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The TeraBeam Era

It is late in February in Seattle, and I am gazing through a dirty window in a small office building off Mercer Street on Capitol Hill. This is the land of fog and microsmog, drizzle and mist. Would you believe that I have a sunburn from a waterfront run this morning? Would you believe that behind this smear of window I am currently basking in the full blaze of the telecosm streaming through at 2 gigabits per second?

Catching the blast of light as it comes through the window and turning it into an incandescence of swashbuckling Sean Connery images, video teleconferencing banter, and file transfer gigabit bursts, is a pastel box the size of a flat panel computer display containing a series of ingenious inventions that reduce its cost to $150. Can you spare a dime for a multimedia gigabit per second?

TeraBeam commands at once the most disruptive and most redemptive technology in all communications. I have been looking for such a company for a decade.

The company I am visiting is **TeraBeam**, and it commands at once the most disruptive and most redemptive technology in all communications–cheap, cellular, wireless multigigabit optics. The terabits will come next year to a location near you. Closing the last mile gap between the wavelength division multiplexed (WDM) floods of fiber and the copper cages of kilohertz telephony is this ingenious new point-to-multipoint technology. Point-to-multipoint, if you can do it, means cheap shared bandwidth, each transceiver at the hub serving scores of customers. It is the first approach that has the potential to operate in the tens of gigabits per second and meet the floods of WDM backbone bandwidth with comparable bandwidth in the last mile.

In This Issue:

I have been looking for such a company for a decade. In the confidence that I could find it, I denounced the spectrum auctions for LMDS (Local Multipoint Distribution Service). But I finally gave up and decided that there would be room for a microwave era before wireless optics inherited the broadband mantle. Surprisingly enough, it turned out to be tediously difficult to shuffle microwaves across a city. Continual delays afflicted the point-to-multipoint gear needed to serve cheaply the target population of some 700,000 U.S. office buildings that have more than a hundred employees. Today literally thousands of companies are struggling with the problem–**P-COM** (PCMS), **Netro** (NTRO), **Triton**, **Nortel** (NT), and **Lucent** (LU). **Teligent** (TGNT), **Nextlink** (NXLK), **Winstar** (WCII), and others are rolling out their systems one by one at T-1 (1.544 Mbps) or T-3 (45 Mbps) bandwidths, nearly all point-to-point, with primitive pairs of microwave radios. After four years, the total number of buildings served by microwave wireless still stands in the low thousands. Teligent is actually adding wireline connections faster than wireless ones (see Chart 1, page 3). Over at Nextlink, when we ask how the radios are doing, they say, "Great, great, we have demand to sustain a year-and-a-half of new installations."

When we breathlessly exclaim our relief that someone has made point-to-multipoint radios that work, our Nextlink friend corrects us: "We meant point-to-point installations."

"What about multipoint?" we ask, knowing that up spectrum is a much less attractive alternative to fiber if the network must be stitched together from point-to-point links.

The first effect of the new wireless optics will be to disrupt the business plans of all the 24 GHz (Teligent), 28 GHz (Nextlink) and 38 GHz (Winstar) microwave companies.

"Well, they're trying very hard."

Trying very hard turns out to mean that among the four finalist vendors announced as Nextlink's future radio makers six months ago–**Ericsson** (ERICY), **SpectraPoint**, **Wavtrace**, and **Digital Microwave** (DMIC)–it is possible that none of them will be on the list when the absolutely positively final finalists are announced in another few weeks. In a world in which all the crucial Telecosm technologies are gleefully rolling downhill, always beating out last month's bandwidth projections, up-spectrum radio seems to be pushing a bandwidth boulder uphill. Our friend asserts his confidence that the $700 million Craig McCaw spent on LMDS spectrum won't be wasted, "because he is a man of vision." Perhaps he can sell it to **AT&T** (T).

I have been listening to the technology. Could it be trying to tell me something?

As TeraBeam founder Greg Amadon puts it, "For the $28 million that McCaw paid for LMDS spectrum in Seattle alone, we can build an entire 100 gigabit per second system." That means a cell with four sectors each handling twenty-four customers with 1 gigabit per second downstream links.

The first effect of the new wireless optics will be to disrupt the business plans of all the 24 gigahertz (Teligent), 28 gigahertz (Nextlink) and 38 gigahertz (Winstar) microwave companies. Less affected will be the vendors of spread spectrum fixed wireless service to residences and smaller offices and the MMDS (Multichannel Multipoint Distribution Service) plans of **WorldCom** (WCOM) at 2.5 gigahertz. These longer wavelength systems may well find application in towns and rural areas where the 3 kilometer span of TeraBeam optics will seem too small.

But a technology so massively superior is chiefly a bearer of huge opportunities. TeraBeam portends the impending end of the last mile problems of the some thirty-nine companies laying fiber optic backbone networks, including Nextlink. The amazing bitstream pouring through this window on Mercer Street throbs with a High Definition Television stream (Sean Connery cavorting in *The Rock*), five big test files of a gigabyte apiece, and an online video teleconference with no perceptible lags, in which an engineer is responding to my questions about the broadband flood. (Among TeraBeam's inventions is a way to remove the half-second delay from MPEG2 video transmissions, rendering them suitable for video teleconferencing.)

Two kilometers away from Mercer Street, across Lake Union on Queen Anne's Hill, marked by a visible red light for tracking, is the source of the bitstream. It is an invisible infrared beam at a 1550 nanometer wavelength. In the past, such a bitstream would demand a fiber optic link. But between us and the house on Queen Anne's Hill is nothing but light and air. It turns out that I was correct in speculating 10 years ago that if you could send a 1550 nanometer optical signal 1000 kilometers down a fiber thread one tenth the width of a human hair, you might eventually be able to send the signal 3 kilometers without the thread.

Since the early 1990s, the fiber distances have lengthened to 3000 kilometers, the colors of usable light have multiplied to hundreds, and erbium doped amplifiers have gained several watts of power. And sure enough, after more limited successes by **Canon** (CANNY), **Jolt**, and Lucent, a group of spectronic wizards in Seattle have mastered most of the challenges of wireless optics. Fiber insulates the electromagnetic signal in glass; TeraBeam insulates it in air. But it is the same stream of pulsed waves.

Amadon's Photonic Epiphany

The story began in March 1997, when a photonic epiphany struck Greg Amadon. A serial entrepreneur with several minor successes in cellular phones and optic devices, he was also working with engineer Richard Rallison, who had launched a LIDAR (laser radar) system used for detecting windshear at airports. Amadon found his attention wandering toward the window during an entrepreneurial luncheon in the Chairman's Room at the Columbia Tower Club. Atop Seattle's tallest building, it was a site where the mind naturally tends to slip into a self-congratulatory haze of condescension toward the rest of the world spread out so far below.

Instead, the twenty venturers were animatedly chattering about the Next Big Thing, which they assumed would be a belt-borne wireless device that could discreetly divulge to others at a bar your availability, preferences, and technical specifications. Of course, if the specs were truly definitive, why go to the trouble of trundling down to the bar? Just send a virtual simulation of yourself over the net. Written in Java, it could be implemented on any operating system without disturbing you at all. Or it could be compiled by a computer aided manufacturing program and extruded in cellulose by one of those devices that delivers plastic models of specified designs. If you get a bite or a buyer, you can hold an eBay auction.

Anyway, if your amusement is already wearing thin, you can understand why Amadon began ruminating on wireless optics. He found himself gazing out the window at the scene below, dense with glass towers. Most of the plans of the Internet entrepreneurs gathered in the Columbia Club tower depended on broadband communications.

How on earth could all these vertical structures be served with fiber optics? he mused. Expensively, he thought. The estimate at the time was some $300,000 dollars per building, with tangled wires in conduits under the streets and along the walls and up the elevator shafts. Government auctions were scheduled for LMDS microwaves, but Amadon wondered where the roof borne antennas could be placed and whether this microwave bandwidth, restricted to the low megabits per second, would suffice in the face of an explosion of Internet traffic. He suddenly arrived at the thought that the real next big thing would be optical wireless cellular communications through all those glass windows.

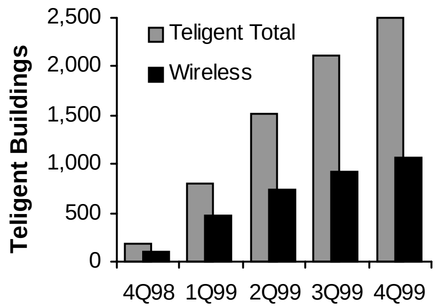
The others at the luncheon raised the usual objections. Fog, snow, rain, sleet, and turbulent air, even the tinted windows themselves would shrink the distance the signals could travel to an unusable few feet. The lasers would burn out people's eyes. Similar objections afflicted the early years of fiber optics, when experts concluded that impurities in the fiber would bar long-distance communications. But Amadon was not convinced. A 1973 Stanford graduate in political science, he had become infatuated with holograms as a student and had built himself a holographic laboratory to contrive those three dimensional images. Then he had gone on to become a White House correspondent during the Carter years and a cameraman for CBS News.

Foreshadowing his later epiphany, one of Amadon's jobs was to cover Ronald Reagan at his ranch outside Santa Barbara. The young amateur engineer set up a telescopic camera on a promontory some five miles away and took a famous picture of a waving Reagan that the President later signed: "There's nothing like being in the public eye." Amadon invented a holographic lens to compress the telescopes into a few score centimeters. TeraBeam would use both holographic and telescopic technology. These proprietary devices, manufacturable for around $150 apiece, could send and receive infrared beams and focus them on tiny photodetectors that could be coupled to fiber optic cores a few microns wide.

Amadon's invention was exactly on target for the telecosm, and indeed he would find his first major funding for the company at our 1999 Telecosm Conference.

Chart 1

Teligent Fails to Exploit Wireless Advantage



Source: Company Reports

Up-Spectrum Ascent

The key to the Telecosm is the shift of the focus of ascendant technology from the particle side to the wave side of the quantum duality, from the solid states of silicon to the spectronics of communications. The ruling realm of waves is the electromagnetic spectrum, which defines an essentially infinite span of frequencies, measured in hertz or cycles per second that begins with DC, or direct current (no cycles at all), and runs all the way up through cosmic rays at the top, measured in the petahertz (10 to the 15^{th}). So far wireless communications has used well under 1 percent of the available frequencies.

For a decade, I have been awaiting the consummation of the spectronics paradigm. Conveying the benefits of a move up-spectrum, higher frequencies bring shorter wavelengths; smaller, more directional antennas; less interference; more capacity; and more bandwidth. More bandwidth, as Claude Shannon showed in his paper launching communications theory in 1948, means less power. In the new paradigm of portable, handheld, fiber optic, battery or solar powered equipment, power would prove to be the most binding constraint and scarcity. But radio engineers have preferred a regime of long and strong, high-powered large wavelengths that can bounce around the globe, scuttle along the ground, and penetrate walls. They have moved up spectrum only when there was no other way to find more capacity.

For example, the two-way wireless industry began at 100 megahertz and accommodated a few hundred ambulances and police cars. Moving up to 400 megahertz in the mid 1970s, the special mobile radio systems served tens of thousands of taxis, delivery vehicles, and other business communicators. In the 1980s, the industry ascended to 800 megahertz and scored millions of users around the world with analog cellular systems. In the 1990s, Personal Communications Systems (PCS) climbed up to a band at 2 gigahertz and moved toward the hundreds of millions of subscribers. In the new millennium, the entire spectrum is opening up and the harvest is rapidly approaching the billions.

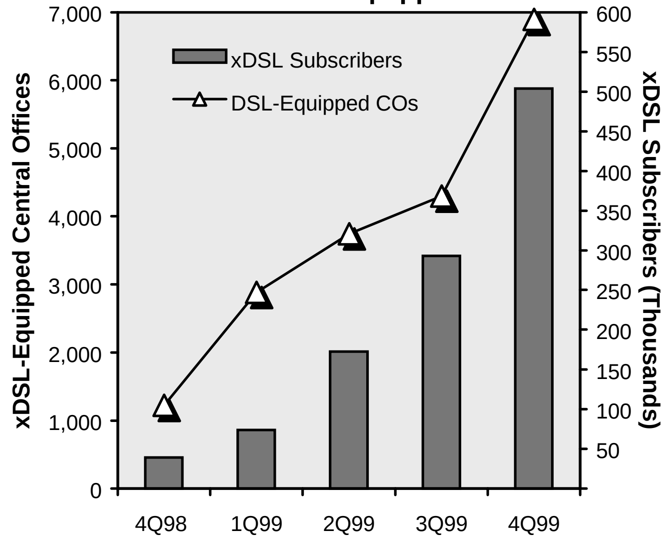
Both at the Telecosm Conference and in the GTR, we have stressed the ultimate promise of optical frequencies in the air and even entertained

TeraBeam portends the impending end of the last mile problems of the some thirty-nine companies laying fiber optic backbone networks, including Nextlink.

Access Update

Chart 2

US xDSL Subscribers Climbing as Telco Central Offices are Equipped for Service



Source: Telechoice

While awaiting fiberless gigabit optical access, we can contemplate lesser last mile links, which are making progress in bringing broadband to our homes and offices. The US and Canadian DSL market hit 600 thousand subscribers in 1999, with US DSL subscribers at 504 thousand (Chart 2). US and Canadian cable modem subscribers topped 1.8 million at year end. Cable modems also maintained their edge in penetration numbers.

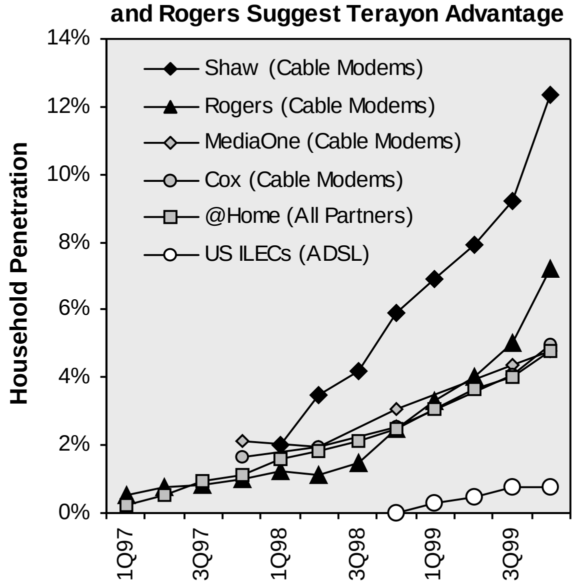
@Home's cable modem subscribers neared 5% of homes passed by two-way service. But even typical cable modem penetration of 5% pales compared to Shaw's deployment of Terayon S-CDMA modems which have exceeded 12% penetration, and Rogers appears to be duplicating Shaw's S-CDMA success with penetration rates popping up in the second half of 1999 following adoption of Terayon's technology (Chart 3). S-CDMA's success is reflected in the latest market share figures that show Terayon leapfrogging Com21 and Nortel to capture second place in 4Q99 (Charts 4, 5). And Terayon just pre-announced higher revenue and earnings expectations for the current quarter in part due to Rogers' continued surge.

The soaring demand for broadband Internet access reflects the increasing dominance of Internet usage. The January Teen Caravan study by Opinion Research Corporation found an amazing 91% of US teenagers use the Internet, 66% at school, 64% at home, 21% from a friend's house and 12% from the library. Furthermore, a 56% majority of US adults now use the Net, with 46% accessing from home, 37% from work, and 21% accessing from other locations according to Harris Interactive's December survey. PC use (any location) has also surged to 79% of adults (Chart 6). With 90% of home PC users online along with 79% of work PC users, the link between PC use and the Internet is clear (Chart 7).

Though Japan has seen a Net driven boom in PC sales, alternative access devices are rapidly emerging. The largest Japanese Internet service provider is now

Chart 3

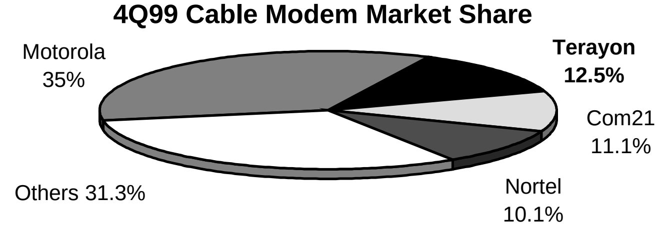
Superior Penetration Figures for Shaw and Rogers Suggest Terayon Advantage



Sources: Company Reports, TeleChoice

Chart 4

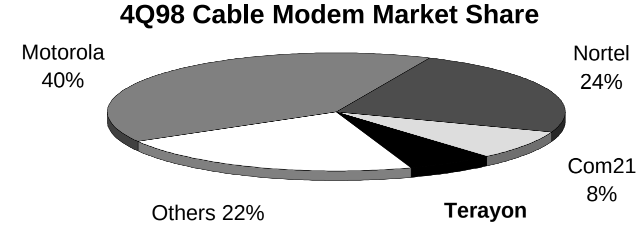
Terayon Surges into 2nd Place in 4Q99 Cable Modem Market Share



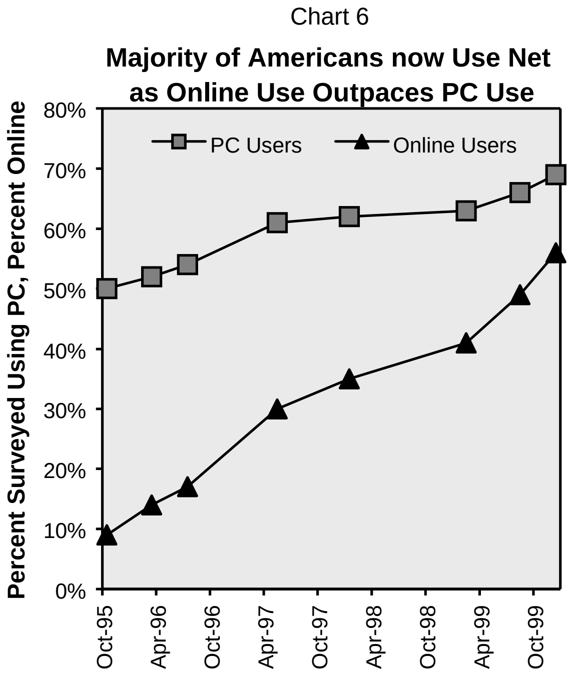
Source: Cahners In-Stat Group

Chart 5

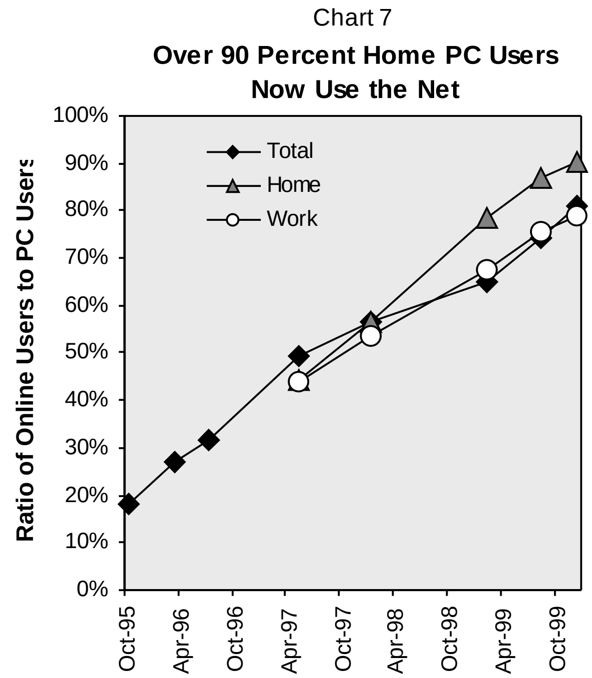
4Q98 Cable Modem Market Share



Source: Cahners In-Stat Group



Source: Harris Interactive

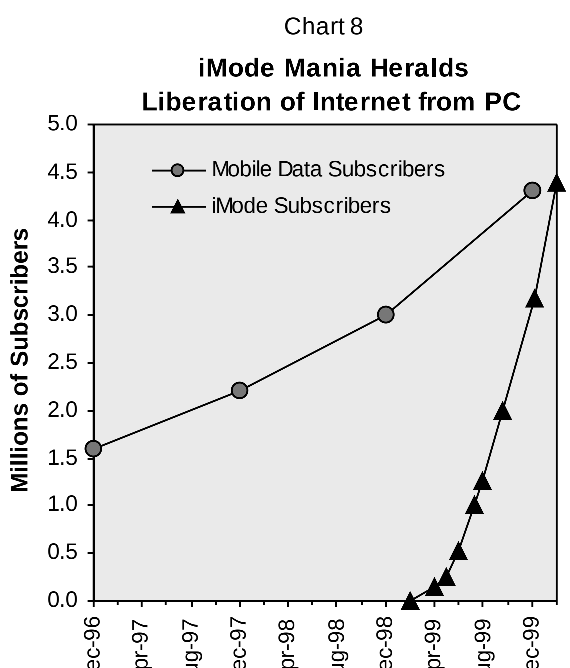


Source: Harris Interactive

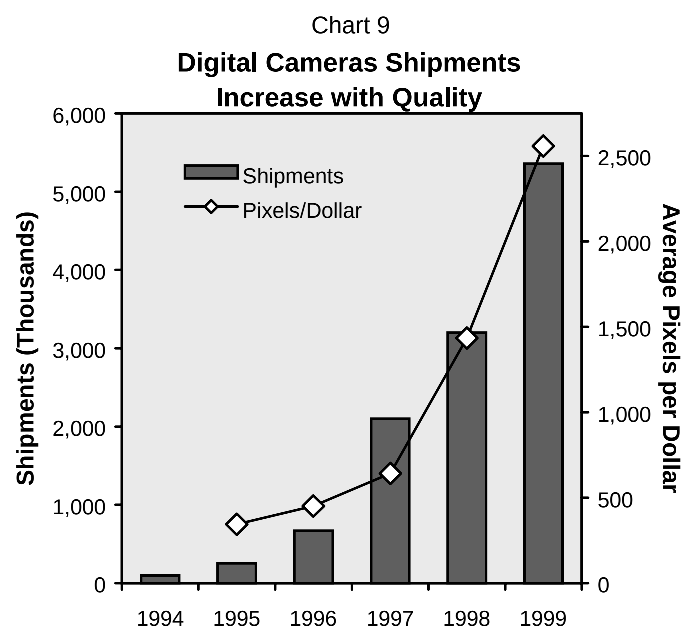
NTT DOCOMO due to the enormous popularity of their mobile wireless data service, iMode. (Chart 8). Slow, clunky, and popularly used by teenage girls passing notes and tracking each other down in the mall, this very narrowband (9kbps) wireless data service nevertheless both demonstrates the enormous underlying demand for wireless data and the ongoing liberation of the net from the PC. IMode-connected pocket email terminals, handheld and in-car personal navigator devices, and digital cameras that can upload photos on the go, join data-ready phones as nascent net devices.

We have long followed the development of the digital camera market in the GTR (Chart 9). The adoption of digital cameras generally represents the progress of the Microcosm in overtaking yet another formerly analog realm. But more specifically, they are dependant on the rapid improvement of single chip systems on silicon, improvements in battery and power consumption techniques, compact storage technology, high resolution color displays, and now even wireless Internet access, all key measures of Telecosmic progress.

-Ken Ehrhart



Sources: Company Reports, Yankee Group, MMTA/TIA



Sources: GTG, Nikkei Market Access, Dataquest

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the idea of ultraviolet. But we have been mostly restricted to military experiments and small enterprises in Israel. At the 1997 Telecosm, Canon announced but refrained from demonstrating its optical Canonbeam. At the 1998 Telecosm, David Medved of Jolt in Tel Aviv explained the physics of over-the-air optics and described his company's several successes and customers. In 1999, Robert Martin, chief technical officer of Lucent, announced the Optic Air Wavestar product. In January of this year, the Lucent device made a stir when it was used at the Superbowl to send uncompressed HDTV signals at 1.5 gigabits per second from a camera in a truck a kilometer away to the ABC hub at the Georgia Dome.

Neither Jolt nor Lucent, however, introduced a fully telecosmic cellular product. Optics cannot be fully disruptive until it can serve thousands of customers in a particular locality at a cost competitive with wireline systems, microwaves, fibers, and power lines. Several other companies offered interesting point-to-point line-of-sight technologies that demonstrated the utility of these optical infrared frequencies. But for actual up-spectrum companies, we have long had to settle for the 24 gigahertz, 28 gigahertz, and 38 gigahertz of LMDS, all far below the 200 terahertz infrared region where fiber, and now fiberless, optics operates. With its obnoxious auctions, exclusive spectrum assignments, and radios that would always be ready next year, LMDS was mostly a default paradigm. But now that episode is over and the TeraBeam era begins.

To achieve the breakthrough, TeraBeam had to invent both a cellular hub and customer premises equipment that could scale to scores of thousands of customers. In the process, the team led by Amadon and his colleague Richard Rallison concocted some seven major innovations.

Crucial was a point-to-multipoint downstream technology from the base station or hub to the customer's premises. Without point-to-multipoint, all the expensive optics would have to be duplicated for every user at both ends. It would be necessary to create Lucent's Superbowl setup for every connection. At present, this is what most LMDS deployments do. They use a pair of point-to-point radios for every customer–a transceiver in the hub and a transceiver on the roof of the office–like a set of citizens band radios or walkie talkies. If wireless optics used that topology, it would be limited to expensive point-to-point applications.

In a compact and cost-effective chassis, the TeraBeam hub broadcasts encrypted signals downstream to all users, while keeping point-to-point upstream links from each individual customer site separate. Each downstream floodlight serves one 90 degree cell sector which contains, potentially, scores of customers. The customers identify their own messages by an IP (Internet Protocol) address, then decrypt them in real time, and send responses back to be detected and routed by the hub.

IRE-Polus' EDFA Breakthrough

As in WDM fiber optics, the most crucial component is the erbium doped fiber Amplifier (EDFA) that can enhance hundreds of separate wavelengths or bitstreams at a time. In fiber optics, the EDFA is installed in the fiber itself, to enhance the signal and extend the distance it can travel without being electronically regenerated. In the TeraBeam system, the base station hub houses the EDFA. There it takes the low milliwatt signals from the network and ratchets up their power to a level where they can be broadcast through a cell with a radius of three kilometers or more.

Without this amplifier, it would be necessary to regenerate each signal separately, duplicating this costly and complex device for every customer. For each gigabit link, the amplifier must provide a 200 milliwatt signal (for lower bandwidth connections, the 200 milliwatt signal can be split into signals of 20 milliwatts or less). Some 200 milliwatts for each of twenty-four users in a sector adds up to 5 watts. TeraBeam's problem was apparently a showstopper. Oriented toward the lower powers of fiber optics, the industry did not manufacture 5-watt EDFAs.

As in fiber optics, the gating component in an EDFA is the external pump laser that powers the device. The key manufacturers of pump lasers are **JDS Uniphase** (JDSU) and **SDL** (SDLI), but for standard applications in WDM, EDFAs need a power of only 200 milliwatts. SDL, with its military origins, makes pump lasers that operate at close to 2 watts. SDL's multiwatt pumps are now in demand as actuators for undersea applications and for Raman Amplifiers. Ramans are needed in the long-distance WDM systems now being rolled out by **Corvis** and Nortel's Qtera to reach 3,000 kilometers through fiber without regeneration. But SDL's pumps do not suffice to propel TeraBeam's signals 3 kilometers through the air.

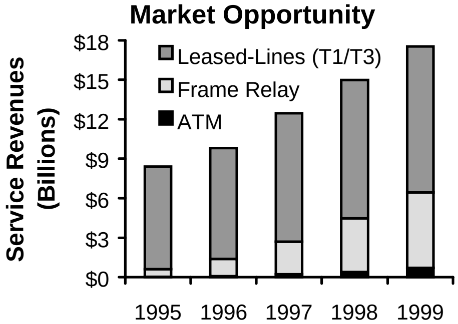
On the TeraBeam advisory board, however, is Valentine Gapontsev, a burly saturnine expert in optics, who in a previous career in Russia specialized in high-powered lasers used to cut sheet steel or intercept missiles. Now CEO of **IRE-Polus Group**–with their U.S. division, IPG Photonics, in Sturbridge, Massachusetts–he runs the world's only company that can make pump lasers that operate at 5 watts. With high-powered uses multiplying in communications, IRE-Polus should become increasingly important to the Telecosm. TeraBeam has negotiated an exclusive contract with IRE-Polus for high-powered EDFA modules used in broadband wireless optics.

The rest of the TeraBeam hub uses lasers and photodetectors similar to those found in fiber optics systems. Focusing on Internet uses and eschewing the complexities of ATM used by Lucent, TeraBeam's routers and switches employ gigabit ethernet to transmit IP packets. Using advanced telescope optics and unique, high-powered amplifiers in the transmitter, Amadon's strategy is to overdesign the hubs in order to enable cheap and robust systems at the customers' premises.

It is at the customers' premises that the full novelty of TeraBeam becomes evident. Crucial is a compact telescopic antenna design that allows transmission through windows without endangering the eyes of anyone who happens to look into the beam. This requirement meant giving up the previous idea of using cheap 780 nanometer lasers manufactured by the billions for CD players. The 780 wavelength is so close to the frequency of visible light that it readily enters and damages the human retina. The 1550 nanometer wavelength used in fiber optics, however, is too large to damage the eye at the power levels used by TeraBeam. At 1550 nanometers, moreover, the tints commonly used in office building glass function as a passband filter rather than as a blocking filter.

Chart 10

Business Data Services Market Opportunity



Sources: Data Communications, Vertical Systems Group, MMTA/TIA

Also needed was a large collecting aperture to receive the light without making the telescope too large to be readily placed in a building window. Made of a proprietary material, Amadon's holographic optical element costs $150 to build and eliminates all the expensive curved lenses that raise the cost of a comparable telescope to $12,000. It enables the 16 inch collector to be incorporated into a receiver no larger than a DirecTV antenna.

Enhancing the system is a pointable beam shaping-technology that allows the transmission of narrow signals to the customer. The directionality of this kind of light permits unlimited frequency reuse since beams can be located side by side. By contrast an LMDS signal would need a 150-foot diameter antenna and elaborate Faraday cage insulation to prevent the different signals from interfering with one another.

The light is narrowly focused to an area of 120 centimeters over a kilometer path. Movement could cause loss of closure. So sophisticated tracking technology enables adjustment to moving targets, such as skyscraper towers shifting in the wind. Although the system automates the adaptive process, it also includes a manual default mechanism.

TeraBeam takes the advances of WDM optics and moves them to the local loop. At the outset, the WDM will be restricted to the company's backhaul systems linking to the larger fiber networks. Relieving any need to use many lambdas in the cell itself is TeraBeam's ability to reuse the same frequency multiple times through juxtaposing the narrow beams of light without interference. But in the future, TeraBeam's technology can also use WDM to multiply capacity and flexibility in the local loop.

The company has a $27 million investment from a major manufacturing partner that is building the systems. TeraBeam currently employs some 130 people in Seattle and is continuing to expand. Its strategy is to retain control of its intellectual property and service business, while outsourcing manufacturing and equipment sales.

TeraBeam's business plan envisages a cost per sector for a 1 gigabit per second initial system as $26,000 a month dropping to $12,000 over time, including the customer's equipment. Anticipated monthly revenues per customer are $6,300. Break even comes at two customers per sector. The initial full load of twenty-four customers will bring in $150,000 per month. Using splitters, WDM, and other enhancements could raise capacity and potential revenue several times higher. A scaleable system, TeraBeam will be able to expand both its bandwidth and capacity in accord with demand.

Planning to become a major player in U.S. cities, TeraBeam has hired as CEO Dan Hesse, a 23-year veteran of AT&T and president of AT&T's wireless unit. Leaving behind some $50 million in options at AT&T on the eve of its wireless IPO, Hesse will lead TeraBeam into a direct competition with all the LMDS companies. It currently commands eight hubs in Seattle and plans to roll out service in five cities by June and in fifty markets over the next 30 months. It also contemplates alliances with network partners such as **Level 3** (LVLT) and **Global Crossing** (GBLX).

George Gilder, March 10, 2000

With high-powered uses multiplying in communications, IRE-Polus—the world's only company that can make pump lasers that operate at 5 watts—should become increasingly important.

TELECOSM TECHNOLOGIES

ASCENDANT TECHNOLOGY	COMPANY (SYMBOL)	REFERENCE DATE	REFERENCE PRICE	FEB-'00: MONTH END	52 WEEK RANGE	MARKET CAP.
CABLE TECHNOLOGIES/SERVICES						
Cable Modem Chipsets	Broadcom Corporation (BRCM)	4/17/98	6 *	197 3/8	46 1/4 - 325 5/8	41.118B
S-CDMA Cable Modems	Terayon (TERN)	12/3/98	31 5/8	257 1/8	25 3/4 - 280	5.605B
MICROCHIP TECHNOLOGIES						
Analog, Digital, and Mixed Signal Processors	Analog Devices (ADI)	7/31/97	22 3/8	157 1/4	24 3/8 - 167 1/4	27.105B
Silicon Germanium (SiGe) based photonic devices	Applied Micro Circuits (AMCC)	7/31/98	11 11/32	275 1/16	16 7/8 - 290	16.338B
Programmable Logic, SiGe, Single-Chip Systems	Atmel (ATML)	4/3/98	8 27/32	49 1/2	7 1/2 - 53 1/2	10.895B
Digital Video Codecs	C-Cube (CUBE)	4/25/97	23	93 1/4	17 1/4 - 77 15/16	3.786B
Linear CDMA Power Amplifiers, Cable Modems	Conexant (CNXT)	3/31/99	13 27/32	98 1/4	8 1/2 - 132 1/2	19.905B
Single Chip ASIC Systems, CDMA Chip Sets	LSI Logic (LSI)	7/31/97	31 1/2	64	12 1/4 - 71	19.040B
Single-Chip Systems, Silicon Germanium (SiGe) Chips	National Semiconductor (NSM)	7/31/97	31 1/2	75 1/8	8 7/8 - 76 1/2	12.997B
Analog, Digital, and Mixed Signal Processors, Micromirrors	Texas Instruments (TXN)	11/7/96	11 7/8	166 1/8	43 3/4 - 170	131.530B
Field Programmable Gate Arrays (FPGAs)	Xilinx (XLNX)	10/25/96	8 7/32	79 3/4	16 7/16 - 84 1/2	25.623B
OPTICAL NETWORKING						
Wave Division Multiplexing (WDM) Systems, Components	Ciena (CIEN)	10/9/98	8 9/16	159 7/8	16 5/8 - 180 3/4	22.372B
Optical Fiber, Photonic Components	Corning (GLW)	5/1/98	40 15/16	187 7/8	74 11/16 - 203 1/4	48.415B
Submarine Fiber Optic Networks	Global Crossing (GBLX)	10/30/98	14 13/16	46 5/8	20 1/4 - 64 1/4	37.077B
Wave Division Multiplexing (WDM) Components	JDS Uniphase (JDSU)	6/27/97	7 1/4	263 5/8	21 3/8 - 280 7/8	93.886B
Broadband Fiber Network	Level 3 (LVLT)	4/3/98	31 1/4	113 7/8	45 1/4 - 126 5/8	40.952B
Wireless, Fiber Optic Telecom Chips, Equipment, Systems	Lucent Technologies (LU)	11/7/96	11 25/32	59 1/2	48 1/4 - 84 1/8	189.805B
Broadband Fiber Network	Metromedia FIber Network (MFNX)	9/30/99	24 1/2	71 15/16	21 1/16 - 83	16.737B
Wireless, Fiber Optic, Cable Equipment, Systems	Nortel Networks (NT)	11/3/97	23	115 7/8	26 1/8 - 126 1/2	157.488B
Broadband Fiber Network	NorthEast Optic Network (NOPT)	6/30/99	15 1/16	112 1/4	12 - 159	1.829B
WIRELESS TECHNOLOGIES/SERVICES						
Low Earth Orbit Satellite (LEOS) Wireless Transmission	Globalstar (GSTRF)	8/29/96	11 7/8	28 1/2	12 5/8 - 53 3/4	2.730B
Satellite Technology	Loral (LOR)	7/30/99	18 7/8	15 1/2	14 7/8 - 25 3/4	3.796B
CDMA Handsets and Broadband Innovations	Motorola (MOT)	2/29/00	172	172	65 3/8 - 175 1/2	104.765B
Nationwide Fiber and Broadband Wireless Networks	Nextlink (NXLK)	2/11/99	20 7/16	110 1/2	23 7/8 - 119 1/8	14.708B
Code Division Multiple Access (CDMA) Chips, Phones	Qualcomm (QCOM)	7/19/96	4 3/4	142 7/16	9 1/8 - 200	100.947B
Nationwide CDMA Wireless Network	Sprint PCS (PCS)	12/3/98	7 3/16	51 3/4	19 1/2 - 57 3/16	48.091B
Broadband Wireless Services	Teligent (TGNT)	11/21/97	21 1/2 *	82 1/8	33 3/8 - 90 3/4	4.443B
INTERNET TECHNOLOGIES/SERVICES						
Internet Enabled Business Management Software, Java	Intentia (Stockholm Exchange)	4/3/98	29	19 7/8	17 1/2 - 35 1/4	0.477B
Network storage and caching solutions	Mirror Image (Xcelera) (XLA)	1/31/00	116	346 1/2	5/8 - 371	9.180B
Telecommunication Networks, Internet Access	MCI WorldCom (WCOM)	8/29/97	19 61/64	46 5/8	40 5/8 - 64 1/2	132.415B
Directory, Network Storage	Novell (NOVL)	11/30/99	19 1/2	33 1/16	16 1/16 - 44 9/16	10.795B
Java Programming Language, Internet Servers	Sun Microsystems (SUNW)	8/13/96	13 3/4	95 1/4	24 9/16 - 99 15/16	166.688B

* INITIAL PUBLIC OFFERING

ADDED TO THE TABLE: MOT

As noted in our last issue, Motorola has increasingly focused on its Telecosmic activities and we place them on the list this month for their achievements in CDMA handsets and broadband innovations.

NOTE: This table lists technologies in the Gilder Paradigm, and representative companies that possess the ascendant technologies. But by no means are the technologies exclusive to these companies. In keeping with our objective of providing a technology strategy report, companies appear on this list only for these core competencies, without any judgement of market price or timing. Reference Price is a company's closing stock price on the Reference Date, the date on which the company was added to the Table. Since March 1999, all "current" stock prices and new Reference Prices/Dates are closing prices for the last trading day of the month prior to publication. Mr. Gilder and other GTR staff may hold positions in some or all stocks listed.

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