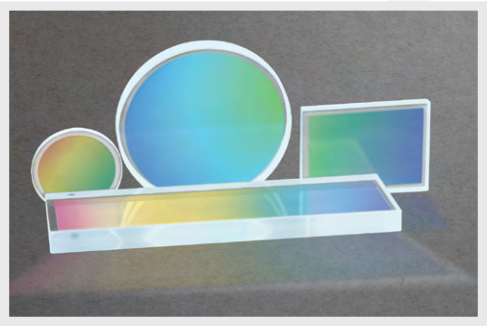
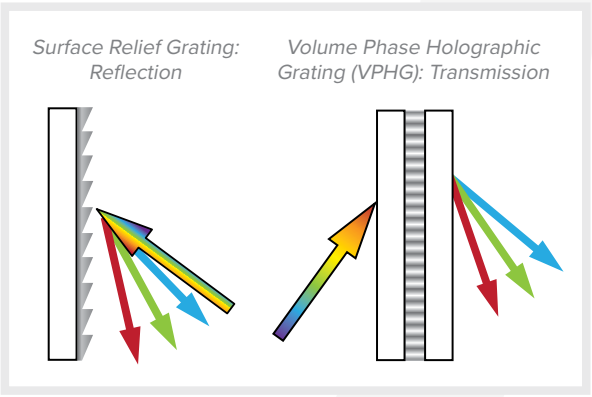
Advantages of VPH Gratings



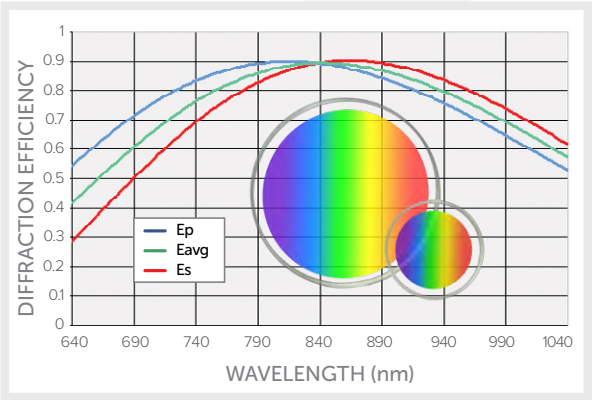
The term 'grating' or 'diffraction grating' often brings to mind a surface relief grating, with ruled lines and a delicate surface. Working in transmission, however, can open up many new options for the optical designer. In this tech note, we consider one special type: volume phase holographic (VPH) gratings. With benefits ranging from superior optical performance and design flexibility to robustness and consistency, VPH gratings are ideal for applications like laser pulse compression, spectroscopy, optical coherence tomography, and astronomy.

Volume phase holographic (VPH) gratings are made by holographically imaging a periodic structure of high and low index of refraction regions into dichromated gelatin sealed between two optical windows. The technique was originally commercially deployed by IBM in holographic barcode scanners, but has since been adapted for use in many optical instruments, as well as telecommunications. The process can be used to manufacture very high quality diffraction gratings in volumes of 1 to 1000 pieces or more. **Every grating is an original, not copied from a master.** With no master grating to wear out or degrade, consistent performance can be achieved from one grating to the next – in volume, and indefinitely. The flexible nature of the manufacturing process also makes it possible to easily and cost-effectively customize and optimize VPH gratings to each application by adjusting groove density, bandwidth, polarization sensitivity, and other parameters – in multiple iterations!



BEAUTIFUL EFFICIENCY CURVES

The transmissive, holographic nature of VPH gratings allows them to operate at high peak diffraction efficiencies, ranging from >80% for a 200-300 nm bandwidth (Wasatch Photonics' patented HD design) to >99% for a single wavelength (typical laser pulse compression grating design). This is up to 40% greater than reflective surface relief gratings, which can also have very jagged, asymmetric efficiency profiles that wreak havoc with system response. A VPH grating's efficiency, in contrast, varies smoothly with wavelength, and can be modeled at the design stage for inclusion in system performance models, and manufactured dependably to the specifications of that design. The encapsulated nature of VPH gratings also allows the application of high-performance, antireflection (AR) coatings on the surfaces of the element. These coatings offer further optimization of performance, and can be customized as needed for OEMs.

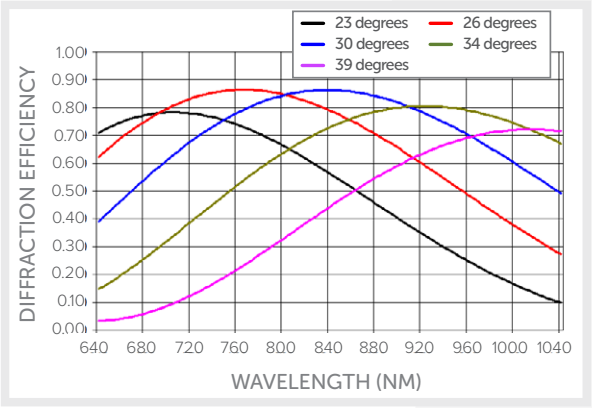


HIGH DISPERSION

VPH gratings can be reliably generated with higher line densities than ruled gratings, delivering high quality gratings with low ghosting and scatter. Line densities ranging from 150 lines/mm to 6000 lines/mm can be imaged, serving applications as diverse as broadband NIR hyperspectral imaging and high resolution atomic spectroscopy. By manufacturing each grating directly rather than by replication, it is possible to easily customize the line density, bandwidth, and center wavelength of operation specifically to each application.

ANGLE TUNING

VPH transmission gratings diffract light using stacked layers of sinusoidally varying index. This stack creates a resonant structure that can be tuned in center wavelength simply by varying the angle of incidence (AOI) by up to ~10°. This allows a single grating to be angle-tuned to study spectral features of interest in different ranges, a common technique in astronomy. In fact, several very large gratings on rotating stages may be used in a single large scale telescope to cover the visible through near infrared continuously.



REDUCED POLARIZATION SENSITIVITY

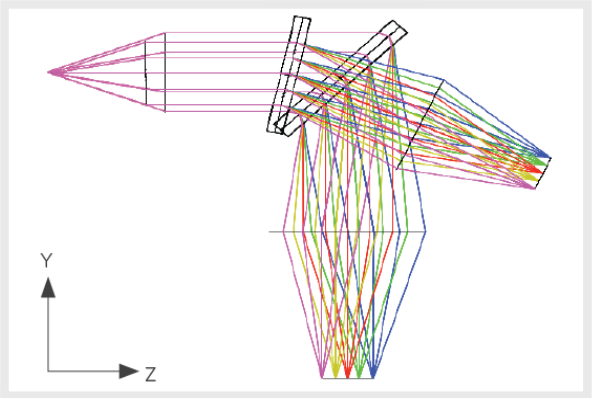
Surface relief reflection gratings typically offer much lower efficiency for *p*-polarization than *s*-polarization, often with very different efficiency response between the two states. This is particularly evident as the line frequency of the grating increases. VPH gratings are far less sensitive to polarization, with the added benefit that the polarization response is both smoothly varying and well understood. By drawing on several design solutions, including our patented Dickson and HD gratings, we can minimize and/or optimize polarization response specifically for your application.

NO GHOSTING, LOW SCATTER

Ruled gratings are prone to “ghosts”, a term used to describe light artefacts which appear in the dispersion plane due to periodic ruling errors. VPH gratings can be designed to eliminate ghosting. They also have 90% less stray light than ruled gratings, excellent spatial uniformity, and very low transmitted wavefront error. These factors are all important contributors to the excellent 1st order diffraction efficiency of VPH gratings.

COMPACT, FLEXIBLE OPTICAL DESIGNS

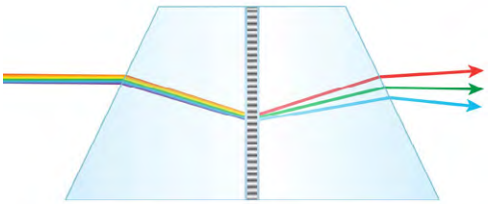
A transmission grating is a very simple way to make an optical design more compact, as transmission gratings can be designed to work in the Littrow configuration ($\theta_d = \theta_i$). In general, transmission gratings offer the optical engineer more geometry options, whether designing a pulse compression system or a spectrometer. The net result is that a system designed around a VPH transmission grating is likely to be smaller, lighter and less expensive than one designed around a conventional reflection grating, in addition to being easier to align.



GRISMS

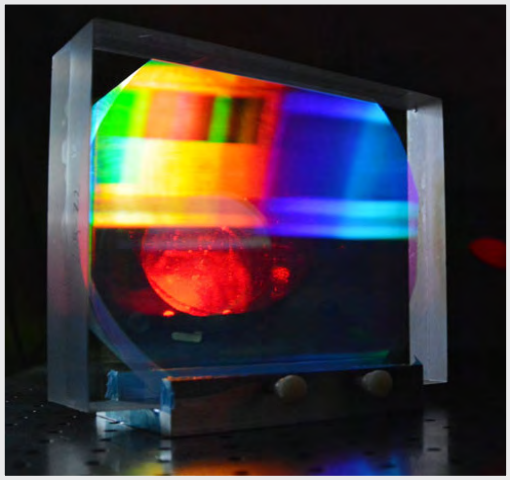
A grating sandwiched between two prisms is called a grism. This compound optic separates light into its components while canceling out the beam deviations caused by each element. Grisms can be used to either create a straight pass dispersive optic or an optic with dispersion higher than is possible with a grating alone. They are convenient for use in imaging, astronomy, spectrally encoded confocal microscopy, and other applications. Learn more about grisms on our website.

Typical straight pass grism design



SIZES & SUBSTRATES – BIG & SMALL

VPH gratings can be made much larger than one might expect – in fact, at Wasatch Photonics we routinely manufacture custom gratings up to 300 mm in size for astronomical spectrographs (larger sizes upon request). They can also be cut to as small as 8 mm across for volume OEM applications. Many different types of glass materials may be used for manufacture, the most common substrates being N-BK7 or equivalent, B270i, and fused silica (UV optional).



EASY TO CLEAN

Never touch a ruled, reflective grating, as they cannot be cleaned. Every speck of dust or fingerprint must remain, as the scratching that would occur from “cleaning” would be worse than the contamination itself! In contrast, encapsulated VPH gratings can be handled and cleaned like any other glass optical component, making them much more manufacturing friendly and reducing cost at every stage, from build through long-term use.

EXCELLENT DURABILITY

The optically active portion of a VPH grating is hermetically sealed between 2 substrates, creating a very robust component that offers excellent thermal stability and environmental performance. Many Wasatch Photonics gratings have been in service for 10+ years with no signs of degradation, while others have been deployed at near cryogenic temperatures. Each grating is rigorously inspected to high quality standards. We stand behind the quality of our optics with advanced interferometric measurement capabilities for critical applications like laser pulse compression, optical coherence tomography, and astronomy. Our metrology lab sports a new state of the art Zygo Verifire™, capable of measuring up to 4” optics.

CONCLUSION

When the founders of Wasatch Photonics began writing volume phase gratings in dichromated gelatin over 40 years ago, it was because they knew VPH grating technology had the performance, flexibility, and ability to scale from prototype to volume for a wide range of applications. Since then, we’ve worked hard to expand our technical capabilities while offering the quality and consistency you should expect from an experienced volume gratings supplier. Contact us to discuss your unique needs today!

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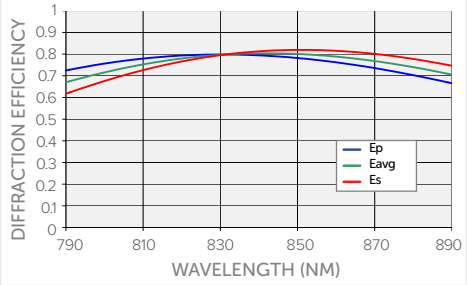
More design technologies to ensure your perfect fit

At Wasatch Photonics, we utilize three distinct design technologies to optimize our gratings to your needs, backed by 15 years of manufacturing experience. We start the process by understanding your application, drawing on our experience in optical design to recommend options and new degrees of freedom to help optimize your system performance. If we don't have a stock grating that matches, we can probably make it!

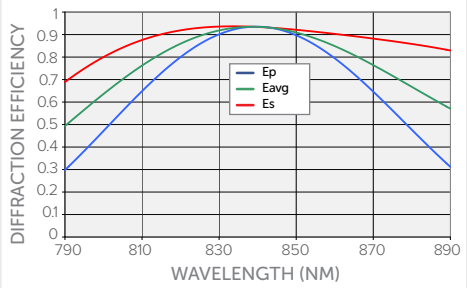
HD Grating 1800 l/mm 840 nm CWL 49.1 deg AOI =AOD



HIGH DISPERSION & EFFICIENCY HD GRATINGS

- Exclusive, patented design available only from Wasatch Photonics
- Consistently high transmission over bandwidths up to 200 nm
- Low polarization sensitivity, smoothly varying efficiency
- Enables faster, smaller OCT spectrometers with greater clarity
- Increased full bandwidth throughput for spectroscopy & astronomy
- Customizable for AOI's >36° and wavelengths 350-2500 nm

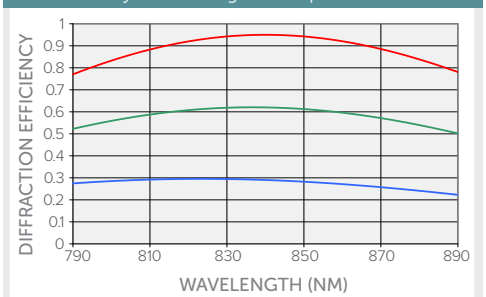
Efficiency vs Wavelength 1800 lpmm 840 nm



HIGH TRANSMISSION DICKSON GRATINGS

- We are the original patent holders and experts on this design!
- Extremely high transmission over bandwidths of 20-60 nm
- Efficiency is high for both *s*- & *p*-polarization, and varies smoothly
- Ideal for astronomy: supports angle tuning & large dimensions
- Enables high dispersion spectroscopy with low polarization sensitivity
- Customizable for AOI's >36° and wavelengths 350-2500 nm

Efficiency vs Wavelength 1800 lpmm 840 nm



STANDARD & SINGLE POLARIZATION GRATINGS

- Capable of exceptionally high tranmission at a single polarization
- Can also be designed as broad bandwidth & polarization insensitive
- Can be manufactured in dimensions up to 300 mm or larger
- Good for astronomy, hyperspectral imaging, and laser filtering
- Ideal for laser pulse compression: minimal beam distortion & scatter
- Customizable for many AOI's and wavelengths 350-2500 nm

OEM & CUSTOM GRATING DESIGN

At Wasatch Photonics, we apply our deep understanding of optical design to support our R&D and OEM customers in creating smaller, more sensitive, cost-effective instruments for a diverse range of applications. With over 15 years of manufacturing experience and extensive in-house processing & metrology capabilities, we have the resources to provide you with high quality, premier performance gratings customized and AR-coated to your specific needs. Contact us today to get started!