

Compact Pulse Compressor for Human Two-Photon Excited Fluorescence Scanning Laser Ophthalmoscopy (TPEF-SLO)

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1. Main Text

Two-Photon Excited Fluorescence Scanning Laser Ophthalmoscopy (TPEF-SLO) is a powerful imaging method that reduces the risk of tissue damage by using near-infrared (NIR) light instead of UV light (<400 nm), which can affect the cornea and lens. TPEF enables deep imaging with (NIR) light, whose lower photon energy minimizes photodamage while allowing visualization of different retinal layers of the retina. Importantly, NIR excitation can indirectly target fluorophores such as retinyl esters and retinol, key molecules in the visual cycle with absorption peaks below to 400 nm. Thus, TPEF-SLO offers a non-invasive way to monitor retinal metabolism and the visual cycle [1][2]. Studying the visual cycle under these conditions provides critical insights into retinal pathologies and their potential treatments.

In humans, efficient excitation in TPEF-SLO relies on finding a balance between the ultrashort pulse duration and repetition rate. This optimization allows ensure for safe and effective ophthalmoscopy, particularly *in vivo* retinal imaging, which must operate under secure light exposure limits. In this context, achieving optimal pulse duration through precise dispersion compensation along the optical path is crucial for high-resolution and accurate imaging [3]. Previously, we use a two-prism compressor configuration. However, this setup increases the overall footprint of the TPEF-SLO system, making it challenging to implement in clinical environment and less appealing for commercial use, where portability and ease of integration are essential features for medical devices.

2. Methods and results

Our TPEF-SLO setup uses a ModeSHG laser source, which offering an autocorrelation FWHM pulse width of <100 fs over a tunable wavelength range of 762–788 nm, at various pulse repetition rates. The current compressor configuration introduces negative group delay dispersion (GDD) and adequate third-order dispersion to compensate for both the internal dispersion of the femtosecond fiber laser and additional optical elements.

Given these characteristics, we propose an adaptation of more compact pulse compressor design for use in our TPEF-SLO. The aim is to reduce the 25.8 cm prism-to-prism separation (set at Brewster's angle) by replacing the dual-prism configuration with a single-prism system. This prism will be rotatable to fine-tune higher-order dispersion, and prism will be on translation stage to be able to compensate dispersion for every available wavelength provided by the Mode SHG [2].

The new configuration incorporates two roof mirrors (Hollow Roof Retroreflectors) which control beam direction in both the vertical and horizontal planes. Combined with a single prism, this setup allows the beam to pass through the prism four times, providing the necessary GDD and third-order dispersion. While previous designs using two prisms achieved adequate dispersion compensation, they required longer optical paths, making them unsuitable for compact or commercial systems [2][4][5].

As an initial step, we verified the pulse duration of the ModeSHG laser using an autocorrelator (PulseCheck by A.P.E.). This verification ensures that the pulses meet the manufacturer's specifications before introducing our proposal of external compressor. According to the datasheet, the pulse duration is below 100 fs at a 5.6 MHz repetition rate. Figure 1 shows the autocorrelation traces measured for all available wavelengths in non-collinear mode, recorded directly at the laser output using the Lorentzian fit type. These measurements serve as a baseline for evaluating the effects of our proposed pulse compressor configuration.

Pulse Duration Wavelengths 760–784nm, NON COLLINEAR MODE

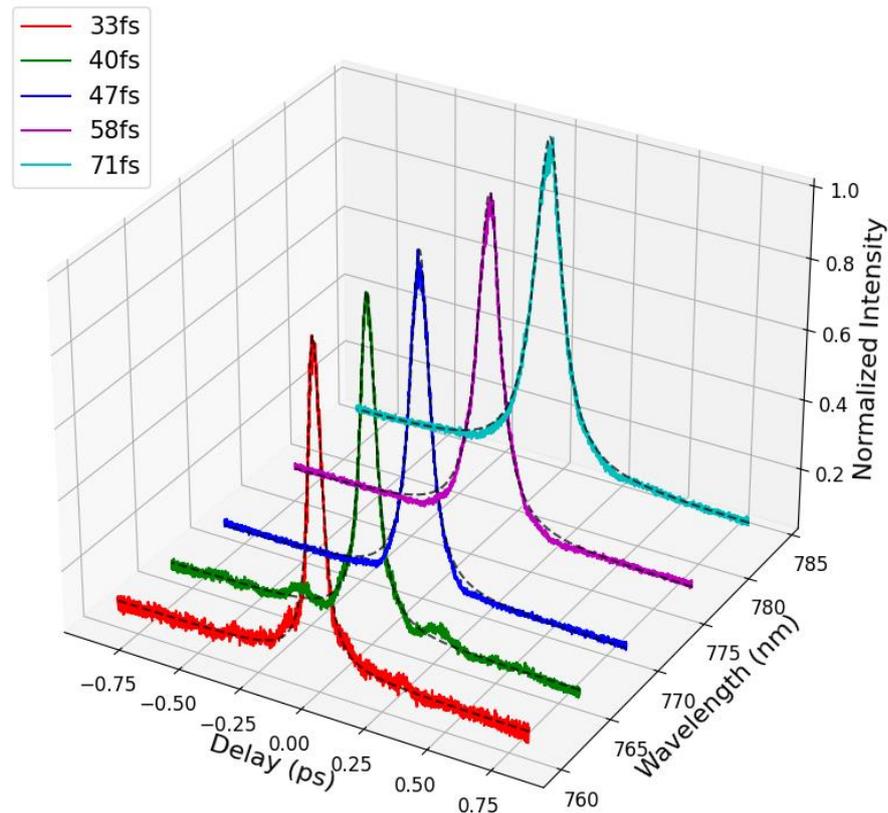


Fig. 1. Temporal intensity traces of ModeSHG output pulses measured at a 5.6 MHz repetition rate in non-collinear mode, across the wavelength range of 762–788 nm, Lorentzian fit type was used to estimate pulse duration time.

The final design is expected to preserve, both dispersion compensation and optical throughput. Our goal is to maintain the pulse duration after the beam passes through all components of the system which include various optical and optoelectronic elements, another reason why reducing the size of the compressor is crucial for a potential commercial applications and use in clinical environments. The poster summarizes the key elements that made this optimization possible.

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4. References

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