Improved quality in nonlinear optical imaging using i^2PIE pulse compression

George Dwapanyin[1], Dirk Spangenberg[1,2], Thomas Feurer[2], Alexander Heidt[2], Gurthwin Bosman[1], Pieter Neethling[1], Erich Rohwer[1]

[1]*Laser Research Institute, Physics Department, Stellenbosch University, South Africa*
[2]*Institute of Applied Physics, University of Bern, Sidlerstrasse 5, 3012 Bern, Switzerland*
Author e-mail address: gwb@sun.ac.za

1. Introduction

The use of ultrafast laser sources in nonlinear (NL) microscopy is on the rise due to the fast repetition rates leading to faster scanning rate with shorter dwell times together with high peak intensities that drive the NL responses at relatively low average powers. Broadband supercontinuum (SC) light sources are also currently being integrated into NL imaging systems as they offer the possibility of further tailoring the excitation pulses to suit different applications. SC generated from all normal dispersion photonic crystal fibres (ANDi-PCF) have been shown to be more stable than SC generated from anomalous dispersion fibres due to the suppression of optical soliton effects in the normal dispersion regime [1]. Knowledge of the spectral phase of the SC can be used to correct phase distortions and compress the pulse to produce a near transform limited pulse using a spatial light modulator (SLM). Recently, a new spectral phase measurement technique known as i^2PIE which is based on time domain ptychography has been developed [2]. In this work, we show the successful use of the novel i^2PIE reconstruction method in our nonlinear microscope to produce improved images of second harmonic generation (SHG).

2. Experimental setup

The experimental setup consists of three essential components: The supercontinuum (SC) generation, the pulse compressor, and the imaging microscope. The SC is generated in a polarization maintaining PCF (PM-PCF) by pumping the fibre with a femtosecond titanium sapphire laser centred at 800 nm with 80 MHz repetition rate. The generated SC source is sent to the pulse compressor, which is the heart of the system, providing near Fourier limited pulses at low average power with high intensity for our custom-built microscope. It consists of a 4f pulse shaper equipped with a 1D SLM which allows for spectral phase measurements that can be used for pulse compression. We apply the novel i^2PIE as a pulse compression technique and compare our results with the commonly used multiphoton intrapulse interference phase scan (MIIPS) [3] pulse compression technique.

3. Results

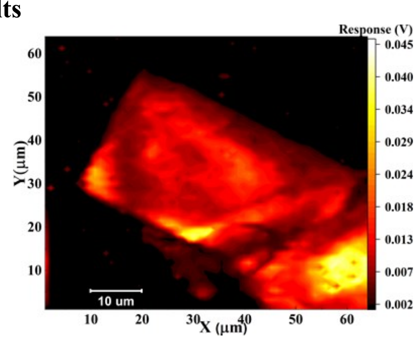

Fig 1. SHG from the epidermis of porcine skin imaged with SC compressed with i^2PIE

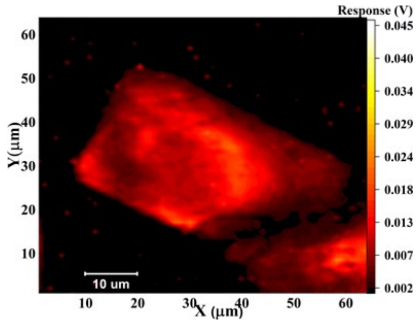

Fig 2. SHG from the epidermis of porcine skin imaged with SC compressed with MIIPS

Figures 1 and 2 show SHG images from porcine epidermal tissue with i^2PIE and MIIPS compressed pulses respectively. The resultant compressed pulses using i^2PIE provides improved contrast (116 vs 70) and signal-to-noise ratios (26:1 vs 11:1) at the same input pulse energy when compared with the MIIPS technique. This means when compared to other techniques, i^2PIE can easily be used with lower energy pulses whilst still providing similar signal strengths which will lead to a reduction in photodamage in biological samples.

3. References

[1] A. M. Heidt *et al.*, "Coherent octave spanning near-infrared and visible supercontinuum generation in all-normal dispersion photonic crystal fibers," *Opt. Express*, vol. 19, no. 4, p. 3775, 2011.

[2] D.-M. Spangenberg, E. Rohwer, M. Brügmann, and T. Feurer, "Extending time-domain ptychography to generalized phase-only transfer functions," *Opt. Lett.*, vol. 45, no. 2, pp. 300–303, 2020.

[3] V. V. Lozovoy, I. Pastirk, and M. Dantus, "Multiphoton intrapulse interference IV Ultrashort laser pulse spectral phase characterization and compensation," *Opt. Lett.*, vol. 29, no. 7, p. 775, 2004.