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This Week's Citation Classic

Personick S D. Time dispersion in dielectric waveguides. *Bell Syst. Tech. J.* **50**:843-59, 1971. [Bell Telephone Labs., Holmdel, NJ]

Coupling amongst guided modes in a multimode waveguide is normally considered to be an undesirable phenomenon. However, when multiple mode excitation or at least some mode coupling is unavoidable, increased mode coupling can actually reduce dispersion caused by group velocity differences amongst guided modes. [The *SCI*® indicates that this paper has been cited over 100 times since 1971.]

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"The idea that mode coupling could be used as a mechanism for reducing dispersion (pulse spreading) in multimode waveguides occurred to me one afternoon in 1970 as a young engineer working at Bell Laboratories in Holmdel, New Jersey. I was on a rotational assignment to a Bell Labs research department at a time when optical fiber technology was in its infancy.

"One of the limitations of multimode optical fibers as a communications medium is the pulse spreading in propagation caused by the group delay differences amongst the guided modes. That afternoon I was trying to model this phenomenon in the hope of finding a new way to reduce the effect. Existing approaches included the use of graded index fibers with less spread in group delay differences, and single mode fibers.

"It occurred to me that a fiber ought to act approximately as a 'power filter,' with the optical output power waveform being the convolution of the input power waveform and a fiber impulse response. I then reasoned (fallaciously) that the impulse response of two fibers in tandem should be the convolution of the impulse responses of the individual fibers. My knowledge of communication theory told me that if this were the case, the pulse spreading in a long fiber would grow as the square root of the fiber length, rather than linearly with the fiber length. However, this square root relationship was not consistent with a simple propagation model. In about an hour I realized that in order for the convolution (root of length) argument to hold, the energy in the fiber modes would have to randomize amongst the modes in a distance short compared to the total fiber length, L. J called this randomization distance the coupling length, L_c. I then derived, in general, that with mode mixing (coupling) the dispersion in a fiber would be reduced by the factor $(L/L_c)^{1/2}$ .Thus the more coupling (shorter L_c) — the more improvement.

"I called my rotational supervisor (Tingye Li) at Bell Labs to tell him my idea. He immediately called an impromptu seminar at the Crawford Hill Lab (a small research facility three miles from Holmdel) for me to present the concept. It was Friday afternoon, and nearly everyone went home after the seminar shaking their heads in total disbelief. By Monday morning several of these same people were ready to file patent applications relating to practical ways to induce mode mixing in fibers and metallic waveguides. One team of two researchers examined some old analysis, and discovered to their amazement that with the proper approximations, they could verify my conclusions. These same two researchers later published a prizewinning paper in the *IEEE Transactions on Microwave Theory and Techniques* which included this result.[1]

"It was several years later that the theoretical result was verified by experiment. Many extensions of the basic ideas have been made, including the relationship between dispersion reduction and increased fiber attenuation due to mode mixing of various kinds.

"I believe that a critical key to my discovery is related to my background in communication theory that gave me certain intuitions that differed from those of the physicists I worked with at the time. Cross fertilization has paid off for me and Bell Laboratories (and TRW) on several occasions since then.

"For a recent review of dispersion in optical waveguides, see *Optical Fiber Telecommunications.*[2-4] I believe that my publication is frequently cited because it was the first disclosure of a somewhat counter-intuitive (but obvious in retrospect) notion "

1. **Rowe H E & Young D T.** Transmission distortion in random multimode waveguides. *IEEE Trans. Microwave Theory* **MTT-20**:349-65, 1972.
2. **Marcuse D, Gloge D & Marcatili E A J.** Guiding properties of fibers. (Miller S E & Chynoweth A G, eds.) *Optical fiber telecommunications.* New York: Academic Press, 1979. p. 38-100.
3. **Gloge D, Marcatili E A J, Marcuse D & Personick S D.** Dispersion properties of fibers. (Miller S E & Chynoweth A G, eds.) *Optical fiber telecommunications.* New York: Academic Press, 1979. p. 101-24.
4. **Cohen L G, Kaiser P, Lazay P D & Presby H M.** Fiber characterization. (Miller S E & Chynoweth A G, eds.) *Optical fiber telecommunications.* New York: Academic Press, 1979. p. 343-99.