## **A Photonic Signal Amplifier**

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Photonics plays an increasing role in telecommunication networks. Traditionally, optical components like fibers were only used to implement passive functionalities. Signal regeneration, in contrast, required optoelectronic conversion and further electronic means for noise rejection. In particular, the former step inevitably introduces noise all by itself, namely Johnson noise and detection shot noise. In order to avoid the detrimental influence of electronic noise, therefore, there is great interest in implementing signal regeneration in an all-optical way. Here we discuss and demonstrate a novel all-optical scheme that can amplify an amplitude modulation by about 60 dB relative to the carrier. This scheme surpasses electronic signal restoration as well as previously conceived optical concepts by orders of magnitude.

Our scheme is based on nonlinear propagation of short optical pulses in a photonic crystal fiber. Launching the pulses into the fiber near the zero-dispersion wavelength invokes a soliton fission scenario, which results in extreme spectral broadening of the pulses into a white-light continuum. This is an extremely nonlinear scenario, with tiniest changes of the input energy resulting in dramatic changes of the resulting white-light spectrum. This extreme sensitivity towards input fluctuations on the quantum noise level is well known to cause strong fluctuations of amplitude and phase of the output pulses, which, in turn, translate into incompressibility of the white-light spectra into a short pulse. In contrast, we now first demonstrate useful exploitation of this extremely high sensitivity towards input fluctuation.

To this end, we place an array of avalanche photo diodes in the spectral plane of a spectrograph resolving the white-light spectra. Each of the diodes is equipped with its own transimpedance amplifier, enabling the detection of individual pulses from a 80 MHz pulse train. The input to the fiber is amplitude modulated with an acousto-optic modulator at 4.5 MHz, and a small fraction of the input light is tapped off and analyzed with a separate photo detector. Attenuating the modulation close to the detection limit, we find a modulation level of 74 dBc in this signal. This is contrasted by a best modulation of 21 dBc in the detector array after the fiber, i.e., a net increase of 53 dB. Coherently combining the signals of 3 diodes, the signal even becomes amplified by 58 dB relative to the carrier. Concomitantly, input noise certainly also experiences amplification. Nevertheless, a comparison between input and output clearly reveals that the signal-to-noise ratio is actually improved by 25 dB in the nonlinear optical process. To our knowledge, these numbers surpass previously reported values for all-optical signal regeneration by more than 10 dB.

We carefully analyzed noise contributions in our experiments. From this modeling, we are able to deduce the impact of our method on related methods, e.g., coherent detection. We find that, with input signals on the few-photon level, it should be possible to improve the signal-to-noise ratio by up to 40 dB. This is contrasted by a best 6 dB improvement of regular coherent detection. We therefore think that our experiments on photonic signal amplification indicate an avenue towards increasing the sensitivity in photodetection to a level that has been previously considered impossible.