Optical Frequency Transfer – Workshop BFTS

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March 20th, 2025

Optical Frequency Transfer by Exail

A. Active noise compensation

B. Regeneration Laser Station - RLS

C. User Module

D. Multi Branch Laser Station – MLS

E. Conclusion

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A) ACTIVE NOISE COMPENSATION

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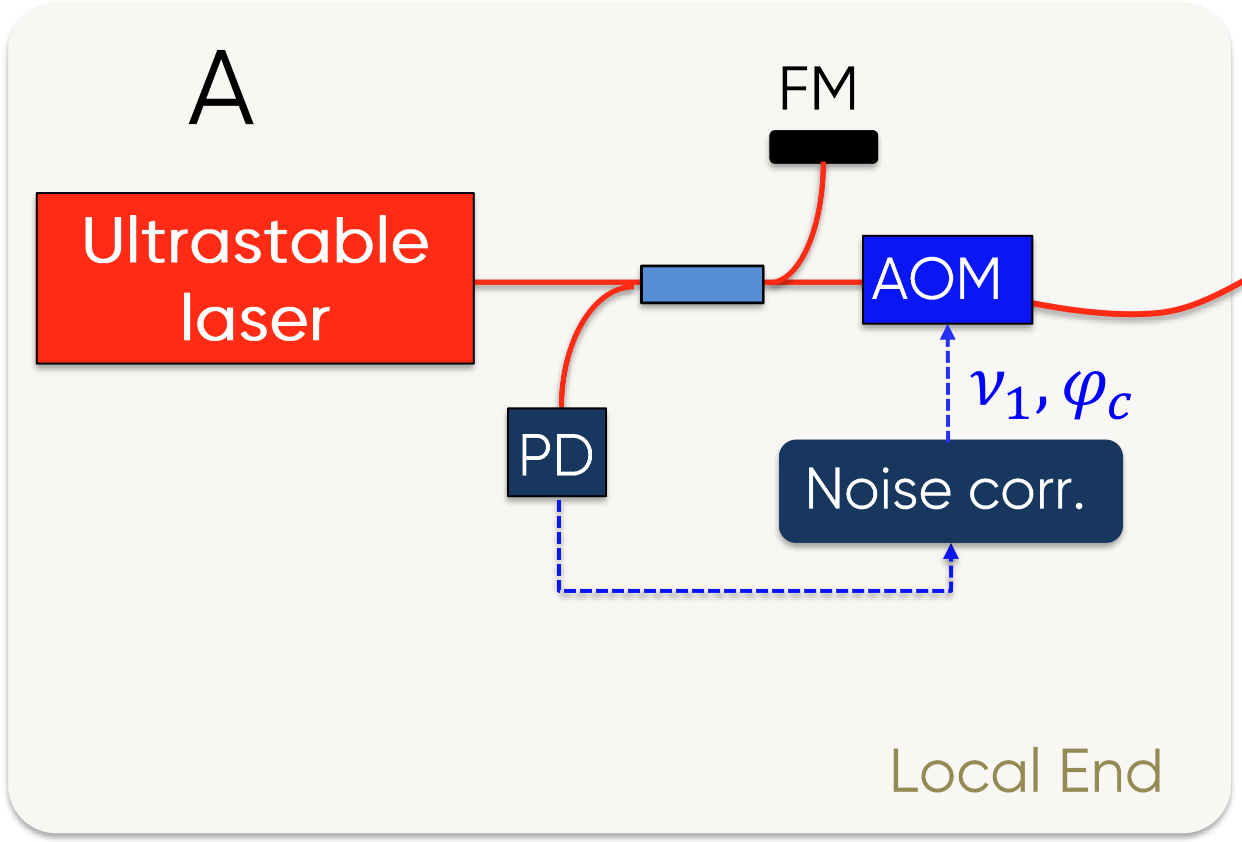
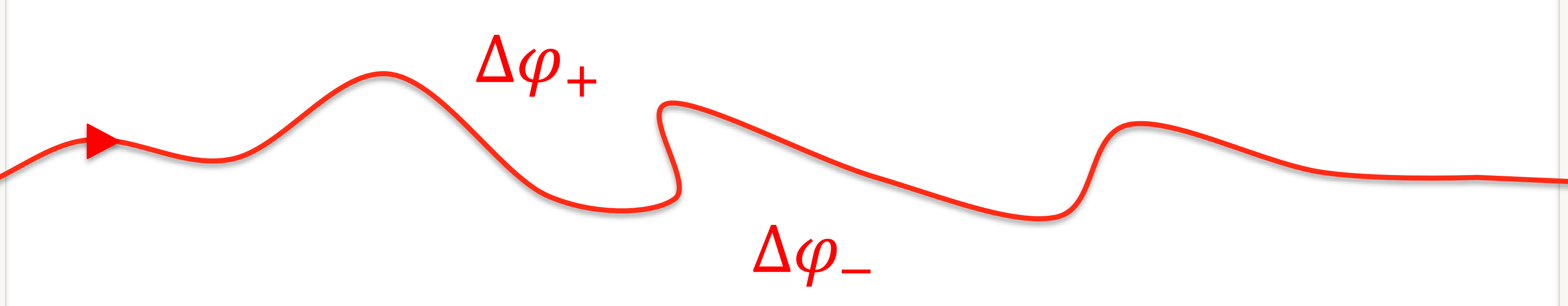
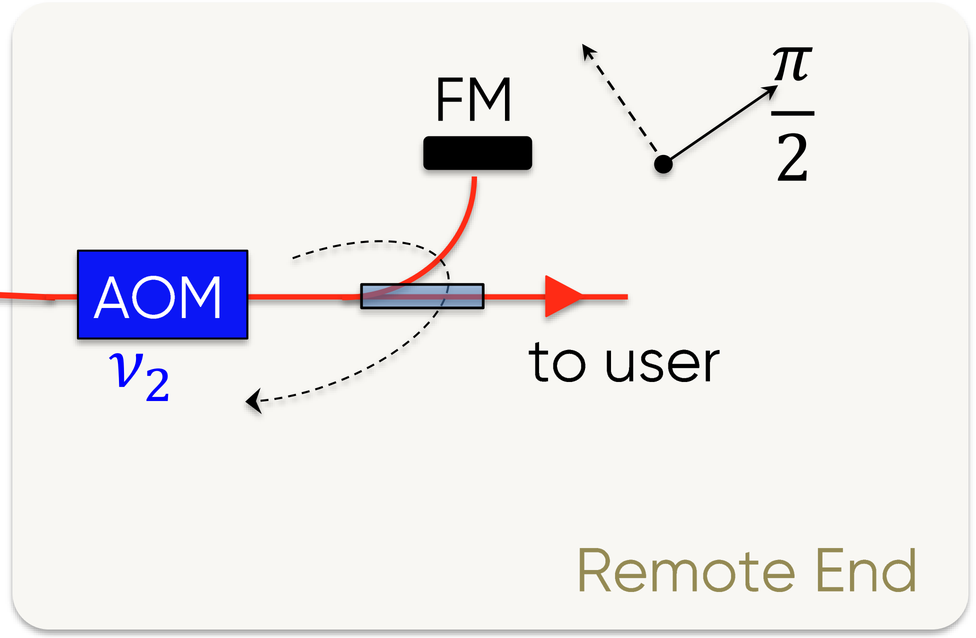
Active noise compensation in an optical fiber link

Strongly unbalanced Michelson interferometer







Accumulated phase noise due to vibrations and temperature changes is far too big

Must be corrected for metrological applications
=> detect round-trip noise and correct

- Assumption of reciprocal phase noise: $\Delta\varphi_+ = \Delta\varphi_- = \frac{\Delta\varphi_{RT}}{2}$
- Noise correction φ_c applied at the link input: PLL imposes $\boldsymbol{2(\varphi_c + \Delta\varphi_{RT}/2) = 0}$
- Remote end AOM at $\boldsymbol{\nu_2}$ distinguishes from in-fibre scattering
- Heterodyne detection: beat at $\boldsymbol{2(\nu_1 + \nu_2)}$
- Faraday mirror switches polarisation, to align polarizations at detection

N. R. Newbury et al., Optics Letters, vol. 32, n° 21, p. 3056, 2007

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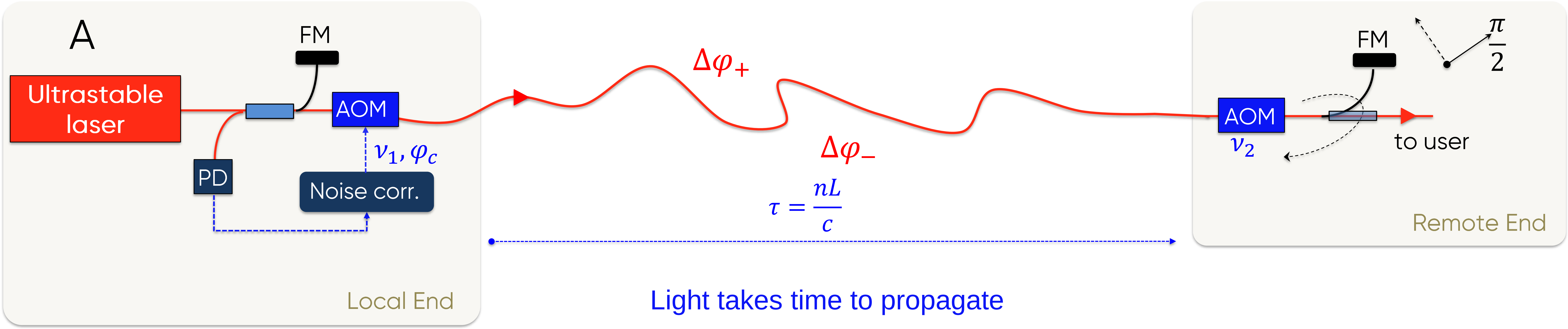
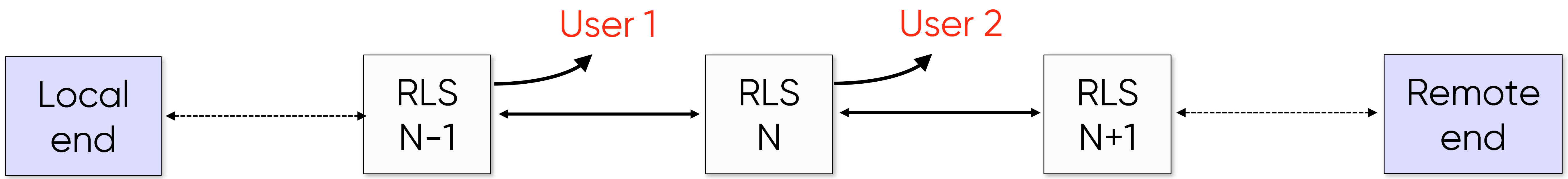
Active noise compensation in an optical fiber link

Phase noise limitation



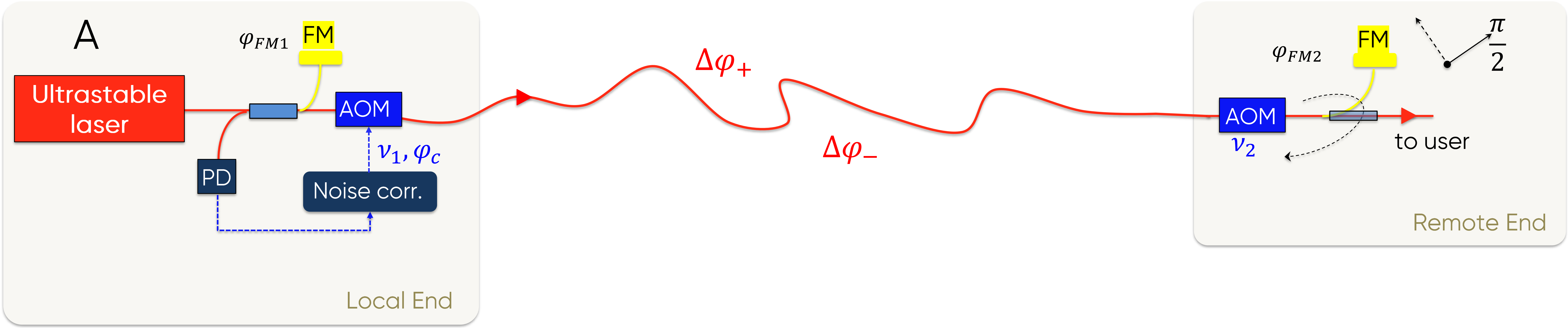
- Limited noise cancellation bandwidth $f_c = \frac{1}{4\tau}$: **500 Hz for 100 km**

- **Solution for 100's of km:** ➡ **Cascaded link** : partition link into several spans with **Repeater Laser Stations (RLS)**



Active noise compensation in an optical fiber link

Interferometer noise



=> Ultimately limit long-term performances

- Keep reference paths short
- Environmental isolation (temperature/vibrations)

B) REGENERATION LASER STATION

Exail Repeater Laser Station (RLS)

Works in the C (CH #44) and L band (CH #07)
(1542.14 nm and 1572.063 nm)

- Automatic polarization optimization
- Low-noise heterodyne detection
  SNR > 90 dBc/Hz
- Needs very low input optical power level
  (few nW)
- Remote control
- Data Storage within RLS

- Two units: Power supply and RLS unit
- Two type: RLS 74 / RLS 76 (Laser lock beat)

Exail Repeater Laser Station (RLS)

Technical Specifications

Optical Characteristics

Operating wavelength	Channel 44 of the ITU grid: 1542.14 nm [1]
Output powers	< 2 mW
Laser class	3R
Laser linewidth	< 5 kHz
Regime	CW
Input power range	between 1 nW and 100 µW
Frequency tunability	50 pm

(1) Other wavelengths available on request (e.g. in L-band)

Interfaces

Ethernet	RJ45
Radio Frequency	SMA
Optical	FC/APC
Communication protocols	IP, SSH, SNMP

Physical characteristics

Dimensions	19'' rack, 545 mm depth max , 7U (RLS: 5U, PS: 2U)
Weight	20.7 Kg (RLS: 16.7 kg, PS: 4 kg)
Material	Aluminium
Supply voltage	100-240 VAC, 50-60 Hz
Electrical consumption	< 110 W

Performances

Relative short-term frequency stability	$< 3 \times 10^{-17}$ @1 s
Relative long-term frequency stability	$< 2 \times 10^{-20}$ @10^3 s
Temperature sensitivity of the interferometer	< 1 fs/K

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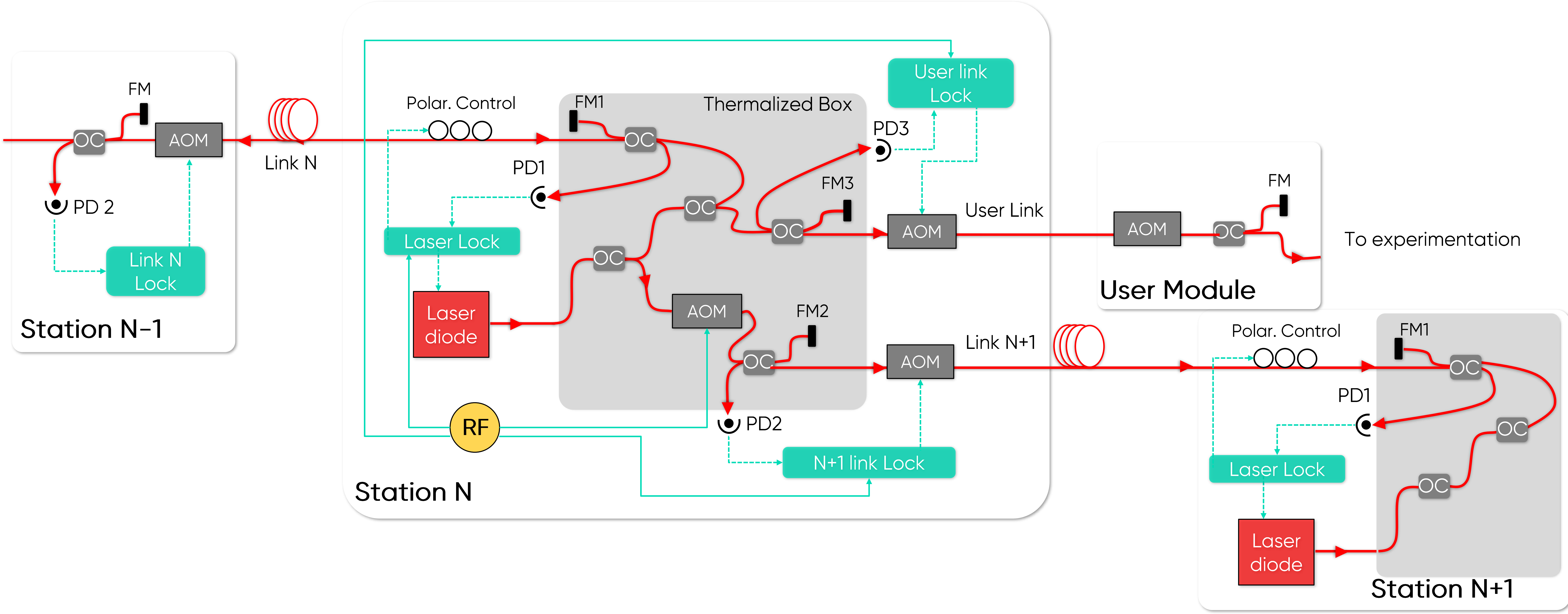
Exail Repeater Laser Station (RLS)



C) USER MODULE

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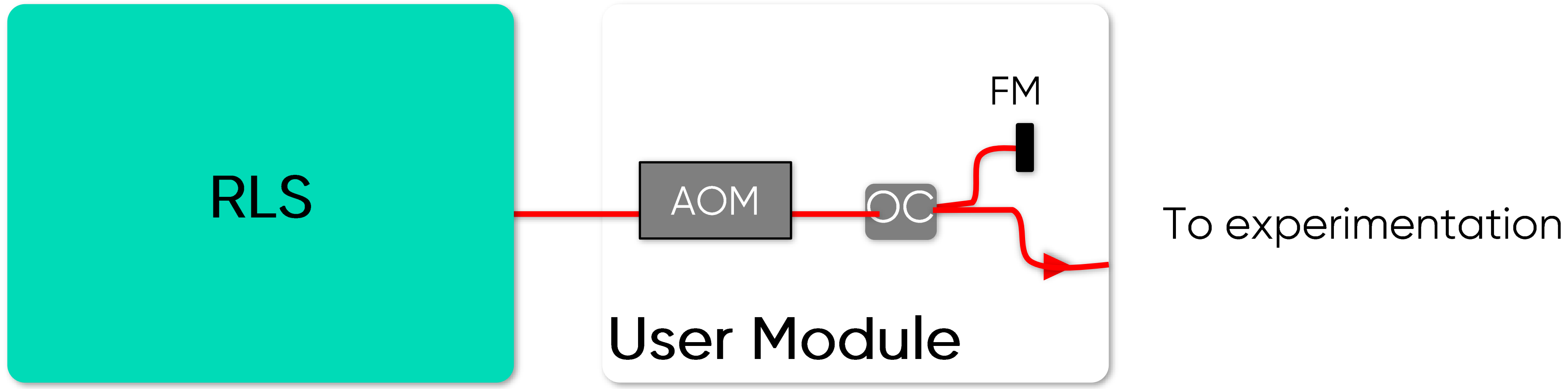
Exail User Module



Works in the C (CH #44) and L band (CH #07) (1542.14 nm and 1572.063 nm)

- To guarantee the link quality right up to your experiment
- Ease of use and implementation

User Module

TECHNICAL SPECIFICATIONS

Optical Characteristics

Operating wavelength	Channel 44 of the ITU grid: 1542.14 nm or Channel 07 of the ITU grid: 1572.03 nm (1)
Insertion Loss	< 13 dB
Regime	CW

(1) Other wavelengths available on request (e.g. in L-band)

Physical Characteristics

Dimensions	19" rack, 242 mm depth max , 1U
Weight	1,7 Kg
Material	Aluminium
Supply voltage	100 - 240 VAC, 50-60 Hz
Electrical consumption	< 2W
Operating temperature	15 °C to 35 °C
Storage temperature	5 °C to 30 °C
Humidity	Maximum relative humidity 80 % for temperatures up to 31 °C decreasing linearly to 50 % at 40 °C.

Interfaces

Optical	FC/APC
Electrical	DC plug hole 2.1mm

D) MULTI BRANCH LASER STATION

Exail Repeater Laser Station (RLS)

Works in the C (CH #44) and L band (CH #07)
(1542.14 nm and 1572.063 nm)

- Automatic polarization optimization
- Low-noise heterodyne detection
  SNR > 90 dBc/Hz
- Needs very low input optical power level
  (few nW)
- Remote control
- Data Storage within RLS

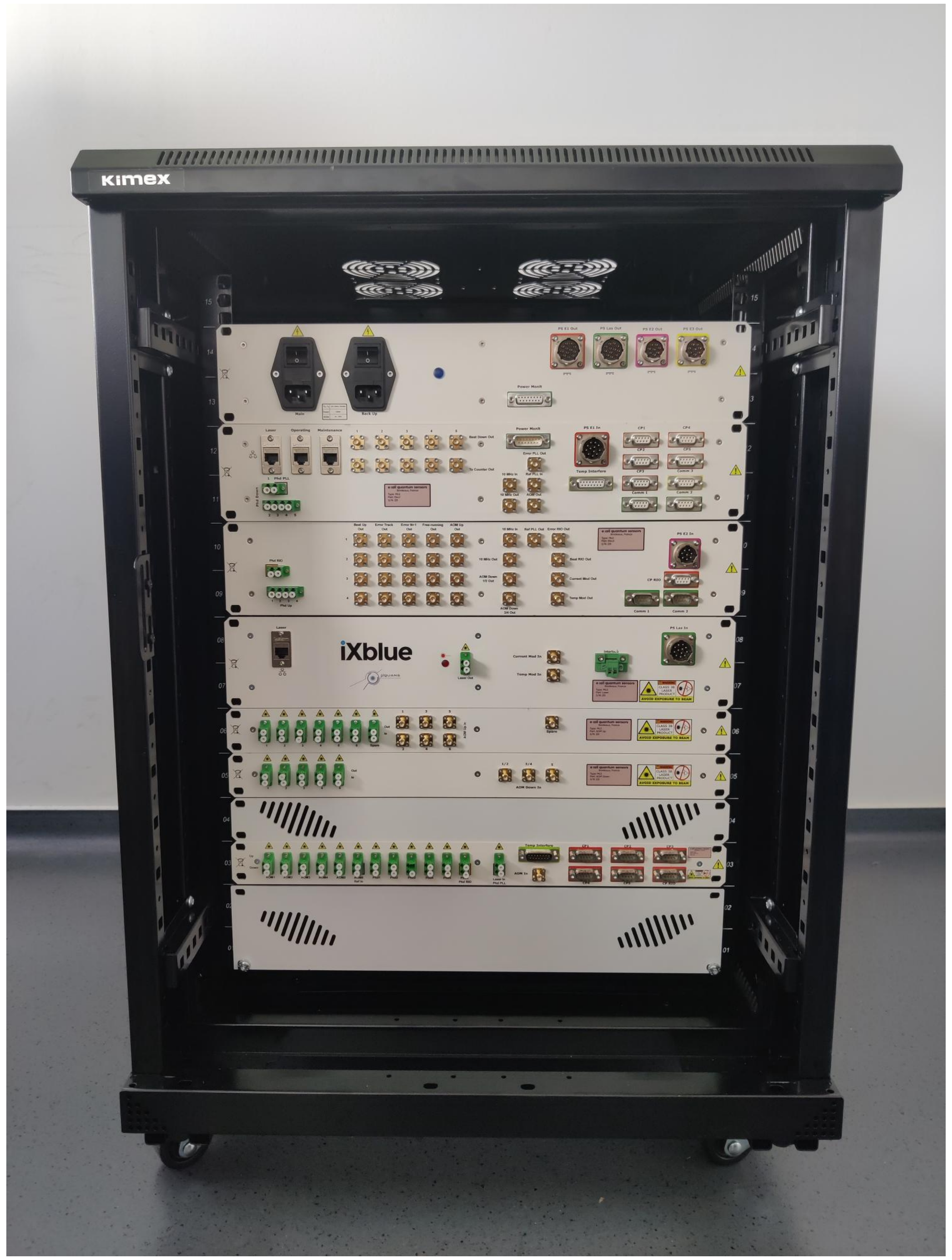
- Two units: Power supply and RLS unit
- Two type: RLS 74 / RLS 76 (Laser lock beat)

Exail Multi-Branch Laser Station (MLS)

Same as RLS ...

Works in the C (CH #44) and L band (CH #07) (1542.14 nm and 1572.063 nm)

- Automatic polarization optimization
- Low-noise heterodyne detection SNR > 90 dBc/Hz
- Needs very low input optical power level (few nW)
- Remote control
- Data Storage within MLS



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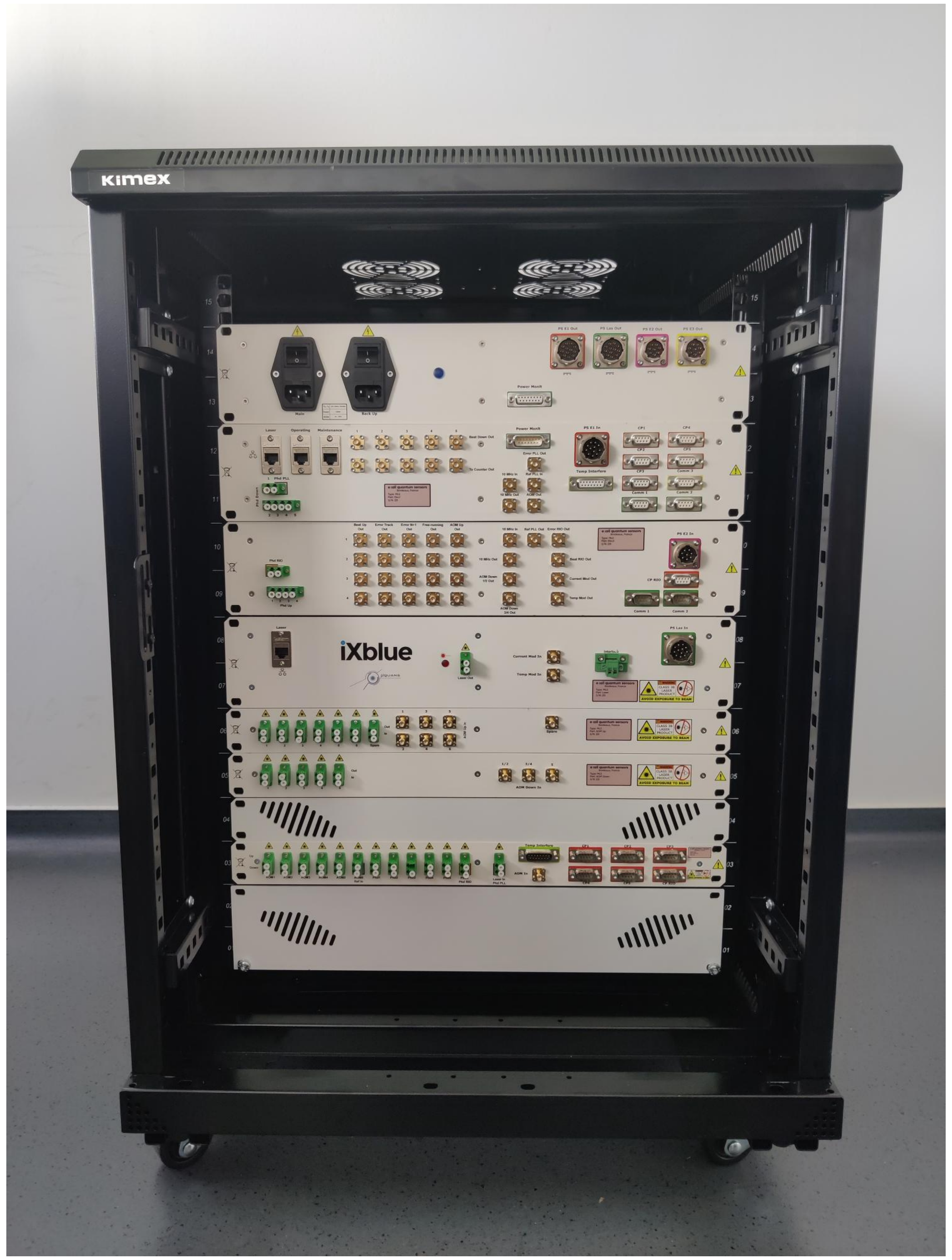
Exail Multi-Branch Laser Station (MLS)

Same as RLS …

Works in the C (CH #44) and L band (CH #07) (1542.14 nm and 1572.063 nm)

- Automatic polarization optimization
- Low-noise heterodyne detection SNR > 90 dBc/Hz
- Needs very low input optical power level (few nW)
- Remote control
- Data Storage within MLS



… With more

- Noise correction electronics up to 6 links
- Link stability assessment
- 13U height (2 RLS) max
  19'' rack
  545 mm depth
- Free space interferometer : sensitivity < 100 as/K
- Relative short-term frequency stability $< 3 \times 10^{-17}$ @1 s [(1)]
- Relative long-term frequency stability $< 2 \times 10^{-21}$ @10^3 s [(1)]

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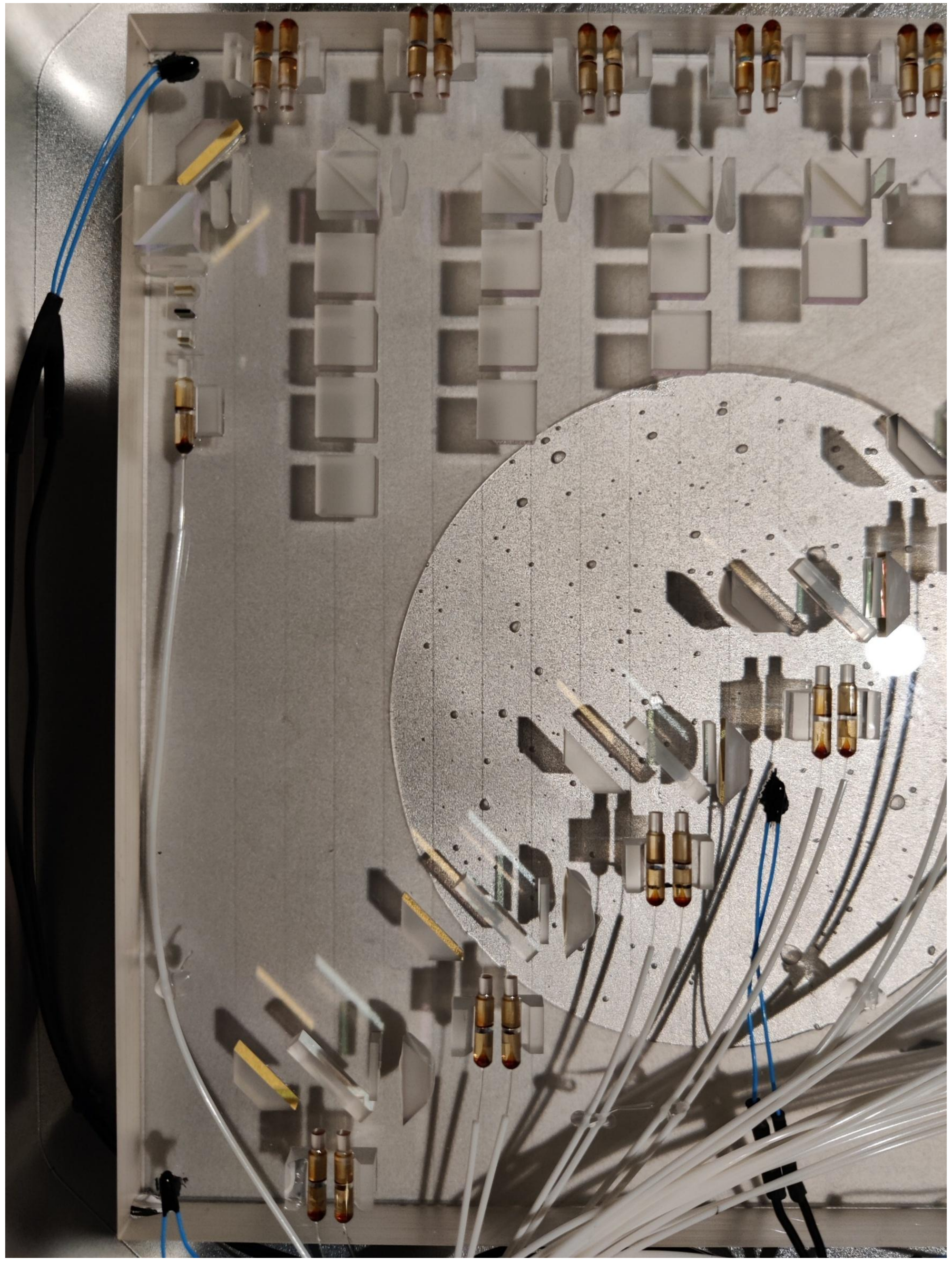
Exail Multi-Branch Laser Station (MLS)

Free space micro-optic

- One input and 24 outputs
  - 12 outputs and their corresponding ‘beat’ outputs
  - Same optical path for all outputs and ‘beat’ outputs
  - Insertion losses control to have the same amount on same output

- 5 CTN to monitor the temperature for post processing

- Expertise of another Exail Division – Integrated Solutions



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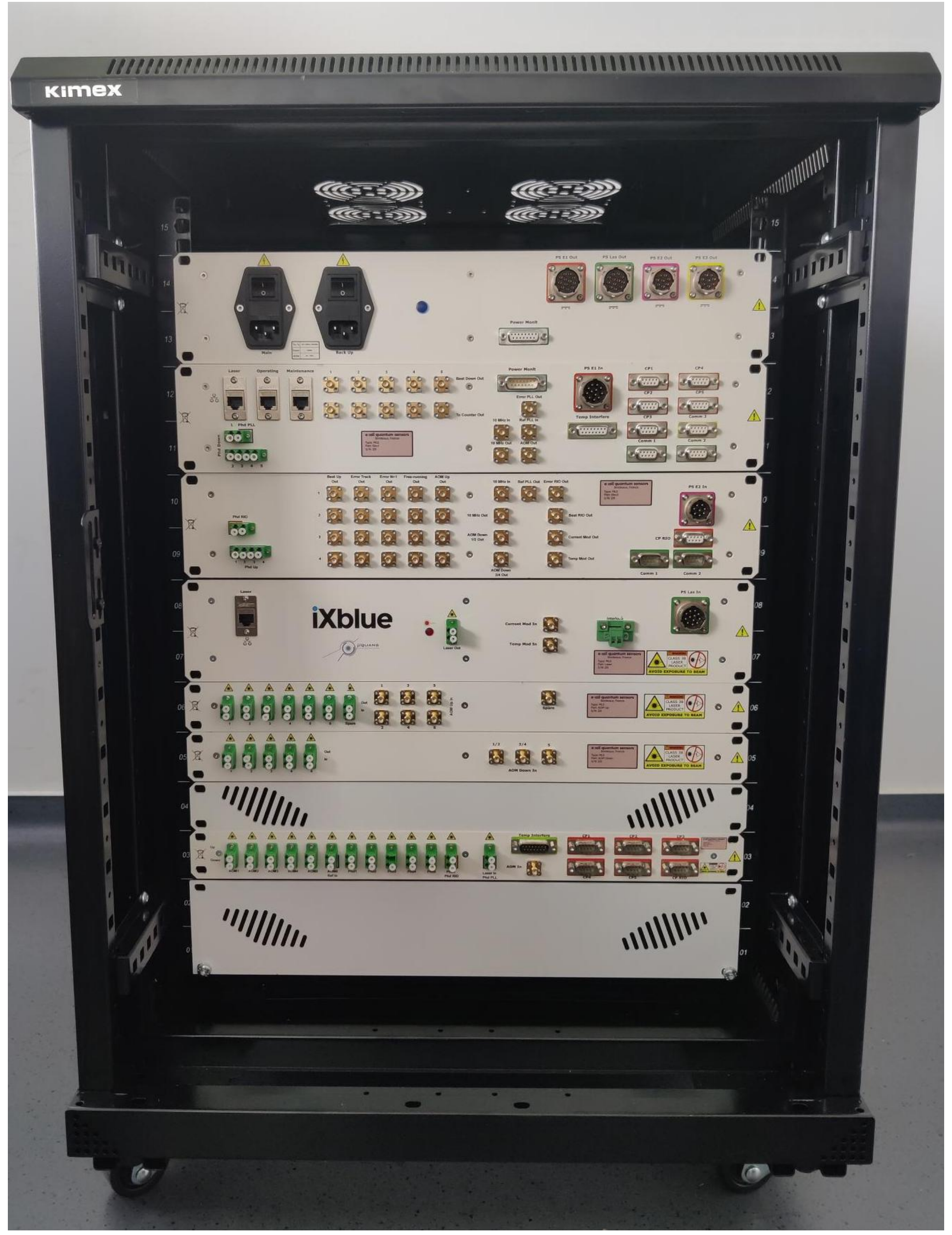
E) CONCLUSION

International product



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