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MTF MEASUREMENTS

Annotation This article describes the importance of the MTF, its methods of measurement, as well as the benefits of measuring by the method of tilting the edge.

Keywords: Measuring technology, slanted edge technique, MTF

INTRODUCTION

A universal characteristic of the quality of image is an optical transfer function, which includes 2 components:

-modulation transfer function (MTF)

-phase transfer function

These characteristics describe the mathematical equation. It shows the dependence of the luminance in the image plane and in the object plane.

$$E(x', y') = \pi\tau \cdot \sin^2 U \iint_{-\infty}^{\infty} A(x' - x_1', y' - y_1') \cdot L\left(\frac{x_1'}{\beta}, \frac{y_1'}{\beta}\right) dx_1' dy_1'$$

where $E(x', y')$ - a function that characterizes the distribution of illumination in the image plane near the point with the coordinates x', y';

τ - optical transmittance;

U - aperture angle of the optical system in the image plane;

$A(x' - x_1')(y' - y_1')$ - optical scattering function;

x_1', y' - variable coordinates near the point with coordinates x', y';

$L\left(\frac{x_1'}{\beta}, \frac{y_1'}{\beta}\right)$ - a function that characterizes the brightness in the plane of the object at a point with coordinates $\frac{x_1'}{\beta}$ і $\frac{y_1'}{\beta}$;

β - optical axis magnification.

OPF is a universal criterion that fully characterizes the quality of the optical system. It shows how the OS plays different spatial frequencies.

Formally, the optical transfer function can be obtained from the equation of the process of obtaining the image recorded in the frequency formula. Mathematically, OPF is the result of the Fourier transform of the scattering function.

$$\tilde{A}(\nu_x', \nu_y') = \iint_{-\infty}^{\infty} A(x', y') \cdot e^{-j \cdot 2\pi(\nu_x' \cdot x' + \nu_y' \cdot y')} dx' dy'$$

Advantages of using MTF:

First, quite often optical systems in which numerous components are used (lenses, films, etc.) have an MTF system equal to the MTF product of individual nodes. That allows you to test in the process of mounting the node.

Secondly, the MTF can be specified at one wavelength or in the wavelength range.

Thirdly, testing of MTF is objective and universal. The engineer is not required to judge the contrast, resolution or image quality.[1]

MEASURING TECHNOLOGY OF ITF

Frequency generation methods

In this method, the operator measures the padding directly. The object of the study consists of templates that have one spatial frequency and are displayed by the object under test. Various mechanisms have been developed that allow you to change the frequency of the source when the image contrast is constantly measured. As one of the example, a rotating radial lattice with a slit hole is used as an object. A pinhole is placed in the focal plane of the lens and the light passing through it is monitored with a detector.

When this grid rotates, black and white stripes are displaced through the hole. Spatial lattices can be changed by moving the lattice relative to the slit. The detector output is synchronized to the rotation and is a direct measure of the MTF at the radial grating spatial frequency and its harmonics.

The advantage of this method is to measure the output directly. The disadvantage of this system is that it is necessary to simultaneously manipulate the source and the detectors.[1]

Scan method

The principles of linear systems theory are used for scanning systems. MTF is combed out from the image by the created lens with the specified input. The image of an infinitely small source will be blurred. Because the speaker output with a single audio input frequency will be tonal. The frequency response of the objective correlates with the quality of the blur. The qualities of the blur similarly indicate the frequency response of the lens.

LSF is typically created by scanning the edge of an image of a pinhole with mechanical dimming. Next, differentiate the output that can be created using the slit sources by moving the hole or the slit. Sagittal and tangential orientation is determined by the vertical and horizontal orientation of the knife. The image is scanned horizontally and vertically when the edge of the knife has a right angle and passes diagonally through the image. Fourier transform LSF is a one-dimensional MTF. Computer algorithms can quickly correct MTF data for a finite aperture size.

We can get a high resolution with the help of scanning systems. Using scanning systems equipped with precision lead screws driven by stepper motors or accurate synchronous motors.[1]

The disadvantage of this method is the duration of the scan. Also, insufficient sampling can significantly affect the measurement accuracy.

Video Methods

Typically, a solid state array is placed at the focal plane of the lens-under-test.

Using the direct Fourier transform we obtain a two-dimensional OTF. Integrating the point distribution functions, we recognize the Edge traces and line spread functions. If the source is used as a source, then performing the one-dimensional Fourier transform is calculated by the OTF.

The advantage of this method is the measurement speed. The MTF can be updated as quickly as the solid state array can be electronically sampled and the Fourier transform calculated. This provides a continuously updated spread function and MTF curve.[1]

The disadvantage is the design of electronic solid state arrays. Since the dimensions of the elements of the detector are of the order of a few microns, the relay optics must be of high quality. It must have a high numerical aperture and must be diffraction limited so as not to affect measurements.

Interferometric Methods

MTF can also be measured using an interferometer. There are two ways: auto-correlating the pupil function of the lens-under-test or analyzing the PSF calculated by Fourier transforming the pupil wavefront. This is very convenient for systems which are suitable for testing in an interferometer and do not exhibit significant chromatic aberrations, and whose wavefront errors do not vary substantially over the wavelength of interest. With scanning, video or discrete frequency methods, the wavelength range can be adjusted by using wide band sources and spectral filters for full polychromatic testing. Interferometers rely on monochromatic sources (i.e. lasers) so that MTF is only available at these wavelengths. [1]

In addition, since phase measuring interferometers have limited wavefront sampling capabilities, the wavefront should be fairly well corrected. Lenses with excessive wavefront errors are difficult to measure with interferometers.

Full polychromatic testing of a wide variety of optical systems is possible using MTF testing methods such as edge scanning, video and discrete frequency targets.[2]

Investigating scanning methods found that one of perspective method for measurement of the modulation transfer function (MTF) is the slanted edge technique.[3] It is based on the numerical analysis of the digital image of an inclined half-plane. This half-plane has a small inclination angle relatively periodical structure of a focal plane array (FPA). The vertically oriented edge (along the FPA columns) allows you calculation of the MTF in the horizontal direction and the horizontally oriented edge is used for identification of the vertical MTF. The principal advantage of the slated edge technique is that only one image is necessary for MTF measurements. For example, using the multi-bar or sinusoidal test-pattern requires the capturing and processing formation of at least one image for each spatial frequency or separation of image parts in a field of view. In case of Fuko technique, the number of input images depends on the desired spatial discretization. In addition, after each test-pattern shift, it is necessary to repeat focusing procedure. It is important that the optical setups for MTF measurements using the slanted edge, multi-bar or stochastic test-pattern are the same: an illumination system that produces uniform irradiation, a unit with a set of test-objects (generally on a motorized rotating stage), a long focal length collimator and the digital camera under test or measurements.

CONCLUSION

One disadvantage of the slated edge technique is absence of precise requirement how to select the optimal edge and its acceptable variations depending on characteristics of an optical system and a FPA of a digital camera. The only recommendation is that the number of pixels on a slanted edge image should be sufficient for the correct MFT measurement. Thus, the smaller angle of the edge requires the bigger area for measurement. The paper discusses the requirement that guarantees the accurate MFT measurement with minimal number of used pixels.

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