Backseeded Higher-Order Parametric Gain in Supercontinuum Generation

Peter M. Moselund, Michael H. Frosz, Carsten L. Thomsen and Ole Bang

The ultra-broadband supercontinuum light source is rapidly becoming the source of choice for many bio-optical imaging applications, including fluorescence microscopy, CARS microscopy and optical mammography. In these applications, a high-power supercontinuum is passed through narrow tunable filters in order to work as a multicolor tunable laser, which may access all wavelengths from blue to near infrared.[1] This freedom in choice of excitation colors has made it much easier to probe the optical characteristics of biological matter.

Today, supercontinuum research is mainly devoted to finding ways of controlling the stability and shape of the generated spectrum. This increases the efficiency of the systems by confining most of the generated light to the wavelengths required for a particular application.

A supercontinuum is normally produced by pumping a photonic crystal fiber[2] (PCF) with high-power laser pulses. The high nonlinearity of the PCF then causes extreme spectral broadening.[3] One way to modify the spectrum is to pump at multiple wavelengths to direct the light generation to a desired part of the spectrum.[4]

In most cases, multi-wavelength pumping has been performed by splitting off part of the pump, frequency-converting it with a nonlinear crystal, and then recombining it with the original pump before coupling it into the PCF. However, supercontinuum generation is already established as one of the most powerful fiber-integrated wavelength conversion effects. We therefore find it more logical to use the frequency conversion in the supercontinuum itself and feed back part of the output to take part in the pumping process.

We have realized this approach using a fiber with two zero-dispersion wavelengths close to the pump wavelength. This gives the fiber two four-wave mixing (FWM) gain bands, one close to the pump and one far from the pump. The light fed back from the supercontinuum was used to seed the outer FWM Stokes gain band at 1,270 nm.

Using this approach, we have demonstrated both numerically and experimentally[5] that strong peaks can be produced in the supercontinuum by utilizing the positive feedback of the cumulative FWM gain buildup. Thus, the power available in the supercontinuum can be increased by up to 15 dB in local peaks at the FWM gain wavelengths. These peaks can be turned on and off simply by turning the feedback on and off. However, for gain to occur, the seed has to be temporally matched with the supercontinuum pulse.

It has been shown previously that PCFs can be used to produce strong FWM peaks far from the pump when pumping in the normal dispersion region or that PCFs can produce a wide supercontinuum when pumping in the anomalous dispersion region. However, we have shown that it is possible to shift freely between generating strong peaks and a wide supercontinuum simply by flicking a mirror. This is an exciting new option for applications where high power and large bandwidth are desirable at different times. ◭

Peter Moselund (pmmo@fotonik.dtu.dk), Michael Frosz and Ole Bang are with DTU Fotonik, Department of Photonics Engineering at the Technical University of Denmark. Carsten Thomsen is with Koheras A/S, Denmark.

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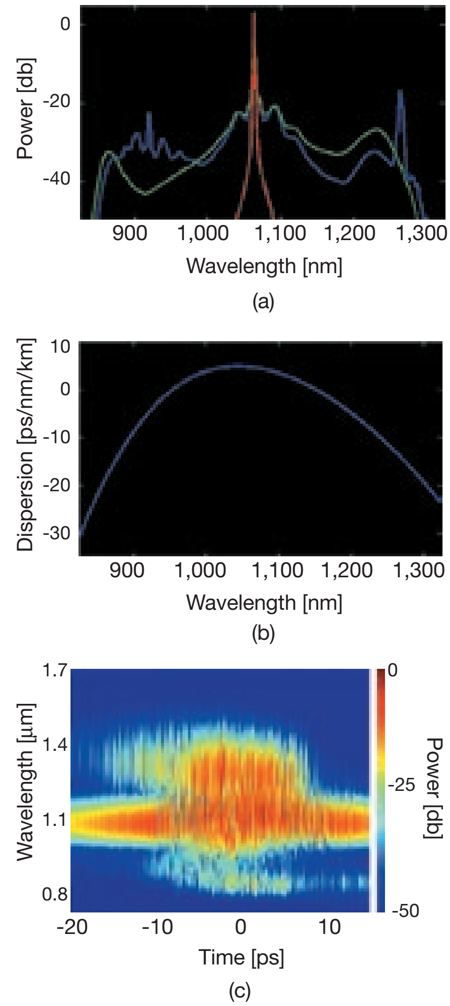

(a) Spectrum of the pump (red) and the generated supercontinuum with (blue) and without (green) backseeding of output light at the FWM gain wavelength at 1270 nm. (b) Dispersion profile of the fiber. (c) The spectral distribution of power as a function of time in the output pulse. The evolution of this distribution along the fiber is available as a movie online (2.2 MB).