Color Characterization of Infrared Two-Photon Vision

Human vision is commonly believed to be constrained to the visible region of the electromagnetic spectrum, with wavelengths ranging from 400 to 700 nm. However, the advent of the first lasers demonstrated that humans have the ability to perceive pulsed near-infrared (NIR) light as visible light with approximately half the original wavelength.[1] This phenomenon is attributed to the nonlinear optical process of two-photon (2P) absorption by the visual pigment.[2] This study investigates color perception in 2P vision and provides a quantitative analysis based on the utilization of color spaces.[3]

We used a psychophysical color-matching paradigm to investigate the interplay between various NIR wavelengths (880 to 1100 nm) and different radiant power levels (10 to 30 μW) at the pupil plane. The study revealed a robust correlation between perceived hue and wavelength, with hues transitioning from reddish-purple at 880 nm to blue, green and yellowish-green at 1100 nm as power was increased. Intriguingly, we observed a power-dependent hue shift for wavelengths approaching the visible spectrum. This effect is due to the intensity-dependent ratio between single-photon and 2P absorption efficiencies of visual pigments.

We believe that the practical implications of this research are significant, as they provide a basis for novel clinical applications and industrial products. 2P vision has the potential to transform retinal diagnostics, circumventing ocular opacities and minimizing chromatic aberrations to enhance the precision of retinal assessments. Furthermore, the development of 2P-RGB displays represents a novel avenue for the advancement of both vision correction and display technology. OPN

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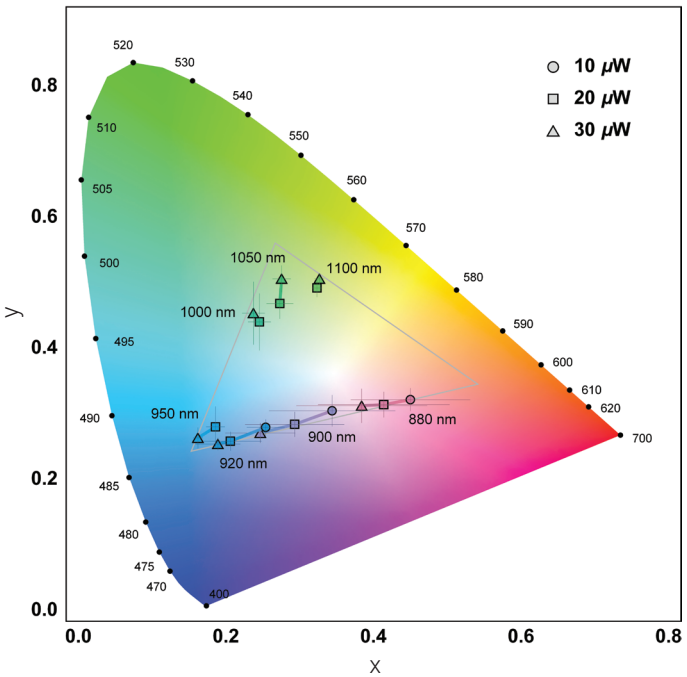
2P vision
CIE 1931 chromaticity diagram



International Commission on Illumination (CIE) 1931 chromaticity diagram displaying the average coordinates of color matched to 2P stimuli. Points corresponding to the same wavelength are connected by lines. Each considered power is represented by a different symbol: circle for 10 μW, square for 20 μW and triangle for 30 μW. The error bars represent standard deviations. The gray triangle represents the gamut of the display.