



VOLUME BRAGG GRATINGS

— *from* —

OptiGRATE
An IPG Photonics Company





“BragGrate™ -
World records in volume Bragg gratings.”

OUR COMPANY

OptiGrate, an IPG Photonics company, is a pioneer and world leader in volume Bragg grating (VBG) technologies. In 1999 OptiGrate pioneered commercial volume Bragg gratings (VBGs) from photo-thermo-refractive (PTR) glass and for 2 decades supplies holographic optical elements to more than 600 customers on 6 continents in optoelectronic, analytical, medical, defense, and other industries.

OptiGrate's vertical integration of VBG manufacturing and our superior ability to optimize PTR glass and VBG characteristics have allowed us to become a reliable supplier of diffractive optical components for many government contractors and industrial manufacturers.

Our state-of-the-art manufacturing facility was designed specifically for VBG production and accommodates the increased demand for our products and allows for future expansion of the company. OptiGrate can mass produce a wide variety of fine-tuned PTR glasses and high-performance holographic volume Bragg gratings that can be customized to meet customer specific requirements.


OptiGrate and IPG Photonics Oviedo Technology Center are located in Oviedo, FL in the Orlando metropolitan area where we design, develop and make all our products.

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*“Vertically integrated manufacturing:
Reliable, fast, customer oriented.”*

OUR PRODUCTS

BragGrate™ Mirror

BragGrate™ Pulse

BragGrate™ Notch Filter

BragGrate™ Bandpass Filter

BragGrate™ Spatial Filter

BragGrate™ Deflector

BragGrate™ Combiner

APPLICATIONS

Laserline Narrowing and
Stabilization

Spectral and Spatial Filters

Raman Filters

Multiband Filters

Compressors for fs and ps-lasers

Spectral Beam Combining

Coherent Beam Combining

Wavelength Multiplexing

High Power Beam Splitting

Beam Steering and Deflection

Angular Magnifiers

Single Photon Counting

Wavelength Tunable Lasers

BragGrate™ - Mirror

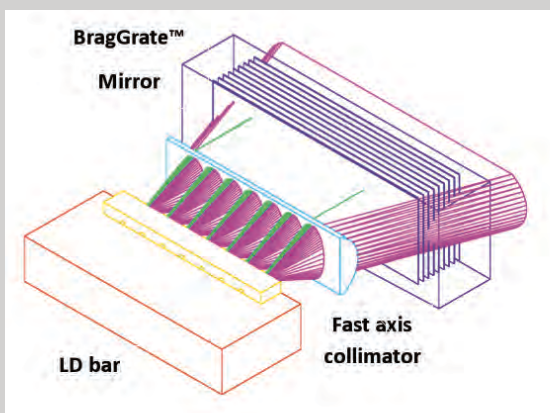
Reflecting Bragg Grating (RBG) for laser mode selection

Product Description

The BragGrate™ Mirror is a reflecting volume Bragg grating recorded in a bulk of photosensitive silicate glass. BragGrate™ Mirrors are placed in a laser resonator which enables spectral and thermal management of the laser radiation. The laser mode structure is controlled by the longitudinal mode selection with the bandwidth down to 10 GHz and the customized central wavelengths with accuracy of 0.1–0.5 nm. BragGrate™ Mirrors have a record low absorption and scattering that allows them to withstand record high optical densities of up to 10 J/cm². This also yields a thermal laser wavelength shift reduction of up to 5 pm/K at 532 nm.

Applications

- Longitudinal and transverse mode selection in laser resonators
- Solid-state lasers
- High-power diode lasers
- MM and SM diode lasers for spectroscopy
- Fiber lasers
- Laser radars, LIDARS, etc...



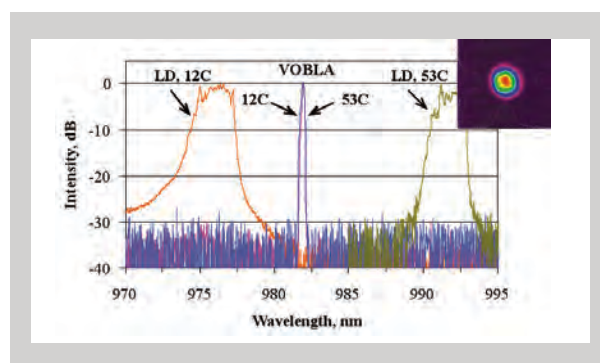
Schematics of LD bar stabilization with a BragGrate™ Mirror.

Specifications

Diffraction Efficiency (DE): up to 99.8%
Spectral Bandwidth: 10 pm to 0.5 nm
Wavelength Range: 350–3000 nm
Grating Thickness: 0.50–20 mm
Apertures: up to 35×35 mm ²
Angular Selectivity: 1–100 mrad
Grating to Surface Tilt Angle: 0–10 deg
Absorption/Scattering Losses: <2%

Advantages & Features

- High power operations, over 1 kW
- High energy operations up to 5 J/cm²
- Low to No power penalty
- Unrestricted lifetime, no degradation of parameters has been detected for over 10 years
- Narrowing of laser line down to 20 pm with superior thermal stability
- Environmental stability
- No polarization dependence
- Unique solutions to achieve SFM oscillations
- Near-diffraction-limited beam quality



Normalized spectra of 2W free running LD and with BragGrate™ Mirror at different T. The narrowed linewidth was < 45 pm.

Insert: mode profile with a 10% DE BragGrate™ Mirror

BragGrate™ - Pulse

Stretcher & compressor for ultra-short pulse lasers

Product Description

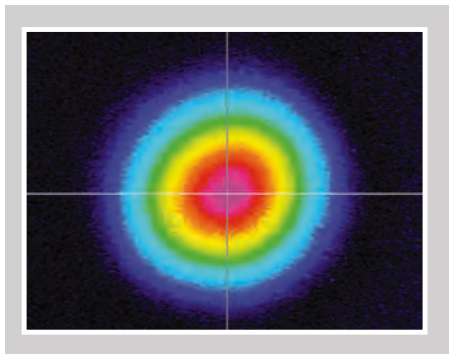
BragGrate™ Pulse is the first commercially available Chirped Bragg Grating (CBG) based product especially designed for the stretching and compression of femtosecond and picosecond laser pulses. It is a volume Bragg grating in reflecting geometry with a period that gradually varies along the direction of the beam propagation (CBG). It is the most compact and robust stretcher/compressor solution for high energy and high average power ultra-short pulsed laser systems.

Product Features

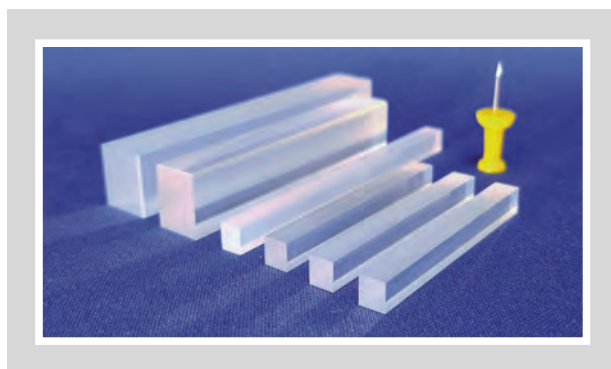
- Compact geometry and easy-to-align
- High power operation (up to 1 kW average power)
- High energy operation (up to 5 mJ pulse energy)
- Environmentally stable
- Robust, easy to handle and clean
- Preserves diffraction limited quality of femtosecond laser beam with diffraction efficiency exceeding 90%

Applications

BragGrate™ Pulse is for temporal stretching of a reflected ultrashort pulse and recompression of this pulse if launched from the opposite side of the grating. Most compact and robust compressors are ideal for industrial and scientific applications.



Output beam shape after passing 30-mm-thick CBG in both directions



Specifications

Operating range: 800–2500 nm

Spectral bandwidth: 1–100 nm

Thickness: 10–50 mm

Stretching time: 10–500 ps (FWHM)

Efficiency: 70–95%

Apertures: up to 8x10 mm²

Typical Specs of BragGrate™ - Pulse for 1030 nm spectral range

Center wavelength: 1032 nm

Spectral bandwidth: 5, 10, 25 nm

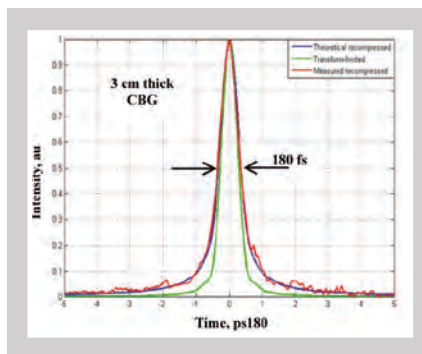
Diffraction efficiency: > 85%

Thickness: 20, 35 mm

Stretching time (FWHM): ~ 150 ps

Dispersion rate: ~ 6, 10, 25, 40, 60 ps/nm (linear)

Compressed pulse duration: < 200 fs



Compressed pulse profile theoretical vs measured data with 30 mm thick BragGrate™ Pulse

BragGrate™ - Notch Filter (BNF)

Ultra Narrow ($<10\text{ cm}^{-1}$) Bandstop Filter for Rayleigh light suppression

Product Description

BragGrate™ Notch Filter (BNF) is a reflective volume Bragg grating recorded in a bulk of photosensitive silicate glass. Ultra-Narrow-Band Notch Filters reflect light with bandwidths as narrow as 5 cm^{-1} while all other wavelength pass unaffected with up to 95% total transmission. BNF's enable simultaneous measurements of Stokes and Anti-Stokes Raman bands down to 5 cm^{-1} with a single stage spectrometer. Our Notch filters can withstand temperatures of up to 400°C and are fully environmentally stable with a practically unlimited life-time. Central wavelengths of the filters can be angle tuned by several nanometers without reduction of the filter optical density.

Standard Parameters

Center Wavelength: 488, 514, 532, 633, 785, 1064 nm (custom wavelengths available)

Spectral Bandwidth (FWHM): $<10\text{ cm}^{-1}$

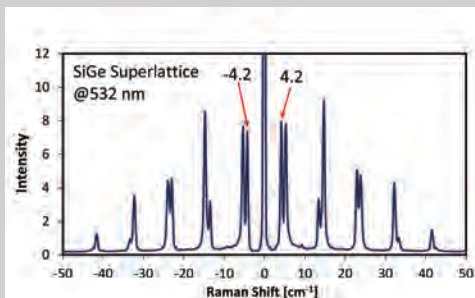
Attenuation: 99.9% and 99.99% (OD3; OD4)

Lateral Dimensions: 12.5×12.5 , $11 \times 11\text{ mm}^2$ (90% clear aperture)

Incident/Diffracted Angles: 12 deg

Applications

Ultra-low frequency Raman spectroscopy



Ultra-low frequency Raman spectrum of SiGe superlattice at 532 nm with LabRAM HR Evolution and BragGrate Notch Filters (Courtesy of HORIBA Jobin Yvon)



Specifications

Attenuation: 90–99.99% (OD1–4)

Spectral bandwidth (FWHM): $<10\text{ cm}^{-1}$

Operating range: 400–2500 nm

BNF thickness: 2–4 mm

Apertures: up to $25 \times 25\text{ mm}^2$

Angular selectivity: 0.1–0.2 deg

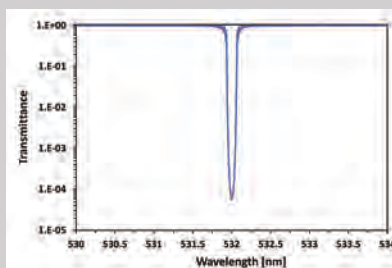
Incident/Diffracted Angles: 0–45 deg

Transmittance: up to 95%

Transmission ripple: $<1\%$ at $\pm 0.5\text{ nm}$ from laser line (@ 633 nm)

Advantages & Features

- Ultra-narrow rejection bandwidth
- Measurements of both Stokes and anti-Stokes modes
- No degradation in high power light
- Environmentally stable: high temperature operation, no humidity effects
- No polarization dependence



Transmission spectrum of OD4@532 nm BragGrate™ Notch Filter

BragGrate™ - Bandpass Filter

Reflecting Bragg Grating (RBG) for spectral filtering

Product Description

BragGrate™ Bandpass Filter is a reflecting Bragg grating (RBG) recorded in a bulk of photosensitive silicate glass. These filters are used to clean up laser spectral noise with a bandwidth as narrow as 50 pm in visible and near IR regions. In Raman spectroscopy applications, combining these Filters with matching BragGrate™ Notch Filters enables Raman shift measurements down to 5 cm^{-1} from the laser line.

Standard Parameters for Raman filtering

Center Wavelength: 488, 514, 532, 633, 785, 1064 nm

Spectral Bandwidth (FWHM): < 7 cm^{-1}

Diffraction Efficiency: > 90%

Lateral Dimensions: 5×5 mm^2

Total Deflection Angle: 20 deg

Standard Parameters for Single Photon Counting (SPC)

Center Wavelength: 780, 813.17, 852, 854, 1341 nm

Spectral Bandwidth (FWHM): < 50 GHz

Diffraction Efficiency: > 90%

Lateral Dimensions: 7×5 mm^2

Total Deflection Angle: 10 deg

Advantages & Features

- High spectral selectivity
- Superior environmental stability, no degradation over lifetime
- High power/energy operations
1 kW and up to 5 J/cm^2
- No polarization dependence
- Diffraction-limited beam quality

Applications

- Spectral filtering and noise cleaning of laser beams
- ASE filters for Raman laser sources
- Spectral detection
- Tunable filters for high resolution spectroscopy
- Pump Signal Separation

Specifications

Diffraction Efficiency (DE): >90%

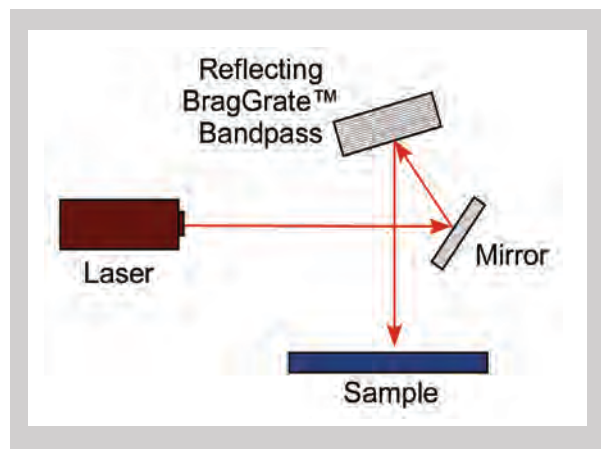
Spectral Bandwidth: 0.02 to 0.5 nm

Operating Range λ : 400–2500 nm

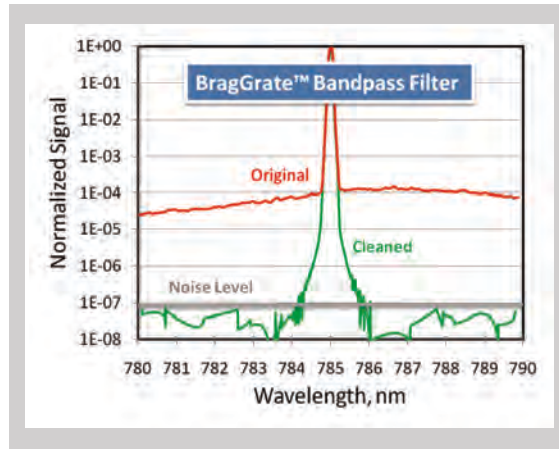
Grating Thickness: 1.5–20 mm

Apertures: up to 10×10 mm^2

Aluminum Housing with 0.5" or 1" Outer Diameter



Schematics of a possible BragGrate™ Bandpass filter configuration



785 nm laser diode ASE background clean up with a BragGrate™ bandpass filter with bandwidth <7 cm^{-1}

BragGrate™ - Spatial Filter (BSF)

Reflecting Volume Bragg Grating for spatial filtering

Product Description

Imperfections in laser optics and variations in laser gain medium cause side fringes and spatially varying intensity. Our spatial filters are designed to “clean up” laser beams from these deficiencies. BragGrate™ Spatial Filters (BSF) provide a simple, compact, and cost effective solution for laser beam spatial filtering. BSF is based on reflecting volume Bragg grating with a narrow acceptance angle that enables filtering of laser beams with a single element, thus replacing pinhole assemblies in case of narrow line laser sources. In addition to spatial filtering, BSF's provide ultra-narrow line spectral filtering and can be used for high-power/high-energy applications. BragGrate™ filters have superior environmental stability and can handle high power optical radiation and high operations temperatures.

Specifications

Diffraction Efficiency (DE): 90–95%

Spatial Noise Suppression: up to 30 dB

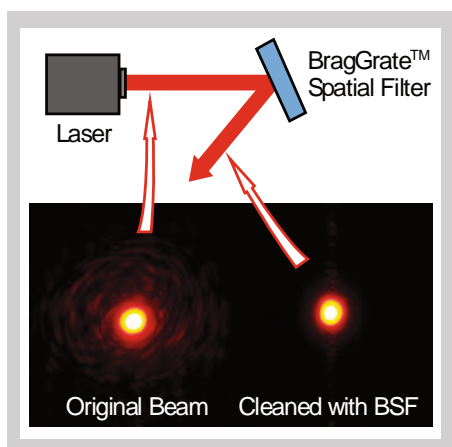
Center Wavelength Range: 400–2300 nm

Center Wavelength Tunability (angle tuning): up to 50 nm

Filter Thickness: 2–5 mm

Deflection Angles: 5–90 deg

Lateral Dimensions: up to 25×25 mm²



Spatial filtering of 632.8 nm HeNe laser with BSF

Advantages & Features

- Spatial filtering without refocusing and pinhole assembly
- Highly cost effective and small footprint
- Easy alignment by angle tuning in standard kinematic mount
- Compatible with high-power operations over 1 kW
- Compatible with high-energy operations up to 5 J/cm²
- Simultaneous spatial and spectral filtering (<5 cm⁻¹ to laser line)
- Supports operation at temperatures up to 400 C

Applications

- Filtering of spatial noise in laser beams
- Ultra-narrow linewidth spectral filtering of laser beams
- ASE filters for diode laser sources
- Wavelength-tunable spatial and spectral filters

Standard Parameters

Center Wavelength: 405, 488, 514, 532, 633, 785, 1064 nm (custom wavelengths available)

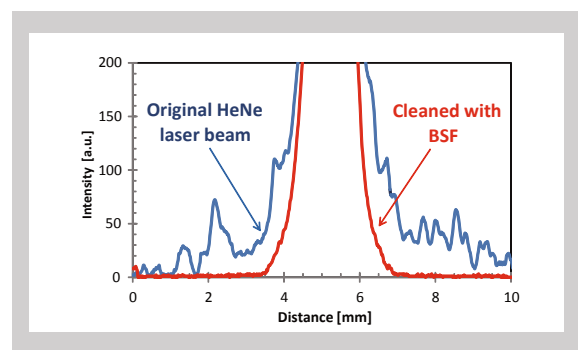
Lateral Dimensions: 5×5 mm²

Thickness: ~3 mm

Angular Acceptance (FWHM): < 5 mrad

Deflection Angle: 20 deg

Aluminum Housing with 0.5" or 1" Outer Diameter



632.8 nm HeNe laser beam profile before and after BSF cleaning

BragGrate™ - Deflector

Transmitting Volume Bragg Grating for angular selection and magnification

Product Description

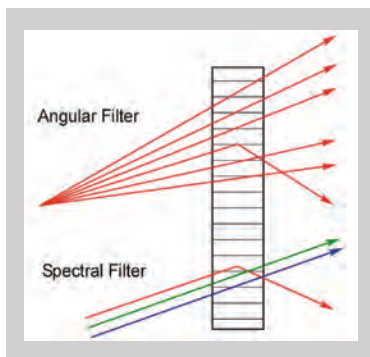
BragGrate™ Deflector is a transmitting volume Bragg grating recorded in a bulk of photosensitive silicate glass. The Deflector acts as a very narrow band mode selector in angular and spectral spaces and, therefore, enables spectrally selective beam steering and angular magnification. The spectral filtering is as narrow as 0.1 nm and can easily achieve deflection angles of up to 45 degrees. The grating is embedded inside the glass material and is stable to light powers exceeding 1 kW, temperatures >400°C, and is fully environmentally stable.

Standard Parameters

Center Wavelength: 532, 1064, 1550 nm
 Spectral Bandwidth (FWHM): 1–10 nm
 Diffraction Efficiency: > 97%
 Lateral Dimensions: 12.5×12.5, 25×25, 35×35mm²

Applications

- 3D beam steering
- Angular magnification in fast switches
- Transmitting spectral and angular selector
- Beam combining
- Beam shaping and filtering



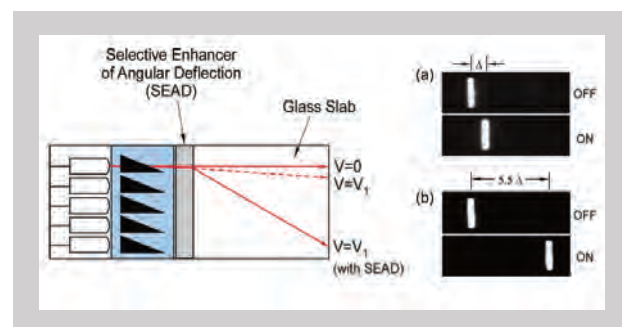
Schematics of a spectral and angular filters with BragGrate™ Deflector. Narrow spectral or angle selection is rejected from the incident beam.

Specifications

Diffraction Efficiency (DE): 5–99%
 Spectral Bandwidth: 0.5 nm to 100 nm
 Operating Range λ : 400–2700 nm
 Grating Thickness: 0.50–10 mm
 Apertures: up to 50×50 mm²
 Angular Selectivity: 0.1–100 mrad
 Total Deflection Angles: <120 deg

Advantages & Features

- High power operations over 1 kW
- High energy operations up to 5 J/cm²
- No degradation over lifetime
- Superior environmental stability
- High angular selectivity
- No polarization dependence at small incident angles
- Near-diffraction-limited beam quality
- Possible multiplexing of different angular selectors in one volume
- Low wavefront aberrations



Angular magnification with BragGrate™ Deflector in electro-optic switches.

BragGrate™ - Combiner

Transmitting or reflecting volume Bragg gratings for spectral beam combining

Product Description

BragGrate™ Combiner is a transmitting or reflecting volume Bragg grating (or set of gratings) enabling Spectral Beam Combining (SBC). It combines laser radiation from numerous sources into a single, nearly diffraction-limited beam with increased energy brightness. SBC by means of our BragGrate Combiners is a simple and robust technique for combining high-power laser radiation with a record spectral brightness. Excellent mechanical properties and a refractive index that is independent of temperature enables the Combiners to withstand high-power laser radiation, thus making them the ideal elements for high-powered SBC.

Standard Parameters

Center Wavelength: 930–980, 1030–1100 nm

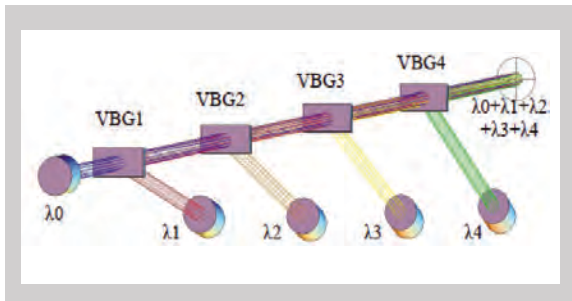
Spectral Bandwidth (FWHM): 0.2–0.5 nm

Diffraction Efficiency 95–99%

Lateral Dimensions: 15x15, 20x20 mm²

Applications

- High power spectral beam combining
- Wavelength multiplexing and demultiplexing
- Latest achievements: 5 beam combining with total output power of 780 W, combining efficiency of > 90%, channel spacing 0.25 nm



Spectral beam combining scheme with 4 BragGrate™ Combiner gratings

Specifications

Diffraction Efficiency (DE): 90–99%

Spectral Bandwidth: 50 pm to 20 nm

Operating Range λ : 400–2700 nm

Grating Thickness: 0.50–10 mm

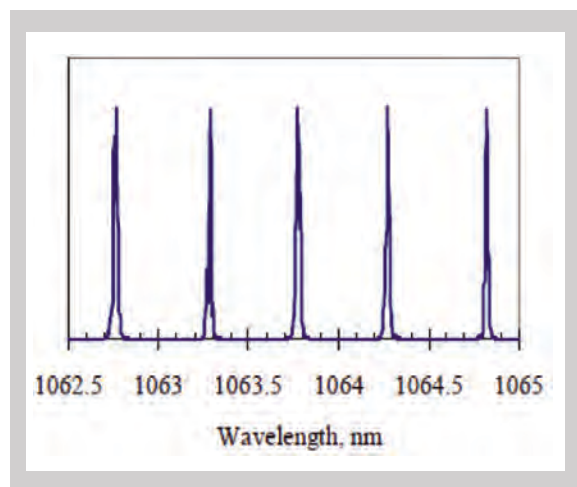
Apertures: up to 50x50 mm²

Angular Selectivity: 0.5–10 mrad

Deflection Angles: 5–45 deg

Advantages & Features

- High power operations up to 10 kW
- High energy operations up to 5 J/cm²
- Unrestricted lifetime, no degradation of parameters has been detected for over 10 years
- High angular selectivity (TBG)
- High spectral selectivity (RBG)
- Superior environmental stability
- No polarization dependence at small incident angles
- Near-diffraction-limited beam quality



Spectrum of spectrally-combined output beam with total power of 780 W and channel spacing of 0.5 nm



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