OPTICS & PHOTONICS
MARKETPLACE

# How to Select a Beamsplitter

Beamsplitters are used in laser systems, optical interferometry, fluorescence, and biomedical instrumentation. They come in three basic forms: plate, pellicle, and cube. All are made using a partially reflecting coating, but due to differences in construction, they differ in power handling. Plate beamsplitters are made using a coated substrate, and thus exhibit beam offset and ghost reflections from the second surface. Cube beamsplitters avoid beam displacement by working at 0° angle of incidence and placing the coated surface between two right angle prisms, but power handling can be limited if epoxy is used to bond the prisms. Optical contacting can increase the laser damage threshold, though ghost reflections from the entry and exit faces can still occur. A pellicle beamsplitter may appear to solve these problems by stretching an elastic membrane (sometimes coated) over a metal frame until it is very thin, but in reality, coating options are limited, and they offer lower power handling than cube beamsplitters. When working with laser light, a plate or cube beamsplitter offers the best combination of optical performance and power handling.

Once the power handling needed and tolerance for ghost reflections has been established, the next step in selecting a beamsplitter is choosing the right coating. Does it need to work just at specific laser wavelengths (laser line), or over a broad range of wavelengths (broadband dielectric and hybrid coatings)? Does it need to separate *s*- and *p*-polarizations (polarizing coatings), or do the reflected and transmitted beams need to retain their polarization ratio (non-polarizing and broadband hybrid coatings)? Whatever the application, CVI Laser Optics has an off-the-shelf or custom solution to fit your needs. Read on to start narrowing your search by beamsplitter type: plate, cube, or integrated construction for variable attenuation.

*NOTE: Custom beamsplitters can be made with different dimensions, different split ratios, and optimized for different wavelengths. Standard beamsplitter coatings can also be applied to almost any right-angled prism.*

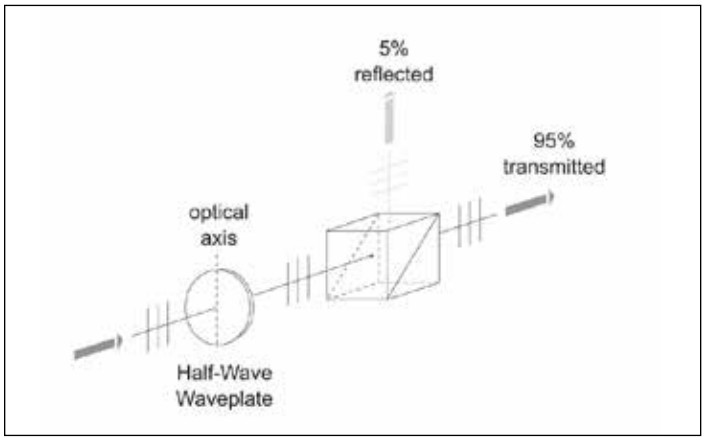



*Fig 1: Orientation of waveplate for maximum p-polarized transmission*

## Plate Beamsplitters:

Plate beamsplitters are flat substrates with a partially reflecting coating on one surface that divides the optical beam based on power or wavelength. No epoxy or optical contacting is used in fabrication, making plate beamsplitters intrinsically suitable to high energy applications. The coating type determines the power handling, with very high laser damage threshold options available (up to 10 J/cm$^2$, 20 ns pulse, 20 Hz @1064 nm).

Plate beamsplitters work at an angle of incidence of 45°, with the beam first encountering the primary coated surface and experiencing partial reflection. As the remainder of the beam travels through the substrate, it experiences some lateral displacement or offset. Upon encountering the back surface of the substrate, a small portion of the light is reflected back along the path of the reflected beam, creating a ghost beam with a small displacement (~0.3x the thickness of the substrate). An AR coating on the back surface of the substrate minimizes this effect, and also maximizes transmission of the beamsplitter.

## Cube Beamsplitters:

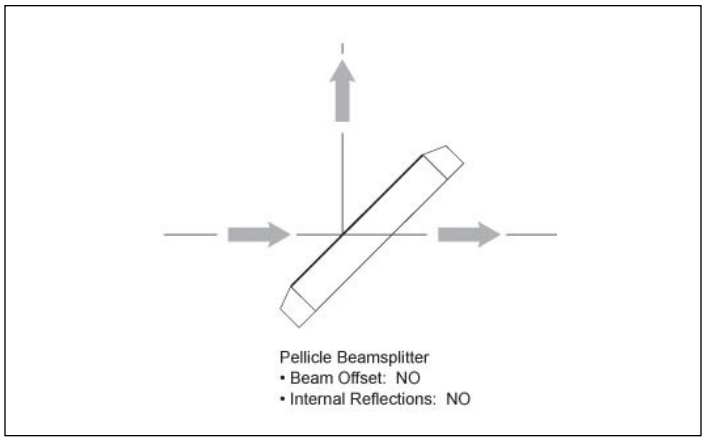
A cube beamsplitter is composed of a prism with a partially-reflecting coating bonded to a second prism, and typically divides a beam based on power or polarization. Antireflection coatings on the entry and exit faces of the cube minimize loss and reduce ghost reflections (though they are still present). Cube beamsplitters eliminate beam displacement without being fragile. They are easy to mount and mechanically durable, but the presence of an interface can limit power handling if epoxy is used for bonding. CVI Laser Optics carries a line of high damage threshold products that use epoxy-free bonding techniques like optical contacting and our Chemically Active Direct Bonding® technology to allow use even at high laser power (up to 10 J/cm$^2$ @ 1064 nm).

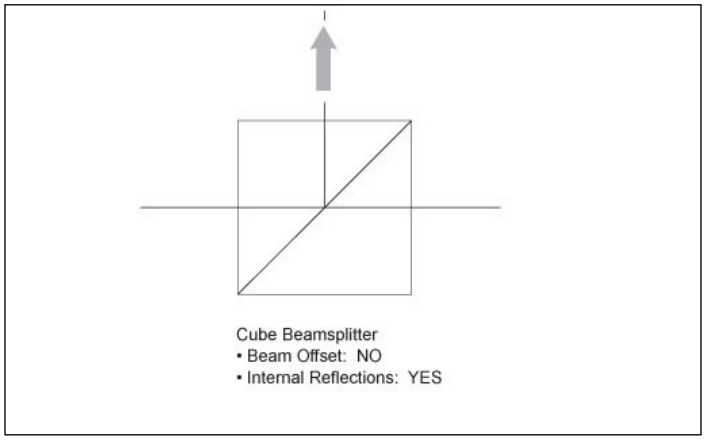
For best spectral performance and transmitted wavefront, cube beamsplitters should be used with collimated or near-collimated light, as convergent or divergent beams will contribute unwanted spherical aberration to an optical system. If one prism is marked with a dot, this indicates the coated prism. For best performance, the optical beam should traverse this prism first.

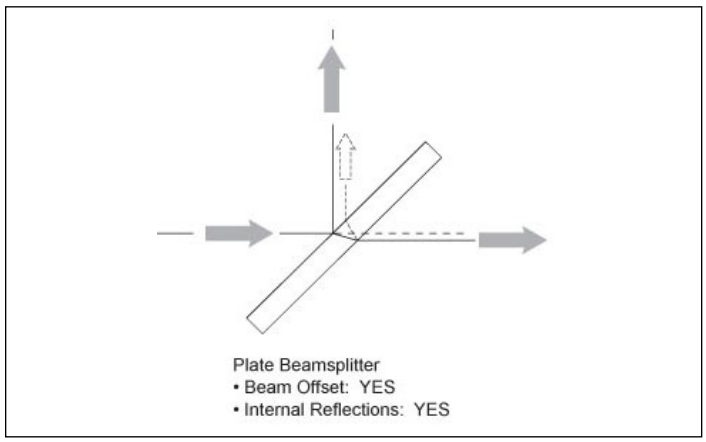
Application tip: Polarizing cube beamsplitters can be used for optical isolation or as a continuously variable beamsplitter when used in combination with a waveplate.

## Basis of separation: Power, wavelength, or polarization

Once the preferred construction type has been identified based on power handling and tolerance to beam displacement, the next step is to narrow the search based on how the beamsplitter needs to divide or combine light. Power separating beamsplitters are used to split beams into two orthogonal paths, and can also combine portions of two different beams into one path to create a single, mixed beam. When a broadband coating is used, these beamsplitters can be used to conveniently blend beams of different wavelength into a single path. Some power separating beamsplitters are non-polarizing, i.e., performance for *s*- vs. *p*-polarized beams does not differ greatly. Others have some degree of polarization sensitivity, in which case averaging the performance for *s*- and *p*-polarized beams yields consistent transmission or reflection values across the operating wavelength range. Wavelength separating beamsplitters use dichroic coatings




*Figs 2-4: Diagrams of pellicle, cube, & plate beamsplitters*

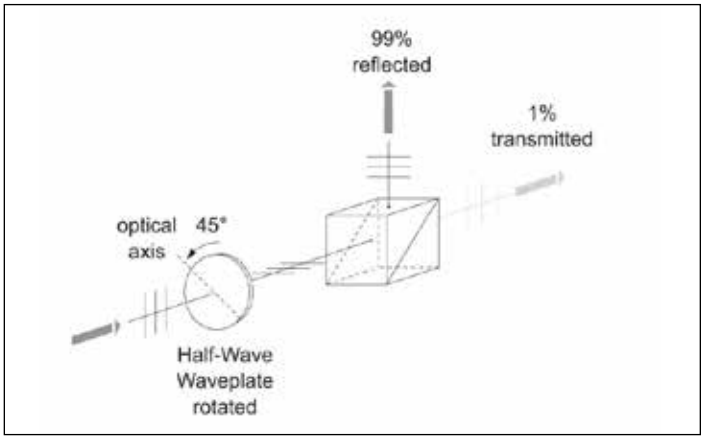



*Fig 5: Aligned for maximum p-polarized transmission*

to reflect at one wavelength or band while transmitting at another. These beamsplitters can separate components of a laser beam based on wavelength, or to truly combine different wavelengths (or bands) with minimal loss, and are thus suitable for high power applications. Polarization separating beamsplitters reflect *s*-polarized light and transmit *p*-polarized light with high efficiency at a specific laser wavelength or over a broad range of wavelengths. This can offer another method to combine and divide laser beams of different wavelengths, provided the polarizations of the two beams are (or can be made) orthogonal to one another.

## Bandwidth of operation: Laser line or broadband

With the form and function of the beamsplitter identified, the search can be narrowed further based on whether laser line or broadband spectral performance is needed. The coatings on laser line beamsplitters are designed for up to three very specific wavelengths, and as such are available off-the-shelf for only the more common laser wavelengths. Operation at other wavelengths should be undertaken only after carefully reviewing the spectral performance away from the specified laser wavelengths, and with the understanding that performance at non-specified wavelengths may exhibit very different characteristics for *s*- vs. *p*-polarization. If a non-standard wavelength is needed, it is best to contact CVI Laser Optics technical support to determine whether a more optimal part is available, or if a custom part should be created. The coatings used on broadband beamsplitters vary by product. Electron beam multilayer dielectric coatings offer higher laser damage threshold and minimal absorption, but with better transmission for *p*- vs. *s*-polarization. Hybrid metal dielectric coatings exhibit moderate absorption, but with very little polarization sensitivity.

## Making the final decision

Once the construction type, basis of separation, and bandwidth have been determined, there may still be several beamsplitter types from which to choose. The decision is then based on factors like split ratio, polarization sensitivity, extinction ratio, and power handling. Within each product line, many options exist for wavelength of operation, size, shape, thickness, and reflection to transmission ratio. If the flowchart and table below don't lead you to the right beamsplitter for your needs, our technical staff is ready to help you find the right product: off-the-shelf, semi-custom, or one fully customized to your application.

## High Energy Continuously Variable Beamsplitters

In addition to plate and cube beamsplitters, CVI Laser Optics also offers an integrated beamsplitter product that allows continuously variable attenuation of linearly polarized light for precise control of transmission from 1 – 95% (*p*-polarization). By combining a half-waveplate and polarizing beamsplitter, continuous tuning of the transmitted *p*-polarized light is achieved through manual adjustment of the waveplate orientation. What is unique about this variable beamsplitter is that optical contacting used in its construction make it is suitable for high power applications (up to 5 J/cm$^2$ @ 1064 nm; 20 ns, 20 Hz pulse).

| Product Code | Description | Basis of Separation | Additional Features | Pol. |
|---|---|---|---|---|
| BS1 | High Energy Plate Beamsplitters | Power | ▪ Reflectivity from 10-99% at a specific polarization<br>▪ Almost no absorption | Y |
| BSNP | Laser Line Non-polarizing Plate Beamsplitters | Power | ▪ 50/50 splitting of the laser line<br>▪ Near equal transmission for *s*- & *p*-polarization | N |
| BBS | Broadband Plate Beamsplitters | Power | ▪ 50/50 laser splitting<br>▪ Available for visible through near-IR<br>▪ For cw and low-energy pulsed laser applications | Y |
| BTQ<br>BTF-VIS<br>BTF-NIR | Standard Plate Beamsplitters | Power | ▪ 30/70, 50/50, or 70/30 splitting<br>▪ Available for UV through near-IR<br>▪ Economical for low-power applications | Y |
| BSR | High Energy Harmonic Separators | Wavelength | ▪ Combines/separates harmonics<br>▪ Nd:YAG & Ti:Sapphire lasers | N |
| LWP | Long Wave Pass Dichroic Beamsplitters | Wavelength | ▪ Reflects short wavelengths<br>▪ Transmits long wavelengths | N |
| SWP | Short Wave Pass Dichroic Beamsplitters | Wavelength | ▪ Transmits short wavelengths<br>▪ Reflects long wavelengths | N |
| NCBS | Laser Line Non-polarizing Cube Beamsplitters | Power | ▪ 50/50 splitting of a laser line<br>▪ Low power applications | N |
| BSD | Broadband Dielectric Cube Beamsplitters | Power | ▪ 50/50 splitting for unpolarized light<br>▪ Highly polarization-sensitive<br>▪ CW and low-energy pulsed laser applications | Y |
| BSC | Broadband Hybrid Cube Beamsplitters | Power | ▪ Hybrid metal dielectric coating<br>▪ 50/50 splitting<br>▪ Some absorption, but low polarization sensitivity<br>▪ CW and low-energy pulsed laser applications | N |
| UPBS | UV Laser Line Polarizing Cube Beamsplitters | Polarization | ▪ 100:1 extinction ratio<br>▪ Low power applications (<10 mJ/cm$^2$ @ 266 nm) | Y |
| PBS | Visible & Near-IR Laser Line Polarizing Cube Beamsplitters | Polarization | ▪ 1000:1 extinction ratio<br>▪ Moderate power applications (1 J/cm$^2$ @ 1064 nm) | Y |
| PBSO | High Energy Laser Line Polarizing Cube Beamsplitters | Polarization | ▪ High extinction ratio<br>▪ High power applications (5 J/cm$^2$ @ 1064 nm)<br>▪ UV through NIR wavelengths<br>▪ Optically contacted | Y |
| PBSI | Ion Beam Sputtered High Energy Laser Line Polarizing Cube Beamsplitters | Polarization | ▪ High extinction ratio<br>▪ High power applications (10 J/cm$^2$ @ 1064 nm)<br>▪ Near-UV through NIR wavelengths<br>▪ Chemically Active Direct Bonding® | Y |
| PBSH | Visible and Near-IR Broadband Polarizing Cube Beamsplitters | Polarization | ▪ 500:1 extinction ratio<br>▪ Moderate power applications | Y |

## Selection Guide: