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**MAKING 40G
 ECONOMICALLY
 FEASIBLE TODAY**

IT HAS BEEN AT LEAST EIGHT YEARS SINCE TRANSPORT EQUIPMENT VENDORS STARTED TALKING PUBLICALLY ABOUT 40G SOLUTIONS. YET 40G HAS MADE LITTLE PROGRESS ACHIEVING ACCEPTANCE IN THE MARKET. WHY IN ALL THIS TIME HAS 40G NOT BEEN ABLE TO DISPLACE 10G IN THE MARKET? THE ANSWER IS SIMPLE. TO DATE, 40G SOLUTIONS OFFERED BY INDUSTRY EQUIPMENT VENDORS ARE NOT ECONOMICALLY SENSIBLE. GIVEN THIS, OTHER THAN A NUMBER OF FEASIBILITY EXPERIMENTS, 40G DEPLOYMENTS HAVE BEEN LIMITED.

:: Let's look at the basic market requirements for 40G that would make a 40G solution economically sound:

1. On a transponder to transponder or muxponder to muxponder basis, 40G transponders/muxponders must cost less than four times 10G transponders/muxponders.

→ **Assumption:** any collateral equipment like PMD compensation is built into the 40G transponder/muxponder cost.

2. From a performance perspective, 40G must perform as well as 10G so that at a network level, 40G does not require more regeneration points than existing 10G deployments. In the case that it does, this additional cost must be compensated for by a lower cost of transponders/muxponders/regens.

3. 40G technologies must be able to run on the same transport systems that were deployed for 10G in concert with 10G wavelengths that have already been deployed. In the ideal case, one must be able to interleave 10G and 40G wavelengths with no guard bands so that bandwidth can be used efficiently without having to forecast 40G and 10G demand.

It seems like these requirements are quite simple. So why then have transport vendors not been able to meet them in eight or more years of trying?

There are a couple of reasons:

1. Native 40G modulation schemes do not perform well in terms of PMD and Chromatic dispersion. At least as compared to 10G. Because of this, vendors have been forced to add expense to 40G transponders to incorporate techniques that help with these issues. These techniques include phase shifting, polarization multiplexing, and coherent receivers. None of them however solve these issues all together although they do help tremendously at a great expense.

2. Unfortunately for transport vendors, the cost goal of four times 10G has been a moving target. In fact, it has been moving lower quite rapidly with improvements to 10G economics. In the last 8 years, 10G xponders/muxponders have dropped on the order of 75% in cost. Each year when a vendor promises to hit the four times 10G target, they are referring to four times 10G at its current price. Unfortunately, by the time the next year comes around, 10G has dropped once again.

So, what is the solution to these issues? WaveBonding® is a technique used by Ekinops to dramatically reduce the cost of 40G implementation by taking advantage of the cost economics of lower rate optics like 10G. WaveBonding® is a technology used to bond lower rate wavelengths that cumulatively provide 40G transmission into the same spectrum as native 40G solutions as follows:

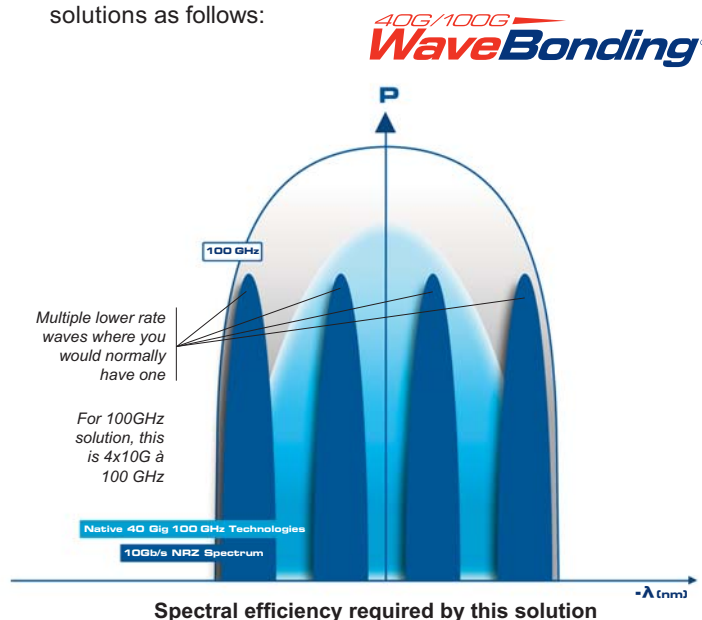


Figure 1. 100GHz Wavebonding® Solution

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Figure 1 shows the Ekinops 100GHz 40G WaveBonding® solution. This same technique will be utilized to create a 40G solution at 50GHz and future 100G solutions (the rates of the underlying bonded wavelengths will vary for each of these solutions for the best price vs. performance tradeoff). This paper will take a more detailed look at the 40G 100GHz solution which is currently being released to market.

Notice that the underlying modulation scheme used for the 40G 100GHz solution is NRZ and that the underlying rate is 10G. These facts bring many advantages to WaveBonding® solutions over traditional 40G products using modulation schemes like DuoBinary, DPSK, DQPSK or some variant of these. In fact, WaveBonding® technology solves all of our market requirements previously discussed.

:: Let's take a look at those requirements again from the perspective of WaveBonding® solutions.

- **Cost of Transponder/Muxponder must be less than four times 10G:** the 100GHz 40G WaveBonding® solution uses underlying 10G optics. This combined with the fact that redundant electronics, optical components, and packaging can be removed from the combined underlying 10G wavelengths means that the WaveBonding® solution is cheaper than four times 10G.

- **Performance of solution must be as good as 10G:** because the WaveBonding® 40G solution utilizes underlying 10G optics, the solution performs pretty much the same as 10G. At least very close. Close enough that most existing 10G deployments in metro, regional, and long haul networks can be overlaid without additional regeneration points.

- **40G must peacefully coexist with 10G line systems and the 10G waves that are being deployed on those line systems:** because the WaveBonding® 100GHz solution is utilizing underlying 10G wavelengths and fits comfortably in the 100GHz grid, it can be deployed on existing 10G line systems and 40G WaveBonded wavelengths can be intermingled with 10G wavelengths with no interference from one technology to the other. In fact, the Ekinops WaveBonding® solution is fully tunable and can be used to overlay other vendor's 10G line systems without any issues as well.

→ **As one can see, the WaveBonding® 40G solution eliminates all of the market inhibitors faced by other 40G solutions.**

:: Now, let's take a look at the performance of the Ekinops 100GHz 40G WaveBonding solution:

WaveBonding® Modulation	Chromatic Dispersion (ps/nm)	DGD (ps)	OSNR	Spectral Efficiency	Approx. Distance (order of)	Estimated Market Price
WaveBonding® (100GHz)	High Performance ~1600ps/nm	~48ps/nm	High 14 dB	100GHz	> 2000km	Less than 4x10G

Figure 2. WaveBonding® 40G 100GHz Solution Performance

→ **As one can see from the above performance figure, the Ekinops 40G 100GHz WaveBonding® solution performance is far superior to other popular 40G modulation schemes and is very much like that of 10G.**

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:: Now, here are some performance examples of the Ekinops 100GHz 40G WaveBonding® solution with a full complement of 40 40G channels, with and without RAMAN amplification.

→ In the following chart:

- “Nb of sections” is Number of sections or hops
 A hop is defined as the span between amplifiers
 There are no regeneration points on these sample routes
- “dB” is the loss on each hop/section
 (they are all the same for each route)
- “Total (dB)” is the total loss on the route
- “km” is the number of kilometers of each hop/section
 (they are all the same for each route)
- “Total (km)” is the total distance of the route

40 channels 40G C Band

EKINOPS PM 4001/4004LH

0.2 dB/km

23 dBm

H: Hybrid (Erbium + Raman)

Number of sections

	dB	Total (dB)	km	Total (km)
1	38	38	190	190
2	34	68	170	340
3	31,5	94,5	157,5	472,5
4	30	120	150	600
5	28	140	140	700
6	27	162	135	810
7	26,5	185,5	132,5	927,5
8	26	208	130	1040
9	25,5	229,5	127,5	1147,5
10	25	250	125	1250
11	24,5	269,5	122,5	1347,5
12	24	288	120	1440
13	23,8	309,4	119	1547
14	23,5	329	117,5	1645
15	23,3	349,5	116,5	1747,5
16	23	368	115	1840
17	22,8	387,6	114	1938
18	22,5	405	112,5	2025
19	22,3	423,7	111,5	2118,5
20	22	440	110	2200

Figure 3. WaveBonding® 40G 100GHz Solution Performance with hybrid Erbium/RAMAN

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40 channels 40G C Band

EKINOPS PM 4001/4004LH

0.2 dB/km

23 dBm

E: Erbium

Number of sections

	dB	Total (dB)	km	Total (km)
1	31	31	155	155
2	27	54	135	270
3	24,5	73,5	122,5	367,5
4	23	92	115	460
5	21	105	105	525
6	20	120	100	600
7	19,5	136,5	97,5	682,5
8	19	152	95	760
9	18,5	166,5	92,5	832,5
10	18	180	90	900
11	17,5	192,5	87,5	962,5
12	17	204	85	1020
13	16,8	218,4	84	1092
14	16,5	231	82,5	1155
15	16,3	244,5	81,5	1222,5
16	16	256	80	1280
17	15,8	268,6	79	1343
18	15,5	279	77,5	1395
19	15,3	290,7	76,5	1453,5
20	15	300	75	1500

Figure 4. WaveBonding® 40G 100GHz Solution Performance without RAMAN

→ Again one can see, the performance of the WaveBonding® 40G solution far exceeds that of other 40G alternatives in the industry.

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Finally, the following table shows the performance of the WaveBonding® 40G 100GHz solution in a single section/hop. The following table uses hybrid Erbium/RAMAN amplifiers at the terminals only and has no regeneration points or inline amplifiers.

40G C Band	Repeaterless system	
	0.2 dB/km	
	H: Hybrid (Erbium + Raman)	
Number Lambda	dB	km
1	61	305
2	58	290
4	56	280
8	54	270
16	52	260
40	50	250

Figure 5. Wavebonding® 40G 100GHz Solution Single Hop Performance

- Up to 250km in a single hop with 40 channels of 40G!
- More than 2000km with 40 channels of 40G without regeneration!
- Finally, a commercially viable 40G solution has arrived on the market!

IN CONCLUSION

The Ekinops 40G WaveBonding® solution is the first 40G solution to meet all of the market requirements. It costs less than four times 10G, it performs as well as 10G, and it can be used to overlay existing 10G routes (Ekinops' or other vendor's), interleaved with 10G wavelengths, with no adverse effects or guard bands. And, going forward, the Ekinops 100GHz WaveBonding® solution will continue to ride the cost curve of 10G maintaining its commercial viability even as 10G continues to drop in price ■

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About Ekinops

Ekinops is a leading designer and supplier of next generation optical transport equipment for service providers and enterprise customers. The Ekinops 360 Dynamic, Multi-Reach Transport System provides DWDM and CWDM on a single platform that addresses Metro, Regional, and Long Haul applications. The Ekinops 360 system relies on the innovative, programmable Ekinops T-Chip® (*TRANSPORT ON A CHIP TECHNOLOGY*) that enables Fast, Flexible, and Cost-effective service delivery for building high speed optical networks.

Using the Ekinops 360 carrier-grade system, operators can increase transport capacity of their networks — CWDM, DWDM, Ethernet, ESCON, Fiber Channel, SONET/SDH, and uncompressed video (HD-SDI, SD-SDI, ASI) – through the industry's most efficient aggregation of services.

The company is headquartered in Lannion, France, with offices in Europe, the USA and Asia.

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:: To learn more about Ekinops solutions, please visit www.ekinops.net

