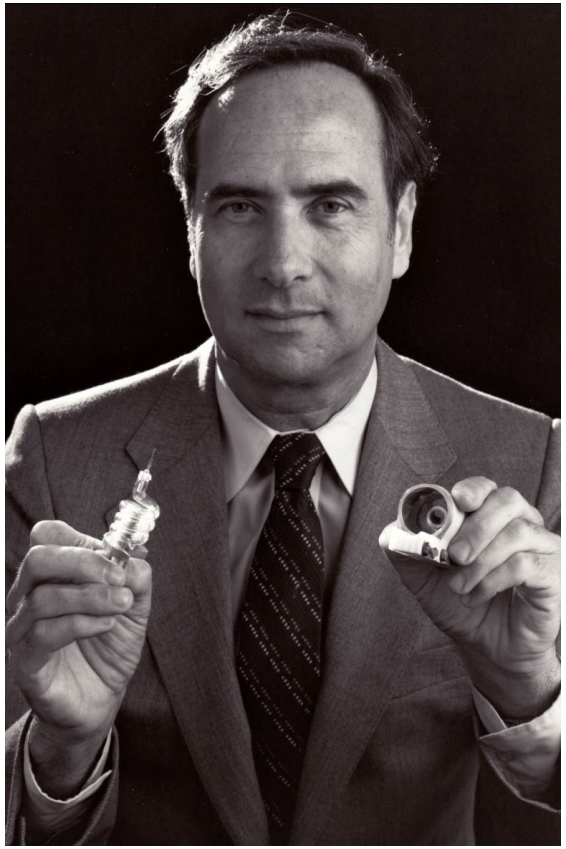
Making the First Low Loss Optical Fibers for Communications:

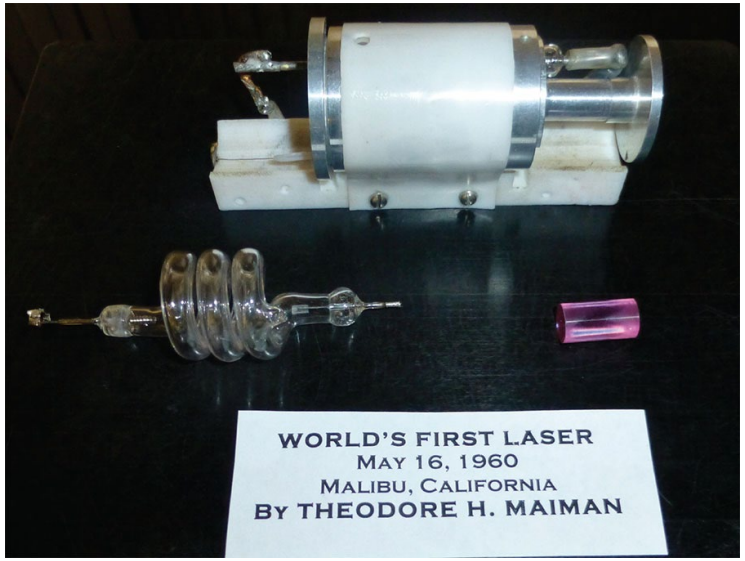
A Firsthand Perspective

Peter Schultz, Ph.D.

Ted Maiman Holding the First Laser (ruby) 694 nm.

Demonstrated May 16,1960 at Hughes Research Laboratories.





Charles Kao (at STL) proposed using fiber optics for laser communications in a paper coauthored with Hockham published in 1966.

Kao encouraged various telecom labs to consider this approach:

- **British Post Office**
- **Bell Laboratories**
- **Standard Telecom Laboratories/ITT**
- **Nippon Telephone and Telegraph**

- Conventional/purified optical glasses
- Double Crucible Method (shown)
- Rod-in-Tube Method

July 18, 1961 J. W. HICKS, JR 2,992,517

METHOD AND APPARATUS FOR USE IN THE FABRICATION OF LIGHT-CONDUCTING DEVICES

Filed Aug. 11, 1958 2 Sheets-Sheet 1

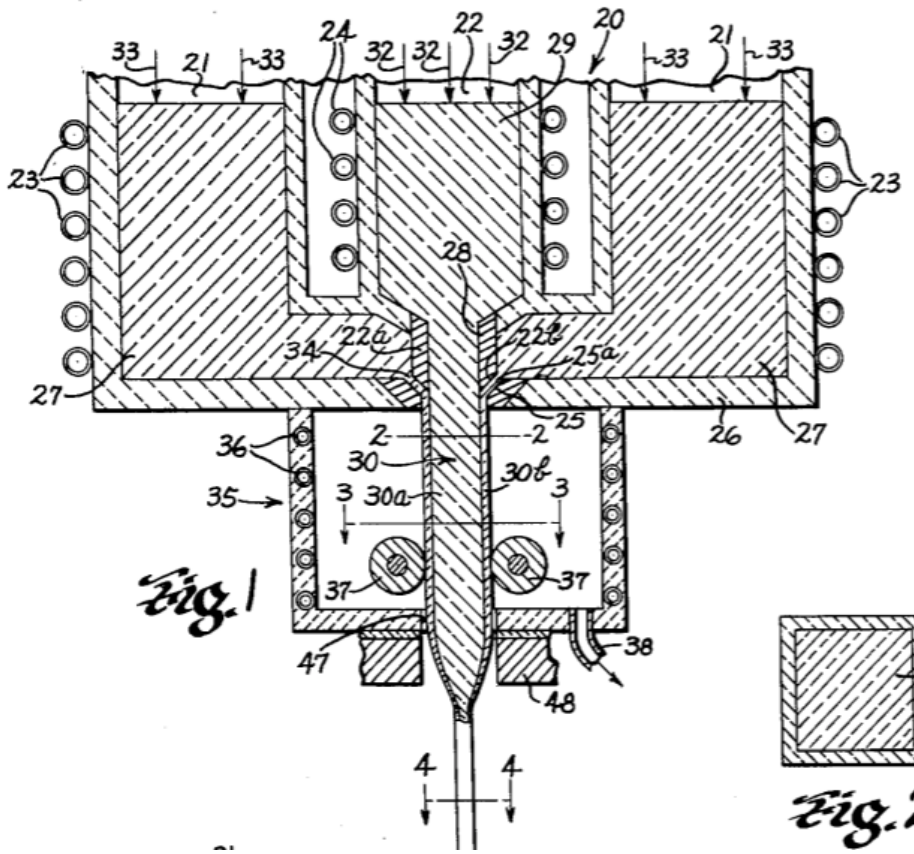


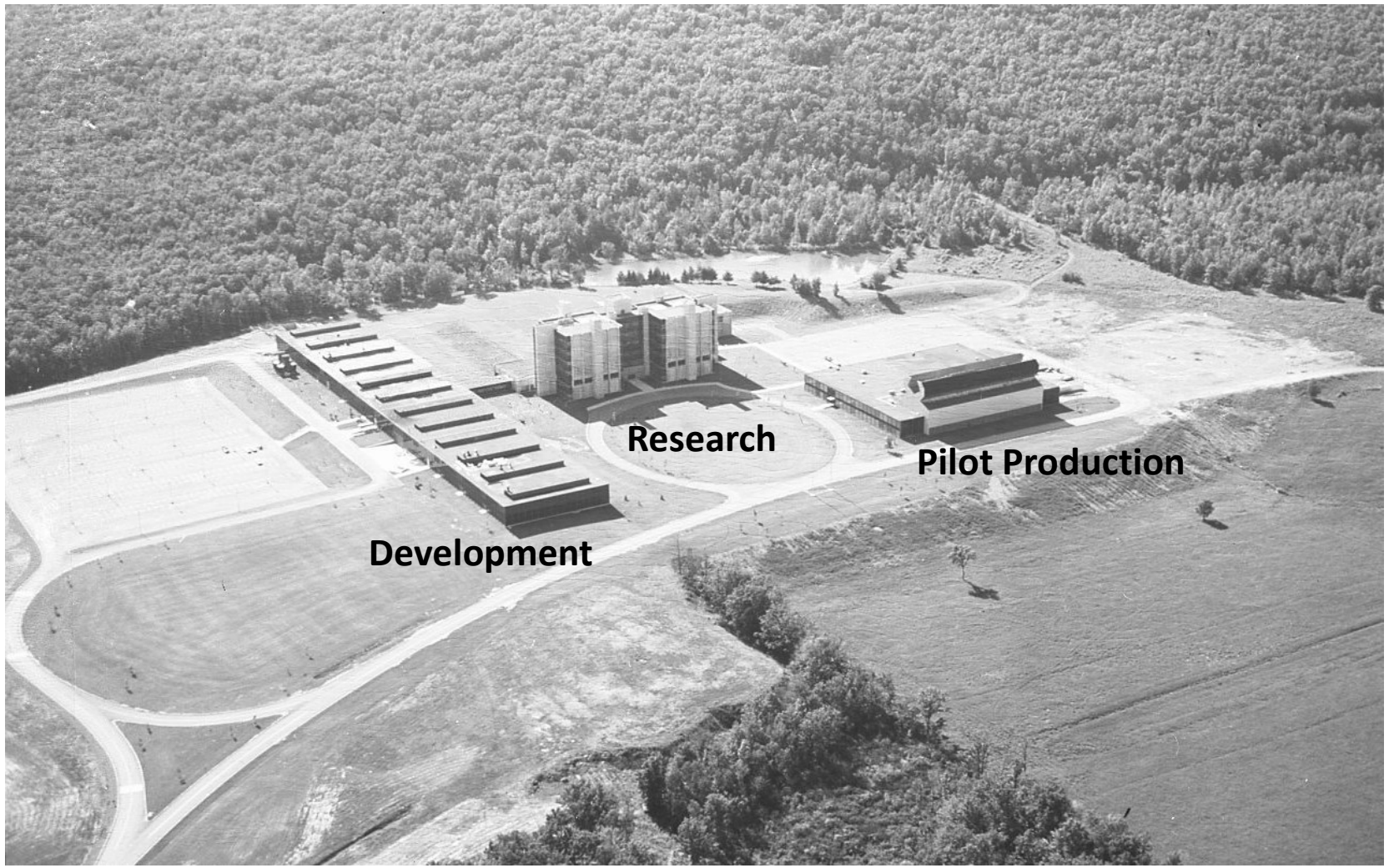
Fig. 1

Fig. 2

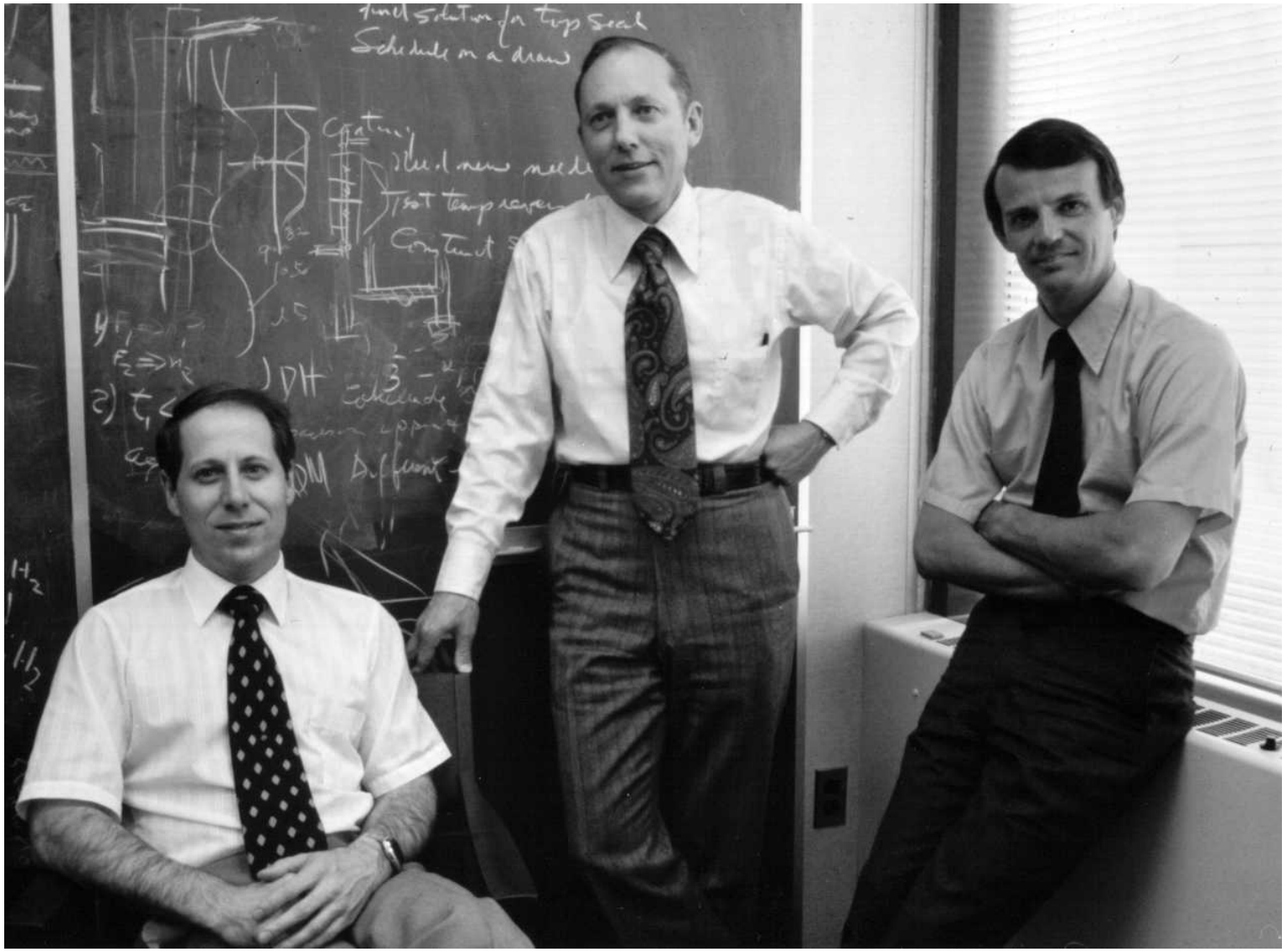
- **Dr. William Shaver (Corning's R&D roving scientist) brought the news in 1966 to Corning of the need for low loss glass optical fibers.**

- **Dr. William Armisted (Corning's VP of R&D) initiated a research project at Sullivan Park to explore the potential to make them.**

Corning Glass Works
Sullivan Park
R&D Center (circa 1966)
Corning, NY

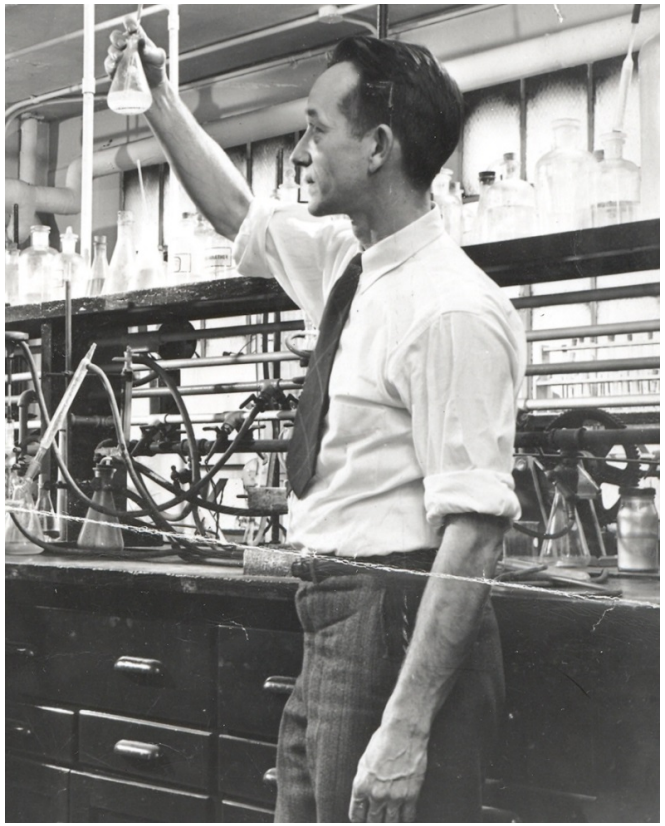


Don Keck, Bob Maurer and Peter Schultz
Corning's fiber research team

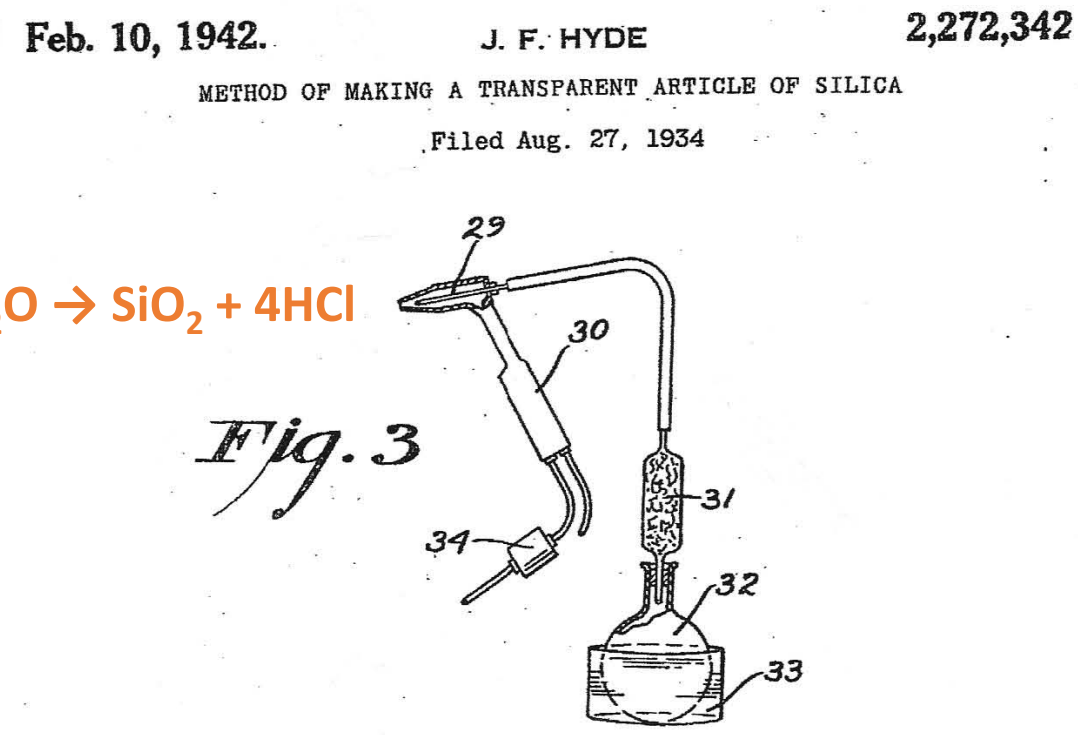


Three Critical Requirements for a Working Fiber

- **Exceptional optical quality** (goal of <20 dB/km). The best conventional optical glasses available in 1966 had losses >1000 dB/km. A 10^{98} improvement required!
- **Perfect single-mode design geometry** (10 microns core in a 125 microns fiber, Δn 1 %, no distortions)
- **High strength and long life** (150 kpsi over 25 years)



$SiCl_4 + H_2O \rightarrow SiO_2 + 4HCl$



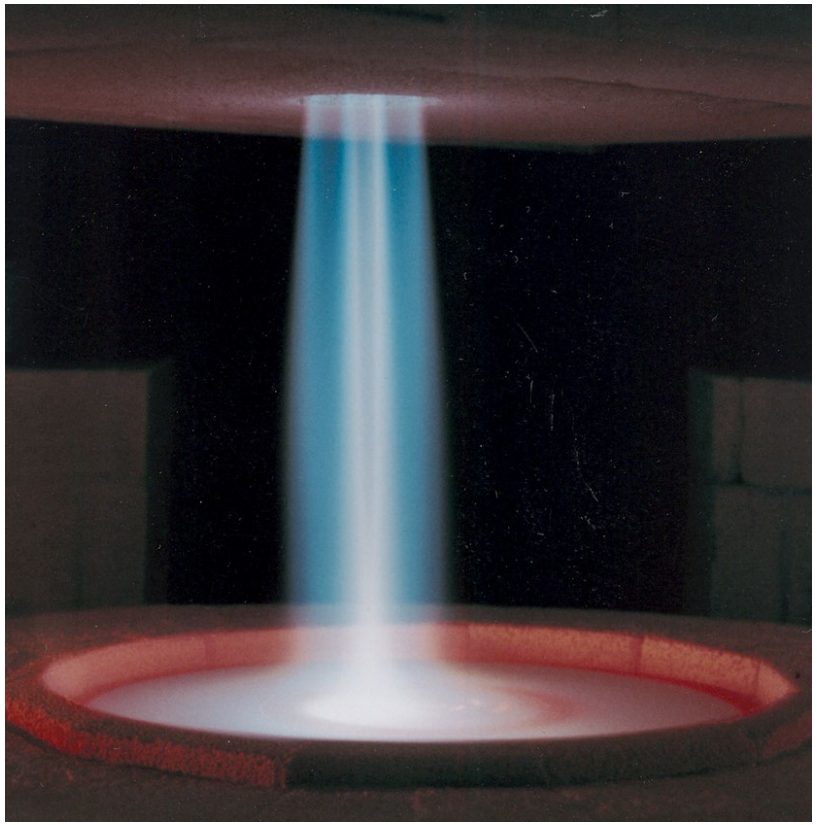
Feb. 10, 1942. J. F. HYDE 2,272,342

METHOD OF MAKING A TRANSPARENT ARTICLE OF SILICA

Filed Aug. 27, 1934

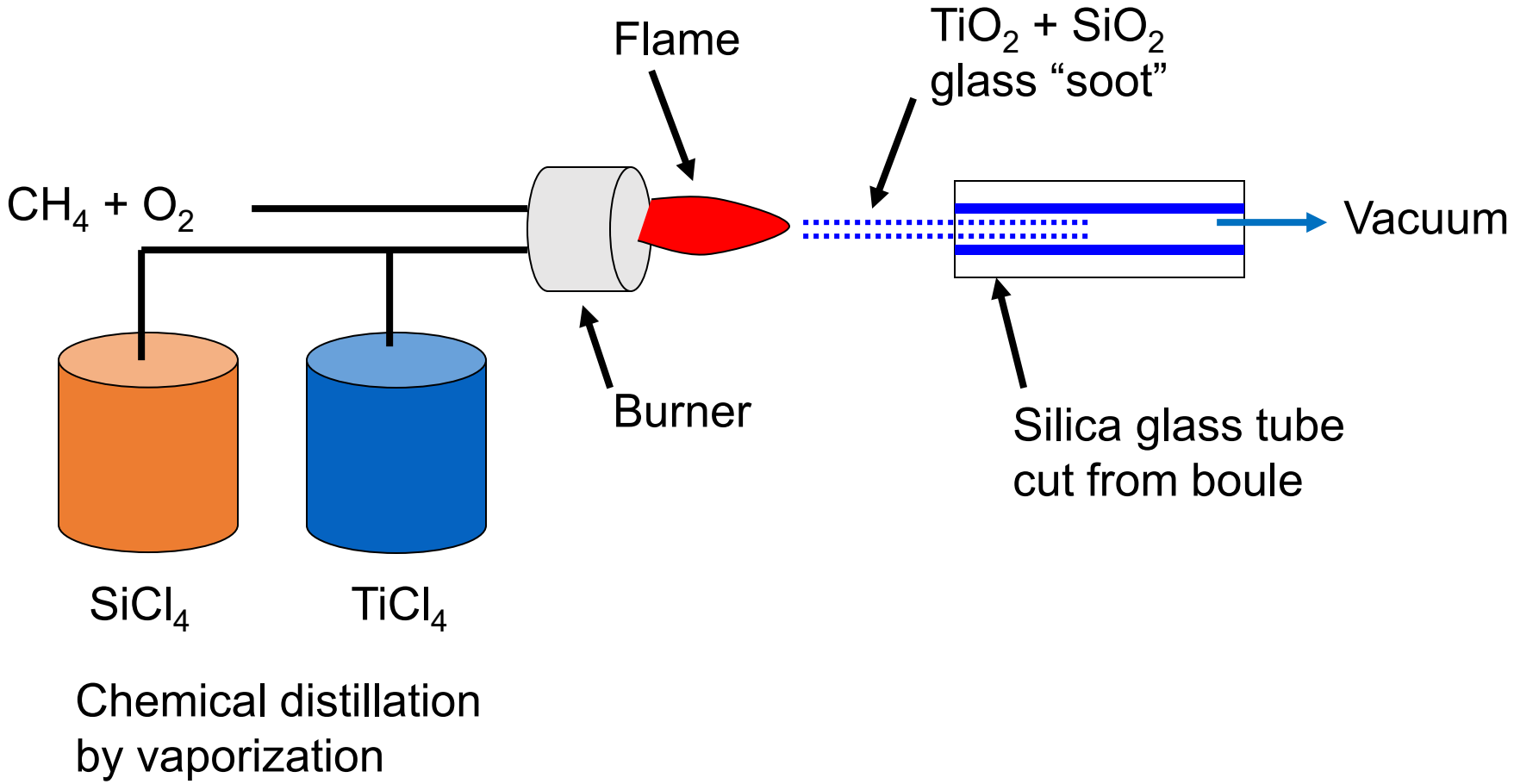
Fig. 3

Flame Hydrolysis Process to Make Fused Silica Glass
Invented by Dr. Frank Hyde, Corning chemist 1934

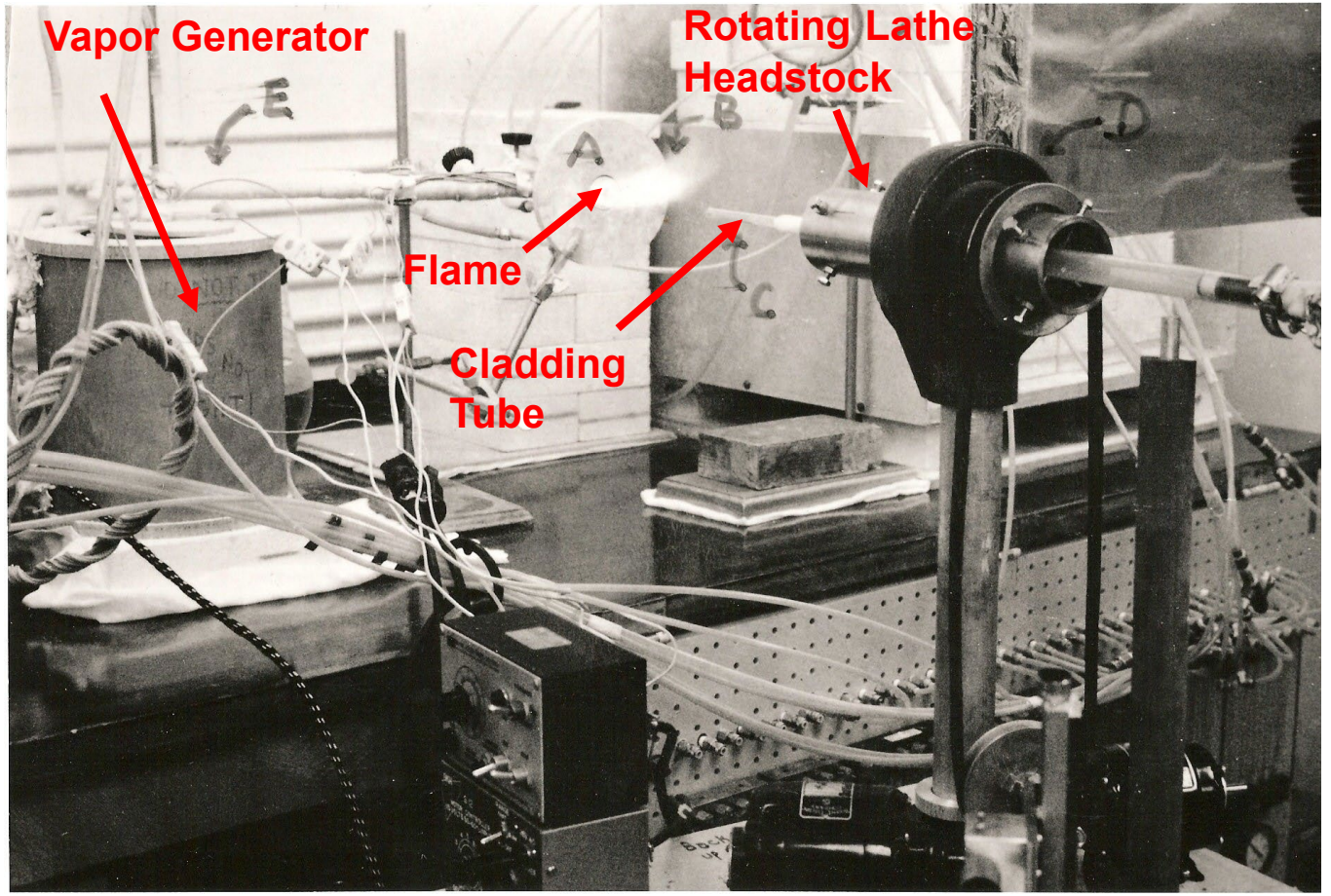


Corning flame hydrolysis fused silica boule process circa 1960’s.

Original “inside” vapor deposition process concept (circa 1969):



Fiber Preform Deposition Apparatus 1970
17 dB/km titania-doped silica fibers




GENERAL ELECTRIC

Next Steps:

- Sinter soot coating on tube inside wall.
- Draw preform (hole collapses) into fiber.
- Anneal bare fiber ~750°C to oxidize $Ti^{3+} \rightarrow Ti^{4+}$
- Etch fiber with hydrofluoric acid to recover strength.
- Coat fiber with enamel for handling.

Then the attenuation is:

$$\beta_t = \frac{10 \log \frac{40}{354}}{29 \text{ meters}} = 17 \text{ db/km} \quad \text{Whoopee!!}$$

Must remeasure this to check!

Left laser and electronics running during lunch, signal is holding constant @ 158 mv. Noise is definitely lower. Maximized signal and found I had to decrease the HV to 850.

HV = 850, RC = 100, R_L = 100 KΩ.

S = 42.2 mv $\quad S_{ref}$ = 158 input in phase

Broke fiber:

S = 48.7 mv $\quad S_{ref}$ = 159 (laser is up slightly)

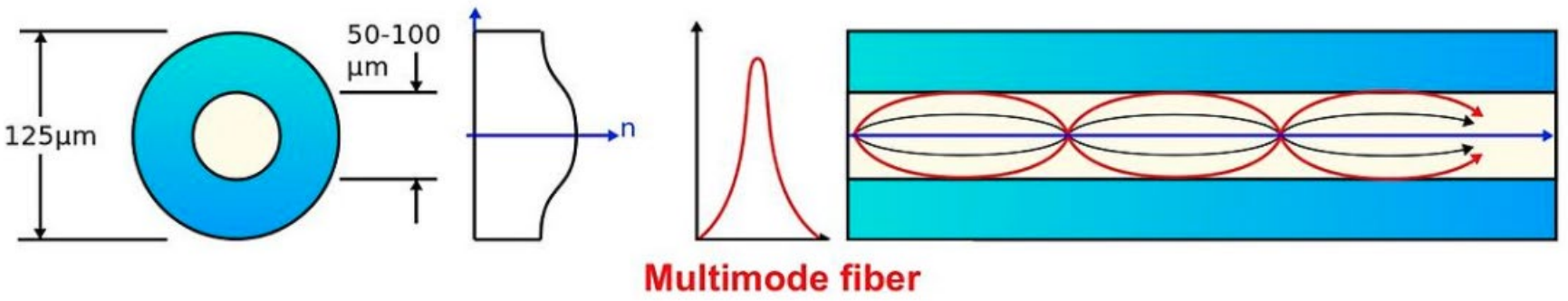
waiting till it comes down again:

S = 47.5 $\quad S_{ref}$ = 158

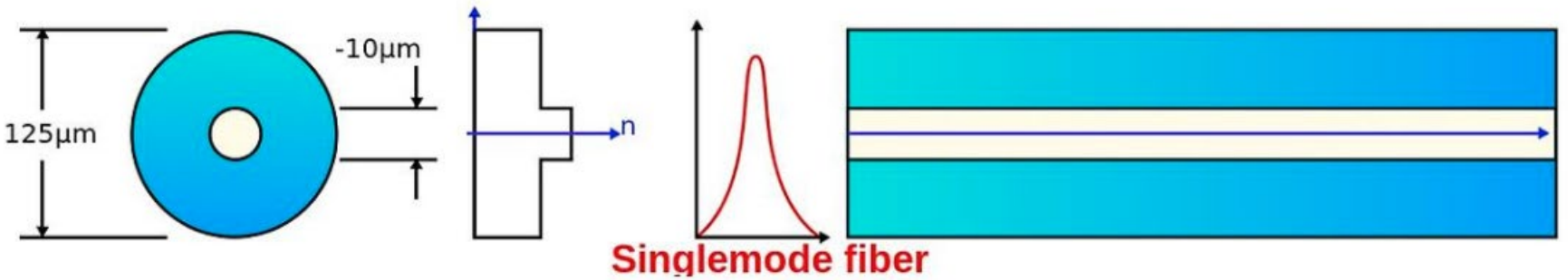
ΔL = 43 turns @ 0.653 = 28.1 meters

From these numbers: $\beta_t = \frac{10 \log \frac{47.5}{42.2}}{28.1} = 18.2$ db/km

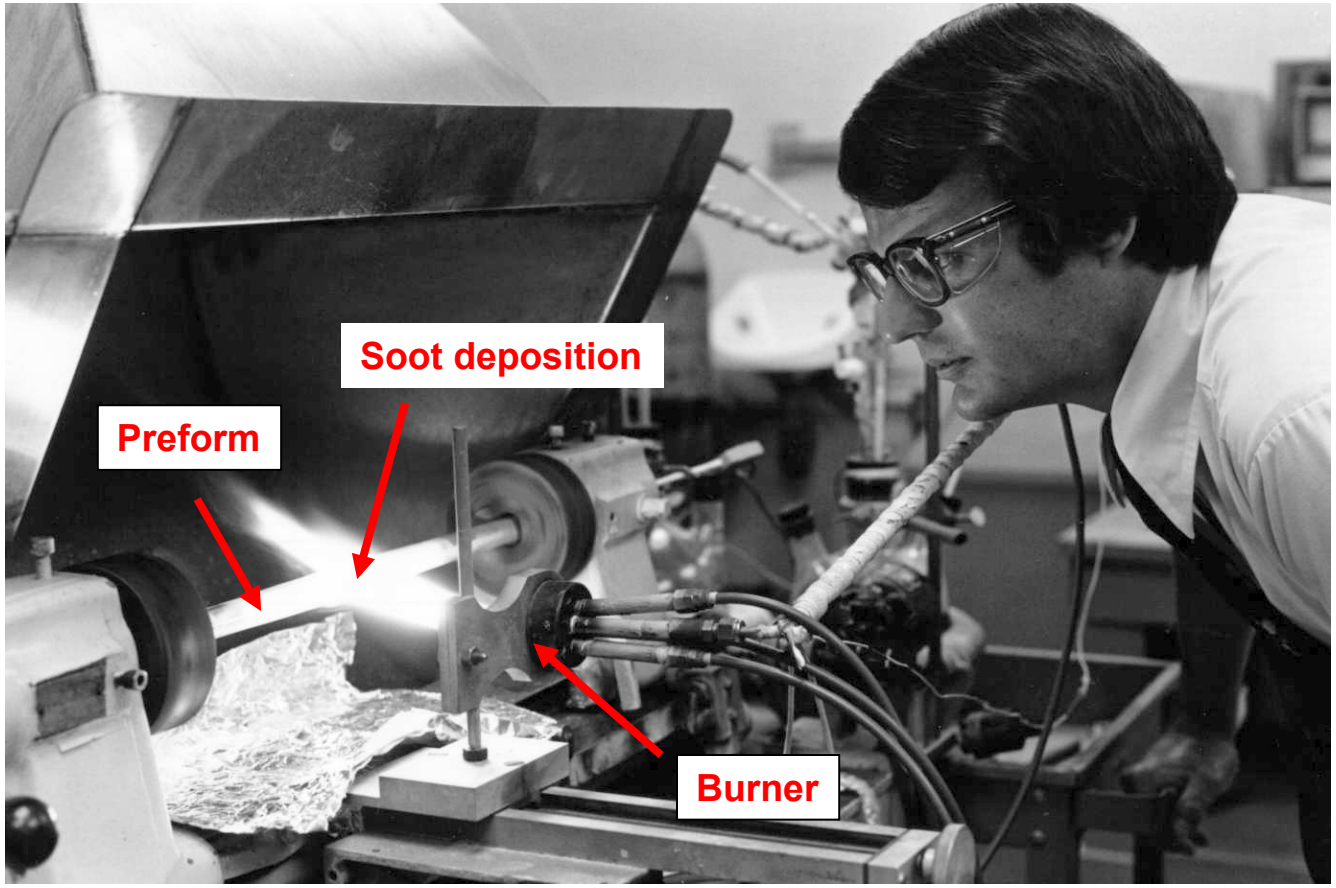
GaAs LED light source

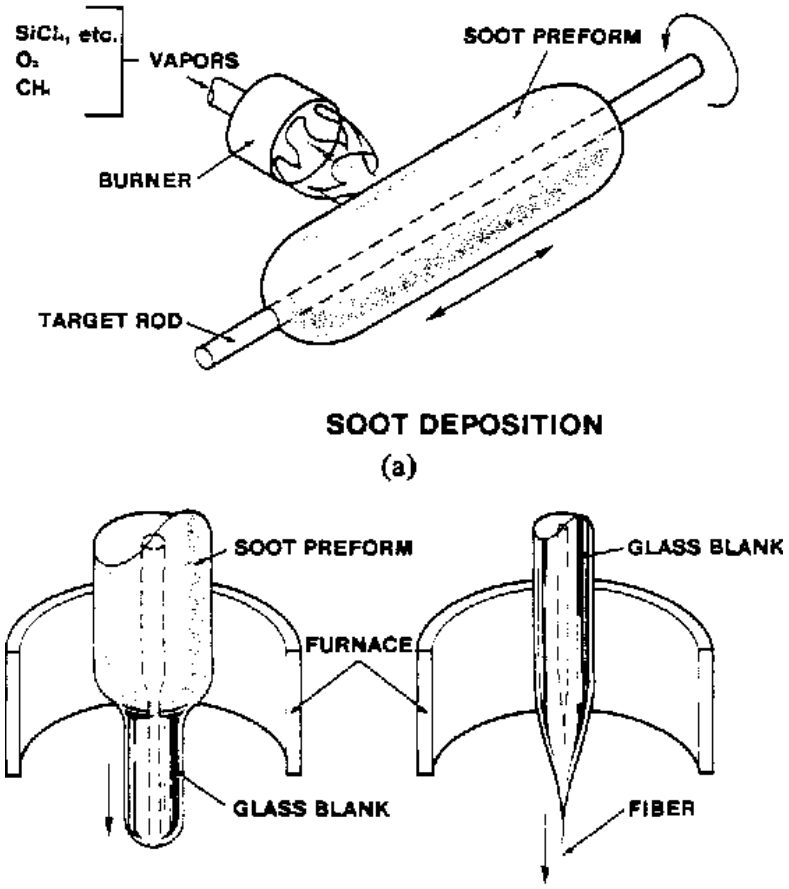


HeNe laser light source

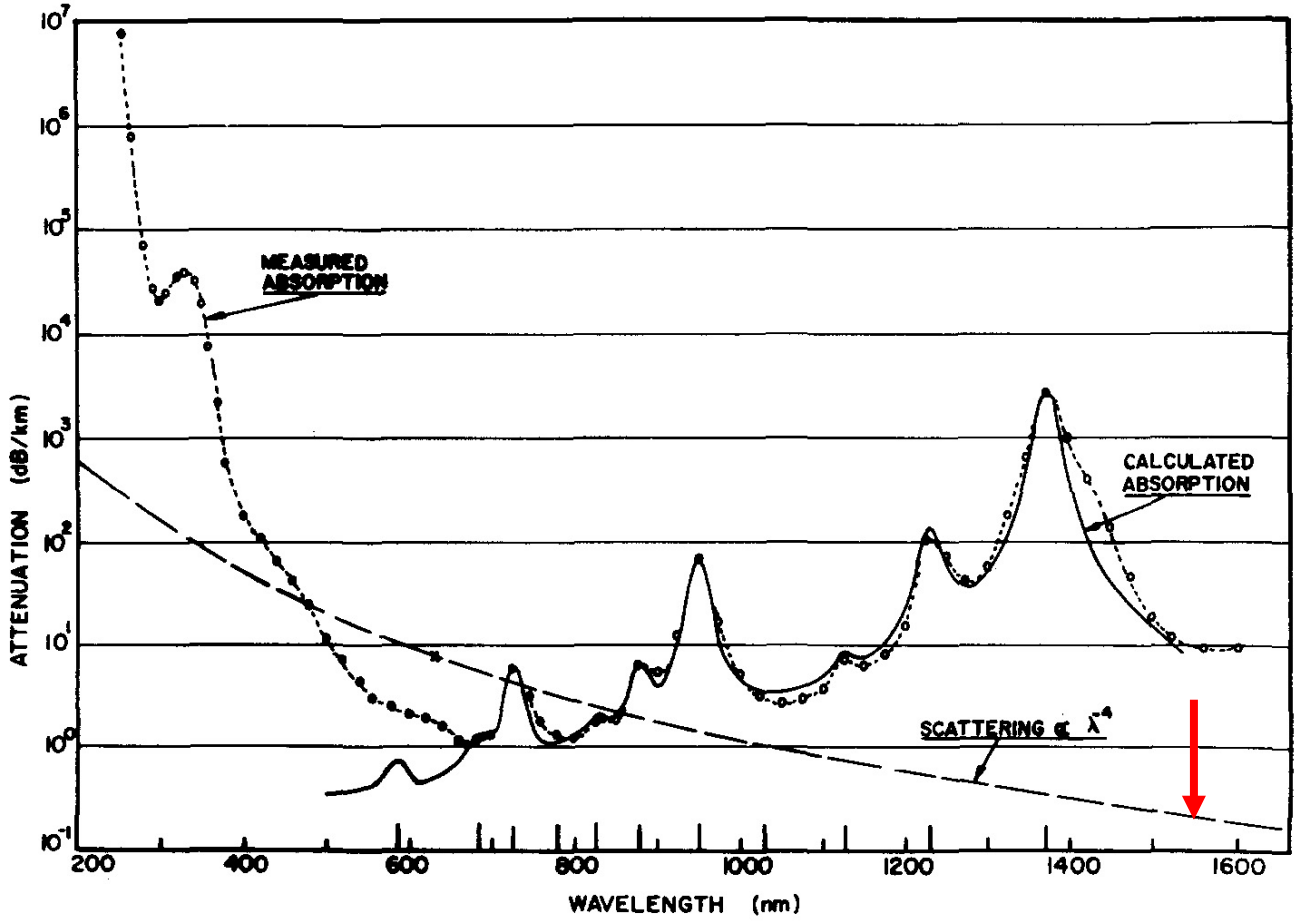


Outside vapor deposition method to make step and graded index optical fiber preforms (~3 km fiber) < 4dB/km germania-doped silica fibers in 1972.




SiCl4, etc.
O2
CH4
VAPORS
BURNER
SOOT PREFORM
TARGET ROD
SOOT DEPOSITION
(a)
SOOT PREFORM
FURNACE
GLASS BLANK
GLASS BLANK
FIBER
SINTERING
(b)
FIBER DRAWING
(c)

Prediction (1973): If OH is removed, then losses ~0.2 dB/km should result at ~1550 nm in GeO_2-SiO_2 core fibers.



From: "On the ultimate lower limit of attenuation in glass optical waveguides", D.B. Keck, R.D. Maurer, P.C. Schultz, Appl. Phys. Lett. 22 (7), 307-309,April 1973

One of the basic patents issued to Corning covering the invention of telecommunication fiber optics.
To this day, all telecom fibers are based on these patents.

United States Patent

Maurer et al.

[15] **3,659,915**

[45] **May 2, 1972**

[54] FUSED SILICA OPTICAL WAVEGUIDE

[72] Inventors: **Robert D. Maurer; Peter C. Schultz,** both of Painted Post, N.Y.

[73] Assignee: **Corning Glass Works,** Corning, N.Y.

[22] Filed: **May 11, 1970**

[21] Appl. No.: **36,109**

[52] U.S. Cl. ..... 350/96 WG, 65/30, 65/DIG. 7, 65/DIG. 8

[51] Int. Cl. G02b 5/14, H01p 3/00

[58] Field of Search ..... 350/96 WG, 175 GN

[56] **References Cited**

UNITED STATES PATENTS

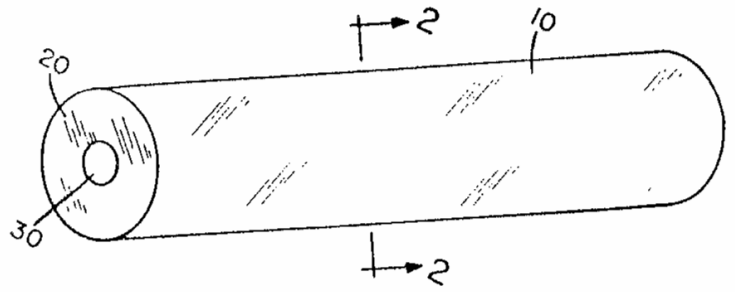
3,542,536	11/1970	Flam et al.	350/96 WG X
3,445,785	5/1969	Koester et al.	350/96 WG UX
3,533,013	10/1970	Seitz	350/175 GN X

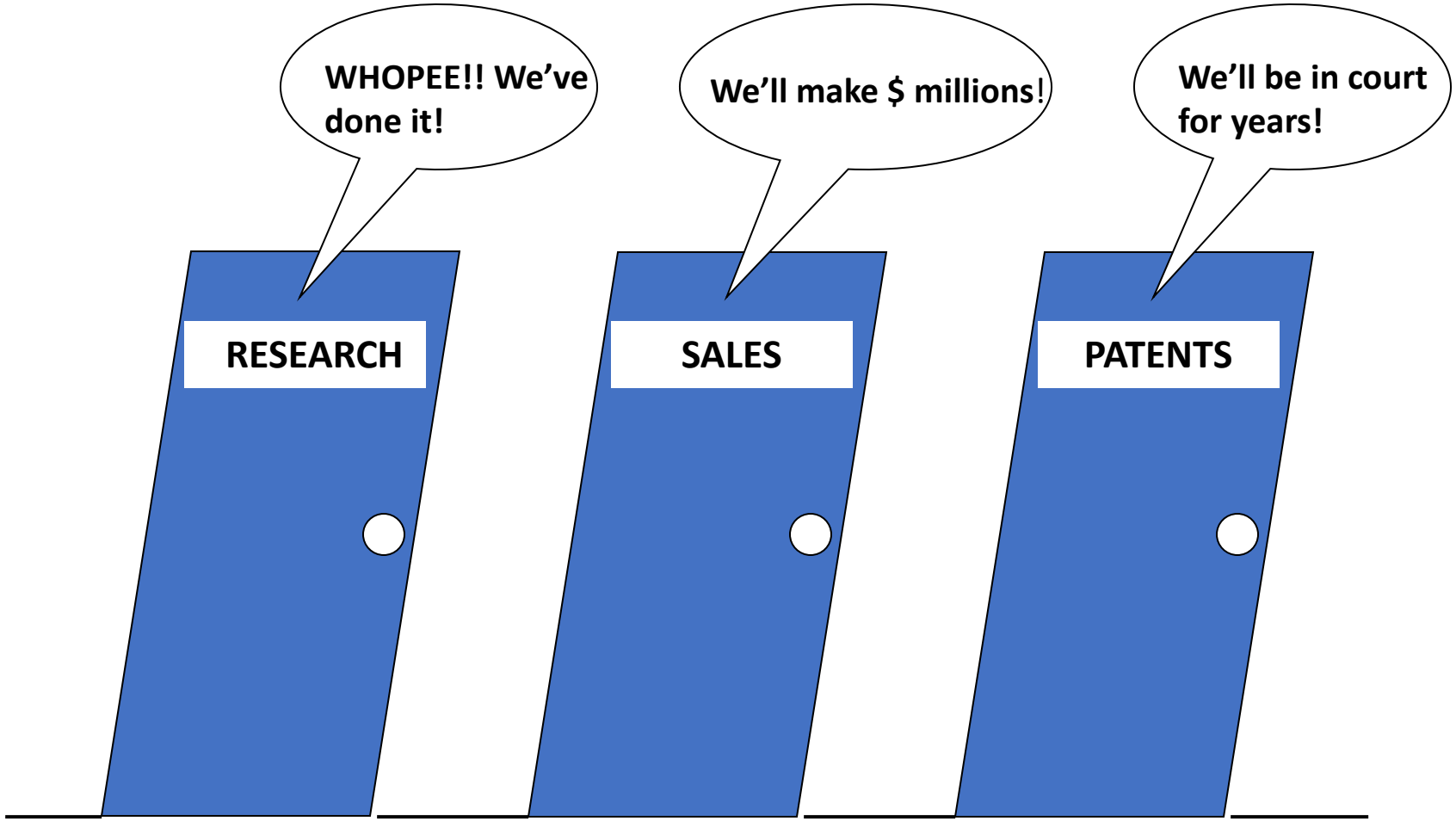
Primary Examiner—John K. Corbin
Attorney—Clarence R. Patty, Jr. and Walter S. Zebrowski

[57] **ABSTRACT**

An optical waveguide having a high purity fused silica cladding layer, and a core of high plurality fused silica doped with a sufficient amount of a multivalent metal oxide so as to increase the index of refraction of the core above that of the cladding layer.

10 Claims, 2 Drawing Figures




WHOPEE!! We've done it!
We'll make $ millions!
We'll be in court for years!
RESEARCH
SALES
PATENTS

Amory (“Amo”) Houghton: Corning CEO

True champion of the optical fiber program at Corning.

Corning Glass Works v. Sumitomo Elec. USA, Inc.

U.S. District Court for the Southern District of New York
December 21, 1987

OPINION AND ORDER

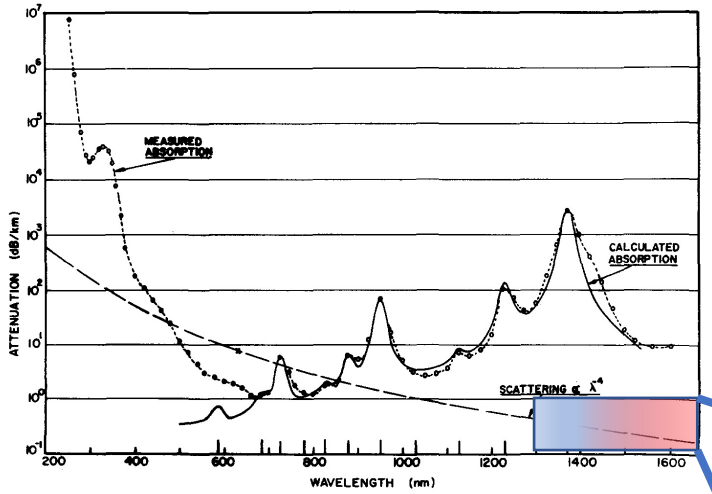
WILLIAM C. CONNER, District Judge

“The '915 patent clearly covers a basic, pioneering invention entitled to liberal construction and a broad range of equivalents.”

Pioneer patent refers to a patent that covers a function or a major technological advance never before performed. Under the U.S. law, the claims relating to a pioneer patent are entitled to broader interpretation and therefore, should be given a broader range of equivalents.

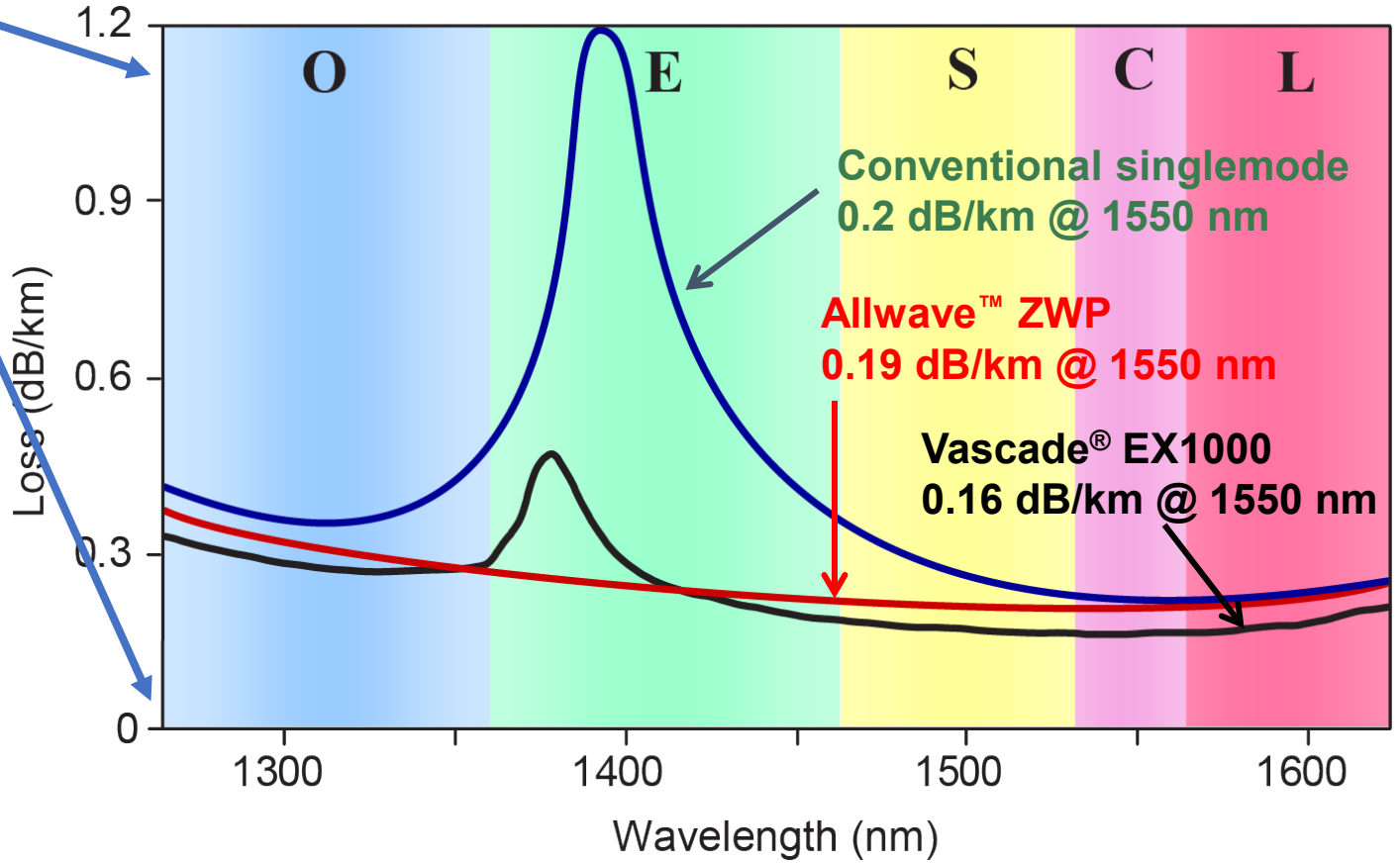
Key process and design improvements over fifty years to lower optical loss, increase bandwidth and process output:

Years	Process Changes	Fiber Design Changes
1970's	Eliminate hydroxyl impurity	Graded index multimode
1980's	Eliminate boron-doping OVD, VAD and MCVD evolve	Singlemode
1990's	Fluorine doping Synthetic tubes for MCVD Rod-in-tube (RIT)	Dispersion-shifted and Dispersion-flattened for WDM
2000's	Rod-in-cylinder (RIC) Direct overclad on core rods OMCTS replaces $SiCl_4$ for overclad High speed fiber drawing	DWDM Bend-insensitive Ultra-low loss pure silica core



Prediction becomes a reality…

Typical low loss singlemode commercial fibers



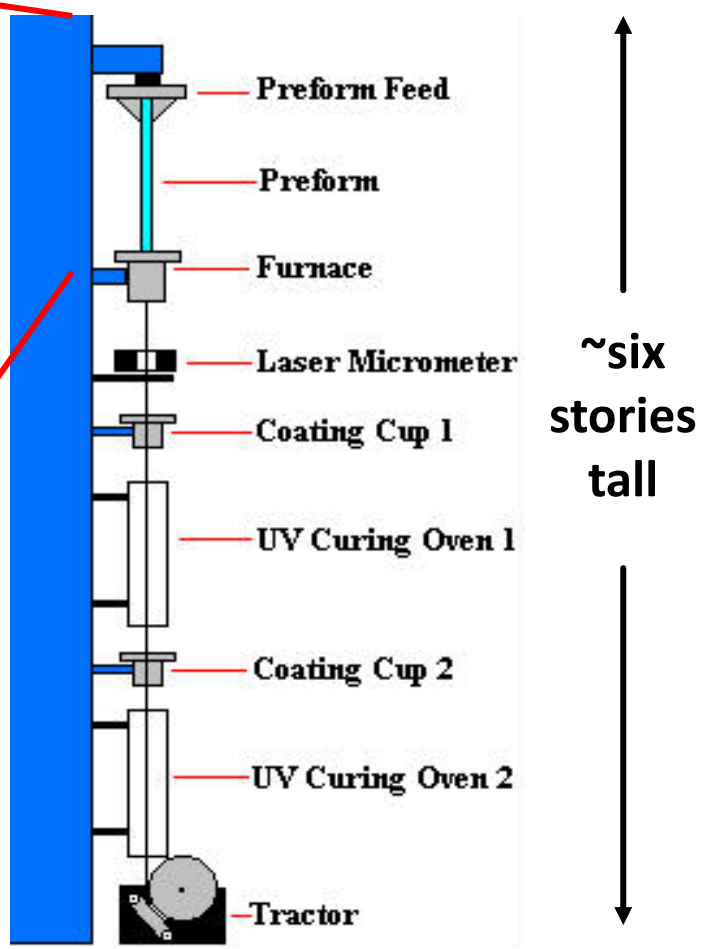
OVD Soot Perform-making Circa 2020

Courtesy of Rosendahl Nextrom Oy (Vantaa, Finland).

Current Fiber Preform Manufacture

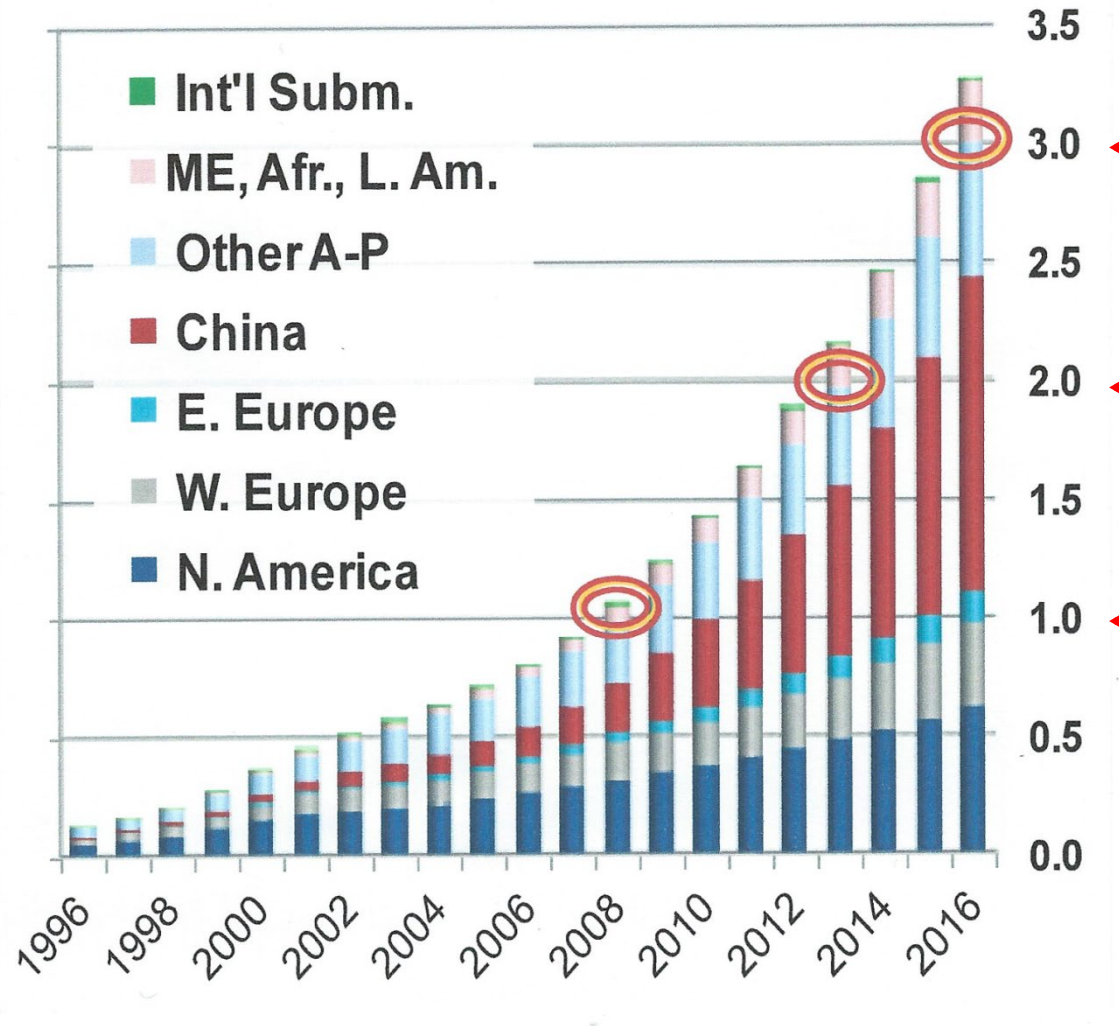
- Single-mode fibers
- Germania-doped silica core
- 6000+ kilometers fiber preform
- Draw speeds >>30 m/sec
- Average 0.182 dB/km loss @ 1550nm
- 150kpsi tensile strength

Preform feed section of state-of-the-art fiber draw tower



Courtesy of Rosendahl Nextrom Oy (Vantaa, Finland).

Cumulative total of cabled fiber installed worldwide (billion fiber-km)



3 years

5 years

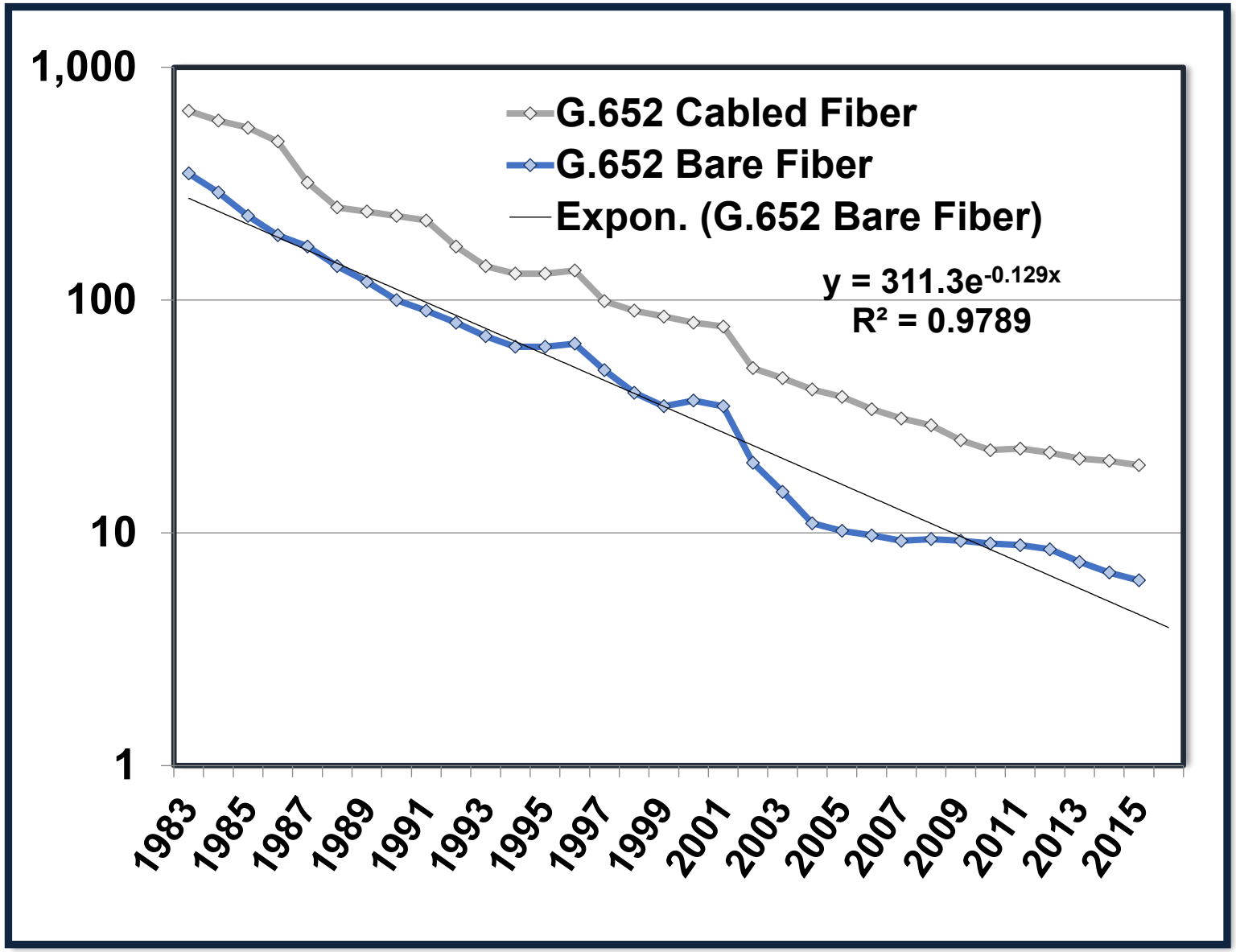
36 years

2019 ≈ 4.5B fiber-km

~distance to Pluto

~100,000X around the earth

Singlemode optical fiber relative price history



Corning’s Sullivan Park Research Center

2021

1966

Some Lessons Learned:

- Keep up-to-date on market needs (e.g., Dr. Shaver roving scientist).
- Corporate R&D is a powerful tool (e.g., Sullivan Park Research Center).
- Inspired/inspiring leadership is critical (e.g., R&D VP Bill Armisted).
- Contrarian solutions can succeed (e.g., fused silica vs conventional glasses).
- Build on the past (e.g., flame hydrolysis capabilities).
- Keep-it-simple-stupid (e.g., lab GE vacuum cleaner).
- Protect/document your work (lab records, patents).
- A corporate champion is critical (e.g., CEO Amo Houghton).
- Disciplined transition of technical solutions (research>development>pilot manufacturing).
- Long term commitment to cost reductions/product improvements.

May your future be…..Light!

Thank you