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Power delivery over Optical Fibre – theory and commercial implementations

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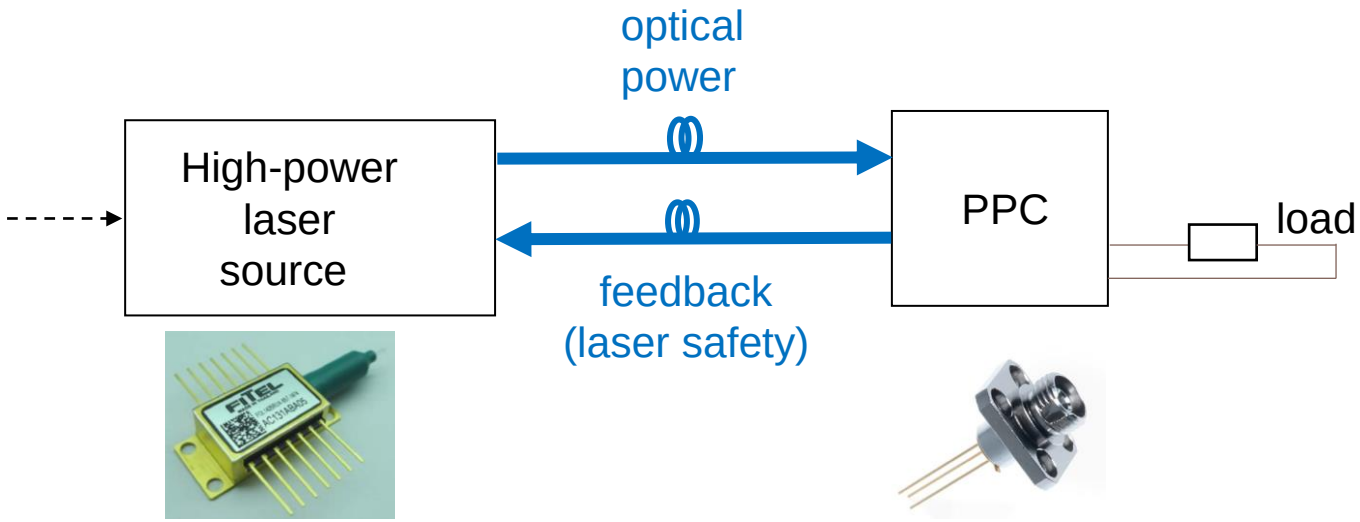
Why would you need to deliver power over fibre?

- Local electrical power is unavailable
- Lightning protection / immunity is required
- A risk to ignition of explosive atmospheres
- Environment is EMI protected and requires dielectric cabling
- Complex planning consents for conductive cables
- Full optical small-cell inhouse coverage for 5G mobile communications and WLAN – GNSS timing for critical infrastructure
- Sensor networks electromagnetically (strong fields) or hazardous environments, mining etc.
- Wind turbine rotor blade monitoring

Delivering Power over Fiber (PoF)



- power supply
- laser temperature controller
- laser safety circuit (loop detector)

- laser safety loop
- photonic power converter(s) (PPC)
- DC/DC converter

PoF advantages / disadvantages

Advantages

- No power supply required
- EMI immunity
- No lightning protection required
- Reduction of deployment cost
- Fiber is flexible and lightweight

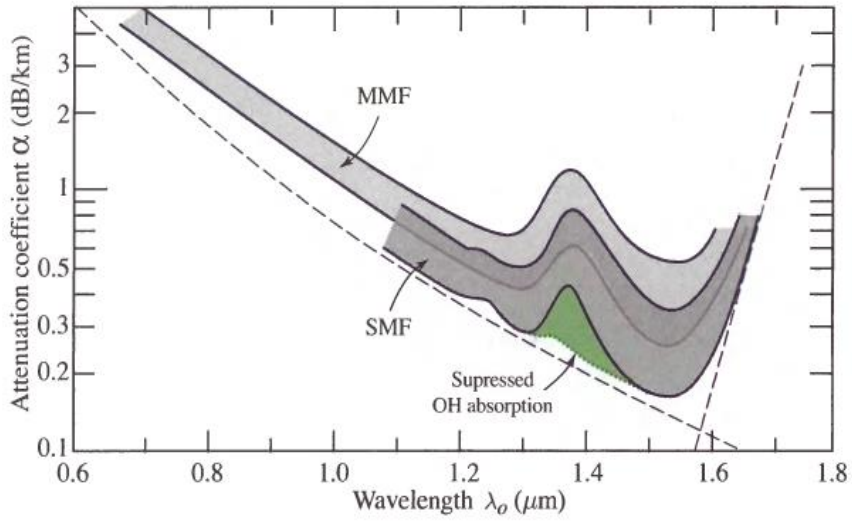
Disdvantages

- Cost
- Transmission length
- Efficiency
- Power limits
- Safety (Laser)

Fiber limitations: passive elements - glass

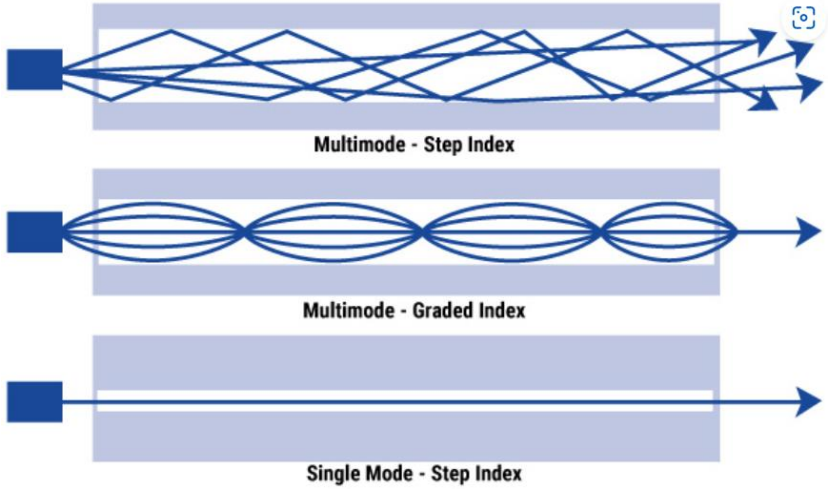
Fiber loss

SSMF:	0.2 .. 0.3dB/km
GI MMF:	2.5 .. 3.5dB/km
SI MMF:	10dB/km



Optical power transmission capacity

SSMF	1.5W
GI MMF	4W
SI MMF	100W



Fiber limitations: passive elements - connectors

Optical Connectors loss & Power

Connector loss:	0.1 – 1.5 dB	depending on fiber type / ferrule
Ceramic ferrule-based	1 - 2W	
Lens-based high-power connectors	3 - 16W	

Critical: Clean fiber end-faces!

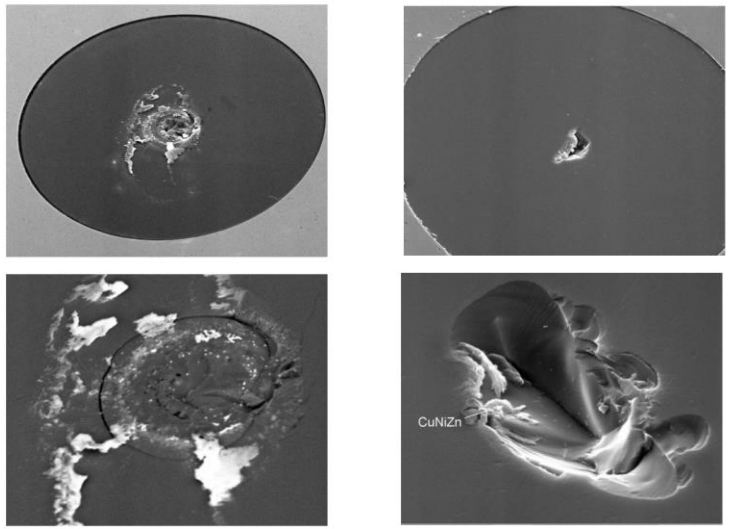


Figure 3 Catastrophically failed connectors

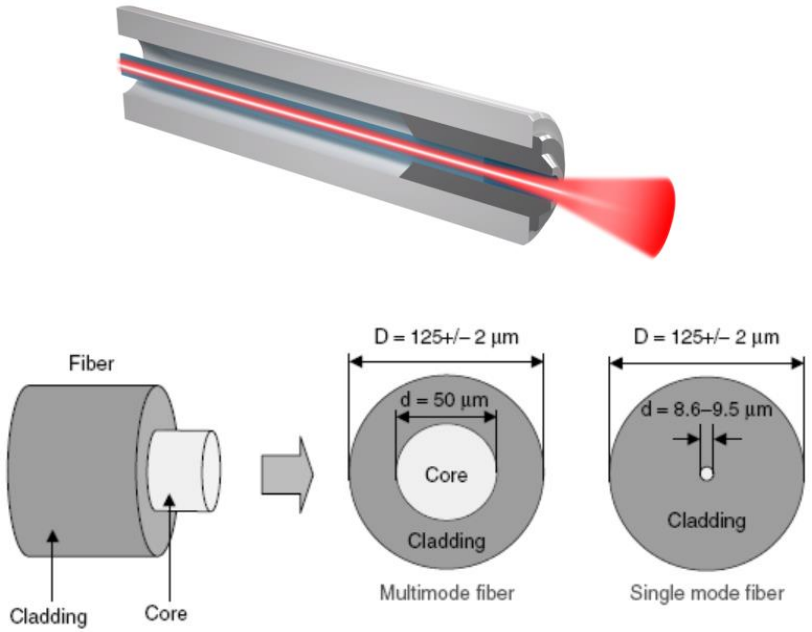
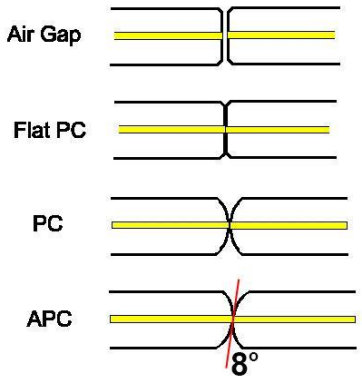
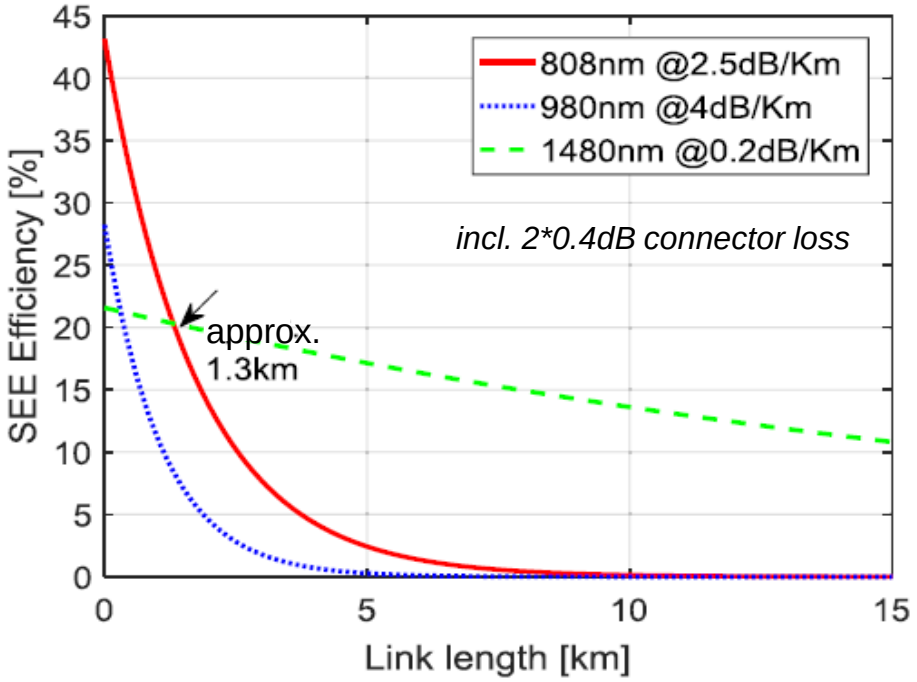


Figure 2.9. Geometric differences between multimode and single-mode fiber.



Fiber limitations: distance



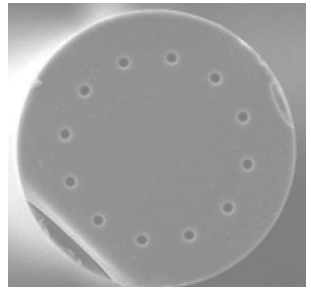
(Lopez-Cardona et al., JLT 36, no. 3, 2018)

Distance	10 – 100 m	100-1000 m	1 – 2 km	5-10 km
Fiber type	SI MMF	GI MMF	GI MMF SMF	SMF
Power	100W	4 W	1.5 W - 4 W	1.5 W
Cost	low	moderate	high	very high

>1.3 km more efficient with SMF fiber

To increase power output multiple fibers are used:

- Multi-fiber connector
- Multi-core fiber



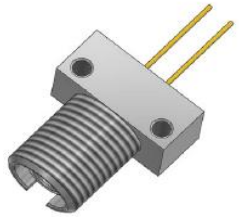
Laser diode and Photonic Power Converter (PPC) device limitations

Laser diode

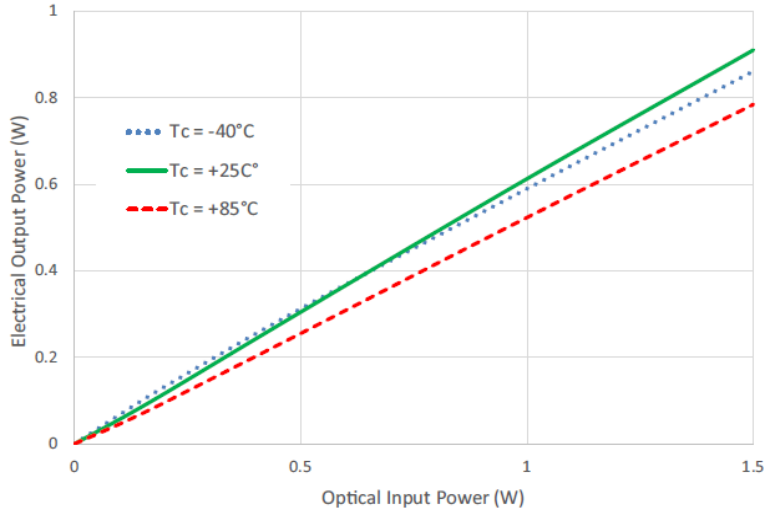
Laser type	MM laser diodes (8xxnm)	SM laser diodes (14xxnm)
Cost	low (~20 CHF)	high (~200 CHF)
Distance	200 m -1.3 km	> 1.3 km
Power output	< 100 W	< 600 mW

PPC

PPC type	808nm (GaAS)	980 (InGaAS)	14xxnm (InP)
Cost	low	moderate	high
Efficiency	50…60%	< 33%	20 – 33%
Fiber type	MM	MM	SM



Efficiency: >60%
λ=808nm,
fiber: GI MMF



Temperature dependency: 0.1% efficiency per 1 °K rise

Optimization

Improve ease of use

- Reduce number of optical interfaces (splice instead)
- Use tapered high-power connectors

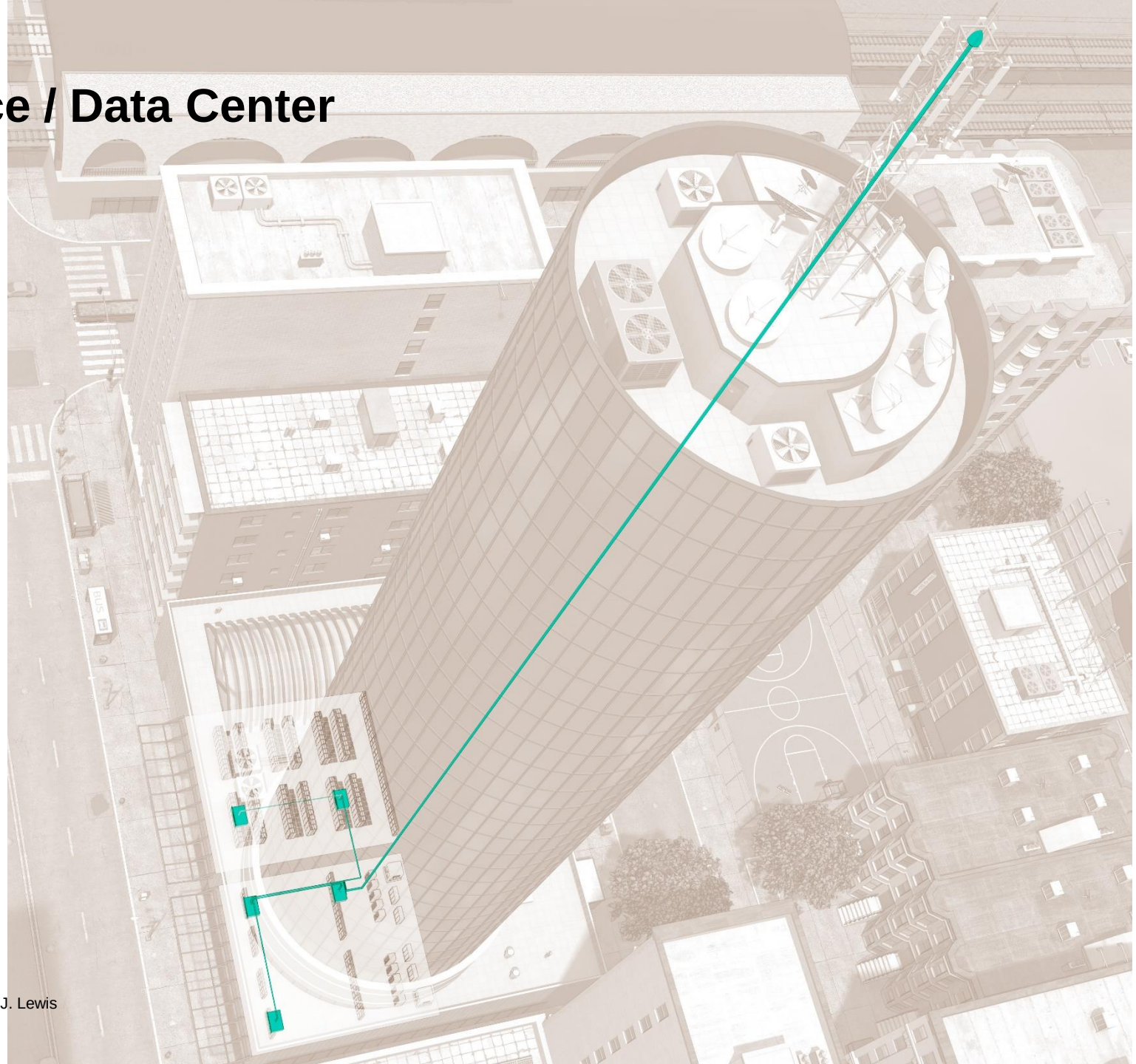
Increase power

- Use multiple fibers/cores (multiply power limit by #cores)
- Energy storage (batteries, supercapacitors)
- Combine multiple PPCs

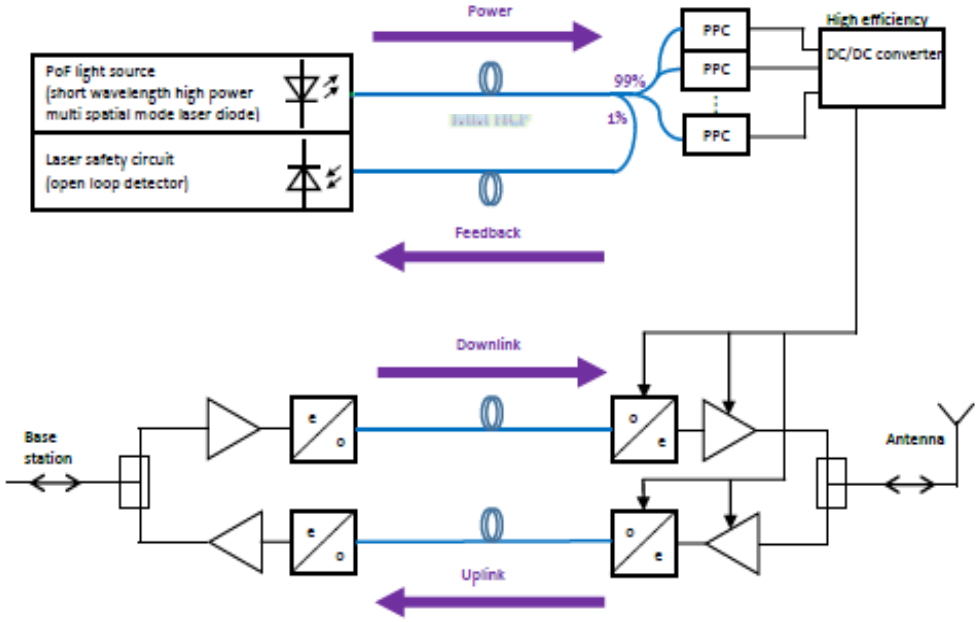
Improve efficiency

- Optimize load regarding power consumption (reduce consumption)
- Power-on-demand (one source is feeding multiple loads during defined time slots)

Central Office / Data Center



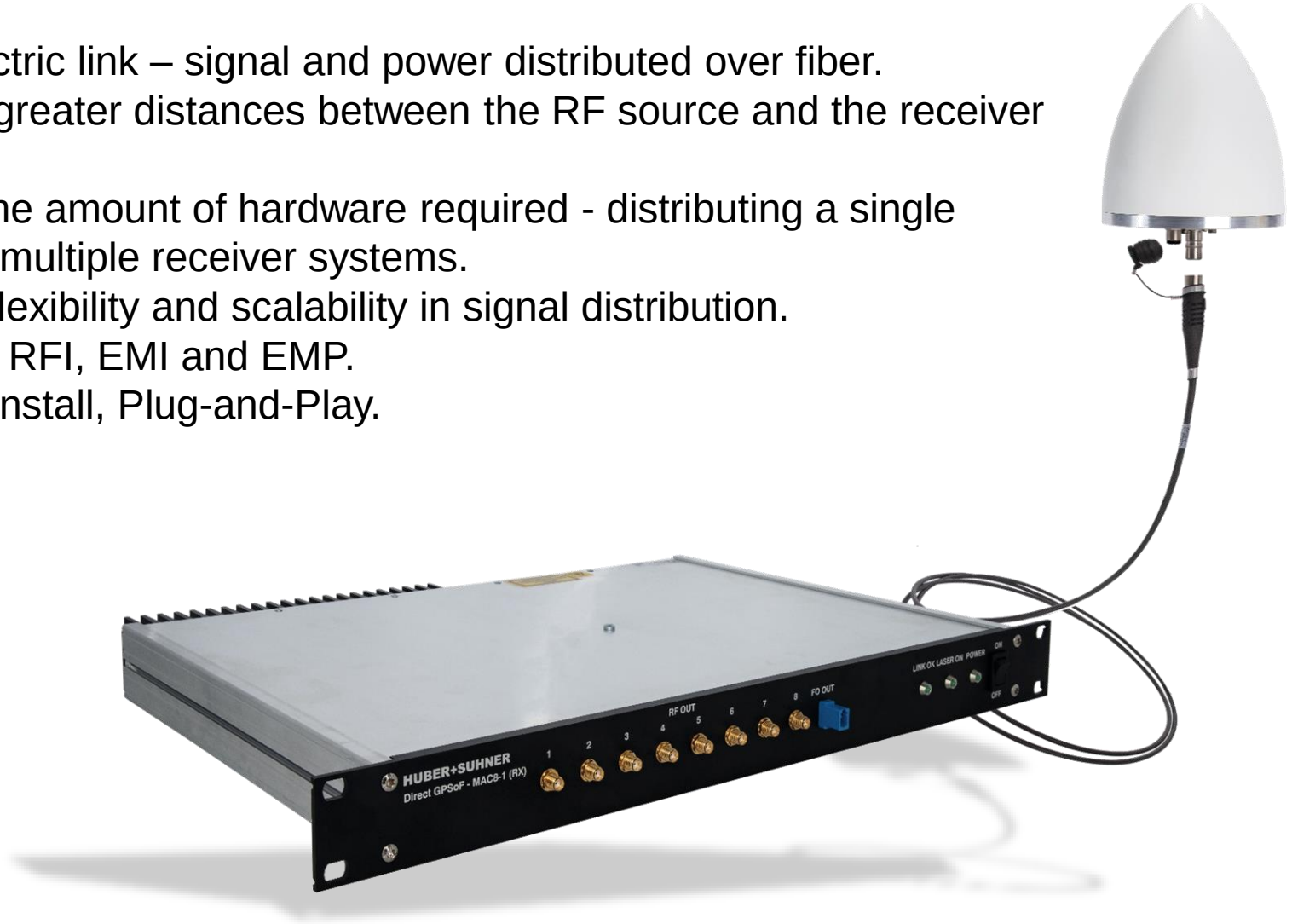
GPSoF / PoF schematic



- 600mW max. optical power for PoF
- Optical power for antenna unit powering is split into two fibers
  - connector protection, power converter limit
  - splitter loss
- Signal and feedback in one single fiber (WDM)
- Laser safety:
  - Feedback loop detects fiber interruption, laser turned-off in case of interruption

GPS and Power over Fiber

- Truly dielectric link – signal and power distributed over fiber.
- Allows for greater distances between the RF source and the receiver system
- Reduces the amount of hardware required - distributing a single signal into multiple receiver systems.
- Unlimited flexibility and scalability in signal distribution.
- Immune to RFI, EMI and EMP.
- Is easy to install, Plug-and-Play.




Connecting – today and beyond