Beam Propagation Method

The beam propagation method (BPM) is widely used in photonics and nonlinear optics. It propagates a beam through nonhomogeneous media and achieves its efficiency by handling the propagation problem one grid slice at a time. The basis formulation assumes one-way propagation under the paraxial approximation. Bi-directional and wide-angle formulations exist.

GEOMETRY OF THE BPM PROPAGATION METHOD

BPM is implemented on a discrete Cartesian grid like the finite-difference frequency-domain method. There are no layers like there are in the method of lines. The grid is computed and interpreted as it is in FDFD. The algorithm and implementation looks more like the method of lines.

FORMULATION OF THE BASIC BPM ALGORITHM

Step 1: Start with Maxwell’s equations.

Step 2: Reduce problem to two dimensions. \( \frac{\partial^2 E}{\partial x^2} = \mu_0 \mu_0 \frac{\partial H}{\partial t} \) \( \frac{\partial^2 H}{\partial x^2} = \varepsilon_0 \varepsilon_0 \frac{\partial E}{\partial t} \)

Step 3: Assume a solution using the slowly varying envelope approximation.

Step 4: Write equations in matrix form.

Step 5: Derive matrix wave equation with small angle approximation.

Step 6: Approximate the \( z \)-derivative

Step 7: Solve field at \( z \)

SNAPSHOTS FROM A TYPICAL MODEL

BENEFITS

- Highly efficient method
- Can easily incorporate nonlinear materials properties. This is very unique for a frequency-domain method.
- Simple to formulate and implement
- FFT-BPM is simpler to formulate and implement.
- BPM is commonly used to model nonlinear optical devices and waveguide circuits.

DRAWBACKS

- Not a rigorous method
- Small angle approximation
- Ignores backward reflections
- FFT-BPM is slower, less stable, and less versatile than FD-BPM

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