1-5-3

Femtosecond optical-pulse nonlinear propagation in microstructure glass fibers and pulse compression

Xiaojun Fang[1], M. Adachi[1, 2], M. Hirasawa[1], S. Kobayashi[3], R. S. Windeler[4], R. Morita[1], M. Yamashita[1]
[1]Hokkaido University & CREST•JST, [2]Nidek Co., [3]Chitose IST, [4]Bell Labs•Lucent Technologies

1) Spectral broadening in a tapered fiber and its phase compensation by an SLM

A tapered-silica fiber has recently been used in producing an ultra-broad band spectrum. By using our second-harmonic frequency-resolved optical gating (SH-FROG) apparatus, the intensity and phase profiles of output pulses from the fiber in both temporal and frequency domains were determined.

We performed pulse compression with a liquid crystal spatial phase modulator (SLM), on the basis of the spectrum phase information obtained by the SH-FROG measurement. This was the first successful pulse compression of an output pulse from a tapered fiber using an SLM. When the group delay dispersion (GDD) of -2000 fs^2 at 800 nm was added by an SLM as an amount of compensation, the shortest pulse (sech: T_p=42 fs) was obtained (Fig. 1). Thus the effective GDD of a tapered fiber output pulse was estimated to be +2000 fs^2. This was mostly in agreement with the GDD value at the time of the FROG measurement. Furthermore, when the absolute value of negative third-order dispersion (TOD) applied by an SLM was increased with a fixed GDD value of -2000 fs^2 at 800 nm, the pulse width increased. For the TOD value of 0 fs^3, the pulse width was the shortest. The compensated pulse had uncompressed wings in comparison with the fiber input pulse. We believe that these wings are based more on spectral structure than on higher-order dispersions.

2) Experimental and theoretical investigation on nonlinear propagation in photonic crystal fibers

Supercontinuum generation in a photonic crystal fiber (PCF) remains far from being well understood, particularly when the input optical pulses are of few cycles and near the zero-dispersion wavelength (ZDW). In our experiment, 12-fs (4.5-cycle), 10-nJ pulses were coupled into PCFs with different lengths ranging from 4 to 61 mm. Output spectra strongly depended upon the length of fibers, as shown in Fig. 2. In order to understand the detail dispersive self-phase modulation (SPM) behavior in the PCFs, a new slowly-evolving-wave approximation (SEWA) propagation equation was derived, which included the self-steepening and the time delayed Raman effects as well as effect of dispersive SPM. As shown in Fig. 3, numerical simulations using this newly derived equation generate the spectra that agree well with the experimental results from fibers of different lengths.

Figures 2 and 3 show split spectra based on SPM and intensity-dependent four-wave mixing. The latter is produced efficiently by the phase matching and the group-velocity matching near ZDW. The simulations also well explain the phase behavior measured by the spectral interferometry technique, and calculated intensity autocorrelation traces are similar to the experimental ones.

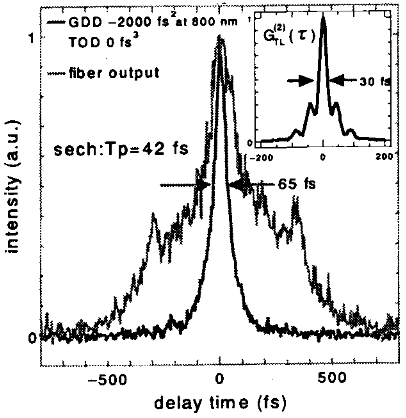

Fig.1 Autocorrelation trace of an optical pulse from a tapered fiber compressed by an SLM. The inset is that of the transform-limited pulse.

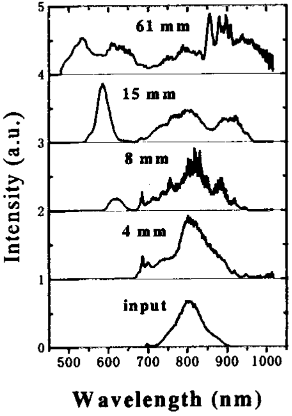

Fig.2 Experimental spectra generated from 4.5-cycle optical pulses in photonic-crystal fibers.

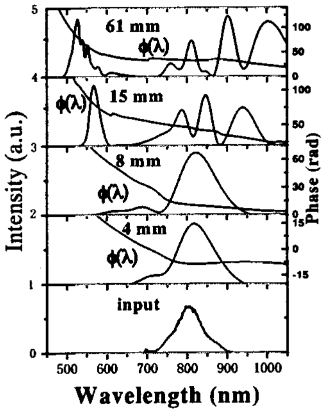

Fig.3 Simulated spectra and spectral phases using an SEWA equation for 4.5-cycle optical pulses in photonic-crystal fibers.