Glass Performance Days 2025

10 – 12 JUNE 2025 | NOKIA ARENA - TAMPERE, FINLAND

GLASS PERFORMANCE DAYS 2025

THE RISK OF OPTICAL DISTORTION BY DIGITAL PRINTING ON GLASS

DIGITAL PRINTING ON GLASS SURFACES CAN ENHANCE THE RISK OF OPTICAL DISTORTION – WHAT IS IT, WHY IS IT APPEARING & HOW TO PREVENT IT.

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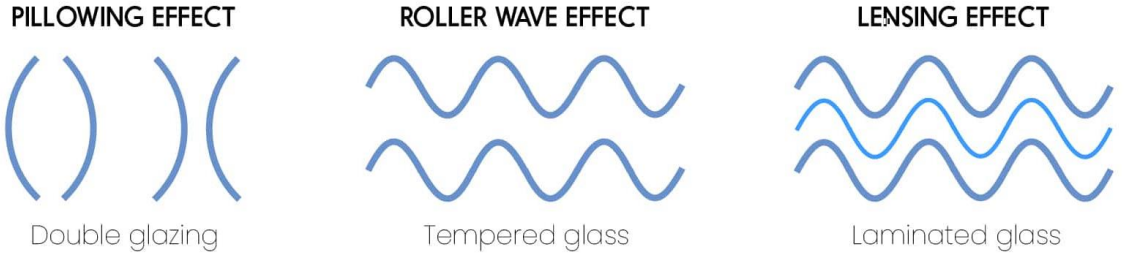
Optical Distortion

Most incident light rays will have their direction changed, which may be perceived as an optical distortion of the image at all angles of view.

Optical distortions reflected by glass surfaces may be caused by various processing operations glass undergoes during its manufacturing term.

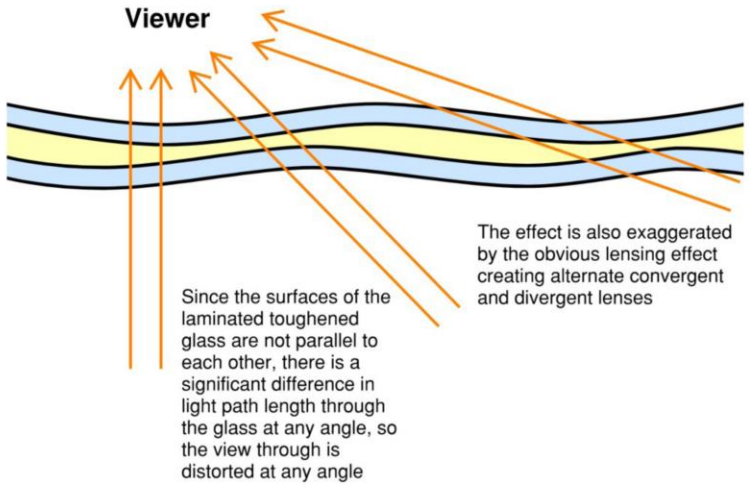
- Bow, Warp, and Pillowing
- Roller Waves
- Anisotropy
- Newton Rings & Brewster's Fringes
- Low-e Banding
- Lensing
- Moiré Effects
- Interference Banding



Lensing

Heat treated glass substrates when laminated may result in a greater degree of visible distortion due to the lensing effect when adjacent glass surfaces are out of phase or non-parallel when bonded together within the laminated makeup.

This lensing effect can result in a magnification of objects when they are viewed through the glass in transmission as well as when viewing reflected images from the surrounded environment



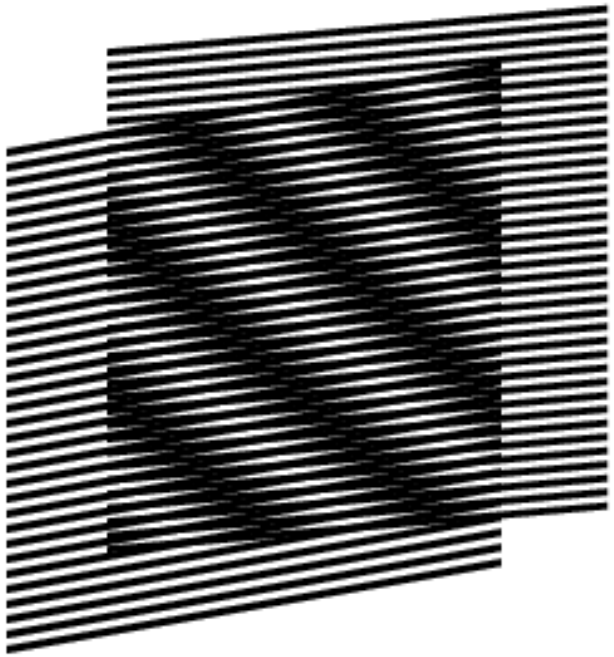
Moiré Pattern

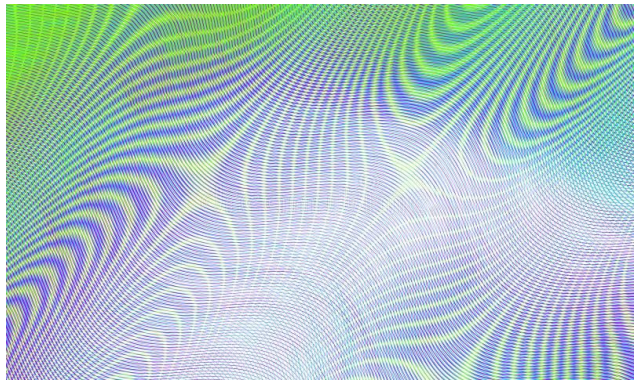
Moiré is an optical phenomenon that typically appears as a wavy, rippled or circular pattern.

It is an interference pattern that arises when two similar repetitive structures are overlaid with a slight offset or misalignment.

Moiré is not a defect in the glass or the printing process but rather a pattern created by the visual perception of the overlapping structures.

Moiré can appear when glass is printed with two patterns or if laminated glass contains mesh fabrics and observed from varying angles.

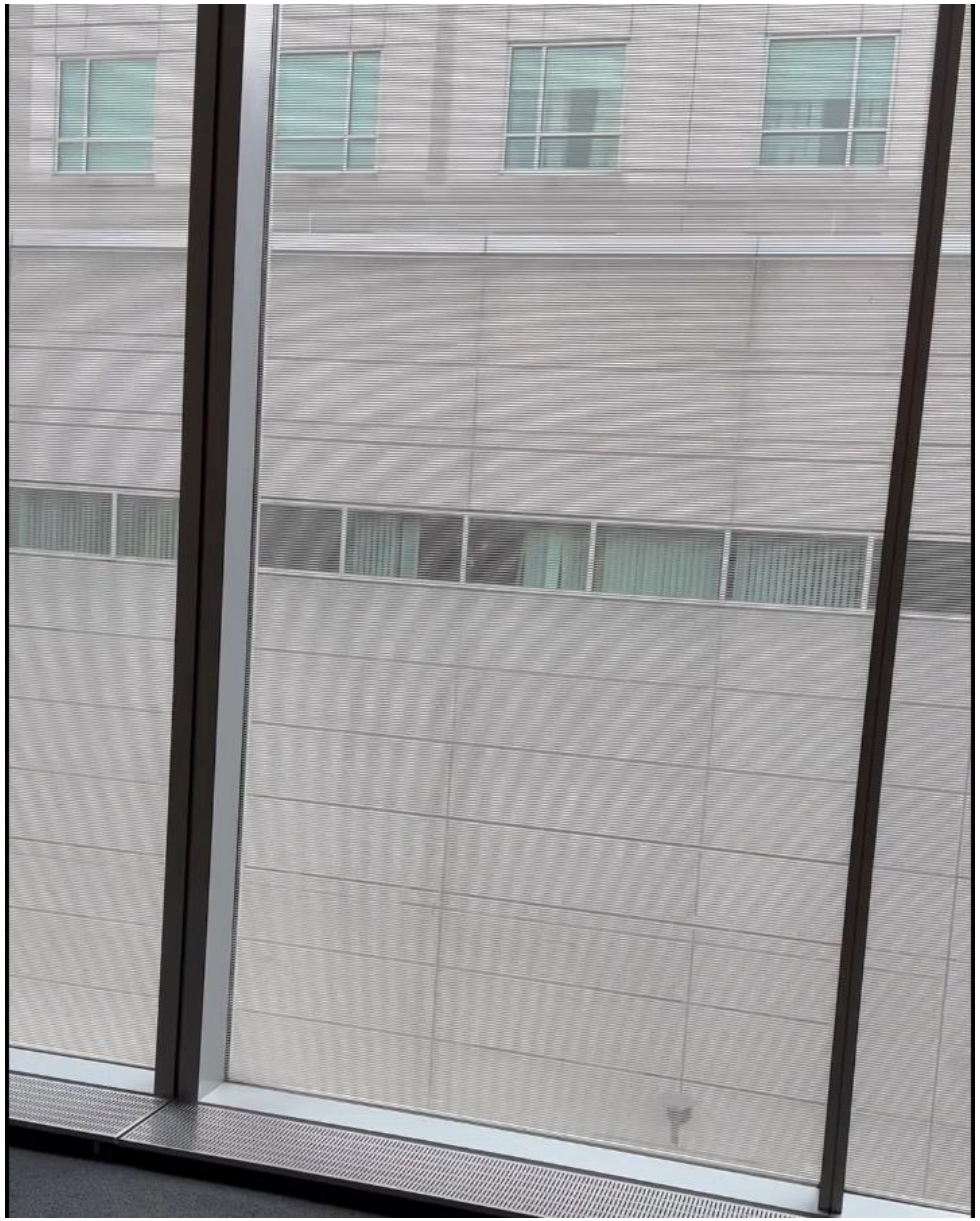




Ceramic Frit Moiré

Not only can moiré patterns be seen when two similar printed patterns are superimposed. A moiré pattern may also become visible if the background of a ceramic fritted pattern appears to have similar geometric patterns compared to the ones on the glass.

Created by the visual perception of the overlapping structures, the moiré pattern even starts to flickering, generating an even larger level of discomfort while perceiving the patterned visual illusion.

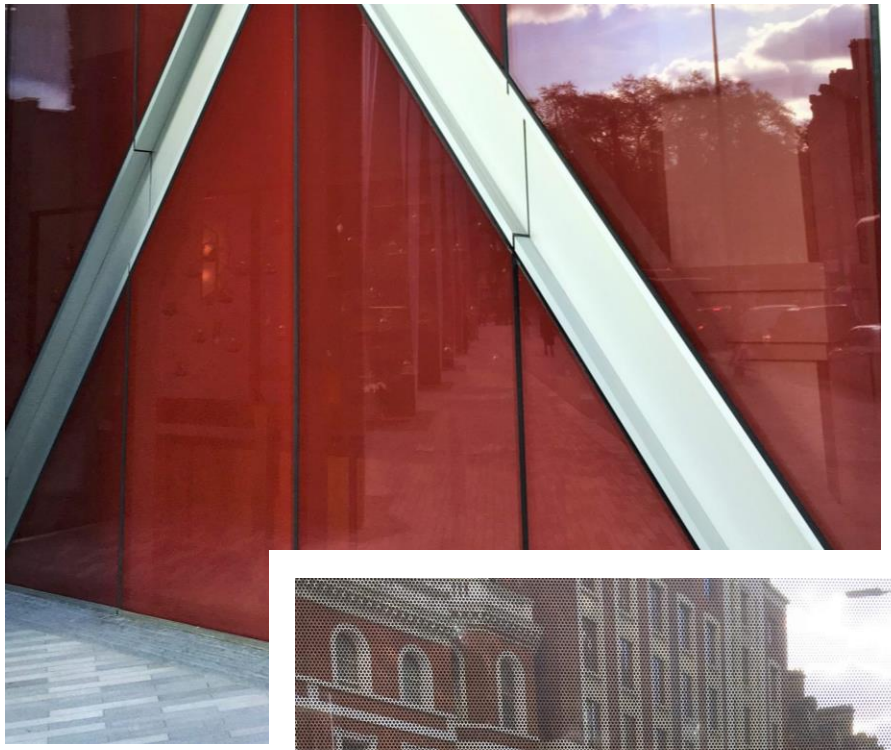


Dual-Pass Print

Dual-Pass prints are processed by screen-printing or digital-printing a pattern (usually dots) of ceramic frit on the same glass surface. The dots are a different color when seen from each side of the glass. This produces a one-way vision effect.

From outside, dots are typically white or brightly colored and achieve a combination of benefits including decoration, one-way vision privacy glass, solar control and shading, and glass manifestation for both humans and to eliminate bird strikes/collisions.

From inside, dots appear black to allow the best possible and most natural see-through.



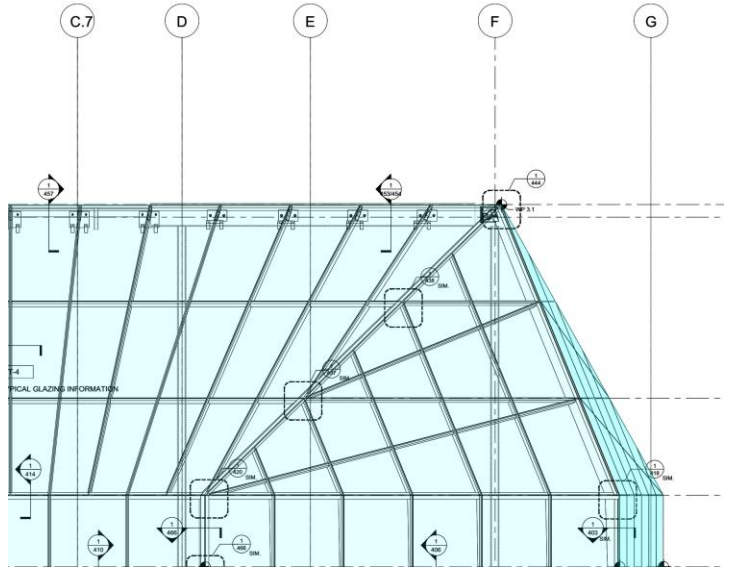
Practice Case

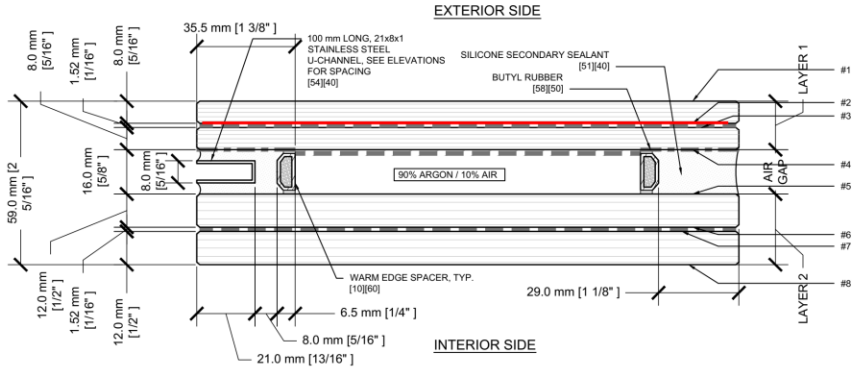
Bespoke architecture offers complex challenges in glass design and material processing under consideration of a broad range of conditions all potentially interacting to confirm visual quality.

Glass Specification

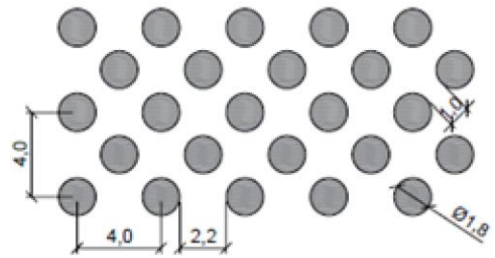
Glass makeup comprises an IGU with inboard and outboard laminated glass, low-e coating on #4 and dual-pass color print on #2. All glass is HS and laminated with PVB.

Print pattern is a dot matrix layout with dot diameters of 1.8mm. External light gray, internal dark gray. Glass layout is irregular shaped units.



Glass Type Description	Glass Type Illustration
GLASS DESIGNATION: GL-02 GLASS TYPE: FLAT, ULTRA CLEAR GLASS MAX THICKNESS: 59.0 mm (2 5/16") LAYER 01: 1x 8 mm (5/16") HEAT STRENGTHENED 1x 1.52 mm (1/16") PVB INTERLAYER 1x 8 mm (5/16") HEAT STRENGTHENED PERFORMANCE COATING #4 (SEE TABLE ON SIDE) AIR GAP: 1x 16.0 mm (5/8") 90% ARGON, 10% AIR WARM EDGE SPACER LAYER 02: 1x 12 mm (15/32") HEAT STRENGTHENED 1x 1.52 mm (1/16") PVB INTERLAYER 1x 12 mm (15/32") HEAT STRENGTHENED	

3021/ 2 dots pattern



First layer: CMIX 508
Second layer: RAL 7010 (CMIX 513)

Glass Appearance

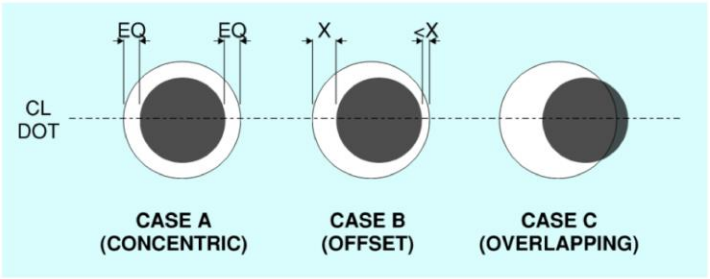
Patches of moiré patterns appeared randomly on units with uniform edge lengths coupled with an atypical phenomena of (frit-) banding in horizontal and vertical directions creates an optical distortion when viewed from varying perspective angles.

Typical appearances of bands and moiré patterns were mostly visible under overcast light conditions and without interior lighting, from angles ranging between 90 - 65 degrees.

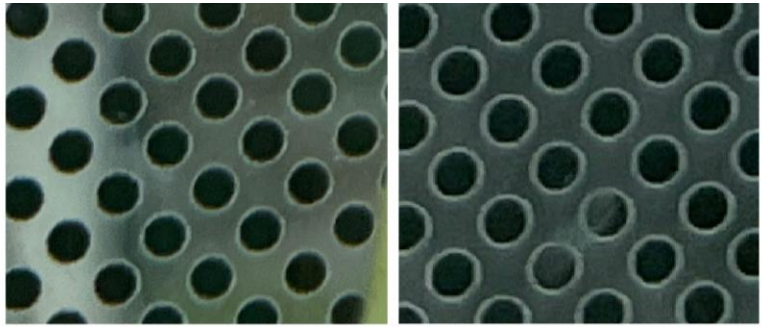
Analysis

Typical frit patterns were observed from the exterior and interior of the curtain wall. The frit was offset from the measuring tool and viewed through layers of glass.

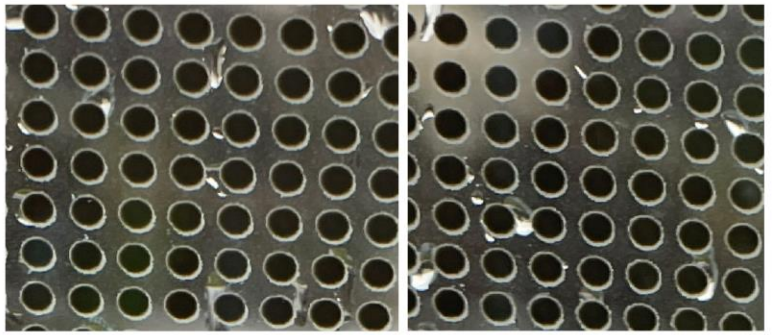
A variety of conditions were detected identifying offset locations between differently colored dots resulting into a Case categorization:



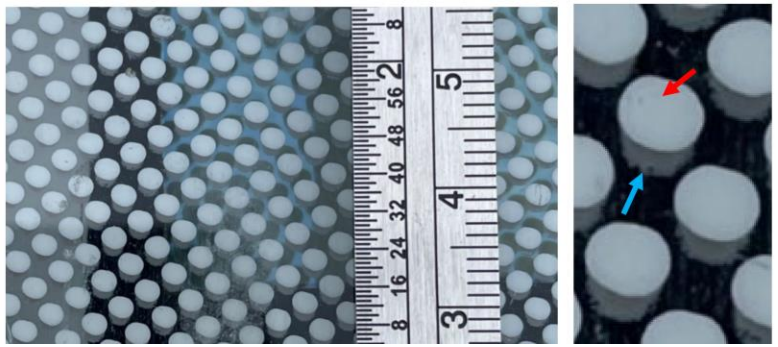
Visible frit bands were likely caused by, but not limited, combinations of offset cases. However, all were well within regular printing tolerances.



View from inside – left & right dots both Case A



View from inside – left & right dots both Case B



View from outside – left & right dots both Case C

Conclusion

Although all project glass was quality controlled during and after fabrication, and visual mock-up units were produced to set fabrication standards as well as for inspection by the client, units apparently being impacted have only been observed after installation into the building with surrounding infrastructure and under certain light conditions.

As a conclusion of the observation and analysis, the following factors appear to contribute to the phenomena of frit Banding in combination with effects of Moiré, Lensing and Roller Waves:

- A-typical shaped glass units in combination with static digital frit direction
- Dot-on-Dot frit pattern with dot diameters too small set into a density layout too close
- Mirco offsets between Dot-on-Dot locations
- Lensing and reflection of dot offsets through multiple glass surfaces
- Slightly scattered frit registration typical for digital prints on glass

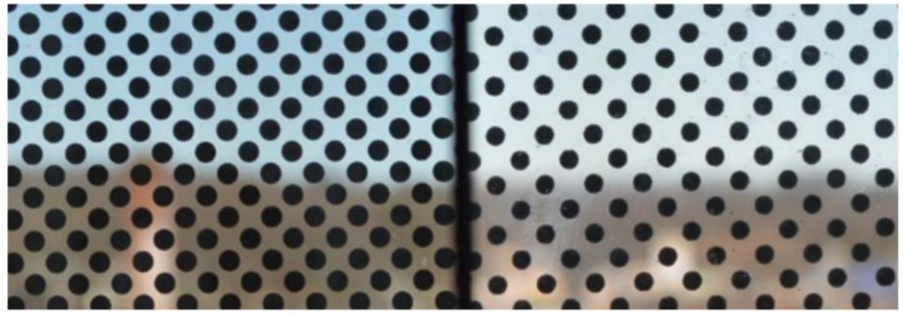
Path Forward

While digital printing on glass is an advanced technique that involves directly applying images, patterns, or designs onto glass surfaces using specialized printers and inks, the process quality highly depends on the used equipment, pre-treatment, printing process accuracy, and design parameters of the image or pattern.

ISO 12647-2, being a standard for graphic technology process control, helps to regulate pixelation, color density, and image sharpness, but only to a single order.

Future regulation is to be developed based on minimum pattern dimensions in comparison to unit sizes, formats and makeups under given and currently achievable industry tolerances.

NGA’s Task Group works on a dedicated GTP.



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