Distributed detection of temperature gradients with single-wavelength phase-sensitive OTDR and speckle analysis methods

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** MOTIVATION **

- Traditional ΦOTDR allows for high-bandwidth vibration detection. But provides no information on temperature changes along the fiber.
- Distributed temperature fiber sensing (ΦOTDR, Raman OTDR, BOTDA) require:
  - More complex setups (and expensive)
  - Longer measurement times
  - Incompatible with vibration detection (need frequency sweep and/or high averaging)

** GOALS **

- Design of a cheap and easy to implement method which allows to extend the operation of traditional (single-frequency) ΦOTDR used for distributed vibration sensing, to the monitoring of distributed temperature gradients.
- Testing its reliability in a temperature-controlled oven hot-spot.

** MEASUREMENT PRINCIPLE AND EXPERIMENTAL SETUP **

1 km fiber + 20 m hot-spot — λ = 1550 nm, P_length = 20 ns

- Standard Φ-OTDR traces are measured @100 M/S/s:
  \[ I(x) = |I(x)|^2 = \sum \cos(\phi_i - \phi_j) \]
- The optical intensity variation \( \Delta I(x) \approx \sum_i r_i r_j \sin(\phi_i - \phi_j) \Delta n \) (\( \Delta n = 10^{-17} \))

Slow gradients make \( \sin(\phi_i - \phi_j) \) linear!

** EXPERIMENTAL RESULTS **

1. Several consecutive traces (along 6 s):
   \( \Delta T \approx 1 \text{ mK/s} \) at hot-spot

2. Differences of the traces:
   \( \phi_i - \phi_j = \omega_2 (x_i - x_j) \frac{2\pi}{\Delta \lambda} \approx 2\pi \)

3. After integrations:

** CONCLUSIONS **

A simple and easy to implement method for temperature gradients detection in real time with single-wavelength ΦOTDR derived from the speckle analysis theory was presented and demonstrated.

The method relies solely on a low-cost post-processing of the standard ΦOTDR traces (already acquired for vibration detection).

Could be implemented without affecting the distributed vibration detection and with a close to zero cost.

A successful test of it has been performed by measuring the temperature decrease of water into an oven as hot-spot.

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