ContactReader: Qualification tool for film production and processing chain

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Abstract

In relation to the activities of the MiLoS project (develop an Open Standard Migration Free Storage and Archival Medium for long term archiving of digital data) FilmoTec and Fraunhofer IPM developed an analysing tool to characterize the properties of new film material due to homogeneity, geometrical and density resolution and RMS. This ContactReader device analyses these film properties independently from any recording or reading hardware realisation and specification and is therefore a powerful tool for advancing film properties. The tests have shown that this ContactReader device is also capable of qualifying the production chain of images on film. By comparing the properties of the images on the actual produced film with the results when the process was implemented the archive can always check and qualify its own film production.

1. Motivation:

In the MiLoS project digital data are stored as small square dots of different grey levels in a size of 6µm as "bits on film" on 35mm film material. For the storage of small information pixel of this size of 6µm the film material has to be capable of realizing high requirements especially in these small dimensions. The requirements are especially crucial due to homogeneity, geometrical and density resolution and RMS. Today most test equipment for film qualification are using test patterns and structures which are optimised by structures of analogue pictures which are significantly bigger in size. But for our application it is crucial to test the quality of 6µm pixels and therefore we had to introduce a new tool for testing and qualifying the film material especially for those small structures. Therefore Fraunhofer IPM has developed a contact film reader, which can characterize these parameters in a short time of only few hours. The tests can be done by typically skilled technicians and examine only the film related properties. The results are independent from other hardware like recording system which would always affects them. FilmoTec has used this testing tool and has shown that this system is a very powerful tool for characterizing the film due to the properties of homogeneity, geometrical and density resolution and RMS. These examinations can be done in house and are easy to handle for fast iteration steps.

We are confident that this testing tool will also be for great help for qualification of the film production chain in the filming institutes of the national or private archives. The new prospects for those users are a precise control of each step of the production process in house.

2. Problem:

For the archives it is always the challenge to keep the quality of the film production always on the same level, independent of the individual hardware components or staff members during whole time of production. It is not at all easy to recognize if failures have occurred and even if you see them in time it is not easy to figure out the reason of these qualities constrains. Using always the same equipment and the same production steps it is often a time consuming task to distinguish if quality failures are resulting from a decrease of the film material, the production hardware like recording system or film processor or even from failures in running the production process. Therefore an archive has sometimes a lot of effort to guarantee the high quality of the produced images on film. With this ContactReader device the produced images can be analysed, qualified and compared with master images so that the cause of some quality losses can be found quite fast.

3. Approach:

As shown in figure 1 the ContactReader is used by FilmoTec as qualification tool for its own film development. Therefore the production chain shown above is applied: A test pattern is recorded on a mask using lithography. The ContactPrinter is copying by contact exposure the pattern of the mask on the film. The pattern on the mask can be produced with a resolution of down to a few µm and is therefore sufficient for qualifying the film. After processing the film stripe is put in the ContactReader shown on the right of the figure together with a typical test pattern. The ContactReader can use film stripes of 35mm x 30mm and inspects the images, typically special b/w patterns, with a microscopic device. The images are captured by a camera. The software can analyze the images and calculate the values for the quality parameters as homogeneity, geometrical and density resolution and RMS.

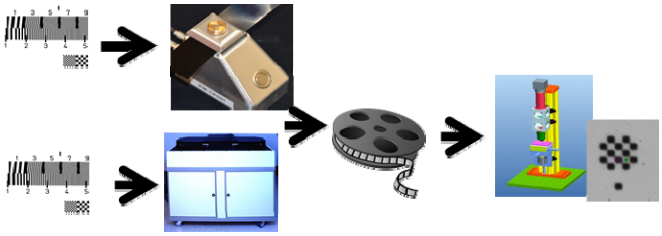

Figure 1: *Comparison of the film production chain typically used in an archive (row below) with the film analysis tool at FilmoTec using the ContactPrinter (row above).Both using the ContactReader as qualification tool, with a typical test pattern illustrated next to it.*

Basically the same test procedure for qualifying the film production chain in an archive can be applied. Whereas the production of the film is quite different (shown in the figure 1 in the base line), the analysis of the film quality will be the same. Therefore the results which are described here can be transferred to production.

4. Procedure:

In first place the system has to be calibrated. Therefore two images are gathered at the beginning: the dark image and the reference image. The dark display is used for two different purposes: (1) determination of the 'dead' pixels of the camera and (2) determination of the thermal noise of each camera pixel. With respect to the possible variation of the illumination it is necessary to 'zero' the system at least once at the beginning of a measuring session; this is done by capturing of the reference display.

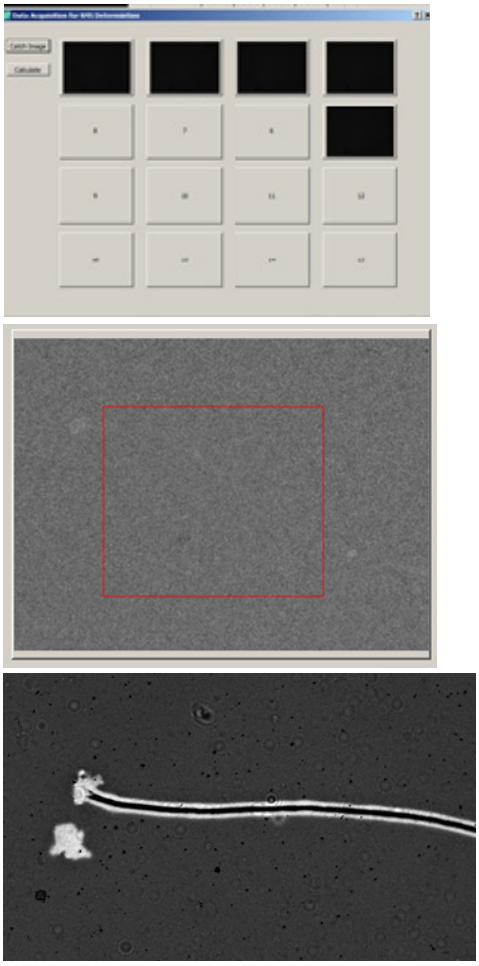

Figure 2: *RMS and densities are measured on basis of more than one frames, the analysed areas of the film are shown in the first picture. The sqares of size 0.5 mm x 0.4 mm are distributed over the whole film of 10 mm x 10 mm. One of these analysed film areas is shown in the second picture: this is a typical pattern used for measuring the RMS and the density of the film.*

Up to now typically the measurement of RMS values is done with respect to ISO 10515 with 42.5µm pixel size. We have experienced that the results can be significantly different analyzing structures of 6µm size, as we use them in MiLoS. Due to the granularity of the film the RMS values of 42.5µm and 6µm differ significantly, as up to now with the ISO norm the granularity in small dimensions was averaged over the whole spot.
In figure 2 the RMS calculation is exemplified: The film region which was exposed by the mask with the ContactWriter with a homogenous density over the whole area of 0.7 mm x 0.7 mm is devided up in several sqares of interest in this example 16 squares, first picture in figure 2). Each of those squares is inspected visually, in order to be sure that no defects or pollutions (as shown in picture 3 of figure 2) are placed in the regions of interest, which are marked with a red square manually (shown in picture 2 of figure 2). This visuable control ensures that the measurement is done correctly and that any artifacts are eliminated in the calculation. On first hand it looks antiquated to use this visual control step, but you have to keep in mind that these artifacts can be made visuable very easy by increasing the illumination manually and due to that detecting even small density changes caused by artifacts on different sections of film quite fast.

The next important parameter to be measured is the MTF value. In figure 3 the picture taken by the ContactReader and the results of the calculation are shown.

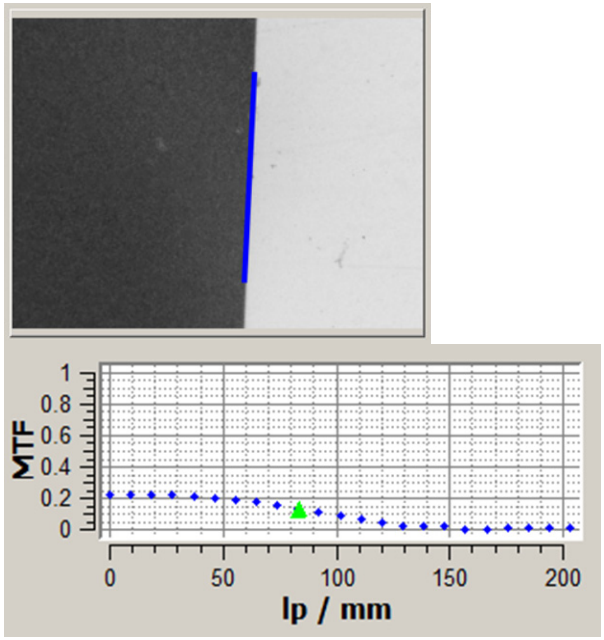

Figure 3: *A typical pattern used for measuring the MTF of the film is shown in the first picture. The calculation of the decrease of black to white gives the MTF. This is also done at various densities. As example picture 2 shows an analysis of the MTF at a density of 0.2 on the diagram.*

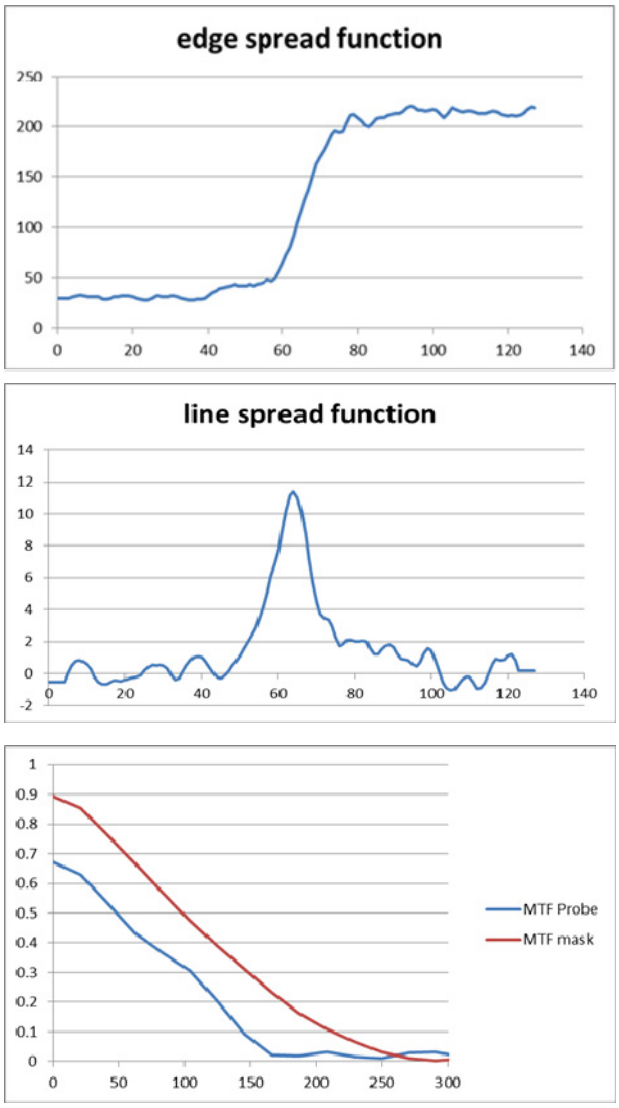

***Figure 4**: The diagrams show the calculated values of the MTF for one film examined with the ContactReader. For the calculation of the edge spread function (ESF) are taken 128 image pixels. The value of the measured grey level is shown in the y-axis (256 grey levels between "black" and "white"). The line spread function (LSF) is the derivation of the ESF showing the change in grey level per pixel in the y-axis. The result from that is shown in the last diagram as MTF. The "MTF mask" is the result of the production chain of figure1 using the mask and the ContactPrinter, the "MTF probe" is the result of the production chain using a conventional production via a recorder system.*

As shown in figure 4 the MTF is measured by building the Fast Fourier Transformation of the line spread function (LSF). The LSF is determined from a horizontal scan over the edge using 128 pixel (edge spread function, ESF). The line spread function (LSF) is generated using the 1st derivative of the ESF. The last diagram actually shows the benefit the archive gets using this tool: The "MTF mask" is the result of an almost "ideal" production condition using contact exposure as it is shown in figure1 in the above row, the "MTF probe" is the result of a typical production chain which includes all constrains due to the hardware specifications like recorder, processor unit or processor chemicals, which affect the quality of the production chain.

We can show that the micro resolution we achieve with the ContactReader helps to calculate accurate values especially for films with low RMS values (using the ISO-norm with 42.5µm pixel values). Each film has its characteristic MTF value and determines the MTF of the production chain. With this system the comparison of different films regarding the MTF can be measured and documented. But even with the same film you can get other MTF due to processing parameters. Each change of any parameter in the production chain can be proofed due to the change of the MTF and therefore this is an appropriate way for qualifying the production. The archival production can be proofed to reproduce always the same quality of the pictures.

The different influences of the production chain have also consequences in the quality of the contrast of the pictures. The contrast is measured by looking at the density for small singular black or white spots, as it is shown in figure 5. The spot density of the pattern shown in figure 5 illustrates results of the measurement done with the ContactReader: the contrast for those small objects of 6µm size identifies even the crystalline structure of the film and shows the reproducibility of the whole production process. For example a wrong processing parameter leads to overlapping of the corners of the structure.

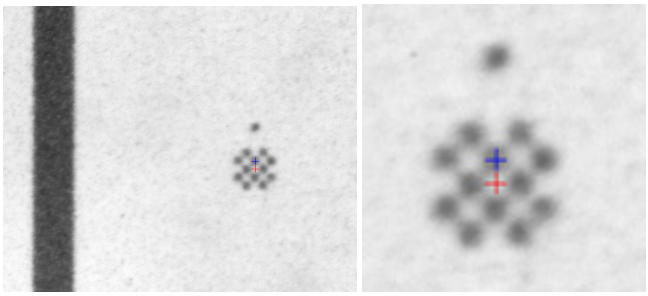

***Figure 5:** A typical pattern used for measuring the spot contrast of the image on film. The software depicts with the red cross the position with lowest mean density, with the blue cross the position with highest mean density*

All these measurements of the different parameters are a useful tool especially for staff running the production process of archiving data (independent of digital bits or analog pictures) on film as it helps them to analyze each production step, starting from the characterization of film material over testing the film recording system and the film processing until to qualifying the ready film for archiving.

5. Results and Conclusions:

We could show that the film stripes with the test patterns can be analyzed by the ContactReader due to the properties homogeneity, contrast, geometrical and density resolution, RMS and MTF. We verified that the ContactReader can establish new possibilities for film production, as it ensures fast development and improvement cycles and as it can analyze effective pitch size down to 6µm. We have also seen that new characterization methods can

(and probably must) be established to characterize also very small pattern sizes, especially extended RMS calculations should be established due to the application.
The results showed that the ContactReader is above all these results a powerful tool for qualifying the archiving chain (e.g. for controlling the quality of the recording system or the film processing step) at work.

6. References:

Project is funded by EU in Eurostar program. Project name is "MiLoS - Develop an Open Standard Migration Free Storage and Archival Medium for long term archiving of digital data" [1].

References

[1] https://www.eurostars-eureka.eu/

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