

Table 1. Improvement in computation parameters compared with G-RCWA

Depth (μm)	100	550	1000	5500	10000
Improvement in Computation Time	5x	8.5x	10.7x	30.2x	33x
Improvement in # of Samples	4.1x	7.5x	8.5x	22x	25.1x

Finally, Fig. 7 shows the normalized intensity of a 1D periodic waveguide array calculated with the proposed method. The waveguide core and cladding refractive indices are 1.554 and 1.550 and the widths are $3.5 \mu\text{m}$ and $5 \mu\text{m}$ respectively. The incident wave is a Gaussian beam with $1/e$ beam width of $3 \mu\text{m}$ at a wavelength of 633 nm and normal angle of incidence. We note that the intensity profile at each height was calculated using the same Bloch eigenmodes and eigenvectors. As the Gaussian beam propagates through the waveguide, it couples into the adjacent waveguides and the diffraction pattern of the waveguide array is observed.

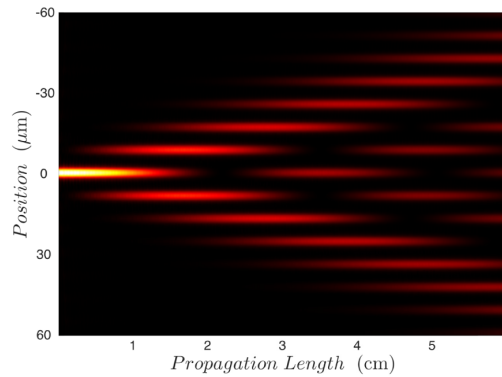


Fig. 7. Intensity pattern of a 1D periodic waveguide array.

5- Summary

An efficient numerical method was proposed to calculate the transmission of an electromagnetic beam through a deep periodic dielectric grating. The incident beam was decomposed into its Fourier spectrum of plane waves and the propagating Bloch waves for the periodic grating region were calculated for each plane wave component using RCWA. The RCWA solution was simplified by considering the forward propagating contributions and it was shown that there is an insignificant difference between the F-RCWA and G-RCWA solutions for deep gratings. As the depth of grating increases the variation of the transmission coefficients becomes faster as a function of spatial frequency, and therefore a larger number of samples is required for accuracy. Individual treatment of the propagating Bloch waves enabled us to calculate the inverse Fourier transform semi-analytically using both analytical integration of individual Bloch waves and FFT. The advantage was using the FFT to maintain the speed while accounting for the fast phase variations through analytical integration to maintain the accuracy of calculations with a smaller number of samples. It was shown that the presented formulations lead to accurate and efficient calculation of the output field.

Acknowledgments

This research was supported by the DARPA SCENICC program under contract W911NF-11-C-0210. The research was conducted while A. Shlivinski was on sabbatical leave at the University of California San Diego. The authors would like to thank Dr. Salman Karbasi for invaluable discussions.