Super-continuum from a short (8-mm-long) microstructure fiber

Qiang Cao, Xun Gu, Erik Zeek, Mark Kimmel, Rick Trebino, and John Dudley

Although ultrabroadband supercontinuum can now be routinely generated using microstructure fiber, its practical applications will require that we understand how best to create it. For example, what if we desire to generate the *shortest* possible continuum pulse? What if we wish to create the most *stable* continuum pulse? What if we wish to create continuum with the *broadest* possible spectrum? What if we wish to create continuum with the *smoothest* possible spectrum? Finding the answers to these questions will require detailed modeling and measurements of the continuum.

Recently, numerical simulations of supercontinuum generation have begun to improve our understanding of the underlying spectral broadening mechanisms involved. In particular, simulations have shown that significant spectral broadening occurs in only the first few millimeters of propagation. Afterward, the incident pulse breaks up into a series of constituent fundamental solitons. Additional nonlinear effects, such as the Raman self-frequency shift, do introduce some additional spectral broadening, but this is relatively minor, and the main result of increased propagation distance is to temporally broaden the continuum (See Fig. 1).

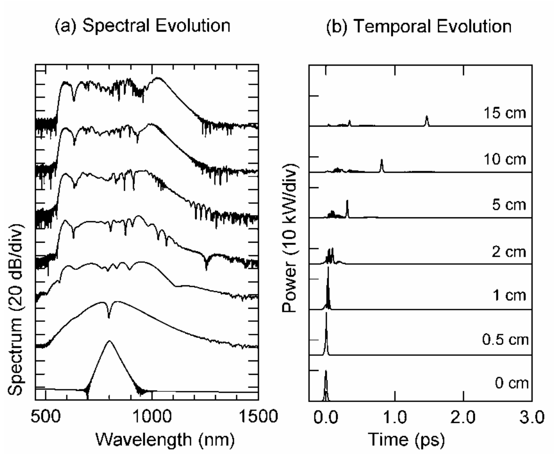

Fig. 1. (a) Spectral and (b) temporal evolution in microstructure fiber of an injected 10kW-peak-power, 30-fs, 800-nm input pulse injected.

The supercontinuum spectral phase (not shown) is predominantly cubic, which is consistent with our previous XFROG measurements on a 120-mm-long fiber continuum, which have clearly shown the parabolic group delay (and hence cubic spectra phase) characteristics of the supercontinuum. The measured pulse length of such continuum was also long: ~4 ps. As a result, we have generated and measured supercontinuum from a short (8-mm) microstructure fiber (using ~40-fs input pulses). And indeed, we find that the continuum is much shorter, and its phase is mush less distorted.

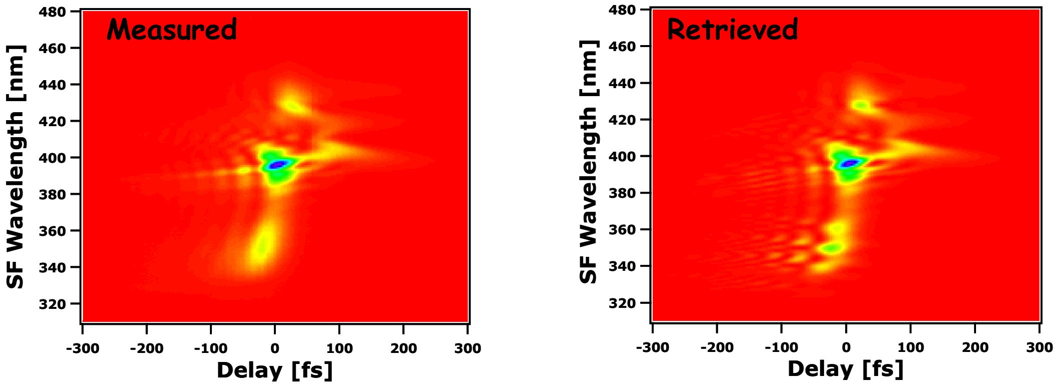

Fig. 2. The measured (left) and retrieved (right) XFROG trace of the 8 mm fiber continuum.

Fig. 2 shows the measured XFROG trace (left) and the retrieved trace (right) of the short-fiber continuum. We see from the figure that the retrieved trace is in good agreement with the measured one, reproducing all the major features (the additional structure in the retrieved trace is due to fluctuations in the continuum that the XFROG algorithm sees and reproduces, but which are smeared out in the measurement over several billion pulses).

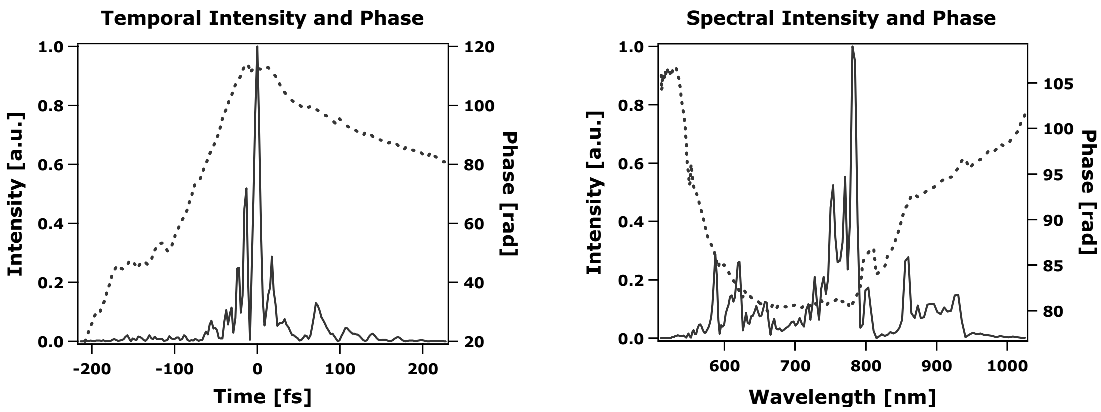

Fig. 3. The retrieved continuum intensity and phase vs. time (left), the retrieved continuum intensity and phase vs. frequency (right).

Figure 3 shows the retrieved continuum intensity and phase. Note that the temporal extent of the continuum from the 8 mm long fiber is shorter than the input 40-fs pulse! It consists of series of sub-pulses, each of which is considerably shorter than the input pulse. Also, the short fiber continuum has less complex temporal and spectral features than the continuum pulses previously measured from longer fibers. The spectral phase of the short-fiber continuum is much less distorted than that from long fiber, varying only in the range of 25 rad (vs. several thousand rad). The experimental results have been compared with numerical simulations, with good qualitative agreement being obtained. Moreover, the simulations have allowed the temporal structure observed in experiments to be interpreted as due to soliton breakup or fission.