Transmission Of Frequency Comb Over 7.7 km Of Hollow Core Fiber

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***Abstract*—We demonstrate the transfer of an optical frequency comb (OFC) through a noise-cancelled hollow core fiber (HCF) link for the first time. We discuss the advantages of using HCF versus standard glass-core single-mode fiber (SMF) for comb transmission.**

Keywords—Optical frequency comb transfer; Hollow-core fiber; fiber noise suppression

I. INTRODUCTION

Noise-cancelled optical fiber links have been extensively used for the transfer of a single optical carrier, primarily for the comparison of optical clocks. Whilst it poses additional challenges, transferring a comb instead of a single carrier has the advantage of delivering to the user tens to hundreds of thousands of optical and RF frequencies all at once, as well as time.

Here, we propose the use of a new generation of optical fiber particularly suited for the transfer of OFC. This new fiber transmits light through a hollow core rather than silica glass, reducing optical nonlinearity by over 3 orders of magnitude, back-scattering by more than 4 orders of magnitude, and chromatic dispersion by an order of magnitude as compared to SMF. All of this with a simultaneous 20-fold reduction of propagation time sensitivity to temperature. Another advantage is that light propagates through HCF at almost the speed of light in vacuum (30% faster than in silica glass), reducing the round-trip time through the fiber and thus increasing the control-loop bandwidth for optical length stabilization.

For our demonstration we use a HCF with a Nested Antiresonant Nodeless geometry which has been shown to be capable of a loss approaching that of SMF (current record: 0.28 dB/km) and offers 3-dB bandwidths of >700 nm. For a proof-of-principle experiment, we transfer an OFC through an optical length-stabilized HCF. Thanks to the significantly lower non-linearity, more power can be transmitted through the HCF, potentially allowing for a higher SNR at the remote end (where the achievable SNR may be limited by the comb power) and enabling splitting of the transmitted comb to more users.

II. RESULTS

When 100 mW of OFC power is transmitted over 7.5km of SMF nonlinear interactions in the silica core leads to sharp peaks at wavelengths of 1568 and 1583 nm, whereas no such nonlinear distortion is observed when using 7.7km of HCF (Fig. 1). Note the HCF has an average loss of 0.65 dB/km and is spliced to SMF pigtails, enabling ready interfacing with SMF-based components. We next characterized the frequency stability after transmitting the comb over the two different fibers in both a free running and noise cancelation mode (Fig.2, the input power to SMF reduced to 10 mW). The free running stability using HCF is found to be several times better than SMF thanks to its lower thermal sensitivity (Fig. 3). After turning the feedback on, the frequency stability using HCF and SMF is almost identical, the stability of the measured optical mode is 4×10^{-17} at 1 s and 2×10^{-19} at 10000 s. Furthermore, the fiber-induced phase noise is both reduced by up to 55 dB and is −50 dBc/Hz at 1 Hz offset from the carrier.

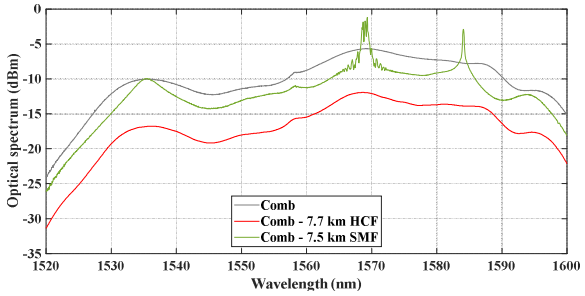

Fig. 1. Comb optical spectrum (black) transmitted through 7.7 km of HCF (red), and 7.5 km of SMF (green).

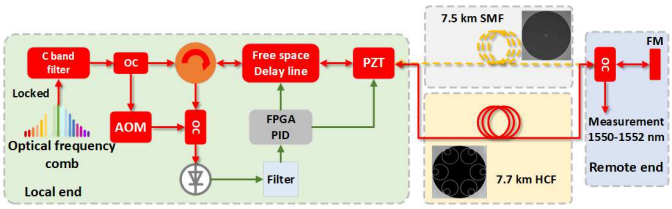

Fig. 2. Experiment set-up. AOM: acousto-optic modulator; MZM: Mach-Zehnder modulator; OC: optical coupler; FM: Faraday mirror. As transmission fiber, we use 7.7 km of HCF or 7.5 km of SMF for comparison.

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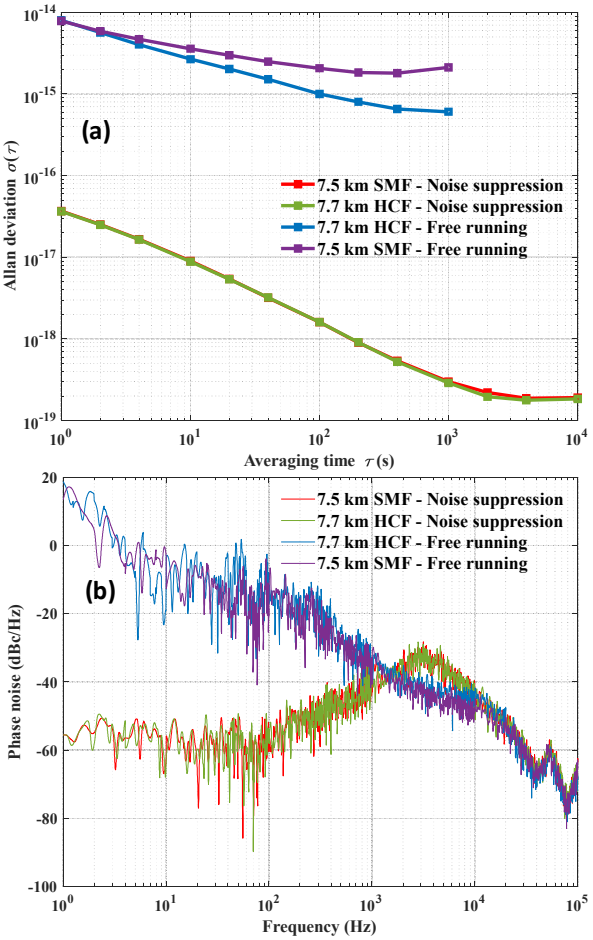

Fig. 3. Optical mode of frequency stability (a) and phase noise (b) comparison of C-band comb (1530-1565 nm) transmission of 7.5 km SMF and 7.7 km HCF.

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