

# Transfer of ultra-low phase noise microwave references over the JANET Aurora fibre network using a femtosecond optical frequency comb

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An ultra-low phase noise microwave frequency is transferred over 82 km of installed fibre by propagation of a 30 nm bandwidth optical frequency comb ( $\sim 10^4$  modes). The phase noise induced along the fibre by vibrations and thermal effects is suppressed by implementing a noise cancellation scheme where a portion of the light is sent back to the transmitter through the same fibre. The 6th harmonic of the repetition rate detected before and after the pulse train has travelled a round trip are phase compared and used to generate an error signal that controls a fibre stretcher to compensate for the fibre-induced phase fluctuations. Optical amplifiers are used to compensate for the fibre attenuation and dispersion compensation modules are also employed.

The actual phase noise of the repetition rate delivered to the ‘user’ end of the fibre is measured by phase comparison with the local repetition rate. A phase noise of the transferred repetition rate of  $-95$  dBc/Hz at 1 Hz offset from the carrier (1.5GHz) is obtained, demonstrating that this technique is suitable for dissemination of state-of-the-art microwave references as well as being compatible with the emerging generation of ultra-low phase noise sources, such as those derived from ultra-high finesse cavity-stabilized lasers. Compared to other available techniques for transferring microwave frequencies over optical fibre networks, this technique is attractive as it simultaneously transfers a large number of optical frequencies [1,2].

- [1] Foreman S M, Holman K W, Hudson D D, Jones D J and Ye J, Remote transfer of ultrastable frequency references via fiber networks, 2007 Feb, *Rev. Sci. Instrum.*, 78 (2), 021101
- [2] Marra G, Margolis H S, Lea S N and Gill P, High stability microwave frequency transfer by propagation of an optical frequency comb over 50 km of optical fiber, February 2010, Accepted for publication in *Optics Letters*

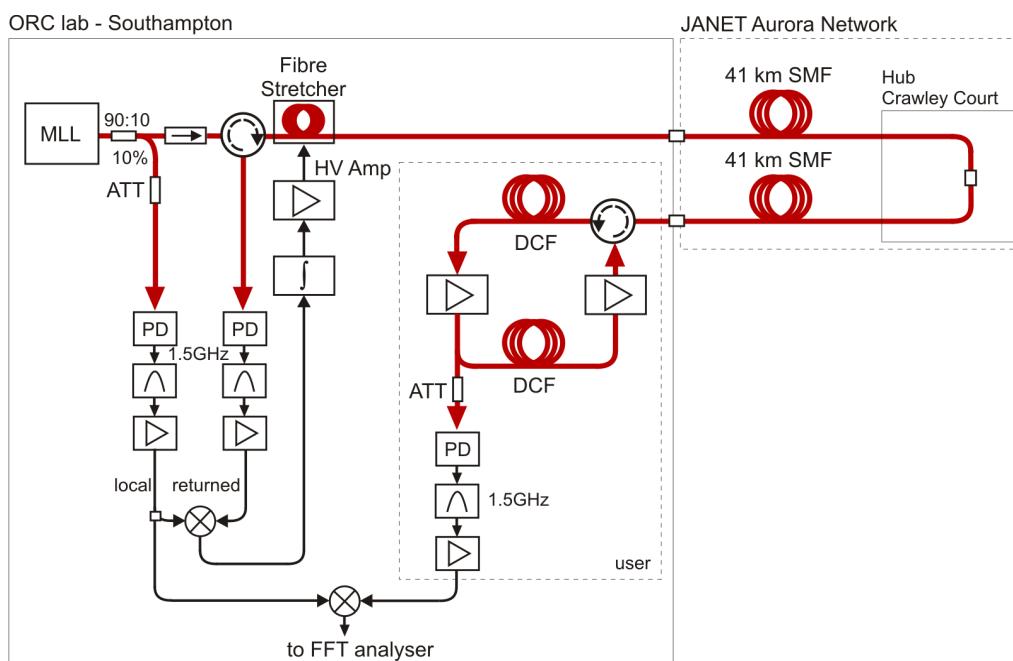


Figure 1: Block diagram of the experimental set-up. MLL: Mode-locked laser; DCF: dispersion compensating fibre; SMF: single mode fibre; HV amp: high voltage amplifier; ATT: attenuator; PD:phase detector.