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Light

UNIVERSITY OF Southampton
Optoelectronics Research Centre

Transfer of an optical frequency comb over the JANET-Aurora network

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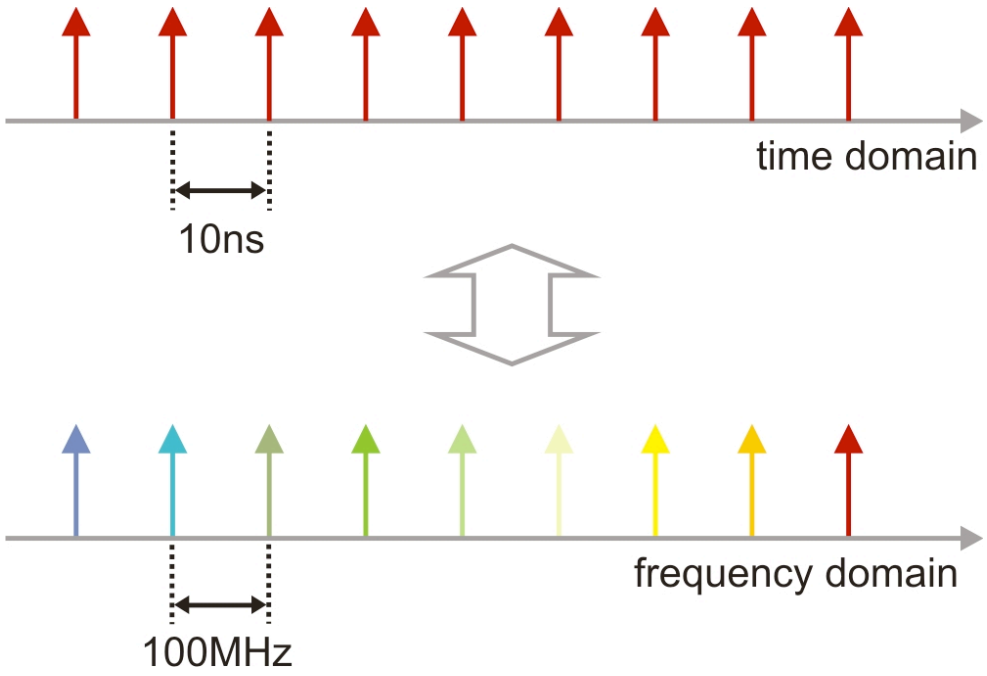
What is an optical frequency comb?

Nobel prize in 2005



A femtosecond frequency comb is a laser that produces a train of extremely short pulses (from tens to hundreds of fs).

In the frequency domain the pulse train corresponds to a comb of equally spaced frequencies with spacing equal to the inverse of the time interval between pulses.

$$\text{Frequency spacing} = \frac{1}{\text{Time interval between pulses}}$$

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What they are used for?

- Ultra accurate measurements of optical frequencies
  - Optical clocks
  - Tests of fundamental physics
- Fast spectroscopy (many lines at the same time)
- Astrophysics (spectrogram calibration)
- Attosecond physics

Telecommunications? Maybe soon…

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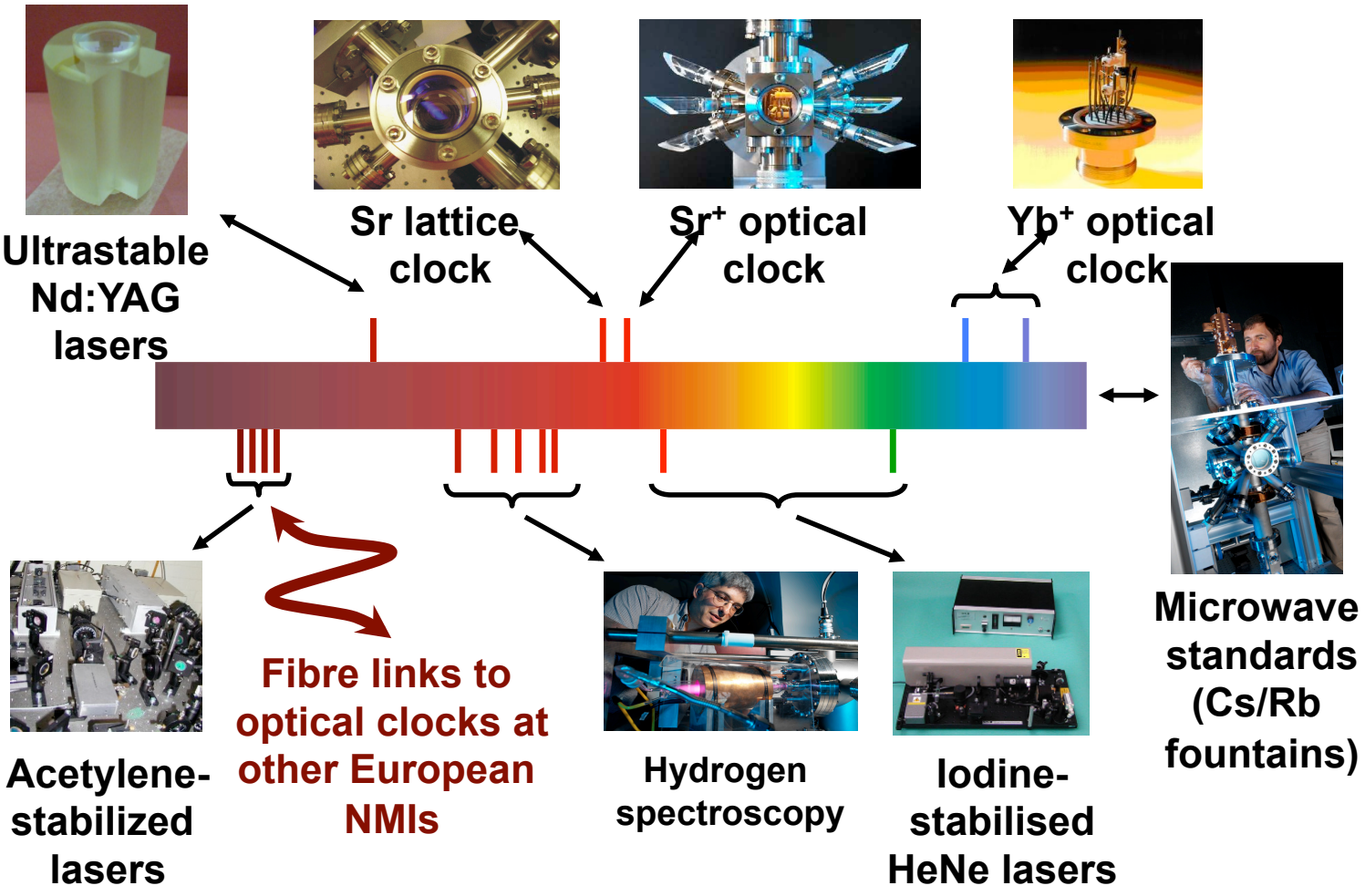
Femtosecond optical frequency combs at NPL



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Frequency comb dissemination

- Ultra stable and accurate optical frequency combs can be generated in frequency metrology laboratories

The frequency of each optical mode can be stabilized below 1 Hz

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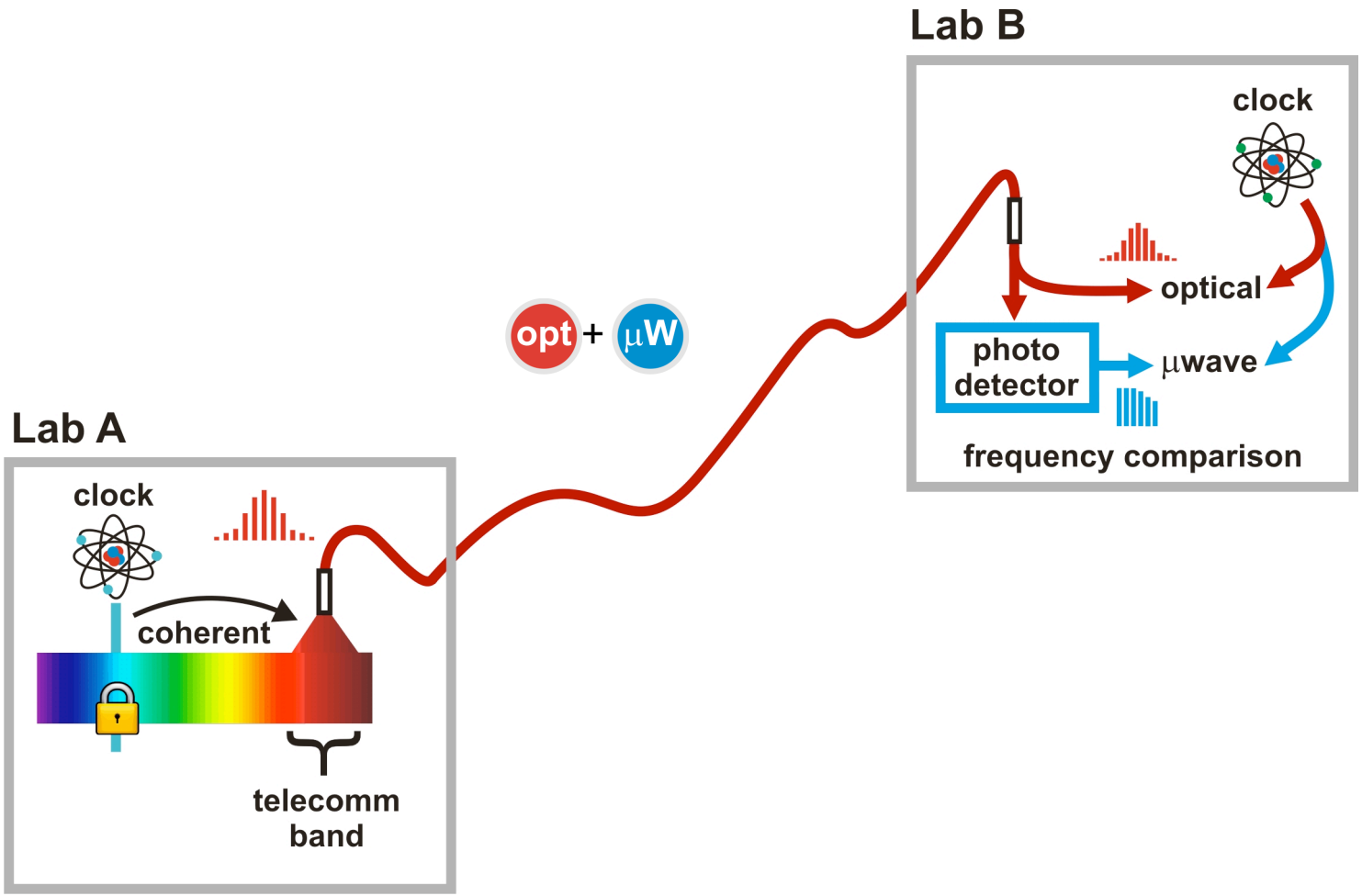
Comb transfer = Optical + Microwave frequencies



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Can an ultra stable comb be disseminated to remote laboratories via optical fibre?

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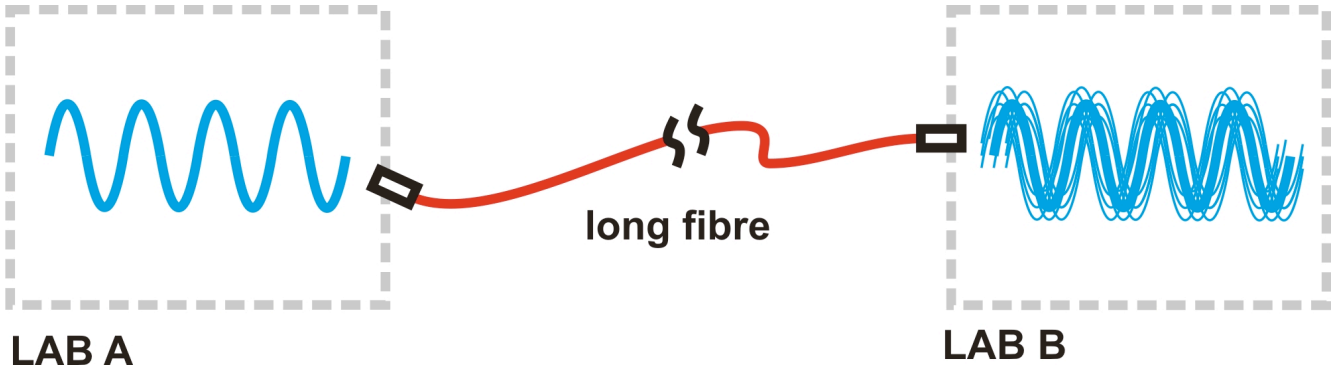
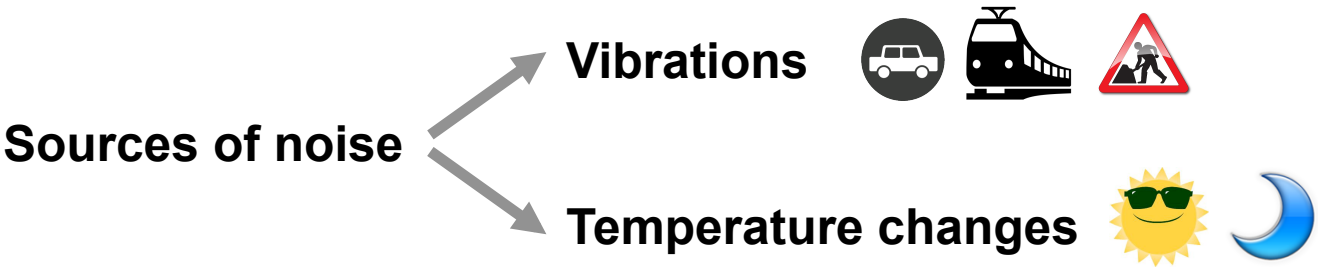
Fibre noise degrades the phase and amplitude stability of the transmitted signal





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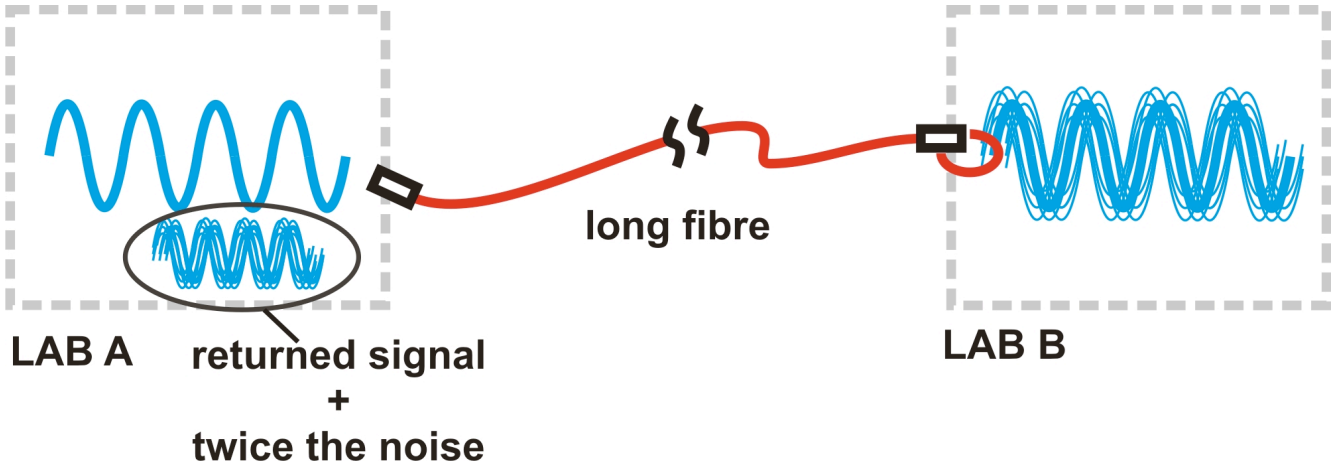
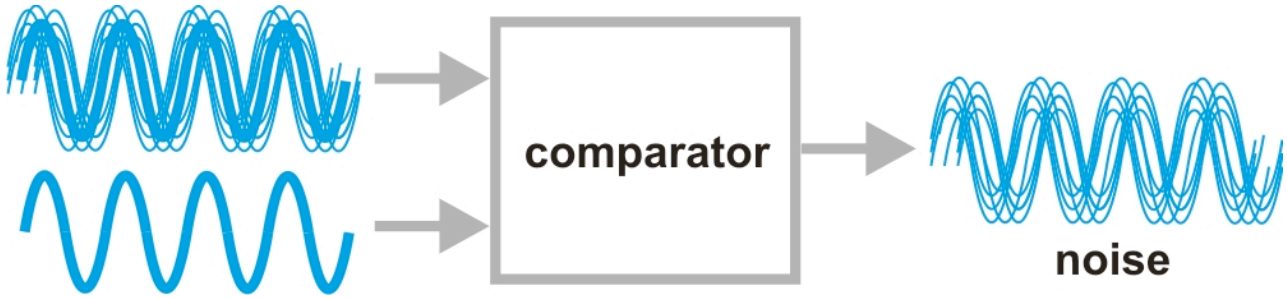
By returning a portion of the signal back to the transmitter, the fibre noise can be measured





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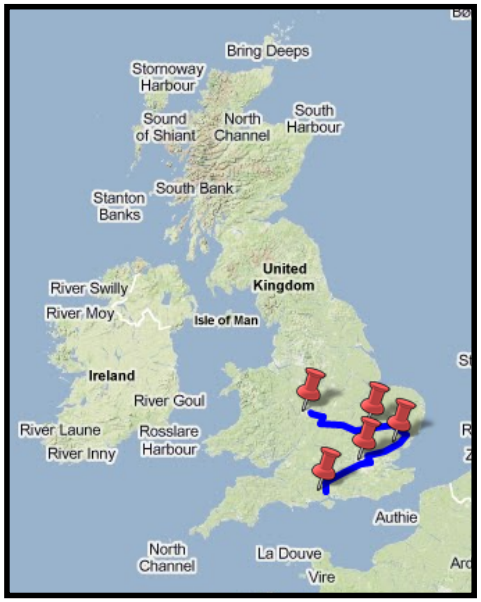
The JANET–Aurora optical network

It links 5 Universities, total span ~800 km



There are two fibres between the University of Southampton and the hub at Crawley Court: by joining the two fibres in the hub we can make a 86 km span with both ends in the laboratory

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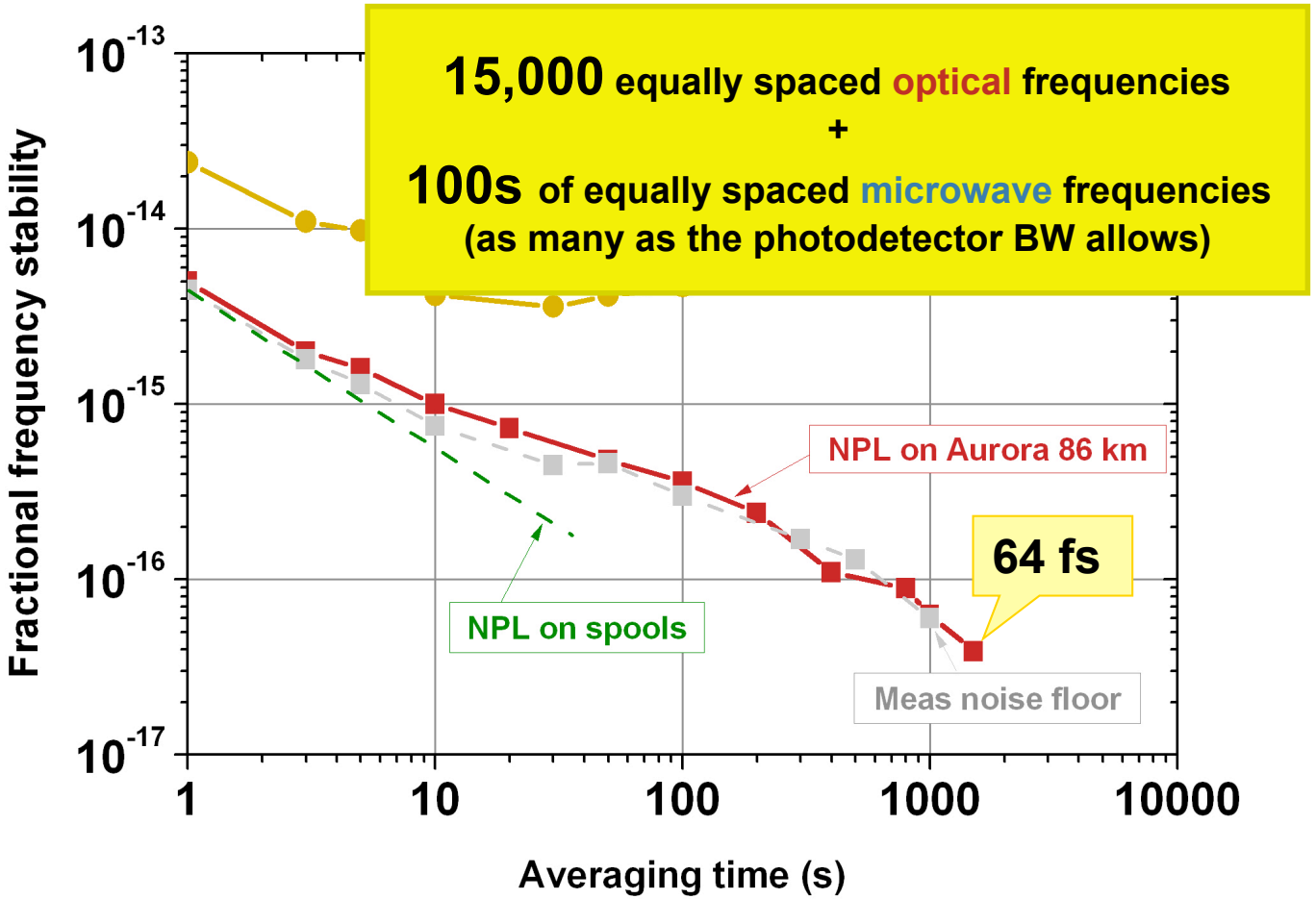
Results: frequency stability of the repetition rate



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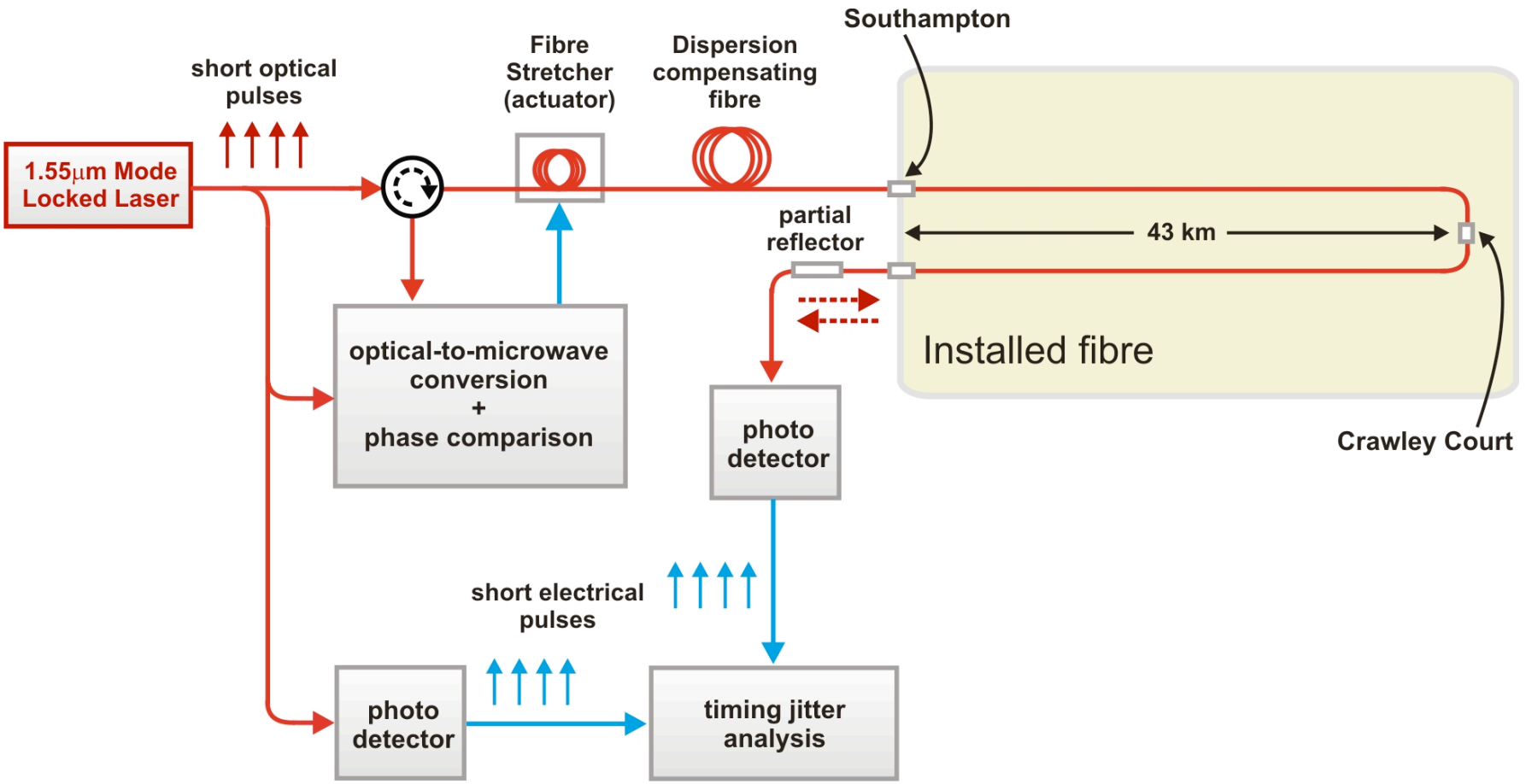
Measurement setup



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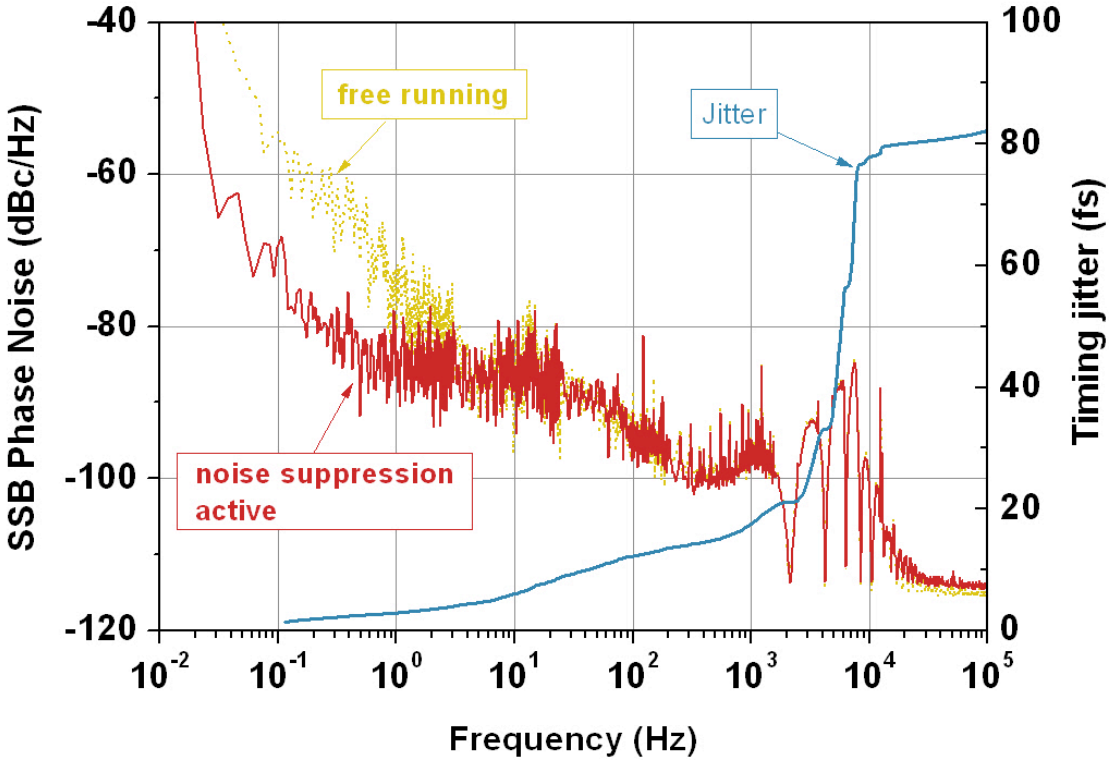
Results: phase noise and timing jitter



Range (Hz)	Jitter (fs)
0.1-1	2.9
0.1-10	6
$0.1\text{-}10^2$	12.2
$0.1\text{-}10^3$	17.4
$0.1\text{-}10^4$	77.9
$0.1\text{-}10^5$	82.2

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Conclusions

We propagated an optical frequency comb over a **86 km**-long installed optical fibre link. By actively cancelling the noise introduced by the fibre we demonstrated that:

Time domain

it is possible to transfer an optical pulse train with timing jitter lower than **100 fs** (measured over short and long time scales)

Frequency domain

it is possible to transfer a 30 nm-wide optical comb (**15,000 optical modes**) where the mode frequency spacing is preserved at parts in $\mathbf{10^{17}}$

Results published in Optics Letters: G. Marra et al., "High-resolution microwave frequency transfer over an 86-km-long optical fiber network using a mode-locked laser," Opt. Lett. 36, 511-513 (2011).

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What can we do with this technique?

- We can transfer ultra stable microwave frequencies (such as those generated at NPL) over long lengths of fibre

- Science fields where ultra precise timing signals are required could benefit from this technique (such as particle accelerators and arrays of radiotelescopes)

Possible applications in the telecommunications field?

Open to discussions!

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