PCF-based Tunable Source of Femtosecond Pulses in the Visible Region

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Abstract: Blue-shifting dispersive waves and soliton trapping in a PCF pumped with a Ti:Sa laser are shown to produce tunable femtosecond pulses in the visible region, with a central wavelength depending upon the input pump power.

1. Introduction

Solitons propagating in the anomalous dispersion region of a Photonic Crystal Fiber (PCF) generate blue-shifted nonsolitonic radiation in the normal region [1]. Further evolution of this dispersive radiation into femtosecond temporal and spectrally-localized waves has been recently explained by the existence of bright-bright soliton-like states [2]. The soliton infrared central frequency undergoes Raman-induced frequency shift, and this effect can be used to build a tunable short-pulse source with pump power as the control parameter [3].

In this paper we study the spectral and temporal characteristics of the generated blue radiation and show that by means of tunable bandpass filters one can obtain a solitary wave source with fast and broad tunability, and average output powers of the order of hundred of microwatts, in the visible spectral region.

2. Experimental setup and simulations

The experimental setup is shown in Fig. 1. The pump source is a Ti:Sa laser that provides 37 fs FWHM pulses centered at 830 nm, at a repetition rate of 94 MHz. The power launched into the fiber is selected by means of an acousto-optic modulator (AOM) controlled by a high-frequency AC power supply. A prism compressor is used to pre-compensate the pulse dispersion caused by passing through the AOM. Pulses with average powers from 2 to 24 mW were launched into 75 cm of a PCF with non-linear coefficient $\gamma = 78\ \mathrm{W}^{-1}\mathrm{km}^{-1}$ and zero-dispersion wavelength $\lambda_0 = 790$ nm. Fiber dispersion is shown in Fig. 2d. The fiber output is sent to an optical spectrum analyzer.

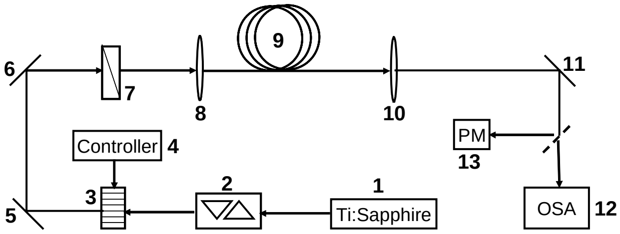

Fig. 1. Schematic diagram of the experimental setup: 1-Ti:Sapphire laser, 2-prism compressor, 3-AOM, 4-AOM controller, 5-6-11-mirrors, 7-halfwave plate, 8-coupling lens, 9-PCF, 10-lens, 12-optical spectrum analyzer, 13-power meter.

To model the light propagation within the PCF, we solved the scalar NLSE using the complete Raman integral:

$$\frac{\partial A}{\partial z}+\beta_1\frac{\partial A}{\partial t}+i\beta_2\frac{\partial^2 A}{\partial t^2}-\beta_3\frac{\partial^3 A}{\partial t^3}+\ldots=i\gamma\left(1+\frac{i}{\omega_o}\frac{\partial}{\partial t}\right)\left(A(z,t)\int_{-\infty}^{\infty}R(t')\left|A(z,t-t')\right|^2 dt'\right),$$

$$R(t)=(1-f_R)\delta(t)+f_R h_R(t)\,,\ \text{and}\quad h_R(t)=\frac{\tau_1^2+\tau_2^2}{\tau_1\,\tau_2^2}\exp\left(\frac{-t}{\tau_2}\right)\sin\left(\frac{t}{\tau_1}\right)\qquad(1)$$

where $A(z,t)$ is the complex envelope of the field, β_k are the usual dispersion coefficients associated with the Taylor series expansion of the propagation constant $\beta(\omega)$ around ω_0, $f_R = 0.18$ represents the fractional contribution of the delayed Raman response h_R, and $\tau_1 = 12.2$ fs and $\tau_2 = 32$ fs. The dispersion coefficients β_k are chosen to fit the dispersion curve shown in Fig. 2d. The other fiber parameters are those of the PCF used in the experiment, listed in the previous paragraph. The split-step Fourier method was used to integrate Eq. (1), applying a fourth-order Runge-Kutta algorithm for the temporal part. The field was discretized using 2^{15} sample points in a 64 ps time window.

3. Results and Discussion

In Fig. 2a, 2b, and 2c we show good qualitative agreement between numerical and experimental output spectra. The simulated pulse shape at the blue extreme of the spectrum is shown in Fig. 3 for three different input pump powers. The arrow in each spectrum shows the central wavelength of the bandpass filter used to obtain the output pulses shown in Fig. 3. The filter bandwidth varies from 4 to 9 nm and is chosen in each case to minimize the output pulse width

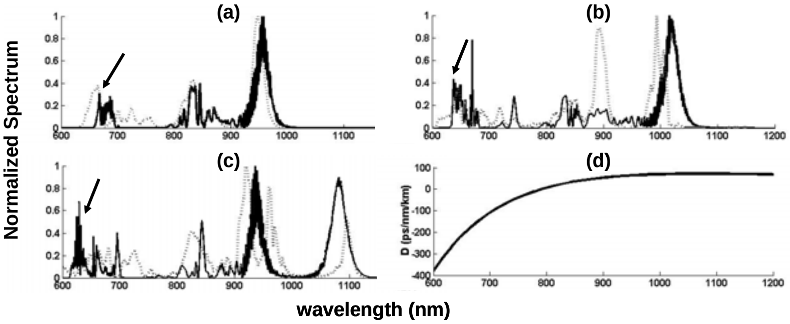

Fig. 2. (a,b,c) Measured (dotted grey) and simulated (solid black) output spectra for three average input pump powers, namely, 8, 11.7, and 16 mW, respectively. Arrows indicate the central wavelength of the region that is filtered in order to obtain femtosecond pulses; (d) Measured PCF dispersion curve.

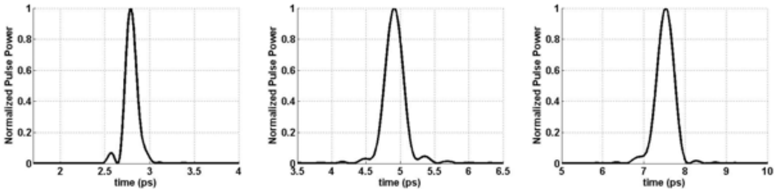

Fig. 3. Simulated normalized pulse shape in the visible region, after bandpass filtering, corresponding, from left to right, to average input pump powers of 8, 11.7, and 16 mW. Corresponding central wavelengths are 667, 637 and 633 nm, shown by the arrows in Fig. 2a, 2b, and 2c. Pulse output powers are shown in Table I.

In Table I we summarize representative results obtained from the simulations, including the average power of the blue solitary waves.

Table I: Simulation Results

Average Input Pump Power (mW)	Soliton Central Wavelength (nm)	Solitary Wave Central Wavelength (nm)	Solitary Wave FWHM (fs)	Solitary Wave Average Power (µW)
8.0	956	667	140	267
11.7	1020	637	354	312
16.0	1163	633	520	337
20.1	1219	592	300	493

Results clearly indicate that solitary femtosecond waves with hundreds microwatts of average powers can be obtained by the use of a bandpass filter. In conclusion, a new method to obtain femtosecond pulses with fast and broad spectral tunability in the visible region of the optical spectrum was presented. Autocorrelation measurements of output pulses are currently underway to further validate the proposed scheme.

4. References

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