Generation of multi-nano-Joule 650 nm optical pulses based on a synchronously driven gain-switched 1300 nm laser diode

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INTRODUCTION In recent years, the pulsed stimulated emission depletion (pulsed STED) microscopy technologies are attracting much attention to reduce the light power necessary for achieving super-resolution microscopy.[1] The simplest method to obtain pulsed STED source is to use a pulsed laser diode (LD) for generating pico- to nano-second duration STED light pulse.[2] A drawback of direct generation of optical pulses from an LD is, however, the limited pulse energy (in general, less than 0.1nJ). We here demonstrate that multi-nano-Joule 650nm STED optical pulses are generated by taking second-harmonic-generation (SHG) of amplified optical pulses from gain-switched LD (GSLD), which is synchronized to an excitation optical pulse source.

EXPERIMENTAL Figure 1 shows the experimental configuration for the generation of multi-nano-Joule STED optical pulses. We employed a 1300nm GSLD to generate ~1ns duration pulses and amplified them to over 50mW averaged optical power with a Praseodymium-doped fiber amplifier (PDFA). The amplified GSLD pulses were focused into a periodic-poled stoichiometric Lithium Tantalate (PPSLT) crystal to obtain 650nm SHG pulses. The GSLD was driven by an electrical pulse generator which had a function of multi-channel flexible time delay control. 1060nm-band seed optical pulses for two-photon excitation were also generated from a GSLD[3,4] using the same electrical control function system. Therefore, the timing of 650nm STED optical pulses were easily synchronized to the 1060nm excitation optical pulses.

RESULT and DISCUSSION The 650nm STED optical pulses of pulse energy 2.1nJ were generated by 1300nm optical pulses of 54nJ. Our previous report shows that by direct generation of LD, the pulse energy was at most 0.1-0.2nJ.[5] Thus, the present method surely provides higher energy. The temporal waveforms for the STED optical pulses were measured by a combination of a high-speed photo-detector and a sampling oscilloscope. Figure 2 shows the typical examples of waveform traces taken by oscilloscope for 1300nm and SHG 650nm optical pulses. It is seen that the first peak of the 650nm optical pulses are enhanced in comparison with 1300nm optical pulses because of the SHG nature. However, considering the STED principle, optical pulse energy would be more important than the temporal pulse shape. Therefore, the present method is expected to be useful for efficient pulsed STED scheme.

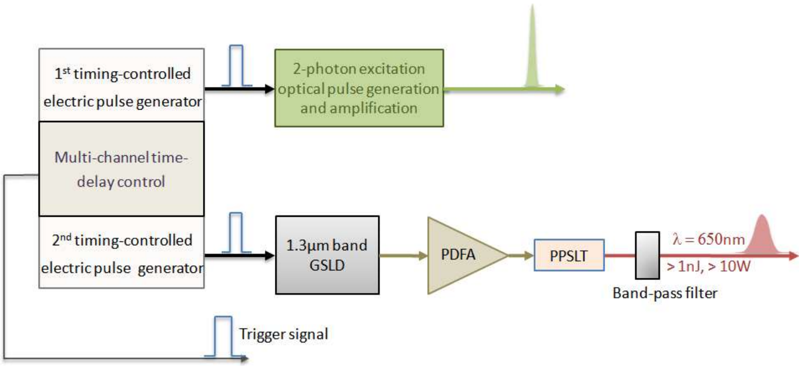

Fig. 1. Schematic of the experimental setup. PDFA: Pr-doped fiber amplifier, PPSLT: periodic-poled stoichiometric Lithium Tantalate.

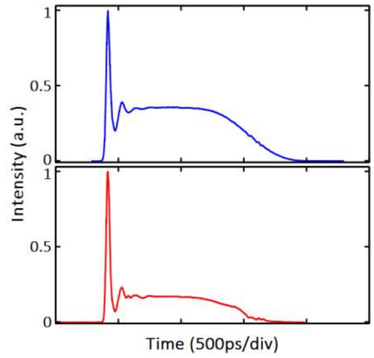

Fig. 2. Typical oscilloscope waveforms for the 1300nm pulse (upper) and 650nm pulse (lower).

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