Compact System of Wavelength Tunable Femtosecond Soliton Pulse Generation in 1.56 - 1.86μm using Optical Fiber

Norihiko Nishizawa, Ryuji Okamura, and Toshio Goto
Department of Quantum Engineering, Nagoya University, Nagoya 464-8603, Japan
Tel: +81-52-789-4556 Fax: +81-52-789-3164 Email: nisizawa@nuee.nagoya-u.ac.jp

1. Introduction

Ultrashort optical pulse plays the important roles in the field of optoelectronics, ultrafast spectroscopy, and ultrafast optical measurement. Recently, the passively mode-locked fiber lasers which generate the femtosecond pulse trains have been demonstrated. Since the system is compact and stable, they absorb the great interests. However, the wavelength cannot be changed in the wide ranges.

In this study, 1.56 - 1.86 μm wavelength tunable femtosecond soliton pulse generation is demonstrated using only the femtosecond fiber laser and optical fibers. The wavelength can be changed linearly and continuously by varying the fiber input power. The characteristics of soliton pulses are numerically analyzed using the strict nonlinear Schrodinger equation.

2. Experiment

When the ultrashort pulse is input into the optical fibers, the new pulse component is generated at the longer wavelength side of the pump pulse through the stimulated Raman scattering.1) Owing to the interaction between the self-phase modulation and group-velocity dispersion, the stable soliton pulse is constructed as the pulse propagation. Owing to the stimulated Raman scattering, the wavelength of the soliton pulse is shifted toward the longer wavelength side with keeping the stable sech^2 pulse shape.2) Since the magnitude of the wavelength shift is dependent on the pump power and fiber length, the wavelength can be shifted by changing these parameters.

The soliton pulse generation system is shown in Fig. 1.3) The pump light source is passively mode-locked Er-doped fiber laser which generates 180 fs pulses at 1.56 μm. As the optical fiber, the polarization maintaining fiber of in which the mode filed diameter is 5 μm is used. The power of pump pulse is changed by using variable optical attenuator and the polarization direction is rotated by using the λ/2 plate. The output of the PM fiber is observed using optical spectrum analyzer and autocorrelator.

When the polarization direction of the pump pulse is adjusted along the birefringent axis of the PM fiber, ideal mono-colored soliton pulse is generated. The optical spectrum of the fiber output is shown in Fig. 2 when the fiber length is 75 m and pump power is 9 mW. The clear sech^2 pulse is observed stably. The spectral width is 17.5 nm and the conversion efficiency is as large as about 75%.

The observed autocorrelation trace of the soliton pulse is shown in Fig. 3. The pedestal free clear trace is observed. The autocorrelation trace is well fitted to that of the sech^2 pulse. The temporal width of the autocorrelation trace is about 315 fs at full width at half maximum and the pulse width is estimated to be 204 fs.

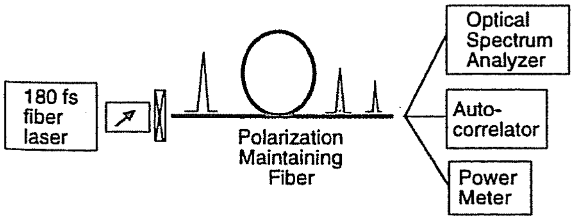

Fig.1 Scheme of wavelength tunable soliton pulse generation

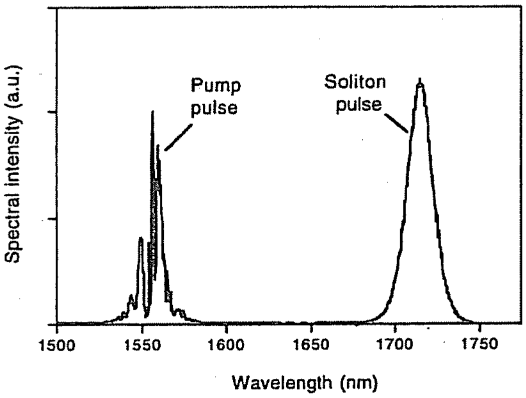

Fig.2 Optical spectra of soliton pulse

0-7803-5661-6 / 99 / $10.00 © 1999 IEEE

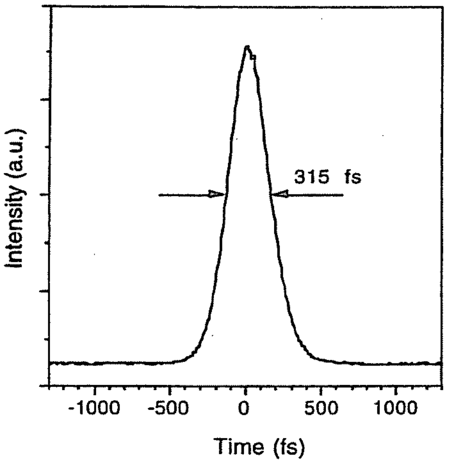

Fig. 3 Autocorrelatioin trace of soliton pulse

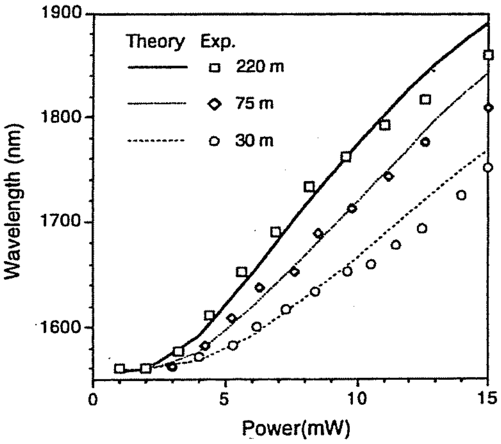

Fig.4 Wavelength shift of soliton pulse as function of input power

3. Discussions

The characteristics of wavelength tunable femtosecond soliton pulse generation is analyzed both experimentally and numerically. The ultrashort pulse propagation is described by the strict nonlinear Schrodinger equation written as[4]

$$\frac{\partial A}{\partial z}+\frac{\alpha(\omega)}{2}A+\frac{i}{2}\beta_2\frac{\partial^2 A}{\partial T^2}-\frac{1}{6}\beta_3\frac{\partial^3 A}{\partial T^3}=i\gamma(\omega)[|A|^2A+\frac{i}{\omega_0}\frac{\partial}{\partial T}(|A|^2A)-T_RA\frac{\partial|A|^2}{\partial T}],$$

where the effects of Raman scattering, self-steepening, and the third-order dispersion are included. Since the wavelength of the soliton pulse is shifted in the wide wavelength region, the wavelength dependence of the parameters are considered.

Figure 4 shows the wavelength shift as a function of the fiber input power. The wavelength of the soliton pulse is almost linearly shifted in terms of the fiber input power above the threshold power. The experimental results are almost in agreement with the numerical ones. When the fiber length is 220 m and the input pump power is about 15 mW, the wavelength of the soliton pulse is shifted to 1.86 μm. If the optical fiber is much longer and the input pump power is much higher, much larger wavelength shift can be obtained. The temporal pulse width is almost dependent on the fiber length and independent on the fiber input power.

When the polarization direction of the pump pulse is inclined from the birefringent axis of PM fiber, the orthogonally polarized two colored soliton pulses can be generated simultaneously.[5] The wavelengths of the teo soliton pulses can be changed by rotating the wave plate.

4. Conclusion

In conclusion, compact system of wavelength tunable femtosecond soliton pulse is demonstrated using compact fiber laser and optical fibers. The wavelength can be changed linearly and continuously from 1.56 to 1.86 μm by changing the power of pump pulse. The experimental results are almost in agreement with the results of numerical simulations. Since this system is very compact and reliable, it is useful for practical ultrashort pulse light source.

Reference

[1] B. Zysset, P. Beaud, and W.Hodel, Appl. Phys. Lett., vol. 50, pp. 1027, 1987.
[2] F.M.Mitschke and L. F. Mollenauer, Opt. Lett. vol. 11, p.659, 1986.
[3] N.Nishizawa and T. Goto, IEEE Photon. Technol. Lett., vol. 11, 1999.
[4] G.P.Agrawal, "*Nonlinear Fiber Optics*", 2nd edition, Academic Press, 1995.
[5] N.Nishizawa, R. Okamura, and T. Goto, IEEE Photon Technol. Lett., vol. 11, 1999.