High Energy Harmonic Separators

CVI Optical Components and Assemblies

Application Notes

Nd:YAG Harmonics

Second, third, fourth, and fifth harmonic generation at 532, 355, 266, and 213nm form a very important part of Nd:YAG laser technology. In many applications, only one harmonic is needed. For those applications, the fundamental and perhaps the second harmonic are (sometimes dangerous) stray beams. An example is pumping a dye or pulsed Ti:Sapphire laser with the second harmonic at 532nm. Only green light should be sent to the laser; 1064nm light should be efficiently shunted into a different channel to be further used or dumped. Other applications require more than one beam, in which case two or more of the beams have to be delivered to the experiment. One example of harmonic generation of an Nd:YAG laser is shown in Figure 1.

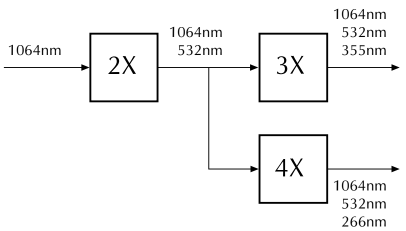

Figure 1. External harmonic generation of a pulsed Nd:YAG laser. Crystal 2X produces the second harmonic at 532nm. In crystal 3X, residual fundamental at 1064nm is mixed with the second harmonic to produce the third harmonic at 355nm. To produce the fourth harmonic at 266nm, the 532nm second harmonic can be frequency doubled in crystal 4X.

Polarization of the Beams

The polarization of the beams is an important consideration when laying out an optical system involving harmonic generation. The user has to be aware of the polarization properties of the crystals employed and should plan in advance the polarizations to be delivered to the experiment. Two common configurations are shown in Figure 2.

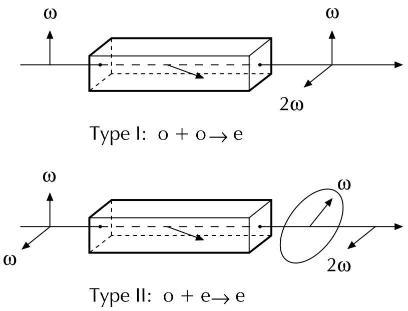

Figure 2. Illustration of Type I and Type II phasematching in second harmonic generation.

In Type I phasematching, the fundamental is an ordinary wave and the second harmonic is an extraordinary wave. Note that the second harmonic is locked to the plane of Z axis of the crystal. In the example above, in order to generate vertically polarized second harmonic without the use of a waveplate, both the crystal and the input fundamental polarization would be rotated 90°. Note that the residual fundamental remains linearly polarized.

In Type II phasematching, ordinary and extraordinary components of the fundamental, here equal, are mixed to generate the second harmonic as an extraordinary wave. This means that the fundamental must be rotated 45° with respect to the plane of the Z axis. Once again, the linearly polarized second harmonic is locked to the plane of Z axis of the crystal. Because the fundamental has ordinary and extraordinary components experiencing differing indices of refraction in the crystal, it experiences birefringence and emerges from the crystal in an elliptical polarization state whose parameters depend in detail on crystal length and orientation. As in the Type I example, in order to generate vertically polarized second harmonic, one would rotate the crystal 90° about the propagation direction.

The above examples have been provided to help you visualize the polarization properties in harmonic generation.

Harmonic Separation Arrangements

CVI supplies harmonic separator mirrors optimized for all combinations of harmonics. Below are some examples of effective systems built from these components. Laser safety practices are of paramount importance in dividing the outputs of a high power Nd:YAG laser. Some suggestions for safe operation are given in Figures 3 and 4.

Design Suggestions

1. Determine which harmonic is "most valuable" (ie. the harmonic that must be preserved most efficiently.)

2. Reflect this harmonic and try to arrange 45° S polarization for this harmonic at the harmonic beam separators. As a rule plan to use two separator mirrors per harmonic. Most systems require two for acceptable purity.

3. If a useful harmonic must be transmitted through a BSR, try to arrange 45° P polarization for that harmonic.

4. Choose the harmonic separator's antireflection coating to transmit the

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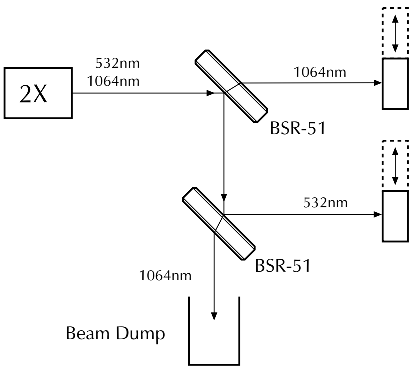

Figure 3. Second harmonic separation system where at least 98% of the 532nm energy is preserved. Two BSR-51s are used to improve the green purity. Residual 1064nm light is trapped in a beam dump. Shutters are placed in both output beams.

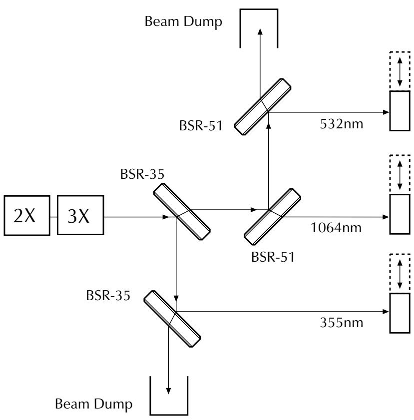

Figure 4. A system in which the object is to preserve and purify both the second and third harmonic. The 355nm light is given priority and separated first with two BSR-35s. Then the second harmonic is separated with a pair of BSR-51s. 1064nm is available in a third beam.

next most valuable harmonic in the beam line if further separation is to be done. If the transmitted beam is going directly into a beam dump, choose the antireflection coating based on the most powerful dumped harmonic.

5. To reduce eye hazard potential, build the separation system to operate in a horizontal plane. Beam dumps (CVI Series **48** Beam Dump ▶ **398**) should be much wider than the beams they are to receive and should be firmly locked to the table. We recommend that barriers or an enclosure surround the perimeter of the system.

6. Always assume that there are significant amounts of unwanted harmonics in beams unless experiments prove otherwise. For greatest purity use multiple pairs of **BSR**s or construct a dispersive system using Pellin Broca (PLBC ▶ **38**) or Brewster Angle Dispersing Prisms (IB ▶ **36**).

7. Most **BSR** Series harmonic beamsplitters for the Nd:YAG harmonics of 1064nm will work at the Nd:YLF harmonics of 1053nm and 1047nm. If you are working with a YLF laser, specify "for 527/1053nm" after the corresponding Nd:YAG part number. Our technical staff will assure that optics selected will meet specifications at the YLF wavelengths.

Bandwidth Considerations

The region of high reflectivity and low transmission of a harmonic separator is called the stop band. The region of high transmission is called the pass band. The region between these bands is called the transition region.

The bandwidth of the stop band is similar to that of a laser mirror. For the **BSR** Harmonic Separators, the approximate bandwidths can be found by consulting the tables for the **TLM1** Narrowband Laser Mirrors.

Note that the transition region cannot be made infinitely sharp, and that there is some "ringing" in the pass band. Because of this, there may be a trade off between the reflectivity and transmission specifications possible when specifying a harmonic separator. Your CVI salesperson will be happy to assist you in determining an optimized design for your experiment.

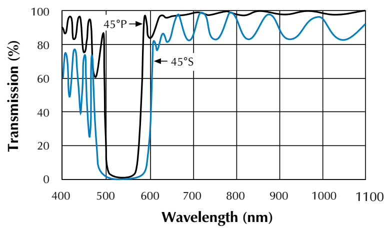

Figure 5. Transmission vs. Wavelength of BSR-51-1025 Harmonic Separator.

Polarization Considerations

Figure 5 is a graph of transmission vs. wavelength for a **BSR** Harmonic Separator 45°.

In this case, the region of high reflectivity for S polarized light is appreciably broader than for P polarized light. There is also generally more passband "ringing" for S polarized light at 45°, resulting in reduced average transmission for this polarization.

Suggestions When Specifying Harmonic Separators

The following is a general rule to be followed when combining or separating polarized laser beams at 45° incidence angle. Use of this rule becomes increasingly important as the reflected and transmitted wavelength bands move closer together.

Polarization Rule For 45° Beamsplitters

Best:	Reflect 45°S	Transmit 45°P
2nd Best:	Reflect 45°P	Transmit 45°P
3rd Best:	Reflect 45°S	Transmit 45°S
Avoid:	Reflect 45°P	Transmit 45°S

continued

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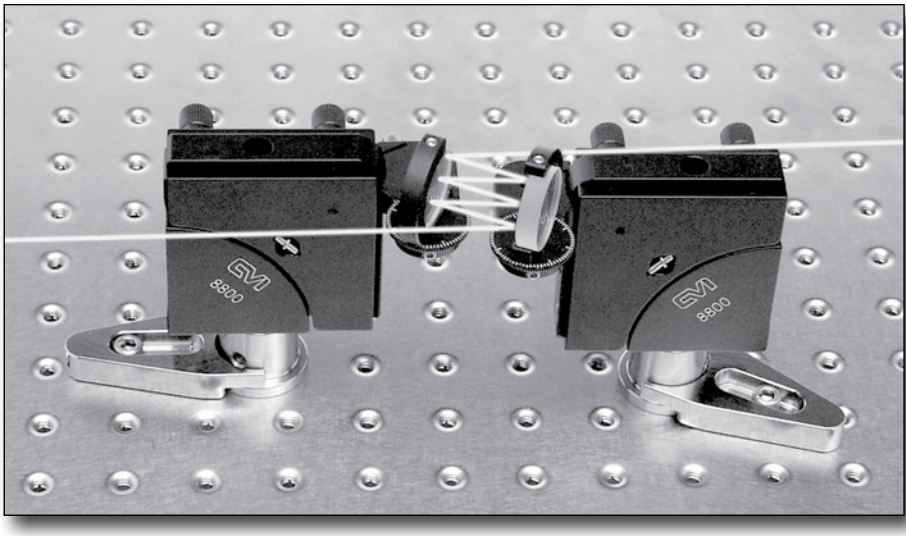
The first choice maximizes both transmission and reflectance bandwidth while the second choice maximizes transmission bandwidth. The third choice maximizes reflection bandwidth and the fourth choice should be avoided unless the two wavelength bands in question are far enough apart.

The next rule concerns efficiency. Sometimes, it is most important to capture every available photon at one wavelength. An example is the common situation of preserving all the energy in a harmonic beam that is buried in a powerful beam at a longer wavelength. A contrasting situation occurs when it is more important to eliminate as many photons as possible at an interfering wavelength, even at the expense of losing some of the photons at the desired wavelength. This situation occurs when your signal is "large", but the obscuring beam is very powerful. The following rule, which handles both cases, follows from the fact that it is easy to make a harmonic separator with R > 99.5%, but it is often hard to guarantee T > 90%.

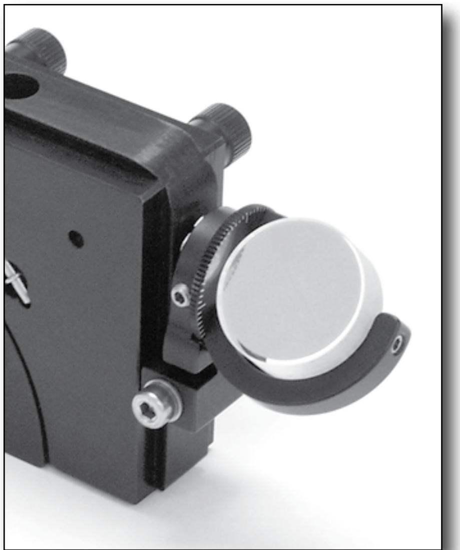
Efficiency Rules For Separators Beam Separation

When Absolute Efficiency at One Wavelength is Most Important, Reflect that Wavelength and Transmit the Other.

When Spectral Purity at One Wavelength is Most Important, Transmit that Wavelength and Reflect the Other.



CVI Super Mount™ and applications can be found on page ▶ **355**



CVI Super Mount™ and Perpendicular Series B carrier. These can be found on page ▶ **355**