erned by an ambipolar diffusion of free-carriers generated by single-photon absorption from the EL2 states (a γI term) and two-photon band-to-band absorption (a βI^2 term) where $I = |E_1 + E_{-1} + E_3 + E_{-3}|^2$. The end result is a complicated coupled set of intensity and phase integro-differential equations that are solved by numerical methods.

A comparison of the numerical results to experimental data is shown in Figs. 2 and 3 where the experimental data points are represented by circles and the theory by a solid line. The experimental data are taken from Ma and Li[3] whose experiments involved transient wavemixing of 50-ps pulses from a Nd:YAG (λ = 1.06 μm) laser in a 0.53-mm sample of GaAs. Figure 2 illustrates the gain dependence vs wave-mixing angle with pump fluence of 31 mJ/cm^2 and a probe fluence of 0.06 mJ/cm^2. As the wave-mixing angle increases, the gain experiences a minimum at about 2°. We found that the diffraction orders persist beyond this point and that strong intensity and phase modulation effects of the multiple waves continue well beyond this point (> 15°). Figure 3 is a plot of the gain dependence on input fluence in which an intensity-varying absorption constant, α = 12 cm^{-1} + (0.421 cm/mJ)E_{pump}, obtained from a simple pump-probe experiment was needed. Also to reduce the computational time of the computer, the free-carrier generation term is approximated by $[\beta I_0 + \gamma]I$ where I_0 represents the total input intensity.

Overall, the four-beam model accurately predicts the gain of a weak probe pulse by a strong pump pulse in GaAs. An additional observation from our experiments was that the magnitude of the weak-side diffraction was equal to or greater than the pump-side diffraction even at pump-probe beam ratio as large as 100 to 1. This unusual effect was indicated by some preliminary numerical results that included the I^2 two-photon grating.

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CWJ77 100-GHz train of femtosecond soliton pulses generated through Raman self-scattering of a dual-frequency beat signal in optical fiber

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Methods for high repetition-rate pulse-train generation based on nonlinear propagation of an optical signal along an optical fiber are an alternative technique to the traditional sources of short optical pulses–namely, mode-locked lasers. The induced modulation instability (IMI) effect has been suggested as a technique for the generation of high repetition-rate pulse train.[1,2] In addition, it has been theoretically shown[3] that a train of femtosecond fundamental soliton pulses can be generated utilizing a combination of IMI and Raman self-scattering (RSS) effects. An alternative technique[4–6] is based on the adiabatic transformation of a dual-frequency beat-signal into a train of solitons as a result of nonlinear propagation in an optical fiber with dispersion decreasing along its length (DDF).

In this paper we demonstrate the generation of a high repetition-rate train of femtosecond solitons formed by the nonlinear propagation of a dual-frequency dual-frequency, beat-signal in a DDF under the influence of RSS.

The experimental configuration is illustrated in Fig. 1. A beat signal was created using two, pig-tailed, single-frequency DFB laser diodes emitted at wavelengths around 1550 nm. The laser wavelength separation was tuned between 0 and 2 nm by independent variation of the laser temperature. The beat signal was then amplified into an erbium-doped fiber amplifier (EDFA) pumped by a Ti:sapphire laser operating at 978 nm. In order to increase the peak output power level from the saturated amplifier, the beat signal coupled into the EDFA was modulated to reduce the duty cycle (square pulses modulation, 100-ns pulses at 300 kHz). Direct current of the laser diodes was employed and allowed the generation of peak power of ~700 mW within the 100-ns pulses. The soliton train was generated in a dispersion decreasing fiber[7] of 1.6 km length. Its dispersion at 1550 nm decreased from Dinp = 10 ps/nm/km to Dout = 0.5 ps/nm/km. A typical spectrum and autocorrelation trace of the soliton train measured at the output of the DDF are shown in Figs. 2(a and b), respectively. In this case the input amplified beat signal was formed by two single frequencies around 1551 nm separated by ~0.8 nm. The output spectrum consists of two separated regions. The first is shifted in frequency toward the longer wavelength and has a pulse-shape envelope with maximum at 1565 nm and half-maximum (FWHM) of ~10 nm. This spectral component corresponds to a train of spectrally shifted solitons, generated through the RSS. The other spectral component is a remnant signal centered around the initial wavelength of 1551 nm. The autocorrelation function (Fig. 2b) clearly demonstrates the generation of a 114-GHz train of well separated 230-fs soliton pulses. There is no intrapulse background. However, one can see the appearance of additional peaks in the autocorrelation trace, which are related to residual radiation at the initial wavelength, and the generated soliton train can easily be spectrally filtered from the rest of the signal.

The technique permits us to tune the repetition rate of the soliton train between 80–120 GHz in this configuration by simply adjusting the frequency and intensity of the input beat signal.

The dynamic of soliton train generation in the DDF was investigated by means of a numerical simulation of nonlinear propagation, taking into account the Raman effect.[8,9] At the initial stage of propagation the combined effects of self-phase modulation and group velocity dispersion leads to frequency modulation at the beat-signal period and results in their compression. As the dispersion decreases along the fiber, the compressive effect is enhanced and results in further broadening of the spectrum. Ultimately, the effects result in the generation of a short-pulse train and an accompanying pedestal. Since the pulses have femtosecond duration the RSS effect becomes significant and results in a red shift of the short-pulse spectral component. As the soliton pulses and residual radiation have different mean wavelengths and consequently different group velocities the soliton train moves through the pedestal and is amplified by it through Raman amplification. The decreasing dispersion leads to further soliton compression. As a result, a periodic train of soliton pulses is generated containing most of the energy of the initial beat signal. The theoretical results are in good agreement with the experiment.

In conclusion, we generated 230–300 fs soliton pulses at repetition rates in the range 80–120 GHz and presented the theoretical interpretation of the generation process.

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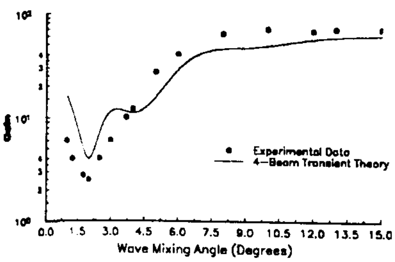
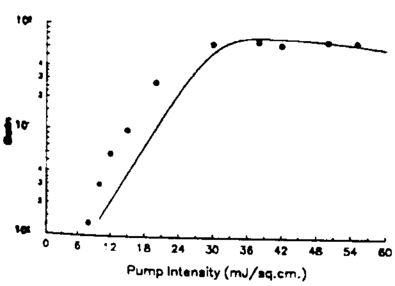
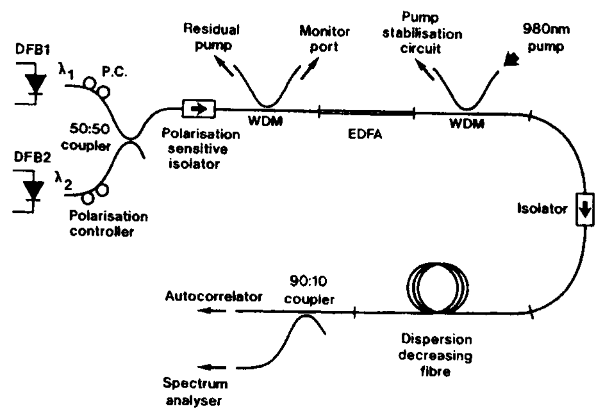


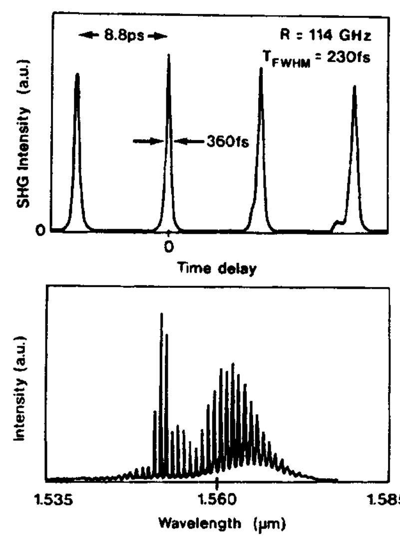
CWJ76 Fig. 2. Probe beam gain as a function of wave-mixing angle (circles-experimental data taken from ma and Li[3]; solid line-four beam theory).



CWJ76 Fig. 3. Probe beam gain as a function of pump fluence (circles-experimental data taken from Ma and Li[3]; solid line-four beam theory).



CWJ77 Fig. 1. Experimental setup.



CWJ77 Fig. 2. Experimental spectrum (a) and autocorrelation trace (b) of 114 GHz/s soliton train. The spectrum consists of many equally spaced (0.8 nm) spectral lines as expected for a periodic signal. The Stokes shifted soliton train contains more than 80 % of the full signal energy.