

Testing fiber-optic recirculating loop transmission using the OSA20

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Introduction

Knowing how important it is these days to guarantee high reliability of data flow, many in the monitoring, maintenance and research fields are taking a keen interest in long-haul transmission system evaluation. Testbed experimental setups for such systems can prove costly, as they typically involve dispersion compensators, multiple optical inline amplifiers, and hundreds of kilometers of optical fiber. This makes optical recirculating loops particularly attractive tools for accurately simulating and evaluating the performance of long-distance communications, given the greatly reduced cost.

This application note focuses on how the OSA20's **Recirculation Loop Transmission (RLT)** mode can provide fast, accurate spectral measurement and analysis of long-haul transmission systems.

Recirculating loops: definition and applications

In a recirculating loop, a trigger-controlled setup sends an optical signal-under-test on several roundtrips around an optical fiber loop, enabling the simulation of long-haul transmissions (> 100 km) without the need for ultra-long spans of fiber or multiple amplification systems.¹ The use of these loops is cost effective and greatly reduces the footprint of the overall experiment.

In effect, recirculating loops are primarily used in conjunction with a bit error rate tester (BERT) to investigate the bit error rate (BER) of a wavelength division multiplexing (WDM) signal, as well as the amplifier's performance in a long-haul configuration. The loops are also suitable for studying phenomena such as pulse propagation, jitter accumulation, modal dispersion and non-linear effects. An optical spectrum analyzer (OSA) can provide a detailed spectral picture of these effects and, more importantly, a direct measurement of optical signal-to-noise ratio (OSNR) that can be linked to the BER. OSNR measurements warn of potential BER deterioration (i.e., of the transmission quality).

1. Neal S. Bergano and C. R. Davidson. "Circulating Loop Transmission Experiments for the Study of Long-Haul Transmission Systems Using Erbium-Doped Fiber Amplifiers". Journal of Lightwave Technology 13, no. 5 (1995).

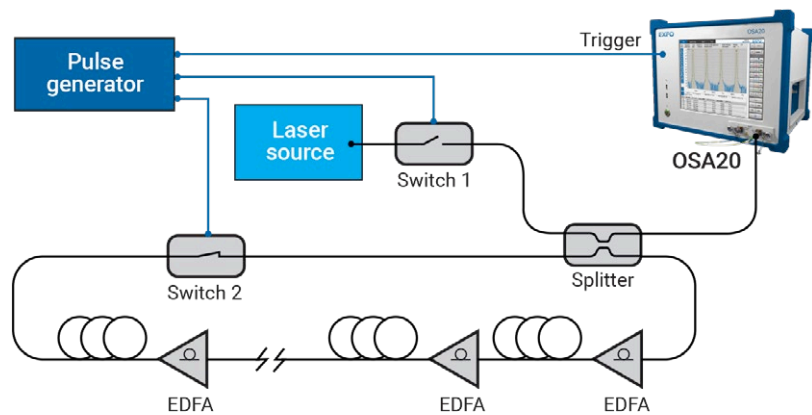


Figure 1. Block diagram of an optical-fiber recirculating loop

As seen in the figure above, a recirculating loop setup typically consists of the following:

- A pulse generator to control the various system triggers
- A laser source as a data transmitter, typically a WDM signal
- An analyzer, typically a BERT or an OSA
- A loop, composed of a set of fiber spools interleaved with inline signal regeneration modules (optical amplifiers and dispersion compensating equipment).

The distance travelled by the signal-under-test depends on the loop length and the number of cycles through the loop. The minimum length of the loop is defined by the bit rate of the signal being tested, since there needs to be enough data loaded in the loop for BER testing. The number of loop cycles (i.e., the total distance that the experiment can simulate) is usually limited by the growth of ASE noise from the optical amplifiers. Care must also be taken when the loop's optical gain equals or exceeds the loop's optical loss, since the whole system would effectively become a resonator laser.

The data is inserted and extracted from the recirculation loop by means of a 2x2 optical splitter and two optical switches, often acoustic optical modulators (AOM). Once the signal has traveled the correct distance, the pulse generator sends a trigger to the analyzer to acquire the data.

The fundamental parameters of recirculating loops include the number of loops transits (m); the loop length (L); the effective propagated distance ($L_{eff} = mL$); and the loop time ($\tau_{loop} = nL/c$)—defined as the roundtrip time delay for the optical signal to travel through the fiber path—where n is the refractive index of the fiber and c is the speed of light in vacuum. For reference, the travel time in a typical optical fiber is $4.89 \mu\text{s}/\text{km}$ at $\lambda=1.55 \mu\text{m}$. The total time of light traveling in the loop is $T_{tot} = m\tau_{loop}$.

In this application note, the analysis of recirculating loop transmissions is performed using an OSA20. The next section presents a general description of this setup

Experimental setup

The EXFO Optics OSA20 includes a RTL mode, an example of which is shown below. Here, the instrument identifies WDM channels and calculates their respective OSNR. The main feature of RTL mode is an acquisition system specifically designed for gated measurement.

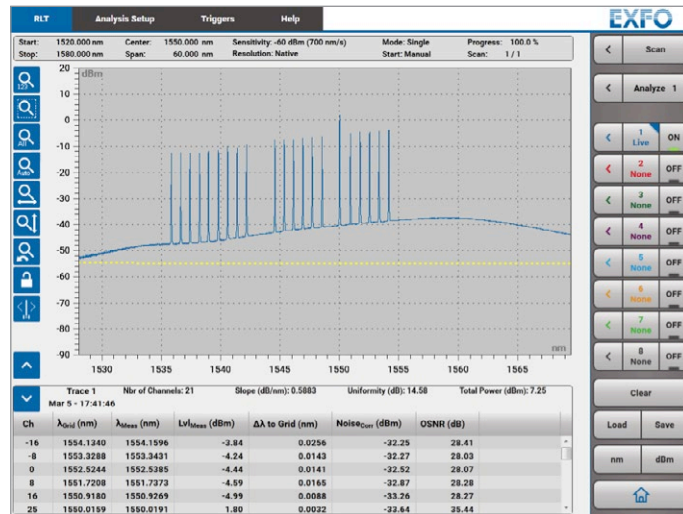


Figure 2. RTL mode on OSA20

The OSA20 uses a gated sweep technique to perform the measurement. As shown in Figure 1, the OSA needs to be synchronized with the other components of the loop to acquire data only through a gated input signal received through the TRIG IN port of the instrument. Over several OSA sweeps, the full spectrum is covered and displayed on screen. An algorithm is used to minimize the number of sweeps required to perform the measurement.

To further described the loop measurement process, three experimental states can be identified:

- A loading state (duration τ_{load}) will load the modulated optical signal from the laser source into the transmission system. As shown in the figure below, the pulse generator will set Switch 1 to enabled, while Switch 2 remains open. The loading time is usually of the order of τ_{loop} .

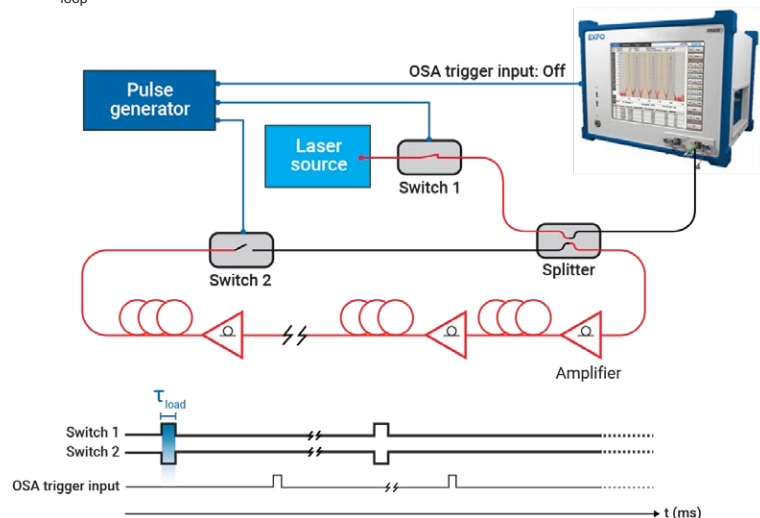


Figure 3. Schematic of the loading state in optical-fiber recirculating loops

- A looping state (duration T_{tot}), circulates the loaded signal over several loop cycles. As shown in the figure below, the pulse generator will set Switch 2 to enabled, whereas Switch 1 is open.

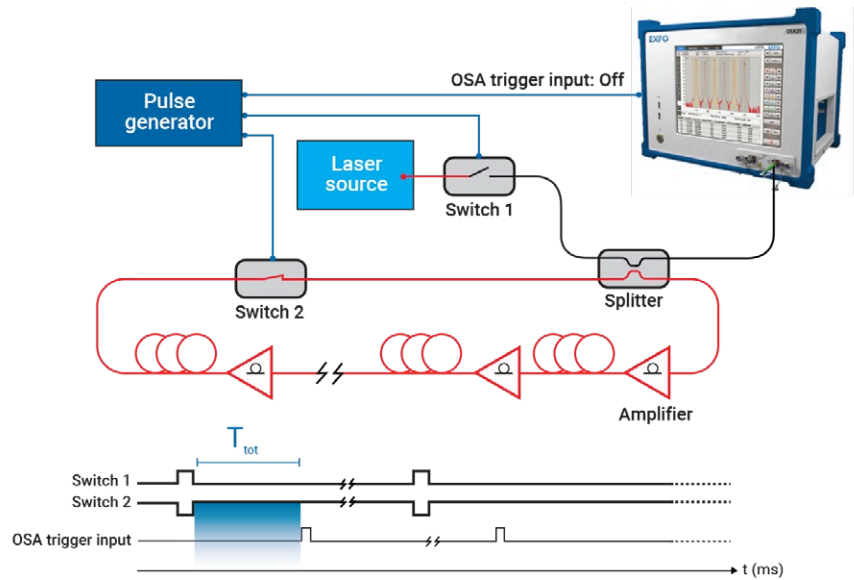


Figure 4. Schematic of the looping state in optical-fiber recirculating loops

- A data collection state (duration τ_{meas}) occurs once the required transmission distance is achieved. As shown in the figure below, the pulse generator sends a trigger to the OSA20 to collect data.

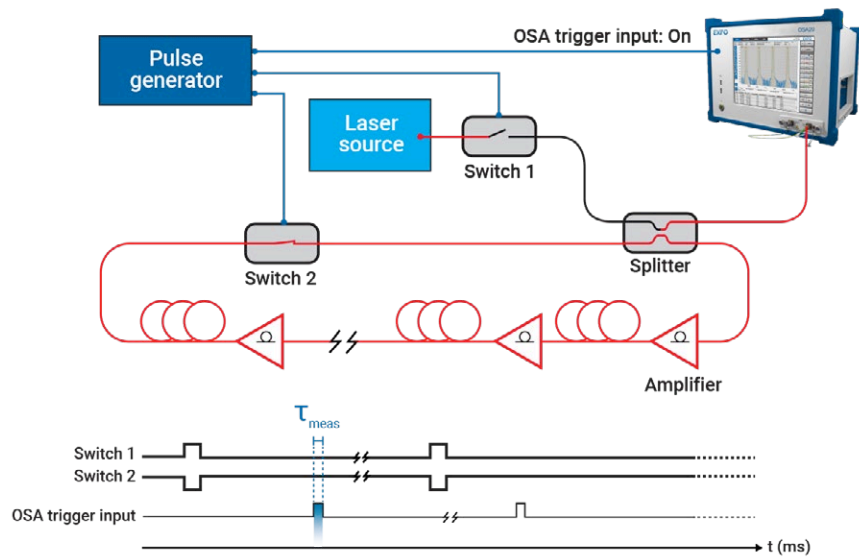


Figure 5. Schematic of the measurement state in optical-fiber recirculating loops



The OSA20 can test transmission lengths from 40 km to 20,000 km.

In practice, the acceptable gate period on the OSA20 trigger input is between 0.2 and 100 ms. As a result, the OSA20 can test transmission lengths from 40 km to 20,000 km. The shortest acceptable loop length is 20 km.

Gated sweep technique

Once the RLT configuration is set up as shown in the previous section, the user can launch the measurement by clicking the Scan option on the OSA20 interface. The OSA20 then automatically performs the acquisition of the spectrum by following the trigger input signal.

To illustrate the optimized acquisition algorithm of the OSA20, an example of a WDM optical spectrum has been recorded using RLT mode and is presented in the figure below.

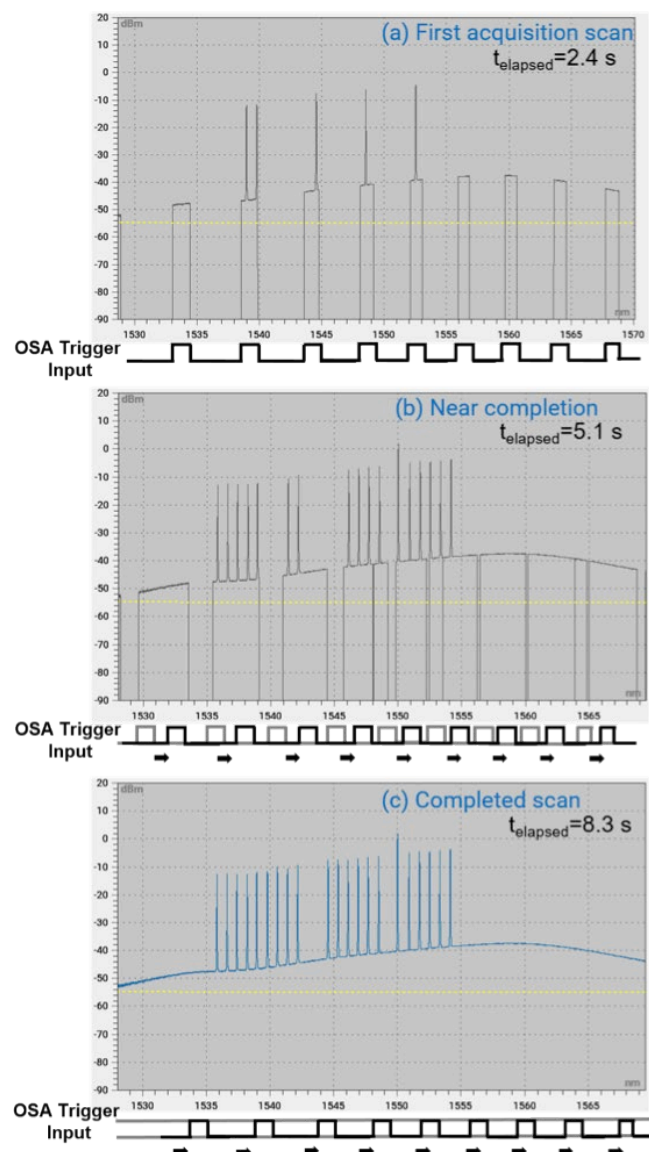


Figure 6. Different measurement stages of recirculating loop transmission using an OSA20



The OSA20's RTL mode is the fastest tool on the market for analyzing recirculating loop transmissions.

The simulation in Figure 6 is equivalent to a recirculating loop length of 500 km and a WDM signal making 3 round trips. The OSA20 performs several sweeps at a speed of 700 nm/s over 40 nm (1525–1565 nm). After the initial sweep, the OSA analyzes the acquired spectrum and runs the subsequent sweeps with an optimization algorithm in order to complete the scan in a minimal amount of time. The trace remains gray until the complete spectrum has been covered, indicating that scanning is still in progress. In the example above, the complete scan took slightly under 10 s.

Summary

The OSA20's RTL mode is the fastest tool on the market for analyzing recirculating loop transmissions. Thanks to built-in software that optimizes data acquisition on the gated input signal, RTL mode minimizes scanning time of the complete spectrum by automatically performing only a minimum number of acquisitions, instead of using a random trigger, which leads to very long scanning times.

In addition, RTL mode provides a broad range of analysis tools for assessing WDM signals per channel, such as the wavelength emission, linewidth and OSNR, which can be useful for determining BER.