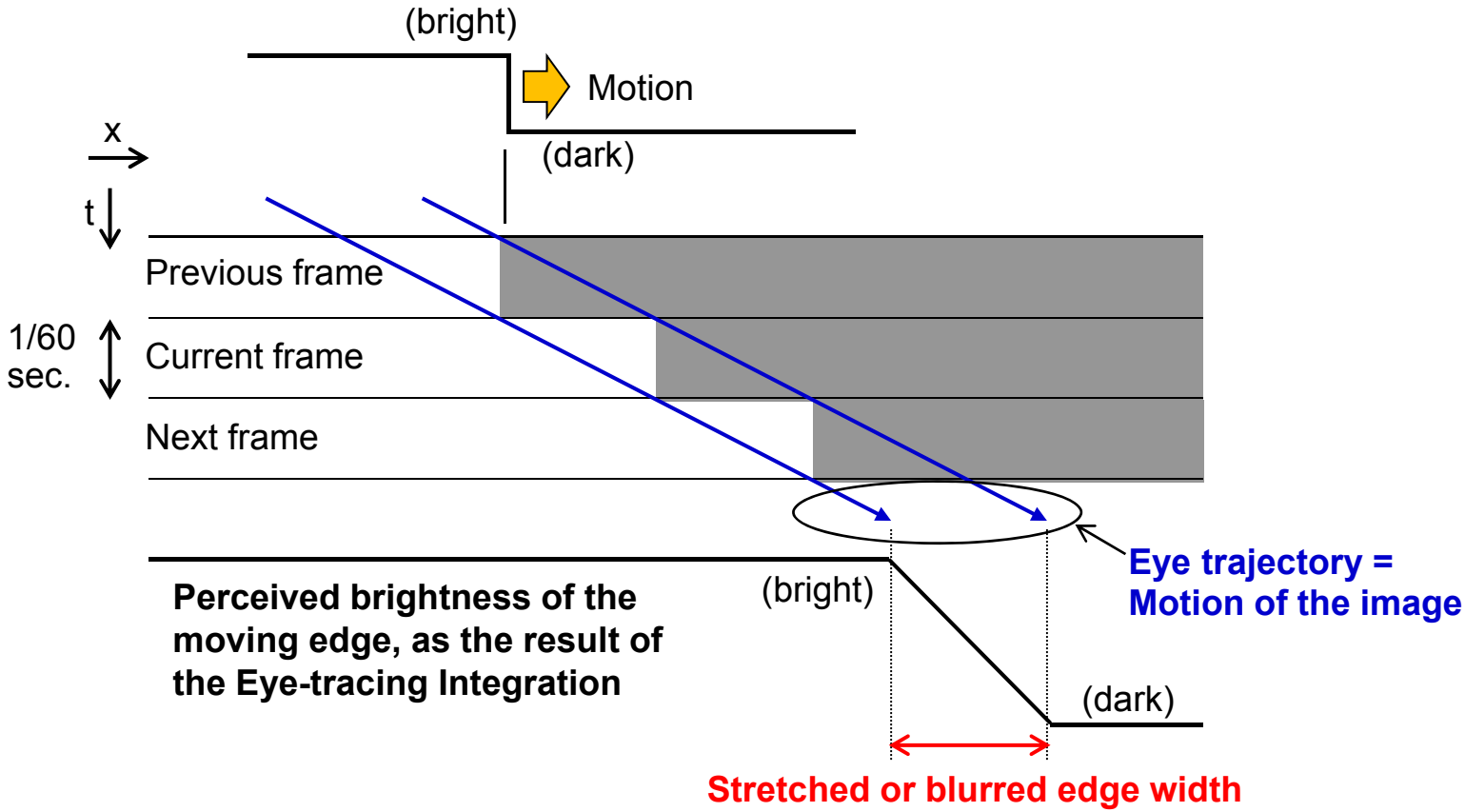
Improvement Method (2) – High Frame-Rate

◆ A method which does not reduce brightness is to display the image with a higher frame-rate. An example is double-rate or 120 Hz.



Edge Blur and Its Measurement Method

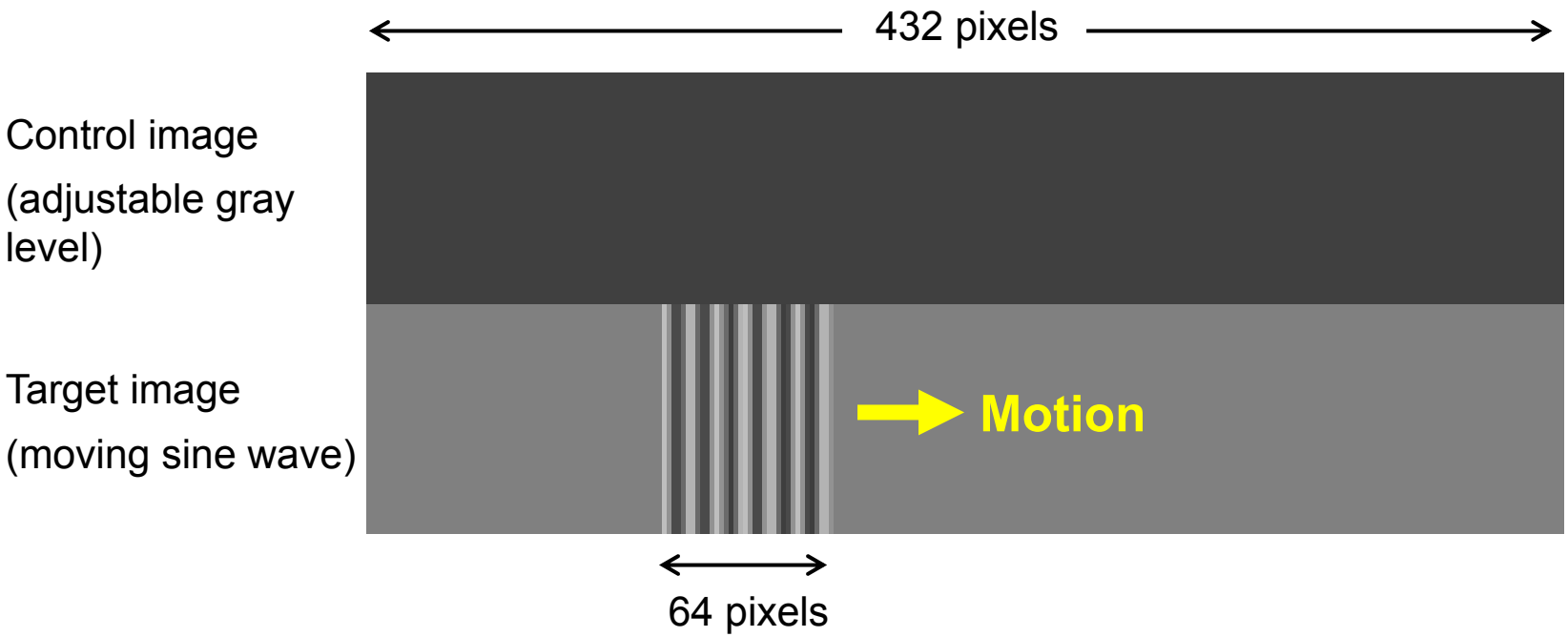
✓ The hold-type motion blur is also observed as edge blur on edge parts in moving images.



✓ This led to the developments of **MPRT** (Moving Picture Response Time) and other moving-edge-blur measurement methods.

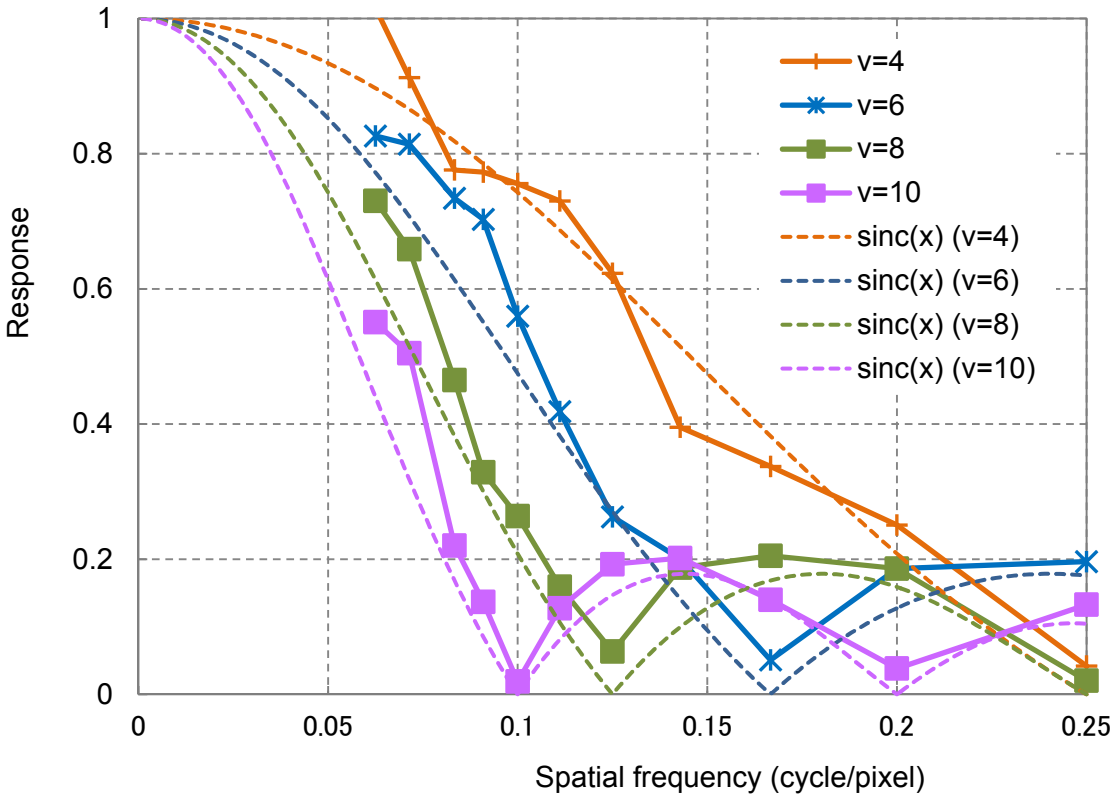
Measurement of Perceived Modulation (by 480 Hz CRT)

- The gray level of the control image is adjustable by the subject.
- The subjects were asked to adjust the level, so that the level of the control image is perceived to be the same as that of the white peak and black peak of the moving target image.
- The difference between the perceived white peak and black peak is the perceived modulation at the spatial frequency.



Effective MTF of Hold-type Display for Moving Images (re.)

- ✓ Effective MTF of hold-type display for moving images degrades along with a sinc function or sin(x)/x derived from the hold-type rectangular response of displayed light.
- ✓ Perceived MTF was measured by a psychophysical test [5].
- ✓ The result agreed well with the theoretical sinc function. **The eye-tracing integration is valid.**



- ✓ It was also confirmed that the visual integration works well at a frame rate of or over 48 Hz [7].

Perceived MTF of hold-type display for moving images (defined by peak-to-peak value)
(v: motion velocity (pixel/frame))

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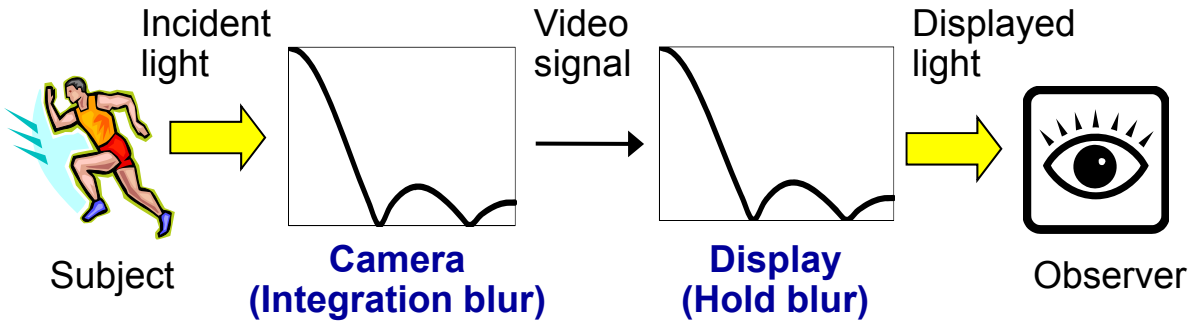
Requirements for High Moving-image-quality

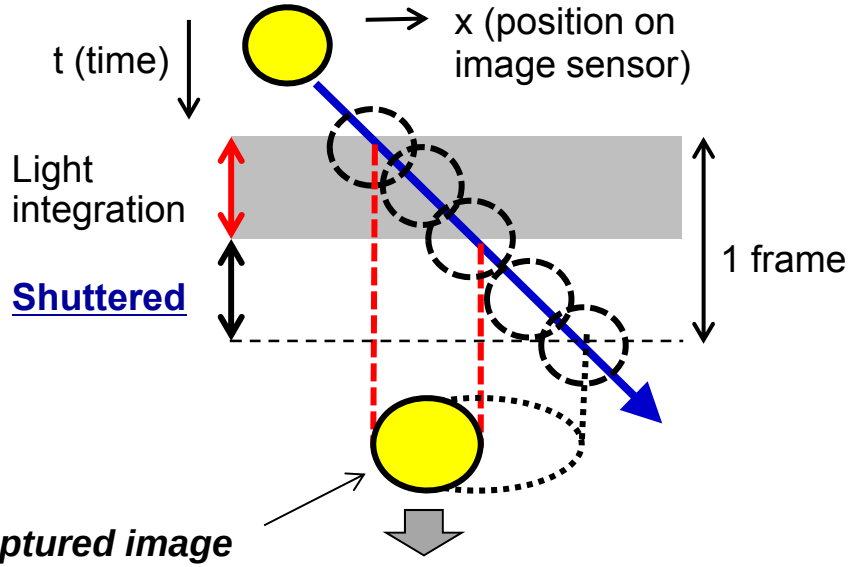
- ✓ Motion blur arises not only in display, but also in video camera.
- ✓ Motion blur in camera is referred as to “integration blur”, which is caused by light integration in image sensor in the camera.
- ✓ Effective MTF of camera for moving images also degrades with a sinc function.
- ✓ Two sinc functions are cascaded in a video system, as shown in the figure.
- ✓ Overall image quality of the system is dominated by the worse MTF.
- ✓ Therefore, **motion blur in camera and display must be both improved to obtain high moving-image-quality**.



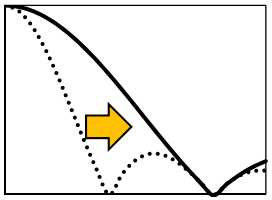
Motion blur in a video system

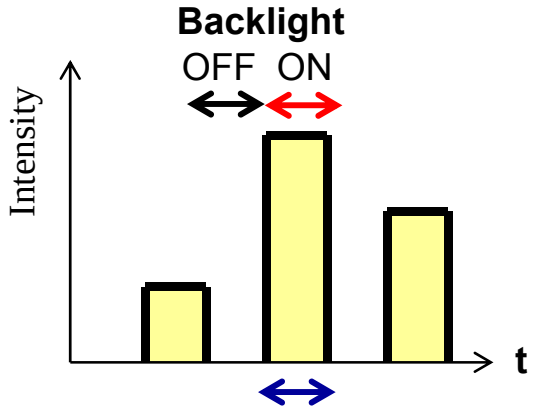
Implementation of Moving-image-quality Improvement

- ✓ Shortening light-integration time in image sensor and the visual system is necessary to improve the motion blur or moving image quality.
- ✓ It is achieved by increasing frame rate and/or setting a temporal aperture for the light integration within a frame period.
- ✓ The latter is implemented by **a shutter in camera**, **backlight flashing** in AM-LCD, and black-insertion driving in AM-OLED.

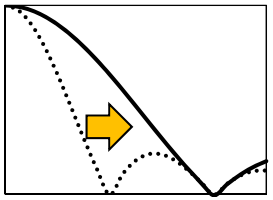


Captured image
The blur is improved.



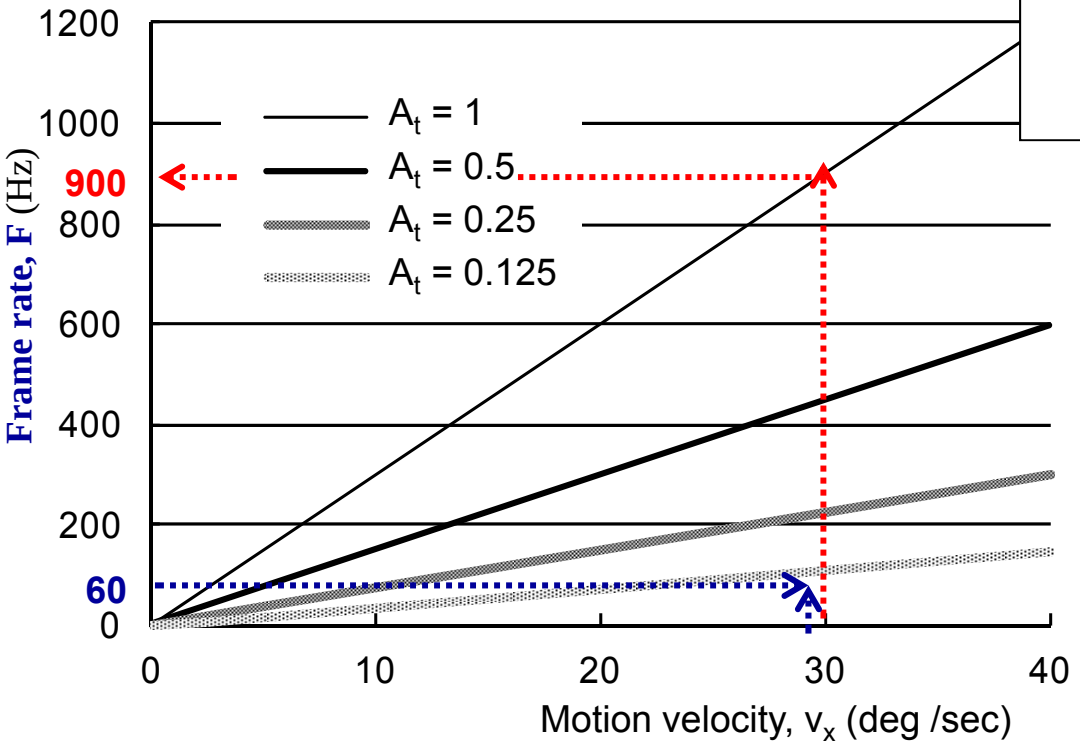


The blur is improved.



A Desired System Parameters

- ✓ What are the target of the common system parameters for good motion-image-quality?
- ✓ Our eyes can trace motion objects up to around 30 degree /second.
- ✓ **Very high-spec parameter values are required** to maintain an effective dynamic response up to the maximum spatial frequency of the system, **at 30 deg/sec**.
  (e.g., 4320 TV lines for 8K)



Frame rate required for good dynamic response.

✓ **$F = 30 \cdot v_x \cdot A_t$**
F: frame rate (Hz)
v_x: motion velocity (deg /sec)
A_t: temporal aperture ratio (to a frame)

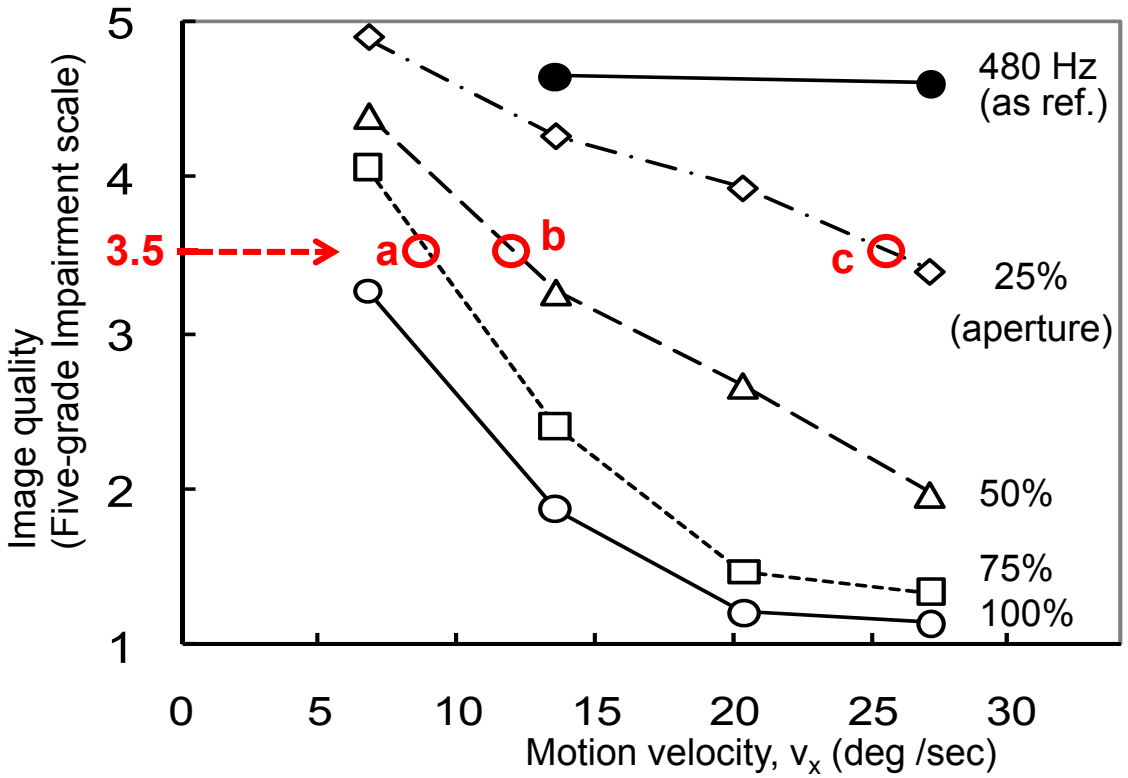
For the case without temporal aperture:
An extremely high frame rate of **900 Hz** is required.

For the case of 60 Hz frame rate:
An extremely small aperture of **1/15** is required.

- ✓ These requirements seem not to be realistic on system design.
- ✓ **An adequate compromise will be necessary**

A Compromised Quality Based on Acceptable Limit (1)

- ✓ An idea of the compromise:
  - **Setting the target to acceptable limit (AL)** of motion-image-quality deterioration.
- ✓ New relation is derived by **extracting the pairs of motion velocity and "aperture time" T_a** (= At/F), **corresponding to AL**.



Frame rate: 60 Hz

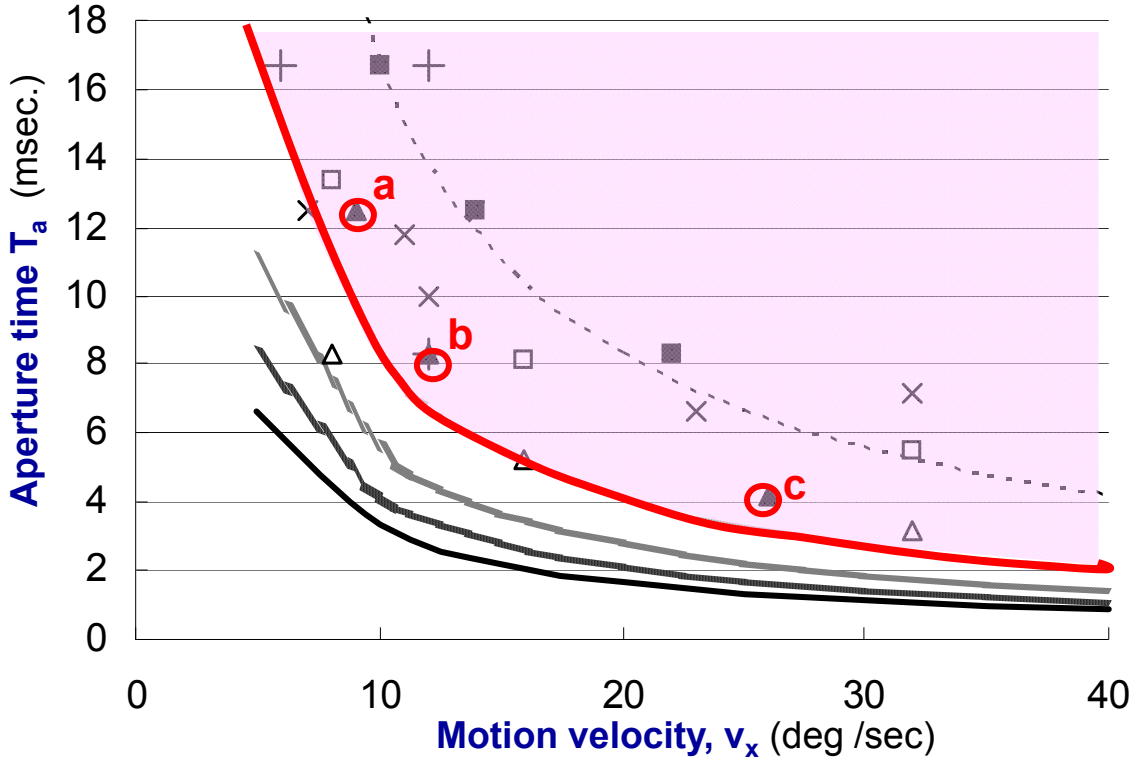
Picture: "Yacht"

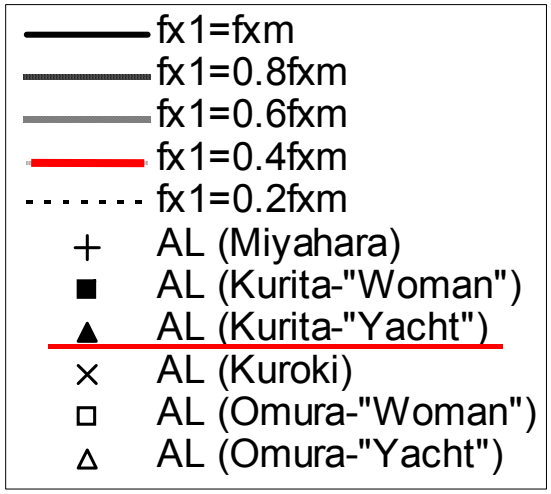
A critical picture for motion blur

A Compromised Quality Based on Acceptable Limit (2)

✓ The data for the acceptable limit were extracted from the several results of subjective evaluation for motion-image quality.

- Set the frame rate as $F = \alpha \cdot 30 \cdot v_x \cdot A_t$ (α= 0 to 1)
- Select the α adequately.



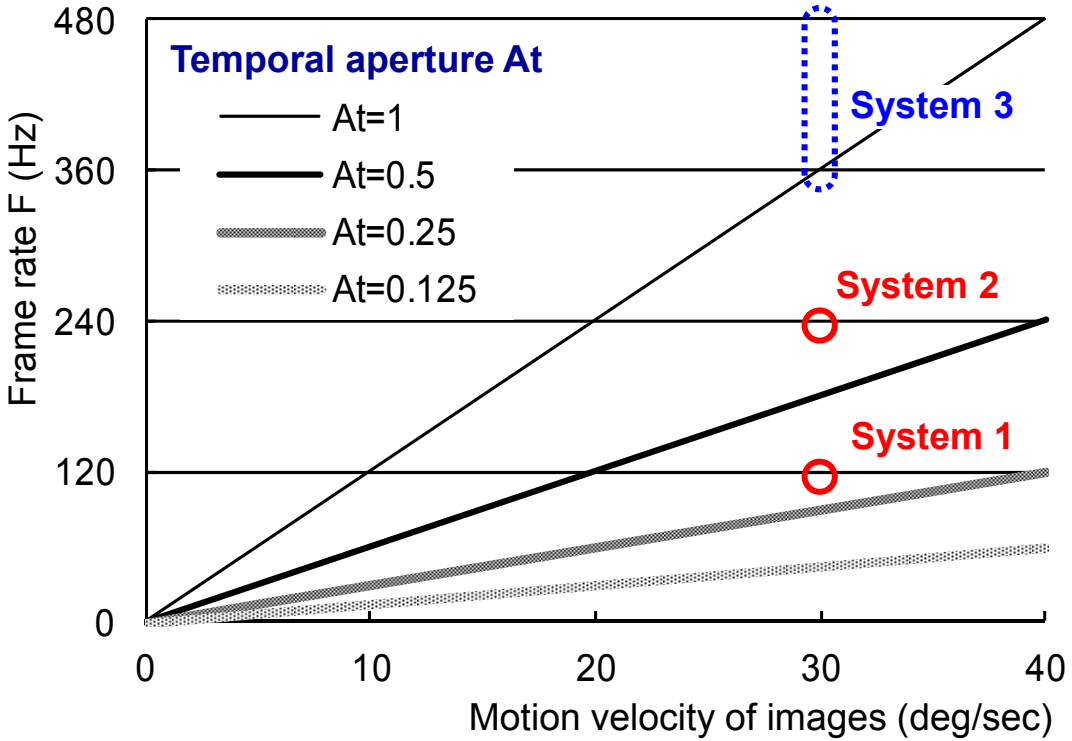


An adequate value:
α = 0.4

$F = 0.4 \cdot 30 \cdot v_x \cdot A_t$

Required Parameter Values

- ✓ Required frame-rate and temporal-aperture to achieve acceptable moving-image-quality were derived from previous results of subjective tests on moving image quality [11].
- ✓ Those depend on motion velocity of moving images. Human eyes can trace moving objects up to around 30 degrees per second [8].
- ✓ Possible sets of the frame rate F and temporal aperture A_t to achieve good motion-image-quality are obtained from the figure.



Examples of desired system parameters

System 1: F = 120 Hz, A_t = 1/3.
System 2: F = 240 Hz, A_t = 2/3.
System 3: F ≥ 360 Hz, A_t = 1.

✓ **Setting a temporal aperture at a frame rate below 100 Hz is not acceptable, because stroboscopic motion and/or flicker may be observed on displayed picture [9] [12].**

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Moving-image-quality Evaluation with an 8K 120Hz LCD

- ✓ CRTs, of which pixel count is 2K or below and screen size is 24-inch or below, were used as the display for the subjective evaluation in the previous researches.
- ✓ Conducting a subjective evaluation test on moving image quality, using a latest FPD with a high pixel-count and large screen, will be meaningful. We conducted it.

Apparatus used in the Test

- ✓ We used 8K 120 Hz equipment in our test.
- ✓ Video Recorder: Four synchronized Keisoku Giken UDR-40S
- ✓ Display: 55-inch 8K 120 Hz IPS-LCD [13]. The LCD used in our test was customized to enable backlight flashing.

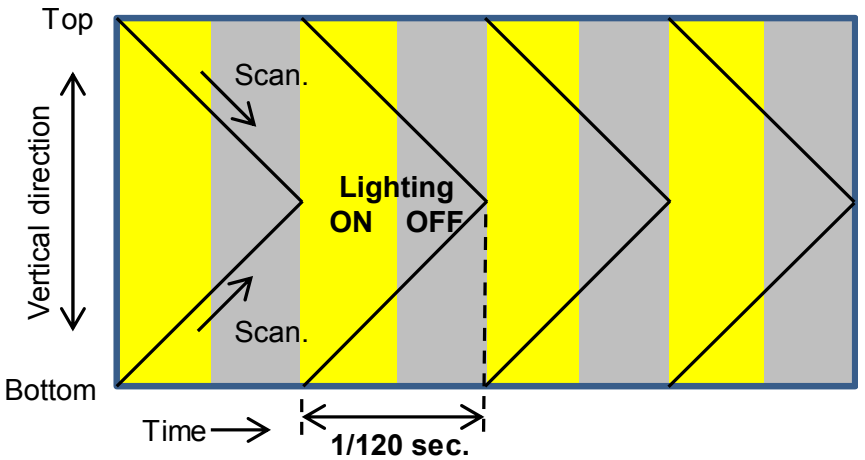
Keisoku Giken UDR-40S × 4

8K 120 Hz Video

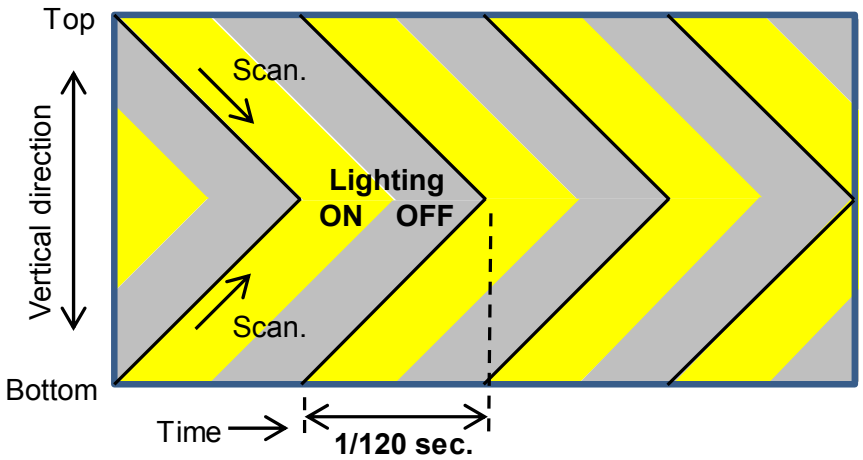
Panasonic LD
55” 8K 120 Hz IPS-LCD

Backlight Flashing to Set a Temporal Aperture

- ✓ There are two backlight flashing methods as is known, blinking backlight and scanning or scrolling backlight.
- ✓ Data lines of the IPS-LC panel are separated into upper and lower halves, and they are driven or scanned simultaneously.
- ✓ The figures illustrate those examples of the temporal-vertical relation between the split panel-scanning and backlight flashing.
- ✓ **The blinking backlight was used** in our test, because of practical limitation of the LCD, although the scanning backlight was preindicated to be better on moving image quality.



(a) Blinking backlight



(b) Scanning backlight

Methods of backlight flashing (examples)

Test Picture and Evaluation Method

- ✓ Test picture used in the test is an 8K (7680 × 4320) picture. The picture material is extracted from an 8K still picture of a landscape of Dubai city.
- ✓ The upper half of the picture is the part for evaluation. The part is horizontally scrolled.
- ✓ The lower half is the part for reference in the evaluation. It is not scrolled or a still picture with the same material as the upper half.
- ✓ Subjects evaluated image quality of the upper half, compared with the lower half.
- ✓ The evaluation scale was Five-grade Impairment Scale.

Test picture (a scroll of "Dubai")

Test Conditions

Item	Conditions	Remarks
Subjects	14 video experts	By practical limitation of the test
Relative viewing distance	1.2 H (H: picture height)	Absolutely 82 cm 0.75H was felt too much close to the 55” display. FoV: horizontally 73 degrees
Motion velocity “v” or the scroll speed	8 or 16 pixels per 1 frame of 120 Hz	10.6 or 21.0 deg/sec, respectively, observed at subjects

Setting of Temporal Aperture and Conditions

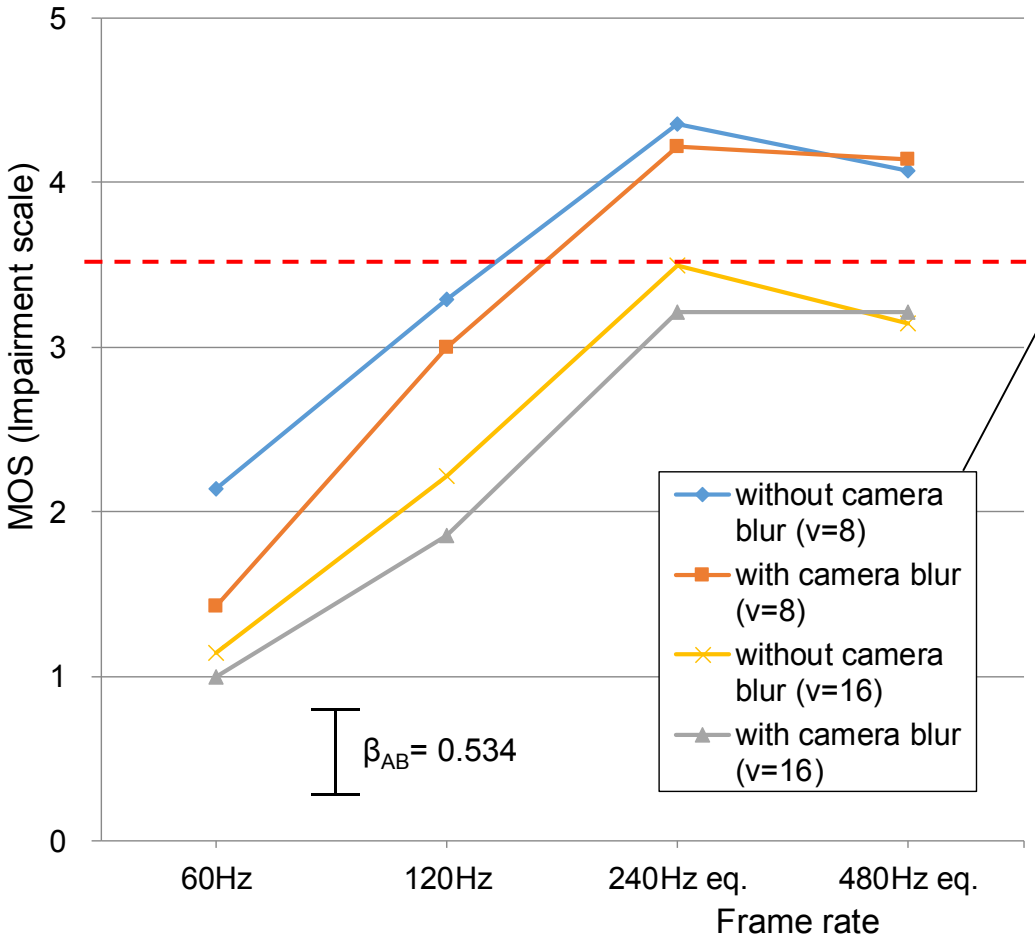
- ✓ Motion blur in camera was simulated on the test picture at some test conditions.
- ✓ Only the upper half of the test picture was blurred by image processing equivalent to light integration in image sensor, at those conditions.
- ✓ Temporal aperture in camera was set by simulation of camera shutter in the processing.
- ✓ Temporal aperture in display was implemented by the blinking backlight of the LCD.
- ✓ The video recorders and LCD operated with the frame rate of 120 Hz at all test conditions.
- ✓ Displayed pictures are simply repeated twice for every odd frame of 120 Hz, at the condition of “60 Hz”.
- ✓ Temporal apertures were set at the conditions of “240 Hz eq. (equivalent)” and “480 Hz eq.”. The apertures are 4.17 and 2.08 msec, respectively.
- ✓ LC response time of the LCD was around 6 msec and longer than those apertures. We optimally adjusted the blinking timing, so influence of the LCRT to moving image quality was minimized.

Temporal Aperture "A_t" of the LCD and Luminance

Condition	At (in msec)	Luminance of the LCD for 100 % White
60 Hz	1 (16.7)	400 cd/m^2
120 Hz	1 (8.33)	400 cd/m^2
240 Hz eq.	0.5 (4.17)	200 cd/m^2
480 Hz eq.	0.25 (2.08)	100 cd/m^2

- ✓ Luminance of the reference part in the test picture was the same as the evaluation part in the same picture, at the all test conditions.
- ✓ It is therefore considered that difference of luminance among the conditions little affected the results.

Scores for Various Temporal Apertures or Frame Rates



Result of the subjective evaluation test for various temporal apertures and frame rates

Remarks

"without camera blur"
The camera blur was not simulated on the evaluation part of the test picture.

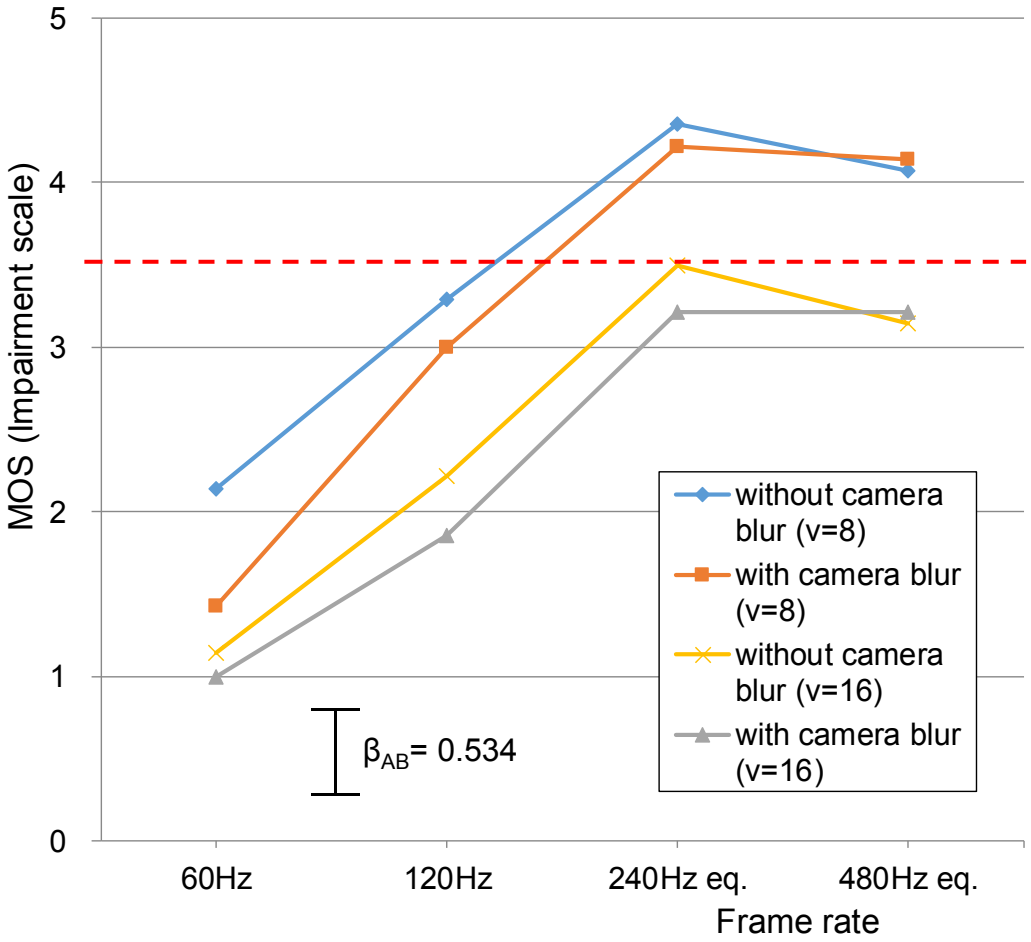
"with camera blur"
The camera blur was simulated.

β_{AB}
Yardstick between arbitrary two data points in the figure, for significant difference of image quality with 5% significant level or risk rate.

Five-grade impairment scale
(Deterioration of image quality is)
5: imperceptible,
4: perceptible, but not annoying,
3: slightly annoying
2: annoying, 1; very annoying

Dotted red line
3.5 on the Impairment Scale. It is referred to as **"acceptable limit"** of image-quality deterioration

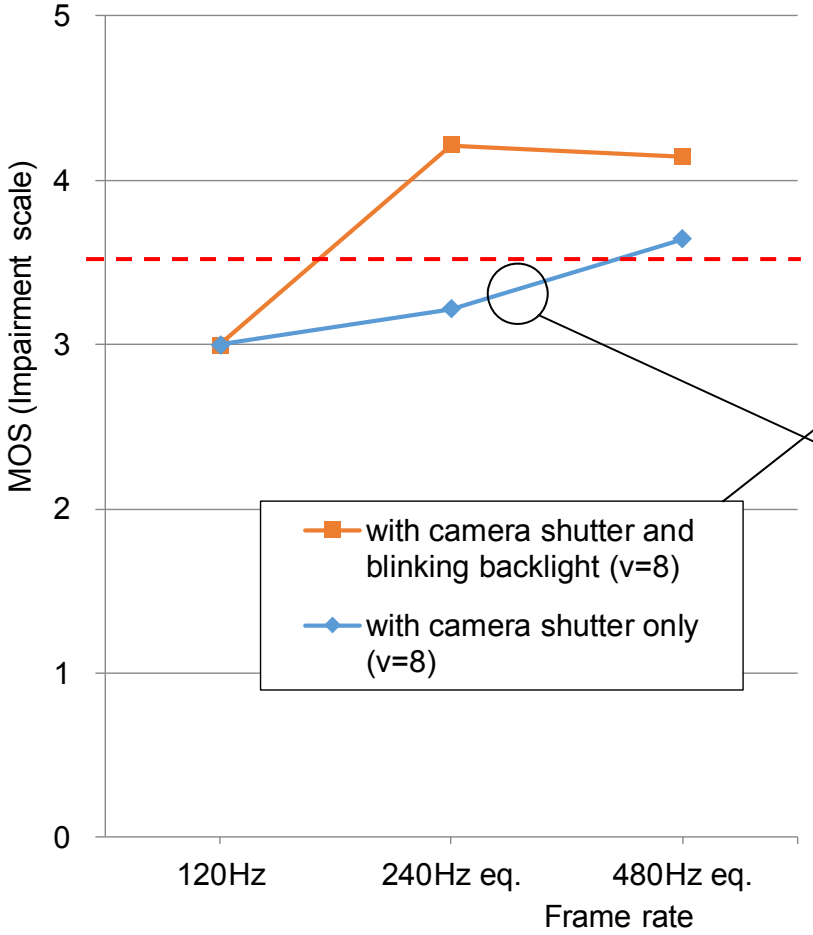
Discussion



Result of the subjective evaluation test for various temporal apertures and frame rates

- ✓ The MOS or resultant image quality increases almost linearly up to “240 Hz eq.” on all four curves in the figure.
- ✓ However, image quality at “480 Hz eq.” is saturated or slightly lower than “240 Hz eq.”.
- ✓ The reason is probably that the optimization of the backlight blinking timing had limitations by the short temporal-aperture of 2.08 msec and the rather long LCRT, so **the blinking caused some image artifacts**.
- ✓ Some subjects indeed claimed after the test that they observed some artifacts like double image or color bleeding at the condition “480 Hz eq.
- ✓ **If scanning backlight and a faster response LCD were used, image quality of “480 Hz eq.” would be better than “240 Hz eq.”.**
- ✓ There is **almost no significant difference** between the conditions “without camera blur” and “with camera blur.

Result with and without Blinking Backlight



Result of the subjective test with and without blinking backlight

"with camera shutter and blinking backlight"
The same as the "with camera blur" in the previous figure.

"with camera shutter only"
The blinking backlight was not used or the temporal aperture of the display was not set at the condition The hold time was constantly 1/120 second at this condition.

✓ **Effect of camera shutter** on moving-image-quality improvement **is small, if short temporal-aperture is not simultaneously used in display.**

むすび (1)

- ✓ 動画表示画質の視覚的側面と要求条件について簡単にレビュー
- ✓ Blinking backlight 付きの最新の 8K 120 Hz LCD を用いて行った動画表示画質の主観評価実験について報告
- ✓ 結果として、短い時間アパーチャと高フレーム周波数による動画表示画質改善の効果が、8Kシステムにおいても確認できた
- ✓ 良好な動画表示画質を得るためには、カメラとディスプレイ双方を改善する必要があることも確認した。
- ✓ しかし、今回用いたバックライト点滅法である blinking backlight では、動画表示画質の改善効果に限界があることも明らかになった

むすび (2)

- ✓ 今回の評価結果でも分かるように、単に120Hzにしただけでは、動画表示画質の改善は必ずしも十分ではない
- ✓ しかし、120 Hz は高い動画表示画質を得るための入り口である
- ✓ フレーム周波数を120Hzかそれ以上にしなければ、映像システムにおいて良好な動画表示画質を得ることはできないと考えられる
- ✓ カメラシャッターと、scanning backlight 付きの高速応答のLCD 、あるいは黒挿入駆動を行ったOLEDを用いれば、8K 120 Hz システムは高い動画表示画質を提供できると考えられる

ご清聴ありがとうございました

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