Self-Powered Smart Contact Lenses with Microfabricated Loop Antennas for Adaptive Optical Control

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Abstract—We present self-powered smart contact lenses integrating microfabricated 900 MHz-1.1 GHz loop antennas and miniaturized energy sources for adaptive optical control. These lenses enable real-time beam shaping, aberration correction, and optical modulation directly on the ocular surface. Simulations and experiments demonstrate compact, efficient antennas supporting wireless power and communication, providing a platform for wearable, autonomous adaptive optics in laser beam applications.

Keywords— Smart contact lens; loop antennas; adaptative optics

I. Introduction

Recent advances in microfabrication, wireless communication, and energy harvesting have enabled the development of self-powered smart 10 mm contact lenses capable of integrating adaptive optical functionalities [1].

II. Dedicated Antennas

We present a multidisciplinary approach combining micro-scale energy sources, 900 MHz-1.1 GHz bandwidth loop antennas [2], and miniaturized control electronics to enable real-time optical modulation directly on the ocular surface. Using microfabricated loop antennas as shown on Fig. 1, the lenses achieve efficient electromagnetic coupling for both data transmission and energy harvesting, supporting continuous operation without external tethering.

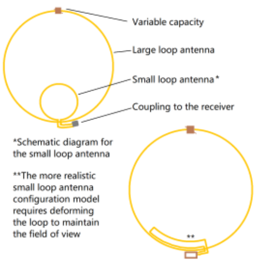

Fig. 1. This figure is illustrating the problem of coupling to the transmitter-receiver antenna with the need to maintain the field of vision through the 9.5 mm lens. Gold loops of the antennas are shown in yellow gold color. The brown rectangle in the lower right corner symbolizes the ASIC.

III. Compact Lens Integration

We discuss the design trade-offs between antenna geometry, dielectric loading by ocular tissues, and regulatory electromagnetic exposure limits, highlighting strategies to maximize power transfer efficiency while maintaining lens transparency and wearer comfort, illustrated in Fig. 2. By integrating autonomous power sources with adaptive optical elements, these lenses enable precise modulation of transmitted and reflected light, offering potential applications in aberration correction, dynamic beam shaping, and augmented reality systems. Experimental validation demonstrates sub-millimeter antenna footprints with GHz-bandwidth communication and power delivery, while simulations confirm the feasibility of adaptive optics control under physiological conditions.

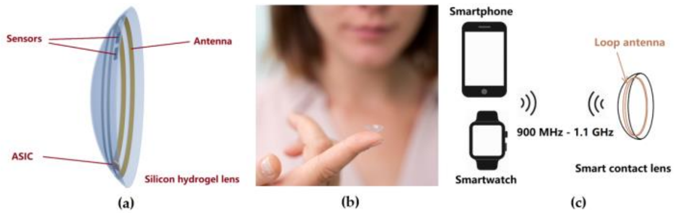

Fig. 2. (a) This Figure illustrates the general principle of making a contact lens, which includes an antenna, an application-specific integrated circuit (ASIC), and sensors to communicate with a smartwatch, a mobile phone, or a computer. The addition of components in a lens allows, if necessary, to position a progressive contact lens by correctly orienting it. These technologies are feasible. (b) Free pic illustrates scale of contact lens. (c) Smart contact lens and a smartwatch and/or a smartphone.

IV. Conclusion

This work underscores the synergy between photonics, RF engineering, and bioelectronics in creating next-generation wearable optical devices. Our results provide a foundational platform for ultra-compact, self-powered adaptive optics systems, suggesting pathways for future integration with ocular imaging, and vision enhancement technologies.

References

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