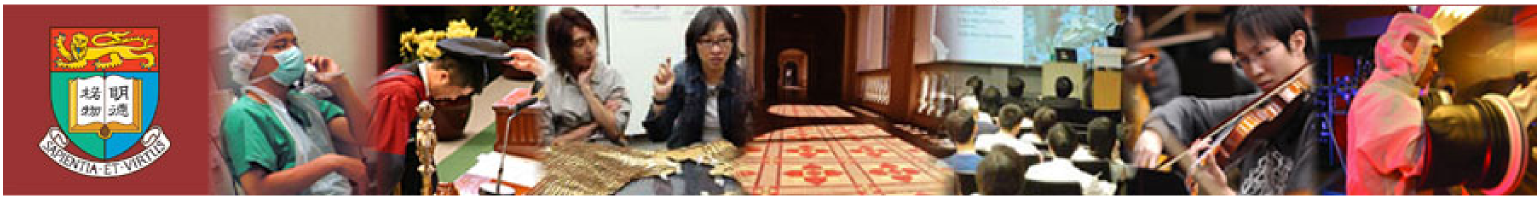

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Effect of the CW-seed's linewidth on the seeded generation of supercontinuum

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***Abstract*—We demonstrate the influence of CW-seed's linewidth on the temporal coherence of the seeded supercontinuum, which enhances the contrast ratio of the interference fringe by ~5 dB and ~3 dB at four-wave mixing sidebands respectively.**

***Keywords*—Nonlinear optics, four-wave mixing; Supercontinuum generation; Coherence.**

I. INTRODUCTION

Supercontinuum (SC) generated by the picosecond or nanosecond pulse, for its broadband spectrum, has been well accepted in the areas such as optical spectroscopy, optical frequency comb, pulse compression and ultrashort pulse source [1]. Unfortunately, this kind of SC driven by the noise-initiated modulation instability (MI) is featured with large shot-to-shot fluctuation and bad temporal coherence outside of the pumped area. In order to improve these shortcomings, few techniques have been demonstrated, including triggering with a pulse-seed [2], introducing a feedback loop [3], modulating the pump pulse train [4], and engineering the dispersion of the fiber medium [5]. In addition, we have shown that the SC generation can be manipulated by using a weak CW-seed experimentally and numerically [6]. When it comes to the effect of the linewidth of the seed source on the generated SC, Sørensen et al. [7] have numerically confirmed that a nearly coherent pulse-seed contributed greatly to the improvement of the noise property of the generated SC. For the CW-seed generated SC, however, no experimental analysis has been investigated yet, which is very important for the implementation of high quality SC. In this paper, based on both experimental and numerical studies, we investigate the effect of the linewidth of the CW-seed source on the temporal coherence and pulse-to-pulse fluctuation of the seeded SC.

II. EXPERIMENT

A 450-m highly-nonlinear dispersion-shifted fiber (HNL-DSF) with a zero-dispersion wavelength (ZDW) of 1554 nm was employed as the medium for the SC generation. Its dispersion slope is 0.035 ps/nm^2/km, while the nonlinear coefficient is 14 W^{-1}km^{-1}. The pump pulse was provided by a 78-MHz pulse source at 1557.8 nm, which offered a pulsed peak power of 5.8 W. The optical spectrum of the unseeded SC is illustrated as the black curve in Fig. 1(a). Before introducing the CW-seed into the system, a wavelength tunable CW laser and a 1-nm filter at 1610 nm were utilized to locate the optimal region for the wavelength of the CW-seed. When the pulse pump together with the wavelength-tuned CW laser were launched into the HNL-DSF, the optical power at 1610 nm filtered out by the filter mentioned above is shown in Fig. 1(b), where the horizontal axis corresponds to the wavelength of the CW laser. With a MI-gain spectral shape, Fig. 1(b) suggests that the optimal wavelength of the CW-seed is falling in the two symmetrical lobes. It should be pointed out that the rightmost peak in Fig. 1(b) is due to the contribution of the CW laser when its wavelength was tuned to around 1610 nm, just where the optical power was measured. Consequently, two CW laser sources at 1534 nm, with linewidth of 2 kHz and 10 MHz respectively, were selected to study the effect of the CW-seed's linewidth on the characteristic of the stimulated SC. Seeded with a 100-μW CW-seed power, the generated SC reveals weak four-wave mixing (FWM) effect and intensity enhancement on the redshifted side of the generated SC, as can be observed from Fig. 1(a).

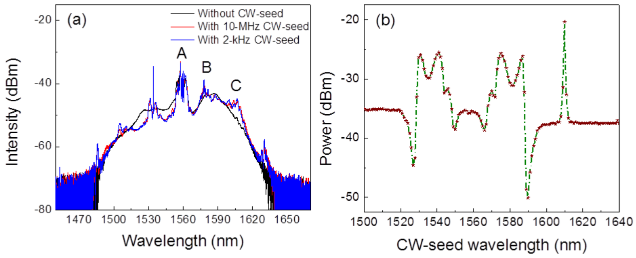

Fig. 1 (a) The optical spectra of the generated SC. (b) The power of the SC at 1610 nm as the function of the CW-seed's wavelength with a tuning step of 1 nm.

In order to investigate the characteristic of the temporal coherence, we launched the SC pulse train into a Mach-Zehner Interferometer (MZI) with a path difference almost equal to the separation of the adjacent pump pulses. With different CW-seeds, the interference spectra corresponding to the regions A, B and C are shown in Fig. 2(a), (b) and (c), respectively. The interference fringes are produced by the

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temporal overlap of the neighboring SC pulses. At region A, both CW-seeds can enhance the contrast ratio of the interference fringe from ~2 dB to ~6 dB. At regions B and C, the 10-MHz CW-seed cannot provide stable interference fringes, which is similar to the case without CW-seed. The 2-kHz CW-seed, on the other hand, can support contrast ratio enhancements of ~5 dB and ~3 dB for regions B and C, respectively. The pulse-to-pulse intensity histograms of regions B and C were also measured by using a tunable 16-nm filter and a real time oscilloscope, and calculated as Fig. 2(d) and (e). The standard deviation seeded by the 2-kHz CW-seed has been reduced by 64% and 40% at locations B and C, respectively.

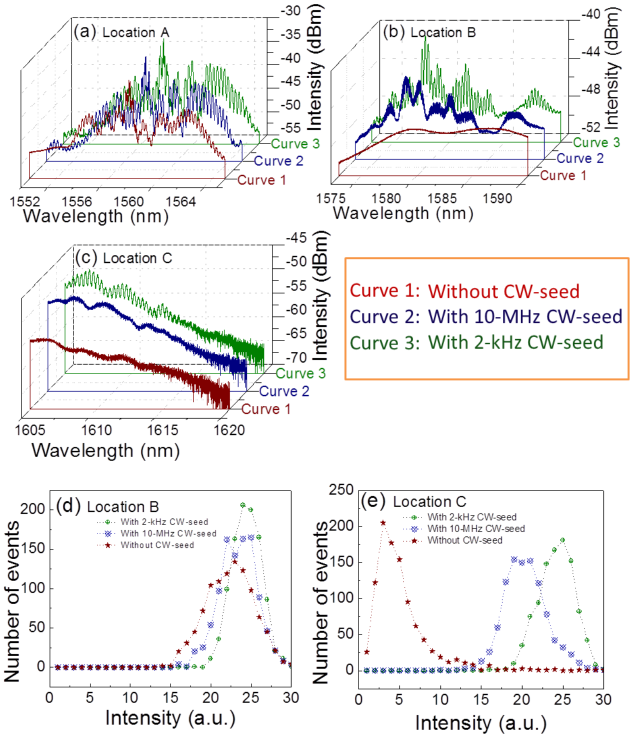

Fig. 2 (a)-(c) The interference spectra at locations A, B, and C. (d)-(e) The pulse-to-pulse intensity histograms at B and C.

III. SIMULATION

To verify the effect of the linewidth of CW-seed on the seeded SC numerically, we performed the simulation based on the model presented by Dudley et al. [1]. The linewidth of the CW-seed was introduced by the phase-diffusion model [7]. For the sake of manageable computational time, the numerical frequency resolution in the simulation was set to 10 GHz, which means that the linewidth smaller than 10 GHz can only be partly resolved in the simulation. Thus, the simulation done here is to verify the trend of the influence of the CW-seed's linewidth on the seeded SC qualitatively. With various background noise and phase noise of the CW-seed from shot to shot, the first-order temporal coherence of the generated SC was calculated. As shown in Fig. 3(a), both CW-seeds with linewidth of 100 MHz and 500 MHz can slightly enhance the spectral intensity of the stimulated SC. The 100-MHz CW-seed, in addition, has improved the temporal coherence at the FWM sideband obviously. The 500-MHz CW-seed, however, cannot realize such function as that of the 100-MHz one, as shown in Fig. 3(c) and (d). As mentioned before, the simulation performed here is a qualitative analysis of the influence of the CW-seed's linewidth on the seeded SC, subject to the limitation of the frequency resolution in the simulation. Nevertheless, it is obvious that a narrower linewidth of the CW-seed facilitates the improvement of the temporal coherence.

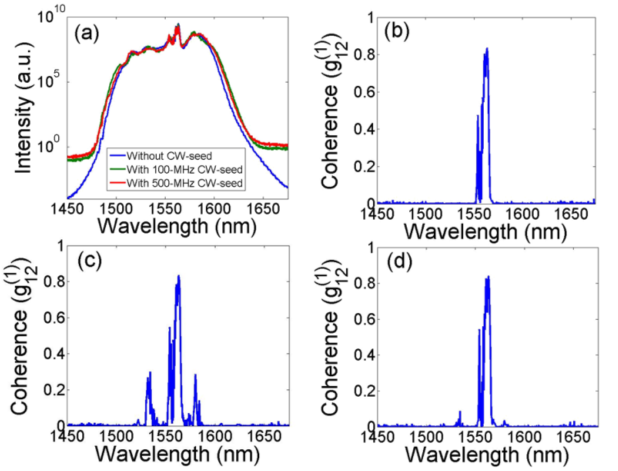

Fig. 3 (a) The simulated SC spectra. (b) The temporal coherence without CW-seed. (c) The temporal coherence with a 100-MHz CW-seed. (d) The temporal coherence with a 500-MHz CW-seed. For each case, 300 simulations have been obtained.

IV. CONCLUSION

We have investigated the influence of the linewidth of the CW-seed on the noise property of the seeded SC, and experimentally confirmed that the temporal coherence of the SC stimulated by a 2-kHz CW-seed can be further improved by ~5 dB and ~3 dB at the FWM sidebands, which is beneficial for the stimulated SC design in the future.

ACKNOWLEDGMENT

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