

## Circuit diagram for transmitting signal lines in a beam splitter



### Overview

A beam splitter or beamsplitter is an optical device that splits a beam of light into a transmitted and a reflected beam. It is a crucial part of many optical experimental and measurement systems, such as interferometers, also finding widespread application in fibre optic telecommunications.

### Key Takeaways

A beam splitter divides an input signal into transmitted and reflected outputs, which can be represented using a simple two-port schematic with defined transmission and reflection coefficients. Conceptual Schematic

A typical beam splitter can be represented as a two-input, two-output system:

Input a  $\text{---} \mid \mid$  Beam Splitter (B)  $\mid \text{---} \mid$  Input b  $\text{---} \mid \mid$   $\rightarrow$  Output a' =  $T \cdot a + R \cdot b$   $\mid \text{---} \mid$   
Output b' =  $R \cdot a + T \cdot b$

- Inputs (a, b): Optical or photonic signals entering the beam splitter. In many setups, one input may be vacuum or unused.
- Outputs (a', b'): Signals after splitting, which are superpositions of the inputs depending on the transmission (T) and reflection (R) coefficients .
- Transmission and Reflection: For a 50/50 beam splitter,  $|T|^2 = |R|^2 = 0.5$ , and the outputs are equal superpositions of the inputs .

Transmission Matrix Representation

The beam splitter can also be described using a unitary transformation matrix:

$$\begin{bmatrix} a' \\ b' \end{bmatrix} = \begin{bmatrix} T & R \\ R & T \end{bmatrix} \begin{bmatrix} a \\ b \end{bmatrix}$$

- Unitary property: Ensures energy conservation (lossless approximation).
- Phase factors: T and R can be complex numbers to account for phase shifts introduced by reflection or transmission .

Quantum Interpretation

In quantum optics, a single photon entering port a can be represented as  $|1\rangle_a|0\rangle_b$ . After the beam splitter:

$$B|1,0\rangle = T|1,0\rangle + R|0,1\rangle$$

- Each output port carries a superposition of the photon being transmitted or reflected .
- This principle is essential for interferometers, quantum circuits, and entanglement experiments.

Practical Notes

- Cube or plate beam splitters are commonly used, with coatings to achieve desired T:R ratios .
- Polarizing beam splitters separate signals based on polarization, often combined with waveplates to control output distribution .
- Circuit diagrams in optical systems often use lines for optical paths and nodes for beam splitters, similar to the schematic above, to represent signal routing in experiments or fiber-optic networks . This schematic provides a clear framework for transmitting and analyzing signals through a beam splitter, whether in classical optics or quantum photonics.

## Article Content

Beam splitter

Overview Designs Phase shift Classical lossless beam splitter Use in experiments Quantum mechanical description Reflection beam splitters

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