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Control of sub-pulse duration in noise-like structures

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INTRODUCTION

For the first time demonstrated are possibilities of control over the duration of sub-pulses within nanosecond noise-like pulse bunches, — from 1.4 ps to 170 fs, — through spectral filtering of radiation. The proposed method is implemented on the basis of an actively mode-locked Yb fibre laser. Prospects of electronic control over sub-pulse duration are analysed and practical applications are further discussed, in which sub-pulse duration may be important.

Experimental Setup

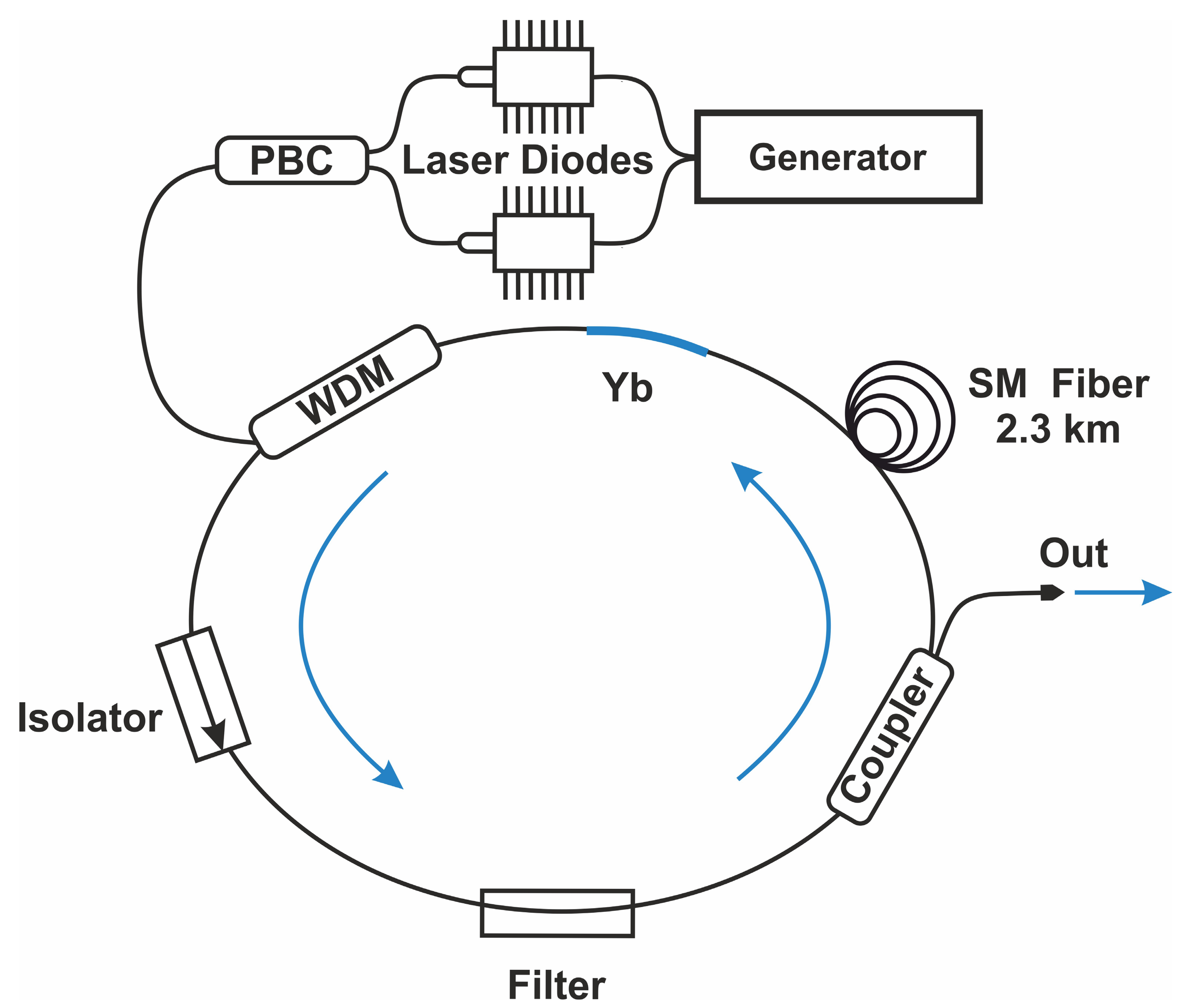

Fig. 1. Laser layout.

As a pump, we used two single-mode diodes with the lasing wavelength near 980 nm and an optical power of up to 0.5 W each. The radiation from the pumping diodes was combined through a fibre polarisation combiner and fed into the laser cavity through a fibre wavelength combiner (WDM). As the active medium, we used a 0.5-m-long fibre segment doped with ytterbium ions. In order to achieve unidirectional radiation propagation, a circulator was installed in the laser cavity, which served as an optical isolator. In order to lengthen the cavity, a 2.3-km-long standard single-mode fibre coil was used. A 30/70 coupler was used to extract 30% of the radiation from the cavity thus forming the laser output. In order to achieve pulsed lasing, the pump diode current was modulated at the resonator bypass frequency, which led to synchronous pulsed optical pumping.
To control the duration of sub-pulses inside pulse trains in the laser, the possibility of changing the optical filters was provided.

RESULTS

When the modulation frequency of the pump laser diode was tuned to the fundamental resonator bypass frequency (13.73612 kHz), the laser generated a sequence of pulses with the envelope duration of one pulse on the order of 880 ns (Fig. 2). Replacement of the laser cavity filter did not modify the duration of the envelope of the pulse trains.

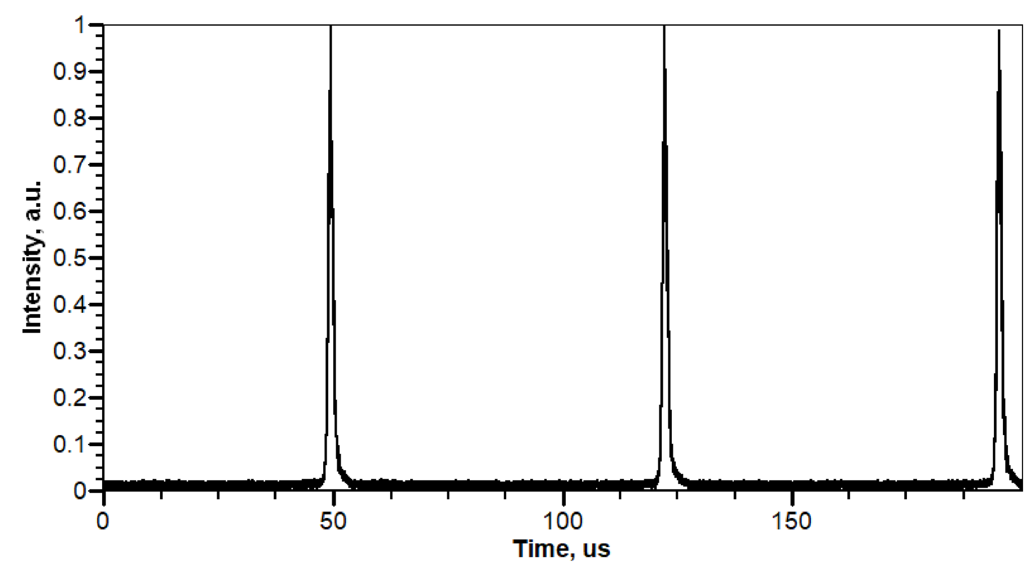

Fig. 2. A sequence of double-scale pulses generated by a laser with synchronous optical pumping.

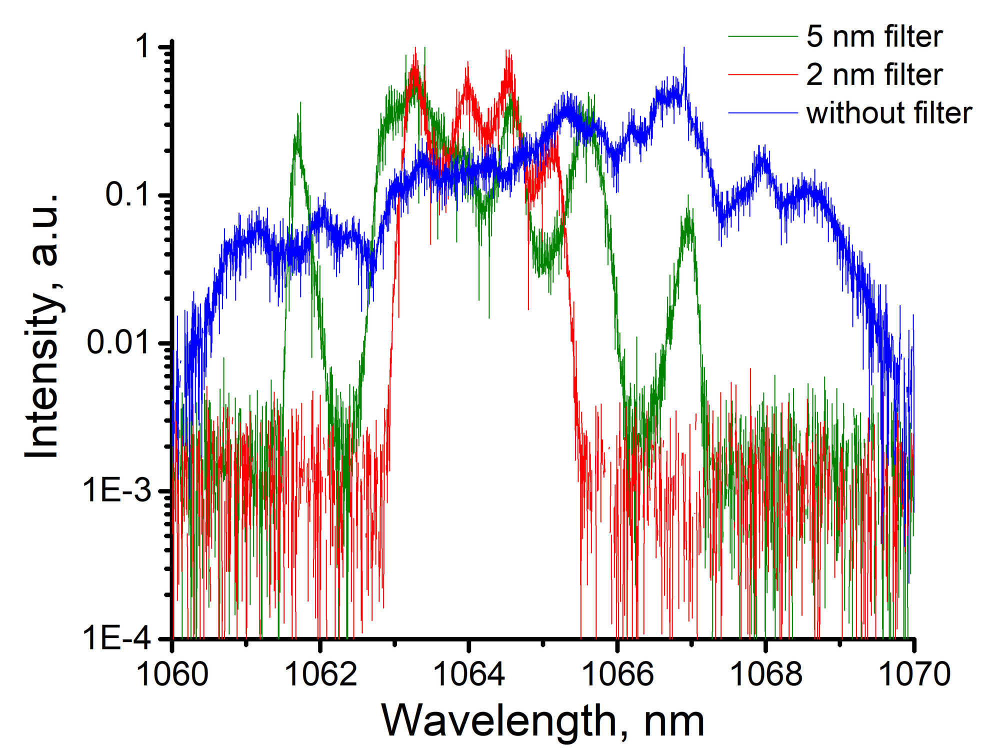

Fig. 3. Combined optical spectra of double-scale pulses measured at different widths of intra-cavity band-pass filter (central wavelength of the pulse spectrum without filtering is 1030 nm (blue curve)).

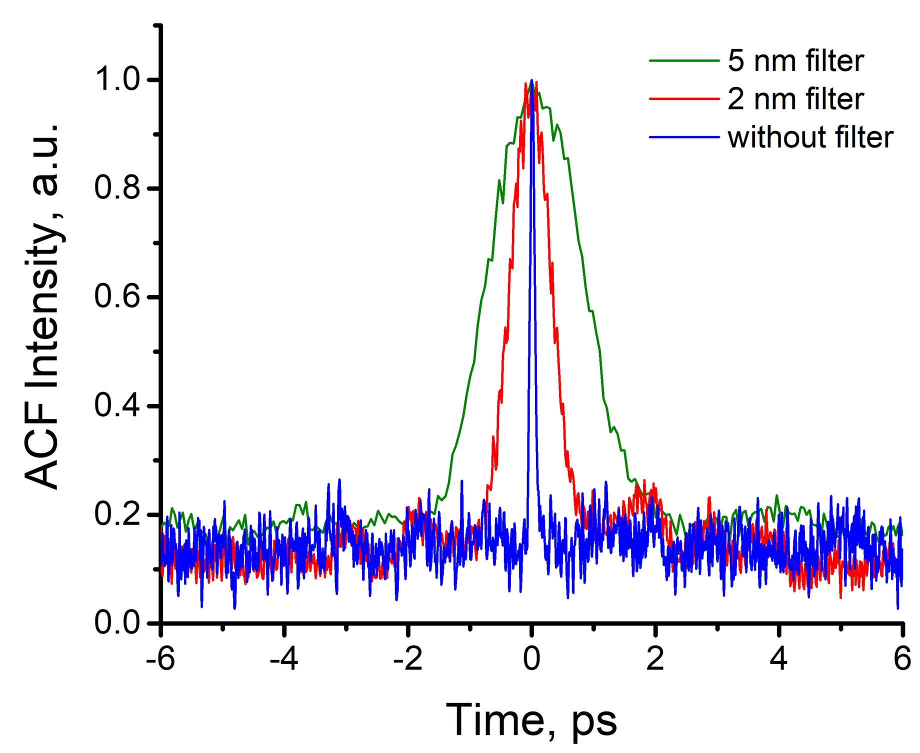

Fig. 4. The central parts of auto-correlation functions of double-scale pulses measured at different widths of intra-cavity band-pass filter.

RESULTS

The use of optical filters led to the generation of radiation with a centre wavelength corresponding to the centre wavelength of the filter, as well as a width corresponding to the filter width. The width of the spectrum at the 0.01 intensity level with a 2 nm filter was 2.44 nm, with a 5 nm filter, 5.62 nm and 9.2 nm without filter. In this case, the tuning of the pulse duration was from 1.7 ps to 110 fs.

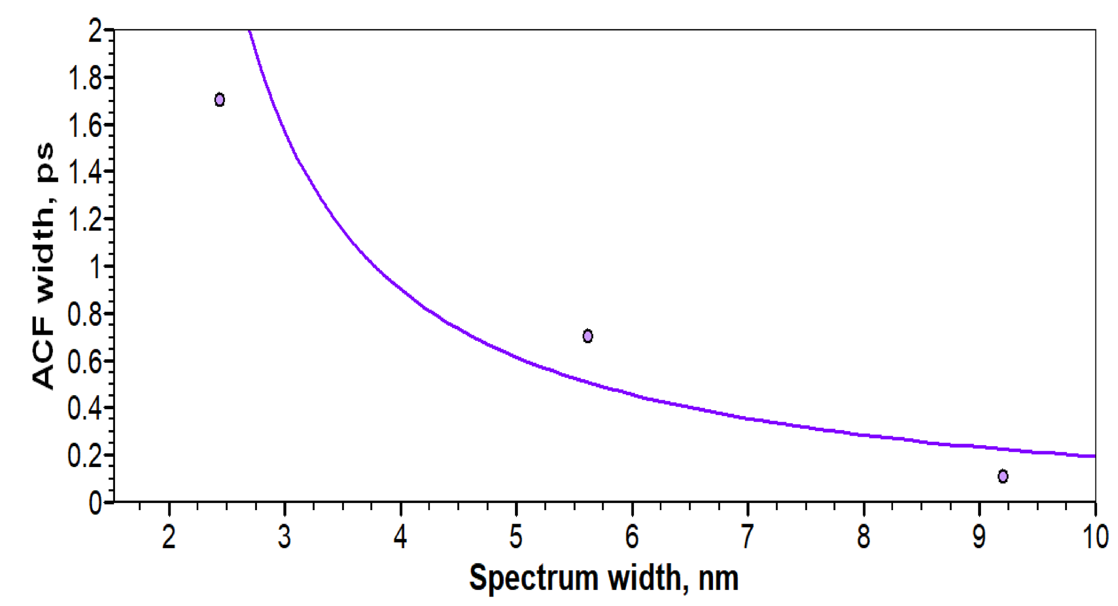

Fig. 5. Dependence of ACF central peak width on optical spectrum width as measured for the studied noise-like pulse bunches.

The results obtained are in good agreement with the models described in [18, 19]. With an increase in the filter width by a factor of 2.5 (from 2 nm to 5 nm), in accordance with this model, the characteristic oscillation time (duration of sub-pulses) should decrease by a factor of 2.5, from 1.7 ps to 680 fs. In the experiment, 700 fs was obtained. The obtained experimental results are in good agreement with theoretical concepts.

CONCLUSIONS

The present work demonstrates, to the best of our knowledge, for the first time adjustment of the sub-pulse duration depending on the width of the filter used. Using an intra-cavity continuously tuneable filter or, alternatively, wavelength-tuneable cavity configuration [20] will enable smooth control over the sub-pulse duration. The use of an electronically controlled tuneable optical filter can provide electronic control of the sub-pulse duration. This method opens up new prospects for the control of two-scale pulses and their application in various fields of science and technology.

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