博士論文（要約）

論文題目　Variable Focus Lens with a Large Aperture and its Applications
(大口径可変焦点レンズとその応用)

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The Abstract of the Doctoral Thesis

In this work, we have presented how to design a variable focus lens with a large optical aperture. The research of variable focus lens has been studied for decades, but a lens with a large aperture size is still a challenge. Through a careful studying on the existing liquid lenses and based on our founding of the physical limitation, named capillary length, we proposed a variable focus lens with liquid-membrane-liquid structure. Elastic force was assumed to take place of interfacial tension so that a longer capillary length could be achieved. Based on the proposed structure, a calculation on the deformation of the elastic membrane and finite element simulation were conducted to confirm the membrane's deformation; its optical characters were deduced to calculate its optical performance. Furthermore, a prototype of a variable focus lens with liquid-membrane-liquid structure was fabricated, and its aperture was designed as 30 mm in diameter, which is larger enough than the existing liquid-filled lenses. A series of experiments were conducted and its variable focus performance was examined that a scale of focal length range was tunable between [-150 150] mm, the minimize F/5 is attainable, and an optical resolution of 8.00 lp/mm could be clearly achieved

In addition, it is found that elastic force is increased gradually based on the external pressure, so that the deformation of the lens in its weak power temporarily performs an asymmetrical shape and results in a low optical performance. It potentially becomes a limitation of the lens's application in the future. In order to improve its weak power area, we proposed to distribute a pretension force on the elastic membrane so that even though a small external pressure could active a stronger force, which in turn a target capillary length achieves faster. Finite element simulation was employed and proved the membrane deflection and the improvement. A fabrication method was proposed and a prototype was fabricated. Experiments were conducted and the results proved the lens could achieve zero diopter with 105.1 nm root-mean-square wavefront error.

Furthermore, an adaptive achromatic doublet was proposed, which could perform a dynamic optical power and the chromatic aberration could be corrected at the same time. The adaptive achromatic doublet was composed by two variable focus lens of liquid-membrane-liquid structure. By choosing different liquid pair, the variable focus lens in front has a low dispersion performance and the lens in the back has a high dispersion performance. The achromatic was confirmed by conducting the experiment, and the chromatic focal shift range was improved from 2.5% of the focal length for singlet lens to around 0.06% for doublet. To realize dynamic focal length and achromatic performance, two variable focus lenses should be controlled cooperatively by following the engaged adjustment strategy.

Finally, an ophthalmological application of presbyopia's vision correction was proposed. Based on the investigation on the presbyopia, it is found that there is no perfect treatment and eyeglasses for their specific needs. Because of losing elasticity of crystals lens and power of ciliary muscle, accommodation range of the eye results in a short value which leads them hardly to observe a near object. They need an additional positive vision correction to see the near object and normally do not need correction for the distant vision. A pair of diopter adjustable glasses was proposed by using the variable focus lens developed above. The proposed glasses has merits as follows: it has a tunable diopter which covers the requirements of presbyopia; the power of the lens is filling in the whole lens, so that it does not have weird distortion like bifocals; wears can friendly control the lens power as they want by touching a roller ball on the right bridge of the glasses. A presbyopia vision was mimicked and a principle experiment was conducted. A series of images were taken during the diopter shifting, and it is shown that presbyopia patients could clearly observe the near object by the assistant accommodation of the glasses.