ALIGNMENT OF A CCD DEVICE INTO THE IMAGE PLANE

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Abstract

Methods and instruments for the alignment of the optical sensors in the spacelabs Vega I. and II. are shown in this article. The determination of the best position of the CCD plane had become more exact applying OTF measurements in the focal plane.

It's known that the Spacelabs Vega I and Vega II took pictures of the comet Halley on the 6^{th} and 9^{th} March 1986. These pictures were recorded by a TV-camera which contained two optical systems with 2–2 CCD-s in their focal-plane. One of these optical systems was an 150 mm wide-angle objective and the other was an 1200 mm reflecting telephoto objective. It's shown in Fig. 1 that a dividing prism near at the focus of the reflecting telescope produces two images for being detected with varried colour filters on different wavelengths. The detectors were Silicium plates with polished surfaces where the images formed were neither visible with unarmed eye nor detectable with microscope. The quality image was expected only if the detector lays exactly in the focal plane of the optical systems since the distance to the comet was about 10 000 km and that means an infinite long distance in the optical practice.

To make a quite good decision about the quality of the optical image it would have been possible through the displayed information on a TV monitor but the accuracy wasn't satisfactory due to the wrong resolution.

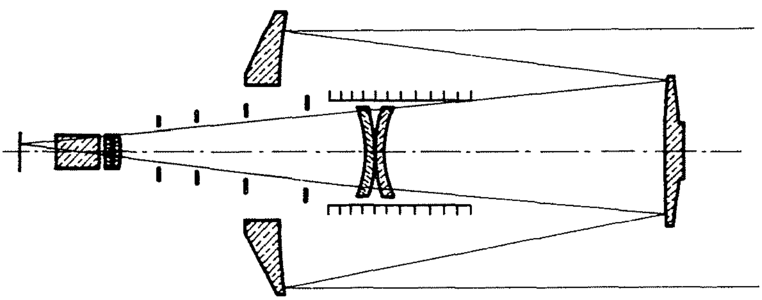

Fig. 1

Finding of the best image plane (best focus) is an old problem in the Optics. We tried to give a solution for this problem by using the OTF (Optical Transfer Function).

The effect was used that the measured OTF was connected with the distance of the image plane, from the supposed ideal image plane of the given optical system.

The MTF (Modulation Transfer Function) represented by the spatial-frequency is scaled on the X-axis and the contrast is scaled on the Y-axis in Fig. 2. The different diagrams represent measurements in different image planes.

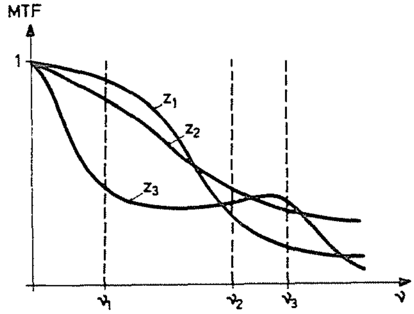

Fig. 2

The deviation of focus is shown on the X-axis and the constrast is represented on the Y-axis in Fig. 3. The diagrams had been measured by different MTF's.

It means a great difficulty to choose the optimal position of the image plane because of its dependency on the spatial-frequencies we have to use this optical system. Of course there is an ideal system without aberrations for every optical system as equivalent, where the OTF is only depending on the aperture and on the wavelength.

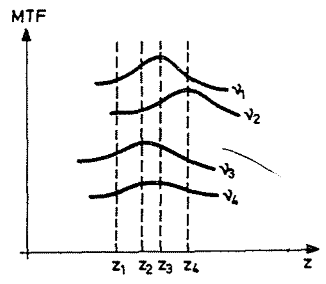

Fig. 3

An optical system and its alignment may be characterized by the difference between the OTF of the system without aberration and the OTF of the realised system.

Figure 4 shows that the quality of such an optical system might be measured by the extent of the ruled area.

$$\frac{dT(z)}{dz}=\frac{d}{dz}\left[\int_0^{\nu_h} MTF_{ab}\,d\nu-\int_0^{\nu_h} MTF(z)\,d\nu\right]=0$$

$$\frac{d^2T(z)}{dz^2}>0$$

where MTF_{ab} is the MTF of the optical system without aberration,
$MTF(z)$ is the MTF expected in z-position of the given optical system
ν_h the highest spatial-frequency is necessary for the information processing.

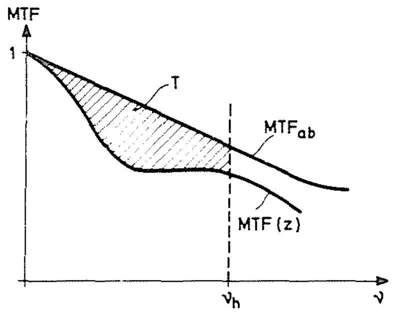

Fig. 4

Measuring of the OTF

It is then to follow by measures the deviations of the focus and the optimal position of the image plane may be found by the minimum of this area.

A „knife-edge" type object was imaged by the given optical system and the image was analysed. The distribution of intensity in the image-plane is shown in Fig. 5. (Direction x is normal to the optical axis).

The OTF may be calculated with computer after scanning and detecting of the intensity by a slit. [1]. If the intensity distribution would have been scanned by an edge with a photomultiplier behind it than the integral of the function would have been given. The OTF can be calculated from this integral too. [2].

In our case there was a small angle between the image of the knife-edge-like object and the CCD-columns. By that, reading out the information on the

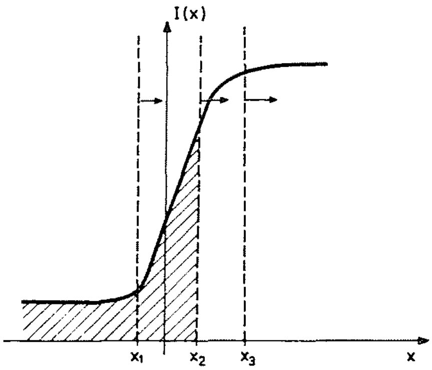

Fig. 5

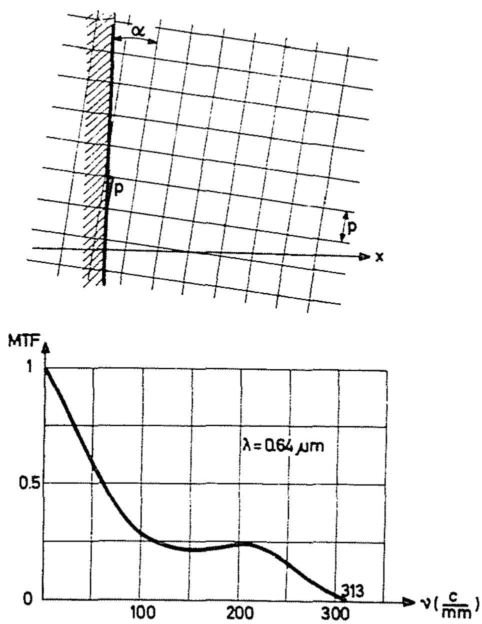

Fig. 6

pixel, the transition from illuminated to non-illuminated section was shifted. This shifting is equal to a virtually moving of the scanner-edge. By this it wasn't necessary to produce moving by the scanning. The measuring problem was traced back to the case showed in Fig. 4. After having measured the OTF with the method reported in this paper, the result was drawn in Fig. 6.

This computer aided method is suitable for the application in a control system. The optimal image-plane may be alignmented with this apparatus by moving a high-precision stepmotor.

References

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