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Introducing DSP-based Coherent Receivers for Wide-area Reference Frequency Distribution in Metrology Applications

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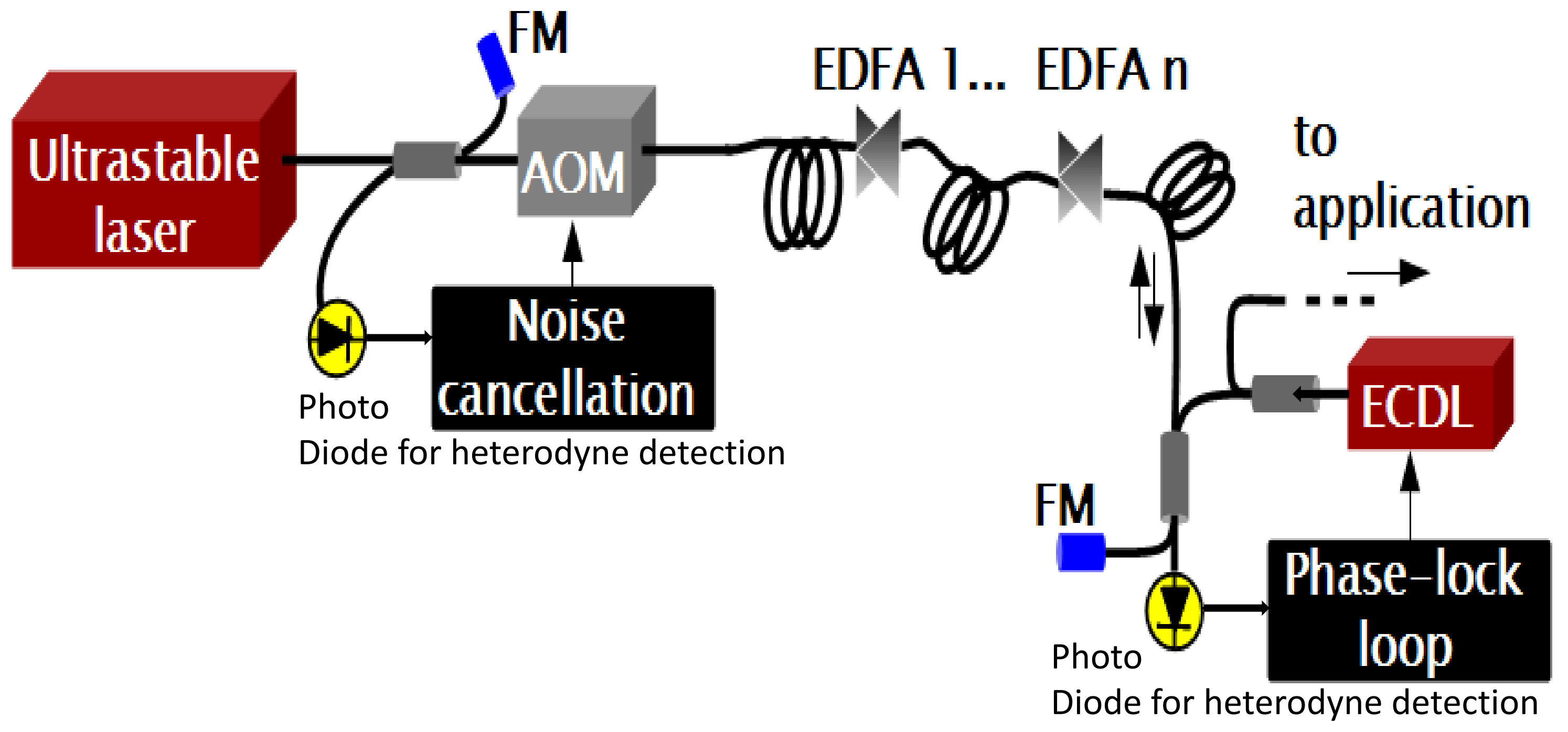
Abstract: *We present the advantages of dual-polarization coherent receivers and digital signal processing in metrology applications for high accuracy frequency distribution over long-distance fiber links. We experimentally demonstrate optical frequency distribution at 10^{-16} accuracy on a 300 km installed fiber link.*

The target: geographically distributing ultra-stable optical frequency references, generated today with relative accuracy up to 10^{-18}

Applications: advanced research in astronomy, geodesy, spectroscopy and fundamental physics



FM: Faraday mirrors, **AOM**: acousto-optic modulator;
EDFA: Bidirectional Erbium-doped fiber amplifier;
ECDL: external-cavity diode laser.

The Doppler noise cancellation scheme

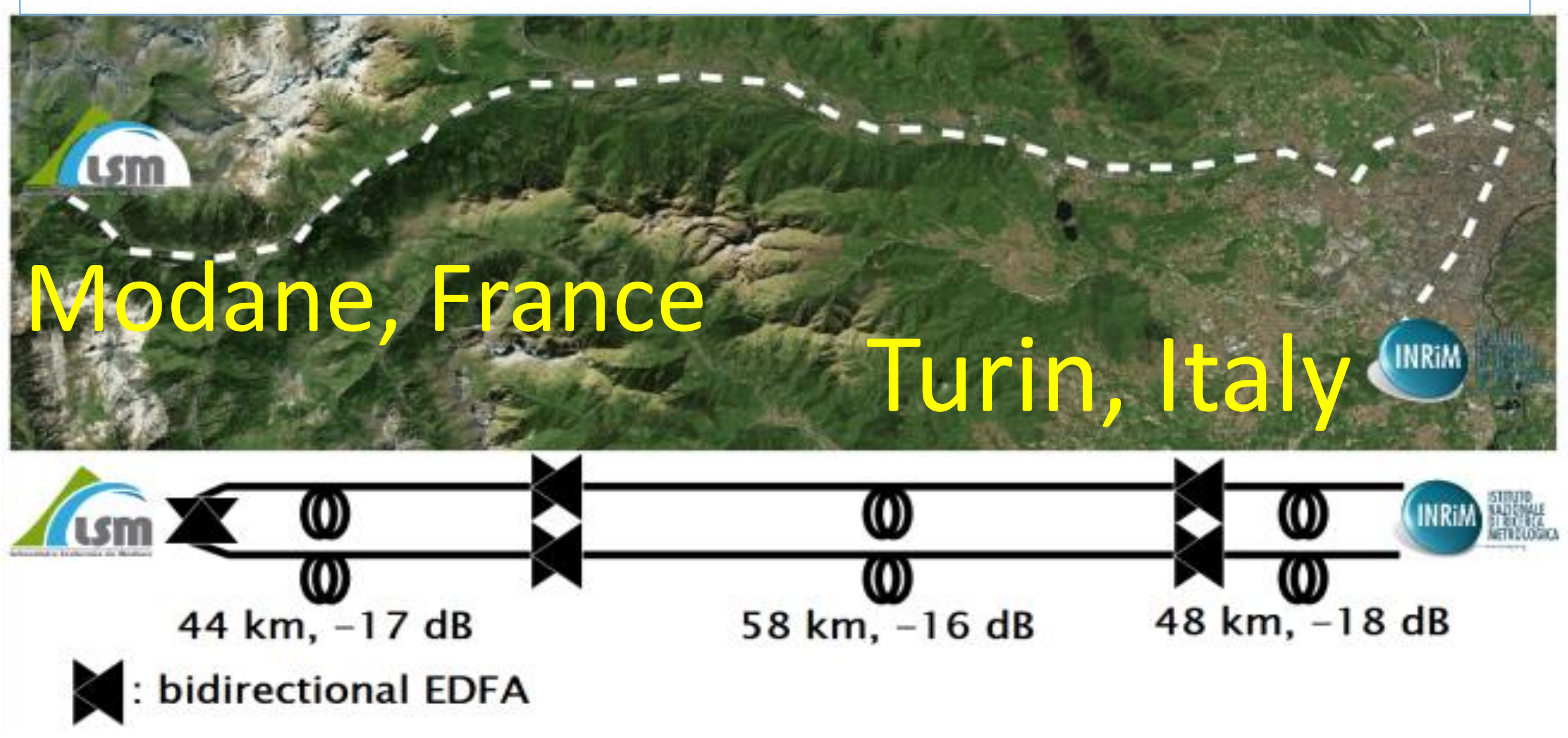
An unmodulated, optical carrier with linewidth < 1 Hz is transferred between remote locations through an optical fiber. The fiber length variations affect the spectral purity of the optical carrier and must therefore be compensated. This is done through the so-called Doppler noise cancellation: a part of the light is reflected back by a Faraday Mirror (FM) and heterodyned with the original light; the accumulated phase-variations are then applied to the carrier with opposite sign using an acousto-optic modulator (AOM).
The same fiber must be used in both directions; hence, special Bidirectional Erbium-doped fiber amplifiers have been developed. At the remote end, light is in most cases regenerated by phase-locking an external-cavity diode laser to the incoming light

The problem: regenerating the signal power at receiving end by phase-locking a laser to the incoming radiation

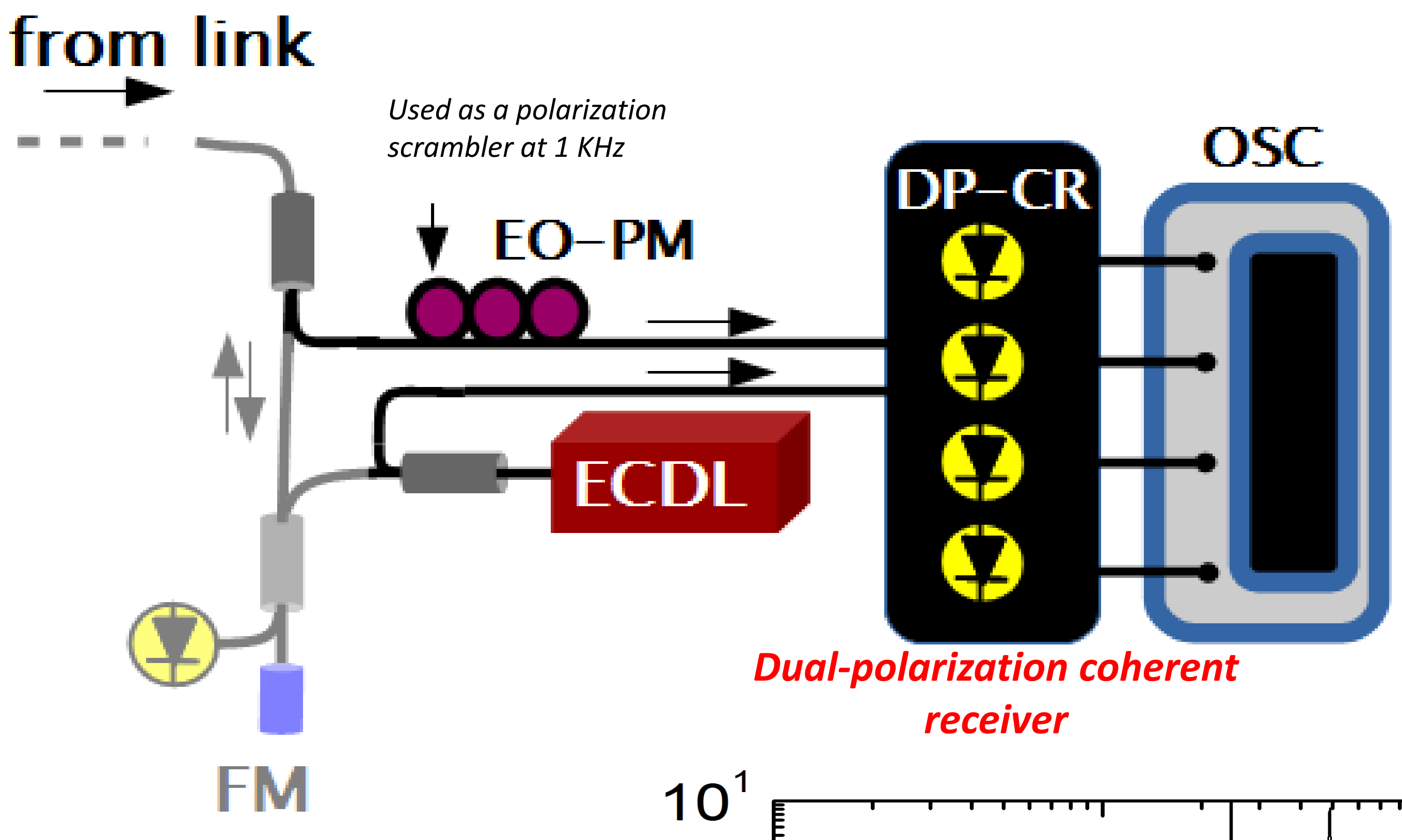
The currently deployed solutions: single photodiode direct detection requiring active polarization tracker

The proposed new setup: use of dual-polarization coherent receivers coupled with DSP (same es those used in long-haul telecom systems)

Map of the deployed 300 km fiber link

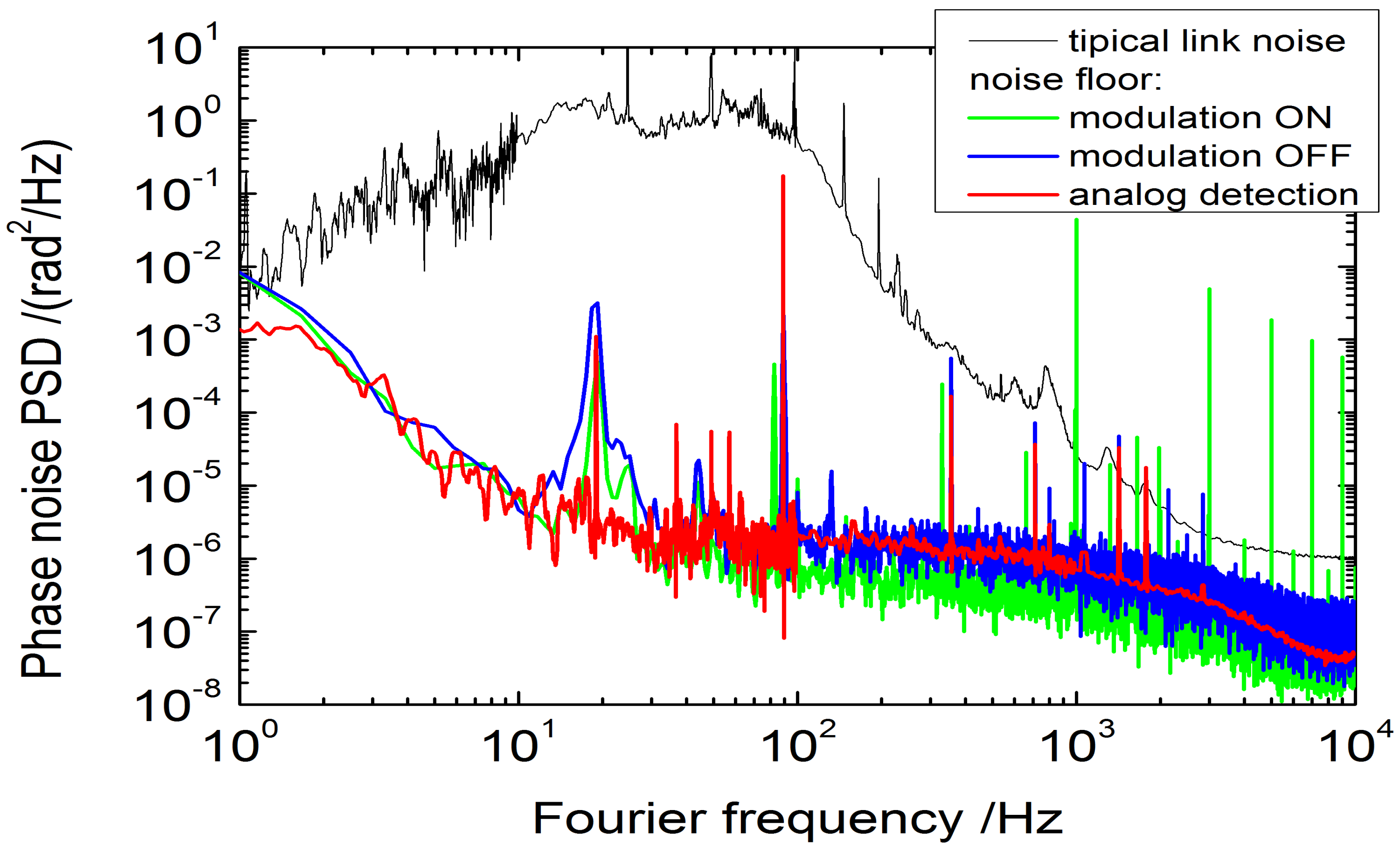


Map of the deployed system
Wavelength #44 of the ITU grid is used for our experiment, while other ITU channels carry normal telecom traffic



The setup implemented for the metrological experiment.

EO-PM: electro-optic polarization modulator;
OSC: real-time oscilloscope;
ECDL: external-cavity diode laser.



Experimental result: The noise floor of the DSP-based optical phase detection system without (blue line) and with (green line) polarization modulation.

The red line shows the noise floor obtained by ”traditional” analog detection (without polarization modulation at 1kHz): same performance as for the proposed system, thus achieving polarization recovery

Black line represents the typical noise of our 300-km link when not phase-compensated.

Planned future activities for Fall 2017:

- Real-time implementation on an FPGA platform
- More advanced algorithms for polarization tracking

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