Time-resolved spectroscopy of brain tissue with an all solid state tunable picosecond UV laser

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Abstract

We present an all diode-pumped tunable picosecond laser based on the common use of Cr:LiSAF and Ti:sapphire crystals and producing 0.2 µJ pulses at 276 nm and 10 kHz. Combining time resolved spectroscopy and optical fiber sensor technology, we investigated deep brain tissue of freely moving rat.

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Introduction

At present there is a great interest to develop an all-solid-state ultrafast laser system with a high electrical-optical efficiency and high compactness for medical and biological applications. In this conference, we present a system producing microjoule picosecond pulses at high repetition rate tunable in the infrared and UV by using two laser media: Cr:LiSAF and Ti:sapphire.

Experimental set-up

Figure 1 displays the experimental set-up. We used a diode-pumped Cr:LiSAF oscillator to produce the ps pulses by active mode locking. The laser was tunable from 810 to 880 nm and typical pulse duration was 50 ps over the whole bandwidth. The average power was 10 mW corresponding to an energy per pulse of 0.1 nJ. As the energy is low, the pulses must be amplified before being

used in non linear spectroscopy experiments. Cr:LiSAF has a long fluorescence lifetime (67 μs) well suited to make an efficient amplifier. However, due to its poor thermal properties [1], it is very difficult to use it in an amplifier, although a diode-pumped Cr:LiSAF regenerative amplifier has been recently developed [2].

To overcome this problem, we decided to use a Ti:sapphire regenerative amplifier because of the common fluorescence bandwidth and the good thermal properties of this crystal. However, Ti:sapphire has an absorption band in the green and a short fluorescence lifetime (4μs). So as a pump laser for the amplifier, we devised a Q-switched frequency-doubled diode-pumped Nd:YVO_4 laser producing 40 μJ, 50 ns pulses at 532 nm and 10 kHz repetition rate. Pumping with ns pulses led to a high single pass gain in the Ti:sapphire (40 % per round trip) that compensates the losses more easily than in the case of a diode-pumped Cr:LiSAF amplifier. An intracavity prism allowed to tune the amplifier wavelength so as to match the injected pulses wavelength. The output energy was 7 μJ at 830 nm and 10 kHz and remained above 2 μJ from 810 nm to 850 nm.

The excitation being in the UV-Visible spectral range, we used two LBO crystals (type I) for non linear conversion. Non optimised harmonic generation provided more than 1 μJ, 50 ps pulses at 415 nm and 0.2 μJ pulses at 276 nm with a UV output wavelength tunable from 270 to 283 nm.

The combination of this laser and a spectrograph (270M, SPEX) and a bidimensional single photon counting method (Streakscope C4334, Hamamatsu) enables measurements of the fluorescence decays as a function of time and wavelength simultaneously.

Results

Photon counting images, B2 and D2, show spectro-temporal properties of *ex-vivo* white matter lamb brain tissue autofluorescence and are compared with *in vitro* solutions of tryptophan derivatives, flavins and milk (not shown). Spectral shapes present a large peak near of 520nm (excitation 415nm). The peak near of 330nm (excitation 276nm) has many molecular origins. Apparent 'decay times' are in the range of 700-900ps. Discussion will consider physical effects (diffusion, absorption..) and molecular attribution of these emissions.

To our best knowledge these results are the first *ex-vivo* white matter autofluorescence 2D single-photon counting images. Such instrument therefore appears as very promising for future developments in biophotonics specially for *in vivo* diagnostics on the range of a few seconds [3].

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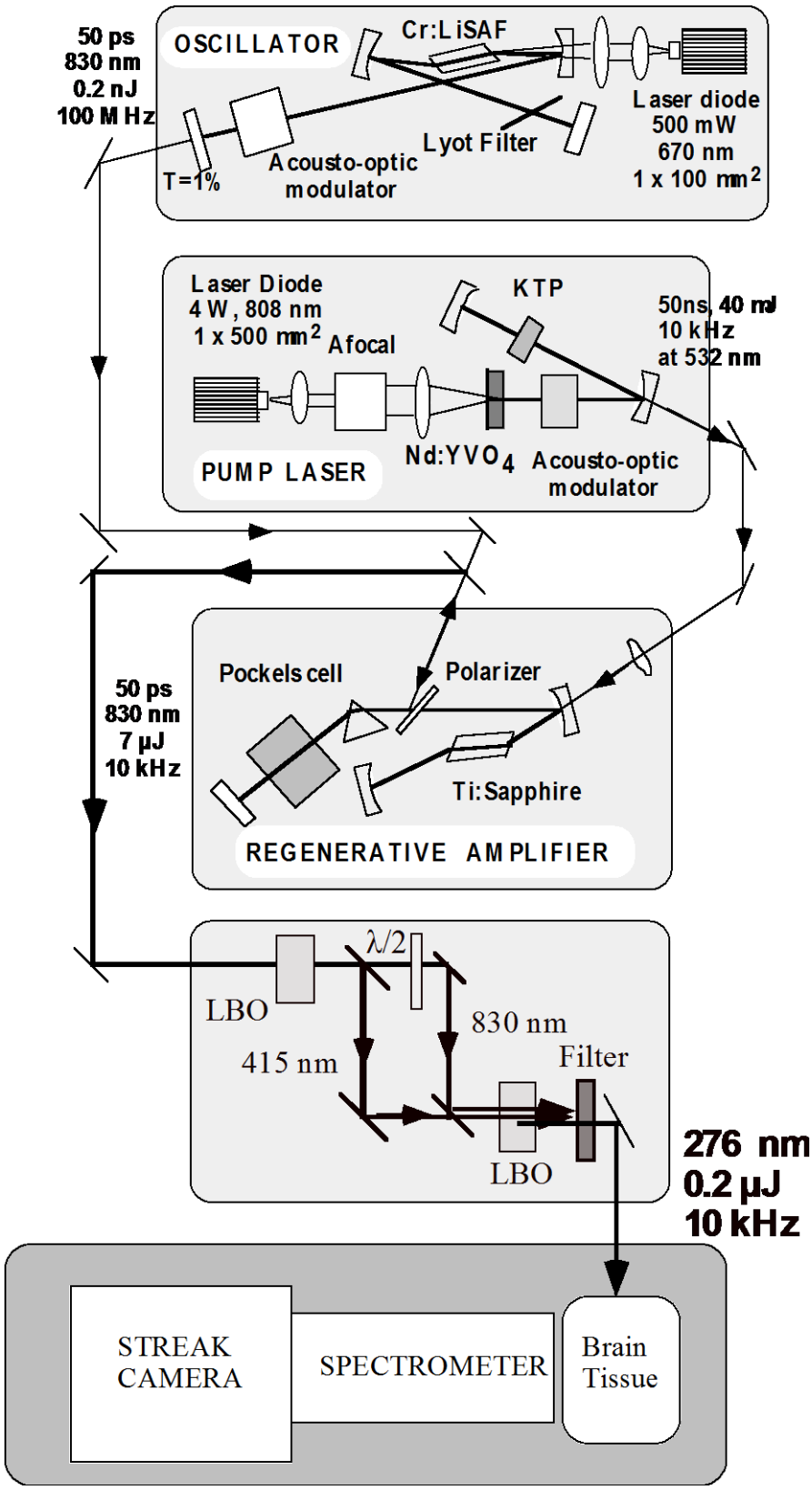

Figure 1 : Instrument configuration.

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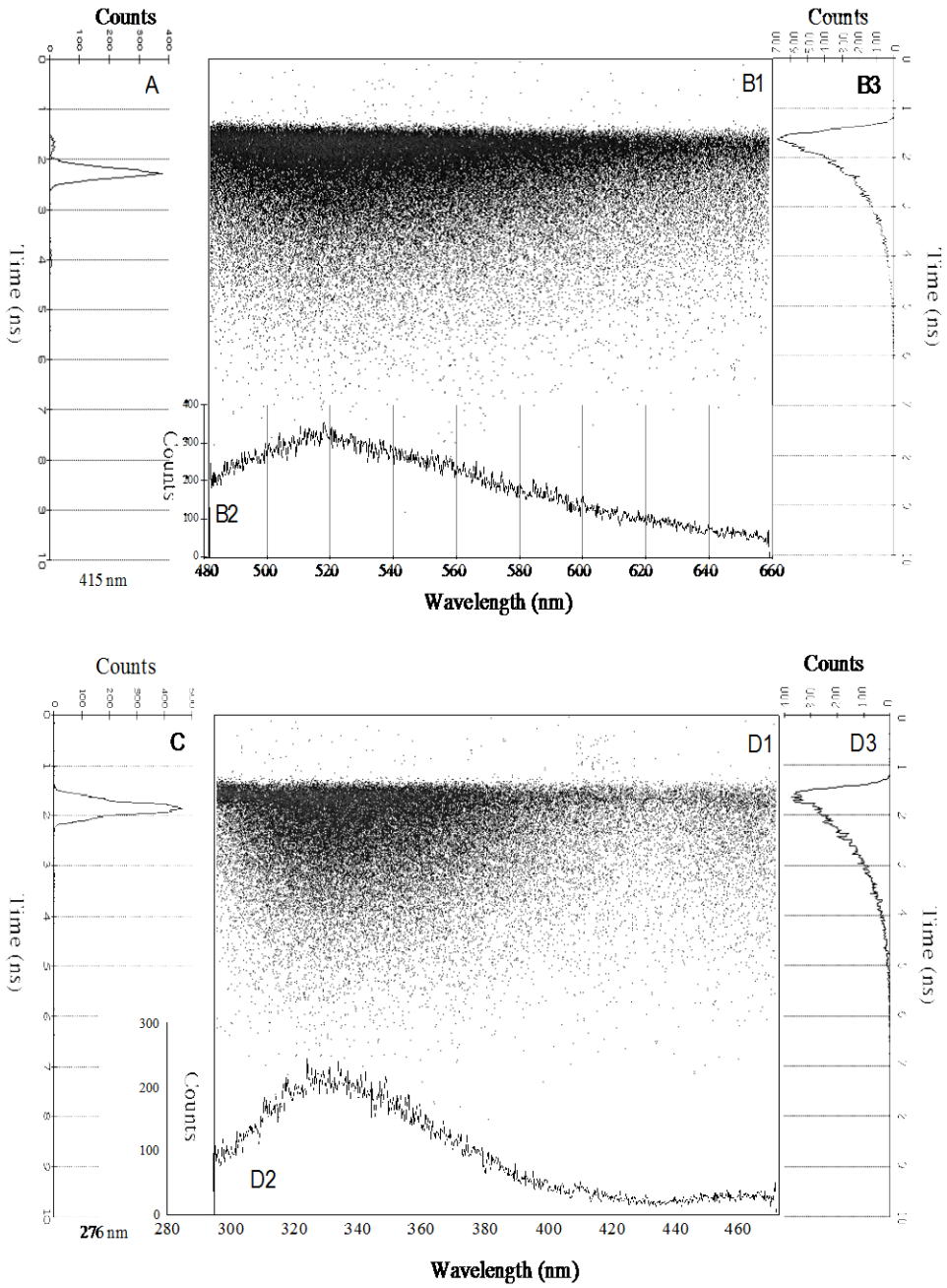

Figure 2 : Results

Fast time-resolved emission spectroscopy of *ex-vivo* brain tissue of lamb (white matter) at two excitation wavelengths (415 nm (part B) and 276 nm (part D)). All measurements are integrated on 2 minutes.

Part A and C of the Fig.2 present the Instrument Response Functions and are enlarged by the jitters. Part B2 and D2 are spectra integrated on the 10 ns range.

Part B3 and D3 are the temporal shapes summed on a spectral window of respectively 515-545nm and of 325-355nm.

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