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# Bidirectional Beam Propagation Method for Second-Harmonic Generation in Engineered Multilayer Photonic Bandgap Structures

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## Abstract

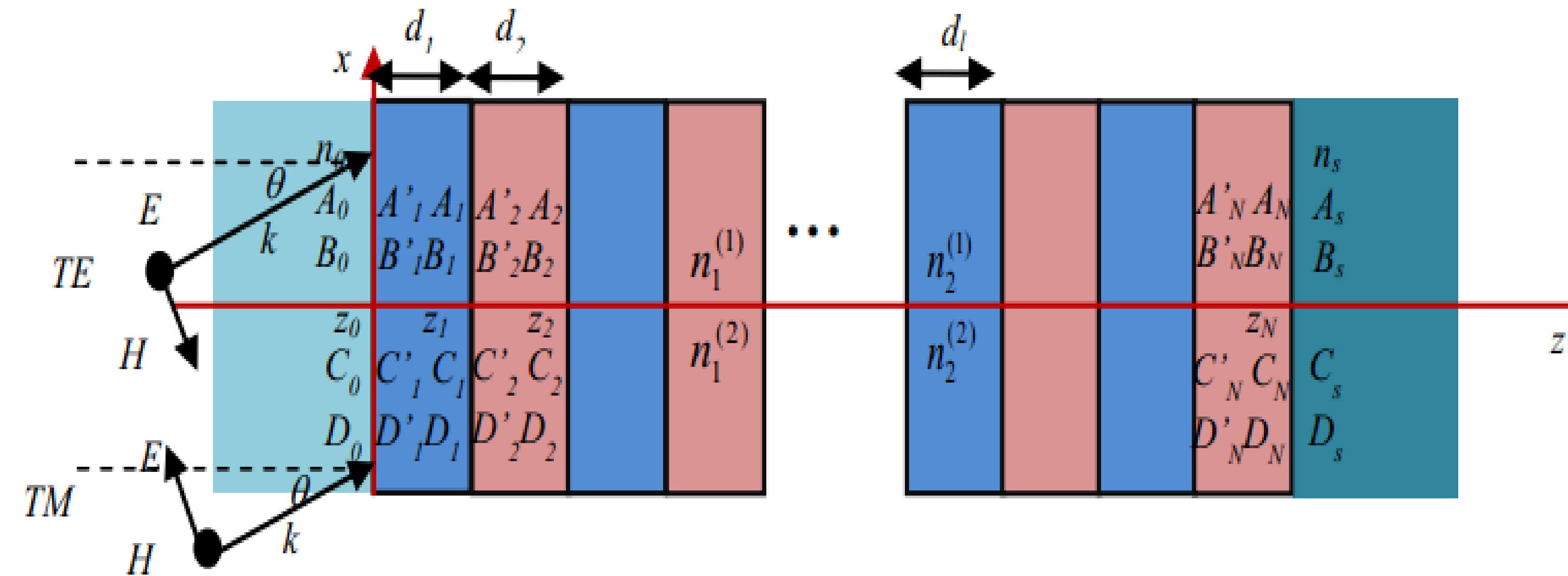
The transfer matrix method (TMM) has been used to analyze plane wave and beam propagation through linear photonic bandgap structures. Here, we apply TMM to determine the exact spatial behavior of TE and TM waves in periodic refractive index nonlinear structures of arbitrary thickness. First, we extend the TMM approach to analyze plane wave propagation through Kerr type nonlinear media. Secondly, In the second order nonlinearity case, the proposed TMM takes into consideration reflections and the interferences between the forward and backward-propagating waves but the nonlinear process is assumed to be weak so that the pump wave is unaffected by the nonlinear process thus the undepleted approximation. Finally in the second order nonlinearity case, the TMM is applied to study beam propagation in such media by applying the TMM to its angular spectrum components.

### Objective

The objective is to systematically investigate propagation of plane waves and arbitrary (e.g., Gaussian) profiles through a multilayer nonlinear structure. The bi-directional fundamental and Second harmonic frequency wave are obtained by using transfer matrix method (TMM). The TMM, developed for plane wave incidence, naturally incorporates interface reflections, as well as the polarization state of the electric field. This approach can be used to calculate the reflected and transmitted waves for a single layer structure and can be readily extended to multilayer structures.

### Methodology

- ✓ Use the transfer matrix method (TMM) to analyze the non-paraxial propagation of a collection of TE polarized plane waves having an initial Gaussian amplitude profile in 1 transverse dimension ( $x$ ) through a stack containing layers of nonlinear materials[1].
- ✓ Under the undepleted approximation, second order nonlinearity is evaluated by coupled wave equations, TMM and angular spectral components of the beam[2].



### Advantages of TMM

- ✓ TMM calculations are exact.
- ✓ Less computationally demanding.
- ✓ Can be performed for arbitrary angular plane wave spectra.
- ✓ Can be used for propagating and non-propagating waves.
- ✓ Can readily give  $E, H$  field details at every point during propagation.
- ✓ Can be readily applied to a wide variety of other cases, e.g., beam propagation through induced reflection gratings in nonlinear media.

### Future work

- ✓ Extend to depleted case.
- ✓ Extend to the third order nonlinearity beam propagation.

### References

- [1] P. P. Banerjee, H. Li, R. Aylo, and G. Nehmetallah, Proc. SPIE **8093**, 80930P (2011).
- [2] M. L. Ren and Z. Y. Li, J. Opt. Soc. Am. B **27**, 1551-1560 (2010).

