CC/NUMBER 21
MAY 21, 1979

This Week's Citation Classic

Marcatili E A J. Dielectric rectangular waveguide and directional coupler for integrated optics. *Bell Syst. Tech. J.* **48**:2071-102, 1969. [Bell Laboratories, Holmdel, NJ]

The transmission properties of a guide consisting of a dielectric rod of rectangular cross-section surrounded by dielectrics of smaller refractive indices are determined. This guide is the basic component in a new technology called integrated optical circuitry. The directional coupler, a particularly useful device, made of two of those guides closely spaced is also analyzed. [The *SCI*® indicates that this paper has been cited over 145 times since 1969.]

E. A. J. Marcatili
Bell Laboratories
Crawford Hill Laboratory
Holmdel, NJ 07733

July 25, 1978

"In 1969 my friend and boss, S. E. Miller, came across the wonderful idea of fabricating the many components of optical transmitters and receivers on a single substrate using highly sophisticated but well known photolithographic techniques. These devices were very small (a few microns across), precise, insensitive to mechanical and thermal transients and, if fabricated in large numbers, economical. Integrated optical circuits were supposed to do for optics what integrated circuits did for electronics.

"It was immediately recognized that the basic component for this new technology was a waveguide consisting of a dielectric rod of approximately rectangular cross-section, surrounded by other dielectrics of lower refractive indices. In those days the analytical solution of such a problem was next to impossible. Even the much simpler questions of propagation in a dielectric rod of circular cross-section surrounded by a single dielectric were extremely difficult to answer. The complexity added by the multiplicity of dielectrics and the cornered cross-section was enough to discourage people from tackling the problem. However, I was lucky enough to recognize that the liability of the rectangular cross-section could be transformed into a very useful asset. In fact, it became obvious that the cross-section of the dielectrics surrounding the core could be divided into a few discrete regions and that the electromagnetic field in some of these regions could be neglected.

"This approximation simplified the problem to such a degree that the mathematics needed to solve the transmission problems became trivial, in fact, so trivial that even the more complicated problem of determining the properties of a directional coupler consisting of two such guides parallel to each other was solved in the same paper.

"Why has this paper been widely quoted? I believe there are three reasons: timeliness, simplicity of the treatment and results, and introduction of the new trick described above. Let me expand these three points. My paper appeared in the same issue of the *Bell System Technical Journal* where S. E. Miller introduced the basic ideas of integrated optics.[1] This coincidence was no accident, and my calculations were filling a need created by his ideas. Had my article been an exact treatment it probably would have been so complicated that readers would have been 'turned off.' Finally, the trick of neglecting the field in some parts of the guide cross-section was neat and has been used in many subsequent articles. Thus, my paper had not only an intrinsic value in itself but also provided dividends in the form of a simple mathematical tool useful elsewhere."

1. **Miller S E.** Integrated optics: an introduction. *Bell Syst. Tech. J.* **48**:2059-69, 1969.