Low-cost monitoring of the wavelength difference of two transmitters for two-way time transfer over optical fibre

***Radan Slavík*[1], *Josef Vojtěch*[2] *and Vladimír Smotlacha*[2]**

1. ORC, University of Southampton, Southampton, SO17 1BJ, UK

2. CESNET, z.s.p.o., Zikova 4, Praha 6, Czech Republic

Accurate time transfer is routinely performed using GPS, however an order of magnitude better accuracy can be achieved when signal transfer over optical fibres is used (e.g., in [1], fibre transfer over 73 km with <100 ps precision was achieved as compared to <700 ps for the GPS-based system). Unfortunately, the propagation delay through an optical fibre changes due to temperature variation. This is commonly compensated for by transferring the time information bi-directionally over a single optical fibre with subsequent cancellation of the propagation delay variations [1]. However, to avoid any signal degradation due to Rayleigh back-scattering and reflections at fibre connectors, it would be advantageous to transmit the information in both directions using different wavelength, each of them in a unidirectional sense [2]. However, this requires two transmitters operating at different wavelengths. Due to the limited stability of (low-cost) telecom-grade transmitters (generally ±0.1nm [3]), the propagation delay in both directions can change in an uncorrelated manner and thus could not be compensated by a known stable difference, degrading the precision of the time transfer.

Here, we demonstrate a low-cost method to monitor the relative difference of two transmitters spaced 2 ITU channels away (200 GHz). Our method can be understood from our experimental set-up shown in Fig. 1a. Two 2.5-Gbit/s telecom lasers [3] operating on two ITU telecom channels 200 GHz apart (e.g., channels 28 and 30 in our experiment) are combined and sent through a 200-GHz filter centred at the channel lying in between them (ITU channel 29 in our experiment). This ensures the two lasers wavelengths are within the leading and trailing edges of the filter. Thus, any change in their relative frequency spacing can be determined by measuring the power transmitted through the 200-GHz filter at the two respective channel wavelengths (Fig. 1a). A standard 200-GHz telecom filter has its central wavelength specified (over the entire temperature range and its lifetime) to ±0.1 nm. Thus, given the laser and the filter tolerances, the leading and trailing edges of the filter are required be linear (in terms of dB/nm) within a ±0.2 nm window. To characterize this, we swapped the two lasers for tuneable ones and characterized the filters transmission characteristics, Fig. 1b. Here, we see that good linearity is obtained at the leading edge over the entire ±0.2 nm range, with a sensitivity of 58 dB/nm (0.5 dB/GHz). At the trailing edge, the filter provides a lower sensitivity towards the pass band edge, but nevertheless, still maintains a sensitivity of better than 20 dB/nm. Considering the power can be read with a 0.1% precision, this translates into an ability to control the relative laser frequencies to < 50 MHz precision.

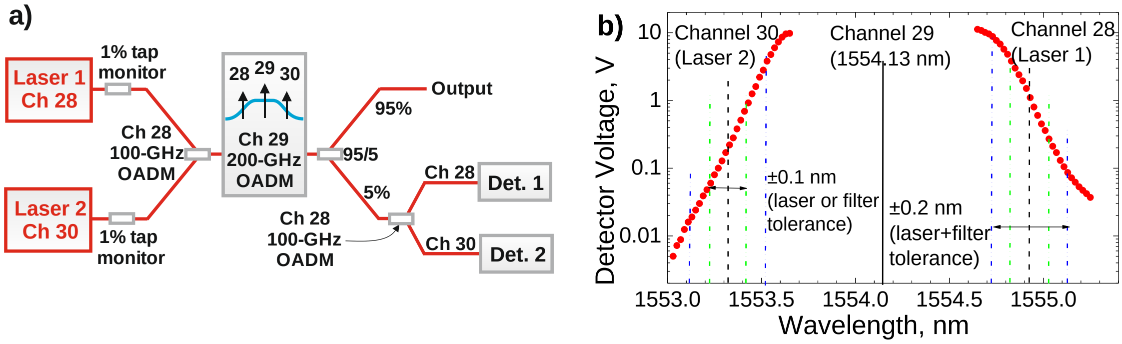

Fig. 1 Experimental set-up (a) and power measured at Detectors 1 &2 as a function of the wavelength of the Lasers 1 and 2 within the vicinity of their central wavelengths.

Given that the dispersion of standard single-mode fibre is 17 ps/nm/km then the achievable precision on the relative frequency of the two lasers should allow a timing error of less than 70 ps over a 100-km long optical fibre. Our stabilization technique uses standard telecom-grade transmitters (that can be used to simultaneously transmit data) and low-cost components (3 filters costing <50 Euro each and two slow photoreceivers), making it highly-affordable.

References

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