1 Concepts Related to Laser *in situ* Keratomileusis Surgery

1.1 Wavefront technology in ophthalmology

When light from a star or another astronomical object enters the Earth's atmosphere, atmospheric turbulence will distort the image. Images produced by any telescope larger than a certain size are blurred by these distortions. In order to overcome this effect from atmospheric turbulence, the idea of adaptive optics (AO) has been introduced into the field of astronomy. The principle of AO can be described in two steps: the first step is measuring an incoming wavefront by a wavefront sensor and the second step is correcting the deformations of an incoming wavefront by deforming a mirror in order to compensate for the distortion introduced by atmospheric turbulence. AO works by measuring the distortions in a wavefront and compensating for them with a device that corrects those errors as does a deformable mirror. This technology has been widely used for improving the resolution of ground-based telescopes since being proposed by Babcock.[1–5]

Human eye tissues also distort the incoming light into the retina and will blur the image on the retina. The principle of how the atmospheric turbulence affects the resolution of ground-based telescopes is the same. The principle of wavefront measurement and compensation of AO was introduced to ophthalmology research in 1978. As early as 1982 at the 6th International Conference on Pattern Recognition in Munich, Germany, wavefront sensing and adaptive optical closed loop control were proposed for aberration-free imaging and vision testing. That was the first time that a system essentially provide an elimination of optical eye aberrations that diminish the fundus image quality. On the other hand, by active focus control and wavefront sensing, the aberrations of the human eye, such as astigmatism of the cornea and spherical aberration of the lens, can be measured.[6]

Three types of aberration measurement devices have been developed: the thin-beam ray-tracing aberrometer, the Tscherning aberrometer, and the Shack–Hartmann method. The most widely used method is the Shack–Hartmann wavefront sensor. It consists of an array of lenses with the same focal length, and each lens is focused onto a photon sensor, such as a CCD. The local tilt of the wavefront across each lens can then be calculated from the position of the focal spot on the sensor. From the spot pattern, the shape of the incident wavefront can be reconstructed based on appropriate curve-fitting algorithms. The principle of the Shack–Hartmann wavefront sensor is demonstrated in Fig. 1.[6]

The new wavefront measurement technology in ophthalmology could record all higher-order ocular aberrations for the very first time. Commercial equipment appeared on the market quickly after the concept of wavefront measurement was introduced in ophthalmology research. One example of such equipment is WaveScan, as shown in Fig. 2.