Richardson Gratings
A Newport Company

Technical Note

Master Gratings vs. Replica Gratings: Separating Myth from Reality

Millions of replicated diffraction gratings have been used in spectroscopic instruments, telecommunications equipment, lasers and tunable light sources, and a wide variety of scientific experiments … so why would anyone use a master grating instead?

Master gratings, also known as original gratings, are generally made using one of two methods: an optical technique called holographic *recording* and a mechanical technique called *ruling*. Both methods create the original groove pattern that gives a diffraction grating its dispersive properties.

Master gratings – either holographic or ruled – are rarely used as optical components. Instead, they are copied using a technique called *replication*. Compared with making master gratings, replication is a faster and lower-cost process that produces faithful copies of the master.

It is cost-prohibitive to make optically identical master gratings due to the inherent challenges of forming an original groove profile. Consequently, part-to-part variation is generally seen when comparing master gratings intended to meet the same specifications; this is especially evident in efficiency measurements, but this variation is also seen in imaging & wavefront flatness characteristics. For these reasons, Richardson Gratings makes many master gratings and chooses the best one to replicate to produce high-fidelity copies of the best master's groove pattern (to match imaging properties) and groove profile (to match efficiency and scattered light).

Gratings replicated from the same master are drop-in replacements for each other – the replica gratings are interchangeable. Replicated gratings can be made to be environmental stable, handling high heat and high humidity, and have been used successfully in extreme environments (such as satellites in deep space).

Slight defects may occur during replication, which are caught and removed during inspection and testing.

The myth that (holographic) master gratings are generally superior to replicated gratings is disproved by the millions of replicated gratings that have been used over the last several decades and in use today. The three charts on the next page demonstrate this: they show that replicated gratings exhibit consistent art-to-part efficiency behavior and low stray light. On the other hand, master gratings used in high volumes are not seen to be interchangeable, due to the variation inherent in processes used to make holographic masters.

Figure 1 shows scattered light curves for a holographic master grating (ARC03 – blue curve), a replicated grating from this master (ARC03-A1 – red curve) and a replicated grating from this replica (ARC03-A1-B1 – green curve). The peaks near 2 degrees show the diffracted order; moving away from this image shows how the scattered light drops by six orders of magnitude about four degrees away. The curves are identical to within the measurement uncertainty of Richardson Gratings' scattered light testing apparatus (λ = 633 nm).

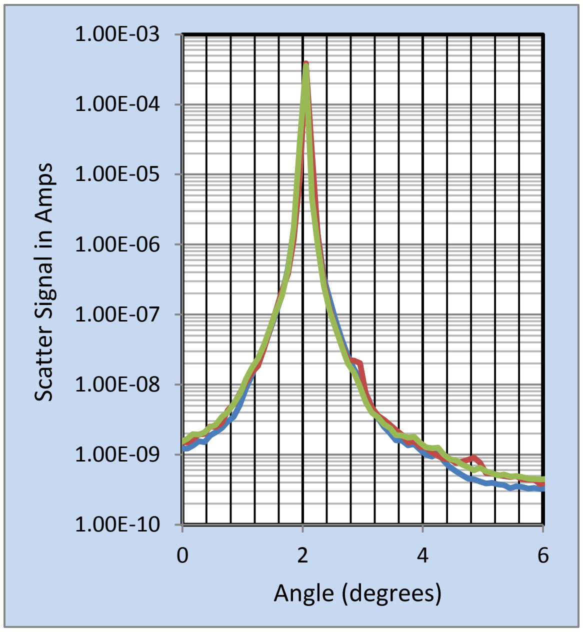

Figure 1 – Scattered light curves from a holographic master grating and two of its replicas. The slight differences in the curves are within the uncertainty of the measuring instrument.

Figure 2 shows diffraction efficiency curves for three replicated gratings from a ruled master measured on one of Richardson Grating's efficiency measuring instruments. To within the measurement uncertainty of the instrument, the efficiency curves are indistinguishable.

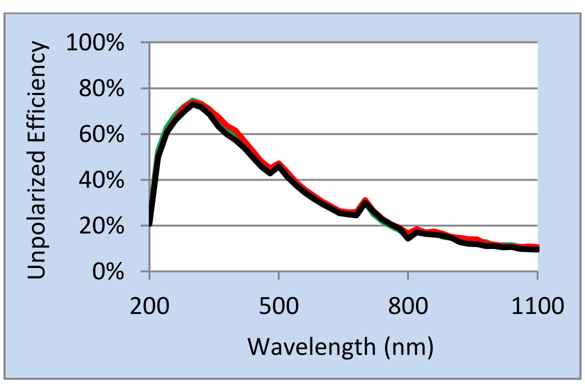

Figure 2 – Diffraction efficiency curves from three replicas of ruled master grating 1092, over the range 200 – 1100 nm. The average of the efficiencies for S and P polarization is shown.

On the other hand, Figure 3 shows efficiency curves of four 'identical' holographic masters made by a competitor; while the efficiency curves of three of these masters are very well matched, the efficiency curve for one master differs considerably across the UV-VIS spectrum. This result is typical when comparing many holographic masters, since the holographic recording process used to make the master gratings has inherently larger variation than the replication process used to make replica gratings.

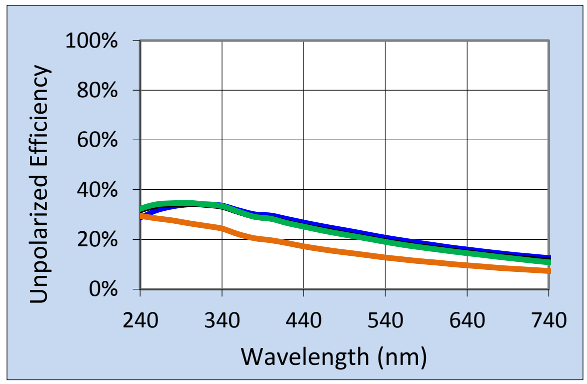

Figure 3 – Diffraction efficiency curves from four (4) holographic master gratings, showing that three are quite similar while the fourth (orange curve) has noticeably different efficiency. The average of the efficiencies for S and P polarization is shown.

While there are a few situations for which masters might be more suitable, such as very high damage threshold laser configurations, for the vast majority of grating applications there is no need for masters, which are too expensive, too long to produce and more difficult to handle in high-volume manufacturing

Replicated diffraction gratings are used worldwide in commercial and scientific instruments, meeting a wide variety of performance requirements. Using master gratings instead, which adds expense and troublesome part-to-part variation, is rarely justified.

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