OPTICAL DESIGN OF AN EYEPIECE

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Abstract. A short description of the designing of a high resolution (20arcsec on axis), wide FOV (48deg), 6.5mm pupil diameter, 6.5percent distorsion, 17.5mm eye relief eyepiece is given in this report.

1. Introduction

In this report we describe the main aspects of the designing of a high resolution eyepiece for a vision instrument.
An eyepiece is an objective with the entrance pupil diameter placed outside from the lenses. At this entrance pupil position the observer will place the eye. The distance from the entrance pupil diameter to the first lens is called eye relief. Typically the eye relief should be about 10mm-15mm to allow a comfortable viewing. Military instruments generally require longer eye reliefs for safety reasons. Short eye reliefs can be found in short focal lengths eyepieces.
The diameter of the entrance pupil position should be chosen in order to fit the environmental working conditions. The iris of the eye varies from 2 mm diameter in bright sun light to 7mm-8mm diameter for dark viewing. It could be helpfull to dimension the entrance pupil diameter D according to the environmental conditions by means of the following empirical formula Ref.[1]:

$$D = 5.3 - 0.55 lnB \tag{1}$$

where B is the scene brightness in ft Lambert. Some representative values of B are given in Table I. The human eye can resolve Ref.[2] a 1 arcmin (central foveal cone vision), about 3 arcmin at 5 deg off axis, and 10 arcmin at 20 deg off axis (rod vision).
The eyepiece magnification M is the ratio of the apparent image size as viewed through the eyepiece to the object size. Since the image is generally imaged at a distance of about 250mm from the eye, the magnification M can be evaluated with

Table 1. Scene Brightness vs. Eye Pupil Diameter

Environment	$SceneBrightness(ftLambert)$	D(mm)
Clear night	0.01	7.8
Dawn/dusk	1.0	5.3
Office	100.0	2.7
Sunny day	1000	1.5

the following formula:

$$M = \frac{(F_e + 250)}{F_e} \tag{2}$$

where F_e is the effective focal length of the eyepiece.

2. Optical design

We needed a high resolution, 48deg field of view (FOV), 6.5mm entrance pupil diameter D eyepiece with an eye relief greater than 15mm. We adopted an optical scheme with six lenses made of high refractive index glasses. The default merit function (DMF) of a commercial optical software was sufficient to optimize the design. Some constraints were added to the DMF in order to keeping small the distorsion value (we had a requirement of 6.5 percent). The exit pupil was bound to match the primary objective. A 45percent vignetting was imposed on the maximum FOV as this should be the condition in the instrument. The spectral range is the visible light.
The eyepiece has a spatial resolution of 20arsec on axis and of 3arcmin on edge FOV.

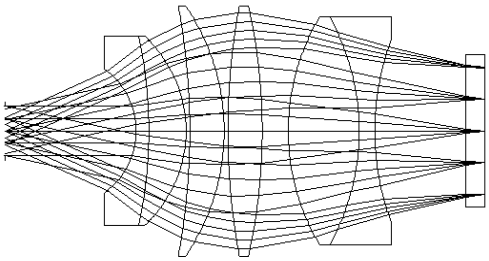

Fig. 1: Optical layout of the eyepiece. A reticule is placed on the focal plane of the eyepiece.

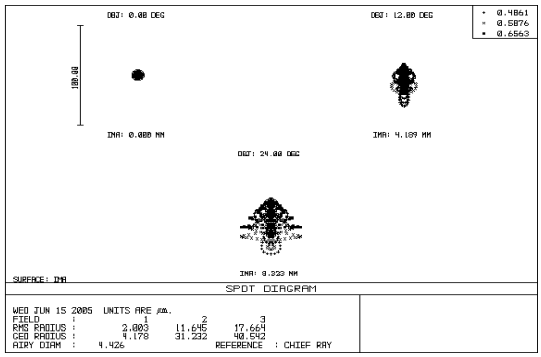

Fig. 2: Polychromatic spot diagrams (expressed in μm and compared to the Airy Disk) of the eyepiece.

TABLE 2. Main optical specifications of the eyepiece

Parameter	*value*
Focal Length	20mm
Spectral range	450-650nm
Pupil Diameter	6.5mm
Resolution (axis)	20arcsec
Resolution (max. FOV)	3arcmin
Eye Relief	17.5mm
Speed F/	3.07
Max. distorsion	6.5percent

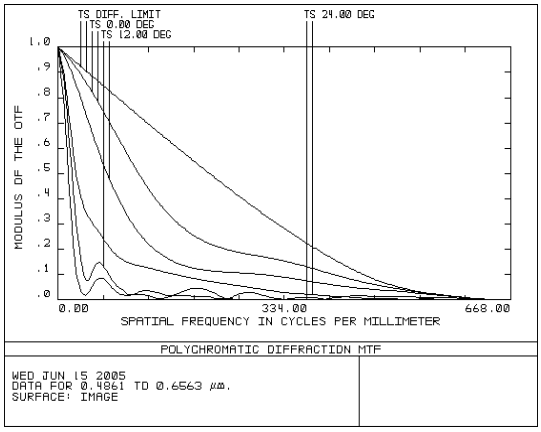

Fig. 3: Polychromatic MTF curves of the eyepiece.

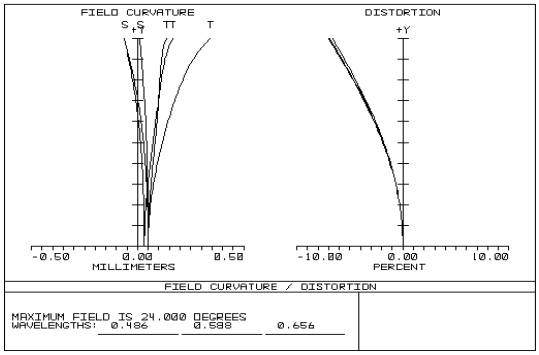

Fig. 4: Field curvature (expressed in mm) and distorsion (percentage) curves of the eyepiece.

REFERENCES

[1] M. Laikin, *Lens Design*, Marcel Dekker Inc, New York, (1990).
[2] K.N. Ogle, *On the Resolving Power of the Human Eye*, JOSA, 41:517 (1951).