Summary. We have developed a prototype of a confocal scanning laser ophthalmoscope that incorporates adaptive optics to correct for the wavefront aberrations of the eye and those induced by the optical system. Two corrector devices were tried out in the experiments: a membrane deformable mirror and a liquid crystal spatial light modulator. We obtained high-resolution images of different parts of the retina with and without the wavefront correction. We also explored alternative adaptive optics configurations to improve on the imaging performance of the system.

33.1 Introduction

Retinal imaging with the scanning laser ophthalmoscope (SLO) is limited by the aberrations of the eye, specially if large diameters of the eye pupil are used. The improvement of the images has previously been accomplished by incorporation of adaptive optics (AO) correcting with a Xinetics mirror in a reflective relay optics system [1]. However, one of the requirements to facilitate the widespread use of these techniques is to simplify the system and to reduce the cost of the components. With this aim we tested two relatively low cost correctors: a membrane deformable mirror (MDM) and a programmable phase modulator in a refractive relay optics scanning laser ophthalmoscope (AO-SLO) set-up.

33.2 Using an Electrostatic MDM in AO-SLO

The MDM (Flexible Optical, Holland) consists of a reflective mirror membrane (Ø15 mm) hanging over an arrangement of 37 electrodes occupying a diameter of ≈ 7.5 mm. Details about the mirror characteristics can be found elsewhere [2–4]. To efficiently control the mirror, the area used must be less than the clear aperture but slightly more than the area covered by electrodes. In this work the Ø6 mm at the eye pupil is transported to a Ø9 mm on the mirror membrane.

The wavefront sensing is done using a Hartmann–Shack sensor consisting of a squared array of lenslets with 6.3 mm focal length and 0.6 mm pitch attached to an IR-enhanced CCD camera. The system has around 60 spots
to determine the wavefront gradient when using the $\varnothing 6\text{mm}$ eye pupil to reconstruct the aberrations to $4^{th}$ order.

The configuration of the system is shown in Fig. 33.1. An IR diode laser is used to illuminate the eye. The beam power is reduced to maintain the illumination of the eye at around $100\,\mu\text{W}$; well below the safety levels for continuous viewing of a collimated beam at 785 nm [5]. The beam scanning is done using two galvanometric scanners (one of them resonant) in conjugate planes with the eye pupil. An important amount of the defocus of the eye is corrected by allowing the displacement of the lens nearest to the eye and the bite bar used to stabilize the head of the subject. The light reflected from the retina is de-scanned and redirected to the adaptive optics components using a beam splitter. The correction used for the acquisition of images is in this set-up static. Thus once the correct voltages for the mirror have been obtained in a closed-loop control scheme, the voltages are maintained and flip mirror is used to redirect the aberration-corrected light to the photomultiplier through the confocal pinhole. This is justified because the movements of the eye are small enough to have a relative stable aberration; normally well below the aberration of the uncorrected eye. The signal of the photomultiplier is digitalized to build images of $512 \times 512$ pixels at a frame rate – limited