UNIVERSITAT POLITÈCNICA DE VALÈNCIA

*iCrea INSTITUCIÓ CATALANA DE RECERCA I ESTUDIS AVANÇATS

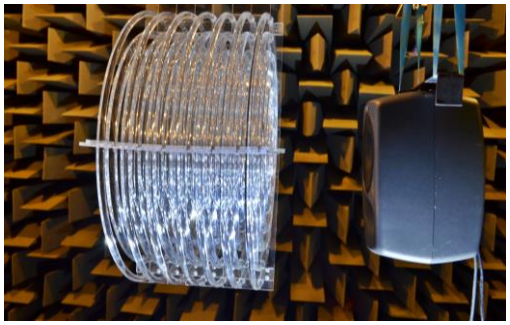
IUMPA

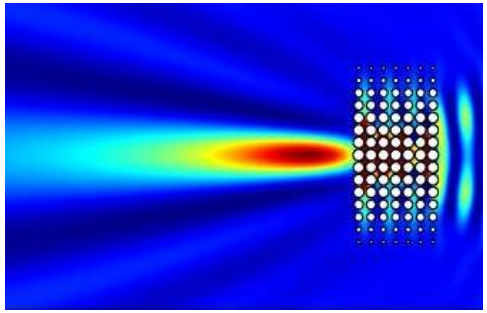
Helical Bessel Beam Formation by an Archimedean Spiral Grating

Noé Jiménez, R. Pico, L.M. Garcia-Raffi, V. Romero-Garcia, V.J. Sanchez-Morcillo, and K. Staliunas

Axisymmetric devices

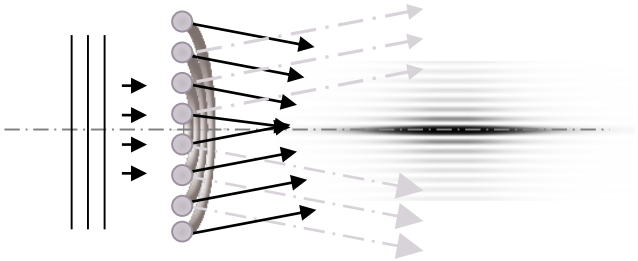
GRIN Lens

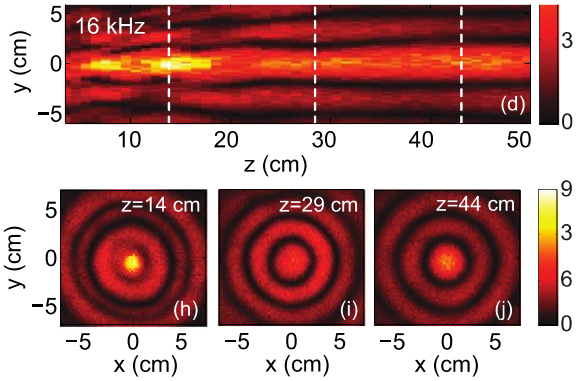




APL, 103, 264106 (2013)

Bessel beam grating





EPL, 106, 24005 (2014)

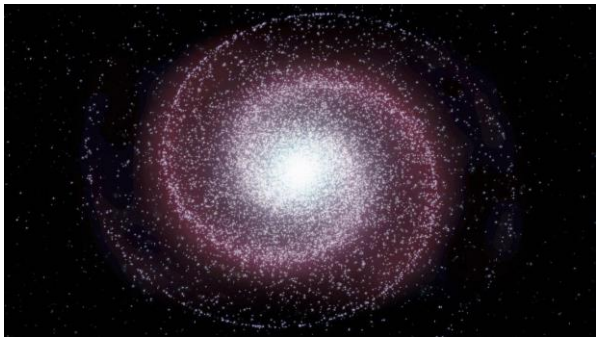
Spirals in nature and man-made

Logarithmic Spiral

$$r(q) = a \cdot e^{b \cdot q}$$



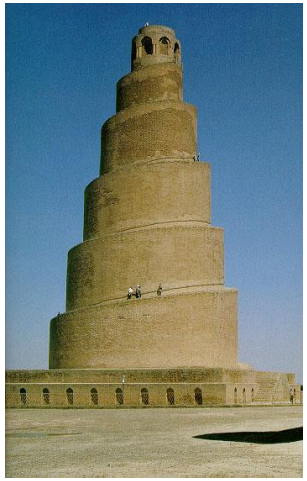


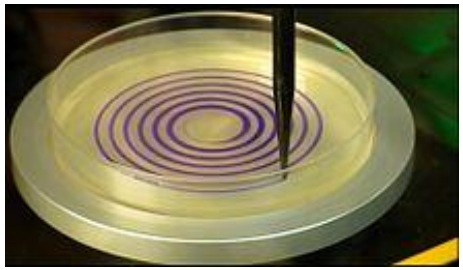


Archimedes Spiral

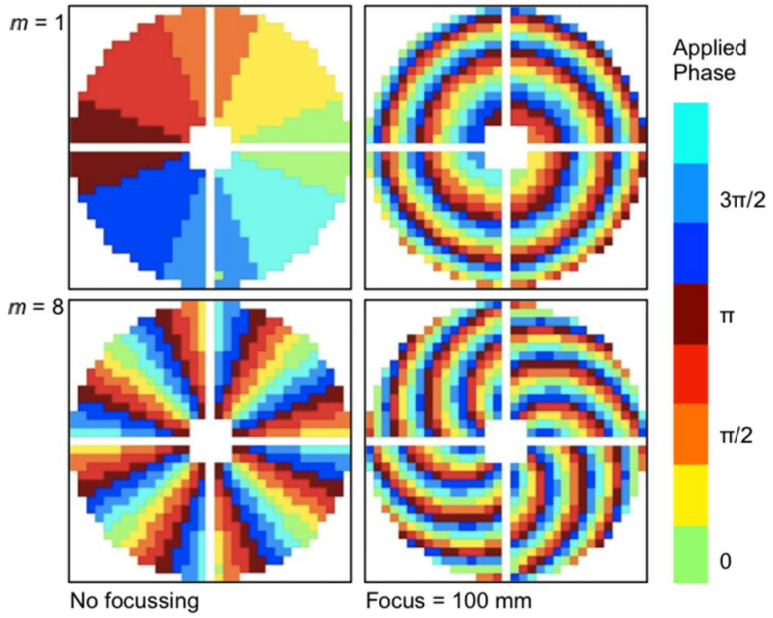
$$r(q) = a \cdot q + b$$



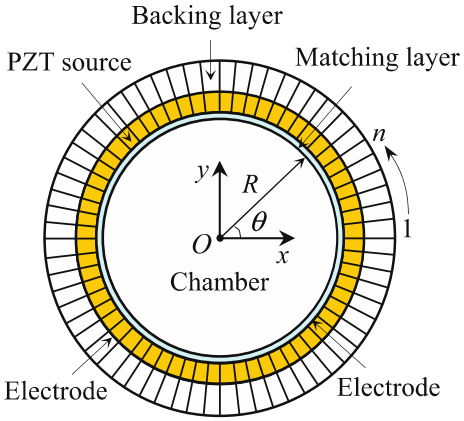


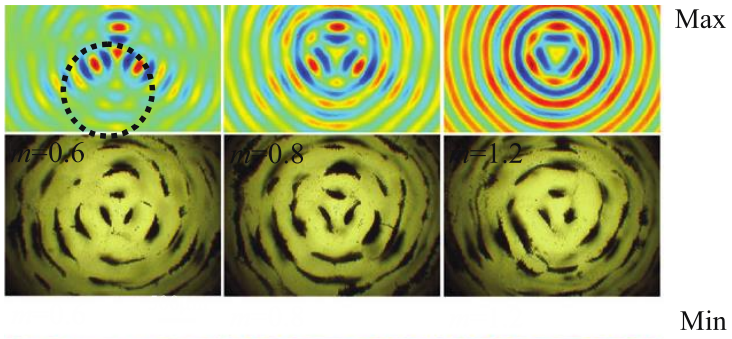


Phase dislocation



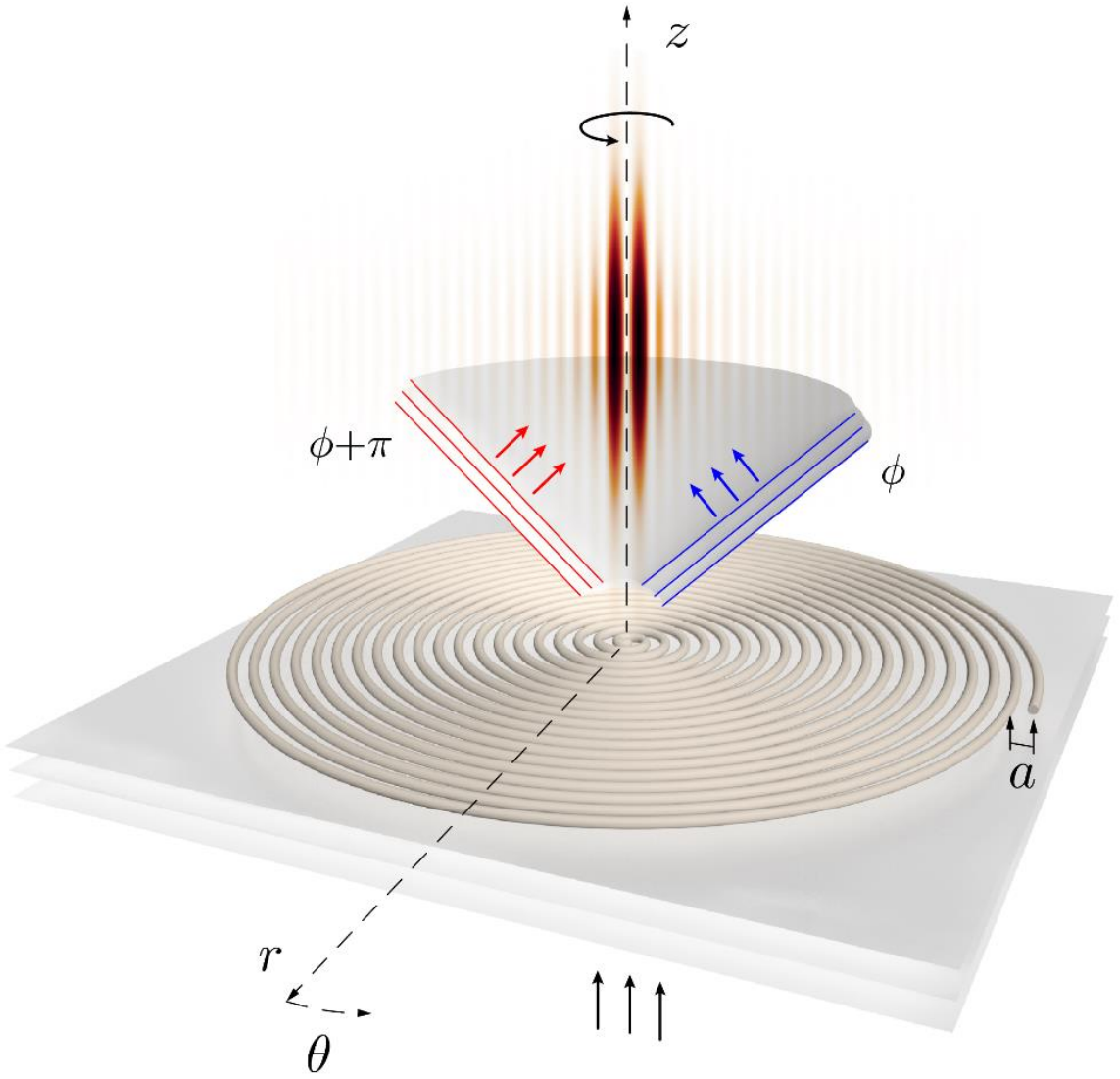
Demore, APL, 103, 264106 (2013)





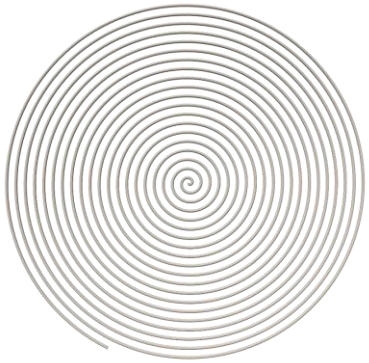
Hong, EPL, 110, 14002 (2015)

Archimedes Spiral Grating

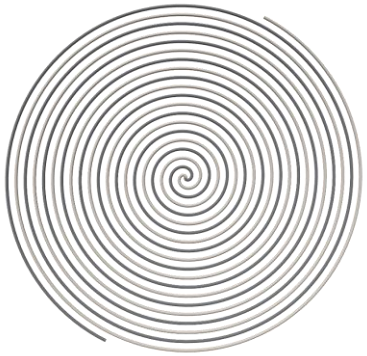


Multiarm Archimedes Spiral

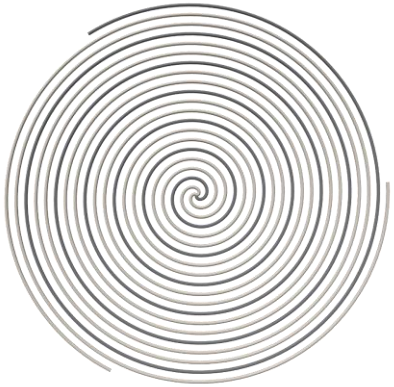
n=1



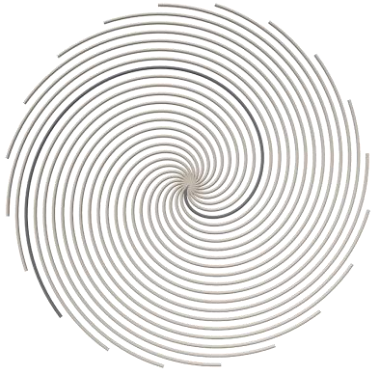
n=2



n=3



n=20



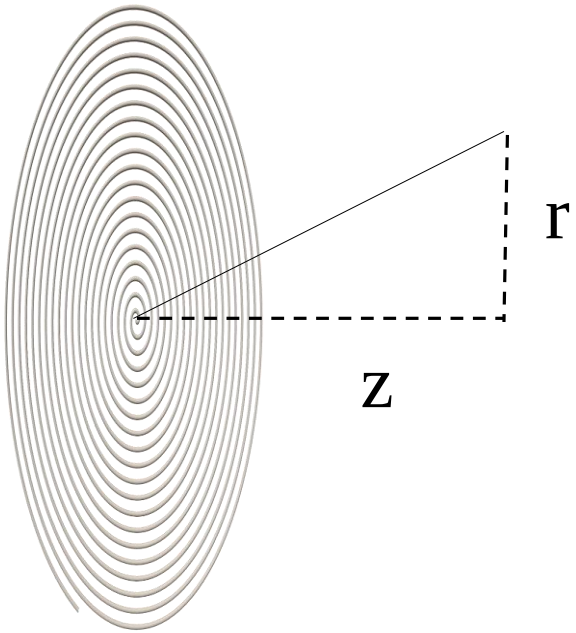
$$r(\theta) = \pm a\left(\frac{2\pi}{n}\left(\theta + 2\pi m\right) + \frac{l}{n}\right) \quad 0 \le l \le n-1$$

Radiation pattern

Phase dislocation	$v_0 = e^{jnq}$
Axicon	$v_0 = e^{jnq} e^{jrr}$
Spiral	$v_0 = e^{jk_r r(q)}$

$$p = \iint_{S_0} dS\, v_0 \frac{e^{-j\vec{k}\vec{r}}}{|\vec{r}|}$$

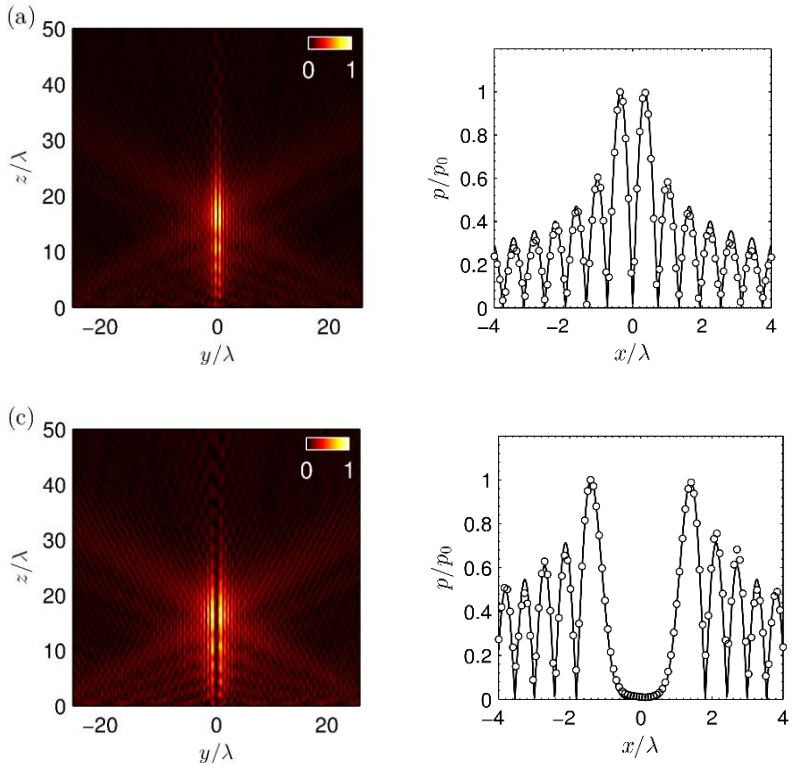
$$p = A \int_0^{\infty} dr_0 r_0 e^{j\left(\frac{k \cdot r_0^2}{2z} - k_r r_0\right)} \int_0^{2\pi} dq_0 e^{jn \cdot q} e^{j\frac{k}{z} \cdot r \cdot r_0 \cos(q - q_0)}$$

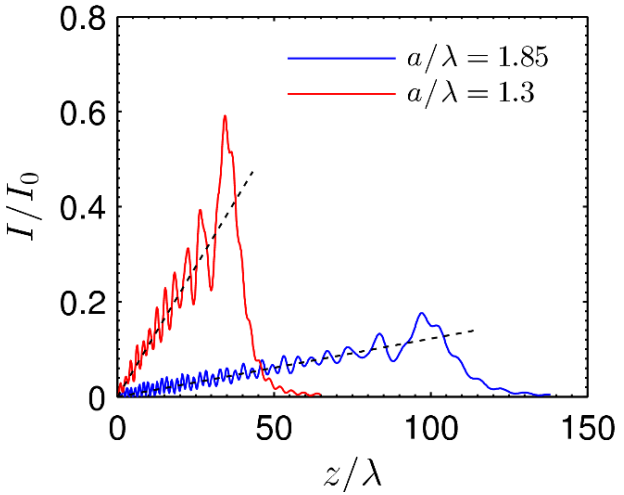


$$I\, a \frac{z}{k \cdot a} e^{j2kz} J_n^2(k_r \cdot r)$$

High-order Bessel Beams

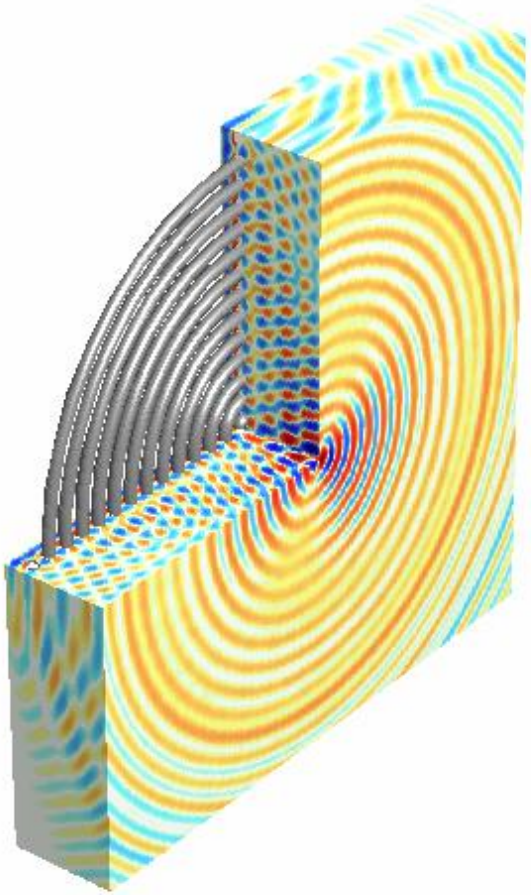
Design equations → high diffraction grating orders

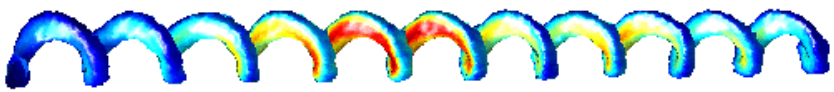


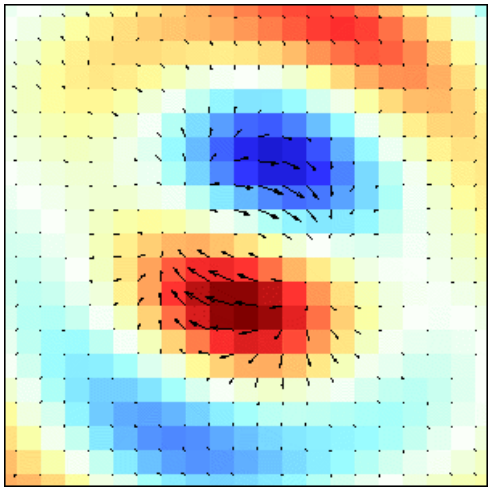


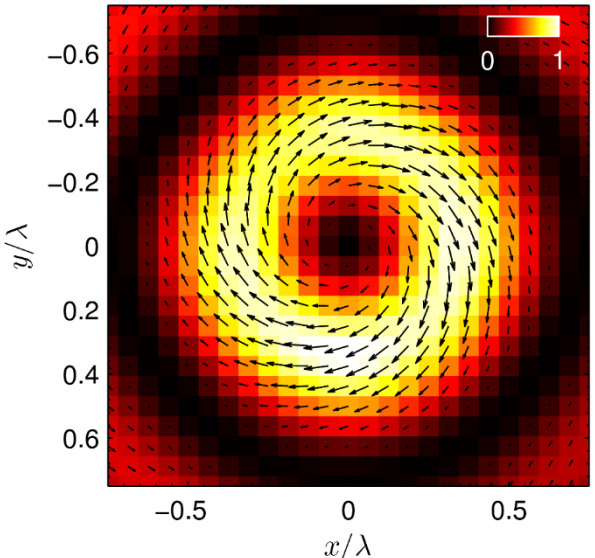
$$I\, a\, \frac{z}{a/l} e^{jkz} J_n(k_r \cdot r)$$

Acoustic vortex. Orbital Angular Momentum





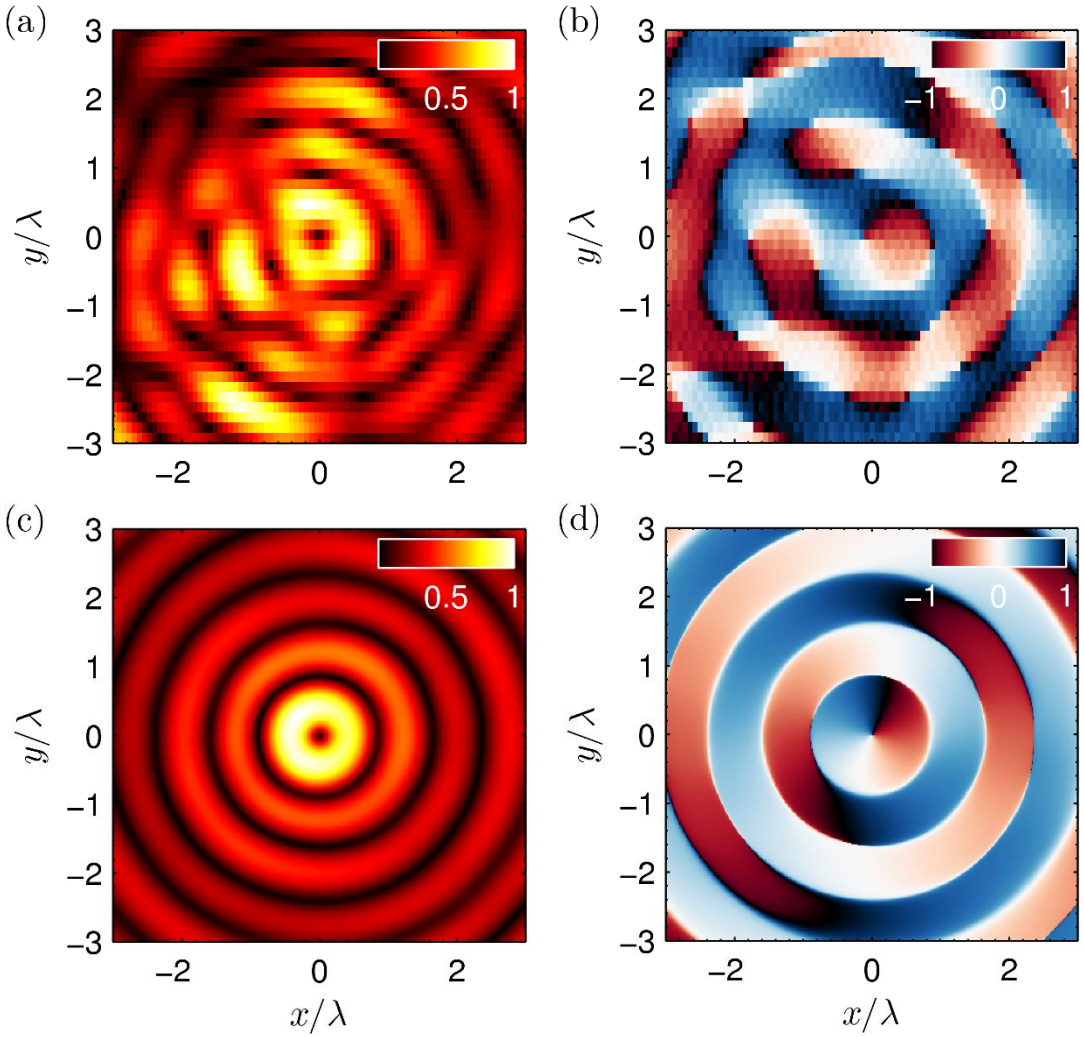




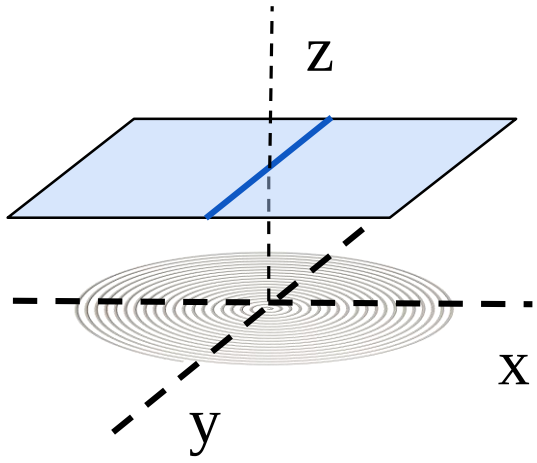
Experimental measurements

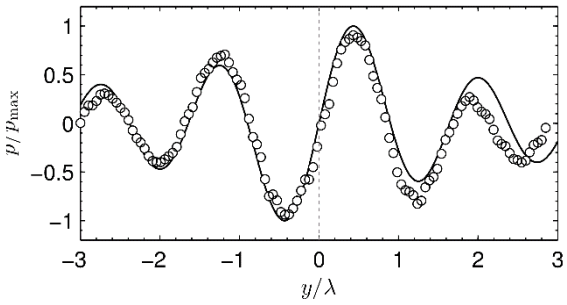
Experimental

Numeric









Conclusions

Archimedes Spiral Grating

- Generation of Higher Order Bessel Beams
- The order is related to the number of arms
- Cheap, robust lens construction
- High frequency bandwidth

Acoustical vortex

- Potential for Acoustic Radiation Torque applications: Particle rotation
- Control of the Increase topological charge with:
  - Number of arms
  - Diffraction order
  - Harmonics
  - Shock waves