Mechanism analysis of Scintillation in Rear Projection TVs

Akihito KAGOTANI, Tomoyoshi KAIZUKA, Satoshi IWATA, Yuichiro SHIMIZU, Kohei MORONAGA, Susumu TAKAHASHI, Osamu MASUTOMI
Optical Device Research Laboratory
Technical Research Institute Toppan Printing Co., Ltd.
Phone: +81-[0]480-33-9050, E-mail: akihito.kagotani@toppan.co.jp

Abstract

Scintillation that is grainy patterns appeared on a screen has been one of a biggest issues in a rear projection TVs. In this paper, with focusing on the average size of random particle, it was proved that the particle size of calculated speckle and the one of measured scintillation are almost the equal. This result shows speckle phenomenon is an important factor of scintillation.

1. Introduction

A light source in a recent optical engine of Rear projection TV has high luminosity and a current rear projection screen is able to achieve high resolution which can correspond to HDTV [1] [2] [3]. But as a rear projection TV gets finer and a light source of a rear projection TV gets brighter, a grainy pattern of random intensity on the screen gets more remarkable. The grainy pattern is called scintillation. This phenomenon resembles speckle that can be seen when laser beam is irradiated to a diffuser such as a rough surface glass. Moreover, a new type rear projection TV which uses laser sources appears recently [4][5]. For this type of TVs, speckle phenomenon also become a big problem. In this paper a correlation of measured scintillation and calculated speckle was investigated with focusing on the average size of random particles.

2. Experimental

2-1. Theoretical speckle size

Phase of light wavelets from a light source are shifted randomly at the rough surface of a diffuser. A speckle pattern is generated by interference of those wavelets. The optical setup used to measured theoretical speckle size is shown in **Figure 1**. An average radius r_{sp} of particles in speckle pattern is given by[6]

$$r_{sp} \cong \frac{1.22\lambda L_1}{2D_i} \qquad 1)$$

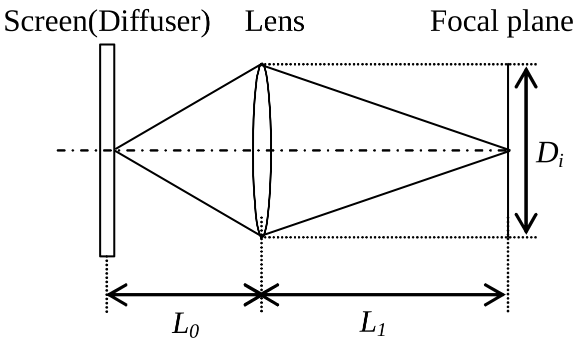


Figure1: Schematic diagram for calculation of theoretical particle size of speckle.

where $2D$ is diameter of a lens (iris diameter), L_0 is length from the screen to the lens. L_1 is length from the lens to the focal plane, λ is a wavelength. Relation between L_0 and L_1 is given by

$$M = \frac{L_1}{L_0} \qquad 2)$$

where M is called magnification of the lens.

As shown in equation 1), theoretical particle size of speckle pattern depends on the following parameters.

1, Wavelength of light source (λ)
2, Iris diameter (D_i)
3, Length from iris to focal plane (L_1)

With changing these three parameters, particle size of scintillation pattern was measured to compare the theoretical particle size of speckle.

2-2. Measurement setup of particle size of scintillation

Measurement setup of particle sizes of scintillation in rear projection TV is shown in **Figure 2**. A DLP projector (Sharp xv-z9000) which has UHP lamp inside was used. Scintillation patterns which appeared on the surface of the screen were collected on a 8-bit 768 × 494 pixel CCD camera (SONY XC-ST50) through the 4-fold magnification lens in which the pixel size is 8.4 × 9.8 μm. This optical system is basically the equivalent as the one shown in **Figure 1**. From the taken images, the particle sizes of the scintillation patterns were calculated with applying two dimensional autocorrelation function. The autocorrelation function C(x,y) is given by

$$W(x,y) = | FT[I(x,y)] |^2$$
$$C(x,y) = IFT[W(x,y)] \qquad 3)$$

where I(x,y) is intensity, W(x.y) is the Wiener spectrum, FT[] is the Fourier transform, IFT[] is the inverse Fourier transform. An average particle diameter of a granular structure in intensity I(x,y) can be estimated as first zero value of autocorrelation function C(x,y). However, the intensity I(x,y) contrast is too low to determine the first zero order value in a simply manner. Therefore, the value was alternatively determined as a zero value of a tangent line passing through a point where the derivative value is maximum.

3. Result & Discussion

Figure 3 is an example of a scintillation images taken with the optical set up shown in **Figure 2**. A typical speckle pattern is also shown for comparison. By applying taken images such as one shown in **Figure 3** to the equation 3), autocorrelation function was calculated to obtain the particle size of scintillation pattern. On the other hand, theoretical particle sizes of speckle patterns were simply calculated with the equation 1).

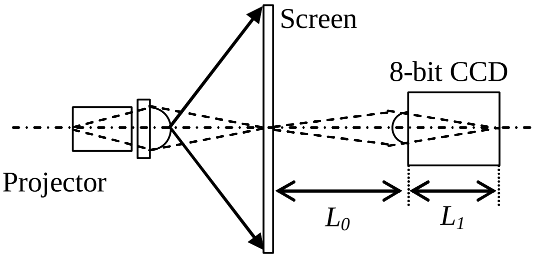
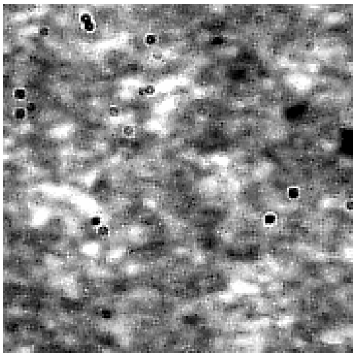
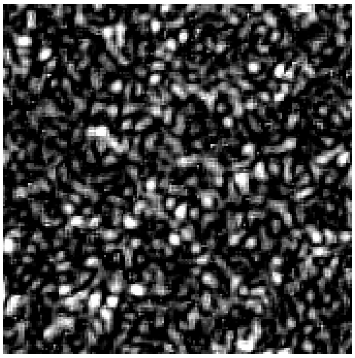


Figure 2: Optical setup used to measure Scintillation images in rear projection TV



a) Scintillation



b) Speckle

Figure 3: Typical photograph of a)Scintillation , b)Speckle

3-1 Wavelength dependence

Two wavelengths; λ 436 nm(blue), λ 548 nm(green) which are bright line in the light source were selected. The peak in the red region is too broad to use. The other parameters in the equation 3) are fixed as ; L_1 = 126.5 mm and D_i = 3.2 mm. **Figure 4** is autocorrelation function of scintillation images for each wavelength. C(x,0) is normalized convenience. From **Figure 4** the particle size of the scintillation was derived for each wavelength as shown in Table 1. The result shows that the measured particle sizes of the scintillation patterns and calculated speckle sizes are mostly same in each wavelength.

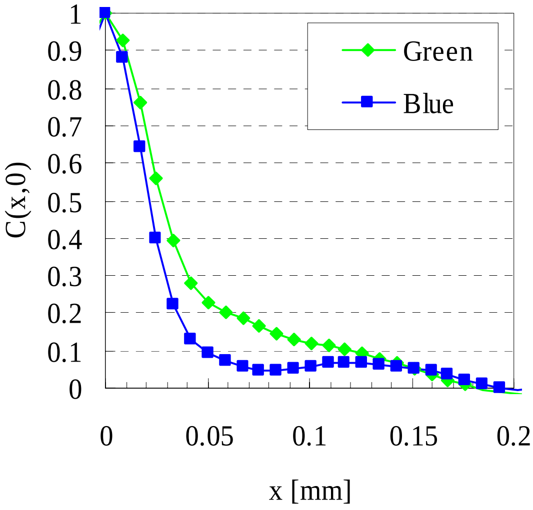


Figure 4: Autocorrelation function of Scintillation image with changing wave lengths. Note that the C(x,0) is normalized

Table 1: Comparison of the calculated particle size of speckle for different wavelengths and measured particle size of scintillation

	Wavelength(λ)	Speckle	Scintillation
Blue	436 [nm]	39.6 [μm]	39.0 [μm]
Green	548 [nm]	49.7 [μm]	49.0 [μm]

3-2 Iris diameter dependence

The iris sizes 5 mm, 3.5 mm, 2.5 mm and 1.7 mm were selected. The other two parameters were as follows. L_1=126.5 mm, λ=548 nm. **Figure 5** is autocorrelation function of scintillation images for each Iris diameter. As shown in Table 2, there is almost no difference in sizes between the measured scintillation and the calculated speckle.

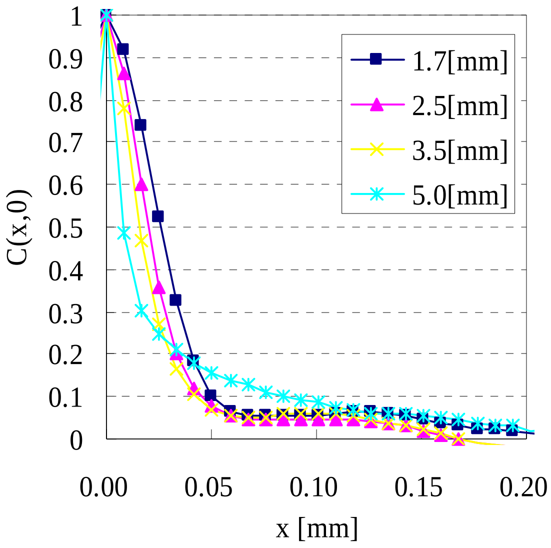


Figure 5: Autocorrelation function of Scintillation image with changing iris diameter.

Table 2: Comparison of the calculated particle size of speckle for different iris diameter and measured particle size of scintillation

D_i	Speckle	Scintillation
1.7[mm]	49.7 [μm]	48 .0 [μm]
2.5[mm]	33.8 [μm]	35.0 [μm]
3.5[mm]	24.2 [μm]	29.0 [μm]
5.0[mm]	16.9 [μm]	16.0[μm]

3-3 Distance dependence

With changing the distance from the iris to the focal plane (CCD) scintillation measurement and speckle calculation were performed under the condition; λ=548 nm, D_i=1.7 mm. **Figure 6** is autocorrelation function of Scintillation images. From the result shown in Table 3 the measured scintillation and the calculated speckle are almost the same again.

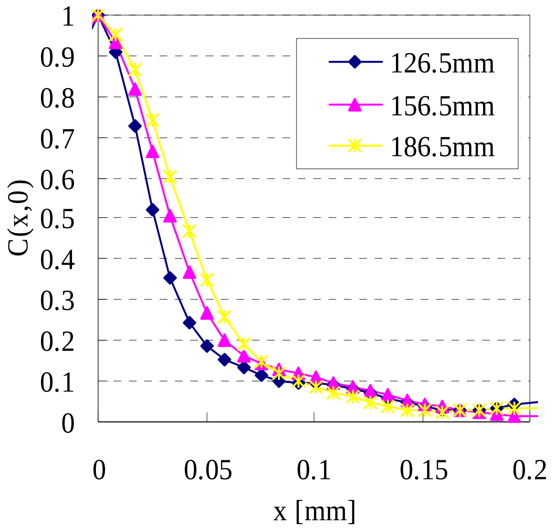


Figure 6: Autocorrelation function of Scintillation image with changing length from iris to focal plane.

Table 3: Comparison of the Speckle theoretical particle size and measured scintillation

L_1	Speckle	Scintillation
126.5 [mm]	49.7 [μm]	49.0 [μm]
156.5 [mm]	61.5 [μm]	62.0 [μm]
186.5 [mm]	73.3 [μm]	72.0 [μm]

4. Conclusion

A correlation of measured scintillation and calculated speckle were investigated with focusing on the average sizes of random particles. The results above revealed that measured particle size of scintillation and the particle size of speckle were almost the equal in each condition. It can be said that speckle phenomenon predominate as the cause of scintillation phenomenon. In other words reduction of Scintillation can be achieved in the same way as of speckle. As for speckle, it has been studied enough till now. We think it is possible to reduce speckle and scintillation in optical engines [5] [7].

5. References

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