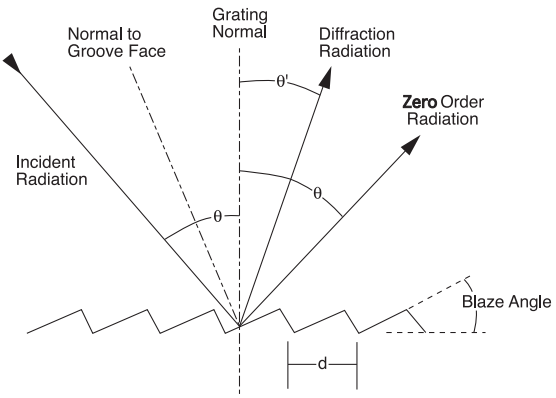
# Introduction to Diffraction Gratings

**Diffraction Gratings (Ruled and Holographic)**
Diffraction gratings can be divided into two basic categories: holographic and ruled. A ruled grating is produced by physically forming grooves on a reflective surface by using a diamond tool mounted on a ruling engine. The distance between adjacent grooves and the angle they form with the substrate affect both the dispersion and efficiency of the grating.




GRATING ANGLES & TERMS

A holographic grating, by contrast, is produced using a photolithographic process where an interference pattern is generated to expose preferentially portions of a photoresist coating.

The general grating equation may be written as

$$n\lambda = d(\sin\theta + \sin\theta')$$

where n is the order of diffraction, λ is the diffracted wavelength, d is the grating constant (the distance between grooves), θ is the angle of incidence measured from the grating normal, and θ′ is the angle of diffraction measured from the grating normal.

The overall efficiency of the gratings depends on several application-specific parameters such as wavelength, polarization, and angle of incidence of the incoming light. The efficiency is also affected by the grating design parameters such as blaze angle for the ruled gratings and profile depth for the holographic gratings.

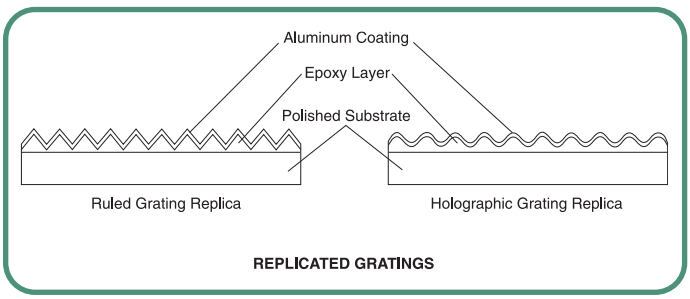
**The Ruling Process**
Ruling an original or master grating requires an appropriate substrate (usually glass or copper), polishing the substrate to a tenth wave (λ/10), and coating it with a thin layer of aluminum by vacuum deposition. Parallel, equally spaced grooves are ruled in a groove profile. Unless otherwise specified, rectangular gratings are cut such that the grooves are parallel to the shorter side. The ruling engine must be able to retrace the exact path of the diamond forming tool on each stroke and to index (advance) the substrate a predetermined amount after each cut. Numerous test gratings are created and measured. After testing, a new original grating is ruled on a large substrate. The original grating is very expensive, and as a result, ruled gratings were rarely used until after the development of the replication process.

**The Holographic Process**
The substrate for a holographic grating is coated with a photosensitive (photoresist) material rather than the reflective coating used in ruled gratings. The photoresist is exposed by positioning the coated blank between the intersecting, monochromatic, coherent beams of light from a laser (e.g., an argon laser at 488 nm). The intersecting laser beams generate a sinusoidal intensity pattern of parallel, equally spaced interference fringes in the photoresist material. Since the solubility of the resist is dependent on its exposure to light, the intensity pattern becomes a surface pattern after being immersed in solvent. The substrate surface is then coated with a reflective material and can be replicated by the same process used for ruled originals. Since holographic gratings are produced optically, groove form and spacing are extremely uniform, which is why holographic gratings do not exhibit the ghosting effects seen in ruled gratings. The result is that holographic gratings generate significantly less stray light than ruled gratings.

**The Replication Process**
In the late 1940's, White and Frazer developed the process for precision replication, allowing a large number of gratings to be produced from a single master, either ruled or holographic. This procedure results in the transfer of the three-dimensional topography of a master grating onto another substrate. Hence, the master grating is reproduced in full relief to extremely close tolerances. This process led to the commercialization of gratings and has resulted in the current widespread use of gratings in spectrometers.

**Transmission Grating**
Transmission gratings simplify optical designs and can be beneficial in fixed grating applications such as spectrographs.

Thorlabs' offering of blazed transmission gratings is designed for optimum performance in the UV, visible, and IR spectrum, with varying dispersiveness. In most cases, the efficiency is comparable to that of reflection gratings typically used in the same region of the spectrum. By necessity, transmission gratings require relatively coarse groove spacings to maintain high efficiency. As the diffraction angles increase with the finer spacings, the refractive properties of the materials used limit the transmission at the higher wavelengths, and performance drops off. The grating dispersion characteristics, however, lend themselves to compact systems utilizing small detector arrays. In addition, the transmission gratings are relatively insensitive to the polarization of the incident light and are very forgiving of some types of grating alignment errors.




REPLICATED GRATINGS

# Choosing a Diffraction Grating

**Factors in Selecting a Thorlabs Grating**
Selection of a grating requires consideration of a number of factors, some of which are listed below. For more information, please see page 874.

**Efficiency:** In general, ruled gratings have a higher efficiency than holographic gratings. Applications such as fluorescence excitation and other radiation-induced reactions may require a ruled grating.

**Blaze Wavelength:** Ruled gratings with a sawtooth groove profile have a relatively sharp efficiency peak around their blaze wavelength, while some holographic gratings have a flatter spectral response. Applications centered around a narrow wavelength range could benefit from a ruled grating blazed at that wavelength.

**Wavelength Range:** The spectral range covered by a grating is dependent on groove spacing and is the same for ruled and holographic gratings having the same grating constant. As a rule of thumb, the first order efficiency of a grating decreases by 50% at $0.66\lambda_B$ and $1.5\lambda_B$, where $\lambda_B$ is the blaze wavelength. Note: No grating can diffract a wavelength that is greater than 2 times the groove period.

**Stray Light:** For applications such as Raman spectroscopy, where signal-to-noise is critical, the inherent low stray light of a holographic grating is an advantage.

**Resolving Power:** The resolving power of a grating is a measure of its ability to spatially separate two wavelengths. It is determined by applying the Rayleigh criteria to the diffraction maxima; two wavelengths are resolvable when the maxima of one wavelength coincides with the minima of the second wavelength. The chromatic resolving power (R) is defined by $R = \lambda/\Delta\lambda = nN$, where $\Delta\lambda$ is the resolvable wavelength difference, n is the diffraction order, and N is the number of grooves illuminated.

# Diffraction Grating Quick Reference

**Custom Grating Sizes Available**

**Ruled**

These replicated, ruled diffraction gratings are offered in a variety of sizes and blaze angles. Ruled gratings typically can achieve higher efficiencies than holographic gratings due to their blaze angles. Efficiency curves for all of these gratings are shown on the following pages to aid in selection of the appropriate grating.

**See Page 876**

**Holographic**

These gratings do not suffer from the periodic errors that can occur in ruled gratings, and hence, ghosted images are nonexistent. Particularly in applications like Raman spectroscopy, where signal to noise is critical, the inherent low stray light of holographic gratings is an advantage. Thorlabs offers these gratings with spacings up to 3600 lines/mm.

**See Page 880**

**Echelle**

These gratings are special low-period gratings designed for use in the high orders. They are generally used with a second grating or prism to separate overlapping diffracted orders. The resolution of an Echelle grating built on a precision glass substrate is typically 80-90% of the maximum theoretical resolution, which makes them ideal for high resolution spectroscopy.

**See Page 882**

**Transmission**

Transmission gratings allow for simple linear (source -> grating -> detector) optical designs that can be beneficial in making compact fixed grating applications such as spectrographs. In addition, the performance of transmission gratings is insensitive to some types of grating alignment errors. Transmission and reflection gratings have comparable efficiencies, which can be optimized for a specific spectral region by selecting the appropriate groove spacing and blaze angle. Transmission gratings are relatively insensitive to the polarization of the incident light. Thorlabs offers gratings optimized for UV, visible, and IR applications.

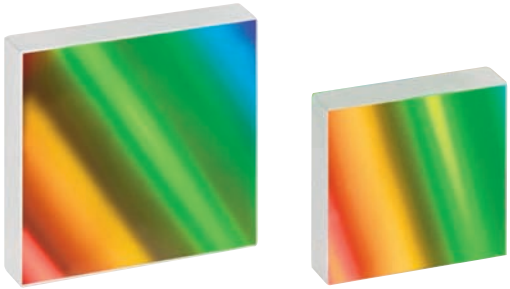
**See Page 883**

**HANDLING OF GRATINGS**
The surface of a diffraction grating can be easily damaged by fingerprints, aerosols, moisture, or the slightest contact with any abrasive material. Gratings should only be handled when necessary and always held by the sides. Latex gloves or a similar protective covering should be worn to prevent transfer of oil from fingers to the grating surface.

Any attempt to clean a grating with a solvent voids the warranty. No attempt should be made to clean a grating other than blowing off dust with clean, dry air or nitrogen.

For current pricing, please see our website.

# Ruled Diffraction Gratings (Page 1 of 4)



NEW versions

## Specifications

- **Efficiencies:** 60-80% at Blaze λ (in Littrow)
- **Dimensional Tolerances:** ±0.5 mm
- **Ghost Intensities:** <0.5% of Parent Line
- **Damage Threshold:** 350 mJ/cm² at 200 ns (Pulsed); 40 W/cm² (CW)
- **Surface Quality:** 60-40 Scratch-Dig

## Highlights

- Higher Efficiencies than Holographic Gratings
- Offered in 5 Sizes
  - 12.7 mm x 12.7 mm x 6 mm
  - 25 mm x 25 mm x 6 mm
  - 50 mm x 50 mm x 9.5 mm
  - 12.5 mm x 25 mm x 9.5 mm
  - 25 mm x 50 mm x 9.5 mm

These replicated, ruled diffraction gratings are offered in a variety of sizes and blaze angles. Ruled gratings typically achieve higher efficiencies than holographic gratings due to their blaze angles. Efficiency curves for all of these gratings are shown on the following pages to aid in selection of the appropriate grating.

### 75 Grooves (lines/mm)

| ITEM # | BLAZE WAVELENGTH | BLAZE ANGLE | DISPERSION | SIZE | $ | £ | € | RMB |
|---|---|---|---|---|---|---|---|---|
| NEW GR1325-07106 | 10.6 µm | 21° 0' | 12.3 nm/mrad | 12.5 mm x 25 mm x 9.5 mm | $ 151.20 | £ 108.86 | € 131,54 | ¥ 1,205.06 |
| NEW GR2550-07106 | 10.6 µm | 21° 0' | 12.3 nm/mrad | 25 mm x 50 mm x 9.5 mm | $ 289.80 | £ 208.66 | € 252,13 | ¥ 2,309.71 |

### 100 Grooves (lines/mm)

| ITEM # | BLAZE WAVELENGTH | BLAZE ANGLE | DISPERSION | SIZE | $ | £ | € | RMB |
|---|---|---|---|---|---|---|---|---|
| NEW GR1325-10106 | 10.6 µm | 27° 0' | 8.5 nm/mrad | 12.5 mm x 25 mm x 9.5 mm | $ 151.20 | £ 108.86 | € 131,54 | ¥ 1,205.06 |
| NEW GR2550-10106 | 10.6 µm | 27° 0' | 8.5 nm/mrad | 25 mm x 50 mm x 9.5 mm | $ 289.80 | £ 208.66 | € 252,13 | ¥ 2,309.71 |

### 150 Grooves (lines/mm)

| ITEM # | BLAZE WAVELENGTH | BLAZE ANGLE | DISPERSION | SIZE | $ | £ | € | RMB |
|---|---|---|---|---|---|---|---|---|
| NEW GR1325-15106 | 10.6 µm | 35° 0' | 4.2 nm/mrad | 12.5 mm x 25 mm x 9.5 mm | $ 151.20 | £ 108.86 | € 131,54 | ¥ 1,205.06 |
| NEW GR2550-15106 | 10.6 µm | 35° 0' | 4.2 nm/mrad | 25 mm x 50 mm x 9.5 mm | $ 289.80 | £ 208.66 | € 252,13 | ¥ 2,309.71 |

### 300 Grooves (lines/mm)

| ITEM # | BLAZE WAVELENGTH | BLAZE ANGLE | DISPERSION | SIZE | $ | £ | € | RMB |
|---|---|---|---|---|---|---|---|---|
| GR25-0303 | 300 nm | 2° 34' | 3.33 nm/mrad | 25 mm x 25 mm x 6 mm | $ 102.00 | £ 73.44 | € 88,74 | ¥ 812.94 |
| GR13-0305 | 500 nm | 4° 18' | 3.32 nm/mrad | 12.7 mm x 12.7 mm x 6 mm | $ 62.50 | £ 45.00 | € 54,38 | ¥ 498.13 |
| GR25-0305 | 500 nm | 4° 18' | 3.32 nm/mrad | 25 mm x 25 mm x 6 mm | $ 102.00 | £ 73.44 | € 88,74 | ¥ 812.94 |
| GR50-0305 | 500 nm | 4° 18' | 3.32 nm/mrad | 50 mm x 50 mm x 9.5 mm | $ 179.60 | £ 129.31 | € 156,25 | ¥ 1,431.41 |
| GR13-0310 | 1 µm | 8° 36' | 3.30 nm/mrad | 12.7 mm x 12.7 mm x 6 mm | $ 62.50 | £ 45.00 | € 54,38 | ¥ 498.13 |
| GR25-0310 | 1 µm | 8° 36' | 3.30 nm/mrad | 25 mm x 25 mm x 6 mm | $ 102.00 | £ 73.44 | € 88,74 | ¥ 812.94 |
| GR50-0310 | 1 µm | 8° 36' | 3.30 nm/mrad | 50 mm x 50 mm x 9.5 mm | $ 179.60 | £ 129.31 | € 156,25 | ¥ 1,431.41 |
| NEW GR1325-30035 | 3.5 µm | 26.5° | 0.35 nm/mrad | 12.5 mm x 25 mm x 9.5 mm | $ 151.20 | £ 108.86 | € 131,54 | ¥ 1,205.06 |
| NEW GR2550-30035 | 3.5 µm | 26.5° | 0.35 nm/mrad | 25 mm x 50 mm x 9.5 mm | $ 289.80 | £ 208.66 | € 252,13 | ¥ 2,309.71 |

### 450 Grooves (lines/mm)

| ITEM # | BLAZE WAVELENGTH | BLAZE ANGLE | DISPERSION | SIZE | $ | £ | € | RMB |
|---|---|---|---|---|---|---|---|---|
| NEW GR1325-45031 | 3.1 µm | 32° 0' | 1.6 nm/mrad | 12.5 mm x 25 mm x 9.5 mm | $ 151.20 | £ 108.86 | € 131,54 | ¥ 1,205.06 |
| NEW GR2550-45031 | 3.1 µm | 32° 0' | 1.6 nm/mrad | 25 mm x 50 mm x 9.5 mm | $ 289.80 | £ 208.66 | € 252,13 | ¥ 2,309.71 |

**Handling of Gratings**

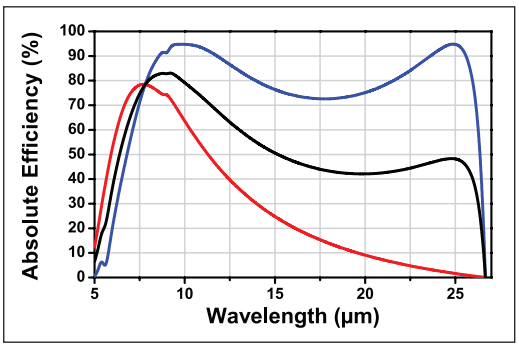
The surface of a diffraction grating can be easily damaged by fingerprints, aerosols, moisture, or the slightest contact with an abrasive material. Always hold these optics by the sides and wear latex gloves or a similar protective covering to avoid the transfer of natural hand oils.

**Warranty Information**

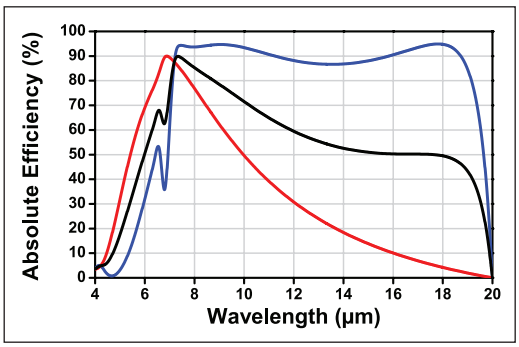
Any attempt to clean a grating with a solvent will void the warranty. Dust should only be removed using clean, dry air or nitrogen. Scratches or other minor cosmetic imperfections on the grating surface do not usually affect performance and are not considered defects.

# Ruled Diffraction Gratings (Page 2 of 4)

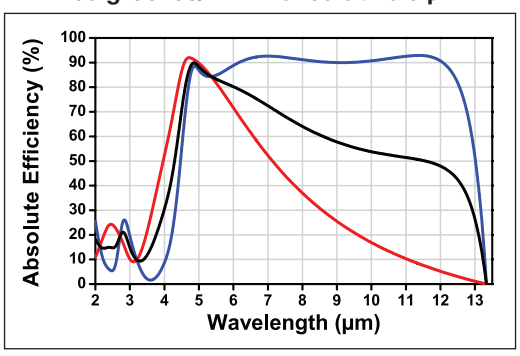
### 75 grooves/mm Blazed at 10.6 µm



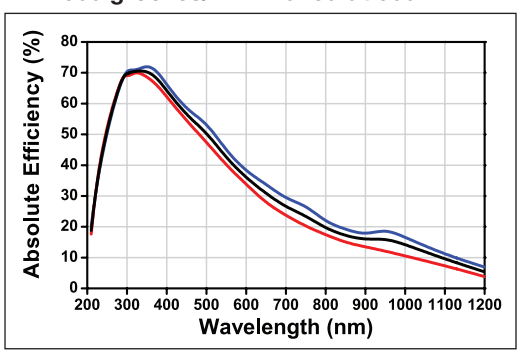

### 100 grooves/mm Blazed at 10.6 µm



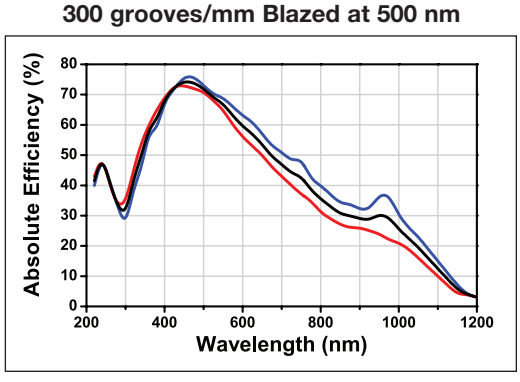

### 150 grooves/mm Blazed at 10.6 µm



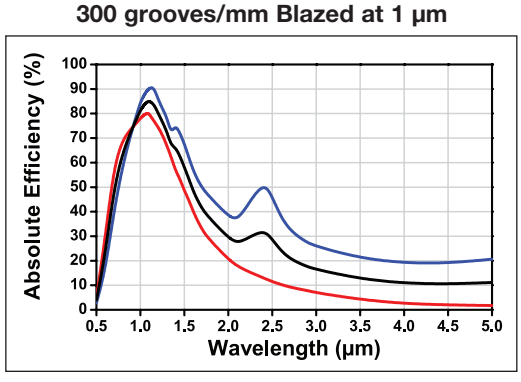

### 300 grooves/mm Blazed at 300 nm



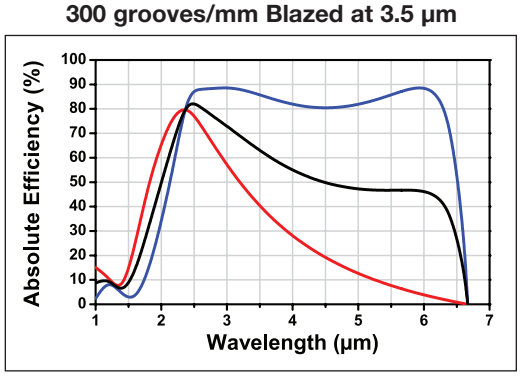

### 300 grooves/mm Blazed at 500 nm



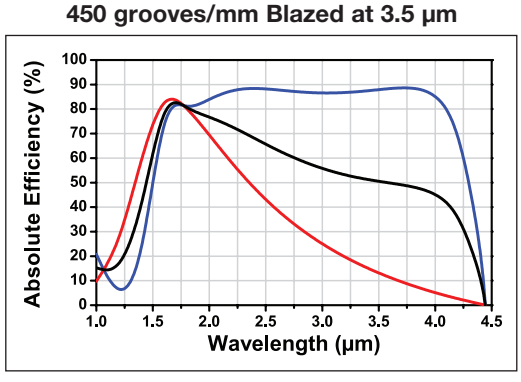

### 300 grooves/mm Blazed at 1 µm




### 300 grooves/mm Blazed at 3.5 µm




### 450 grooves/mm Blazed at 3.5 µm




S-Polarized Polarization
P-Polarized Polarization
Average

**Efficiency Curve Key**

All gratings are measured in the Littrow mounting configuration and utilize an aluminum reflective coat.

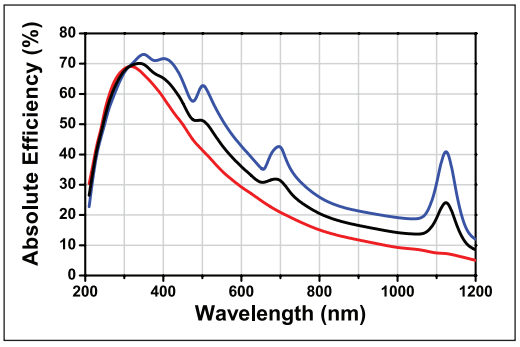
For current pricing, please see our website.

# Ruled Diffraction Gratings (Page 3 of 4)

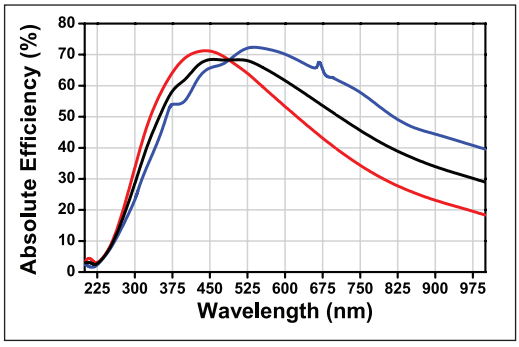
## 600 Grooves (lines/mm)

| ITEM # | BLAZE WAVELENGTH | BLAZE ANGLE | DISPERSION | SIZE | $ | £ | € | RMB |
|---|---|---|---|---|---|---|---|---|
| GR50-0603 | 300 nm | 5° 9' | 1.67 nm/mrad | 50 mm x 50 mm x 9.5 mm | $ 179.60 | £ 129.31 | € 156,25 | ¥ 1,431.41 |
| GR13-0605 | 500 nm | 8° 37' | 1.65 nm/mrad | 12.7 mm x 12.7 mm x 6 mm | $ 62.50 | £ 45.00 | € 54,38 | ¥ 498.13 |
| GR25-0605 | 500 nm | 8° 37' | 1.65 nm/mrad | 25 mm x 25 mm x 6 mm | $ 102.00 | £ 73.44 | € 88,74 | ¥ 812.94 |
| GR50-0605 | 500 nm | 8° 37' | 1.65 nm/mrad | 50 mm x 50 mm x 9.5 mm | $ 179.60 | £ 129.31 | € 156,25 | ¥ 1,431.41 |
| GR13-0608 | 750 nm | 13° 0' | 1.62 nm/mrad | 12.7 mm x 12.7 mm x 6 mm | $ 62.50 | £ 45.00 | € 54,38 | ¥ 498.13 |
| GR25-0608 | 750 nm | 13° 0' | 1.62 nm/mrad | 25 mm x 25 mm x 6 mm | $ 102.00 | £ 73.44 | € 88,74 | ¥ 812.94 |
| GR50-0608 | 750 nm | 13° 0' | 1.62 nm/mrad | 50 mm x 50 mm x 9.5 mm | $ 179.60 | £ 129.31 | € 156,25 | ¥ 1,431.41 |
| GR13-0610 | 1 µm | 17° 27' | 1.59 nm/mrad | 12.7 mm x 12.7 mm x 6 mm | $ 62.50 | £ 45.00 | € 54,38 | ¥ 498.13 |
| GR25-0610 | 1 µm | 17° 27' | 1.59 nm/mrad | 25 mm x 25 mm x 6 mm | $ 102.00 | £ 73.44 | € 88,74 | ¥ 812.94 |
| GR50-0610 | 1 µm | 17° 27' | 1.59 nm/mrad | 50 mm x 50 mm x 9.5 mm | $ 179.60 | £ 129.31 | € 156,25 | ¥ 1,431.41 |
| GR25-0613 | 1.25 µm | 22° 1' | 1.55 nm/mrad | 25 mm x 25 mm x 6 mm | $ 102.00 | £ 73.44 | € 88,74 | ¥ 812.94 |
| GR50-0613 | 1.25 µm | 22° 1' | 1.55 nm/mrad | 50 mm x 50 mm x 9.5 mm | $ 179.60 | £ 129.31 | € 156,25 | ¥ 1,431.41 |
| GR13-0616 | 1.6 µm | 28° 41' | 1.46 nm/mrad | 12.5 mm x 12.5 mm x 6 mm | $ 62.50 | £ 45.00 | € 54,38 | ¥ 498.13 |
| GR25-0616 | 1.6 µm | 28° 41' | 1.46 nm/mrad | 25 mm x 25 mm x 6 mm | $ 102.00 | £ 73.44 | € 88,74 | ¥ 812.94 |
| GR50-0616 | 1.6 µm | 28° 41' | 1.46 nm/mrad | 50 mm x 50 mm x 9.5 mm | $ 179.60 | £ 129.31 | € 156,25 | ¥ 1,431.41 |

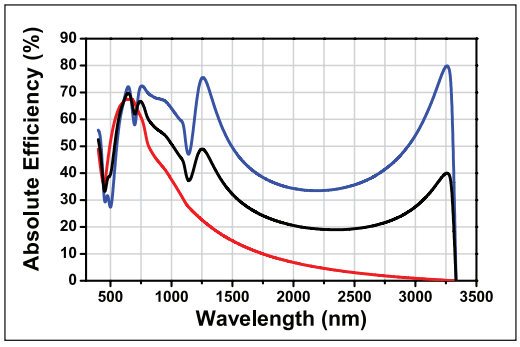
### 600 grooves/mm Blazed at 300 nm



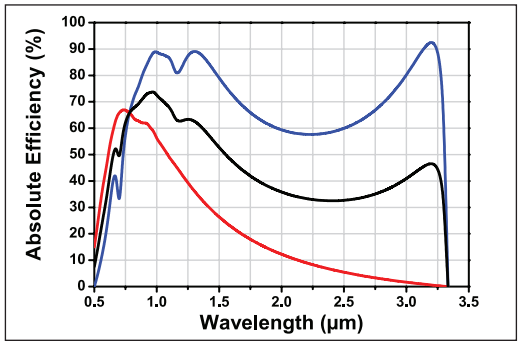

### 600 grooves/mm Blazed at 500 nm



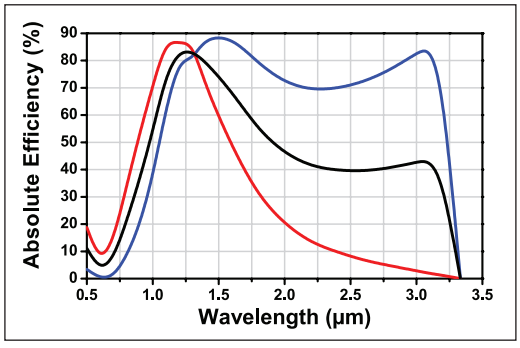

### 600 grooves/mm Blazed at 750 nm



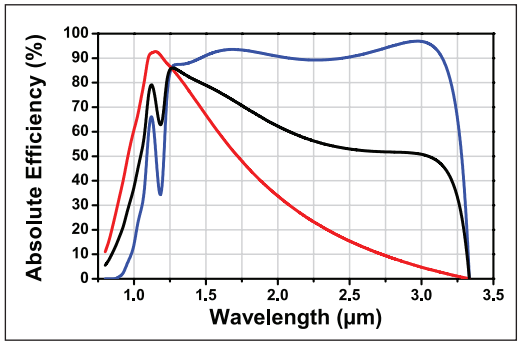

### 600 grooves/mm Blazed at 1 µm




### 600 grooves/mm Blazed at 1.25 µm




### 600 grooves/mm Blazed at 1.6 µm




S-Polarized Polarization
P-Polarized Polarization
Average

**Efficiency Curve Key**

All gratings are measured in the Littrow mounting configuration and utilize an aluminum reflective coat.

# Ruled Diffraction Gratings (Page 4 of 4)

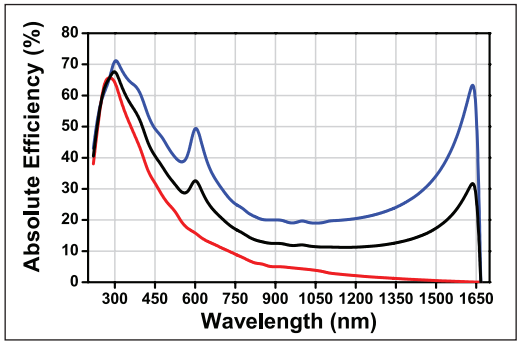
## 1200 Grooves (lines/mm)

| ITEM # | BLAZE WAVELENGTH | BLAZE ANGLE | DISPERSION | SIZE | $ | £ | € | RMB |
|---|---|---|---|---|---|---|---|---|
| GR13-1203 | 300 nm | 10° 22' | 0.82 nm/mrad | 12.7 mm x 12.7 mm x 6 mm | $ 62.50 | £ 45.00 | € 54,38 | ¥ 498.13 |
| GR25-1204 | 400 nm | 13° 53' | 0.81 nm/mrad | 25 mm x 25 mm x 6 mm | $ 102.00 | £ 73.44 | € 88,74 | ¥ 812.94 |
| GR50-1204 | 400 nm | 13° 53' | 0.81 nm/mrad | 50 mm x 50 mm x 9.5 mm | $ 179.60 | £ 129.31 | € 156,25 | ¥ 1,431.41 |
| GR13-1205 | 500 nm | 17° 27' | 0.80 nm/mrad | 12.7 mm x 12.7 mm x 6 mm | $ 62.50 | £ 45.00 | € 54,38 | ¥ 498.13 |
| GR25-1205 | 500 nm | 17° 27' | 0.80 nm/mrad | 25 mm x 25 mm x 6 mm | $ 102.00 | £ 73.44 | € 88,74 | ¥ 812.94 |
| GR50-1205 | 500 nm | 17° 27' | 0.80 nm/mrad | 50 mm x 50 mm x 9.5 mm | $ 179.60 | £ 129.31 | € 156,25 | ¥ 1,431.41 |
| GR13-1208 | 750 nm | 26° 44' | 0.74 nm/mrad | 12.7 mm x 12.7 mm x 6 mm | $ 62.50 | £ 45.00 | € 54,38 | ¥ 498.13 |
| GR25-1208 | 750 nm | 26° 44' | 0.74 nm/mrad | 25 mm x 25 mm x 6 mm | $ 102.00 | £ 73.44 | € 88,74 | ¥ 812.94 |
| GR50-1208 | 750 nm | 26° 44' | 0.74 nm/mrad | 50 mm x 50 mm x 9.5 mm | $ 179.60 | £ 129.31 | € 156,25 | ¥ 1,431.41 |
| GR13-1210 | 1 µm | 36° 52' | 0.67 nm/mrad | 12.7 mm x 12.7 mm x 6 mm | $ 62.50 | £ 45.00 | € 54,38 | ¥ 498.13 |
| GR25-1210 | 1 µm | 36° 52' | 0.67 nm/mrad | 25 mm x 25 mm x 6 mm | $ 102.00 | £ 73.44 | € 88,74 | ¥ 812.94 |
| GR50-1210 | 1 µm | 36° 52' | 0.67 nm/mrad | 50 mm x 50 mm x 9.5 mm | $ 179.60 | £ 129.31 | € 156,25 | ¥ 1,431.41 |

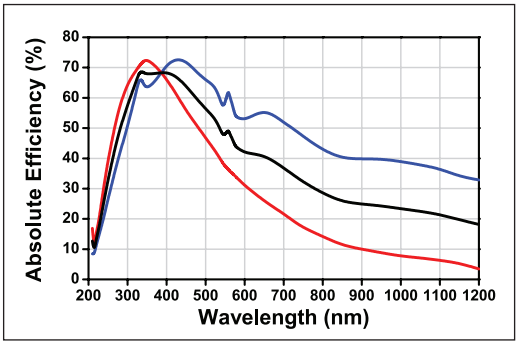
## 1800 Grooves (lines/mm)

| ITEM # | BLAZE WAVELENGTH | BLAZE ANGLE | DISPERSION | SIZE | $ | £ | € | RMB |
|---|---|---|---|---|---|---|---|---|
| GR13-1850 | 500 nm | 26° 44' | 0.50 nm/mrad | 12.7 mm x 12.7 mm x 6 mm | $ 62.50 | £ 45.00 | € 54,38 | ¥ 498.13 |
| GR25-1850 | 500 nm | 26° 44' | 0.50 nm/mrad | 25 mm x 25 mm x 6 mm | $ 102.00 | £ 73.44 | € 88,74 | ¥ 812.94 |
| GR50-1850 | 500 nm | 26° 44' | 0.50 nm/mrad | 25 mm x 50 mm x 9.5 mm | $ 179.60 | £ 129.31 | € 156,25 | ¥ 1,431.41 |

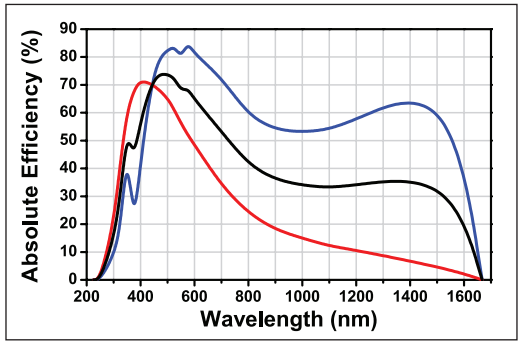
### 1200 grooves/mm Blazed at 300 nm



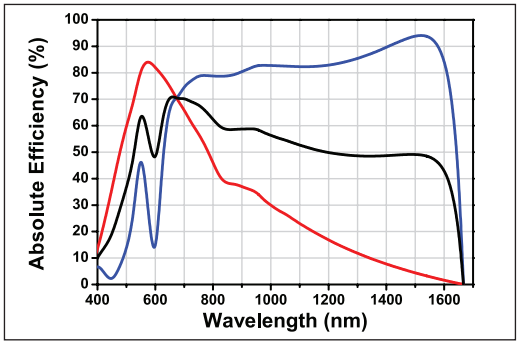

### 1200 grooves/mm Blazed at 400 nm



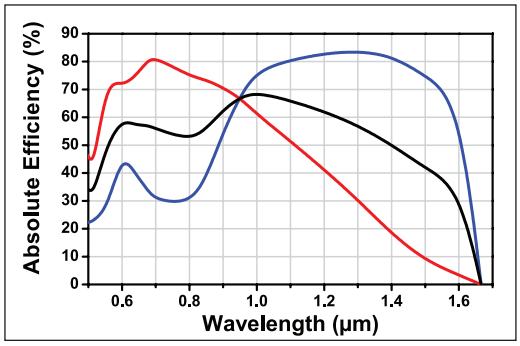

### 1200 grooves/mm Blazed at 500 nm



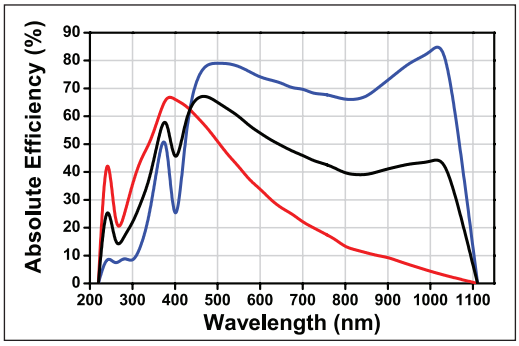

### 1200 grooves/mm Blazed at 750 nm




### 1200 grooves/mm Blazed at 1 µm




### 1800 grooves/mm Blazed at 500 nm




Gratings are easily damaged. Please see the Handling and Warranty Information on page 875.