

The Same Glass Became **5000** Times More Transparent

— Window glass drops the light to **1** per cent in **20** m; an optical fibre takes **100** km to do the same — that decides whether crossing the Pacific needs **90** repeaters or **450,000** — [Paper 415]

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— *From thinking to syncing.* —

Abstract

An optical fibre is described as “made of glass”. A window is also glass. This paper shows that within one material name there is a factor of **5000**—and that this factor decides whether a submarine cable is possible at all. No new theorem or law is claimed. First, this is the core of the paper. To reach the same 1 per cent transmission, window glass gets **20** m and a fibre gets **100** km. The ratio is exactly **5000** (Section 2). Second, the ratio of attenuation coefficients, 0.2 against 1000 dB/km, is also exactly **5000**, and agrees with the ratio of distances (Section 2). Third, a fibre still carries **95.4993** per cent after a kilometre (Section 2). Fourth, crossing the Pacific, 9000 km, needs **90** repeaters with fibre (Section 3). Fifth, the same crossing built from window glass would need **450,000**. Four orders of magnitude apart (Section 3). Sixth, the separator is the name of the material against the quantity of impurity. Not the composition but the removal of iron ions by a factor of 10^9 (Section 4).

Scope of this paper (scope note): No new theorem or law is claimed—the Beer–Lambert law, the definition of the decibel, and the low-loss window of silica fibre are all standard. No theorem is proved—exponential attenuation is used as known, and only numbers are put in. Manufacture is not discussed—processes such as vapour-phase axial deposition are not the subject. The physics of the loss is not decomposed—separating Rayleigh scattering from infrared absorption is not the subject; 0.2 dB/km is taken as given. Dispersion is not treated—pulse spreading, nonlinear effects and polarisation-mode dispersion are not the subject. Repeater spacing here is set by loss alone, whereas in practice dispersion also counts. One value is used for window glass—1000 dB/km is representative and varies with the kind of plate glass. Relation to earlier papers: Paper 414 showed that the same “hour” varies by 1.5 with the season—there one name covered two lengths; here one name covers two transparencies. Paper 300 showed that common root and distinct root can be decided—“transparent because it is glass” and “transparent because it is pure” are distinct roots by that criterion. Paper 412 showed that “nearest” is not defined until the distance is—here “transparent” is not defined until the distance is. Paper 413 showed that adding a peg destroys the closed form—there a degree of freedom broke the formula; here an impurity breaks the distance. What is added is giving the distance to the same transmission for both, showing that the ratio of coefficients and the ratio of distances are both 5000, giving the survival after one kilometre as 95.4993 per cent, giving the repeater counts for a Pacific crossing as 90 against 450,000, and placing the separator at “name or impurity”.

1. Notation and the Question

Setting: After L km in a medium of attenuation a (dB/km), the transmission is

$$T = 10^{-aL/10}$$

Take $a = 0.2$ dB/km for fibre at 1550 nm and $a = 1000$ dB/km as representative of window glass.

Observation 1.1

Window glass is transparent. One sees through a plate a few millimetres thick—hence “glass is transparent”.

Observation 1.2

Change the thickness and the statement changes. Stack hundreds of the same plates and nothing is visible—“transparent” means something only paired with a thickness.

Question: How thick, then, can it be made.

2. Twenty Metres Against a Hundred Kilometres

Computation 2.1: Give the transmission at several distances for both.

Distance	Fibre	Window glass
1 m	0.9999539	0.7943282
20 m	0.9990794	0.0100000
1 km	0.9549926	10^{-100}
100 km	0.0100000	0

Observation 2.2

Window glass reaches exactly 1 per cent at 20 m. Because $1000 \times 0.02 = 20$ dB—and 20 dB is exactly one hundredth.

Observation 2.3

Fibre reaches exactly 1 per cent at 100 km. Because $0.2 \times 100 = 20$ dB, the same value—the same 20 dB is spent over 20 m in one case and 100 km in the other.

Computation 2.4: Take the two ratios.

The ratio of attenuation coefficients is $1000/0.2 = 5000.0000$. The ratio of distances to the same transmission is $100,000/20 = 5000.0000$.

Observation 2.5

That these agree is a property of exponential decay. Divide the coefficient by k and the distance to a given loss multiplies by k —each can be derived from the other, which serves as a self-test of the computation.

Observation 2.6

A fibre still carries **95.4993** per cent after a kilometre. Window glass would be at 10^{-100} —not one photon arrives.

3. Ninety Repeaters, or Four Hundred and Fifty Thousand

Computation 3.1: Placing a repeater each time 20 dB is spent, how many are needed for the 9000 km Pacific crossing?

With fibre, $9000/100 = 90$. With window glass, $9000/0.02 = 450,000$.

Observation 3.2

Ninety can be built. Four hundred and fifty thousand cannot. It would mean powering a device on the sea floor every 20 m—it fails on power and failure rate before it fails on the devices.

Observation 3.3

So the factor of 5000 is not a difference of degree but of possibility. Not “five thousand times better” but “can or cannot”—submarine cables stand on these four orders of magnitude.

Observation 3.4

And the difference is not the composition. Both are mostly silicon dioxide—what differs is the impurity, above all transition-metal ions such as iron.

Observation 3.5

When 20 dB/km was proposed as a target in 1966, the glass of the day was at 1000 dB/km. A fiftyfold improvement was said to be needed—what arrived was 0.2 dB/km, a factor of 5000.

4. The Separator

The separator: is it settled by the name of the material or by the quantity of impurity.

Observation 4.1

“Transparent because it is glass” settles it by name. Give the composition and the property follows—over short distances that suffices.

Observation 4.2

But the factor of 5000 lives inside the name. The same word “glass” runs from 0.2 to 1000—a name fixes a range, not a value.

Observation 4.3

These are distinct roots by the criterion of Paper 300. The ceiling on transparency is set by composition—the actual transparency is set by impurity. One word, two quantities.

Observation 4.4

And “transparent” means nothing until a distance is fixed. Window glass is transparent at 3 mm and opaque at 20 m—the same shape as “nearest” demanding a distance in Paper 412.

Observation 4.5

To be honest—setting repeater spacing by loss alone is a simplification. In practice dispersion, nonlinear effects and accumulated noise all count—the figure of 90 is there to show the order of magnitude, not as a design value.

Observation 4.6

One last thing—0.2 dB/km has a physical floor. Rayleigh scattering remains even with no impurity at all—so the factor of 5000 is not “still not enough” but close to the limit.

5. Roll Call and Closing

1. Window glass at 1.0000 % after 20 m (Computation 2.1): **20 dB.**
2. Fibre at 1.0000 % after 100 km (Computation 2.1): **the same 20 dB.**
3. Ratio of coefficients 5000.0000 (Computation 2.4): **1000 to 0.2.**
4. Ratio of distances 5000.0000 (Computation 2.4): **the inverse agrees.**
5. Fibre keeps 95.4993 % after 1 km (Observation 2.6): **almost undiminished.**
6. Window glass at 10^{-100} after 1 km (Computation 2.1): **not one photon.**
7. **90** repeaters across the Pacific (Computation 3.1): **9000 km.**
8. **450,000** with window glass (Computation 3.1): **four orders apart.**
9. The difference is impurity, not composition (Observation 3.4): **both silicon dioxide.**
10. The separator is name or impurity (Observation 4.3): **distinct roots by Paper 300.**

Closing: An optical fibre is described as “made of glass”, and a window is also glass—but to reach the same 1 per cent transmission, window glass gets **20 m** and a fibre gets **100 km**. Both spend 20 dB; one spends it over 20 m, the other over 100 km. The ratio of attenuation coefficients is $1000/0.2 = 5000.0000$ and the ratio of distances is $100,000/20 = 5000.0000$; that these agree is a property of exponential decay, and since each can be derived from the other it serves as a self-test. A fibre still carries **95.4993** per cent after a kilometre, where window glass would be at 10^{-100} and not one photon arrives. And the factor of 5000 is a difference not of degree but of possibility—placing a repeater each time 20 dB is spent, the 9000 km Pacific crossing needs **90** with fibre and **450,000** with window glass. Ninety can be built; powering a device on the sea floor every 20 m fails on power and failure rate long before it fails on the devices. Submarine cables stand on these four orders of magnitude. The difference is not the composition—both are mostly silicon dioxide, and what differs is the impurity, above all transition-metal ions such as iron. When 20 dB/km was proposed as a target in 1966 the glass of the day was at 1000 dB/km and a fiftyfold improvement was said to be needed; what arrived was 0.2 dB/km. One thing separates them—the name of the material or the quantity of impurity. “Transparent because it is glass” settles it by name, which suffices over short distances, but the factor of 5000 lives inside the name: the same word runs from 0.2 to 1000, and a name fixes a range, not a value. They are distinct roots by the criterion of Paper 300, the ceiling being set by composition and the actual value by impurity. And “transparent” means nothing until a distance is fixed—window glass is transparent at

3 mm and opaque at 20 m, the same shape as “nearest” demanding a distance in Paper 412. To be honest—setting repeater spacing by loss alone is a simplification; dispersion, nonlinear effects and accumulated noise all count, and the figure of 90 shows an order of magnitude rather than a design value. One last thing—0.2 dB/km has a physical floor, since Rayleigh scattering remains even with no impurity at all. The factor of 5000 is not “still not enough” but close to the limit.

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