

Fast initialization of a F!T tube

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Abstract

We describe a new method to initialize the raster and convergence of a flat intelligent tracking (F!T) tube. By splitting up the initialization algorithm into three parts, it can comply with the variety of boundary conditions that are stated for a consumer product. Experiments on raster initialization have shown that the new algorithm speeds up the initialization by one order of magnitude.

1. Introduction

Cathode-ray tubes (CRTs) are the dominant display technology for monitor and television application. They are characterized by providing an image with good resolution, high brightness and contrast, and an as yet unequaled price/performance ratio.

In color CRTs, a shadow mask is used for color selection. Recently, a maskless CRT has been proposed and realized, in which the electron beams are tracked along phosphor lines [1,2]. This CRT, referred to as Flat-Intelligent-Tracking (F!T) tube, uses a tracking structure and a tracking mechanism to provide color selection without color errors.

In contrast to a shadow mask tube, in a F!T tube the scanned raster needs to be in perfect alignment with the screen structure. In addition, the mutual distance between the beams (convergence) needs to be set to a predefined value. In previous papers it was discussed that these tasks are done with two separate tracking loops [3,4]. The first loop, the so-called slow loop, compensates the raster and convergence errors, which are either static or varying very slowly. The second loop, the so-called fast loop, compensates errors that are due to fast varying electromagnetic fields. In this study we focus on the slow loop.

The first working version of the slow loop initialized the tube in the following way. The raster errors of the tube-coil assembly (TCA) were removed by measuring and correcting the position of the central beam while driving this beam at constant current. Thereafter, the convergence errors were removed by relating their positions to the corrected raster. Although this version of the slow loop has a high reliability, it has two disadvantages. First, since the loop needs many iterations to remove all the errors, it is unacceptably slow. Second, since the loop needs a small spot size to determine the beam position, a moiré pattern is visible to the viewer. These disadvantages make the loop unacceptable to use in a product.

In this study we demonstrate a new kind of slow loop that is divided into a number of parts. Each part of the loop is optimized for the boundary conditions that are valid during that part. This enables the loop to be both fast and hardly visible to a consumer, so that it can be used in a product.

2. Screen structure and position signals

In this section it will be explained how the screen is constructed and how the beam position is detected. The consequences for the slow loop will become clear.

The structure of the screen is built up in the following way (see

figure 1). First, black matrix is deposited on the front screen in horizontal stripes. In between them, stripes of alternating red, green and blue image phosphor are deposited. On top a thin layer of aluminum is deposited. So far, the screen is identical to the screen of a conventional CRT. To measure the position of the beams in the vertical direction, two kinds of fast-decaying tracking phosphors are deposited on top of the mirror and they are positioned above and below each of the display phosphors in horizontal lines.

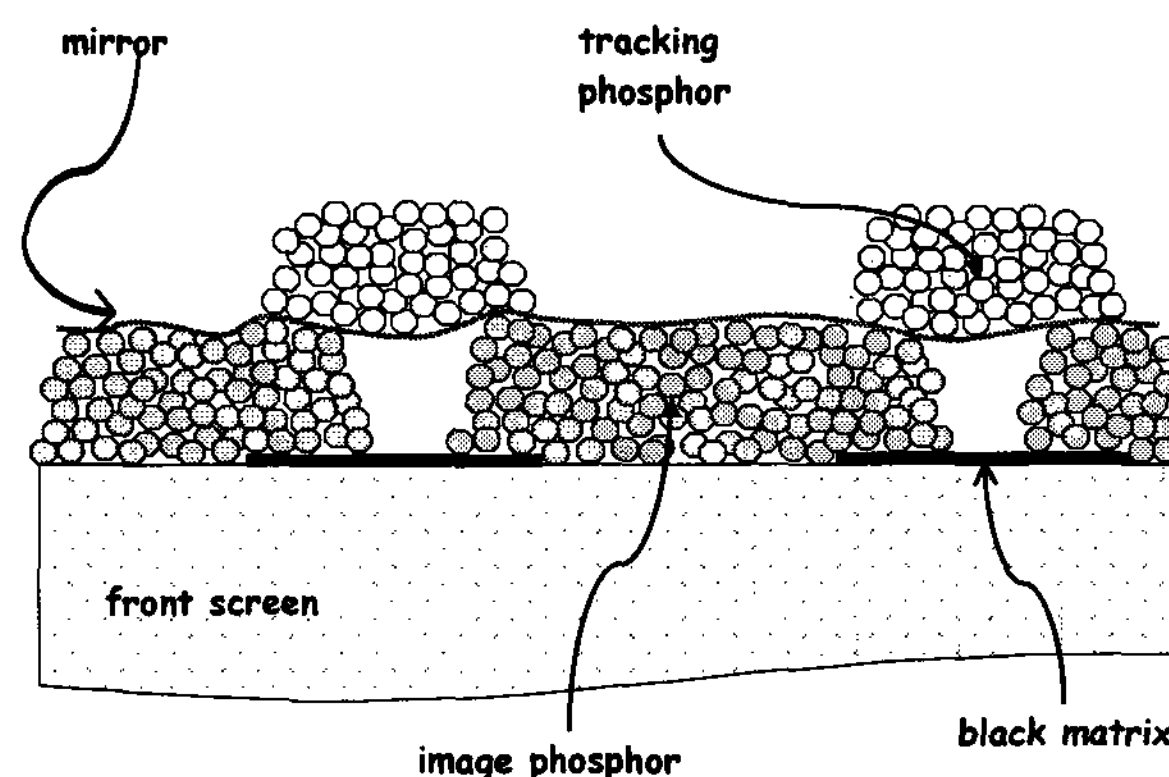


Figure 1 Cross section of the F!T screen.

In order to initialize the tube a beam position signal needs to be generated. This so-called error signal is built up in the following way. When the tracking phosphors are irradiated with an electron beam one of them emits blue light and the other green light. The light from the phosphors is detected by at least one pair of detectors that is mounted on a window in the cone. One of the detectors has been equipped with a filter that does not transmit light from the blue tracking phosphor; the other detector has not been equipped with a filter. By a number of linear operations a signal can be constructed that is linearly dependent on the difference between the light from the green and the light coming from the blue tracking phosphor [3,4]. By dividing this signal by the sum of the light from the blue and the green tracking phosphor, a normalized error signal is obtained.

The relationship between the position of the beam and the error signal in the case that only one beam is active, is shown in figure 2a and b. When the active beam is exactly on top of the blue tracking phosphor all the light is coming from that phosphor. Since the error signal is normalized to the sum of the light, it will have value one at that position. If the beam is exactly in between the tracking phosphors, i.e. on a display phosphor, equal amounts of electrons are hitting both tracking phosphors and the error signal is zero. Taking this in consideration, it is easy to see that a straight non-horizontal beam trajectory results in a periodically varying error signal with amplitude one.

In order to indeed get an error signal with amplitude one, the size of the beam in the vertical direction has to be so small that only

one color of tracking phosphor is hit when the beam is centered on a tracking phosphor. At the same time, such a small spot size results in a visible moiré pattern on the viewer side of the screen. This pattern is caused by the mismatch between the written raster and the screen structure. Hence, a slow loop that uses the error signal for detecting the beam position will always result in a visible moiré pattern.

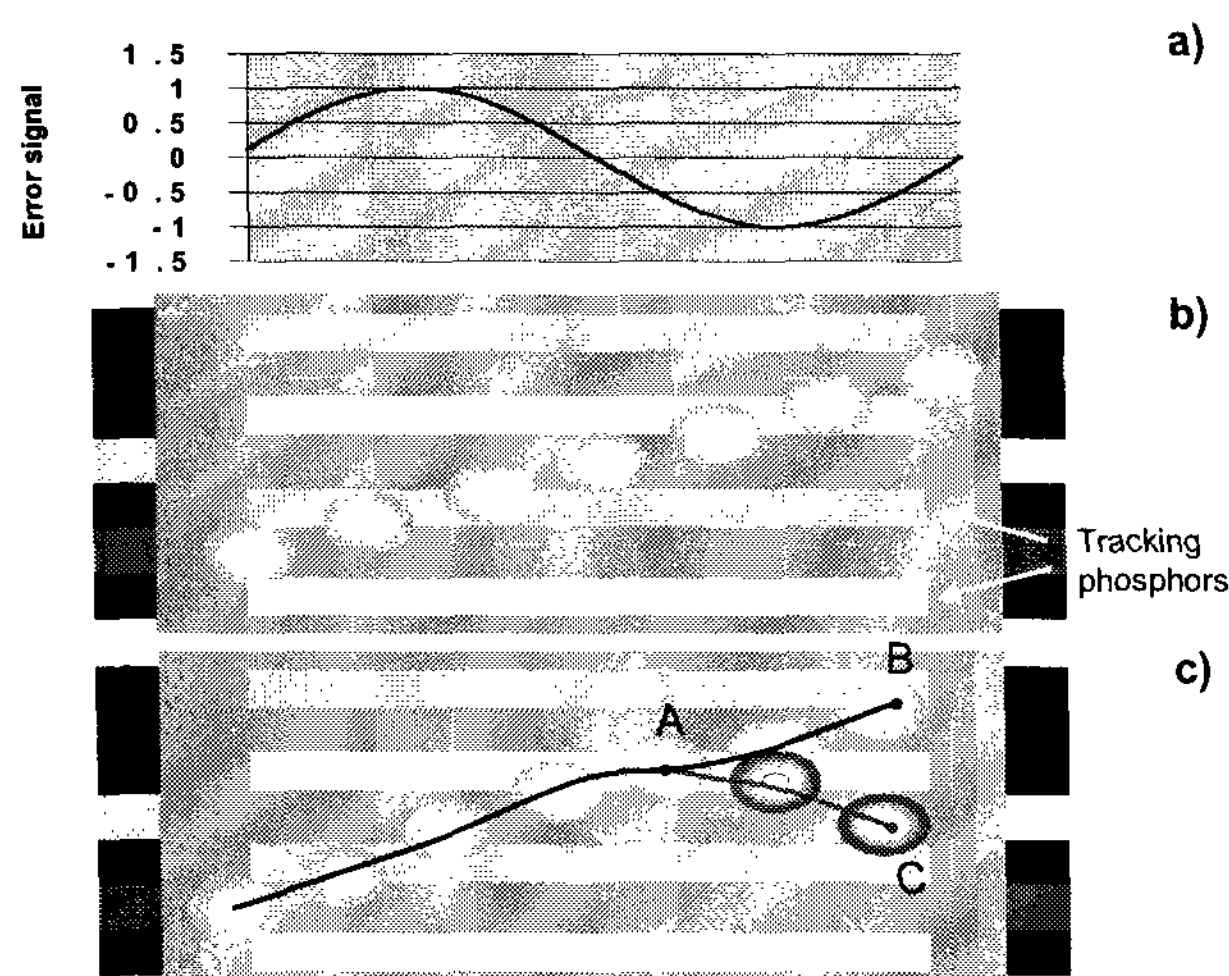


Figure 2 Illustration of the relation between the beam position (b) and the error signal (a). Two traces that give identical error signals(c).

There is a second problem associated with the use of the error signal to detect the beam position: the beam position cannot be determined unambiguously from the error signal. In Figure 2c a beam trajectory (black line) has been indicated that increases monotonically from left to right. When the beam is exactly on top of the green tracking phosphor it could also follow the red trajectory A-C. Please note that trajectory A-C is constructed by mirroring the line part A-B with respect of the center of the green tracking phosphor. Since the blue tracking phosphor is deposited symmetrically around the green tracking phosphor, the error signal will increase in the same way for both traces. Therefore, it is impossible to reconstruct the beam position from a single measurement of the error signal. Since the slow loop only uses the error signal as an input, it can never calculate the beam position over the entire screen in one iteration step. Instead, the beam position is corrected only locally and it is corrected with small steps compared to the calculated mis-landing. This ensures the convergence of the loop, but at the same time requires many iterations.

3. Improved slow loop

We have designed a new slow loop that does not have the disadvantages that are stated in the previous section. The most difficult aspect in designing a slow loop is that it has to be able to operate under diverse boundary conditions. We have split the tube initialization into three application phases, according to the boundary conditions they have to comply with: The factory initialization, the start-up initialization and the operation during use. This enables us to develop tailored software routines for each phase. The phases are explained in more detail in the next paragraphs.

3.1 Three application phases of the slow loop

The factory initialization. In this phase the tube and deflection yoke have been matched in the factory. The boundary conditions for the loop are:

- The loop has to be able to measure and correct raster and/or convergence errors that can be several millimeters;
- The software may run on a powerful external processor that is positioned in the factory line;
- Due to the limited number of positions in the factory line, the time for the loop to converge is restricted;
- The displayed video content can be chosen freely.

The start-up initialization. In this phase the TCA is mounted in a TV set. The values of the correction signals that were obtained during the factory initialization are stored in the tracking electronics that are supplied with the set. The start-up initialization has to run every time that the TV set is turned on. The boundary conditions for the loop are:

- The raster and convergence errors are due to thermal drift and a different orientation of the tube with respect to the earth's magnetic field. The raster and convergence errors due to the former distortion are expected to be small. The magnitude of the latter distortion is quite large, but it is homogeneous so that the required corrections can be predicted;
- The software has to run on a processor that is supplied with every tube. Hence, this will be a cheap processor with limited memory and processing power;
- The converging time of the loop can only be a few seconds in order not to annoy the viewer;
- The video information displayed is limited to one or two test patterns. It is demanded that the loop is operated at low beam current and that a moiré pattern is not visible.

The operation during use. This phase directly follows the start-up initialization phase and, hence, all the beams are positioned correctly. The loop has the following boundary conditions:

- The loop has to work in parallel with the fast loop. Any positioning errors that are due to slow thermal drift and which appear as large amplitudes in the fast feedback correction signal have to be corrected;
- The loop has to run on the same cheap processor as used during the on-time of the TV set; The video content can not be adjusted to avoid any visible artifacts.

3.2 Method for the factory initialization

During the factory initialization it is possible to choose the video content freely even when resulting in a visible moiré pattern. It is therefore possible to use the error signal for position detection. However, extra measures are needed to unambiguously relate the error signal to the beam position. This is done in the following way.

By adding a small DC component to the frame current the complete raster can be shifted vertically by half the phosphor pitch. The beam trace that is sketched in figure 2c and figure 3 (solid trace) will now be at the position of the dotted trace in figure 3. Without the shifted raster the beam is positioned on the

center of a tracking phosphor at point A, causing a minimum in the error signal. With the shifted raster point A is translated to point A', which is located exactly between two tracking phosphor stripes. Taking figure 2a and b in mind, this implies that the error signal is zero. More importantly, now it is possible to distinguish between the two traces, since for trace A'-B' the error signal changes sign upon passing point A', whereas for trace A'-C' it doesn't. From this simple example it becomes clear the described method unambiguously determines the beam position. Therefore, it is possible to correct for the raster errors in a single iteration step that needs two measurements.

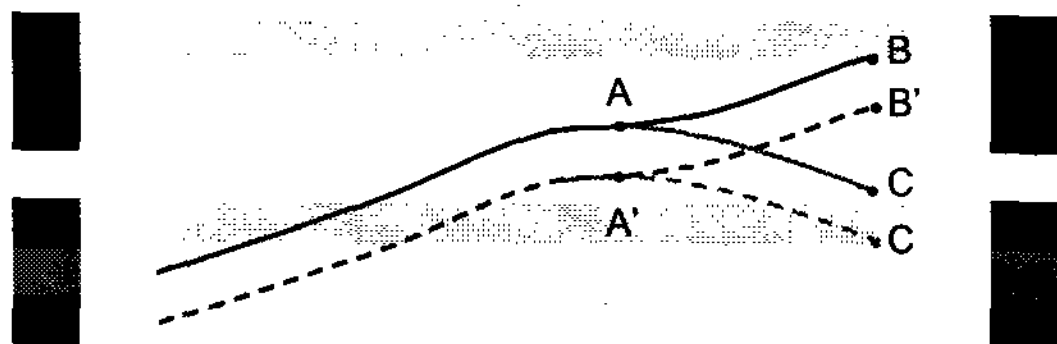


Figure 3 Illustration of the effect of shifting down the raster lines by half the phosphor pitch.

3.3 Method for the start-up initialization

During the start-up initialization the video content cannot be chosen freely. Furthermore, it is unacceptable that a moiré pattern is visible for the viewer. Therefore we have chosen for the following method.

In the first step one of the beams is activated, while at the same time the focus voltage of the gun is adjusted such that the beam hits at least three display phosphors. In this way a gray image is visible to the viewer, which is more likely to be acceptable. In order to measure the beam position, the screen of the F!T tube was adapted at a number of positions. At these positions part of the tracking phosphor lines were omitted as is illustrated in figure 4. When the electron beam passes the omissions no light is generated. This is detected by monitoring the signal from the detector that has not been equipped with a filter. Since we want to be sure that no light is generated during at least one video line, the omissions in the phosphor lines should range over at least four tracking phosphor lines. In practice, an omission in nine consecutive lines is chosen to handle beams that have been defocused more than needed. The minimal size of the omissions in the horizontal direction is limited by the bandwidth of the beam detection system. Please note that the omissions of the tracking phosphor lines are not visible to a viewer, since they are positioned behind the black matrix lines.

With this method a minimum in the sum signal can directly be related to an absolute position of the screen. It is therefore possible to detect the beam position with a global reference. Since the omissions of the phosphor lines are arranged in a matrix-like pattern it is possible to detect the beam position over the entire screen. By interpolating the beam positions a correction signal can be constructed that guides the beam to its intended position.

3.4 Method for operation during use

During the operation of the tube the beams should be positioned correctly by definition. If beams would drift from the position that was determined in the start-up initialization, this will be corrected by the fast tracking loop. However, the drift can become so large

that it exceeds the driving range of the fast loop. To prevent this from happening, a fraction of the amplitude of the fast loop is coupled back in the slow loop. Since thermal drift is expected to occur very slowly, the update frequency of the slow loop during use can be low.

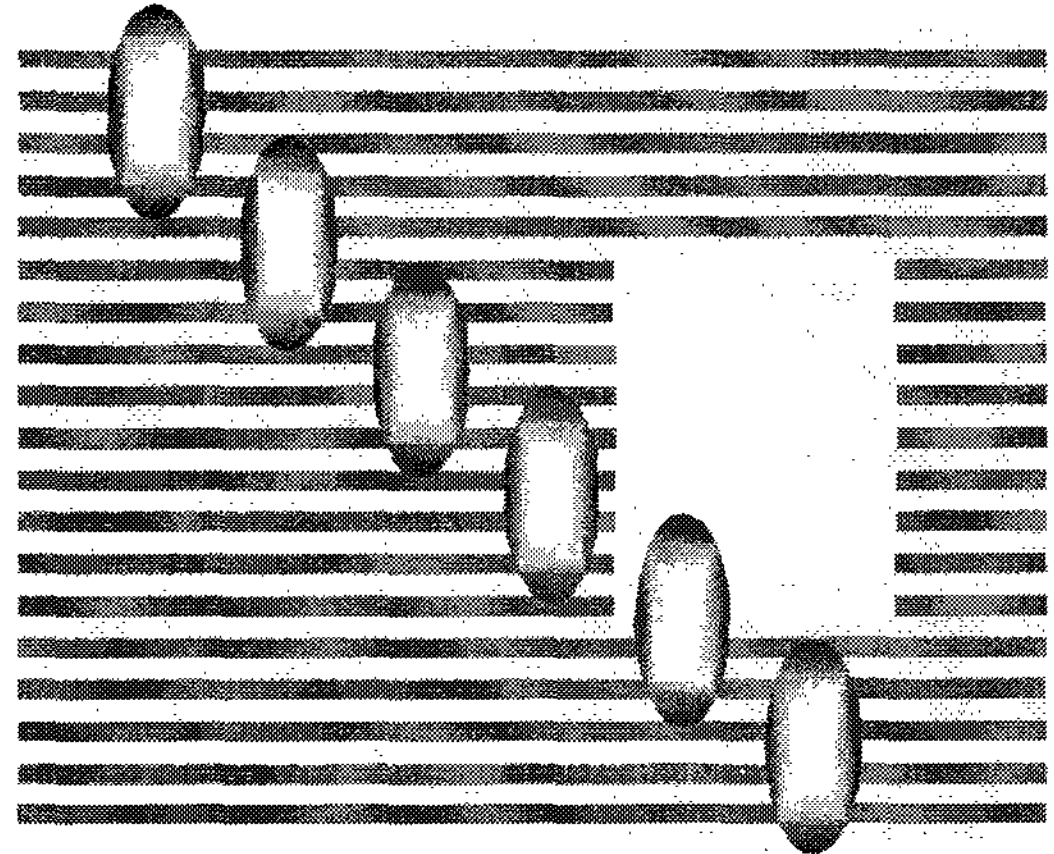


Figure 4 Illustration of the omissions in the tracking phosphor lines that are used to detect the beam position. For ease of viewing the display phosphors have not been shown.

4. Results and conclusions

The performance of the slow loop during the factory initialization and the start-up initialization was evaluated in a 32" wide screen slim prototype. The deflection yoke was optimized for scanning over 120 degrees and it was equipped with 2py, 4py and 6py correction coils to position each of the beams individually. The tube had 480 color triplets, resulting in a phosphor screen pitch of 256 μm . The tube was equipped with a gun that was optimized for the low current in a F!T tube in order to have a small spot over the entire screen for all three beams. More details on the used set-up can be found elsewhere [3]. The tube had such raster deviations that it could be initialized with the original version of the slow loop. It turned out that this loop needed more than 100 iteration steps to correct the raster deviations.

In the first experiments the convergence rate of the factory and start-up initialization were tested by running both types of initialization with no prior knowledge of the needed corrections. The results are shown in figure 5.

Figure 5a shows the image on the tube that is observed at the beginning of the initialization process with only the central beam active. Due to the imperfect raster a color moiré pattern is clearly visible. Figure 5b, c and d show the image on the tube during the factory initialization after 1, 2 and 11 iteration steps, respectively. It is clear that the bands in the moiré pattern have almost completely been removed after two iteration steps, indicating that the beam deviations have been reduced to at most one phosphor pitch for almost the entire screen. It turned out that in an initial version of the factory initialization this was the maximal accuracy that could be obtained. This was because only positions, at which the error signal changed sign were used for the calculation of the feedback signal. Therefore, the loop was refined by also taking the value of the error signal into account. This was done by adding a fraction of the error signal to the correction signal. Although the

refinement adds nine iterations steps to the procedure, it has the advantage that the end result of the loop is an initialized raster with position errors that are much smaller than the phosphor pitch. It should be noted that, although the raster errors have been corrected with large precision, the beam does not land on the intended phosphor. The reason for this will be discussed later. Compared with the original loop that took more than 100 iterations, the new factory initialization has improved the convergence speed of the loop by a factor of nine.

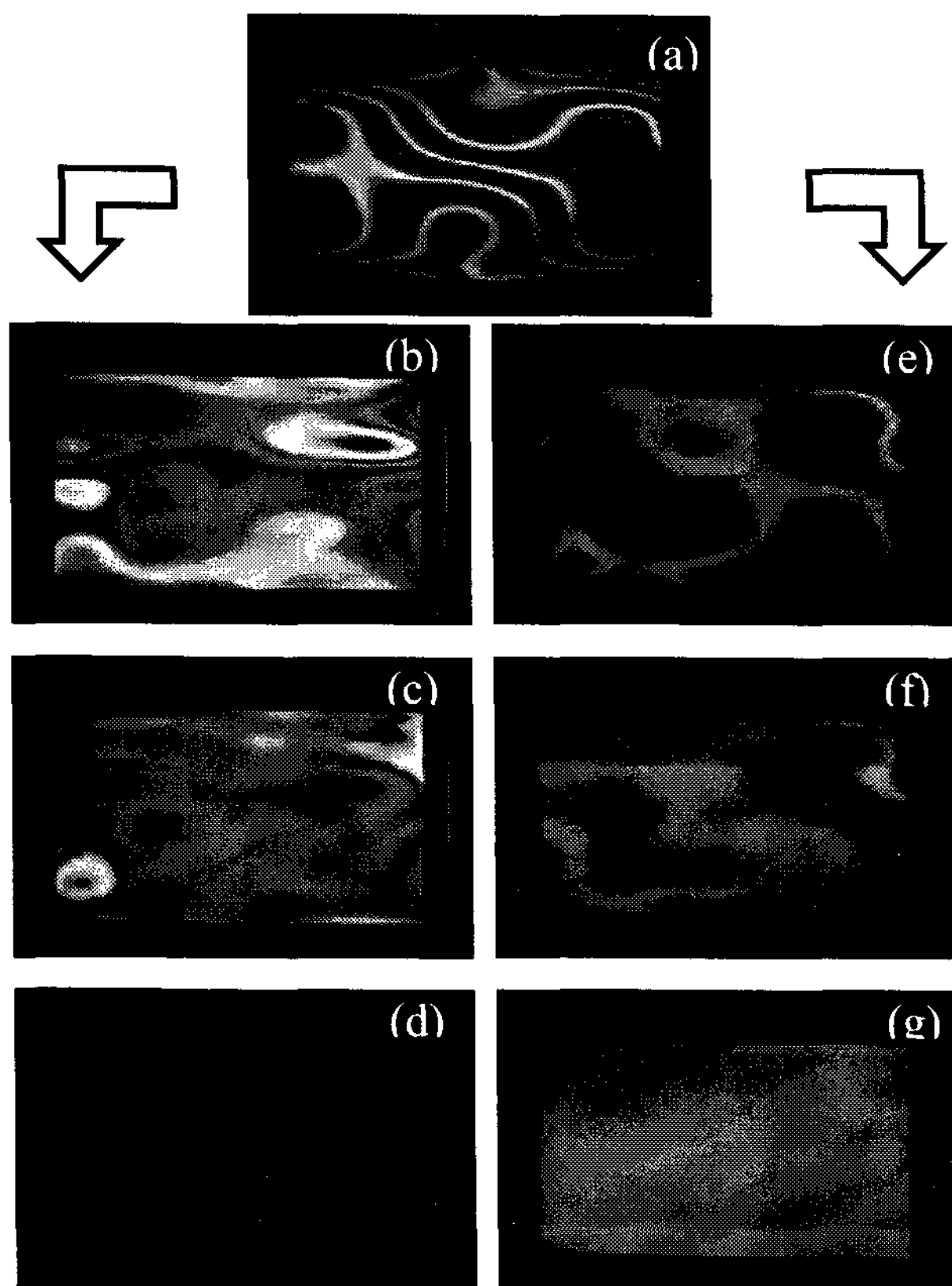


Figure 5a shows the image on the tube prior to initialization. **Figure 5b, c and d** show the image after 1, 2 and 11 iterations, respectively, of the factory initialization; **figure 5 e, f and g** show the image after 1, 2 and 7 (plus operation during use) iterations, respectively, of the start-up initialization. The bright horizontal bars in the image are due to interference of the camera with the update rate of the tube.

Figure 5e, f and g show the images that are obtained after 1, 2 and 7 iteration steps, respectively of the start-up initialization. Please note that the beam is out of focus during the start-up initialization, resulting in a gray image (not shown here). The images shown here are obtained by refocusing of the beam after each iteration step to visualize the status of the raster errors. Comparing figure 5c with figure 5f, it appears that the convergence speed of both loops is approximately the same. This is true for almost the entire screen. At the upper and lower edges of the screen color bands are still visible for the start-up loop. As can be seen in figure 5a from the densely stacked moiré bands, the initial raster errors are quite

large in these areas. Since the start-up loop uses only a limited number of sample points (145 omissions for this particular screen), the loop needs more iterations to converge. By choosing a pattern of omissions that matches with areas where the nominal raster and convergence errors are largest, the initialization can still be accelerated. In figure 5g the end result of the loop has been shown. This was obtained in seven iterations of the loop, followed by typically ten iterations of the loop that is ran during operation.

Comparing the performance of the two loops we notice two things. First, at screen positions where the beam position distortions varied rapidly in space, the factory initialization loop converged more rapidly. Moreover, one particular tube that suffered from excessive raster errors, could only be initialized by the factory loop (data not shown). Hence, only this loop can be used under such boundary conditions. Secondly, the factory loop suffered from having no global reference. This can be seen from figure 5d, showing that an image with the central beam give a color pure image, but with the wrong color. In a next version of the factory initialization loop this can be solved by using a global reference on the screen to detect the absolute position.

We also ran both loops to correct the convergence errors. A similar convergence rate of the loop was observed during these experiments.

In this paper we have shown that a new kind of slow loop was developed that can be used in a consumer product. By splitting the slow loop into three parts, the loop can fulfill the variety of boundary conditions it has to comply with. In the factory initialization we use differential measurements of the error signal to determine the beam position over the entire screen. In the start-up initialization we use omissions in the tracking phosphor stripes to determine the beam position. The latter method allows to use a defocused beam, thus preventing disturbing color moiré on the front screen.

By comparing the convergence rate of the new slow loop with the old one we have shown that the convergence rate was improved by one order of magnitude. The new loop enables an acceptable initialization, both in the factory as well as at the end-user.

5. Acknowledgements

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6. References

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