Periodic structures and anisotropic media: a comparison of the numerical results obtained by integral and differential methods

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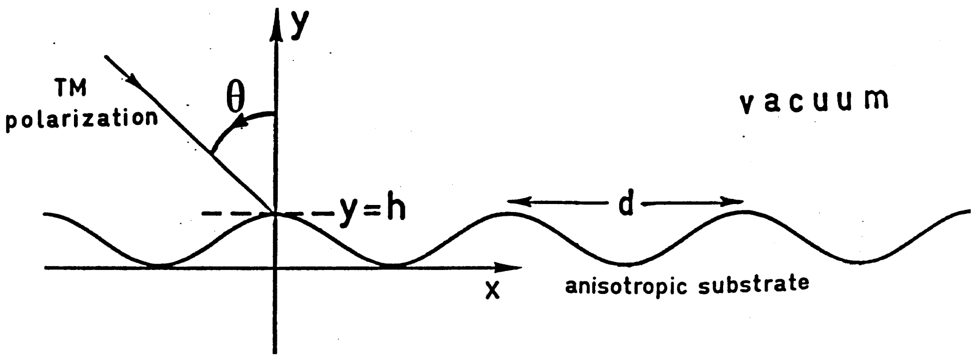
ABSTRACT

When both the integral and differential methods are applicable in the study of anisotropic gratings, we show that they lead to numerical results which are in good agreement. We think that it is a convincing proof of the reliability of our computer programs.

This paper must be considered as a companion paper of the one headed "Reasearches on gratings made with anisotropic materials: how is the work progressing in our Laboratory" presented at the same session by the same authors, and in which the classical differential method (C.D.M.) and the integral method (I.M.) have been depicted. Notations are the same in both papers and will not be exposed again.

We consider the following problem (fig. 1), which can be solved by our computers programs based either on the C.D.M. or the I.M.. An anisotropic sinusoidal grating made with a dielectric material of permittivity $[\epsilon_2] = \begin{bmatrix} \epsilon_x & 0 & 0 \\ 0 & \epsilon_y & 0 \\ 0 & 0 & \epsilon_z \end{bmatrix}$, where $\epsilon_x = 6.31$, $\epsilon_y = 6.81$, $\epsilon_z = 7.34$ is illuminated under the incidence $\theta = 20°$ by a plane wave. The wave vector of the incident wave lies in the xy plane. We only consider the case where the incident wave is TM polarized. Its wavelength is $\lambda = 0.6$ µm. The grating period is $d = 0.5$ µm. Consequently, the grating gives birth to two reflected and four transmitted orders which propagate in the same directions as those described in our companion paper (section 4.3.). There is no change in polarization and the diffracted field is also TM polarized.

Figure 1.



In the I.M., the accuracy of the results depends on three parameters N, ND and NSOM: N is the number of Fourier coefficients used to represent the kernels and the unknowns, ND is the number of sampling points (for one period) used for the integrations via discrete Fourier transform, and NSOM represents the number of terms retained for the summation of series giving the kernels. As for the D.M., the accuracy depends on two parameters: N again which is the number of generalized Fourier coefficients used to describe the fields, and J which is the number of steps used for the integration of the differential system betwwen y=0 and y=h.

We have computed the diffracted efficiencies for two values of h. We also give the computation times on CRAY 2 (they are approximately the same as those obtained on IBM 3090).

Table 1 shows for h = 0.1 μm the results given by the two methods. Our experience inclines us to trust those given by the I.M., which are however very closed to the C.D.M. results. We can also see, as it has already been emphasized [1], that the energy balance is always verified by the C.D.M., provided that the numerical process has been well conducted. One will note that the computation times are better with the I.M..

Table 1. h = 0.1 μm

	order	C. D. M.			I. M.	
		N=15,J=90	N=21,J=150	N=41,J=150	N=7,ND=15 NSOM=20	N=11,ND=21 NSOM=30
reflected efficiencies	-1	0.0695	0.0695	0.0695	0.0695	0.0695
	0	0.0730	0.0731	0.0733	0.0736	0.0735
transmitted efficiencies	-2	0.0015	0.0016	0.0018	0.0019	0.0019
	-1	0.0573	0.0573	0.0572	0.0571	0.0571
	0	0.6357	0.6337	0.6314	0.6288	0.6291
	1	0.1630	0.1648	0.1668	0.1691	0.1689
sum of efficiencies		1.0000	1.0000	1.0000	1.0000	1.0000
computation time		3 s	12 s	61 s	1 s	3 s

Table 2 has been computed with h = 0.2 μm (h/d = 0.4), and we see that the C.D.M. converges slower than for h = 0.1 μm. Higher values of the parameters (for instance N=31, J=200) lead to numerical troubles with the C.D.M.. Even for N=21 and J=200, the sum of efficiencies differs from 1., which means [1] that we are near the limits of the C.D.M.. Nevertheless, we see that the accuracy of the computed efficiencies is about 0.02 with the C.D.M., and it is probably sufficient in most practical applications.

Table 2. h = 0.2 μm

	order	C. D. M.		I. M.		
		N=15,J=90	N=21,J=200	N=7,ND=15 NSOM=10	N=11,ND=25 NSOM=20	N=25,ND=45 NSOM=30
reflected efficiencies	-1	0.0914	0.0913	0.0914	0.0923	0.0923
	0	0.0002	0.0002	0.0003	0.0003	0.0003
transmitted efficiencies	-2	0.0055	0.0061	0.0082	0.0078	0.0078
	-1	0.2512	0.2521	0.2608	0.2530	0.2530
	0	0.2436	0.2369	0.2185	0.2230	0.2231
	1	0.4081	0.4130	0.4275	0.4238	0.4235
sum of efficiencies		1.0000	0.9996	1.0067	1.0002	1.0000
computation time		3 s	16 s	1 s	3 s	11 s

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REFERENCE

1. R. Petit, G. Tayeb, "On the use of the energy balance criterion as a check of validity of computations in grating theory", Proceedings of SPIE, Vol. 815, p 2-10, 1987