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2001: A Lambda Odyssey

Chorum switches and Avanex muxes, unblemished by electronics, will vaporize problems faster than Ciena can solve them

The year 2000 was the year Alan Greenspan took on the Telecosm. And won. At least according to the stock market. Even high-energy, up-spectrum quantum photons, it seems, cannot always be relied on to tunnel through an ohmic wall of tight money, marked by the lowest commodity prices in fourteen years, the highest real interest rates in more than a decade, a yield curve from Death Valley, and a simultaneous soaring dollar.

The move into 2001 signals the end not of the Telecosm era but of the ersatz era of neo-Keynesian macroeconomics where growth of supply and innovation is deemed inflationary and across-the-board tax rate reductions cost money and cause deficits. Even if the Telecosm ends up rescuing the U.S. from an official recession, the Fed can no longer ignore old physical laws and new economic realities. The ascents of optical bandwidth and storewidth, and the lesser but still powerful progress of computer processing, have propelled the economy to a permanently higher non-inflationary growth path. The Telecosm economy has just begun.

Wavelength division multiplexing (WDM) lambdas are proliferating quicker than Moore's Law, with total bandwidth per optical fiber increasing faster still—perhaps four times a year. **Corning** (GLW) is expanding its manufacturing facilities in a desperate attempt to shorten year-long waits for tens of millions of kilometers of fiber on order for deployment everywhere except to your house. Corning continues its intense competition with **JDS Uniphase** (JDSU) in erbium doped fiber amplifiers (EDFAs) and low-end WDM modules. At the same time building a brand new industry of tunable lasers destined for use in virtually every piece of communications hardware across the web, JDSU, **Nortel's** (NT) **CoreTek**, and **New Focus** (NUFO) seek to fill those thousands of lambda slots being opened up at **Avanex** (AVNX) and **Chorum**.

Free storage is combining with the explosion of Gigabit and 10 Gigabit Ethernet to make networked storage and caching—storewidth—more effective and less expensive than stuffing your bits under a floppy mattress or in an isolated local hard drive. **StorageNetworks** (STOR) exemplifies this paradigm but is hovering at its initial offering price. **Mirror Image Internet** (XLA) now has 22 operational content access points (CAPs) on four continents, connections to over 350 networks and 137 service providers, and lots of (happy) customers, but its stock is only one-

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sixth of what **Exodus** (EXDS), also temporarily earthbound, paid for its equity at the beginning of 2000. Mirror Image and its imminent IPO offer an inviting opportunity.

Residential connectivity will be dominated by highly integrated **Broadcom** (BRCM) chips and **Terayon** (TERN) home gateways. With only 3.5 million U.S. cable modem links, fewer than 2 million successful DSL connections to date, and even lower penetration rates for the rest of the world, the untapped market is large. But the slower than expected roll out in both DSL and cable, like **WorldCom's** (WCOM) troubles, has to do with incompetence at the FCC and DoJ and the 1996 Telecom Act. The fastest way to spread broadband is to deregulate the local loop and halt the effort to impose the kind of "open" administered competition in which no one is allowed to win, or make any money, except the communications bar and the politicians. Yes, that means to free the regional bells and the cable vendors to compete any broadband way they like.

Scores of companies are clinging to TDM to conserve bandwidth at a time when bandwidth is abundant and it is connectivity that is scarce

In wireless, **Qualcomm** (QCOM) remains the ultimate and sure connectivity play. But unconditional success of the connectivity paradigm requires **Globalstar** (GSTRF). With botched marketing and much improvable customer equipment, the low earth orbit satellite service seemed in early January to be heading toward a bankruptcy. That will give some enlightened entrpreneur – will it be Jac Nasser of **Ford** (F), Richard Waggoner of **General Motors** (GM), Gary Winnick, Greg Maffei, Charles Levine of **PCS** (PCS), is anyone home? – the chance for global leadership in the wireless Telecosm for the next decade.

The next generation wireline carriers, meanwhile, were left for dead in 2000, somehow ignored for what they are, nothing less than the foundation of all industry, education, and communication in the twenty-first century. **Global Crossing** (GX) has landed on Hong Kong, greatly extending its seamless network, now the world's most advanced and comprehensive financial nervous system. **Metromedia** (MFNX) hums along as simply the best, and sometimes the only, source of metropolitan fiber. Maybe its biggest competitor and customer in the northeast, **NEON** (NOPT) has a new CEO, Steve Courter, who seeks to exploit unmatched cheap utility access into a potential 980 buildings in Manhattan and another 200 in Philadelphia. His new mantra: "Capillarity." Entire carrier webs are banishing expensive, bandwidth-conserving Sonet as **360networks** (TSIX) employs an optical WDM mesh in the core and partners with Ethernet virtuoso **Telseon** in the metro to deliver cheap plug-and-play connectivity across continents and oceans. **Williams** (WCG) is shedding bitrate and protocol-dependent electronic add-drop multiplexers in favor of all-optical add-drops from **Corvis** (CORV).

The all-optical network and its increasingly broadband wireless tentacles are not two or four or ten times as good as the electronic long distance and analog cellular networks they are replacing. Collectively, they are millions of times as powerful. And Raymond Kurzweil's Law of Time and Chaos tells us these trends will only accelerate. Indeed, as we visit the new stars of the telecosmic firmament, we are finding that this is increasingly true. The *rate of change* is speeding up.

Even as optical opportunities break out all over the global network, Avanex sage Simon Cao, along with your GTR analysts, stand almost alone in their vision of a hyper-rainbow of photons transforming the fibersphere – where the physical layer is the fiber itself – into the lambdasphere where the physical layer consists of myriad "colors" of light. Known to physicists as lambdas, these wavelength colors can *each* bear more information than the entire telephone network of a few decades ago. But more important to Simon Cao and the GTR, these lightwaves can soon multiply into the millions and provide a cornucopia of connections. Connectivity by color rather than by numerical address can bring broadband links to the entire internet.

Nonbelievers, however, urge lambda anemic networks bloated with software "intelligence" to make up for lack of connectivity. We still find most carriers leaning on Sonet or similar restoration and quality of service (QoS) schemes to make up for unreliability for which bandwidth and lambda abundance are the definitive remedy. We see scores of companies clinging to time division multiplexing (TDM) to conserve bandwidth at a time when bandwidth is abundant and it is connectivity that is scarce.

The quintessential Cerent

Focusing sharply into a rearview mirror, a component vendor told us as recently as August, at the National Fiber Optics Engineers Conference (NFOEC) in Denver, that the largest carriers only want 40 lambdas in the metro; forty 10-gigabit-per-second channels is "a lot of bandwidth." Furthermore, all-optical systems don't perform the critical add-drop metroland function.

The company? **Cyras**. Now being purchased by **Ciena** (CIEN) for $2.6 billion, they should have spoken first with **Cogent**, currently using Avanex's PowerExchanger all-optical add-drop multiplexer in its network. Instead, from across the expansive table in Cyras's swank hotel suite, we hear a bristling "Who says Sonet is going away?" Photonic switching, decry Cyrasians, switches empty lambdas; pure lambda switching in the metro is spectrally inefficient. True, they admit, today's Sonet is no good for data. "But next-generation Sonet will be a data optimized Sonet." Saving bandwidth galore, statistical multiplexing across the entire fabric will make Sonet better, and Cyras plans to be the first to cash in.

Riding on this vision, the company was busy building what it called a multiservice next-generation (NxG) Sonet transport and switching platform for the metro, four times denser, they claimed, than Cerent's platform, and destined to become the world's largest crossconnect, handling 40 WDM channels at about one-third the power of an equivalent system and eventually scaling to 10 gigabits per second. Unlike Cerent, which is targeting smaller CLECs, the Cyras box will be "rugged and carrier class" for the Big Carriers.

"For a long time we have been told that WDM would take over in the metro. It hasn't yet. The market today is zero." Cyras is not going to take a big bet on a small market. Neither, apparently, is its new parent Ciena. And why not? The Cyras vision is the Ciena vision. Just three months prior, back at Atlanta's SuperComm, Ciena CEO Pat Nettles trumpeted to us customer needs over technological possibilities. We might be able to give everybody a lambda, but everybody doesn't need a lambda. Channel capacity isn't the issue—our ability to manage the channels is.

What Nettles fails to grasp is that a network that is able to waste bandwidth is much easier to manage than a network that needs to conserve it. So, like **Cisco** (CSCO), Ciena acquired a Cerent—a bigger Cerent. The quintessential Cerent. Call it Cyras.

Ciena turns out the light

Systems integrators like Ciena always tend to be conservative and customer bound. But, Ciena has been more exclusively focused on optical networking than either of its two major competitors, **Lucent** (LU) or even Nortel. As great an optical company as Nortel is—and more so all the time—they have huge legacy customer accounts that induce them to install billions of dollars worth of Sonet systems. Some customers have no choice but to demand them because of what they have already built out or because 'carrier class' standards require protection and restoration schemes that we may regard as obsolete in an optical network but which today are still a non-negotiable requirement in the telco world. A far younger company and a WDM pioneer, Ciena has been relatively less burdened with legacies than its older, larger competitors.

No longer. A pilgrim journeying toward Optical City, Nortel has acquired **Qtera**, **Xros**, and CoreTek over the last year as it struggles to cast off its Sonet burden. Reaching out to catch the Sonet load is Ciena as it whisks past Nortel in the opposite direction on its way to the Network of Confusion.

AT&T (T) made new investments in voice in 1997. Now, as if on cue, Ciena invests in Sonet in 2000 in a transaction expected to become accretive during the latter half of fiscal 2002.

Ciena's one-box approach will integrate an "all-optical" switch fabric (the technology or number of lambdas or ports has not been revealed) into its mostly CoreDirector to give us "one intelligent system," including networking software and management, switching at granularities down to 50 Mb, grooming and protecting along the way. Ciena believes it can eliminate the need for single-purpose switches with a unified platform that traps its customers into an inflexible o-e-o system completely dependent on Ciena/Cyras.

Marching with Custer

Could this be Software's Last Stand? Ciena's strategy reveals the futility of trying to paint over a color-rich WDM landscape with a black-and-white TDM Telco antique. Already metro optical systems company **ONI** (ONIS) dedicates 60 percent of its engineers to software. MEMS photonic switchmaker **Calient** says that all their current hiring is in software. And Krishna Bala of optical switch vendor **Tellium** foresees optical companies becoming 80 percent software and 20 percent hardware.

As Simon Cao told us while ruminating on *all-optical* crossconnects (OXC), we're talking about "Old World" thinking here. Back in Richardson, Avanex's network expert Charles Mao agrees, calling OXCs a mirror image of what people are doing in the electrical domain. Networkers have an electrical switch, so in the optical domain they believe they need an optical switch, too. Switched networks, as Mao describes them, require big routers to feed them. Then we must perform centralized "dispute management"—first you recognize the problem, then you identify alternative paths, and finally you switch. Mao explains, "The entire network, the infrastructure, as far as the software is concerned is not ready to take that task." And by implication never can be.

In all-optical networking, Ciena envisions a massive connectivity and QoS nightmare, an ever more entangled patch-panel of lambda circuits connecting increasingly numerous and complex optical components, sub-networks, and Internet devices each requiring a unique address. With a "unified system" Ciena vainly attempts to solve these "problems" which will go away in a true passive optical system faster than they can solve them. All the while they blind themselves to the connectivity millions of lambdas ably afford. As Bill Joy of **Sun Microsystems** (SUNW), recently affirmed to us, the great benefit of all-optical hardware is that it "tunnels through the complexity barriers" of o-e-o systems and their bloated software.

Ciena's attempt to solve problems with a "unified system" blinds them to the connectivity millions of lambdas afford

The best remedy for the connectivity dearth is Avanex's PowerMux technology, a nonlinear adaptation of the Fabry-Perot etalon of classical optics. But in news and analyst reports the Avanex devices remain in the shadows of scarce-lambda multiplexing technologies such as arrayed waveguide gratings, fiber Bragg gratings, and thin-film filters. Unlike the PowerMux, which fuses or filters colors by their frequency in essentially unchanging free-space, these rival devices sort frequencies across treacherous paths through silicon or other solid state materials susceptible to changing temperatures and dependent on exquisite control of dimensions.

Signals emerging from Fremont, California, and Richardson, Texas, however, hint at a different story—the

THE LOST MILE

Got Broadband? Quite possibly no ... at least not at home.

In 2000, only nine percent of U.S. Internet subscribers had broadband connections (Chart 1). That figure is expected to reach fourteen percent within the next year. Six out of seven U.S. Internet users will remain dial-up subscribers. The majority of broadband converts will continue to be of the cable persuasion.

There is clearly a digital divide between the workplace LAN and the sclerotic analog home dial-up connection. Office surfers will continue to come home wondering: why can't I get that in my living room (Chart 2)?

So what's the hangup? Regulatory myopia just might have something to do with it. RBOC footdraggin and CLEC frustration (Chart 3), the not surprising outcomes of perverse incentives and dysfunctional relationships mandated by Congressional and Judicial meddling, have hampered the nationwide rollout of DSL. Forced collocation of fierce competitors may work in prisons, but it's no way to run a complex technological industry. In wireless, MMDS offerings continue to be delayed by licensing requirements. And cable, the clear winner in 2000 (Chart 4), may have just walked head-first into its own '96 Act in the form of nebulous "open-access" conditions attached to FCC/FTC approval of AOL-Time Warner. The urge to superimpose a level playing field on the undulating terrain of commerce springs eternal in the heart of the wonk.

The gap is narrowing between the number of dial-up and broadband connections (Chart 5), but broadband coverage is far from universal (Chart 6). And universal residential broadband is a telecosmic imperative. Without it, thousands of not-yet-developed bandwidth-hungry applications will remain in The Great Perhaps, keeping the future waiting.

Until the truck rolls for you, why not whistle a happy tune?

(to the tune of "On The Street Where You Live")

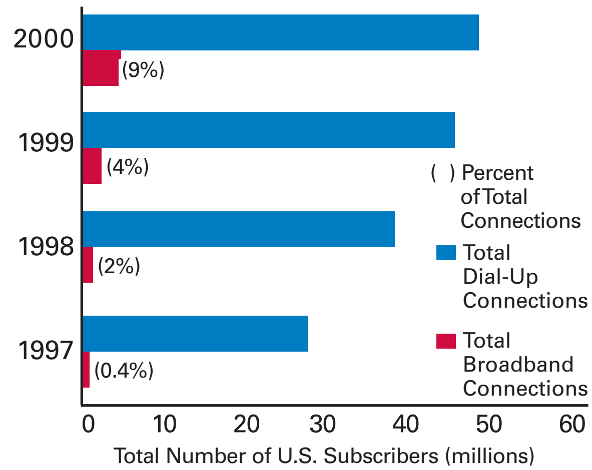
I have often surfed
On the net before
56K dialup-that's all I could
get before
Now my local Bell
Offers DSL
Only not on the street
where I live!

There are cable nodes
In one part of town
They've got LMDS coverage
in the heart of town
Some new buildings get
10-gig ethernet
But they're not on the street
where I live!

- Jeff Stambovsky

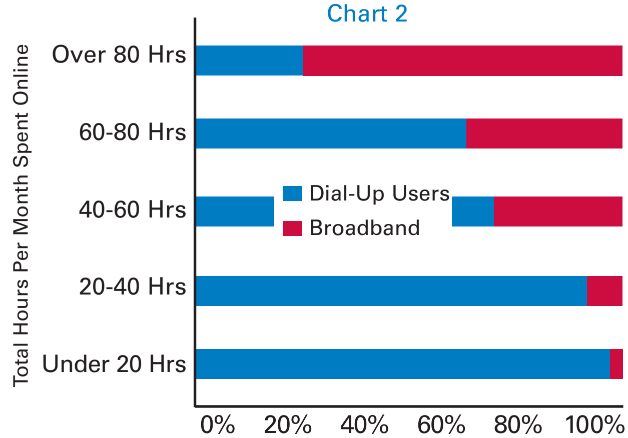
Ninety-One Percent of U.S. Internet Connections are Dial-up

Chart 1



Broadband Users Spend Considerably More Time Online

Chart 2



Data Sources: FCC, The Telecomm Analyst, Jupiter Research, Research Portal.com, xdsl.com

real story, the unstoppable story–a new era marked by surging Avanex sales propelled by the PowerMux … by promises of major tunable-laser breakthroughs this year from New Focus and CoreTek … and by announcements of WDM systems with hundreds of channels enabled by Avanex interleaver multiplexing technology.

In the tranquility of the mid-winter Texas sunshine on the plains just north of Dallas, in Richardson, dwarfed by a forest of Telecosm redwoods such as Avanex customers WorldCom, **Fujitsu** (FJTSY), and Nortel, stand both the headquarters of Chorum Technologies and Avanex's new Photonics Center. Having visited Chorum a year and a half ago and having followed the company around the Telecosm since, we arrived in Texas during the wee hours of January 3 exhausted, yet hopeful. What we discovered pays to Simon Cao the sincerest kind of compliment, which is imitation—even if partly inadvertent—while confirming the Avanex vision and propelling the lambdasphere forward. For inside Chorum reside yet two more Simon Caos.

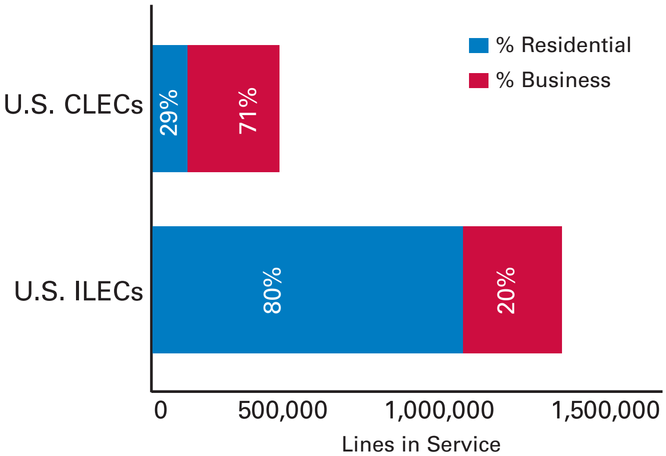
Avanex, Chorum, and roads less traveled

When University of Colorado research associates J. Y. Liu and Kuang Yi Wu founded Chorum as Macro-Vision in 1996 in Boulder, they were working on SBIR (Small Business Innovative Research) contracts for the military and the National Science Foundation. Then October 1997 saw their first venture capital funding, and Chorum left the launch pad, introducing products in the fall of 1999 and ballooning from 115 employees then to 700 hundred today. Over a quarter of these devoted to developing new products using a radical new technology based on a familiar material substrate, liquid crystals.

In optical communications, scientists manipulate the properties of lightwaves. Undulating through a point in space

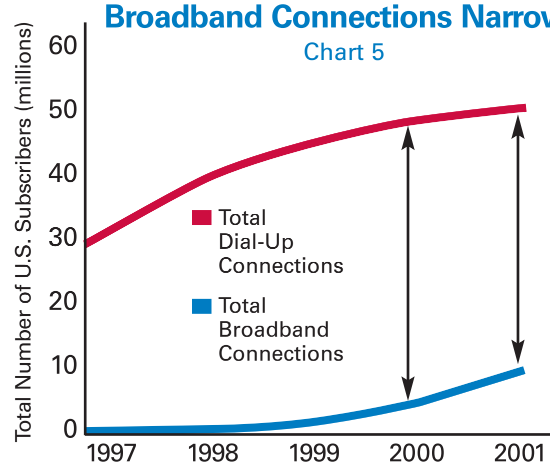
ILECs Dominate in Residential DSL Build-Out

Chart 3



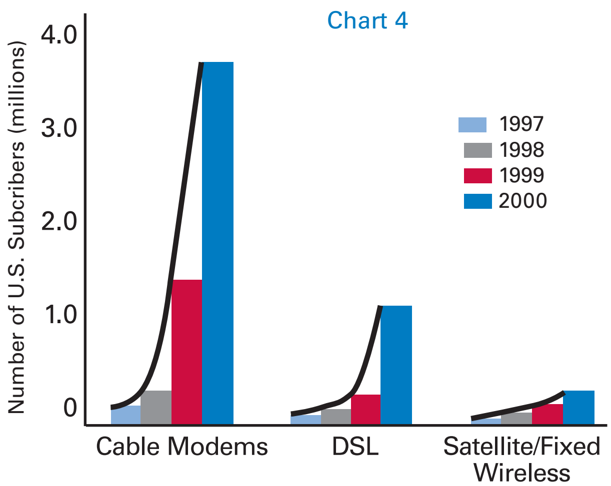
Gap Between the Number of Dial-Up and Broadband Connections Narrows

Chart 5



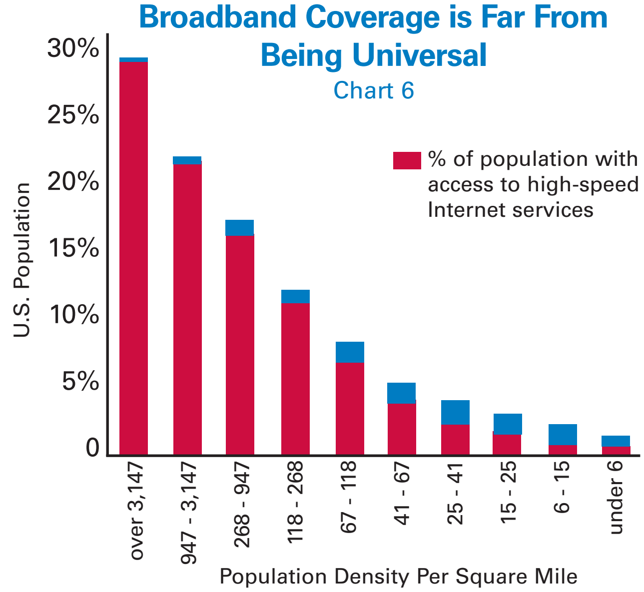
Cable Leads in Number of U.S. Broadband Subscribers

Chart 4



Broadband Coverage is Far From Being Universal

Chart 6



like a sine function, the waves exhibit characteristics of length (the distance from one wave peak to the next), frequency (the number of waves passing a fixed point in one second), and amplitude (the height of the peaks and troughs). In a given medium each color of light has a unique frequency and a unique wavelength. By causing these lightwaves to interact, or interfere, in such a way that some colors are aligned additively at their peaks and hence strengthen, while other colors' peaks are aligned with troughs and hence cancel, we can combine (multiplex) more than one color simultaneously onto one fiber. By reversing the process, we can separate (demultiplex) these same WDM waves when we need them.

Each wavelength or frequency, also called a channel, bears information in an optical network. The more channels the more connectivity, as each lambda can form a connection much the way fiber itself does when only one channel is present. As WDM channels multiply, they become more densely spaced on the frequency spectrum and require more compact, box-like shapes so they don't overlap, a phenomenon called crosstalk.

Avanex's triumph comes on two roads less traveled, one in technology and the other in philosophy. The Fabry-Perot (F-P) etalon, two mirrors facing each other, has long been recognized a superior interference technology. Elegantly simple, the F-P interferometer accurately separates and combines wavelengths or channels of virtually any number and spacing based only on the spatial separation of the two mirrors. As light resonates between the mirrors, wave peaks add and subtract to give the desired results. In contrast, arrayed waveguide gratings (AWGs), fiber Bragg gratings, and thin-film filters rely on numerous complex spatial relationships between gratings and filters, as many or more spatialities as channels themselves. These technologies, therefore, scale poorly. They could never enable a lambdasphere.

So why has F-P been ignored? It is relatively slow (the mirrors move in milliseconds rather than the nanoseconds needed for switching packets) and it also yields channels that are not ideally shaped. Simon ingeniously solved the shaping problem by making the F-P interferometer nonlinear, meaning that outputs differ from inputs. The waves can be sharpened with the device. The slowness problem is solved by his lambdasphere concept. Lambda circuits stay up for the duration of the call like telephone circuits. In the Telecosm of bandwidth abundance, it is not necessary to conserve bandwidth by statistically multiplexing packets, each with a separate address, and cramming as many as possible on every lambda. The law of the Telecosm is to waste bandwidth in pursuit of the service that people want: broadband connections. Cao understood that in the coming network of lambda circuits, processing speed will take a back seat to connectivity. And along with Carver Mead and Claude Shannon, he knew that light behaves better at finer granularities. The real race is to make more, better-shaped lambdas, and to process those lambdas in a way that will give the greatest network simplicity.

Chorum switches and Avanex optical add-drop multiplexors may be the real bridges to a switchless network

Chorum's crystals

Enter Chorum and the third less-traveled road. The Liu-Wu philosophy is remarkably similar to Simon's. The difference is in the technology.

In addition to length, frequency, and amplitude, light has the characteristic of polarization. Lightwaves are oscillating electro-magnetic fields, with the electric fields always perpendicular to the magnetic field. Together the waves' polarities can be rotated any direction in space.

In a fiber, the polarization of light can be a nuisance because the poles react differently to inevitable asymmetries in the glass and cause the dreaded PMD (polarization mode dispersion) as different light polarities pass through the glass at different speeds. Especially at bitrates above 10 gigabits per second and in older fibers, PMD and polarization dependent losses can seriously degrade a signal.

Non-linearities—the tendency of similar input signals to become dissimilar output signals to become noise—create the most irksome nuisance for network engineers who want their carefully perfected carrier waves to put out the same information that was put in. But virtually all the nonlinear properties of light—no matter how problematical at the outset, from phase shifts and dispersion to multiple colors and attenuation rates—have become crucial tools of WDM. And polarization is one of the most attractive nuisances of the lot.

Any crystals that show sharp differences in refractive index for vertically and horizontally polarized light are called birefringent and can split light into two polarized beams of equal power. Joined with electrically controllable *liquid* crystals (LCs), and used in billions of portable screens, these crystal combinations can sort and manipulate lambdas. Other asymmetric materials, called polarization rotators, alter the direction of polarization as light passes through.

Crystals, however, claim the traditionalists, have slow switching speeds, poor channel shape, temperature sensitivity, and high signal attenuation. Well, you can write the rest of the story. Liu and Wu's lambdasphere cares not about switching time, and so they forged ahead to solve the other problems through proprietary, highly disciplined process and characterization technology.

With a panoply of birefringent and liquid crystals and polarization rotators, Chorum possesses the technology to create an impressive array of wavelength selective switches, multiplexers, and dynamic attenuators with almost any number of channels, almost any channel shape, and almost any gain profile needed in an all-optical network.

Liu and Wu were not lured out from Hamlin as children by the seductive pipes of Simon Cao. Independent thinkers, they focus on a different characteristic of light and will likely diverge from Simon Cao on product offerings (though polarization is also used in the initial stage of Avanex's interleaver). As such, Chorum triumphantly confirms the approaching lambdasphere and Cao's Law. Liu and Wu speak of lambdas in abundance, thousands on a fiber as early as mid-2002, enabled in part by their third-generation interleaver, already in beta testing.

As perfected by Avanex and Chorum, interleavers are high-end multiplexers that make massive channel-count WDM possible by reducing drastically the cost of marginal lambdas. In an interleaver, tightly packed lambdas in one fiber are converted into loosely packed lambdas in two fibers, or vice versa. Cascadable in multiple stages, these devices work in the frequency domain and obviate the impossible challenge of lining up thousands of lambdas across perfectly defined interference paths in solid state devices, such as arrayed waveguide gratings.

Chorum offers an inviting transition to a mostly switchless network: use a 4-stage interleaver to demux 1,280 WDM channels into sixteen 80-channel WDM signals. Plan the network so that the groups of 80 channels connect over the same path. With the same 10 fibers, we now only need a 160-port device, well within reach of a future Chorum liquid crystal switch which, port for port, eats a million times less power than MEMS and boasts no moving parts for higher reliability.

Paradigm quake rocks Calient, Tellium

Could it be at this time of historic paradigm shift, akin to the Industrial Revolution, some cutting-edge technologies will be eclipsed almost before they are deployed? With leapfrogging advances in tunable lasers, muxes, and photonic processors anticipated over the next 18 months, Chorum switches and Avanex optical add-drop multiplexers may be the real bridges to a switchless network rather than MEMS photonic crossconnects.

Like Simon Cao, Liu and Wu understand that real world networks will long rely on some switching, particularly at the edge. But Cao's ultimate vision is to use hundreds of thousands of optically submultiplexed channels that can be added and dropped without electronic conversion as required today.

Currently, metro WDM companies such as **Kestrel** and **Centerpoint Broadband** offer electronics-intensive frequency division muxes, not to waste bandwidth and increase connectivity but do the very opposite—to pile more bits on a lambda and reduce the number of channels accordingly. If successful, Avanex will turn these business models on end and pry open a trove of endless connectivity.

In pursuit of its strategy, Avanex will use the cheap holographic gratings from its acquisition Holographix in the back end of its next-generation PowerMux for use where widely separated channels do not require stringent processing technology. This will give systems integrators and networks a complete multiplexing solution and help drive the cost of marginal lambdas much lower and reduce the footprint a remarkable 80 percent.

While both Avanex and Chorum pursue their superior multiplexing technologies, which include all-optical routing capabilities, Avanex advances in another direction with its unique PowerShaper dynamic, second-order dispersion compensator. This device uses Cao's nonlinear optics to extend all-optical signal reach without Raman amplification and other overly-integrated, costly components, not only in the ultra-long-haul backbone but also in the metropolitan and regional networks. Both companies are eyeing these proliferating and connectivity-intensive portions of the all-optical network with the relish of an impending coup d'état. When the lambdasphere invades metro, who survives?

ONI leaves grooming at the alter

Today, of course, with Sonet at its brilliant zenith, with tunable lasers still problematical and all-optical add-drops just moving out of beta-testing—and prior to Avanex's and Chorum's next-generation interleavers—opto-electronic metro startups are giving us the best shot. But the Law of Wasted Bandwidth tells us that the companies that exploit bandwidth recklessly will win. The first movers of metroland WDM, though, tout a bandwidth-conserving paradigm as entrenched as the Sonet fixation of so many legacy systems-vendors. The current window of opportunity before the lambdasphere arrives will likely slam shut on the fingers of the metro people just as they reach for the profits. There may not even be an Indian summer like the current boom in small Sonet boxes from Cerent (Cisco).

Among the more promising metro players is ONI Systems. Tucked away in a private booth on the euphoric SuperComm 2000 convention floor last summer, CTO Rohit Sharma explained that network intelligence already resides in the servers, not the routers. As you move up into the network from the LAN (the local area, or enterprise, networks), you encounter more servers which get bigger and less intelligent. The process reverses itself as you move out toward the edge. Yet, today, routers control network intelligence, while transaction details are created at the edge. Dr. Sharma has dedicated ONI to the task of taking network intelligence out of big Cisco routers and switches and placing it in servers on the edge.

ONI's new products will make lambdas on the edge more flexible, easier to deploy, and cheaper

ONI would move *grooming*—the capability to dynamically mix, match, and stack lower bitrate data on WDM channels, inherently a bandwidth-conserving activity—from the core where bandwidth is abundant toward the network "edge" where it is needed. Suddenly, we feel a chill wind for Ciena's hybrid electrical-optical CoreDirector switch which grooms to a shine both in the network core and now also in the farther reaches of metro.

Stealthy Sorrento

Offering the ability to optically add-drop a changeable number of lambdas at each node and to dynamically equalize channel power, ONI's new products will make lambdas on the edge more flexible, easier to deploy, and cheaper.

ONI's current "66 unprotected channels expandable to 160" with dynamic add-drop is quite an achievement which, combined with real-time lambda management and internetworking protocol capability, makes them a leader in regional networking systems.

Look also to optical guru Xin Cheng, a friend of Simon Cao's from their days together at E-Tek. Cheng harbors a vision of metro WDM in line with that of Rohit Sharma. His company, Sorrento Networks, uses Simon's PowerMux in his multiprotocol 32/64/128 channel systems. In addition to dynamic lambda management capabilities similar to ONI's, Sorrento also boasts an *all-optical* switch scalable from 4 x 4 through 512 x 512 ports. Currently in beta-release to companies unspecified, is it MEMS? Bubbles? … Or liquid crystals? Cheng, who exhibits symptoms of David Huber–like stealthiness, won't say. So Sorrento remains a focus of expectation until further notice and Chorum and ONI join our list. Sadly, Ciena leaves it.

George Gilder and Charles Burger
January 16, 2001

TELECOSM TECHNOLOGIES

ASCENDANT TECHNOLOGY	COMPANY (SYMBOL)	REFERENCE DATE / PRICE		DEC '00: MONTH END	52 WEEK RANGE	MARKET CAP
WINGS OF LIGHT						
Wireless, Fiber Optic Telecom Chips, Equipment, Systems	Lucent (LU)	11/7/96	11 25/32	13 1/2	12 3/16 - 75 3/8	45.8B
Wireless, Fiber Optic, Cable Equipment, Systems	Nortel (NT)	11/3/97	11 1/2	32 1/16	30 - 89	98.0B
Optical Fiber, Photonic Components	Corning (GLW)	5/1/98	13 41/64	52 13/16	34 5/16 - 113 5/16	48.2B
Wave Division Multiplexing (WDM) Components	JDS Uniphase (JDSU)	6/27/97	3 5/8	41 11/16	37 - 153 7/16	40.1B
Adaptive Photonic Processors	Avanex (AVNX)	3/31/00	151 3/4	59 9/16	41 5/8 - 273 1/2	3.9B
All-Optical Cross-Connects, Test Equipment	Agilent (A)	4/28/00	88 5/8	54 3/4	38 1/16 - 162	24.9B
Tunable Sources and WDM Components	New Focus (NUFO)	11/30/00	20 5/16	34 3/4	16 - 165 1/8	2.2B
Crystal-Based WDM and Optical Switching	Chorum (private)	n/a	n/a	n/a	n/a	n/a
WDM Metro Systems	ONI (ONIS)	12/29/00	39 9/16	39 9/16	22 1/4 - 142	5.2B
THE LONGEST MILE						
Cable Modem Chipsets, Broadband ICs	Broadcom (BRCM)	4/17/98	6*	84	74 3/4 - 274 3/4	19.8B
S-CDMA Cable Modems	Terayon (TERN)	12/3/98	15 13/16	4 1/16	3 1/2 - 142 5/8	267.7M
Linear Power Amplifiers, Broadband Modems	Conexant (CNXT)	3/31/99	13 27/32	15 3/8	13 3/4 - 132 1/2	3.7B
THE TETHERLESS TELECOSM						
Satellite Technology	Loral (LOR)	7/30/99	18 7/8	3 13/16	2 11/16 - 23 5/8	947.6M
Low Earth Orbit Satellite (LEOS) Wireless Transmission	Globalstar (GSTRF)	8/29/96	11 7/8	29/32	3/4 - 46 3/8	96.3M
Code Division Multiple Access (CDMA) Chips, Phones	Qualcomm (QCOM)	7/19/96	4 3/4	82 3/16	51 1/2 - 200	61.5B
Nationwide CDMA Wireless Network	Sprint (PCS)	12/3/98	7 3/16 *	20 7/16	19 3/8 - 66 15/16	19.1B
CDMA Handsets and Broadband Innovation	Motorola (MOT)	2/29/00	56 53/64	20 1/4	15 13/16 - 61 1/2	44.2B
Wireless System Construction and Management	Wireless Facilities (WFII)	7/31/00	63 5/8	36 1/4	27 1/8 - 163 1/2	1.6B
THE GLOBAL NETWORK						
Metropolitan Fiber Optic Networks	Metromedia (MFNX)	9/30/99	12 1/4	10 1/8	9 1/8 - 51 7/8	5.6B
Global Submarine Fiber Optic Network	Global Crossing (GX)	10/30/98	14 13/16	14 5/16	11 1/4 - 61 13/16	12.7B
Regional Broadband Fiber Optic Network	NEON (NOPT)	6/30/99	15 1/16	5 7/8	3 1/2 - 159	110.2M
Telecommunications Networks, Internet Backbone	WorldCom (WCOM)	8/29/97	19 61/64	14 1/16	13 1/2 - 52 1/2	40.5B
Global Submarine Fiber Optic Network	360networks (TSIX)	10/31/00	18 1/8	12 3/4	10 - 24 3/16	10.4B
CACHE AND CARRY						
Directory, Network Storage	Novell (NOVL)	11/30/99	19 1/2	5 7/32	4 7/8 - 44 9/16	1.7B
Java Programming Language, Internet Servers	Sun Microsystems (SUNW)	8/13/96	6 7/8 †	27 7/8	25 1/8 - 64 11/16	89.8B
Network Storage and Caching Solutions	Mirror Image (XLA)	1/31/00	29	3 11/16	2 13/16 - 112 1/2	391.2M
Disruptive Storewidth Appliances	Procom (PRCM)	5/31/00	25	12 31/32	10 1/4 - 89 3/4	150.7M
Remote Storewidth Services	Storage Networks (STOR)	5/31/00	27*	24 13/16	16 1/2 - 154 1/4	2.4B
Complex Hosting and Storewidth Solutions	Exodus (EXDS)	9/29/00	49 3/8	20	19 7/16 - 89 13/16	8.5B
THE MICROCOSM						
Analog, Digital, and Mixed Signal Processors	Analog Devices (ADI)	7/31/97	11 3/16	51 3/16	41 5/16 - 103	18.3B
Silicon Germanium (SiGe) Based Photonic Devices	Applied Micro Circuits (AMCC)	7/31/98	5 43/64	75 1/16	25 1/4 - 109 3/4	22.2B
Programming Logic, SiGe, Single-Chip Systems	Atmel (ATML)	4/3/98	4 27/64	11 5/8	9 3/8 - 30 11/16	5.4B
Digital Video Codes	C-Cube (CUBE)	4/25/97	23	12 5/16	8 7/8 - 106 1/4	609.0M
Single-Chip ASIC Systems, CDMA Chip Sets	LSI Logic (LSI)	7/31/97	15 3/4	17 3/32	16 3/16 - 90 3/8	5.5B
Single-Chip Systems, Silicon Germanium (SiGe) Chips	National Semiconductor (NSM)	7/31/97	31 1/2	20 1/8	17 1/8 - 85 15/16	3.5B
Analog, Digital, and Mixed Signal Processors, Micromirrors	Texas Instruments (TXN)	11/7/96	5 15/16	47 3/8	35 - 99 3/4	82.0B
Field Programmable Gate Arrays (FPGAs)	Xilinx (XLNX)	10/25/96	8 7/32	46 1/8	35 1/4 - 98 5/16	15.2B
Seven Layer Network Processors	EZchip (LNOP)	8/31/00	16 3/4	9 5/8	5 5/8 - 43 3/4	62.1M
Network Chips and Lightwave MEMS	Cypress Semiconductor (CY)	9/29/00	41 9/16	19 11/16	18 1/4 - 58	2.6B

DELETED FROM THE TABLE: CIENA **ADDED TO THE TABLE: CHORUM and ONI** † SPLIT ADJUSTED THIS ISSUE * INITIAL PUBLIC OFFERING

NOTE: The Telecosm Table is not a model portfolio. It is a list of technologies in the Gilder Paradigm and of companies that lead in their application. Companies appear on this list only for their technology leadership, without consideration of their current share price or the appropriate timing of an investment decision. The presence of a company on the list is not a recommendation to buy shares at the current price. Reference Price is the company's closing share price on the Reference Date, the day the company was added to the table, typically the last trading day of the month prior to publication. Mr. Gilder and other GTR staff may hold positions in some or all of the stocks listed.

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