The Propagation and Leakage of Waveguide Modes in a Waveguide with Randomly Rough Surfaces

N. P. Puente[1], E. I. Chaikina and E. R. Méndez[2], and A. A. Maradudin and T. A. Leskova[3]

[1] Facultad de Ingeniería, Universidad Autónoma de Baja California, Apartado Postal 2732, Ensenada, México.

[2] División de Física Aplicada, Centro de Investigación Científica y de Educación Superior de Ensenada, Km. 107 carretera Tijuana-Ensenada, Ensenada, B.C. 22860, México

[3] Department of Physics and Astronomy and Institute for Surface and Interface Science, University of California, Irvine, California, 92697, U.S.A.

The propagation of waveguide modes in a disordered waveguide has been widely studied both theoretically and experimentally. It was shown that the intermode mixing is strong, so that on a scale of the scattering length all modes supported by the waveguide are excited with uniform efficiency irrespectively of the illumination conditions. Thus, the diffusive regime of propagation of waveguide modes occurs in volume disordered waveguides. The situation is quite different in waveguides with randomly rough surfaces: bulk and surface disorders are not equivalent. The intermode mixing in waveguides with randomly rough surfaces depends strongly on the mode index, so that different propagation regimes can coexist.

In this work we present experimental and theoretical studies of the scattering of light propagating along a waveguide, a finite part of whose surface is randomly rough. As a model of a quasi-one-dimensional disordered system in our experiments we used a multimode commercial optical fiber. The diameter of the fiber is $D = 200$m. The part of the fiber with a randomly rough surface is $L_1 = 10$ mm, much smaller that the length of the fiber $L = 100$ mm. We have measured the differential intensity of the light emerging from a finite piece of the rough surface as a function of the parameters of the roughness and the position of the particular piece on the rough surface. The angular distribution shows a strong dependence on the distance of the "radiating" section from the front edge of the rough part of the waveguide. The experiments are supported by theoretical model calculations. By means of a rigorous numerical approach we study the propagation of waveguide modes through the randomly rough part of the planar dielectric waveguide. We calculate the angular distribution of the intensity of the light scattered into the vacuum from the rough part of the waveguide, as well as the the field distribution of the waveguide modes transmitted through it.