FIR INTEGRATED OPTICS: SCATTERING OF GUIDED WAVES DUE TO SINGLE PARALLEL WIRES AND WIRE GRID COUPLERS

Thomas Löhe and Maurus Tacke

Physikalisches Institut der Universität Würzburg
Röntgenring 8, D-8700 Würzburg, F.R. Germany

Received March 30, 1985

Introduction

Wires that are mounted parallel to the surface of an open dielectric waveguide can serve as optical elements, as reflectors or couplers. Periodic arrays of conducting stripes or wires are known to be useful as grating couplers [1,2], and may get important as distributed Bragg reflectors, if used in a nonradiative geometry [3]. Such grids will have low to moderate losses, in contrast to integrated optics in the visible. Additionally, due to the long wavelengths in the submm range, wire grids can be mounted with an adjustable separation to the waveguide, so that one may expect them to be a useful tool in FIR integrated optics.

In this paper we shall first treat the scattering of a single wire. This two-dimensional problem was solved following the procedure for three-dimensional scattering in Jackson's textbook [4]. It was necessary to derive the two-dimensional formulation for numerical evaluations. We use a notation in close analogy to Jackson, so that not all intermediate steps had to be discussed in detail. If necessary, they can be derived using the formulae of this paper and Jackson's reasoning. The scattering of a periodic array of wires will then be treated as a superposition of the single wire solutions.
Two major assumptions will be used throughout the calculations, sometimes they enter tacitly into the arguments: the conductance of the metals is taken to be good, that is \((\sigma/\varepsilon_0 \omega) \gg 1\), with the conductivity \(\sigma\), dielectric constant \(\varepsilon_0\) and the angular frequency \(\omega\) of the radiation. This is usually very well valid; even the quite poor conductor titanium has \(\sigma/\varepsilon_0 \omega \approx 10^5\) in the FIR. Second we assume, that the optical elements do not influence each other strongly. For instance, we neglect the reflection of the dielectric surfaces of the waveguide. This is reasonable as long as the scattered fields do not have notable plane wave components near grazing incidence to the low refractive index material.

**Scattering by a single wire**

Due to the symmetry of the problem, shown in figure 1, the scattered waves are treated in cylinder coordinates \(r, \varphi\). We assume no dependence on the third coordinate, \(d/\mathrm{dy} = 0\), so that the general solution of the Helmholtz equation in vacuum is for the field component \(\Psi\):

\[
\Psi = \sum_{m=-\infty}^{\infty} h_m(\kappa r) \exp(i m \varphi).
\]

![Diagram](image)

**Fig. 1.** The geometry of a wire of radius \(r_w\) suspended at a distance \(\ell\) from the center of a dielectric waveguide having the width \(2d\). Both sets of coordinates, \(r, \varphi\) and \(x, y, z\) will be used.