Optical line technologies for rates above 100G

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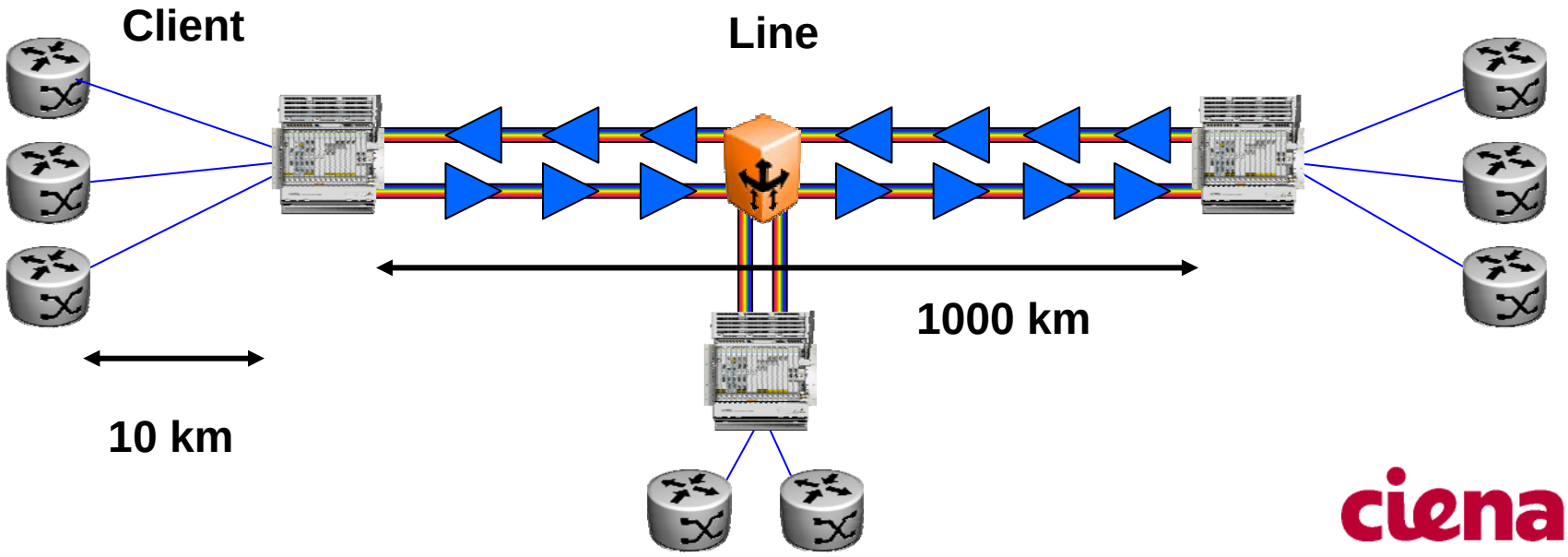
Line vs Client

The requirements for optical line technology are different from those on the client interface.

- **Long distance transport made economic by sharing of optical line infrastructure (amplifiers, ROADMs etc.) across many channels.**
- **Spectral efficiency (bit/s / Hz) and reach before needing O-E-O regeneration are key parameters.**



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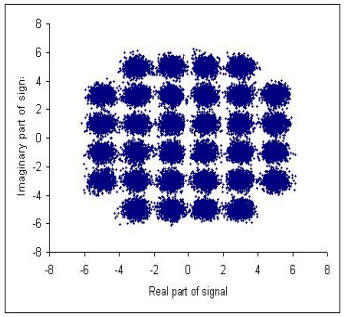
Three ways of capacity evolution

Amplitude
Phase

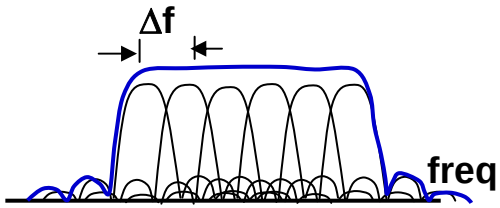
QPSK

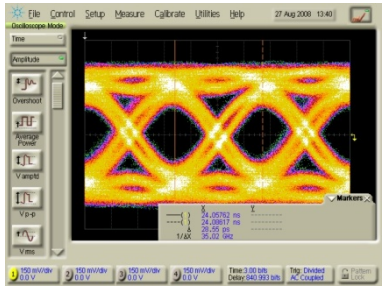


Constellational multiplicity

Symbol rate

subcarrier multiplicity





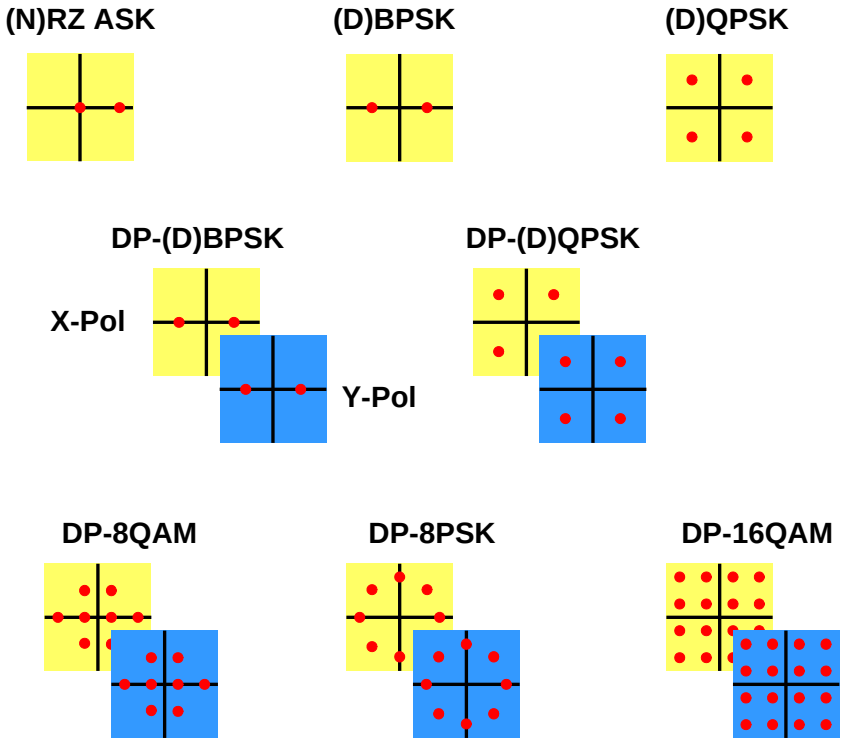
increase

- Constellational multiplicity
- Subcarrier multiplicity
- Symbol rate

Constellations

Modulation formats on each optical carrier

Modulation Format	Bits/Baud	Baud Rate (GBaud) for 450Gbit/s	Baud Rate (GBaud) for 1120Gbit/s
(N)RZ IM	1	450	1120
(D)BPSK	1	450	1120
(D)QPSK	2	225	560
DP-QPSK	4	112.5	280
DP-8QAM	6	75	186.7
DP-8PSK	6	75	186.7
DP-16QAM	8	56.25	140



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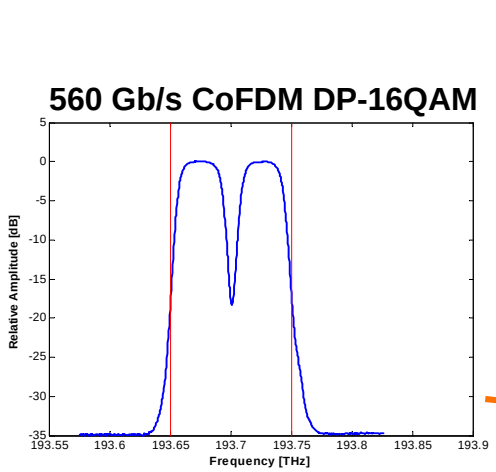
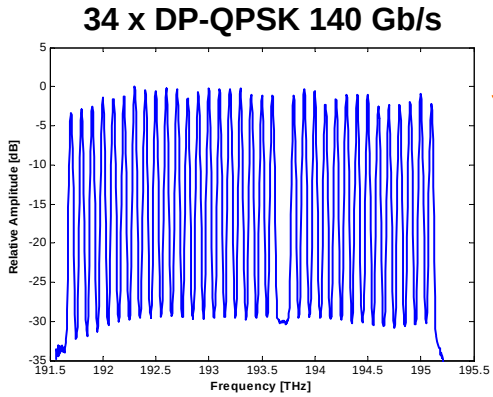
560Gbit/s CoFDM DP-16QAM experiment

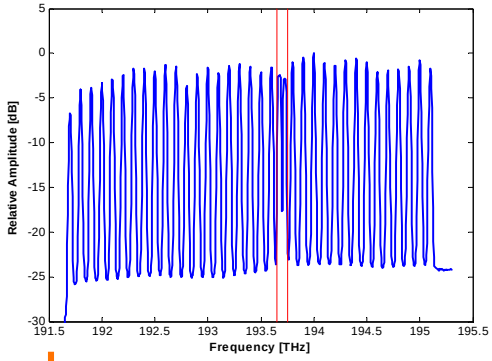




Advanced Modulation Formats

Test Channel Transmitter

WDM Transmitter



Channel Spacing 100 GHz

Link

Demux Filter

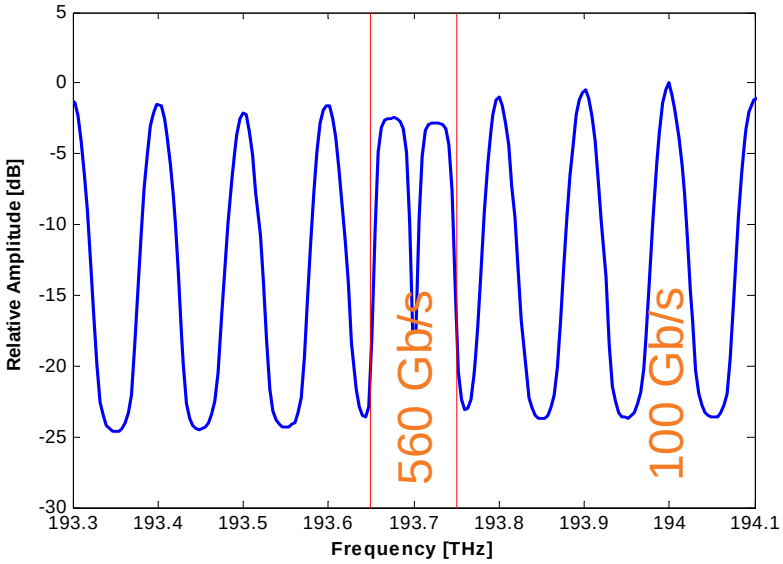
Coherent Receiver

5 spans x 80km/span NDSF

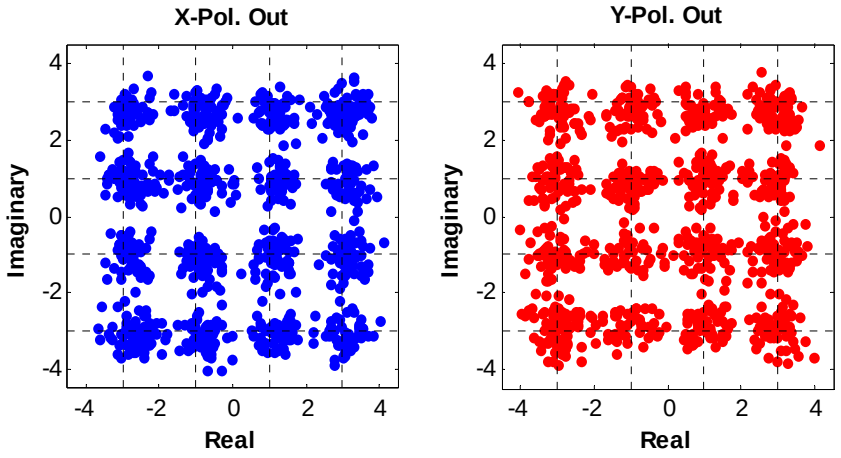
Data Capture & Post- Processing

560 Gb/s

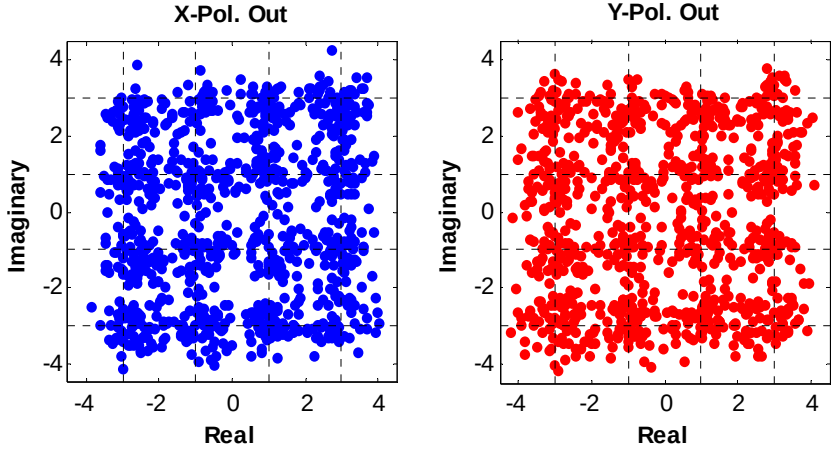
- Dual Carrier DP-16-QAM
  - 100 GHz WSS
- 35 Gbaud Nyquist Generation
  - SiGe BiCMOS DACs
  - 2^{15}-1 pattern



Back-to-Back



5 x 80 km = 400 km NDSF



[Charles Laperle Oct 2009]

BER = 0.019

Recently reported results

Rate Gbit/s	Format	Spectral efficiency bit/s / Hz	Reach km	Published
224	PDM 16-QAM	4	1,200	OFC 2010 PDPB8
448	CO-OFDM 16-QAM	5.2	2000	OFC 2010 PDPC2
560	CoFDM DP-16QAM	5	400	OFC 2010 Workshop
640	RZ Conjugation	0.25	100	OFC 2010 PDPC6
1.08	CO-OFDM	3.3	600	OFC 2009 PDPC1
1.21	PDM-OFDM QPSK	3.3	400	OFC 2009 PDPC2

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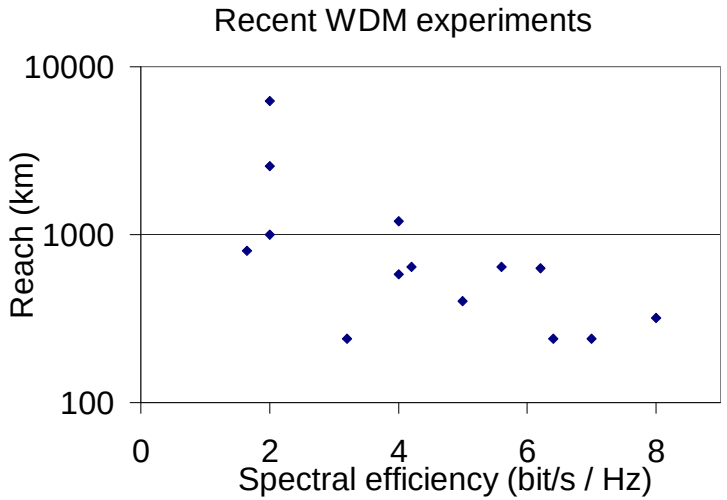
Spectral efficiency evolution

Recently deployed optical line technology has achieved considerable improvement in spectral efficiency with each successive generation:

10 Gbit/s channels on 50 GHz grid – 0.2 bit/s / Hz

40 Gbit/s channels on 50 GHz grid – 0.8 bit/s / Hz

100 Gbit/s channels on 50 GHz grid – 2.0 bit/s / Hz



- **450 Gbit/s on 100 GHz grid – 4 bit/s / Hz probably achievable with acceptable reach.**
- **1Tbit/s channels probably won't see improved spectral efficiency over this unless reach is significantly compromised**

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Summary

To achieve 400G or 1T channels for long distance transport with acceptable reach and spectral efficiency, advanced modulation formats are required that involve combinations of:

- **complex constellations**
- **high symbol rate**
- **multiple sub-carriers**

Experimental results that demonstrate feasibility of 400G and 1T channels is emerging.

1 T channels will require multi-carrier technology and may not show significantly better spectral efficiency than 400G channels depending on reach. If this proves to be the case then the benefit of going to 1T is less compelling.

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Thank You