Research Project of Making Multimedia Data Base with Proven Quality as Primary Samples
High Fidelity Digital Image Data of Tibetan Tripitaka Beijing Edition: Photo Taking Process

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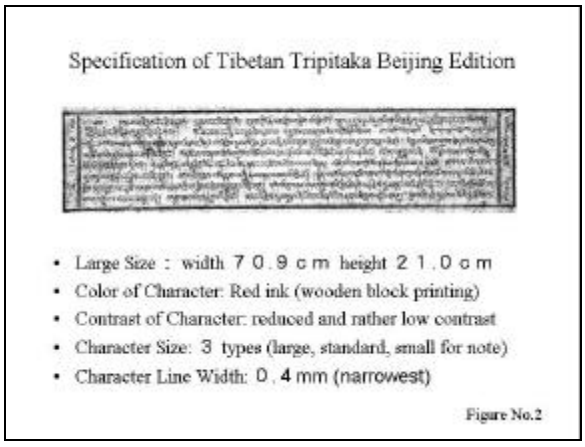
The Tibetan Tripitaka Beijing Edition at Otani University has enough quality for a High Fidelity Digital Image Database of Tripitaka. And we have researched to realize the Hi-Fi digital image data base of the Tripitaka.

Many trials of making digital image data have been done so far. But most of the digital images have no proof to be used as primary samples. Even in the case of printed texts on papers or micro-films, the careful consideration has not been given to their readability and artifacts. If we have to use the low fidelity copy for digital text, we cannot rely on it. Therefore, it is important to make a research to ensure essential information in originals and each step to make digital image should be proven. By the Hi-Fi digital images, it may possible to say that problems from low fidelity images are removed.

First of all, we analyzed the quality of monochrome micro-films and hard-printing on papers. Then criteria to be ensured as Hi-Fi digital image were determined. The results can be used to testify current digital and printed data. And the determined conditions and process of photo-taking will be reported in this talk.

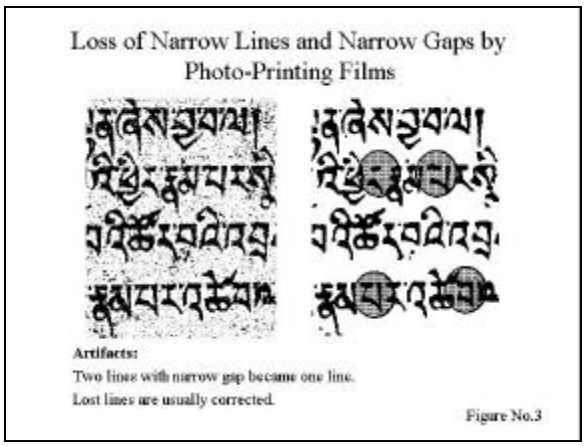


Before starting making digital image data, characterizing the original is essential. As we know, digital image is created by collection of small dots called pixel. The size of pixel must be enough smaller than the smallest line on the original. If the size of pixel is not enough smaller, quantum noise strikingly reduced readability. Also the overall size of the original can be used to determine the process and procedure of digitizing.

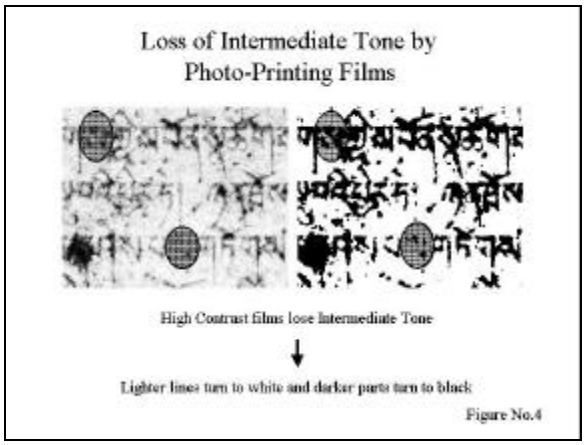
Since the size of the original is too large to digitize by ordinary scanners, the original should be digitize by digital cameras or by photo-film scanner after taking photograph. But digital cameras have not enough resolution for the size.And each photo sensor in digital camera has different sensitivity. Thus, following steps are determined.

1) taking a photograph by color reversal 35 mm film with ultra high resolution and color fidelity.
2) digitizing the film by film scanner not with cylindrical lens, but with high quality camera lens.

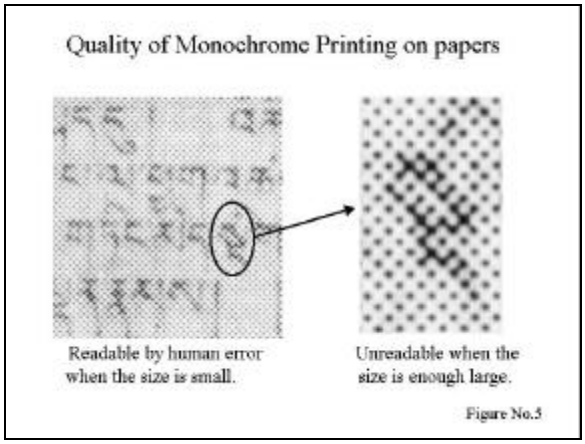
0.4 mm is the narrowest width by wooden print. When the original is printed in the reduced size, 0.4 mm line cannot be appeared on papers. But if a digital data has enough resolution, it is possible to show by magnification on a monitor display.



Here is the example of Photo-Printing quality. The left figure is taken by the good scanner, and the right figure is a simulation of photo-printing.
Photo-printing uses very high contrast micro film. By this kind of films, narrow lines are removed, and narrow gaps between lines turn black. Thus, *tsek* is connected to next character. Those de-quality phenomena always happen when high contrast films like micro film are used to make white and black 2 value data. And it is not unusual that lost lines are corrected by photographers or by printing company without notice. It is true in the case of the photo printings of the Beijing edition of Otani University and the Derge edition published in Taipei too. Therefore we find many changes of "pa" and "ba" in the book style Derge edition.

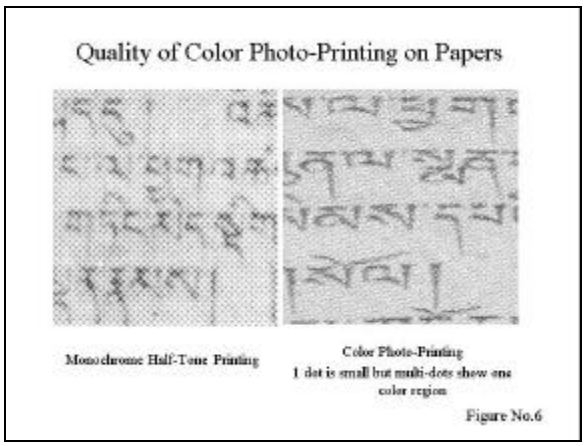


The originals often have dirty parts and lighter characters. Since the high contrast films remove half tone, those intermediate tones cannot be held.
Those artifacts are not relating to resolution of films. And the artifacts cannot be corrected.
Tibetan Tripitaka Beijing Edition is colored and contains intermediate tones. Thus, taking by monochrome micro films cannot be used for our purpose.
On the other hand, color film can retain intermediate tones. Even dirty spots are on the originals, it is possible to read by the difference of the color of the spots and the color of characters.
Note that micro film readers are not good at displaying intermediate tone.



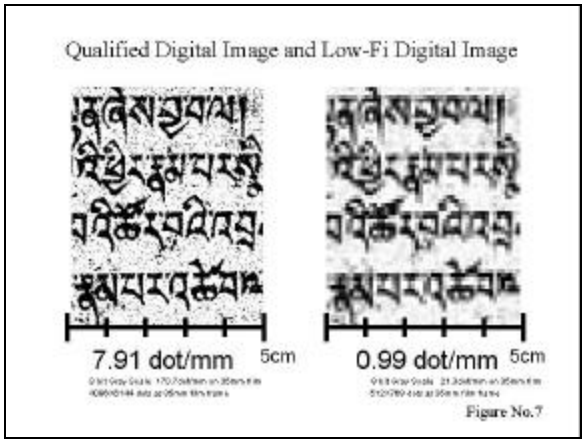
Half tone monochrome printing uses different size of dots to show half tone. In this case, multiple dots show one small region. Thus, resolution of half tone monochrome printing is lower than the value of resolution. This means half tone monochrome printing on papers contains large quantum noise.
Sometimes, we consider that such rough dot images can be read. This consideration is done by readers speculation of the shape. This kind of speculation is one of human errors. This speculation is also one of artifacts.

Thus, mathematical proof is required for readability.



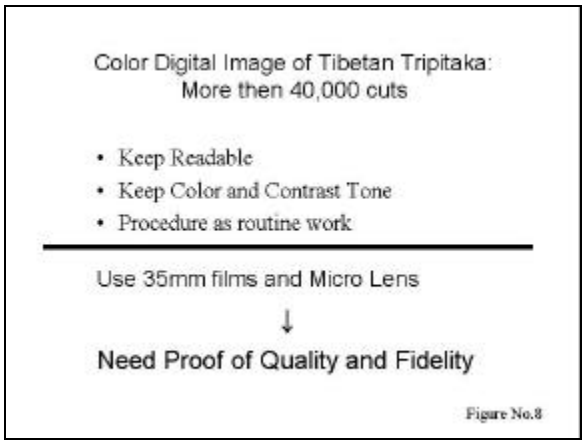
Color photo-printing is also using small dots to show one color region. This dot is smaller than that of monochrome. To show a color, multiple dots are printed. But each basic color dots are not printed at the same place. If the basic color dots are printed at the same place, the required color is not correctly shown. As the result, the region of a color is bigger than the basic color dots. And when a color of a point on an original is reduced to basic colors, the point is just one. But the basic color dots are placed at the different places by the above reason.

Therefore, color photo-printing contains larger quantum errors than that we consider.
By this analysis, it may be possible to say that micro films and printed materials are not suitable for the High Fidelity distribution.

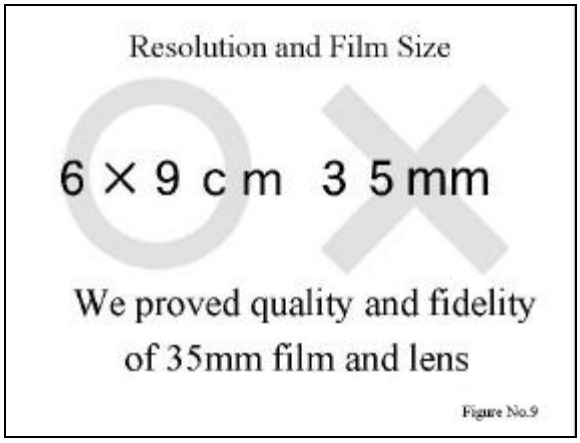


To be high fidelity data, Tibetan Tripitaka at Otani University will be distributed by digital image data with quality proof.
The proven digital images should ensure resolution, density, color tone and contrast tone as readable.
Left example is a digital image with 8 dot par mm. In this image, quantum errors can be ignored. On the other hand, the right image with 1 dot par mm has large quantum errors. 0.4 mm narrow lines contains almost 100% error. Mathematically, this image cannot be readable, even if we think it is readable.

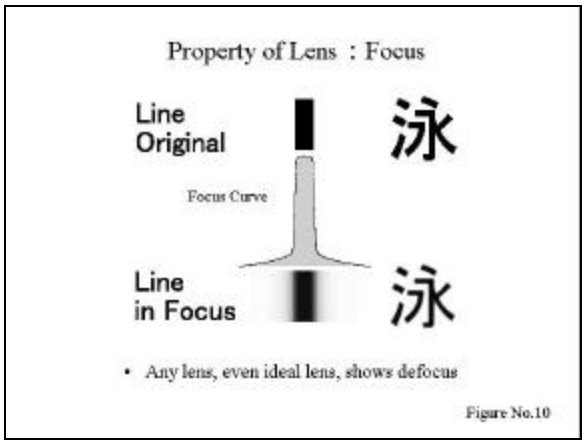
Thus, we tried to get criteria and condition for the best quality digital image used as primary sample.



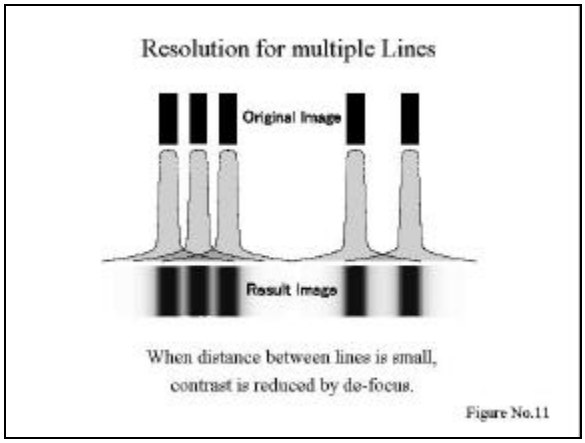
Since the size and amount of Tripitaka Beijing Edition are too large, 35mm reversal color film with micro lens was selected. 35mm camera is easy to use and cost of 35mm film is not large. For more than 40,000 cuts, conditions for the routine work should be determined.
Thus, quality proof for above condition was researched.



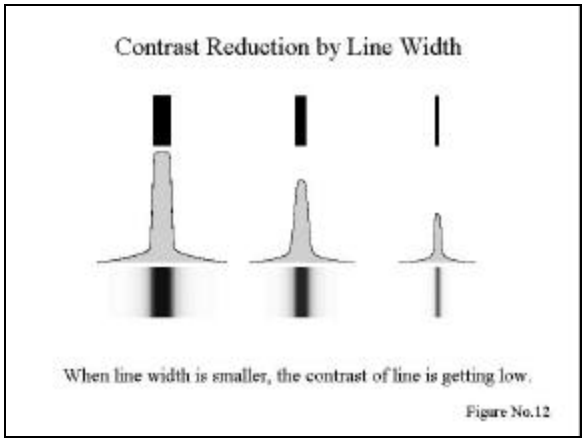
It is said that the resolution of 6 by 9 film is better than that of 35mm film. But the resolution is determined by the quality of both film and lens. And no data for such resolution was opened. Thus, we measured the real resolution with the best 35mm film and micro lens.
Color reversal film was selected by its high resolution and color fidelity quality.



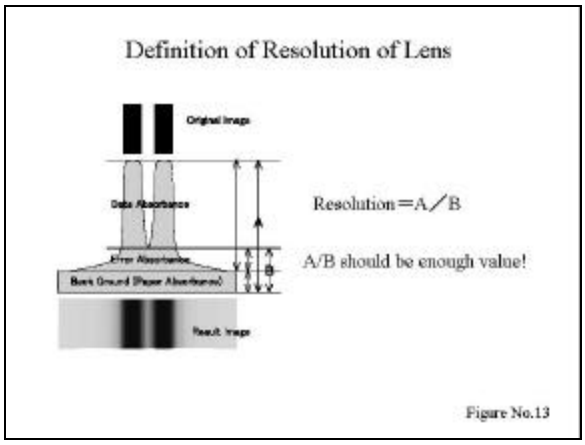
In order to get the criteria for evaluations, all factors for quality and fidelity were considered.
Resolution is one of the most important factors for fidelity. And resolution is determined by multiple factors.
First of all, focus of a lens effects directly resolution. Even if ideal lens is used, de-focus always happens. Thus, contrast is reduced by the ability of a lens.



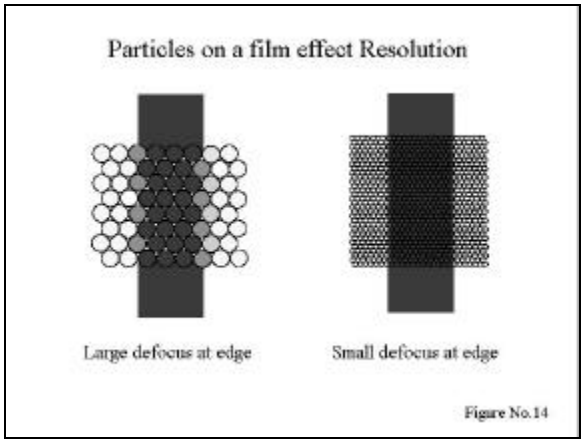
Since Tripitaka Beijing Edition is a character-base text, resolution of multiple lines are the most important. By the de-focus effect, the gaps between two lines are getting dark. Thus, the contrast among lines is reduced in proportion to the line distance.
The smallest gap on the original is about 1mm, tsek and character.
1mm distance on the original is reduced to 0.038mm on the 35mm film. Thus, about 30 lines par mm must be resolved on the film.
Here, resolution means that having enough contrast between lines.



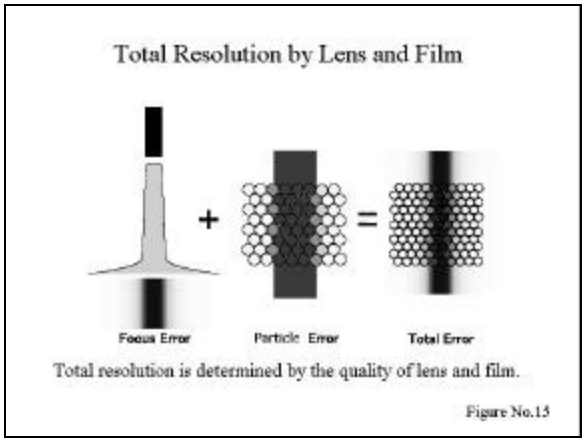
By the aberration of a lens, the contrast of narrower line is getting low. And the reflection from crystals on a film reduces the contrast of narrower lines.
Therefore, before taking photo of the original, the sample lines with a gray scale should be taken. And the density of darkness of lines should be measured. Since the narrowest line width of the original is 0.4mm, the national certified metal scale was used for this purpose. The width of a line on the scale is about 0.15mm.



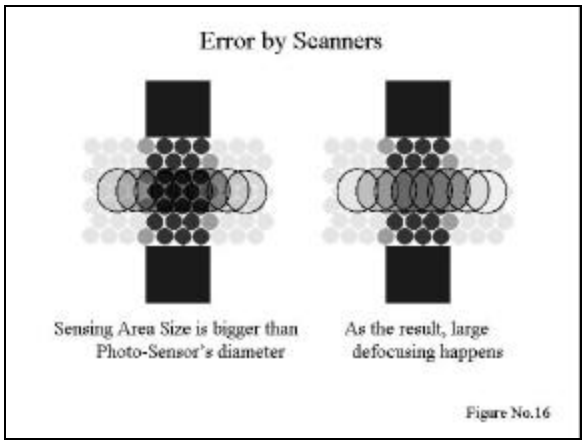
Resolution of a lens can be expressed like this slide.
Proportion between A and B must be enough. When the color is the same, the brightness steps is only 256 by 8bit. Thus, the brightness of gap between lines should be much bigger than that on the lines. Note that 256X256X256 colors (16,700,000 colors) can be used. But brightness is 256 steps.
0.5mm line distance on the certified scale was used to determine the resolution of a micro lens that we selected.



The size of halide-silver particle on a film effects the resolution too.
If the size is bigger, the brightness of edge of a line will be reduced. Note that the brightness of all location of one particle is the same.
Also, the shape and packing of particles on a film strongly effect the resolution.
Thus, the external developing film was selected by its size and packing of particles.
Since the developed film would be scanned by a scanner, the size of a particle must be small enough for the errors of the scanner.

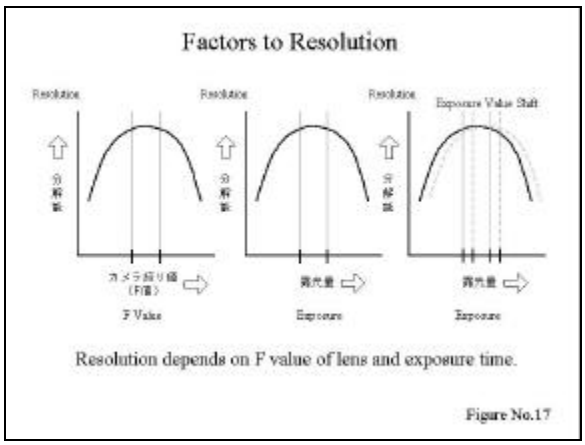


As the result, total resolution is determined by the quality of lens and film.
To determine real resolution, measuring the real photograph by microscope with scale is the way. 250 magnification microscope with internal scale was used for this purpose.



The largest error comes from scanners. Since the size of sensing area for one photo-sensor in a scanner is much bigger than the diameter of the photo-sensor, defocusing error by a scanner is very large. Note that focusing area for a sensor is overlapped together. This overlapping is very large when cylindrical lens scanner is used. Note that most of scanners including film scanners are using such cylindrical lens. Drum scanners have very high density but the error of lens is large, so the same result would happen.

Finally we found very high quality flat bed film scanner. Even using such special scanner, resolution on the film is quite important and the resolution effects scanner's resolution. I'll report about scanner in the next time.



The aberration of a lens can be reduced by larger F value. But if the diameter of aperture is too small, the resolution is getting worse by the diffraction effect of diaphragm.
The best exposure brings the best resolution, see the center. When overexposure, the line width would be narrower.
Since Tibetan Tripitaka at Otani University is lighter than 18% gray that is the standard reflection value, the proper exposure value should be shifted, see right.

The best exposure value was determined by photo-taking.
Since the edge of the film is the worst resolution, the measurement was done at the corner of the film.

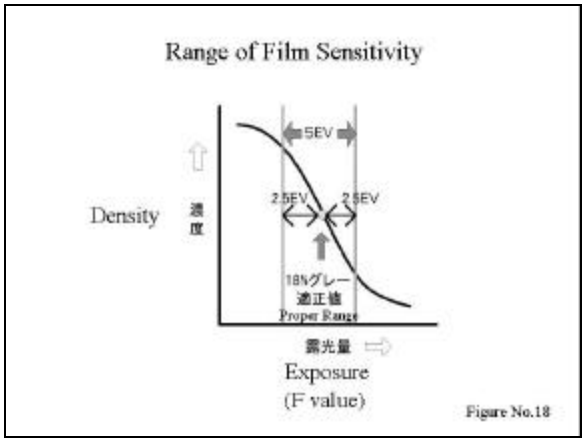


Figure No.18

Reversal color films have about plus-minus 2.5 EV sensitivity around 18% gray.
Tibetan Tripitaka at Otani University is within the range of plus-minus. The brightness density was measured by gray scale.

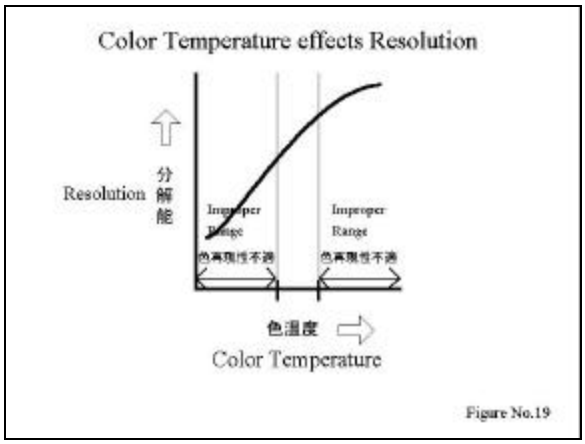


Figure No.19

For the fidelity of colors on the original, the color temperature should be set at 5,500 degree K.
The color temperature of flushes was measured by color meter. By our experiments, the error of color temperature must be within 50k. To know the color fidelity, the color chart was used by photo-taking.
Since the color of characters is red, the lower color temperature reduces the resolution very much. When the color temperature gets lower, the light turns to red.

The red light cannot catch the red ink on the original. Thus, measuring color temperature is quite important.

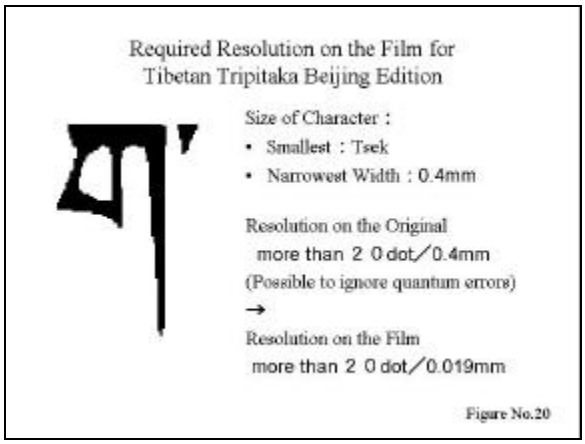


Figure No.20

Based on our research, at least 20 dots for 0.4mm on the original was required to ignore quantum errors. Of course, this dot density is specific to the original.
This value means 1,000 dots par 1mm on the film.
As the complete separation of line resolution, 50 lines par 1mm on the film are required.
Both values are not so big but taking photo of this quality is usually difficult.

Factors for Resolution and Fidelity

Film	The smallest Particle size
Lens	Aberration, Diffraction, Focus depth
Exposure fidelity	Best exposure ± 0.1EV
Exposure shift	Difference from the 18% Gray
Color temperature	Resolution for Red color
Brightness range	Film sensitivity (<5EV)
Room temperature	Keeping film sensitivity

Figure No.21

Here is the list of factors effecting the resolution.
The most important factor is the particle size of the film.
We found the best condition by experiments for each factor.
Since the emulsion number of the film effects the particle size and sensitivity of the film, we used the same emulsion number of the film.

Selected Equipment

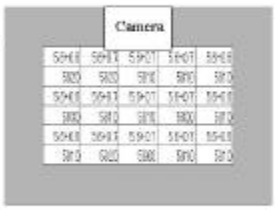
Film	Kodachrome 25 Pro.	Kodak
Camera	F3HP	Nikon
Lens	Micro Nikkor 55mm F2.8	Nikon
Flush	2 of CT-150	COMET
Umbrella	2 of Diameter 65cm	COMET
Flush meter	Flash Meter V	Minolta
Color meter	Color Meter IIIF	Minolta
Room Color	18% Gray sheet	Kodak
Temperature	25 ± 1 ℃	

Figure No.22

Here is the list of selected equipment.
Kodachrome 25 professional is the best particle film. The film is color reversal and it is known as the best fidelity of color.
Micro Nikkor 55mm is most commonly used for this purpose. Also it is said that the lens is better than the lens for 6X9.
The flush is very high quality. Its error of flushing is less than 0.03EV. Also the error of color temperature is less than 10 degree K.

Setting of Camera and result values

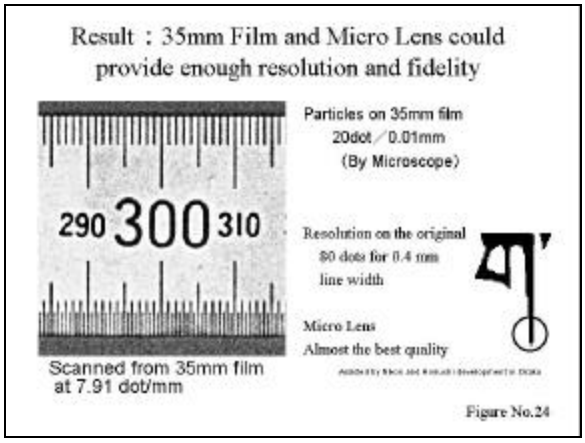
Camera Setting



Upper: Exposure(F Value+EV Value)
Lower: Color Temperature (degree K)

Figure No.23

This slide shows the condition of photo-taking.
Matrix shown at right side is the results of exposure value and color temperature.
As shown on this slide, exposure value is less than ±0.1EV, and color temperature is less than ±20 ° K. And the slant degree of camera and the object is less than 1 to keep focus plane.
This condition is almost ideal but this condition is just required to provide the high fidelity photo-taking.
Light and color were measured by the direct measure method.
The optimal condition was obtained by 0.3 EV step exposure at the experiment.



This slide shows our result that is a scanned data of the photo of certified metal scale from 1.3m distance. 0.15mm width lines with 0.5mm distance can be clearly separated.

By the microscope test, the number of the particle on the film is about 2,000 par 1mm. This separation is completely enough to take a high fidelity photo for Tibetan Tripitaka Beijing Edition.

The F 8.0 and 0.3EV underexposure was the optimal condition.

By our research, it was proved that 35mm color reversal film can be used for Hi-Fi photo. And each factor is quite critical to determine resolution and fidelity.

Since the film scanning to digital image data and compression data formats require huge research, we will report for those in the future but soon.