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1.56-2.03 μm Widely Wavelength Tunable Femtosecond Soliton Pulse Generation Using Optical Fibers

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Introduction Femtosecond(fs) optical pulse sources are important light sources in the field of ultrafast optoelectronics, ultrafast spectroscopy, optical communications, and laser processing, etc. The Er-doped fiber laser is one of the reliable fs laser sources which can generate the fs pulses at 1.55 μm. Since the system is consisted with the optical fiber devices, it is compact and stable, and is one of the most practical laser sources. The wavelength tuning range is, however, limited by the amplification bandwidth of the Er-doped fiber amplifier and is about 50 nm.

Recently, we have demonstrated the compact system of wavelength tunable femtosecond soliton pulse generation using fiber laser and optical fibers.1-3) The ideal sech2 soliton pulse is generated and its wavelength can be changed almost linearly from 1.55 to 1.75 μm as the fiber input power is changed.

In this paper, using the high power ultrashort pulse fiber laser and optical fibers, the quite large wavelength shift of femtosecond soliton pulse from 1.56 to 2.03 μm is successfully demonstrated. The ideal sech2 shaped pulse spectra is confirmed up to 2 μm for the first time.

Experiment In this experiment, the compact and stable ultrashort pulse fiber laser (IMRA femtolight 780/1550) is used as the laser source. The optical spectrum of the output pulse is shown in Fig. 1(a). The spectral width is about 60 nm at full width at half maximum (FWHM) and the center wavelength is 1558 nm. The autocorrelation trace of the temporal pulse shape almost corresponds to that of the sech2 pulse. The corresponding pulse width is 110 fs at FWHM.

As the optical fiber, the diameter reduced type polarization maintaining fiber (3M FS-PM-7811) is used in this experiment. The mode field diameter is 5.8 μm and the group-velocity dispersion β2= -15 ps2/km at 1.55 μm. The input power is controlled by the half-wave plate and the polarization beam splitter. The output pulse is observed using the optical spectrum analyzer, monochrometer, autocorrelator, and wavelength insensitive power meter. When the intense optical pulse is inputted into the optical fibers with the anomalous dispersion, the ultrashort soliton pulses are generated at the longer wavelength side due to the stimulated Raman scattering and soliton effect.3,4) Figure 1(b) shows the optical spectra at the fiber output for the fiber length of 110 m and fiber input power is 8 mW. Owing to the stimulated Raman scattering, the center part of the pump spectra is shifted towards the longer wavelength side and the clear sech2 spectrum is constructed at 1690 nm.

Figure 2 shows the wavelength shift of optical pulse as a function of the fiber-input power. The center wavelength of the soliton pulse is monotonically increased as the fiber input power and the fiber length are increased. For the shorter fiber such as 2.5 or 7.5 m fiber, the wavelength is almost linearly increased as the fiber input power is increased. On the other hand, for the longer fiber such as 110 or 220 m fiber, the ratio of the wavelength shift is gradually decreased as the wavelength is increased. The reason is that the optical loss and mode field diameter in the optical fiber are increased as the optical wavelength is increased. When the fiber input power is 43 mW and the fiber length is 220 m, the wavelength of the soliton pulse is shifted up to 2008 nm. When the fiber input power is increased to 55 mW, the maximum wavelength shift of 2033 nm is observed. This wavelength shift of the optical pulse as large as 475 nm is the maximum value in the optical fibers as far as we know.

Figure 3 shows the temporal shape of the soliton pulse when the fiber length is 40 m and the fiber-input power is 15 mW. The center wavelength of the soliton pulse is 1750 nm. The pedestal free good trace is observed and the autocorrelation trace is fitted to that of the sech2 one. The temporal width of the autocorrelation trace is 250 fs and the corresponding pulse width is 180 fs at FWHM. The spectral width is 10 nm and the time-bandwidth product is 0.32. This value is almost in agreement with that of the transform-limited sech2 pulse. The temporal pulse width and the spectral width are almost constant for the same fiber length. When the fiber length is 220 m, 110 m, 7.5 m, and 2.5 m, the temporal widths are 245 fs, 208 fs, 120 fs, and 85 fs, respectively.

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Figure 4 shows the spectral shape of the soliton pulse at 2008 nm. The fiber length is 220 m and the fiber-input power is 43 mW. The ideal sech2 shape is clearly observed. The spectral width is 7 nm at FWHM. The observation of the sech2 spectral shape at such long wavelength is for the first time as far as we know. If the transform-limited pulse is generated, the corresponding time width of the pulse is 610 fs at FWHM.

Reference 1) N.Nishizawa and T.Goto, IEEE Photon.Technol.Lett.,vol.11, 325 (1999). 2) N.Nishizawa et al., IEEE Photon.Technol.Lett.,vol.11, 421 (1999). 3) Zysset et al., Appl.Phys.Lett.,vol.11, 659(1986)
4) N.Nishizawa et al., to be published in Jpn.J.Appl.Phys.,vol.38, (1999)

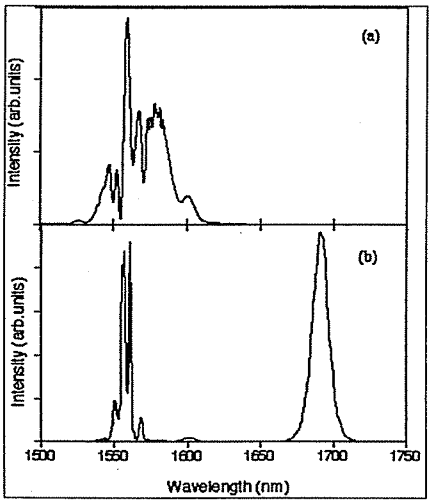

Fig.1 Optical spectrum of (a) pump pulse and (b) 110m fiber output.

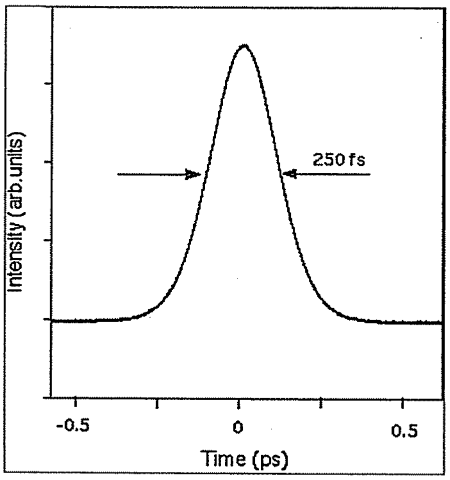

Fig.3 Autocorrelation trace of soliton pulse for 40m fiber and 5 mW input power.

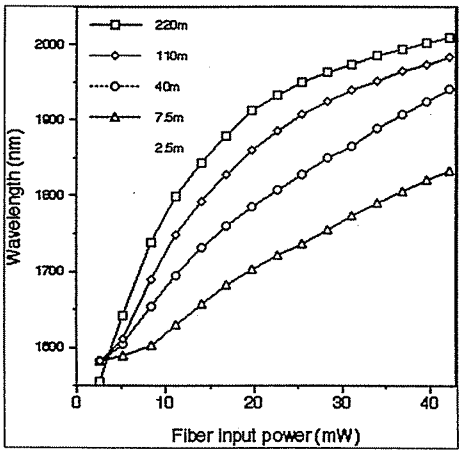

Fig.2 Characteristics of wavelength shift as a function of fiber input power.

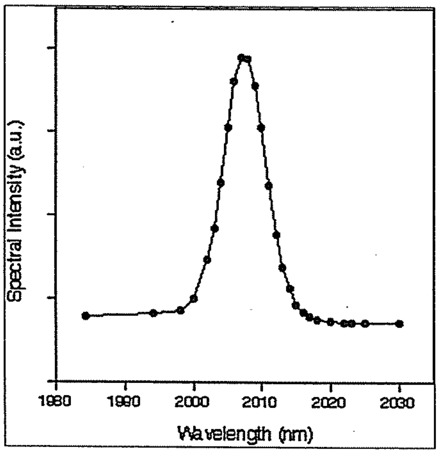

Fig.4 Observed spectral shape of soliton pulse at 2008 nm.