Beam Quality-Preserving Speckle Reduction for Scanned Laser Displays

Fergal Shevlin, Ph.D.

DYOPTYKA

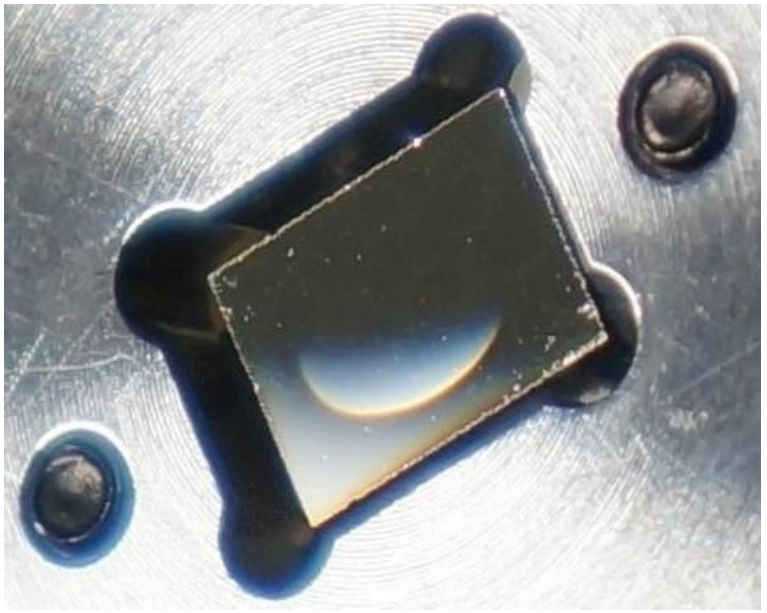
LDC'15

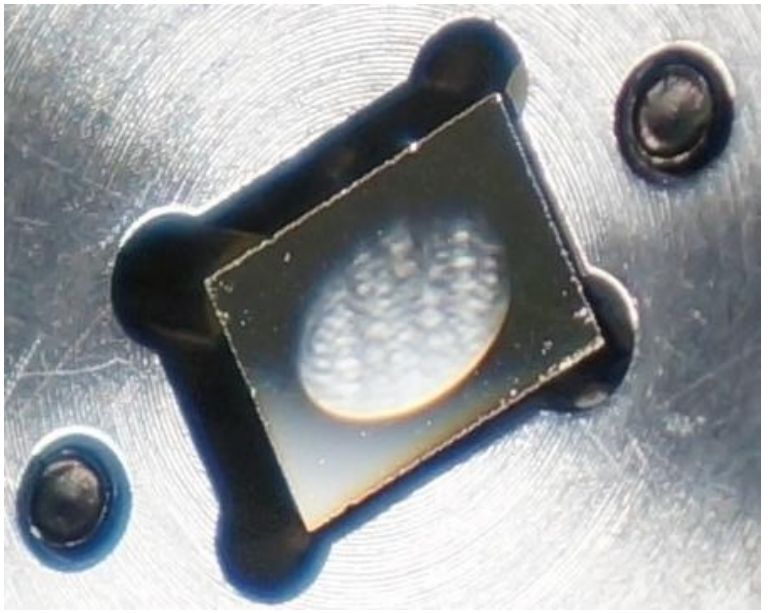
Laser Display and Lighting Conference

Yokohama, Japan, 2015-04-22

Fergal.Shevlin@dyoptyka.com

Phase randomizing deformable mirror

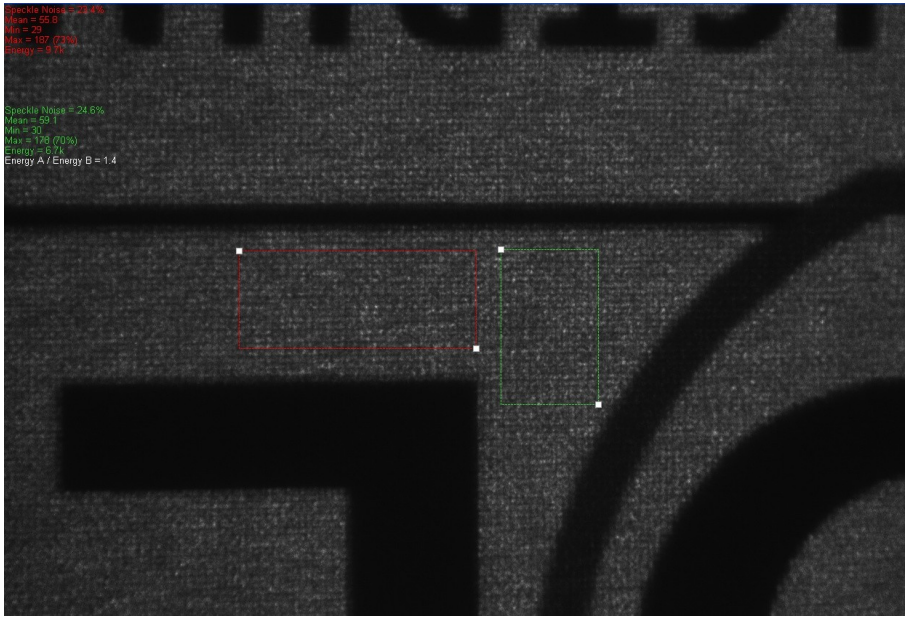


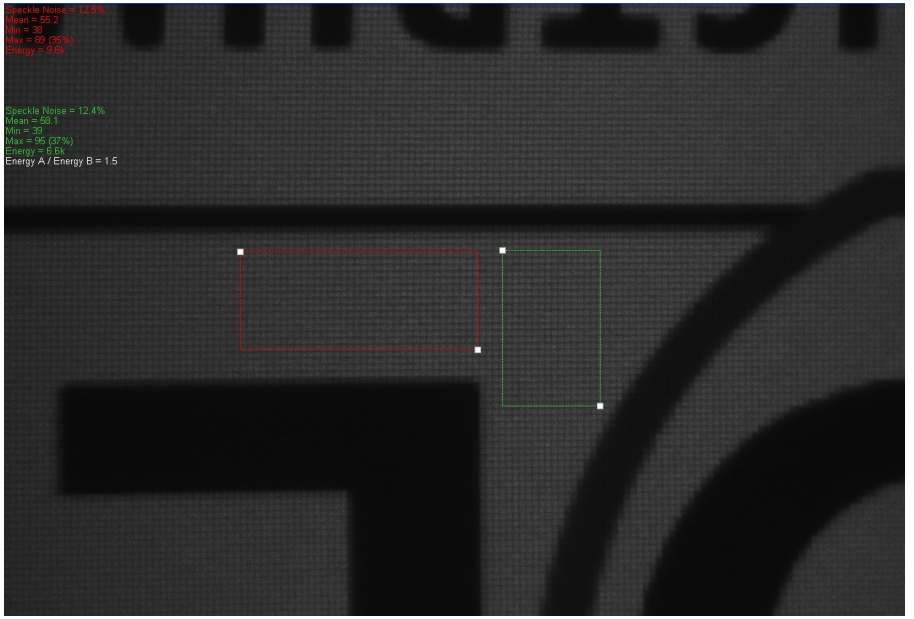


- Creates uncorrelated speckle patterns at >1 MHz.
- High optical efficiency, approx. 99% with dielectric coating.
- Different active area dimensions available to suit system etendue.
- 5 W to 150 W damage thresholds. Higher possible.

Fergal.Shevlin@dyoptyka.com.

Effective and Efficient Speckle Reduction

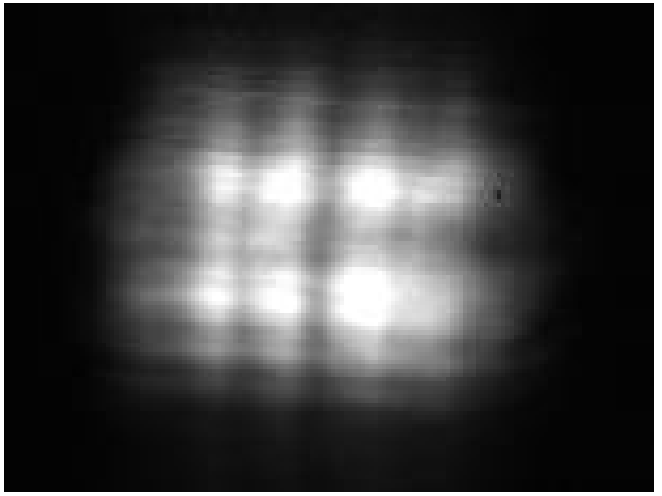


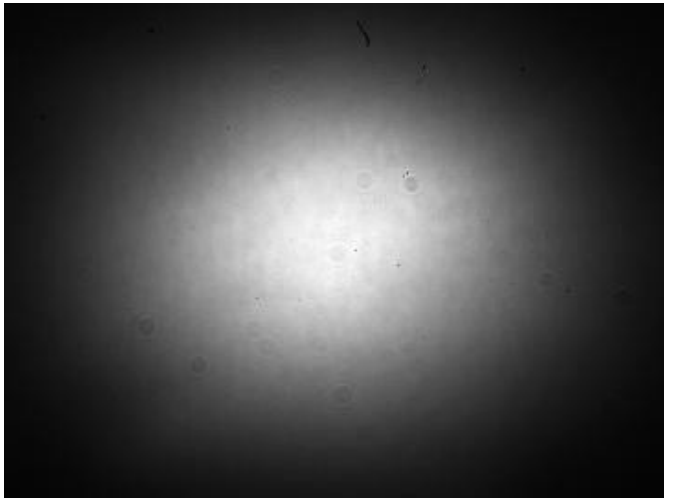


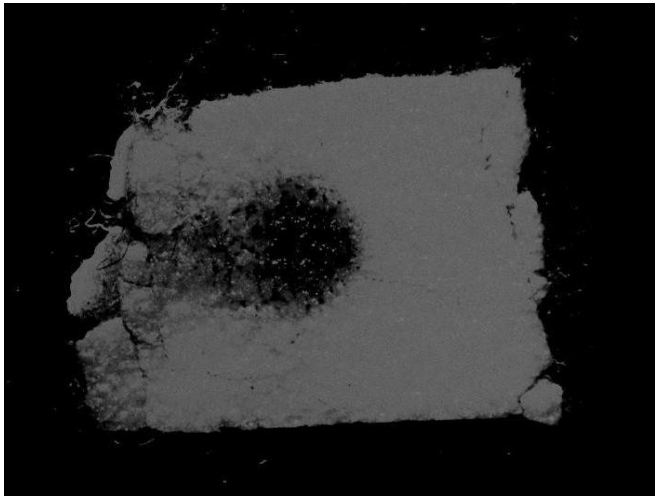
- Display applications: projection, front-lit and back-lit, HUD and HMD.
- Other applications: microscopy, interferometry, inspection, spectroscopy ...

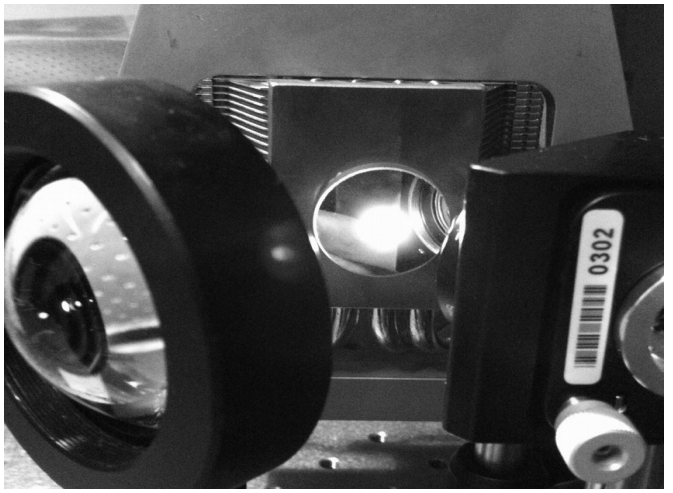
Fergal.Shevlin@dyoptyka.com.

Laser-phosphor illumination and display: DM prevents hot spots on phosphor





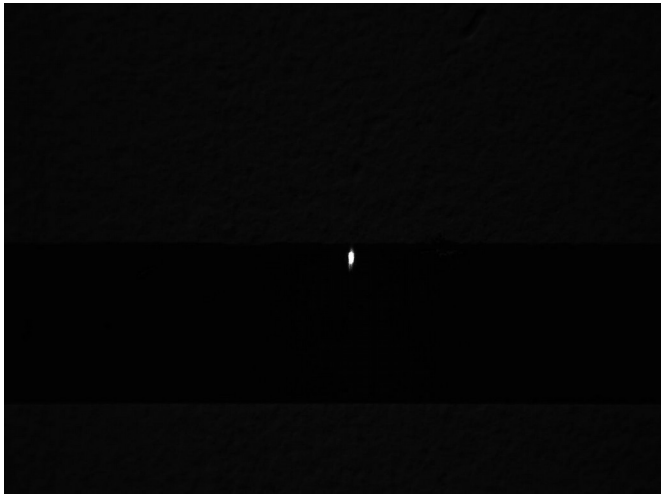


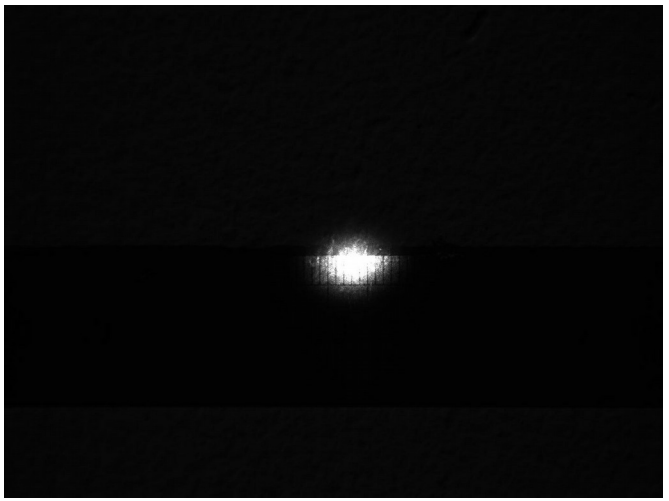


See our IDW 2013 paper *"Speckle reduction for illumination with lasers and stationary, heat sinked, phosphors."*

99% optical efficiency, low-angle, band-limited, randomized divergence

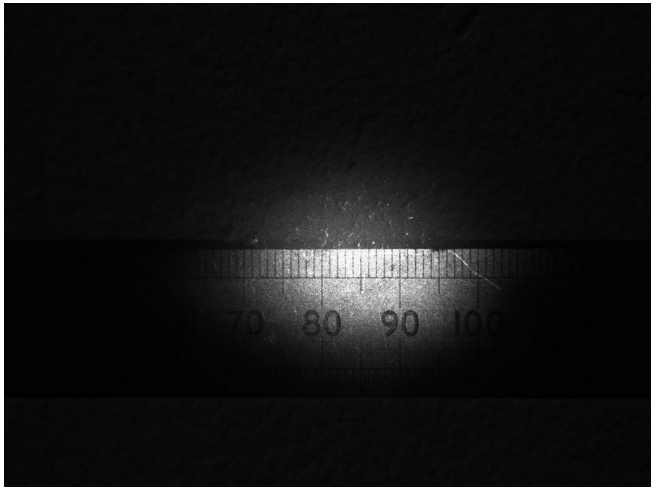
Mirror off: no divergence.

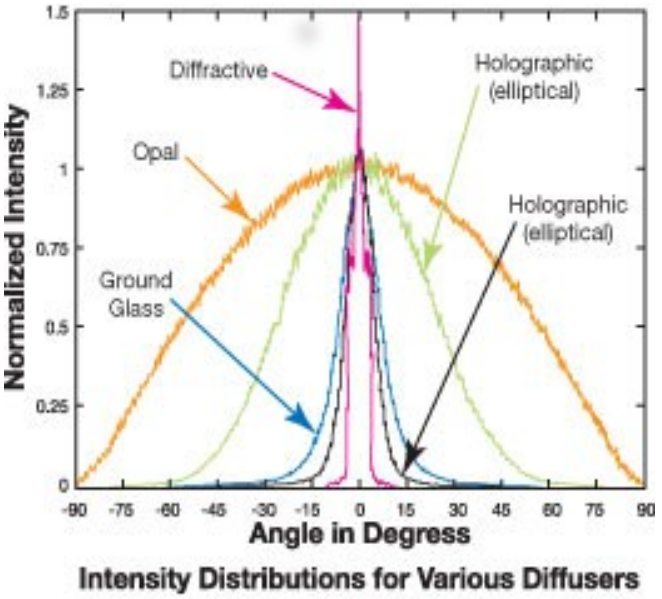




Mirror on, 1.8V: divergence 0.5 deg.

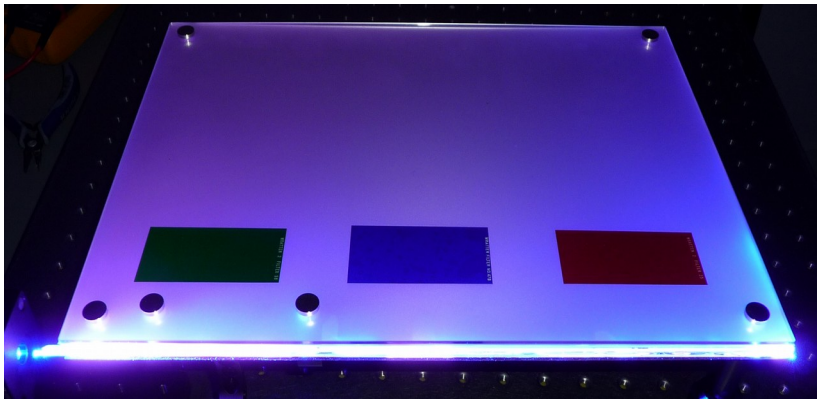
Mirror on, 3.3V: divergence 2.0 deg.

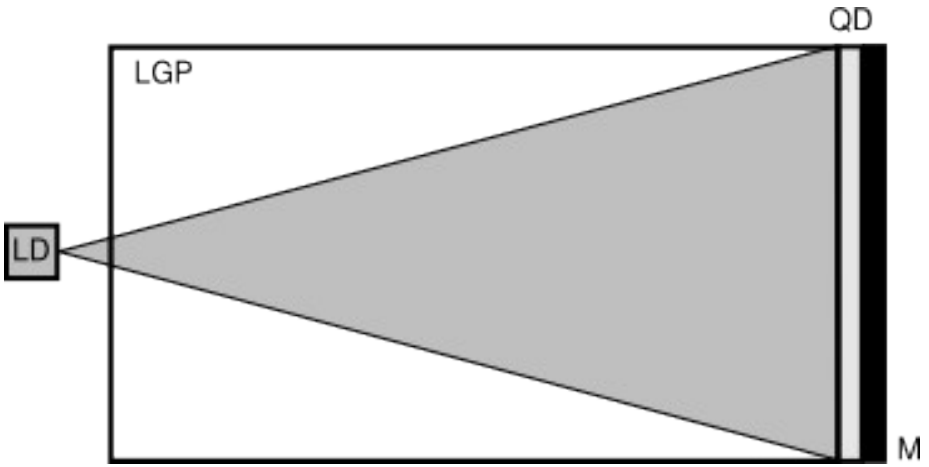


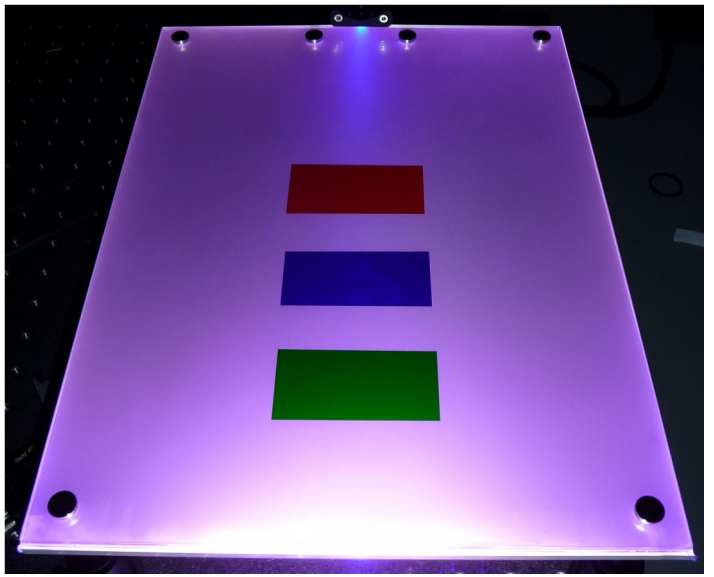


(Figure from Thorlabs.)

DM enables use of LD through thin LGP, e.g. 1 mm glass

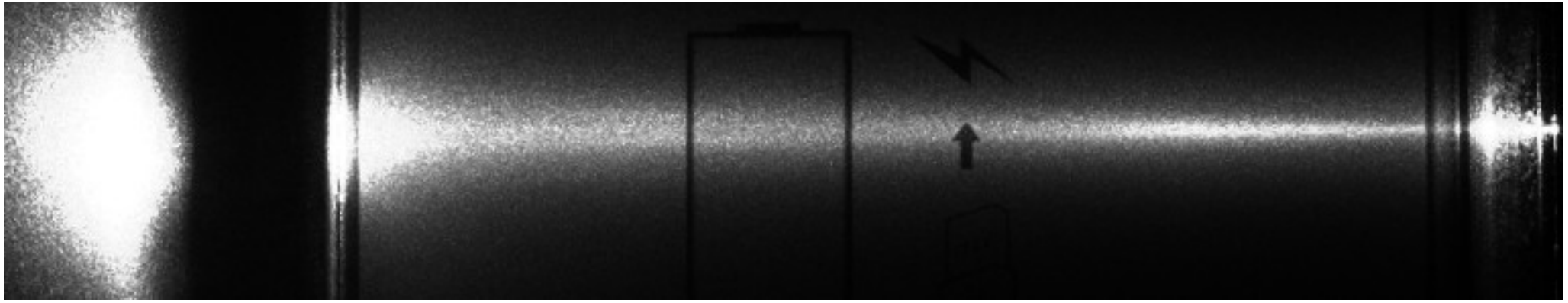


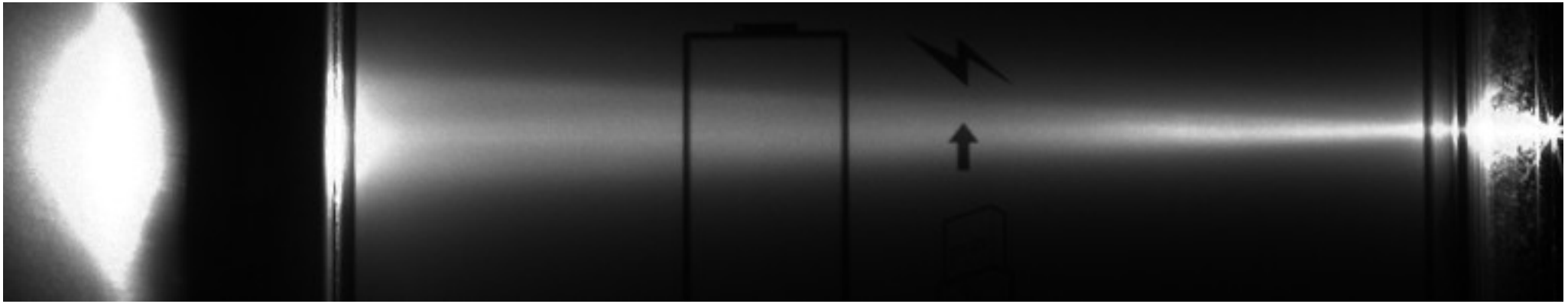




See our IDW 2014 paper *"Light guide plate illumination with blue laser and quantum dot emission."*

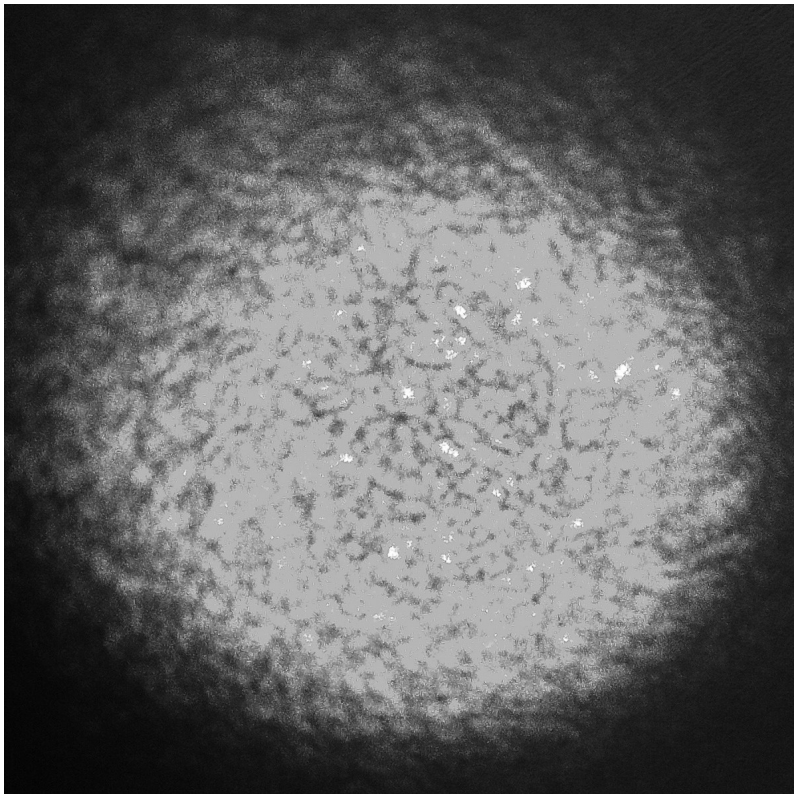
Front-lit display LGP, e.g. Amazon Kindle.

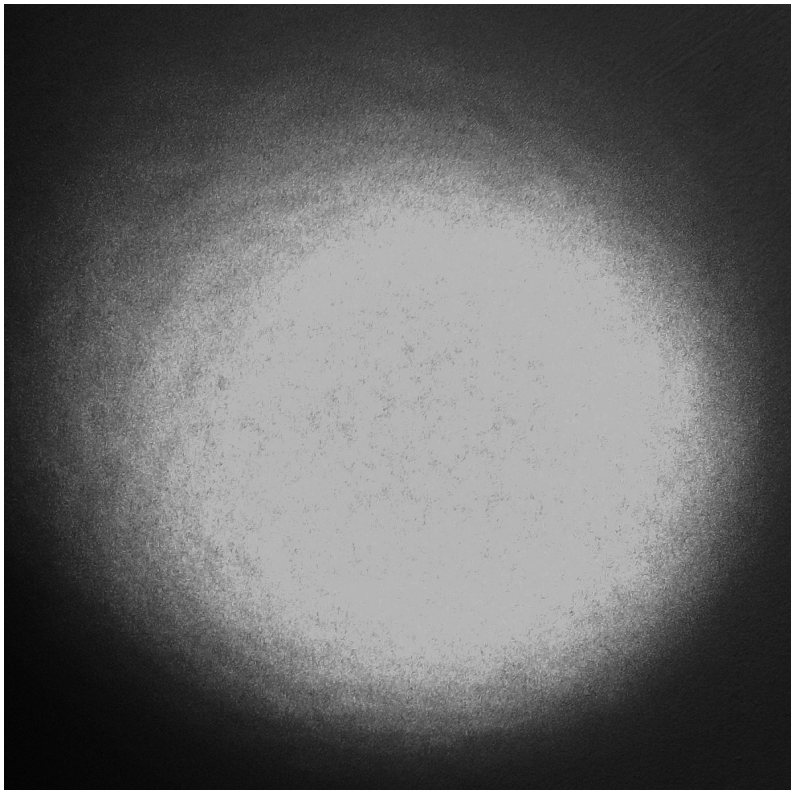




See our LDC 2014 paper *"Light guide plate illumination by laser through optical fiber."*

Scanned laser display: our first concept for DM integration

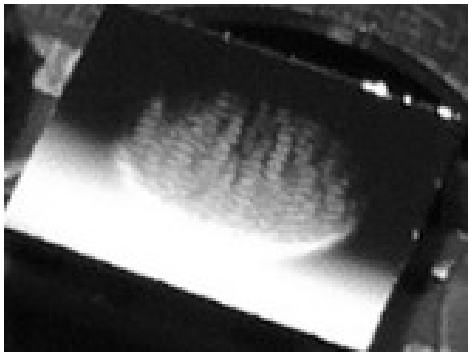


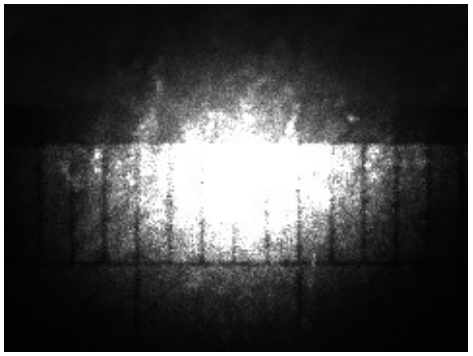


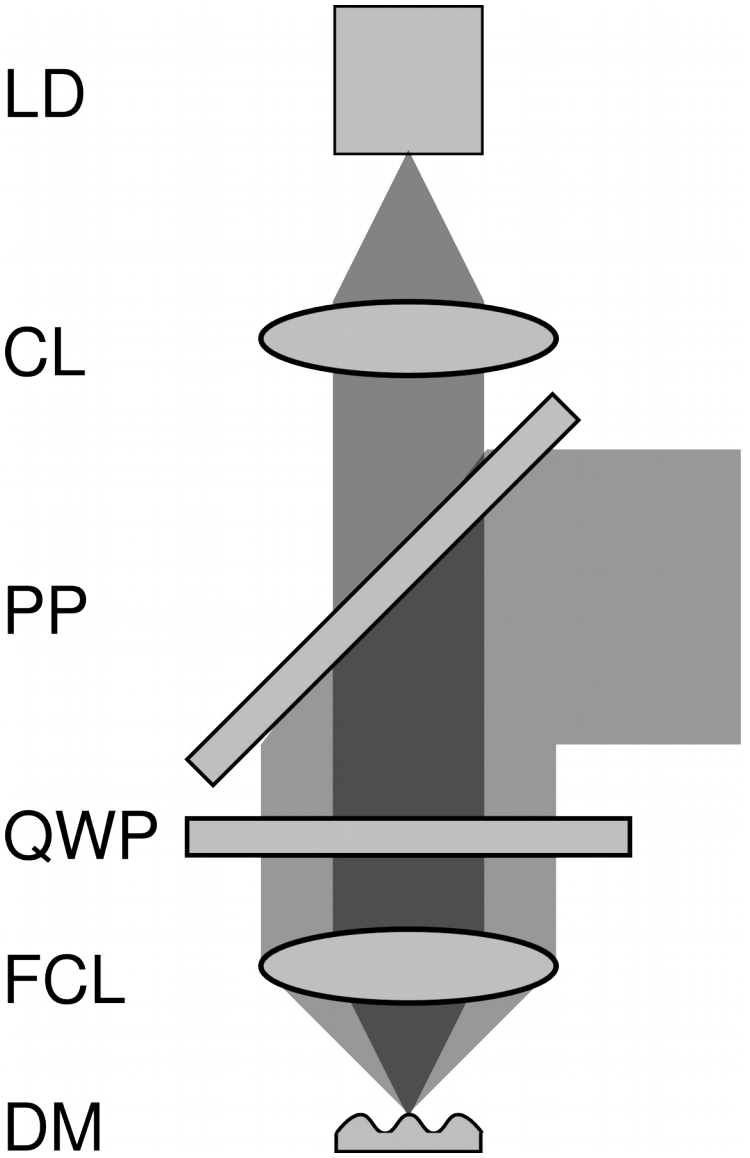
Laser → collimating lens → DM → coupling lens → multimode fiber, e.g. 105 um, 0.22 N.A. → collimating lens.

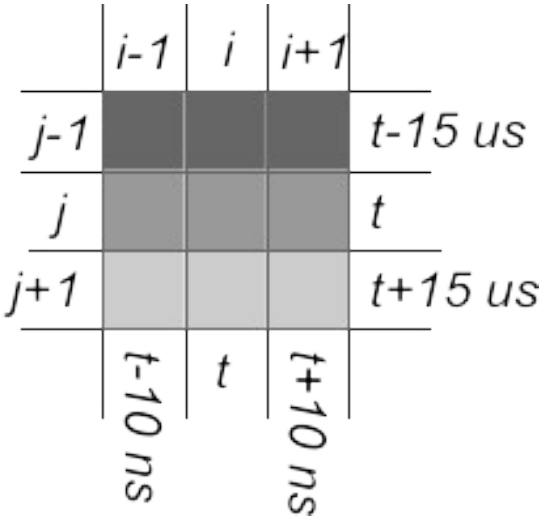
Fergal.Shevlin@dyoptyka.com.

Scanned laser display: DVD-inspired concept



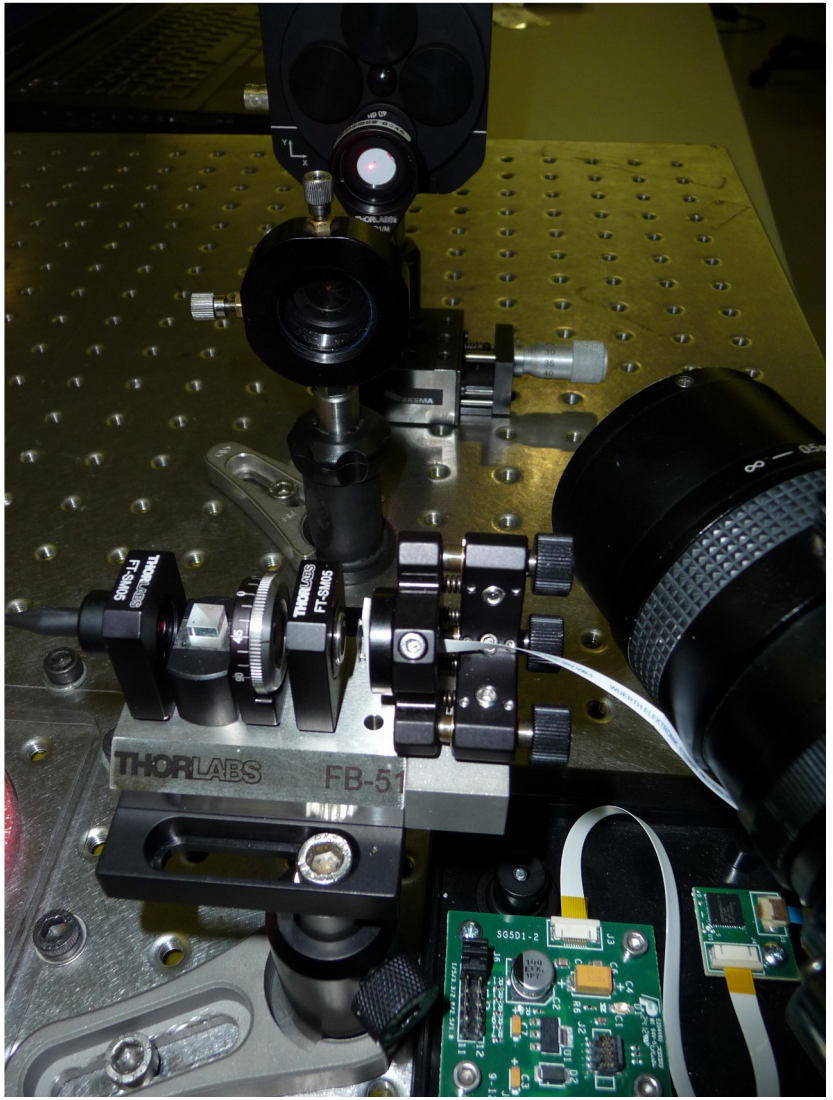


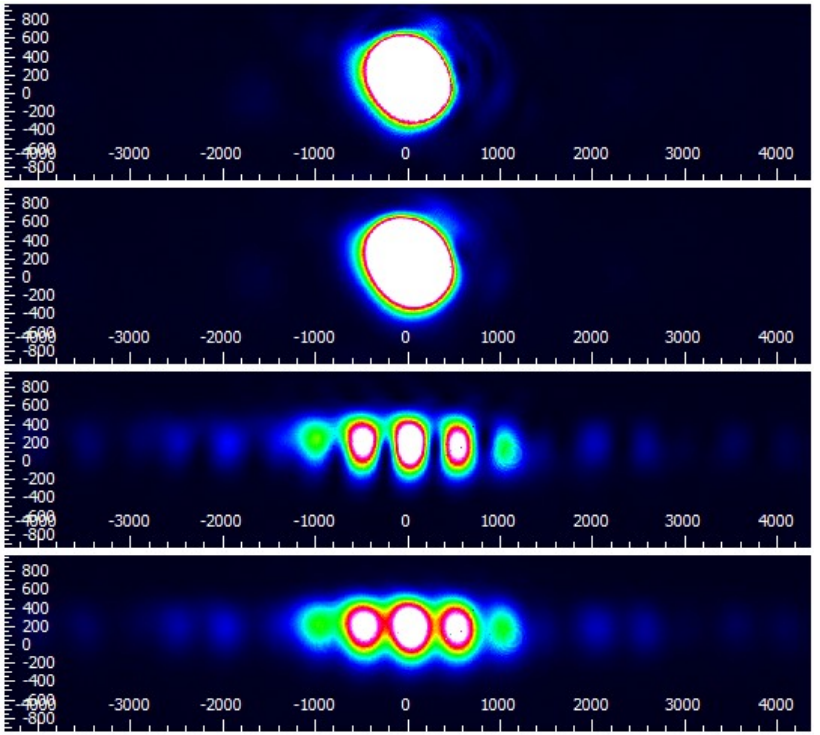




- DM fast enough for effect between image rows.
- SCR reduction by √3 possible?

Apparatus and beam observations

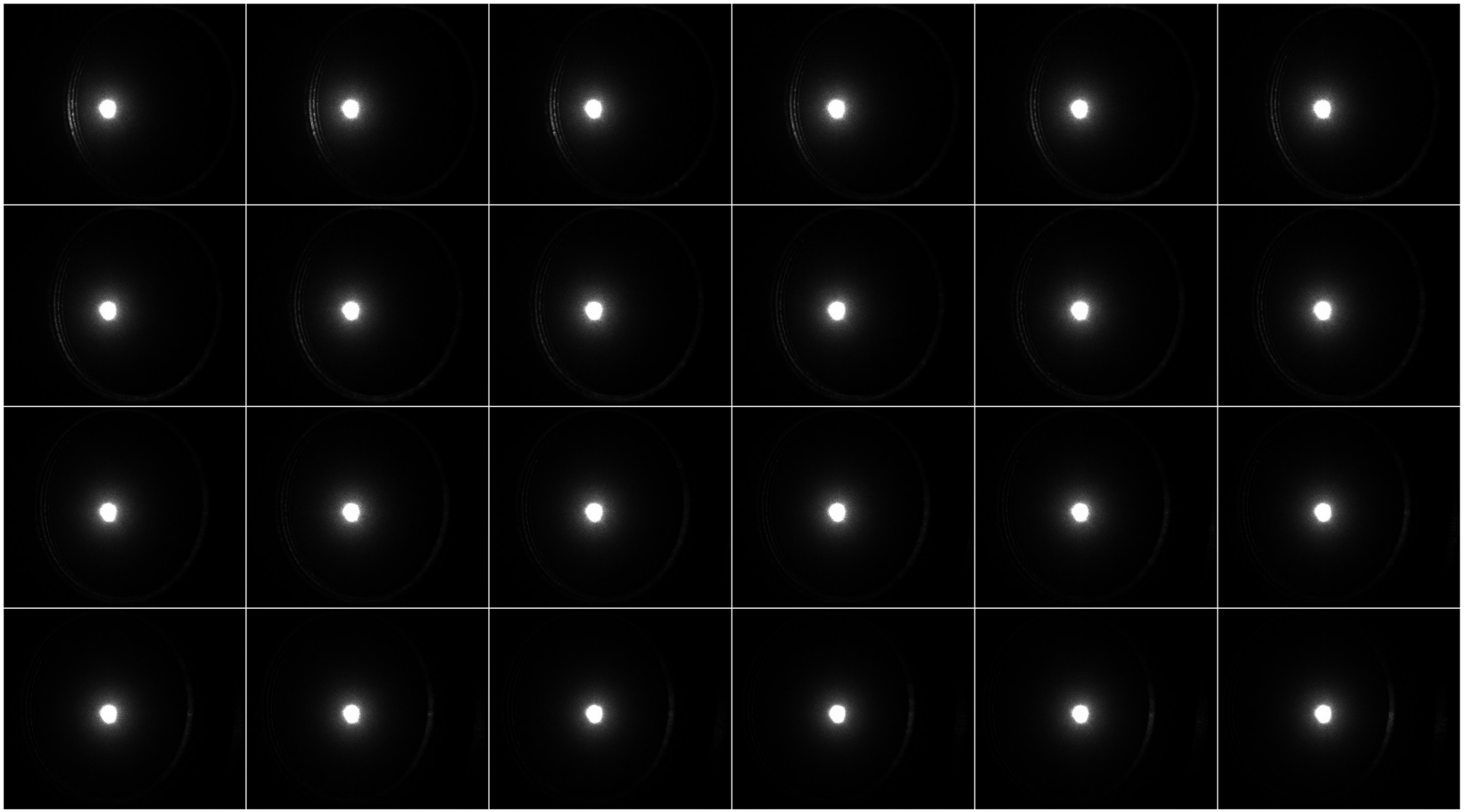




- Beam diameter increase approximately 10%.
- Fringe contrast shows spatial coherence reduction.

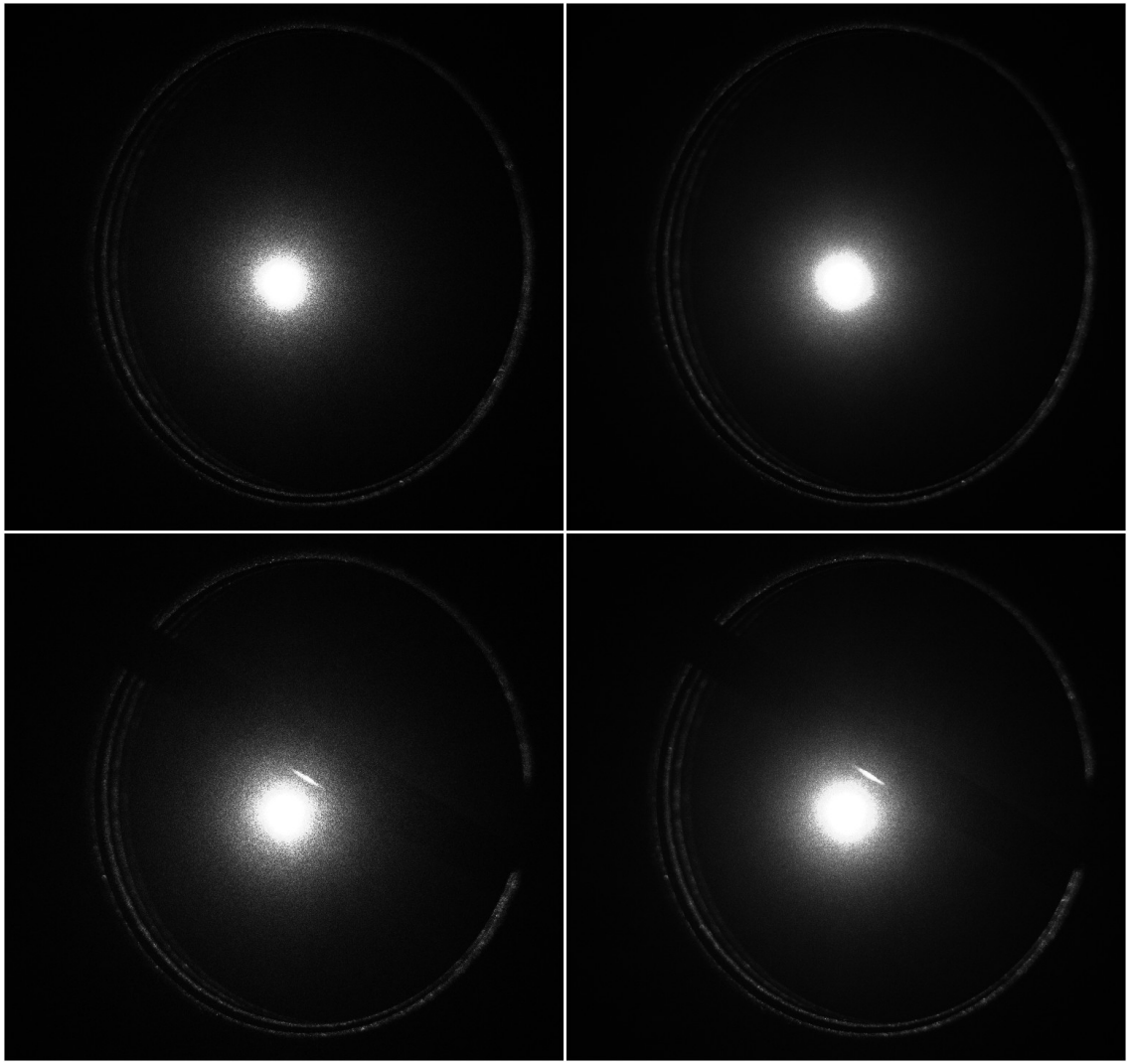
Fergal.Shevlin@dyoptyka.com

1 mm dia. pixel on paper observations



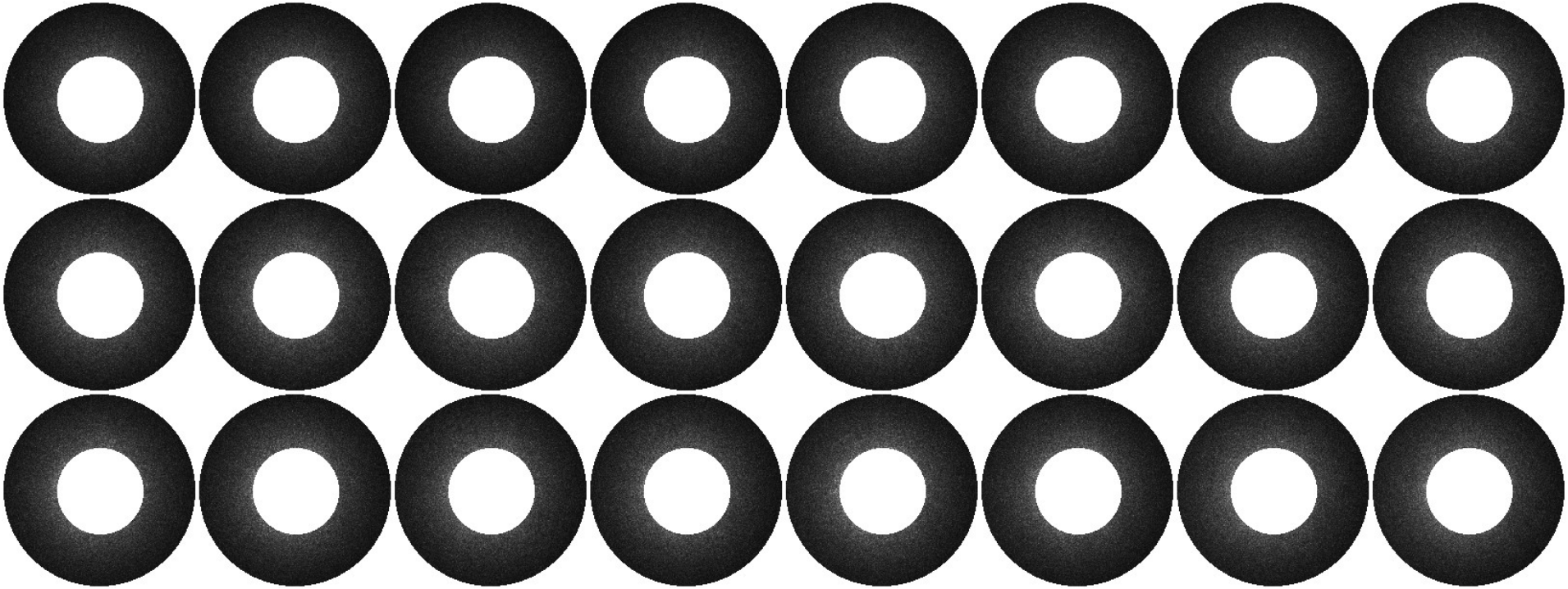
Fergal.Shevlin@dyoptyka.com

“Pupil speckle” observations, DM Off/On



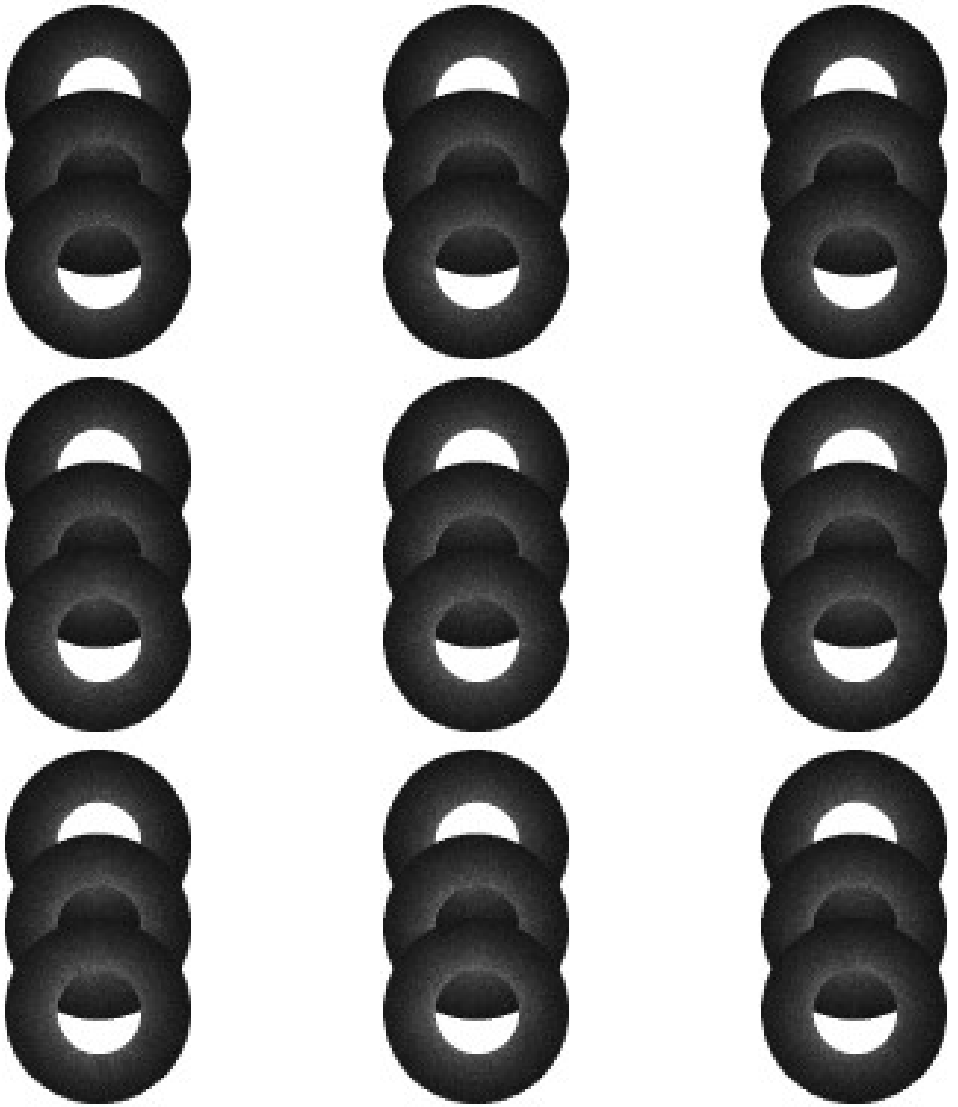
Fergal.Shevlin@dyoptyka.com

“Pupil regions” of 1 mm pixels



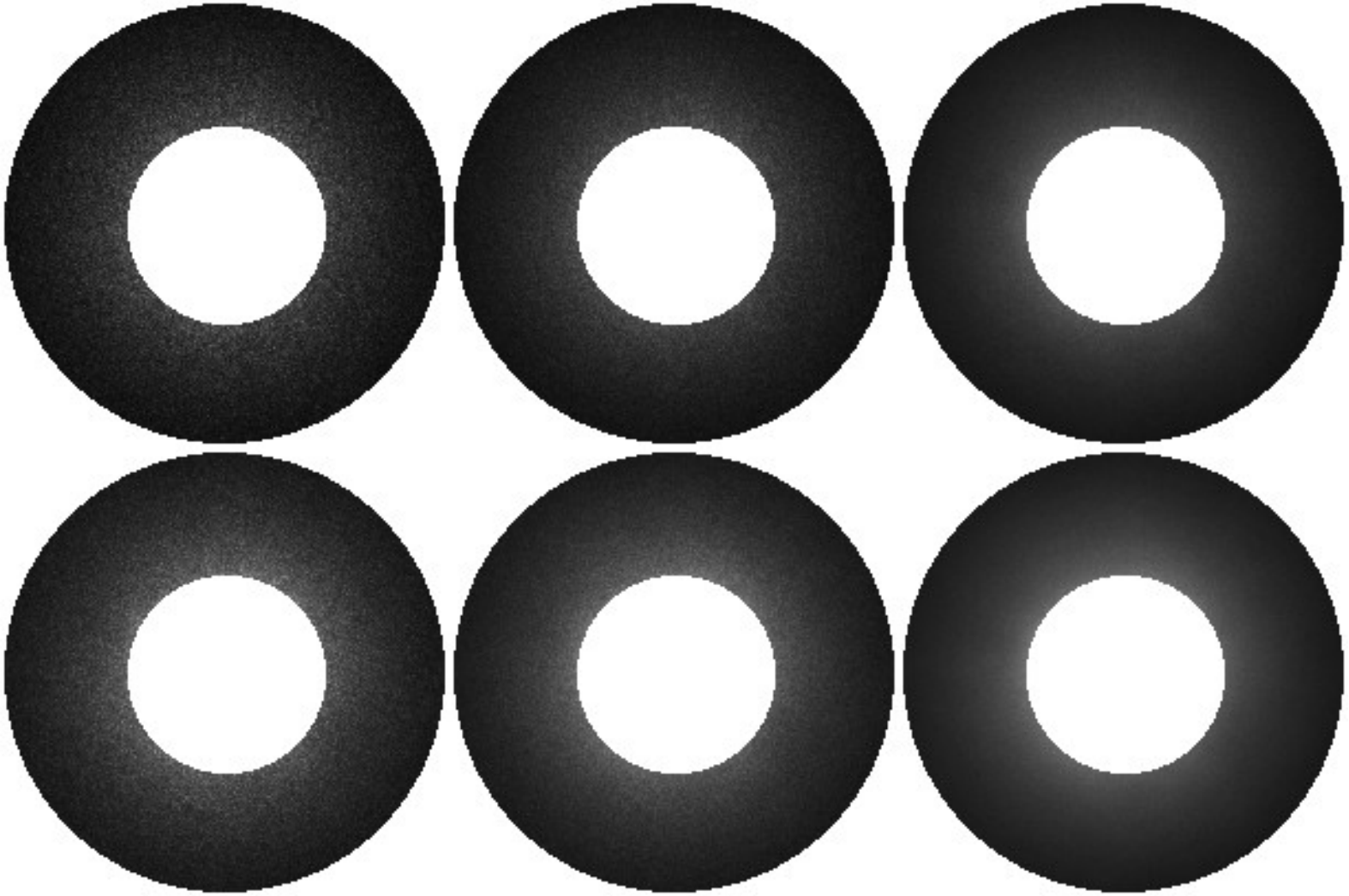
Fergal.Shevlin@dyoptyka.com

Pupil regions of 1 mm pixels and their +/-1 mm neighbors



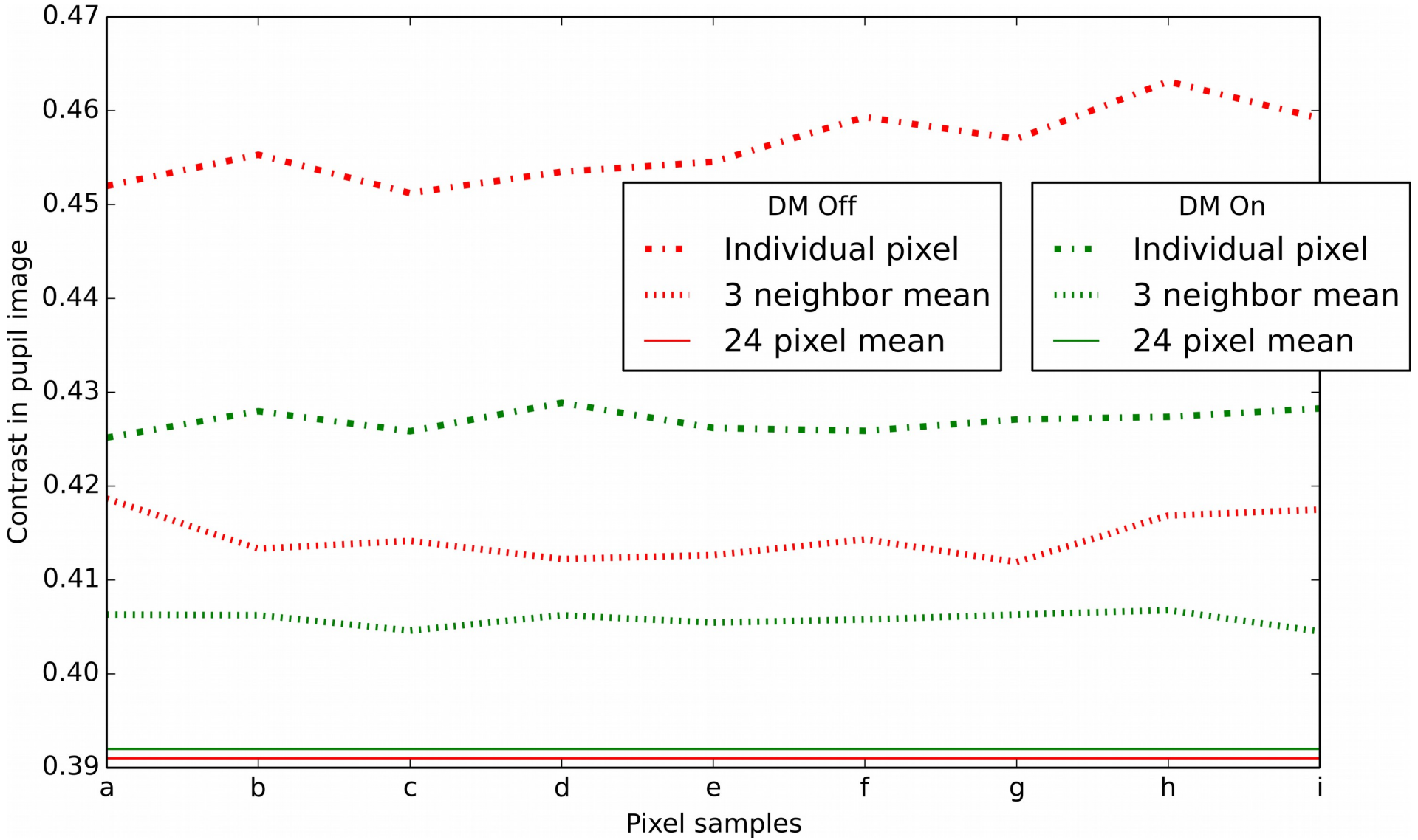
Fergal.Shevlin@dyoptyka.com

DM Off/On for 1 pixel, 3 neighbor mean, and 24 pixel mean



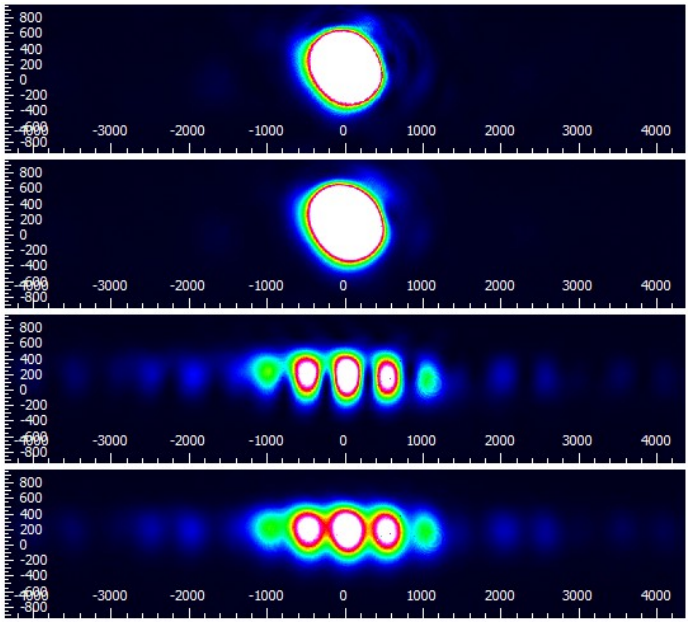
Fergal.Shevlin@dyoptyka.com

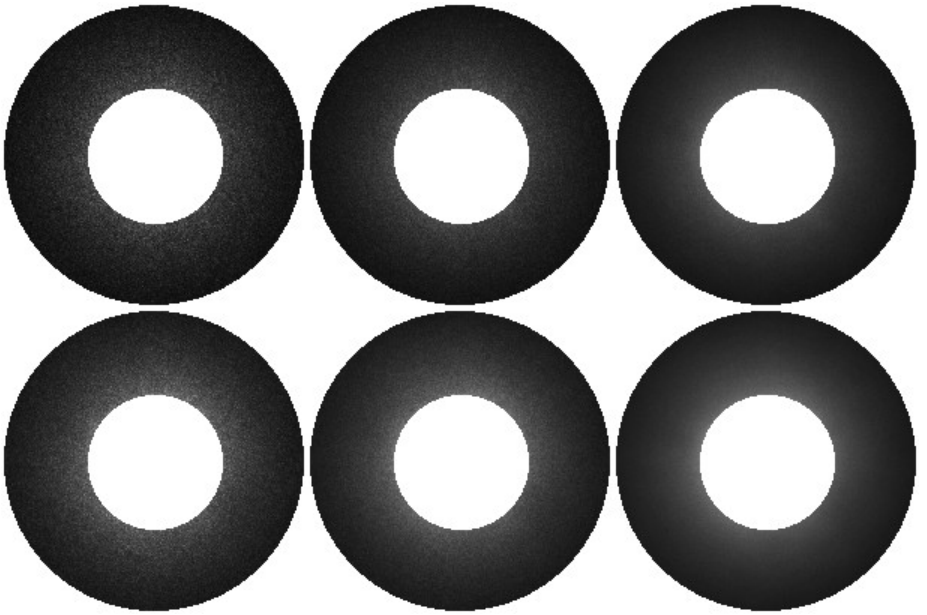
Pupil image contrast at 9 different pixel positions



Fergal.Shevlin@dyoptyka.com

Conclusions about DM for scanned laser displays



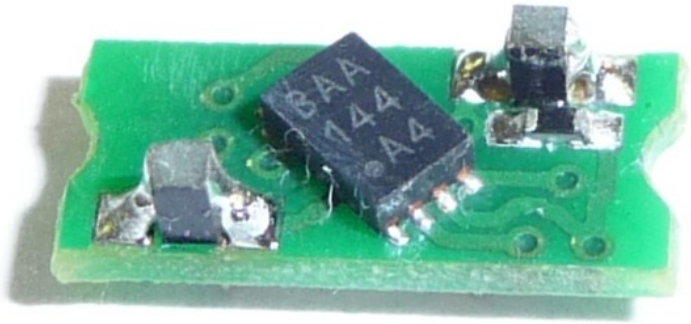


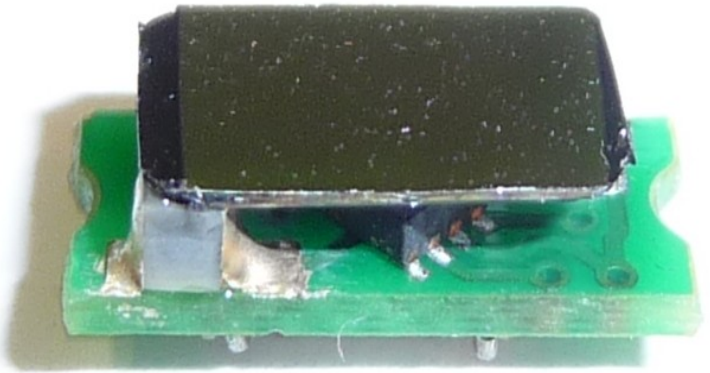
Beam quality preserved, perceptible and measurable reduction in “pupil speckle” contrast achieved for neighboring pixels separated by sufficient time for DM to have an effect.

Effect in full 2-D scanned image to be determined ...

Fergal.Shevlin@dyoptyka.com

Dyoptyka uDM2 for mass production





- Reflectivity ≥ 98%
- Actuation voltage ≤ 5 V
- Shock tolerance ≥ 2500 g
- Integrated control electronics
- Laser damage threshold ≥ 5 W
- Power consumption ≤ 75 mW
- Height ≤ 5 mm
- Lifetime ≥ 20,000 hours

See our IDW 2014 paper *"A Compact, Low Cost, Phase Randomizing Device for Laser-Illuminated Displays."*

Fergal.Shevlin@dyoptyka.com