Light at the Dawn of the Internet

The Foundation

What innovation led to the explosive growth of the Internet?

Some would say the free release, by Tim Berners-Lee, of the World Wide Web (WWW)[1] on April 30, 1993. Others cite Version 1.0 of the graphical browser, Mosaic, introduced on November 11, 1993.[2] While these garnered well-deserved recognition, let us consider another, less well known candidate.

During this formative era, Dr. David Huber and Kevin Kimberlin began working together to make high-capacity optical networking systems. Based on his pioneering research at General Instrument and Optelecom Inc. (the firm started by the inventor of the laser,) Huber incorporated and the two formally launched their new company by filing its corporate charter and issuing themselves the founder's shares on November 12, 1993 -- one day after the arrival of Mosaic.[3] [4] [5]

Ciena co-founders David Huber and Kevin Kimberlin

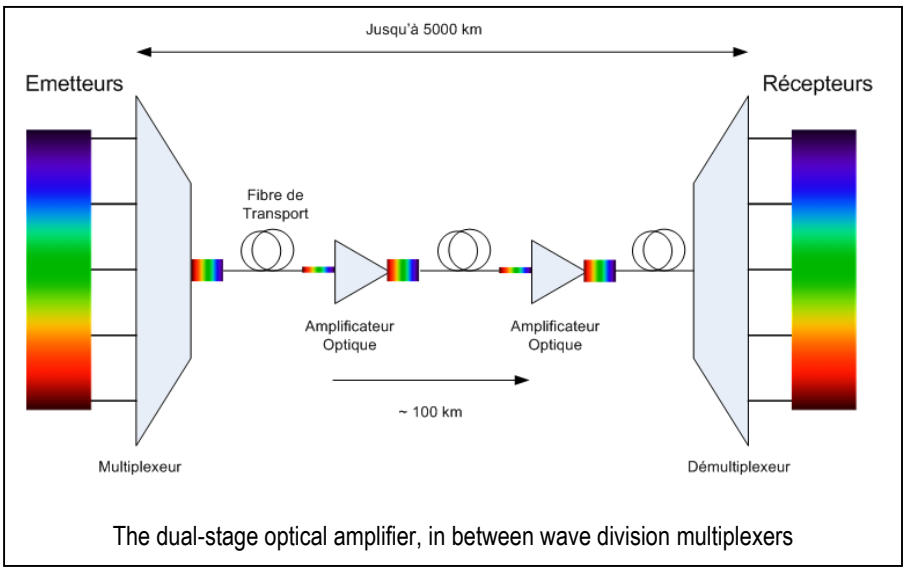
And so CIENA Corporation sprang to life.

An initial equity investment by affiliates of Spencer Trask & Co. was followed by strategic and venture investors as noted in *Fiber Optics and Communications*: "Prior to the IPO, private equity investors following Spencer Trask included AT&T Venture affiliates, Siemens AG Venture affiliates and Sevin Rosen."[6] Spencer Trask then rounded out the start-up funding with a $3 million equipment lease financing from Dominion Ventures.

Conquering Light

With this firm footing, CIENA hired 15 people and licensed 28 patents developed by Dr. Huber. The team, then led by CEO Pat Nettles, set out to make a communication system based on light.

It was a devilishly tricky proposition, transmitting information at 186,000 miles per second. The major problem? The tendency of light to dissipate in even the clearest fiber optic. To compensate for this loss, CIENA tried to exploit Albert Einstein's theory about the spontaneous emission of light– the cornerstone of both the optical amplifier and the laser. Unfortunately, when the team tried this to transmit data on more than one wavelength, the shorter (bluer) of the waves arrived at the compensation amplifier a few nanoseconds after the longer (redder) ones. A few such cascades turned the light-encoded message into gibberish.



The dual-stage optical amplifier, in between wave division multiplexers

This was a showstopper that the engineers at CIENA sweated over for nearly two years. Finally, they emerged from their lab with the crown jewel: a dual–stage, all–optical amplifier. Correcting the wayward wave shifts in a first amplifier *before* regenerating the signal in a second amplifier, CIENA, for the first time, could divide and multiply the many 'dense' wavelengths simultaneously. The engineers held the key to a flawless transmission of data over transcontinental and transoceanic distances.

CIENA filed its patent on the dual-stage amplifier on November 13, 1995.[7] Sensing a landmark event, technology pundit George Gilder proclaimed its significance:

> "CIENA Corp., a small, venture-funded vendor of optical netowrks is now supplying the next generation of backbone gear…**The first application of the all-optical technology in public networks**.[8] Two years later, struck by its profundity as he saw the power of the CIENA gear, Gilder wend even further…"Popularized by Ciena Corporation….the all-optical amplifier...is an invention **comparable to the integrated circuit."**[9]

The Partner

The invention increased fiber bandwidth by orders of magnitude – at least in their lab. But would it work in the real world? To find out, Dr. Huber and Pat Nettles needed a customer with

real backbone – a fiber-optic backbone specifically. Their timing was perfect: just as a ravenous hunger for bandwidth emerged from three distinct corners.

(1.) Commercial – After Tim Berners-Lee unleashed the WWW, the number of Web servers in the world quickly rose from 500 at the end of 1993 to 10,000 by December 1994. Sprint Corporation, because it ran the first long-distance *commercial* Internet service, was well positioned to serve this new demand. Needless to say, CIENA zeroed in on Sprint.

(2.) Government Privatization – At that time, the National Science Foundation ran the nation's optical backbone called NSFNet, a network reserved exclusively for *academic and government users*. But, in response to growing corporate and consumer pressure, Congress passed that National Information Infrastructure Act of 1993. As a result, the NSF transitioned the fiber optic backbone to commercial operators, a privatization that was completed on May 31, 1995. Overnight, SprintLink and the "Sprint and Washington D.C. Network Access Points....began to carry much of the traffic for the U.S. Internet."[10]

Sprint planners were caught flat-footed by the World Wide Web and the privatization of NSFNET.[11] In one year (between 1992 and 1993), their fiber utilization grew from 55% to 65%. By 1995, certain routes were completely overloaded. Sprint's Director of Network Planning, Doug McKinley, succinctly laid out the problem, "We had huge customers (who) wanted everything -- voice, video, data – and they wanted it fast. How were we going to give them the capacity they needed?"

He found the answer in a partnership that would change the world – "teaming with CIENA..…developing high-capacity fiber-optic transmission systems called Dense Wave Design Multiplexing (DWDM)."[12] Making good on their end of the bargain, the CIENA team incorporated their breakthrough dual-stage optical amplifier into a 16 channel wave division configuration. After several tests in Sprint's live backbone, they pronounced the overwhelming success reported by The New York Times:

> "CIENA is the first company to market with a technology called wave division multiplexing"[13]

C. David Chaffee, in his book, *Building the Global Fiber Optics Superhighway,* wrote "CIENA enjoyed the brief golden age that all vendors dream of: The best product, highly in demand, which no competitor could duplicate…As Gilder correctly points out, the reason that WDM was able to take off was the advent of the EDFA" (Erbium-Doped Fiber Amplifier).

Goldman Sachs analysts also took notice, writing in a research note, "If WDM changes network design permanently, as we believe it will, the combination of early adopters at Sprint and Ciena will receive much of the credit."[14]

(3.) Consumer -- Sprint then took one more giant leap, its confidence bolstered by the prospect of much greater bandwidth. On August 20, 1996, just eight weeks after CIENA delivered the first-ever scalable DWDM system, Sprint made its "comprehensive Internet capabilities *directly available to the general public*."[15] Only 200,000 residential customers were invited to 'test-drive' the new service, so it received little notice at the time. But nonetheless, it opened up Sprint's high-speed, low-cost communication network to all comers.

These three data streams – commercial, government and, for the first time, consumers – all converged in the summer of 1996 to make Sprint "the world's largest carrier of Internet traffic."[16]

This was the dawn of the popular Internet.

The Public Offering

By scaling Sprint's network, CIENA grew rapidlym a fact also spotted by Goldman Sachs analysts.

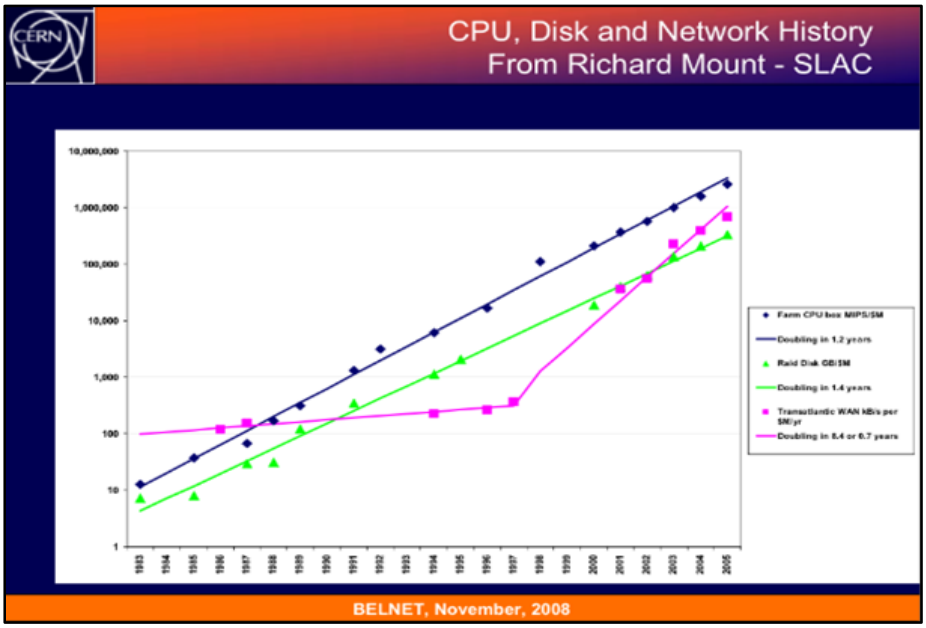
> "CIENA continues to rack up the records:
> (1.) steepest revenue ramp for any company in history, we believe, in the first 12 months of product shipments;
> (2.) most profitable company ever in its first year of product shipments"[17]

CIENA then went public to take full advantage of the opportunity it had created, completing what *The New York Times* said was "the largest stock offering by a start-up in history."[18] At the time of this IPO, *The Wall Street Journal* called CIENA "one of the biggest payouts in venture capital history."[19]

Free Communications

We are now in a position to determine which innovation is most responsible for the explosive growth of the Internet. Consider several seminal networking developments: the ARPANET and optical fiber, both arriving in 1969, and then five years later, the Ethernet and TCP/IP protocols. Later, in that creative cauldron of 1993, the free World Wide Web was released to the public; so too was Mosaic and 'Archie' (the first Web search engine). These and other advances were necessary steps, certainly. But anyone using a 1993 network lumbered along what can only be described as a 'slow lane.' Fundamental as these developments were, we cannot attribute undue credit to any one of them for the explosion of communications that followed. That required capacity -- lots of it.

But something else happened in 1993: CIENA began the paradigm shift in communications" to the "data superhighway" as forecasted in its first business plan. From day one, the firm was chartered to "obsolete the existing plant of the telecommunications industry." Using CIENA gear, data transmission efficiency on single mode fiber (as measured in bits per dollar) rose some 40,000 fold. For all intents and purposes, this pushed the *cost* of transmitting an incremental bit of information *to zero.*



Actual purchasing data from the Stanford Linear Accelerator (Courtesy: SLAC)
Pink: Bandwidth transmission bits per dollar
Blue: Memory storage per dollar
Green: Moore's law.

In that pivotal year of 1993, the Internet transmitted a mere 1% of all telecom traffic. By 2008, it carried 97%.[20] This came about largely because, in just those handful of years, DWDM became the basis of nearly every high capacity metro, regional and long-distance optical system in the world.[21] [22] Now virtually all human communication travels through the wave multiplexers responsible for lighting up the backbone of the Information Age.[23] Considering the centrality of the Internet in human affairs, it is no stretch to say that these light-powered networks are to the 21st century what electricity-powered networks were to the 20th – the infrastructure of civilization. Holding these thoughts in mind makes it clear that open DWDM both enabled the explosive growth of the Internet -- and serves as its foundation today.

[1] "The World's Technological Capacity to Store, Communicate, and Compute Information", Martin Hilbert and Priscila López (2011), Science, 332(6025), 60–65; free access to the study through here: martinhilbert.net/WorldInfoCapacity.html
[2] University of Illinois at Urbana-Champagne, National Center for Supercomputing Applications. ftp://ftp.ncsa.uiuc.edu/Mosaic/Windows/Archive/MosaicHistory.html
[3] Anders, George. *The Wall Street Journal*: "For Ciena's Investors, a Jackpot for the Record Books." June 5, 1998.
[4] Confidential Private Offering, Ciena Corporation, page 58; http://www.scribd.com/doc/96950407/Ciena-PPM-1993-Beneficial-Owner-of-More-Than-5
[5] *Securities and Exchange Commission Registration Statement*, Ciena Corporation, page 50, footnote 19; Feb 7, 1997. http://www.secinfo.com/dsvRq.89x.htm#42it
[6] *Fiber Optics and Communications*, vol. 20 No. 4, May 1997
[7] United States Patent #5696615; *"Wavelength division multiplexed optical communication systems employing uniform gain optical amplifiers."* (USPTO)
[8] Angst and Awe on the Internet, George Gilder; first published in Forbes ASAP, December 4, 1995
[9] http://massis.lcs.mit.edu/archives/george.gilder.essays/coming.of.the.fibersphere -- MCI ID: 409-1174 "Into the Fibersphere" and Forbes Magazine, *"Dark Fiber, Dumb Network,"* George Gilder.
[10] http://www.merit.edu/research/nsfnet_article.php
[11] Mullaney, Timothy J., *"Ciena founder resigns to start new venture Huber quits supplier after Linthicum company shifts focus",* The Baltimore Sun, May 13, 1997
[12] Dense Wave Division Multiplexing; https://aresu.dsi.cnrs.fr/IMG/pdf/dwdm_ciena.pdf
[13] Markoff, John. "Fiber-Optic Technology Draws Record Stock Value" *The New York Times* March 3, 1997
[14] The Goldman Sachs Tech Team Speaks, *Goldman Sachs Global Research*, p. 2, Week of February 23-27, 1998.
[15] http://www.thefreelibrary.com/Sprint+announces+plans+to+launch+consumer+Internet+service.-a018607156
[16] http://www.thefreelibrary.com/Sprint+announces+plans+to+launch+consumer+Internet+service.-a018607156
[17] ibid
[18] Markoff, John. "Fiber-Optic Technology Draws Record Stock Value" *The New York Times* March 3, 1997.
[19] Anders, George: "For Ciena's Investors, a Jackpot for the Record Books." *The Wall Street Journal* June 5, 1998.
[20] "The World's Technological Capacity to Store, Communicate, and Compute Information", Martin Hilbert and Priscila López (2011), Science, 332(6025), 60–65; free access: martinhilbert.net/WorldInfoCapacity.html
[21] Klaus Grobe, Michael Eiselt; Wavelength Division Multiplexing: A Practical Engineering Guide, John T Wiley & Sons, October 2013.
[22] IEEE Innovation Award http://www.ciena.com/connect/blog/Ciena-CTO-Steve-Alexander-honored-by-IEEE.html
[23] Kaminow, Ivan, Li, Tingye, Willner, Alan E., *Optical Fiber Telecommunications, Volume VIB: Systems and Network,* pg 1, Academic Press, May 2013.