Chapter 3

Physical Stimuli Analysis

3.1 Introduction

The mechanism of CBU phenomenon and the theory of the investigation and improvement methods have been already introduced in the previous chapters. From the framework outlined in chapter 1, the simulation model of CBU qualitative and quantitative analyses for realistic observe is then developed.

3.2 Modeling

The target of the model is to quantify CBU for matching the actual perceptual result under different physical conditions and to evaluate the viability of CBU in moving image under fixation view. The flow chart of each primary step in the simulation model, which simulates the signal processing in the visual system, is described in Fig. 3-1.

The simulation model has two phases. Phase one is physical stimuli analysis. The CBU effect is modeled by using several viewing conditions to predict perception of entire image with CBU. Phase two is psychophysical evaluation. The evaluation of CBU phenomenon is easy to be perceived or not by using a set of convenient apparatus. Accordingly, the indistinguishable value of evaluation index can be figured out by this model. Then, the simulation result will be used as the foundation to design the compensation algorithm. Experiment is performed to verify the simulation result and performance of CBU suppression. If the experiment result is acceptable, the compensated data are regarded as the input image. If not, we should go back to modify the simulation parameters or the compensation algorithm. Finally, the objective of the research is to apply this model to FSC LCD to improve the image quality.

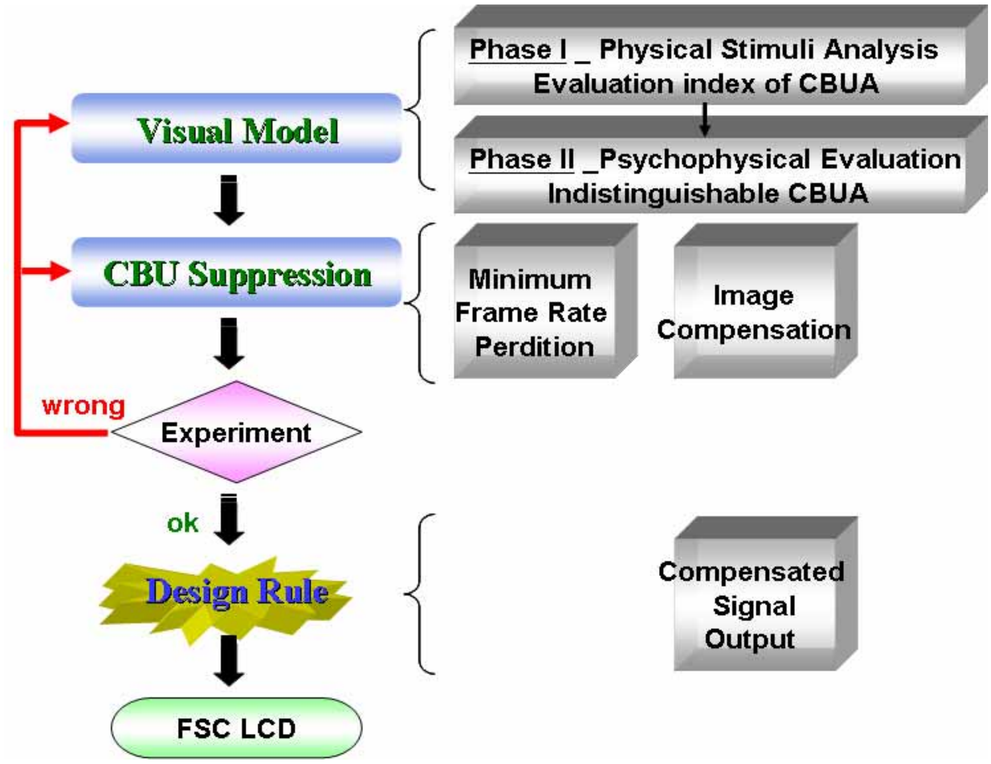


Fig. 3-1. The experiment flow chart of the proposed model for establishing a visual evaluation index of CBU.

3.3 Physical Stimuli Analysis

Before applying this visual model, the definition of the CBU quantification standard and certain considered parameters are required to be introduced. In our simulation model, Color Break-Up Angle, CBUA, the angle between target edge and color band along the moving direction, is the measurement of CBU. The definition of CBUA in this model follows following equation and shown in Fig. 3-2.

$$CBUA = \tan^{-1}\left(\frac{T}{2D} + \frac{V}{FD}\right) - \tan^{-1}\left(\frac{T}{2D}\right) \qquad (3\text{-}1)$$

where T is the target width of the test pattern (mm), D is the viewing distance between the object and observer (mm), V is the speed of the eye movement (mm/sec), and F is the field rate of the display (Hz). Based on eq. (3-1), simulation was performed to rudimentarily confirm the order of severity of the CBU in physical conditions.

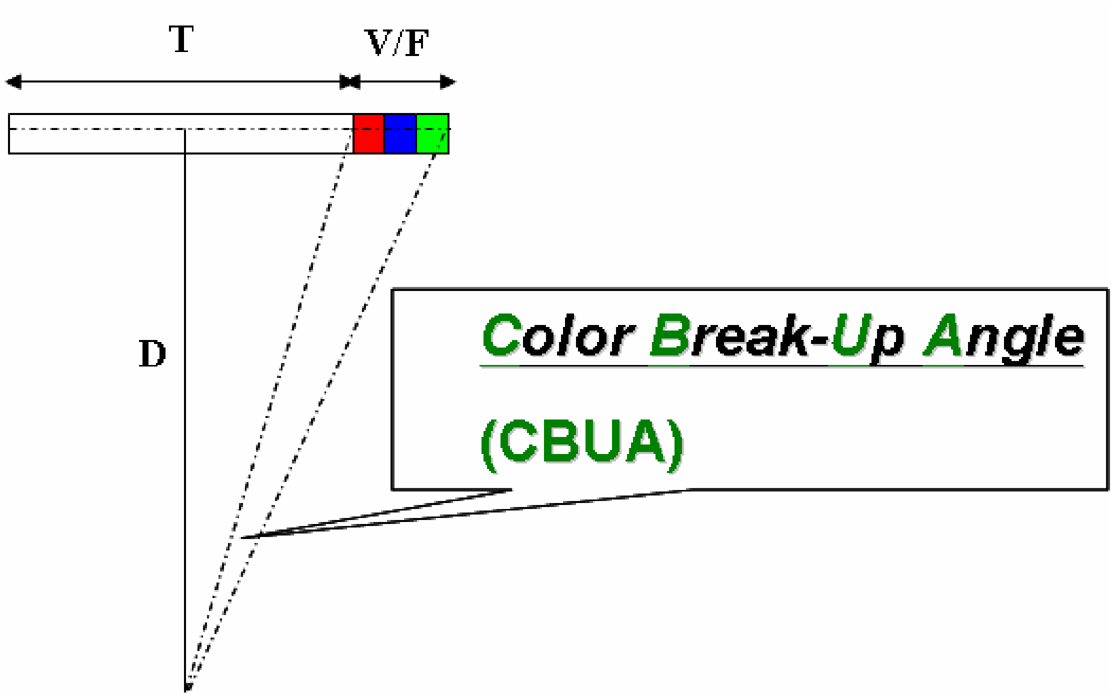


Fig. 3-2. The schematic definition of CBUA.

3.4 Measuring CBU

The main purpose of this experiment is to measure CBUA for verification of CBU on measurement devices in physical conditions. Therefore, the experiment apparatus and experiment process will be introduced in following section.

3.4.1 DLP Projection System

DLP projection is an excellent representation by using FSC method. It is an optical semiconductor known as the Digital Micro-mirror Device (DMD), or DLP chip. When a DLP chip is coordinating with a digital video or graphic signal, a light source, and a projection lens, its mirrors can reflect an all-digital image onto a screen or other surface. The whole structure is shown in Fig. 3-3.

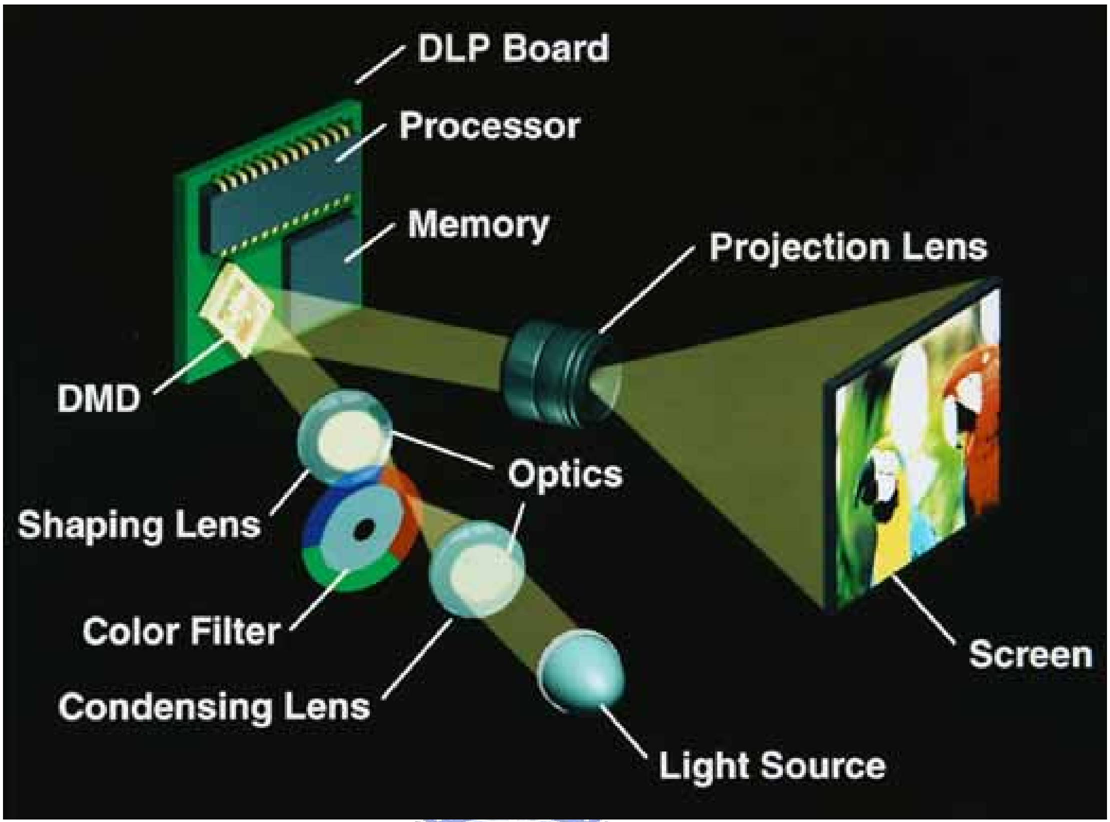


Fig. 3-3. One chip DLP projection system.

A DLP chip's micro-mirrors are mounted on tiny hinges that enable them to tilt either toward the light source in a DLP projection system (ON) or away from it (OFF)-creating a light or dark pixel on the projection surface. The bit-streamed image code entering the semiconductor directs each mirror to switch on and off up to several thousand times per second. When a mirror is switched on more frequently than off, it reflects a light gray pixel; a mirror that's switched off more frequently reflects a darker gray pixel. In this way, the mirrors in a DLP projection system can reflect pixels to convert the video or graphic signal entering the DLP chip into a highly detailed grayscale image. The single pixel of DMD is shown in Fig. 3-4.

Fig. 3-4. The structure of a single pixel of DMD and the relative light gray pixel.

The white light generated by the lamp in a DLP projection system passes through a color wheel as it travels to the surface of the DLP chip. The color wheel filters the light into red, green, and blue, from which a single-chip DLP projection system. The “on” and “off” states of each micro-mirror are coordinated with these three basic building blocks of color. For example, a mirror responsible for projecting a purple pixel will only reflect red and blue light to the projection surface; our eyes then blend these rapidly alternating flashes to see the intended hue in a projected image.

White light passes through a color wheel filter, causing red, green and blue light to be shined in sequence on the surface of the DLP chip. The switching of the mirrors reflects the gray light. The human visual system integrates the sequential color and sees a full-color image.

In this kind of DLP (Ben-Q Pb7220) projection system we used, the color wheel has four segments, red, green, blue, and white color fields. Added the white color field is mainly aimed to increase the luminance of the projection system. Then, the wheel at a 120 Hz field rate achieves color mixing in our eyes.

The mainly difference and the waveform diagram (time chart) of two types FSC displays were shown below.

	DLP projection	FSC LCD
Light Valve	DMD	OCB
Intensity Modulation	Time	Transmittance
Refresh	Whole plane / bit	Row by row
Response Time	~4 μs	3~4ms
Field Rate	480 Hz	180 Hz
Color Breakup Solution	2x or 4x frame rate	TBD

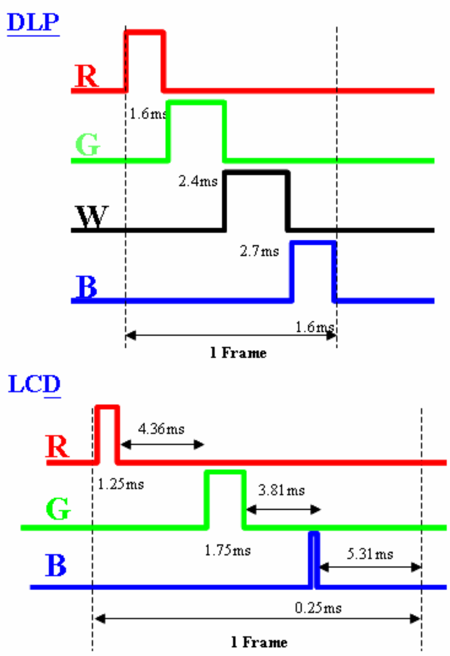


Fig. 3-5 Comparison the specification of DLP projection system with FSC LCD.

3.4.2 Digital Still Camera

In the CBU measurement system, the DSC is an essential equipment to capture the image with CBU. In fact, the image information mechanism of the DSC is similar to the human vision system. DSC generally uses a Color Filter Array (CFA) for arranging RGB color fields on a square grid of photo sensors over a Charge-Coupled Device (CCD). Each square of four pixels has one filtered red, one blue, and two green (the human eye is more sensitive to green than either red or blue). The result of this is that luminance information is collected at every pixel. Then, three color fields will integrate on image sensor and the colorful image can be perceived. The illustration of CFA of CFs on the pixel array of an image sensor is shown in Fig. 3-6.

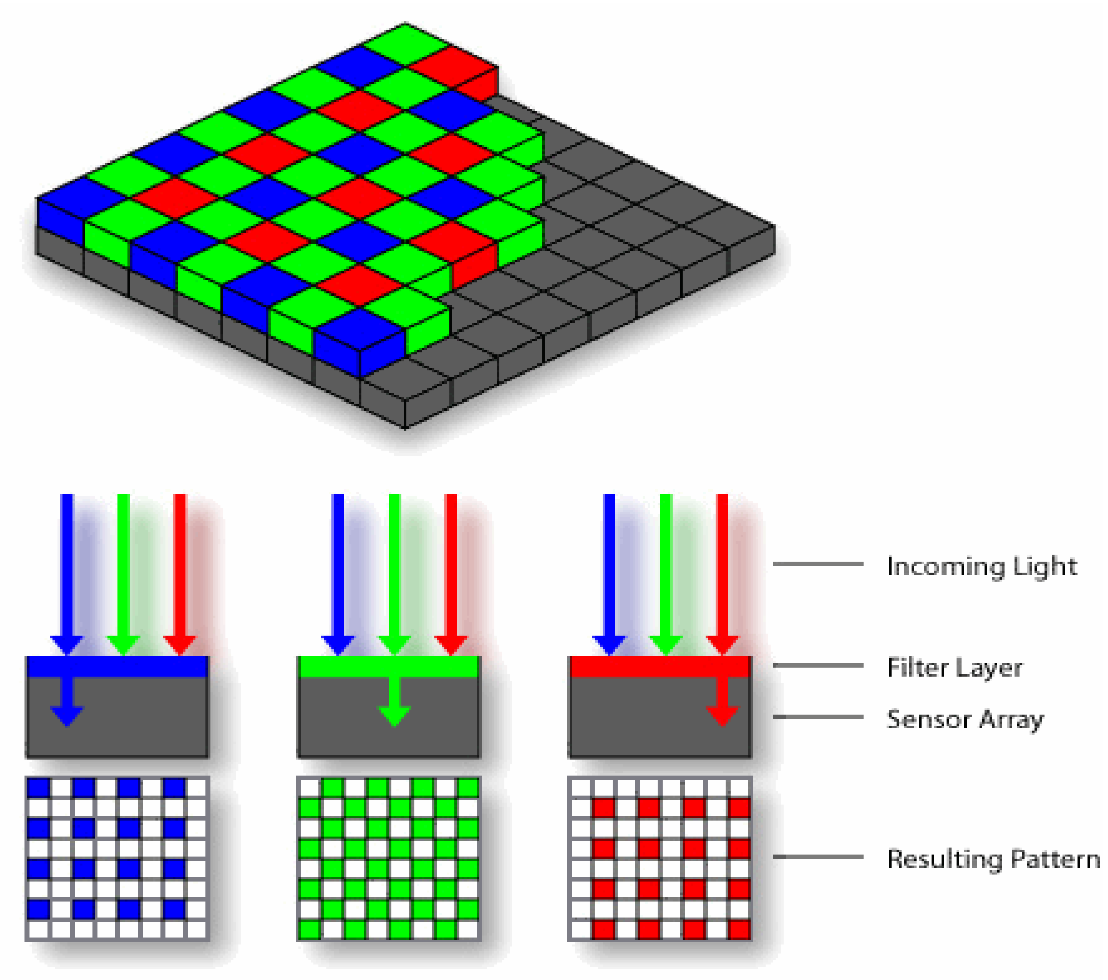


Fig. 3-6. The color field array of color filters on the pixel array of an image sensor.

In this experiment apparatus, the DSC is capable of taking 1250 images per second. The frame grabbing rate of DSC is fast enough to adapt to available FSC displays of 120 Hz. The capture action of DSC is tragger by remote controller, and the window of the remote capture operation is shown in Fig. 3-7.

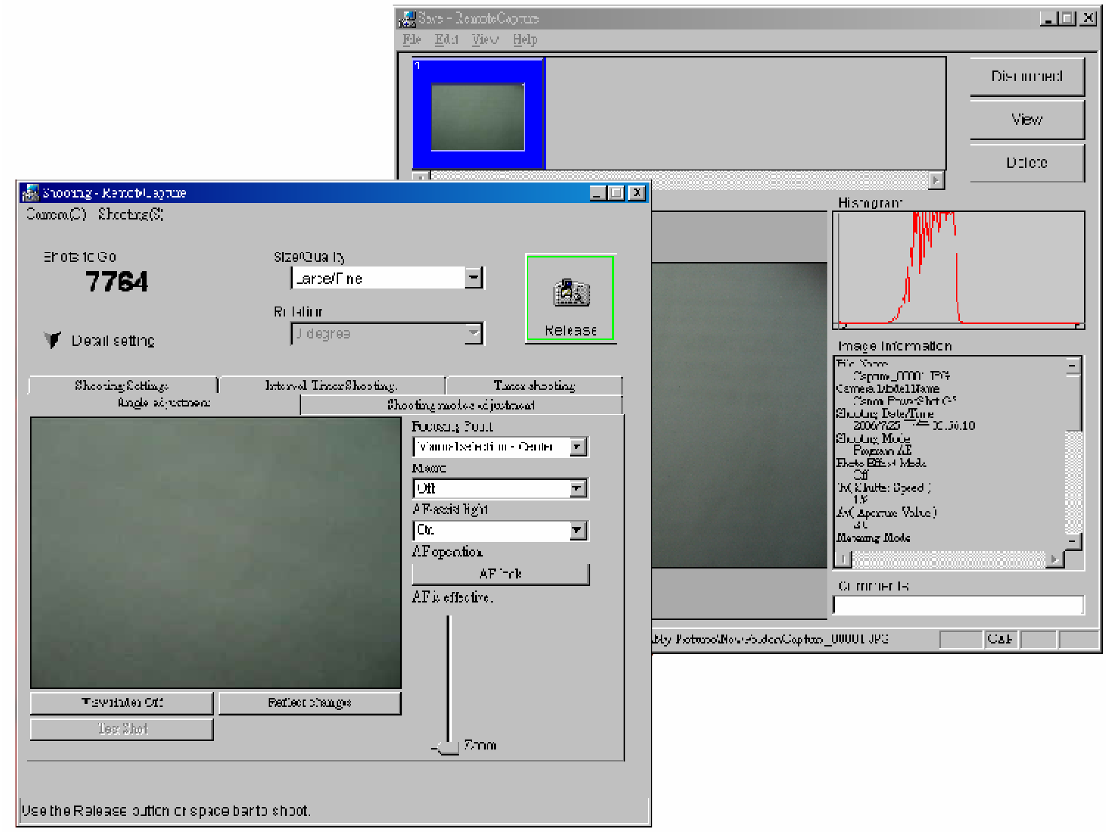


Fig. 3-7. The window of controller signal soft of the DSC.

3.4.3 Experiment Procedure

A simple test pattern, white split image, is designed for the experiment in order to be representative for display structure. In this section, both of the DLP projection system and FSC LCD were be used as the platform to demonstrate the simulation result with stationary images. The schematic for the measurement system is shown in Fig. 3-8.

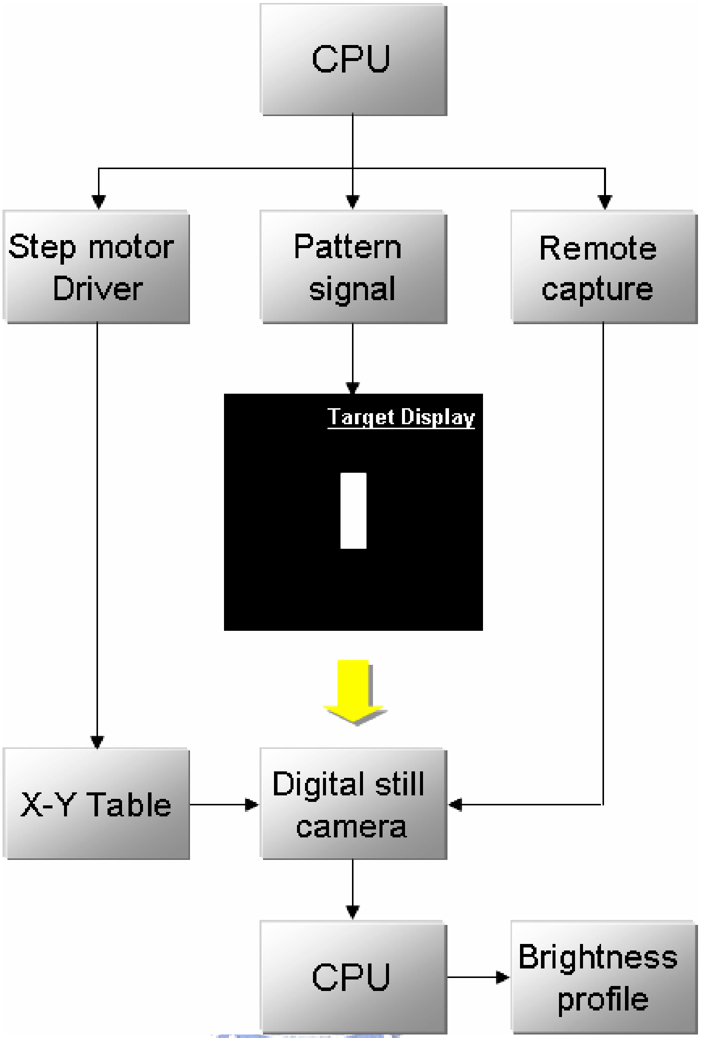


Fig. 3-8. Schematics for the measurement system.

First of all, the DLP projector (BENQ PB7220) functions as the light source displaying red, green, white and blue fields sequentially at sub-frame rate 120Hz. The white screen, placed just in front of the projector and illuminated by the projector, is used to display the white vertical test pattern for CBU measurement. And then, a conventional Digital Still Camera (DSC) placed in front of screen is used to capture the image with CBU. Moving speed of the DSC (Canon G5), driven by dual motion step motor, correlates with the retina velocity. The same procedure will be performed in FSC LCD again for demonstration. For each FSC type display, each of the task had 8 levels for moving velocity (e.g. 100, 200, 300, 400, 500, 600, 700, 800mm/s in both type displays), 6 levels for target width (e.g. 8, 16, 31, 47, 63, 79 in projected 19” DLP projection system and 17, 35, 70, 105, 140, 175mm in 32” FSC LCD), and 7 levels for viewing distance (e.g. 865, 688, 570, 484, 420, 368 ,327cm in projected 19” DLP projection system and 1845, 1467, 1214, 1032, 894, 785, 698cm in 32” FSC LCD) of stimulus. The whole experiment apparatus for CBU verification of phase I under DLP projector platform and FSC LCD were photographed in Fig. 3-9 and 3-10. The detailed descriptions are shown in next page.

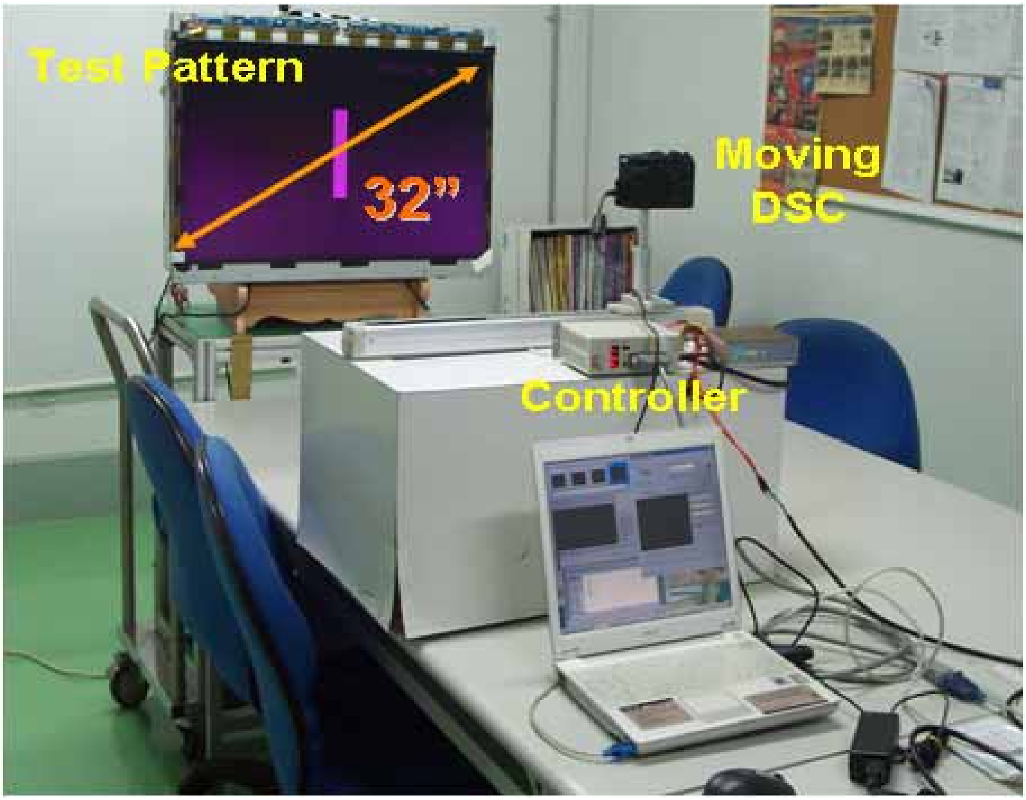


Fig. 3-9. The measurement system measure CBU under FSC LCD.

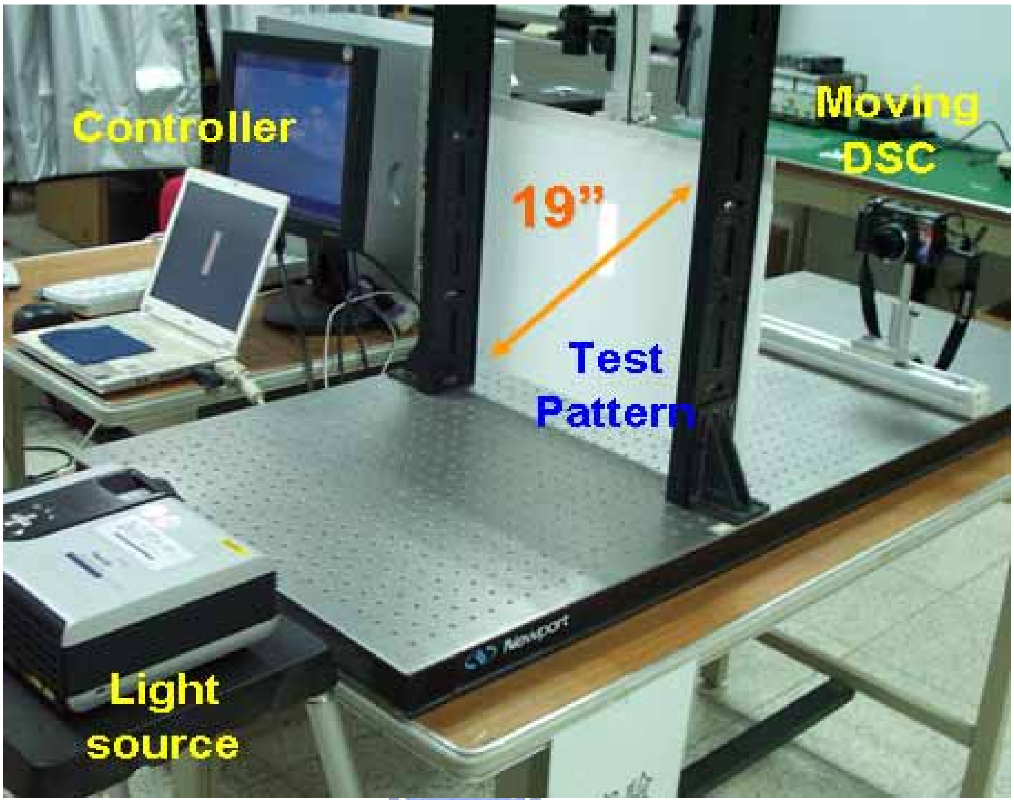
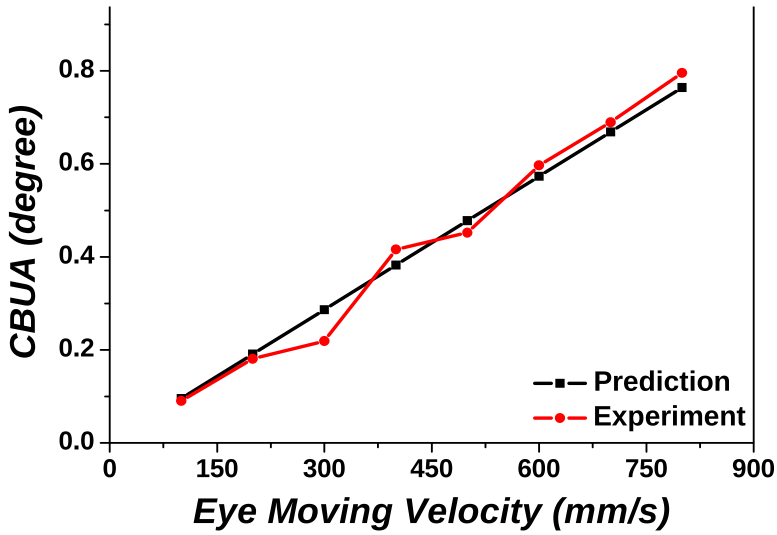


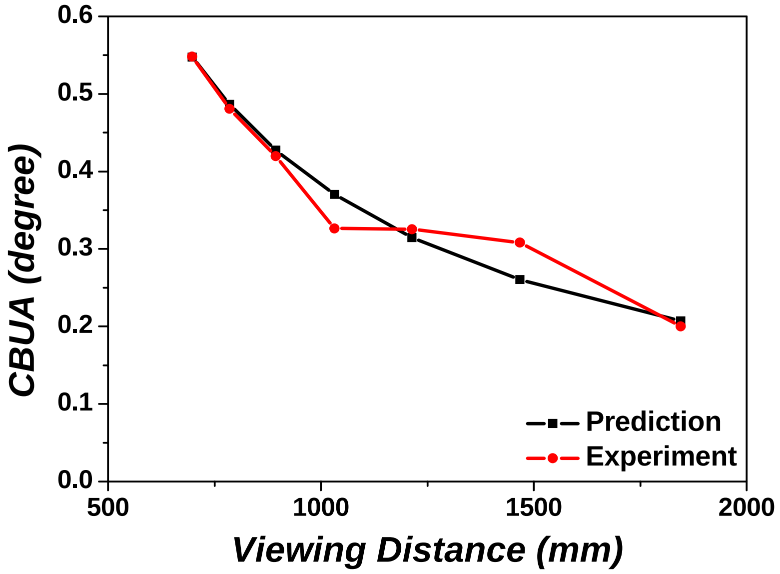
Fig. 3-10. The measurement system DLP projection system.

3.5 Simulation and Experiment Results

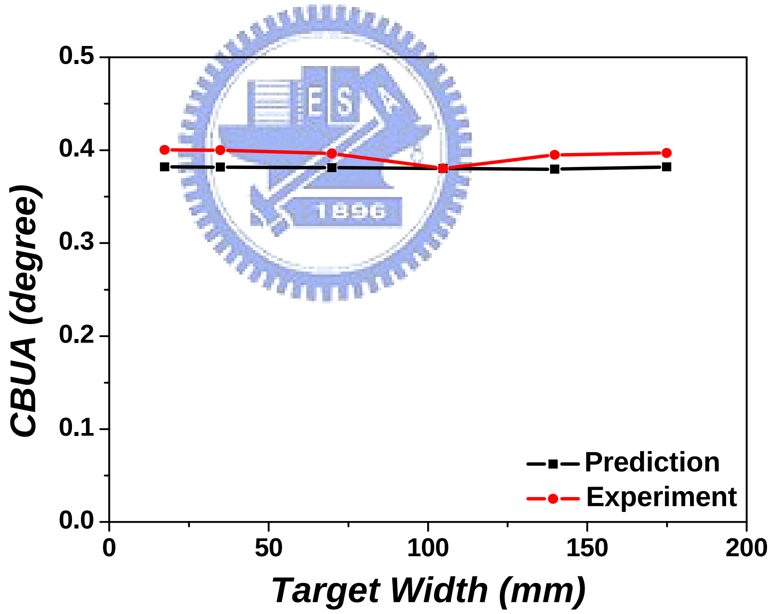
According to simulation model, all of the mean values of CBUA were found in the experiment. The simulation and experimental results with DLP projector and FSC LCD were shown in Figs. 3-11 and 3-12.



(a)

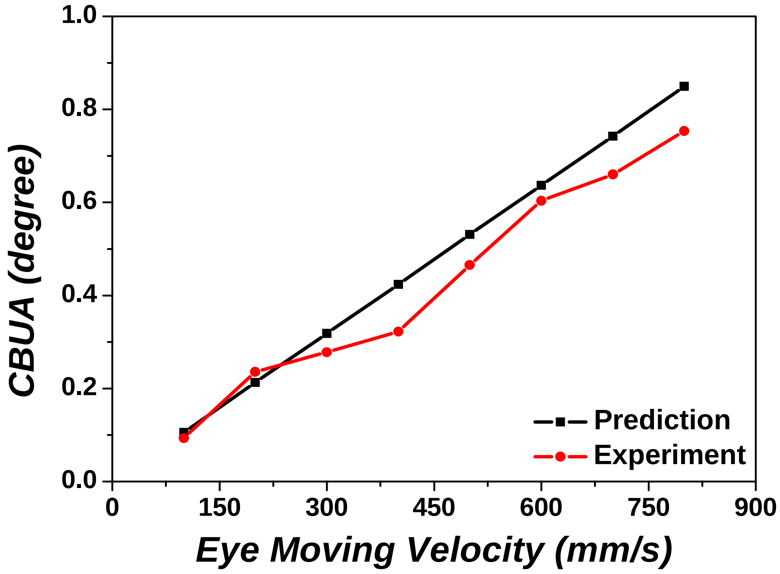


(b)

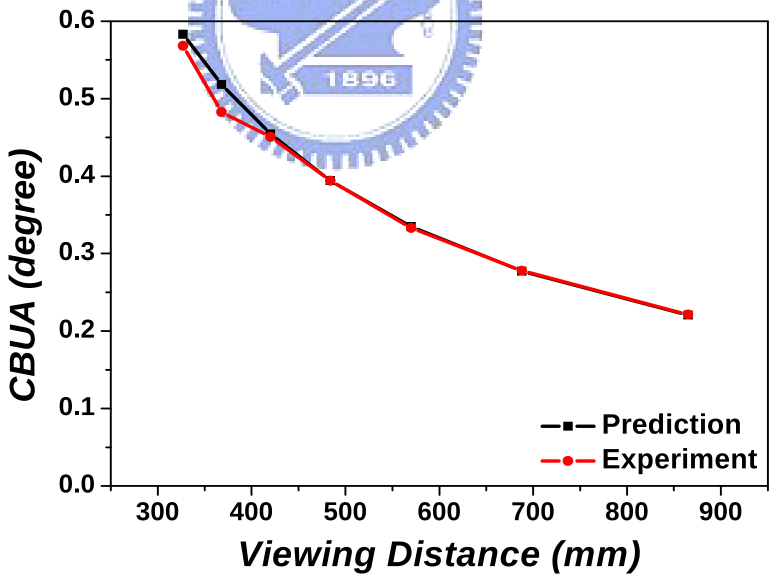


(c)

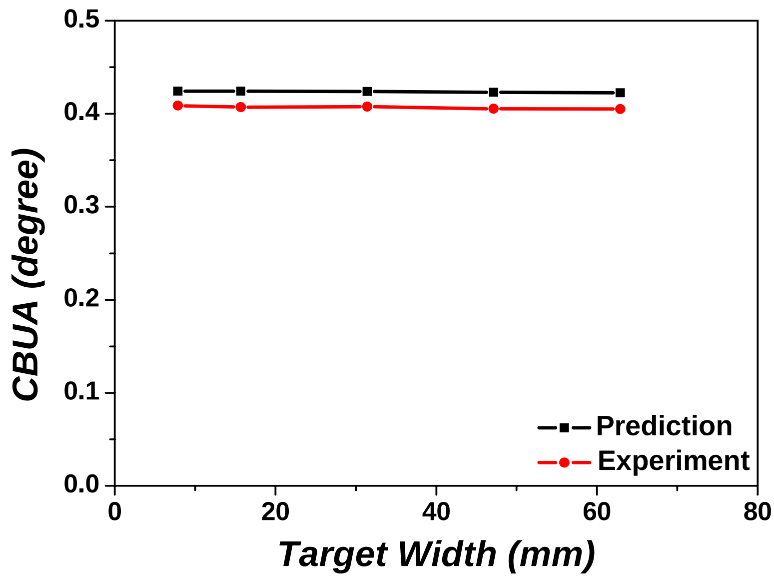
Fig. 3-11. Experimental results of measuring CBU between CBUA and the a) eye moving velocity, b) viewing distance, and c) target width with FSC LCD.


CBUA (degree)
1.0
0.8
0.6
0.4
0.2
0.0
0
150
300
450
600
750
900
Eye Moving Velocity (mm/s)
Prediction
Experiment

(a)


CBUA (degree)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
300
400
500
600
700
800
900
Viewing Distance (mm)
Prediction
Experiment

(b)



(c)

Fig. 3-12. Experimental results of measuring CBU between CBUA and the a) eye moving velocity, b) viewing distance, and c) target width with DLP projection system.

Two tendencies, both shown in Figs. 3-11 and 3-12, were presented in measuring CBU. One is higher velocity of the eyes and shorter viewing distance increase the visibility of CBUA. Another is, CBUA that was captured on the target edge to be narrower as target size was increased. Since the CBUA variation in target width is less than two other viewing parameters. Therefore, we can conclude that, CBU depends strongly on eye moving velocity and viewing distance in our simulation model.

For example, a 17mm wide image captured with CBU was photographed in Fig. 3-13. The colorful band on the target edge was captured CBU image. The shifted position and width of CBU can be analyzed by MATLAB. The standard deviation of measured CBUA is about 0.026° . Since the prediction from our model and experiment results agree with each other, as shown in Figs. 3-11 and 3-12, the CBUA is proved reasonable. Therefore, the index CBUA for quantifying color break-up was verified.

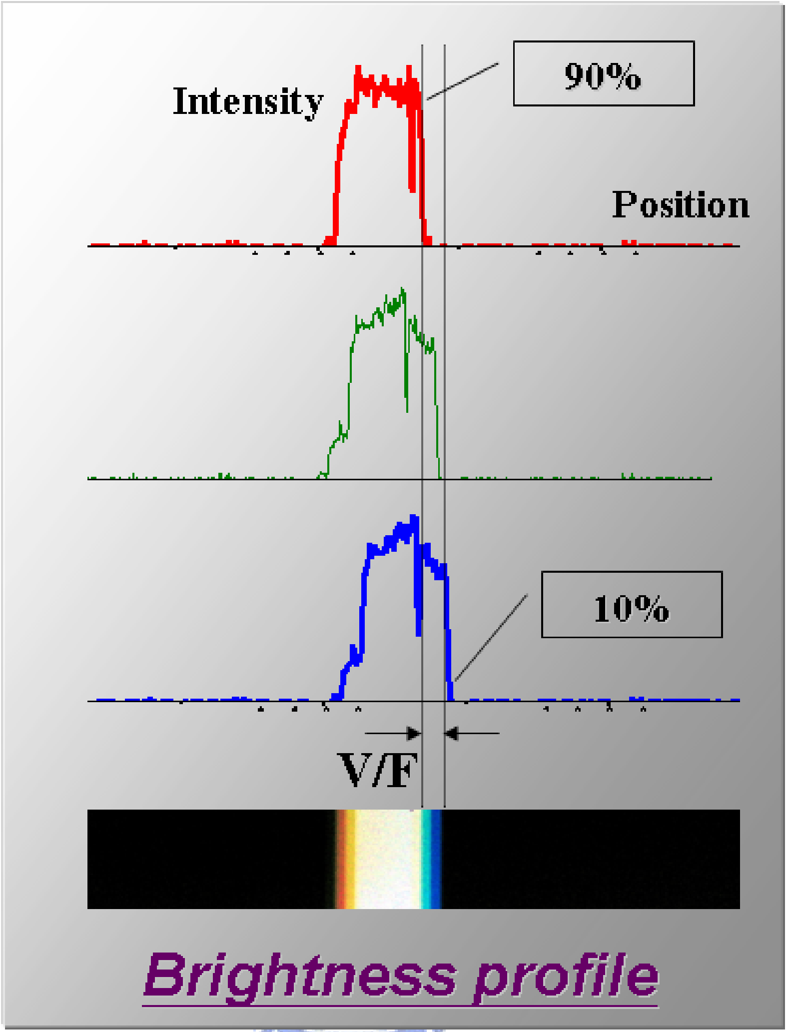


Fig. 3-13. Experimental result captured by the horizontal moved camera under FSC LCD and analyzed by MATLAB.

3.6 Summary

We have presented the measurement systems and experimental methods of CBU quantification. In addition, the proposed CBUA, used to quantify CBU was also demonstrated by this experimental system. The distinguishable CBUA will be examined in next chapter.