

# Regeneration Laser Station

## Turn-key industry-grade solution for optical frequency transfer over optical fibers

Exail proposes all the hardware and software to enable long-haul optical frequency dissemination over optical fibers. Regeneration Laser Stations and bi-directional optical amplifiers are cascaded along an optical fiber to cover distances as long as thousands of kilometers while preserving the frequency stability provided by the best optical clocks in the world. Our technology was designed to transfer the metrological optical reference signal on a dark channel of the DWDM spectrum in parallel of Internet data traffic, but it can also work on a dark fiber. Exail offers the world's only industry-grade solution at this level of performance.



## The supervision tool

Exail's solution for optical frequency transfer can be deployed within a few days and has shown to provide uptimes as high as 99 % over a week. This is enabled by the remote and automated operation of the hardware supervised by a global supervision tool. The supervision tool is composed of:

- **A supervision software:** to monitor and control the REFIMEVE+ performances
- **A database:** store all the information useful to the network management
- **A human-machine interface:** for end users, academic teams and the telecom network manager

The supervision software is in charge of

- Monitoring the proper functioning and remotely control the equipment parameters in real-time.
- Detecting and managing bugs and alarms (cycle slips, polarization optimizations, ...)
- Uploading the information collected on the field and store in the database (alarm, events, ...)
- Administrating and troubleshooting system configurations
- Pre-processing data: outliers detection, Allan Deviation calculation, ...

The supervision tool of the REFIMEVE+ network currently monitors more than 150 pieces of equipment (EDFA, RLS, frequency counters). It enables the secured full remote access to all the equipment (RLS, ES, UM, EDFA) via the hosting telecom network infrastructure.

## Key features

- Fully secured communication for supervision protocol: SSH, SNMP
- Supervision tool deployable through usual internet connection
- User-friendly webapp interfaces
- Remote access and real-time data retrieval

## Specifications

### Typical performances

The Regeneration Laser Station (RLS) is a stand-alone system that actively compensates the phase noise introduced by the fiber links and provides an ultra-stable output laser in the ITU channel 44 (1542,14 nm, other wavelengths available on demand). It enables also to cascade fiber links in order to set-up long-distance frequency dissemination. It has been designed to be installed in a Telecom network nodes in respect to NF/EN 60950-1 and NF/EN 60825-1 norms. It can work both on a dark channel and on a dark fiber.

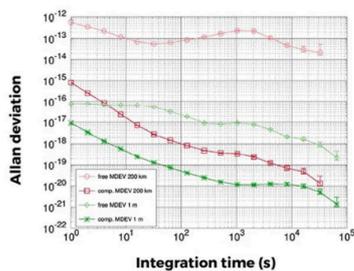


Fig. 1

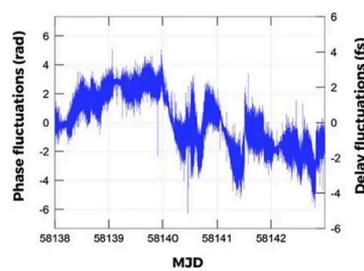


Fig. 2

- Fig. 1: Fractional frequency instability calculated from data recorded with  $\pi$ -counter and 1 s gate time versus averaging time. Dark red squares, modified Allan deviation for a compensated 200 km laboratory link; light red circles, modified Allan deviation for the free-running 200 km laboratory link; dark green stars, modified Allan deviation for a short link to estimate the noise floor of the RLS; light green diamonds, modified Allan deviation for the free-running sho
- Fig 2: End-to-end phase fluctuations after propagation over a 680 km fiber link. Data from F. Guillou-Camago et al., « First industrial-grade coherent fiber link for optical frequency standard dissemination », Applied Optics, Vol. 57, No. 25 (2018)

Central wavelength	1542 nm (ITU Channel 44) (other wavelengths in option)
<b>RLS NOISE FLOOR</b>	
Relative short term frequency stability	$< 3 \times 10^{-17}$ @1 s
Relative long term frequency stability (noise floor)	$< 2 \times 10^{-20}$ @103 s
Typical accuracy of fiber link	$< 1e^{-19}$ , depending on link characteristics
Temperature sensitivity of the interferometer	$< 1$ fs / °C
Typical maximum range between 2 RLS on standard telecom fiber links	500 km
<b>PHYSICS PACKAGE</b>	
<b>MASS AND DIMENSIONS</b>	
Number of boxes	2
Mass	16.7 kg for the RLS 4 kg for power supply
Dimensions	5U 19" rack for the RLS (485 mm x 222 mm x 540 mm) 2U 19" rack for the power supply unit (485 mm x 90 mm x 250 mm)
<b>ELECTRICAL RATINGS</b>	
Supply voltage	100–240 Vac
Frequency	50–60 Hz
Power	$< 110$ W
Current	2A
<b>OPTICAL RATINGS</b>	
Class	3R
Output power	$< 3$ dBm
Input power	$-60$ dBm $< P < 3$ dBm
Wavelength	1542 nm + custom
Regime	CW
<b>SYSTEM INTERFACE &amp; CONTROL</b>	
Optical connectors	FC/APC
Communication connectors	RJ45
Communication protocol	SSH, SNMP
Degree of Ingress Protection	IP 30
<b>ENVIRONMENTAL &amp; PHYSICAL SPECIFICATIONS</b>	
Operating temperature	[15 ; 35] °C
Storage temperature	[5 ; 30] °C
Humidity	Maximum relative humidity 80 % for temperatures up to 31 °C decreasing linearly to 50 % relative humidity at 40 °C