Tunable, Low Repetition Rate, Femtosecond Pulse Ti:Sapphire Laser for In Vivo Imaging by Nonlinear Microscopy

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Abstract: We report on a broadly tunable, long-cavity, low-pump-threshold, pulsed Ti:Sapphire laser. The laser delivers nearly transform limited ~300 fs, ~10 nJ pulses at 22 MHz repetition rate being ideal for nonlinear microscopy.
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1. Introduction

In this paper, we present a new approach for reduction of the laser induced damage in specimen in nonlinear microscopy, which is specially important issue in *in vivo* diagnostics. Biochemical, genetic and thermal mechanical damage is likely to occur at even low power threshold applying two-photon excitation of biological specimen. We reduce the laser repetition rate by a factor of four relative to standard, tunable, femtosecond pulse Ti:sapphire lasers in order to minimize the laser average power on the sample, but to have the same signal to noise ratio. We demonstrate this effect on flourescencent beads, where we measure the fluorescence intensity for a 80 MHz and our our new, 20 MHz laser system. Having the same spectral bandwidth, average power and beam profile, a factor of 4 increase in the fluorescence intensity was observed. In the following, we briefly introduce our novel laser system.

2. Laser setup

Our laser oscillator utilizes a so-called Herriott-cell (or multi-pass cavity), which is a common feature of long-cavity laser setups [1]. Our laser operates in the negative dispersion-regime (solitonlike mode-locking), but due to the moderate repetition rate of 22 MHz and moderate pump power (~2.5 W), the intracavity pulse peak intensity can be kept below the multi-pulsing limit by properly choosing the intracavity net dispersion. This repetition rate is achieved with a Herriott-cell comprising two ∅2" mirrors having 4000 mm radius of curvature. The distance of the mirrors is 1172 mm and there are 2-2 reflections on each one to provide a unity ABCD matrix. The initial resonator which was extended with the Herriott-cell was a standard ~76 MHz, astigmatically compensated resonator setup. The required amount of negative dispersion in the resonator is provided by an SF10 prism pair with apex distance of 750 mm.

The laser can be easily mode-locked with the hard aperture Kerr-lens mechanism. In our current setup, the wavelength could be tuned over a 165 nm wide range between 715 nm and 880 nm, in mode-locked operation without changing cavity optics except the output coupler (“SW OC” for the 715-810 nm range and “MW OC” for the 810-880 nm range). The maximum of the measured average output power was 205 mW (at 790 nm), which corresponds to a pulse energy value of 9.2 nJ at 22 MHz repetition rate. The measured second-order autocorrelation trace indicates nearly transform-limited pulses with pulse duration of ~300 fs. We are convinced that by using ultrabroadband chirped mirror optics [2] grown by ion beam sputtering technique, a typical tuning range of 680-1040 nm can be obtained at similar pump power levels.

In conclusion, we reported on a new laser concept for a low repetition rate, ultrashort pulse ($\tau < 300$ fs), tunable laser source being pumped at moderate pump powers. These features result in a higher signal to noise ratio, a lower photodegradation of the biological samples and a more cost efficient construction than its 80 MHz predecessors, and hence this laser construction is ideal for nonlinear microscopy applications.

3. References

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