MAIA: Technical Development of a Novel System for Video Observations of Meteors

S. Vítek, K. Fliegel, P. Páta, P. Koten

Abstract

A system for double station observation of meteors now known as MAIA (Meteor Automatic Imager and Analyzer) is introduced in this paper. The system is based on two stations with gigabite ethernet cameras, sensitive image intensifiers and automatic processing of the recorded image data. This paper presents the measured electrooptical characteristics of the components and the overall performance of the new digital system in comparison with the current analog solution.

Keywords: imaging systems, image processing, ethernet camera, image intensifier, system testing, astronomy, meteors.

1 Introduction

Double station observation of meteors using two video systems coupled with image intensifiers started at the Ondřejov observatory about a decade ago[1]. It was shown that the properties of the system with an image intensifier allow detection of meteors down to masses of fractions of one gram. Good time resolution of events with meteors is provided by the video technique, which enables us to calculate the atmospheric trajectory and many other properties of meteors. However, the precision of the image data captured by the video recording both in spatial resolution and in dynamic range is lower than with a photographic approach [2].

This paper describes the evolution of the current project to replace analog S-VHS camcorders with a new design in which gigabit ethernet cameras are used. The direct digital output will have many advantages in the enhanced parameters of the system, and especially in the advanced automation of the observation process.

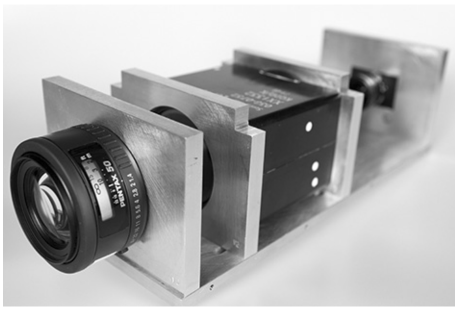


Fig. 1: System inner housing with installed components

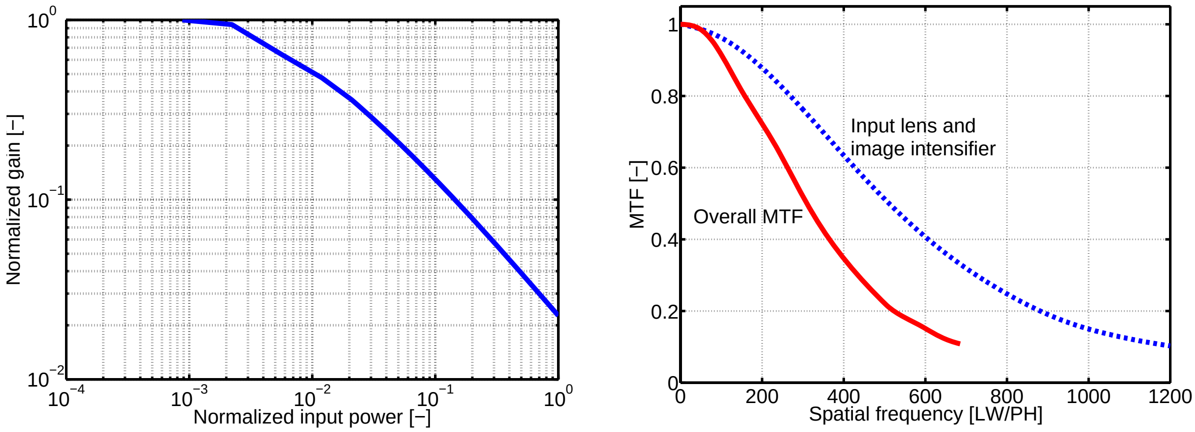
2 Design of the new system

The design of the new video capturing hardware is based on experience with the current analog system — the main components of the image sensing hardware are the input lens, the image intensifier, the camera lens, and the camera itself. The central part of the system is the XX1332 image intensifier manufactured by Philips (now Photonis). These image intensifiers are characterized by the very large diameter input 50 mm and output 40 mm apertures, the high gain (typically 30 000 to 60 000 lm/lm) and the good resolution (typically 30 lp/mm).

Since the diameter of the photocathode in the image intensifier is 50 mm and the angle of view for meteor observation should be about 50°, the most suitable focal length of the input lens comes at about 50 mm. The aperture of the input lens plays an important role in the overall sensitivity and signal-to-noise ratio of the system. After an extensive search, the fast lens Pentax SMC FA 1.4/50 mm was considered as a compromise between aperture, sharpness and price. This 50 mm lens contains 7 optical elements in 6 groups, offers aperture F/1.4 and angle of view 47°. The lens features an SMC multi-layer coating to lower the surface reflection, reduce ultraviolet rays and deliver clear, high-contrast images.

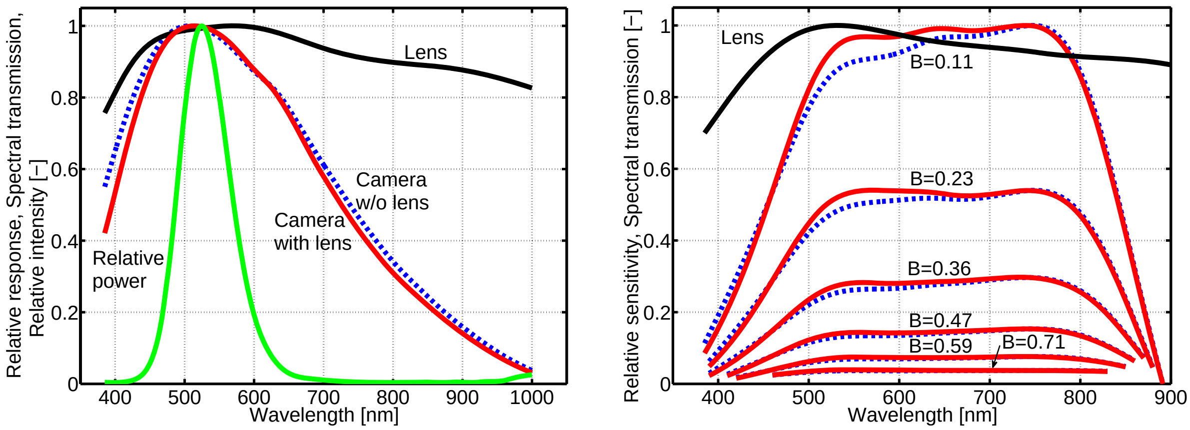
The parameters of a suitable camera for video observation of meteors should be better than in the case of the analog S-VHS camcorder used in the current system. This means that the camera should offer at least the frame rate and resolution common for the PAL standard, i.e. 50 interlaced fields per second and digitized resolution 720 × 576 pixels. These requirements are met in the JAI CM-040GE camera with 1/2 progressive scan CCD sensor offering resolution of 776 × 582. The gigabit ethernet interface allows maximum framerate 61.15 fps and 10 or 8-bit output.

The focal length of the camera lens was selected to get a perfect match between the output screen of the image intensifier (diameter of 40 mm), the height of the CCD (4.83 mm) and a suitable distance between the camera and the image intensifier (about



(a) (b)

Fig. 2: The normalized gain of the system (measured at 650 nm) describes the automatic gain control as nonlinearity in the image intensifier (a), the overall MTF of the system including the camera (solid line) and the partial MTF of the image intensifier with the lens (dashed line) (b)



(a) (b)

Fig. 3: Relative spectral response of the camera with (or without) a lens, and the relative power of the light at the output screen of the image intensifier (a), relative overall spectral sensitivity of the system for different digital levels B in the output image ($B = 1$ white, $B = 0$ black) (b)

10 cm). The fast lens Pentax H1214-M 1.4/12 mm was selected — the vertical viewing angle is approximately 22° with the selected camera. The image of the screen can be focused easily on the CCD with the 250 μm spacer ring. The image intensifier screen to focal plane distance is about 120 mm in this configuration.

3 Measurement of the electrooptical characteristics

The spectral transparency of both lenses (input and camera), the spectral sensitivity of the image intensifier, the spectral sensitivity of the camera, the spectrum of the light at the output of image intensifier, the spatial resolution of the input lens and the image intensifier, and the spatial resolution of the whole system are among the most important parameters tested and presented in this paper.

3.1 Spectral response

The spectral response was measured independently for all parts of the system [3]. The experimental setup consisted of the LOT-Oriel collimated halogen light source, the LOT-Oriel Omni 150 computer controlled monochromator, the expander to get even illumination of the image sensor, and the Avantes AvaSpec-3648 fiber optic spectrometer. The measurement results are shown in Figure 3.

3.2 Spatial resolution

The MTF was measured using a test chart according to ISO 12233. This chart can be used to evaluate MTF with two different approaches, utilizing a slanted edge (an approx. 5° slightly slanted black bar used to measure the horizontal or vertical spatial frequency response), or a line square wave sweep with the spatial frequency range 100–1 000 LW/PH (line widths per picture height). In our case, slanted edges were used to determine the spatial frequency response – see Figure 2(b).

4 Conclusions

This paper has presented the design of a new system for double station video observation of meteors now known as MAIA. The basic electrooptical characteristics have been measured and the functionality of the proposed image sensing part of the system has been verified. The achieved parameters have proved that the proposed system can be used for the intended task.

Measurements of the spectral characteristics of the image intensifier and the camera show the two devices are well matched. The overall spectral response of the system is broad, and it can be used easily in the range 455–845 nm. The time resolution of the selected camera (i.e. 61.15 frames per second) is above the frame rate offered by the analog S-VHS camcorder used in the current system. The only limiting factor is the lower effective spatial resolution of the selected camera (approximately 0.24 megapixels) in comparison with the spatial properties of the image intensifier (0.95 megapixels).

Acknowledgement

This work has been supported by the grant No. 205/09/1302 "Study of sporadic meteors and weak meteor showers using automatic video intensifier cameras" of the Grant Agency of the Czech Republic.

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