

Two-photon vision for Augmented Reality

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1. Introduction

One of the key challenges in augmented reality (AR) technology lies in balancing the brightness and quality of both the real-world image and the overlaid augmented content. Achieving satisfactory visual performance for both typically requires compromises. Most current AR solutions rely on waveguide technology, which, although effective in transmitting augmented images, interferes with the natural light path from the environment. This results in a dimmed and sometimes distorted view of the real world. The problem becomes even more complex when the waveguide must accommodate multiple display colors.

Two-photon vision offers a promising alternative [1]. This mechanism of visual perception is based on two-photon absorption in visual pigments, which triggers phototransduction in retinal photoreceptors [2]. The phenomenon extends the range of electromagnetic radiation that can be perceived by human sense of sight to 800-1300 nm. By exploiting the difference in wavelengths between ambient light and augmented stimuli, two-photon vision can facilitate the integration of both optical paths in AR glasses.

Another benefit is that one-photon and two-photon vision are governed by different physical principles. Specifically, the perceived brightness in one-photon vision is linearly related to light intensity, whereas in two-photon vision, it depends quadratically on the power of the stimulating beam [3]. The two-photon vision is effective only when the beam is focused on the retina. These differences can be harnessed to display sharp, high-contrast augmented two-photon content without compromising the quality of the real-world image. Our recent research has demonstrated that two-photon stimuli over a one-photon background are characterized by better contrast than one-photon stimuli over the same background [4]. Moreover, the two-photon augmented content is not visible to bystanders, which could be a valuable feature for users requiring privacy or discretion.

To translate these findings into practice, we are currently developing a first prototype of two-photon AR glasses at ICTER. This presentation aims to share our progress and discuss the challenges associated with the project.

2. Methods and results

The scheme of two-photon AR glasses prototype is shown in Fig. 1 a). The software for the prototype is written in LabVIEW. Whole system contains a tunable femtosecond fiber laser, acoustooptic modulator AOM and glasses frame consisting MEMS mirror and pupil camera (CAM). The calibrated power sensor PS in the optical path allows for constant monitoring of power of stimulating laser entering the eye. The tunable laser, with pulse train optimized for two-photon vision, emits in the range 960-1030 nm and is perceived as blue (960 nm) through green, up to yellow-green (1030 nm) color. The glasses frame are connected with the laser by the optical fiber. The clock signal from MEMS driver is used by multifunction DAQ card for synchronization the AOM with MEMS enabling the projection of the stimuli of different shapes. AOM will be also used for control the stimuli brightness. The small pupil camera mounted on the glass frame is used to localize the subject's pupil and direct the beam into the eye mitigating anatomical differences between subjects.

The idea for projection the two-photon augmented content is schematically shown in Fig. 1 b): the scanning beam will be reflected from dichroic mirror to the subject's pupil displaying two-photon stimuli directly on the retina. Details of the optical system of the glasses are not shown. The dichroic mirror will transmit the ambient light from visible range. The augmented content will be overlaid on real world view allow for testing the properties of two-photon vision stimuli in realistic background scenes. The series of psychophysical tests: measurement of visibility thresholds and contrast sensitivity are planned to define the range surrounding illuminance upon which the two-photon content will be clearly visible. Fig. 1 c) shows the exemplary E-letter stimuli, used for contrast sensitivity testing, displayed with the MEMS mirror on the artificial eye camera upon prototype development process.

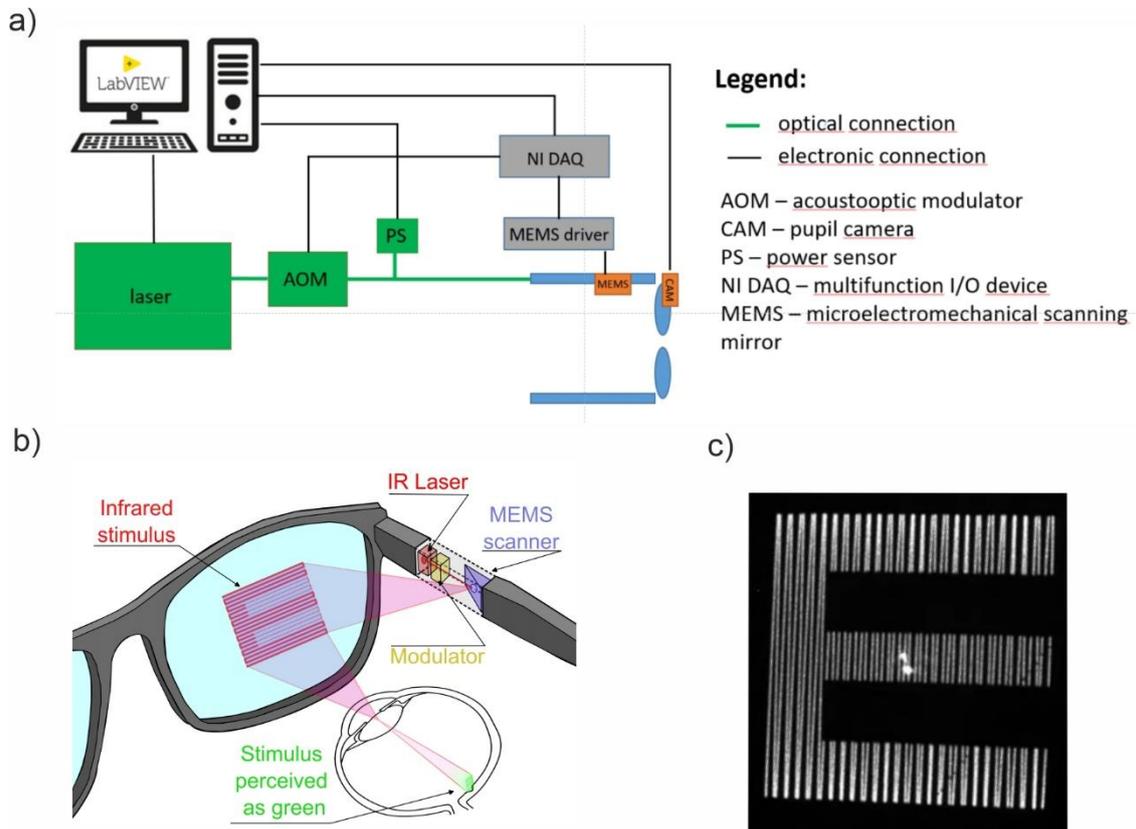


Fig. 1. The scheme of two-photon AR glasses prototype: a). The idea of projecting two-photon augment content: b). The exemplary E-letter optotype displayed on the camera of artificial eye due to MEMS scanner synchronization with stimulating laser.

3. Acknowledgements

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