Momento angular orbital de un haz luminoso: Generacion, Deteccion y Aplicaciones.

Jornadas Cientificas 2014, Bucaramanga,

Cristian Hernando Acevedo,

Yezid Torres, Angela Guzman, Aristide Dogariu, Jesus Mendoza, Carlos Diaz, Juan Vilardi, Vladimir Jerez, Kyle Douglass.

Noviembre 28, 2014

Universidad Industrial de Santander

CREOL UCF

Contenido

- Momento angular de un haz luminoso.
- Generación de un haz con MAO.
- Detección de un haz con MAO.
- Aplicaciones de un haz con MAO.

Momento angular Orbital de la luz

PHYSICAL REVIEW A VOLUME 45, NUMBER 11 1 JUNE 1992

Orbital angular momentum of light and the transformation of Laguerre-Gaussian laser modes

L. Allen, M. W. Beijersbergen, R. J. C. Spreeuw, and J. P. Woerdman
Huygens Laboratory, Leiden University, P.O. Box 9504, 2300 RA Leiden, The Netherlands
(Received 6 January 1992)

Como se calcula el MAO de un campo EM

Partiendo de las ecuaciones de Maxwell,

$$\left.\begin{pmatrix} \nabla\cdot\vec{E} & =0 \\ \nabla\cdot\vec{B} & =0 \\ \nabla\times\vec{E} & =-\frac{\partial\vec{B}}{\partial t} \\ \nabla\times\vec{B} & =\epsilon_0\mu_0\frac{\partial\vec{E}}{\partial t} \end{pmatrix}\right\} \longrightarrow (\nabla^2+k^2)\begin{Bmatrix}\vec{E}\\ \vec{B}\end{Bmatrix}=\vec{0}\longmapsto(\nabla^2+k^2)\begin{Bmatrix}\vec{r}\cdot\vec{E}\\ \vec{r}\cdot\vec{B}\end{Bmatrix}=\vec{0}.$$

Utilizando:

$$\vec{B}=\sum_{l,m}\left(a_{E(l,m)}f_l(kr)\vec{r}_{l,m}-\frac{i}{\omega}a_{M(l,m)}\nabla\times g_l(kr)\vec{r}_{l,m}\right)$$

$$\vec{E}=\sum_{l,m}\left(\frac{ic^2}{\omega}a_{E(l,m)}\nabla\times f_l(kr)\vec{r}_{l,m}+a_{M(l,m)}g_l(kr)\vec{r}_{l,m}\right),$$

siendo $a_E(l,m)$ y $a_M(l,m)$ coeficientes multipolares, ademas usando

$$u=\frac{1}{2}\left(\epsilon_0E^2+\frac{1}{\mu_0}B^2\right)\qquad \vec{j}=\frac{1}{\mu_0}\left(\vec{r}\times(\vec{E}\times\vec{B}^*)\right),$$

Se concluye para estado m, la luz transporta Momento angular como

$$\frac{J^{(c)2}}{U^2}=\frac{m^2}{\omega^2}\xleftarrow{N\text{ grande}}\frac{J^{(q)2}(N)}{U^2(N)}=\frac{Nm^2+Nl(l+1)-m^2}{N\omega^2}.$$

De las expresiones clásicas de los campos EM:

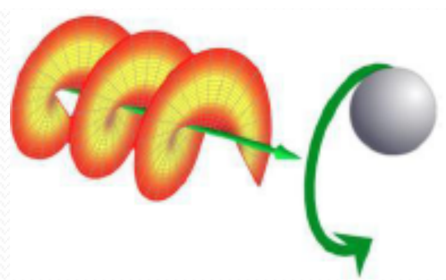
$$\begin{Bmatrix} \vec{E} & = -\nabla\Phi - \frac{\partial \vec{A}}{\partial t} \\ \vec{B} & = \nabla \times \vec{A}. \end{Bmatrix} \longmapsto \nabla \cdot \vec{A} = 0 \;\; y \;\; \Phi = 0 \longmapsto \begin{Bmatrix} \vec{E} & = -\frac{\partial \vec{A}}{\partial t} \\ \vec{B} & = \nabla \times \vec{A}. \end{Bmatrix}$$

Se obtiene clásicamente que la *i*-ésima componente de Momento angular del haz es

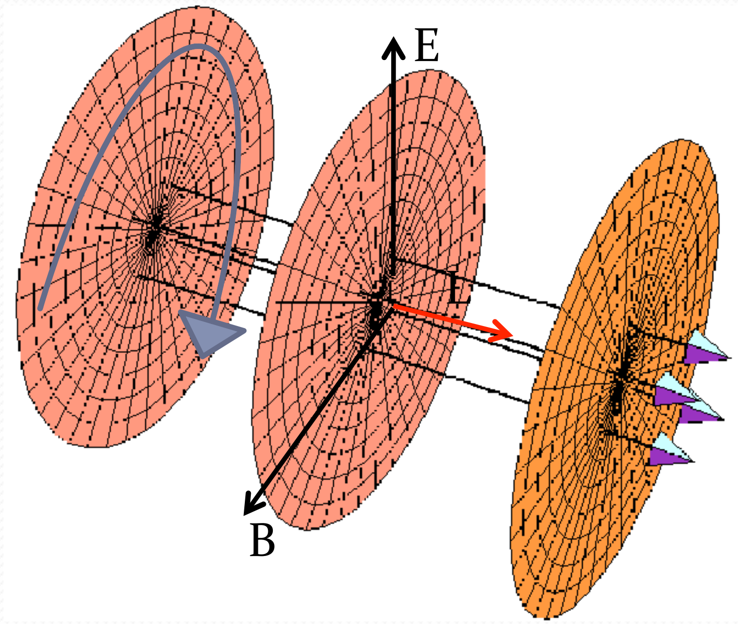
$$J_i = \underbrace{\frac{1}{\mu_0}\epsilon_{ijk}\int A_j \dot{A}_k d^3 r}_{MAS} + \underbrace{\frac{1}{\mu_0}\int \underbrace{\epsilon_{ijk} x_j \partial_k}_{L_i} (\dot{A}_p)\dot{A}_p d^3 r}_{\textbf{MAO}} \longrightarrow \vec{J} = \vec{S} + \vec{L},$$

mientras cuánticamente la *i*-ésima componente de Momento angular del haz es

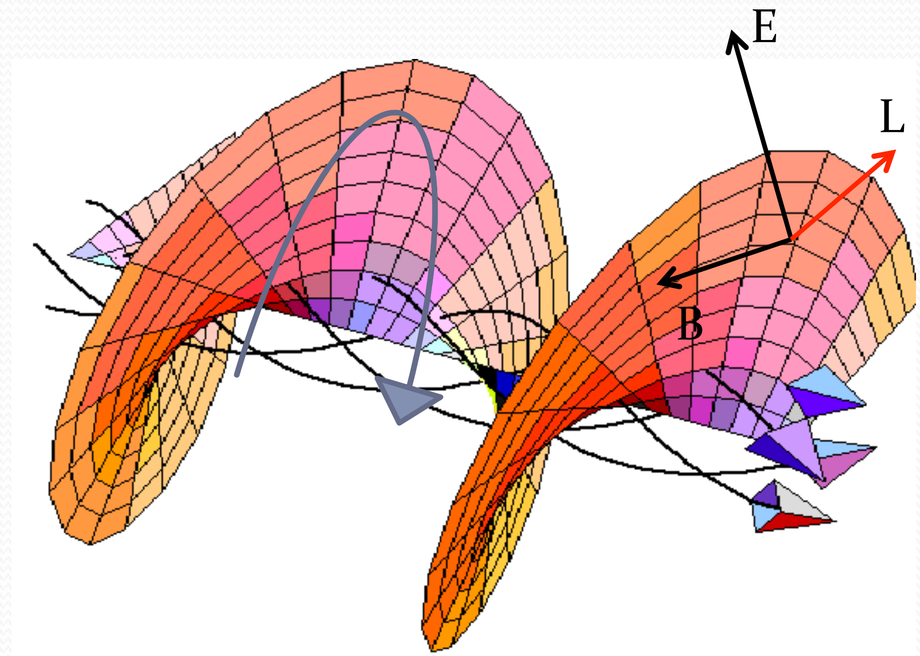
$$\hat{J}_i = \underbrace{\frac{1}{\mu_0}\int \hat{E}_j^* \underbrace{(-i\epsilon_{ijk})}_{\hat{S}_i} \hat{E}_k d^3 r}_{MAS} + \underbrace{\frac{1}{\mu_0}\int \hat{E}_j^* \underbrace{(-i\hat{\vec{r}} \times \hat{\nabla})_i}_{\hat{L}_i} d^3 r}_{\textbf{MAO}} \longrightarrow \hat{J} = \hat{S} + \hat{L}.$$



Momento angular Orbital de la luz



L=0



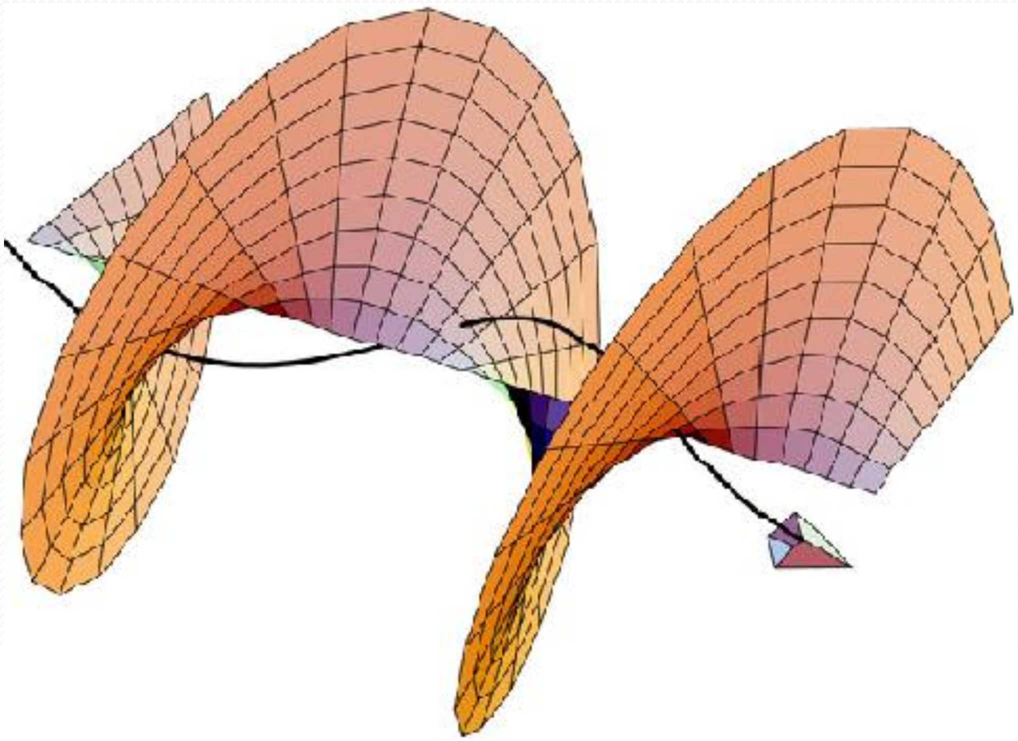
L≠0

Momento angular de un haz

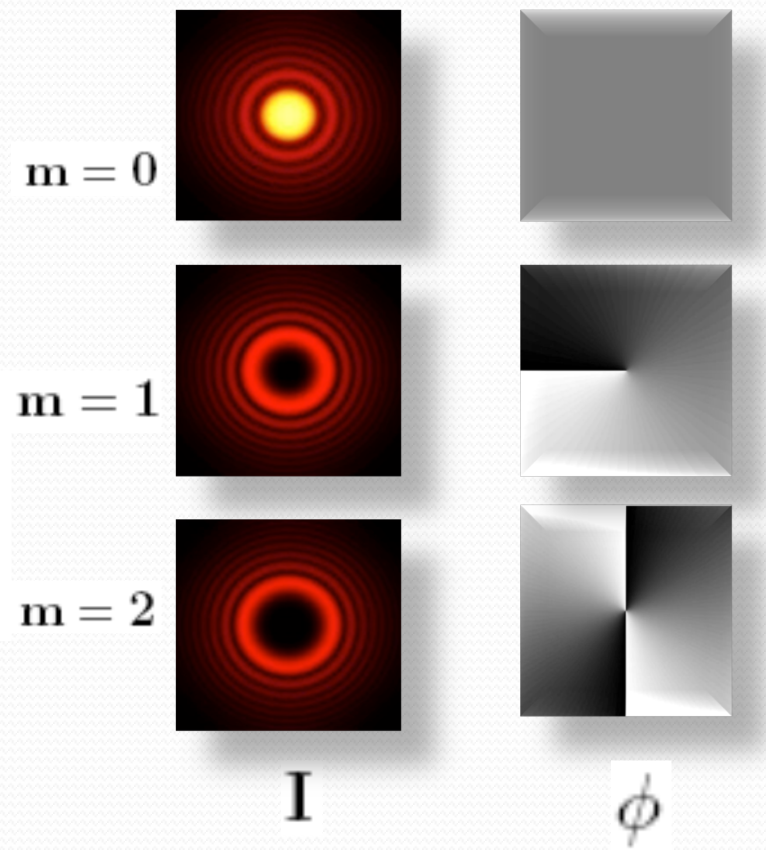
Fase, $2\pi \geq \theta \geq 0.$

$$\phi = \mathrm{m}\theta.$$

Intensidad, $\mathrm{I} \geq 0.$

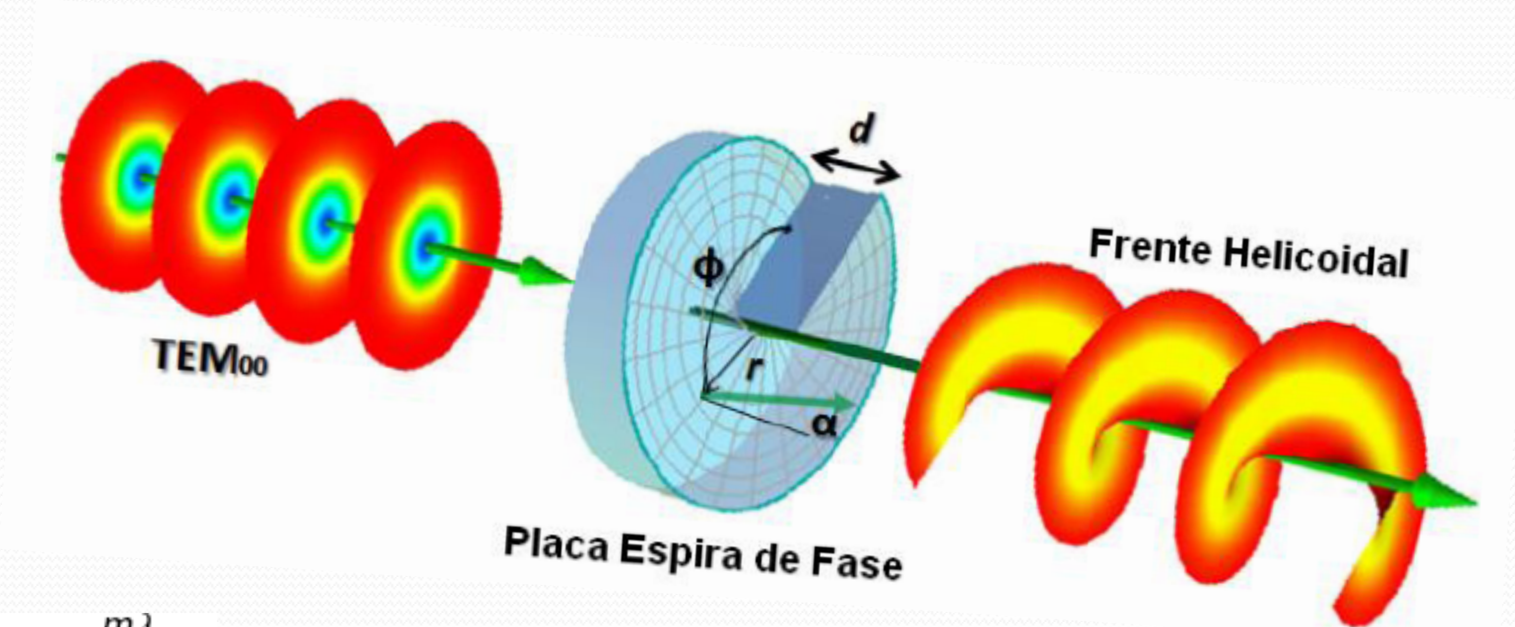


http://www.gla.ac.uk/schools/physics/research/groups/optics/research/orbitalangularmomentum/



Generación de Haces con MAO

- Placas de espiral de Fase

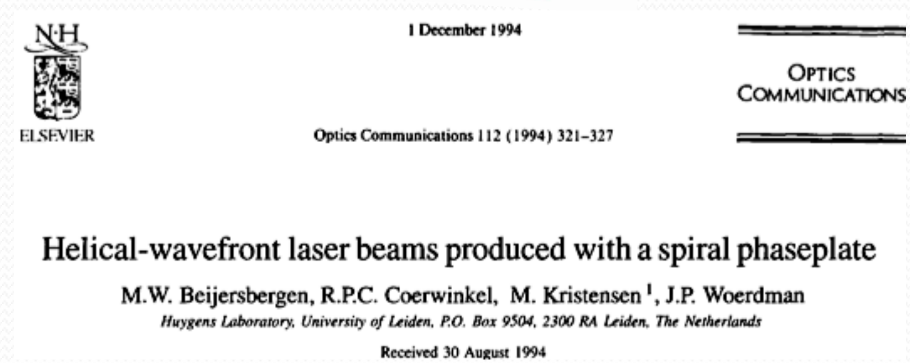


Con

$$d = \frac{m\lambda}{(n_1 - n_2)}.$$

Fase introducida y MAO

$$\delta = \frac{(n_1 - n_2)d}{\lambda}\phi, \qquad \text{y} \qquad \boxed{L_z \approx m\hbar}$$



N·H
ELSEVIER
1 December 1994
Optics Communications 112 (1994) 321–327
OPTICS COMMUNICATIONS

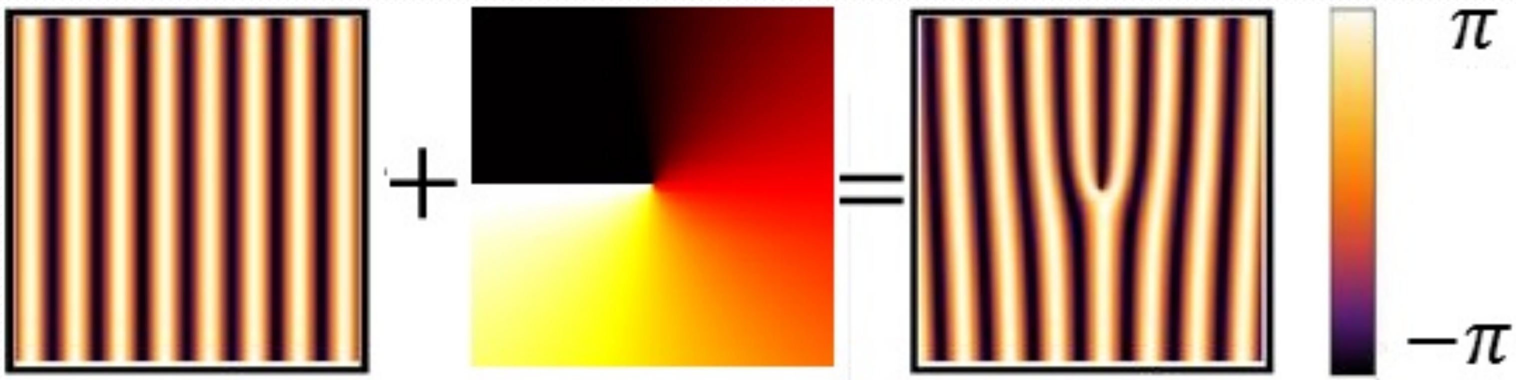
Helical-wavefront laser beams produced with a spiral phaseplate

M.W. Beijersbergen, R.P.C. Coerwinkel, M. Kristensen [1], J.P. Woerdman
Huygens Laboratory, University of Leiden, P.O. Box 9504, 2300 RA Leiden, The Netherlands

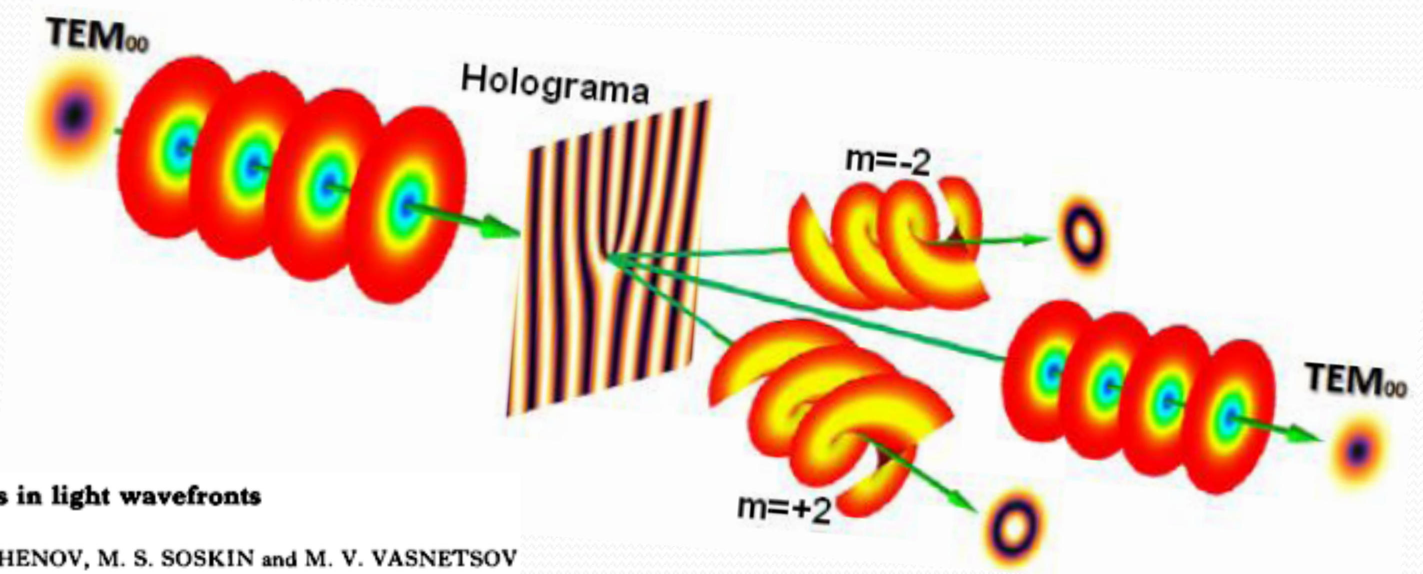
Received 30 August 1994

- Hologramas en forma de tenedor

m=1



Luego,



Screw dislocations in light wavefronts

V. YU. BAZHENOV, M. S. SOSKIN and M. V. VASNETSOV
Institute of Physics, Academy of Sciences of Ukraine,
252650 Kiev, Prospect Nauki 46, Ukraine

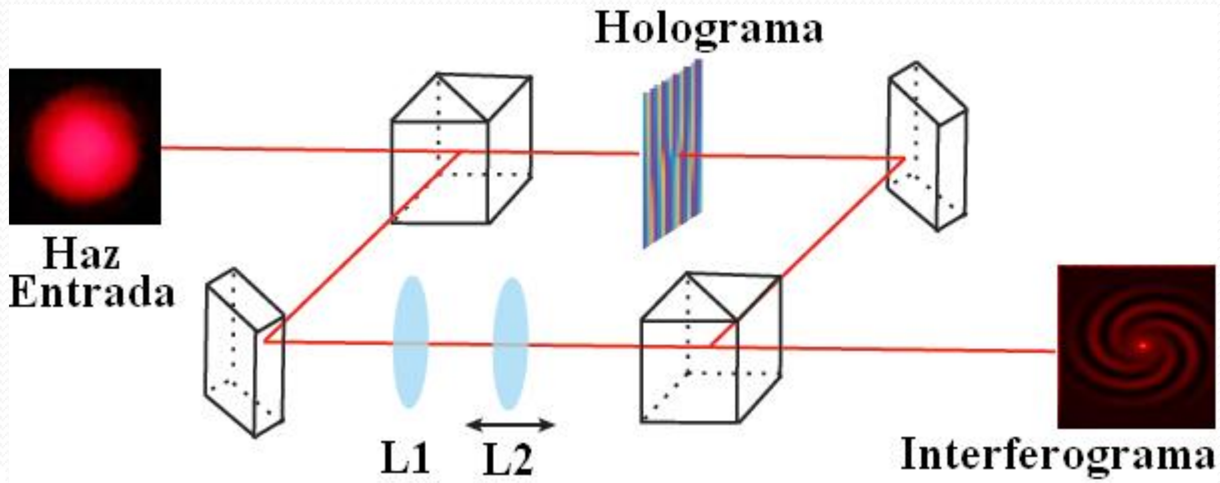
(Received 14 June 1991; revision received 8 January 1992)

Detección de haces con MAO

- Interferometría

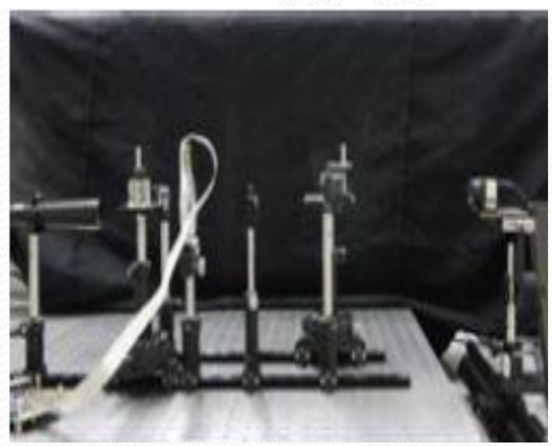
El numero de espirales es igual a la 2m.

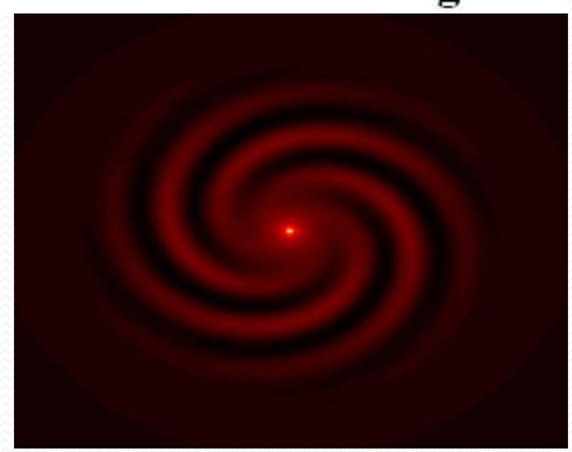
- Es para muchos fotones.



Intensity of a beam with integer and non-integer charge angular orbital momentum in far field

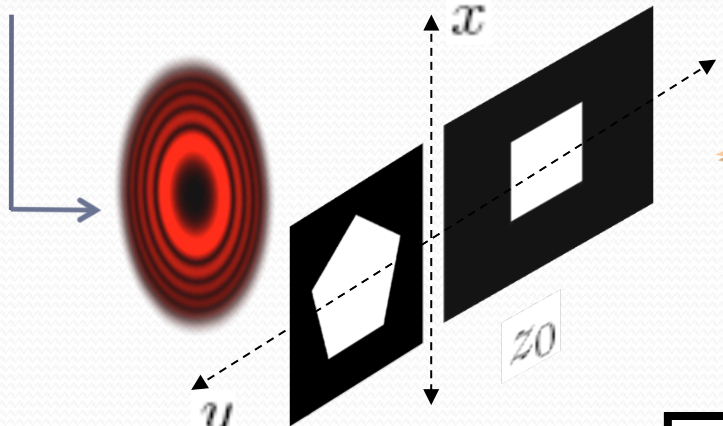
Cristian Hernando Acevedo Cáceres*
Carlos Fernando Díaz Meza**
Yezid Torres Moreno***
Universidad Industrial de Santander (Colombia)

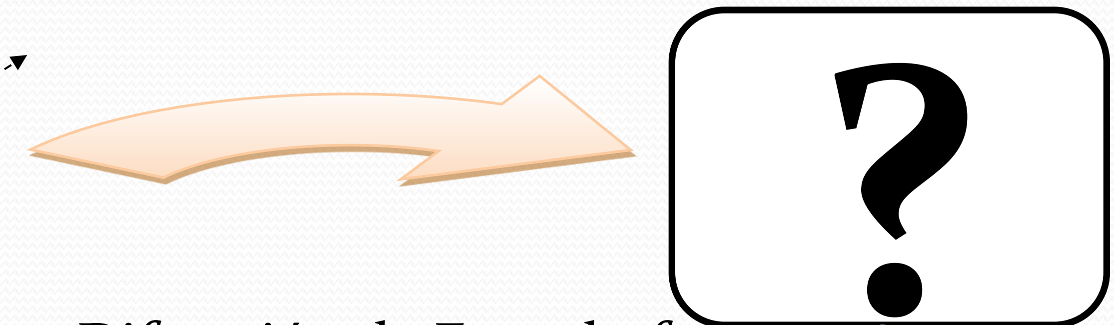




- Difracción a traves de aperturas

$$U(\rho,\theta,z_0) = c_0 e^{-\frac{\rho^2}{2w^2(z_0)}} e^{im\theta} \rho \left[I_{\frac{m-1}{2}}\left(\frac{\rho^2}{2w^2(z_0)}\right) - I_{\frac{m+1}{2}}\left(\frac{\rho^2}{2w^2(z_0)}\right)\right]$$





Difracción de Fraunhofer

$$\boxed{U(r,\varphi,z) = f(z)\left[(-i)^m e^{im\varphi} H_n\{U_\rho(\rho)\}\right]_{r\to r/\lambda(z-z_0),\theta\to\varphi}}$$

con

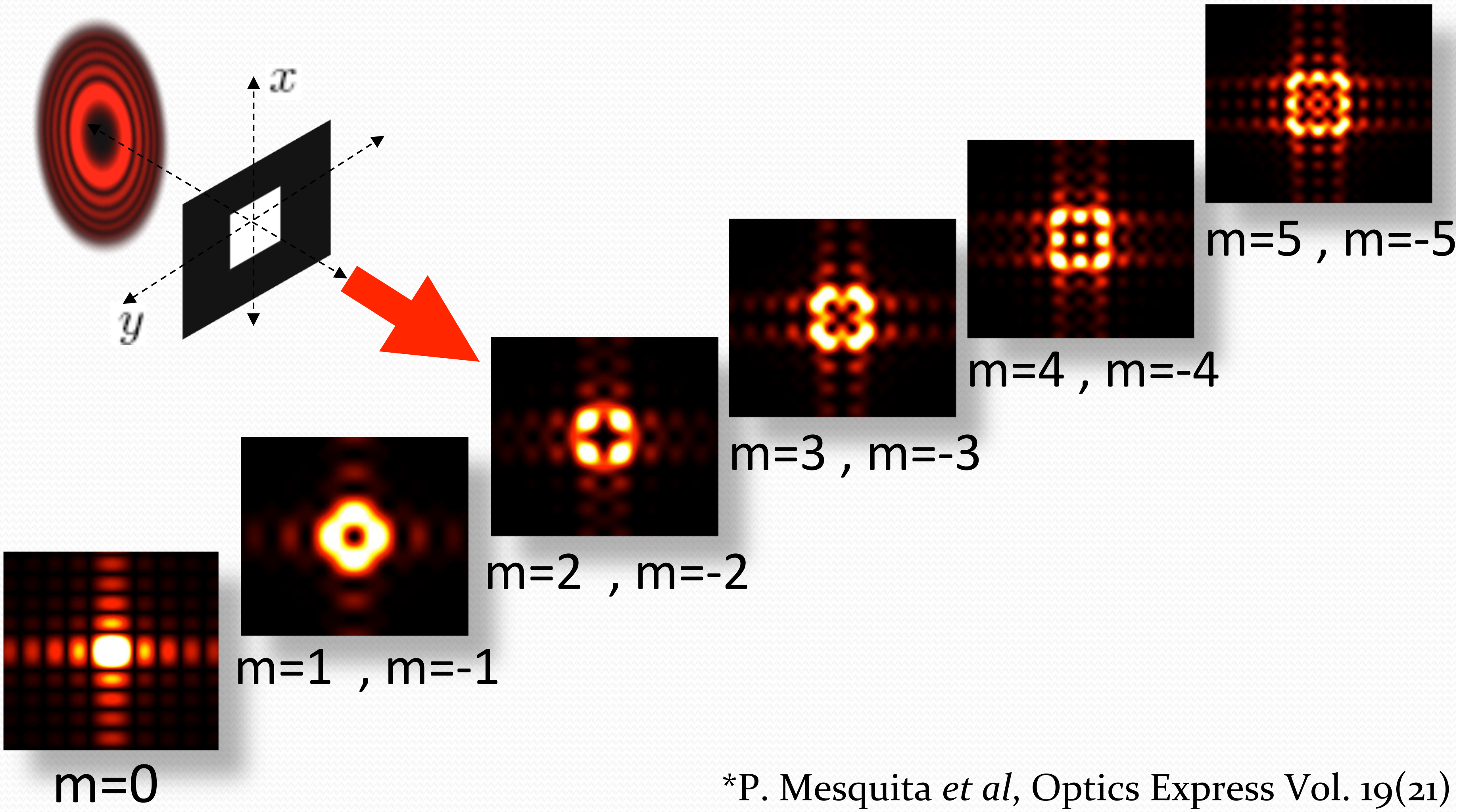
$$H_n\{U_\rho(\rho)\} = 2\pi c_0 \int \rho^2 t(\rho) e^{-\frac{\rho^2}{2w^2(z_0)}} \left[I_{\frac{m-1}{2}}\left(\frac{\rho^2}{2w^2(z_0)}\right) - I_{\frac{m+1}{2}}\left(\frac{\rho^2}{2w^2(z_0)}\right)\right] J_m(2\pi r\rho) d\rho.$$

DETERMINACIÓN DE LA CARGA TOPÓLOGICA DE UN HAZ BESSEL MEDIANTE EL PATRÓN DE DIFRACCIÓN A TRAVÉS DE UNA RENDIJA TRIANGULAR EQUILÁTERA

Cristian Hernando Acevedo, Carlos Fernando Diaz y Yezid Torres Moreno.

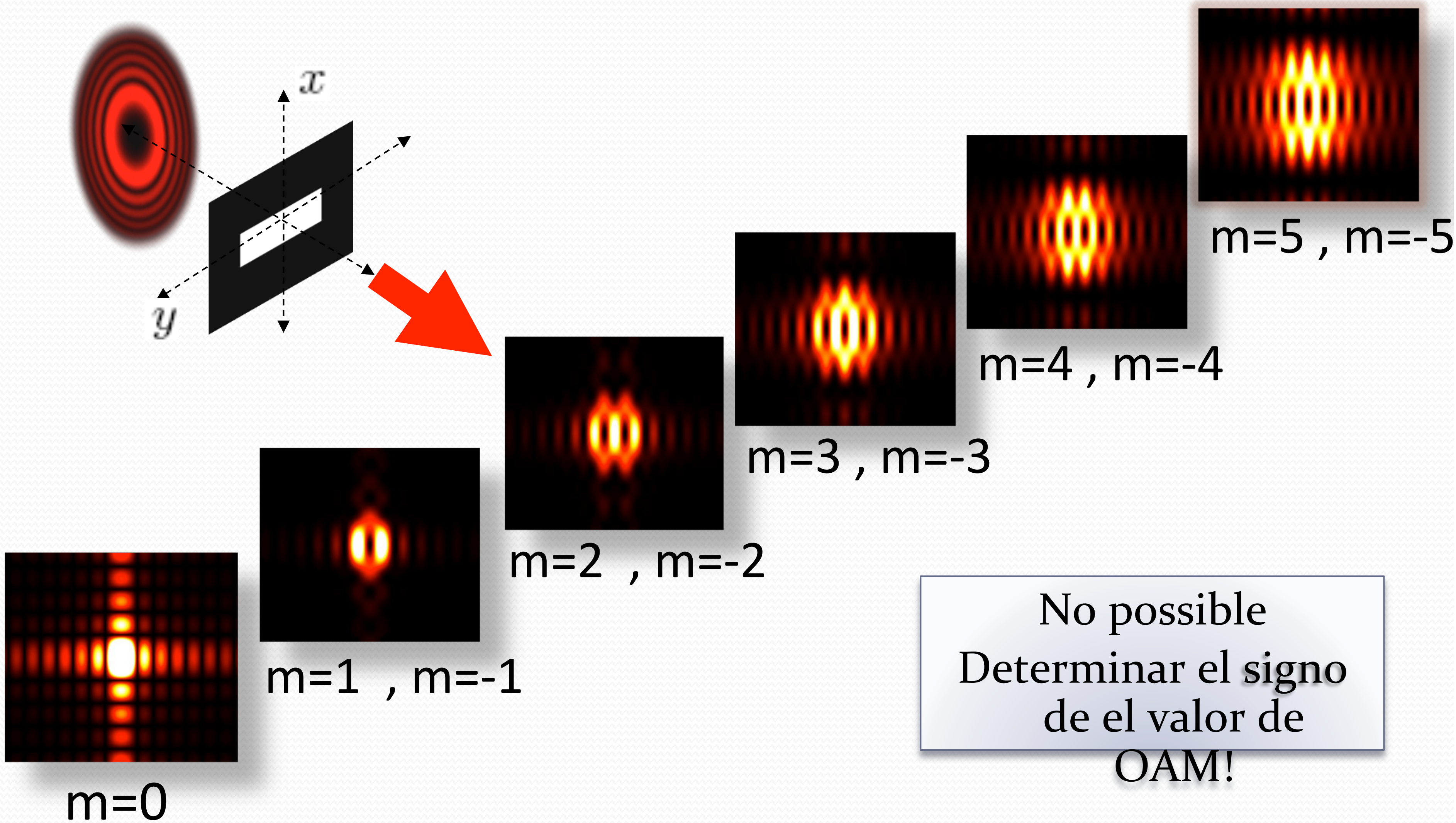
Resultados Numéricos

- Abertura cuadrada*



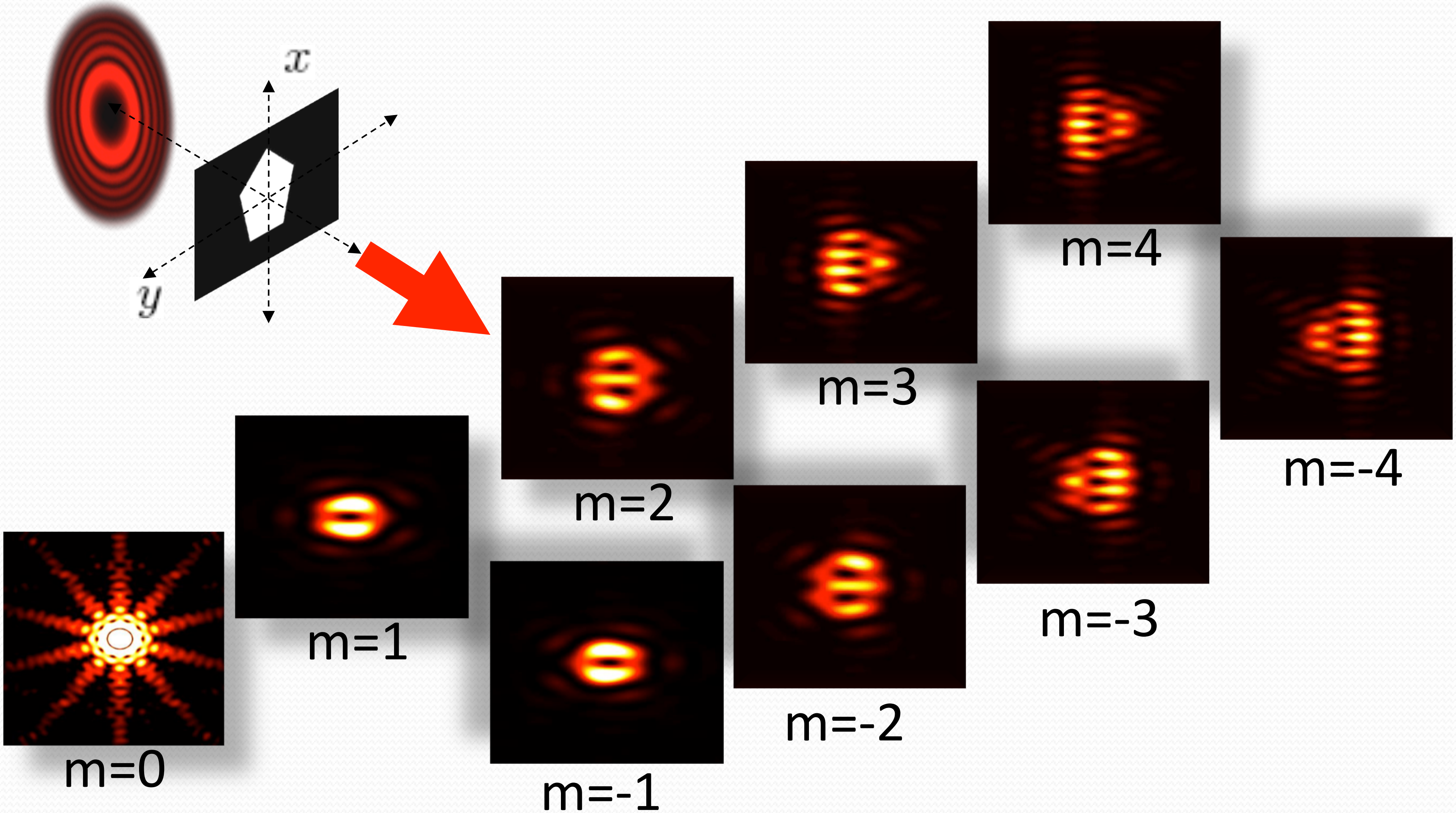
*P. Mesquita *et al*, Optics Express Vol. 19(21)

- Abertura rectangular

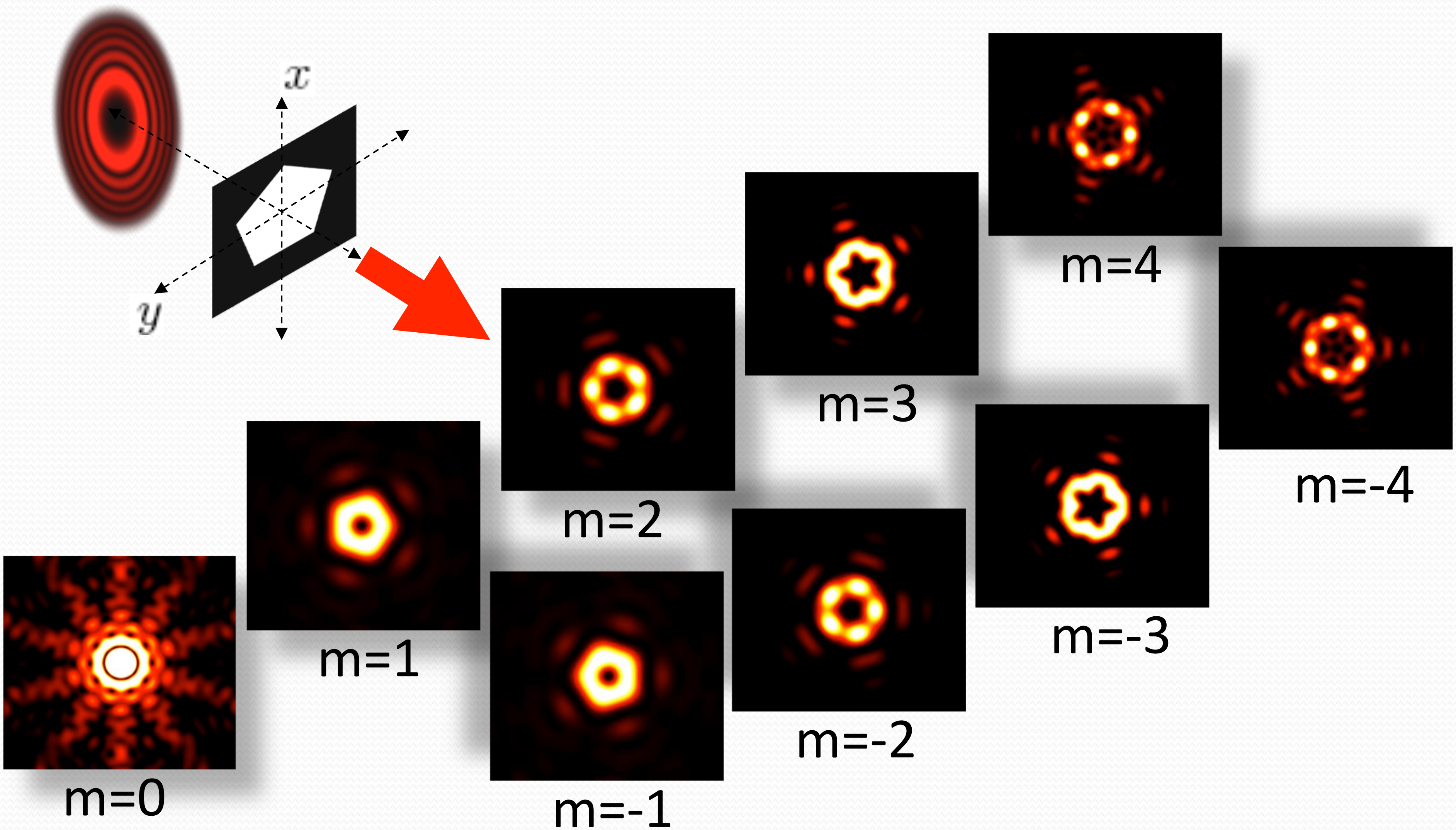


No possible
Determinar el signo
de el valor de
OAM!

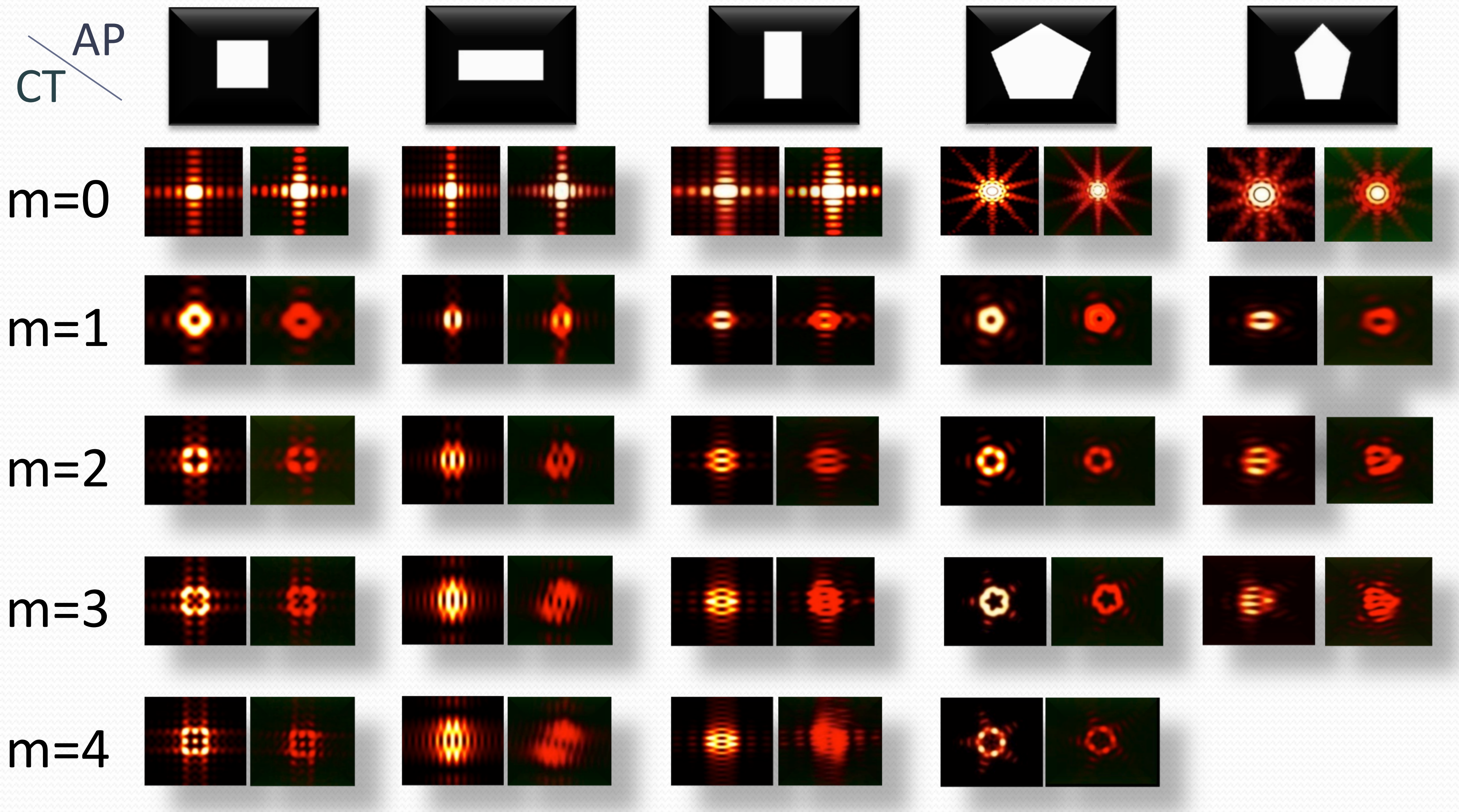
- Abertura pentagonal equilátera



- Abertura pentagonal no equilátera

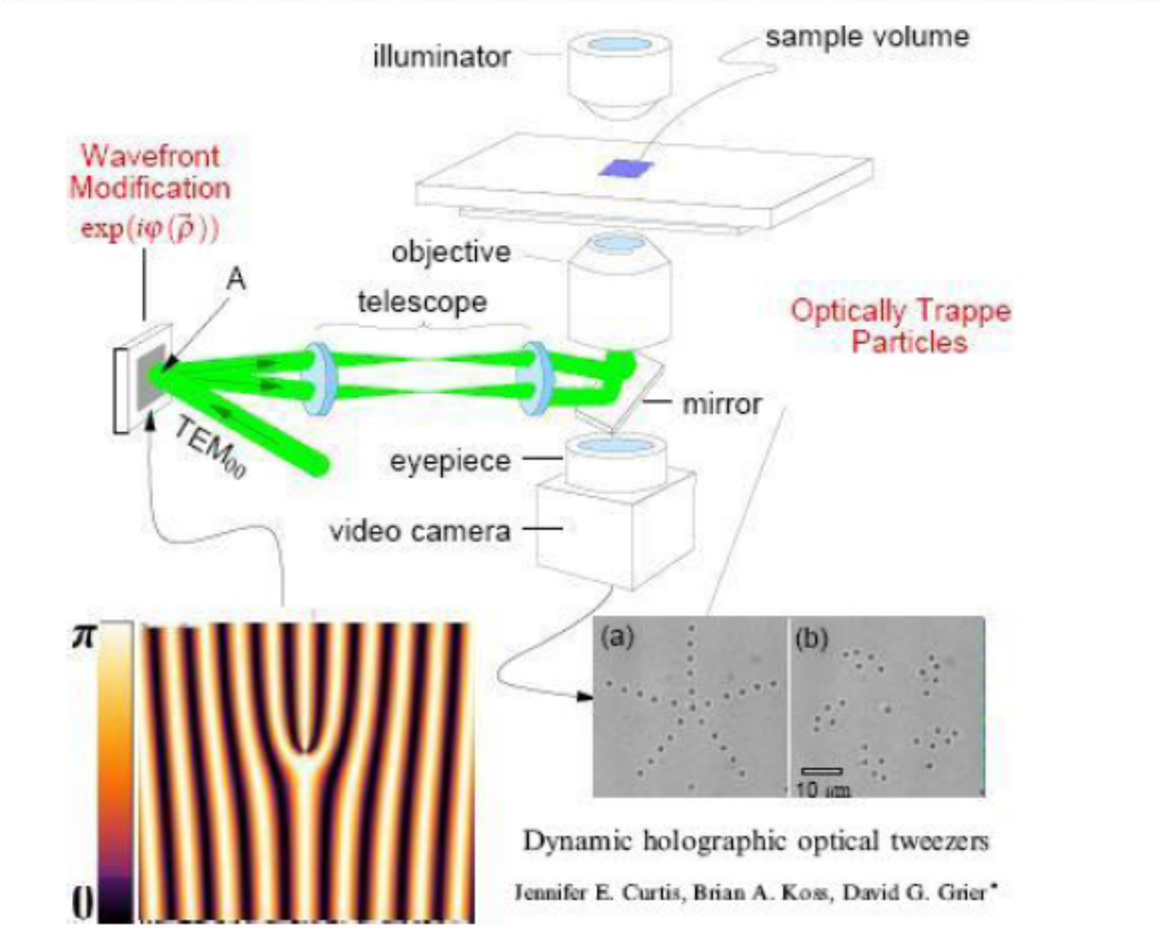


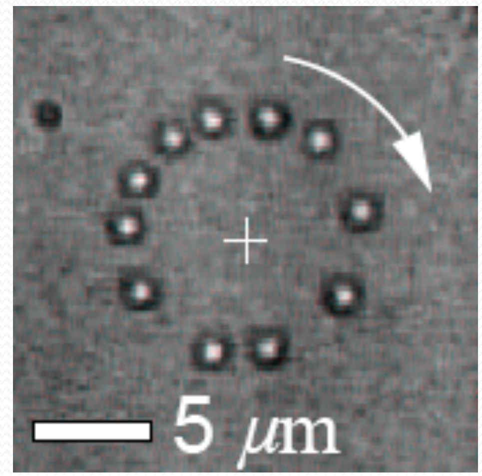
Resultados Generales



Aplicaciones de haces con MAO

Pinzas Opticas*





* D. Grier and E. Curtis, Physics review letters, Vol . 90(133901)

** P. Marinelli, *et al*, Electronics Letters, Vol. 47(17).

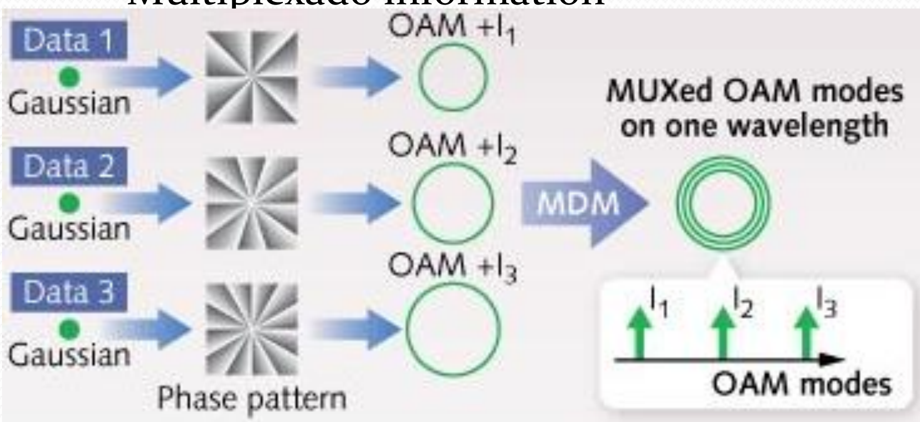
- Codificación de Información

m=m1

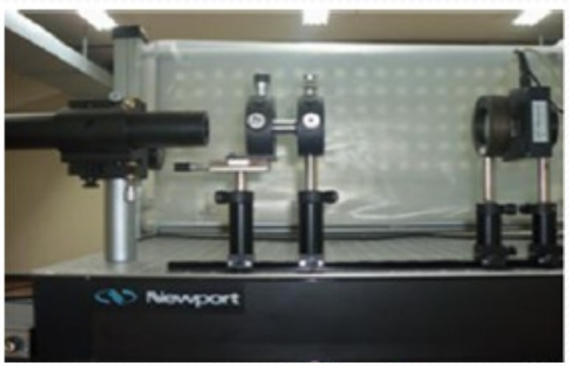
m=m2

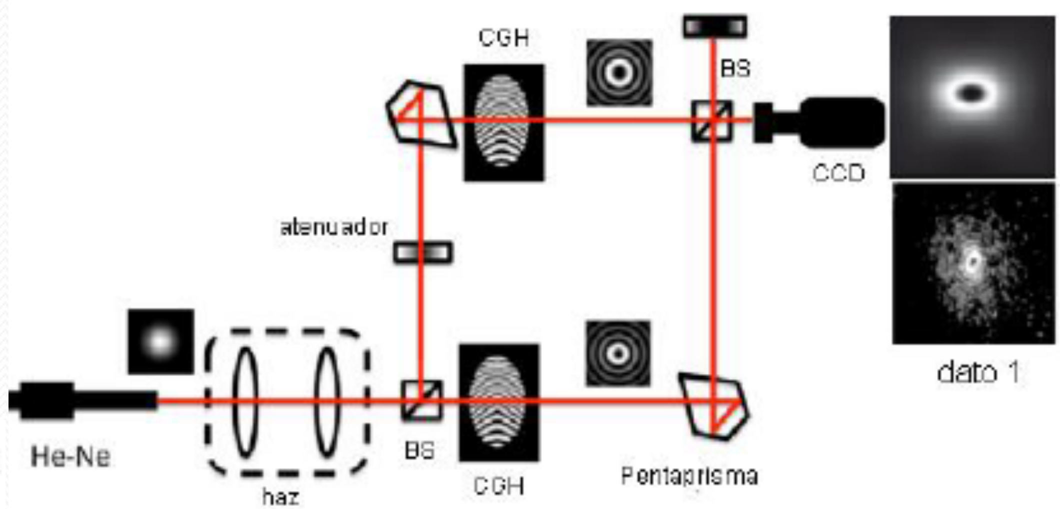
m=m3

Multiplexado information



- Es posible codificar al orden de Terabits



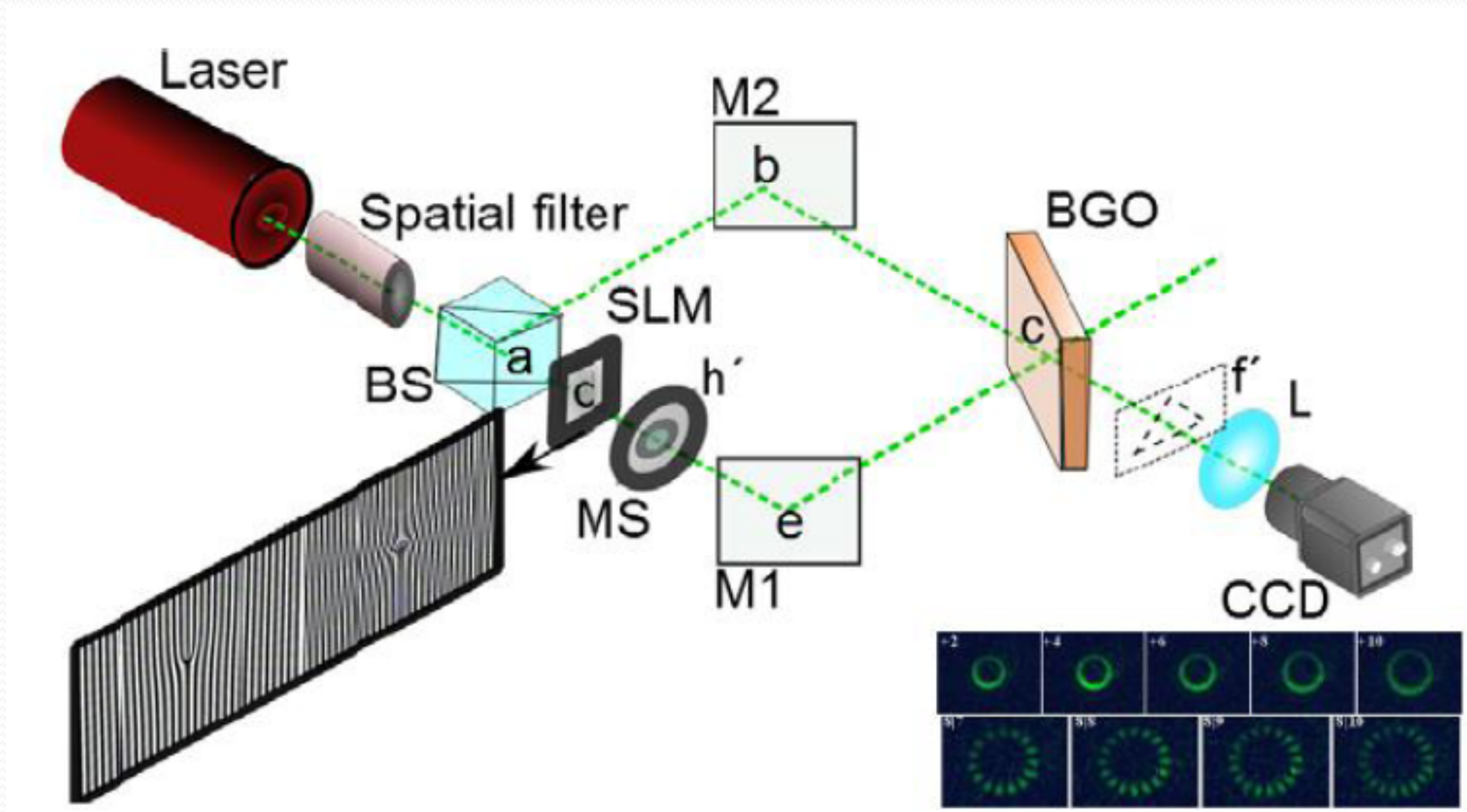


Preliminary Optoelectronic Encoder Modeling for Data Transfer Through the Orbital Angular Momentum of Light

CARLOS FERNANDO DÍAZ MEZA CRISTIAN HERNANDO ACEVEDO CÁCERES YEZID TORRES MORENO JAIME GUILLERMO BARRERO PÉREZ

Perspectivas*

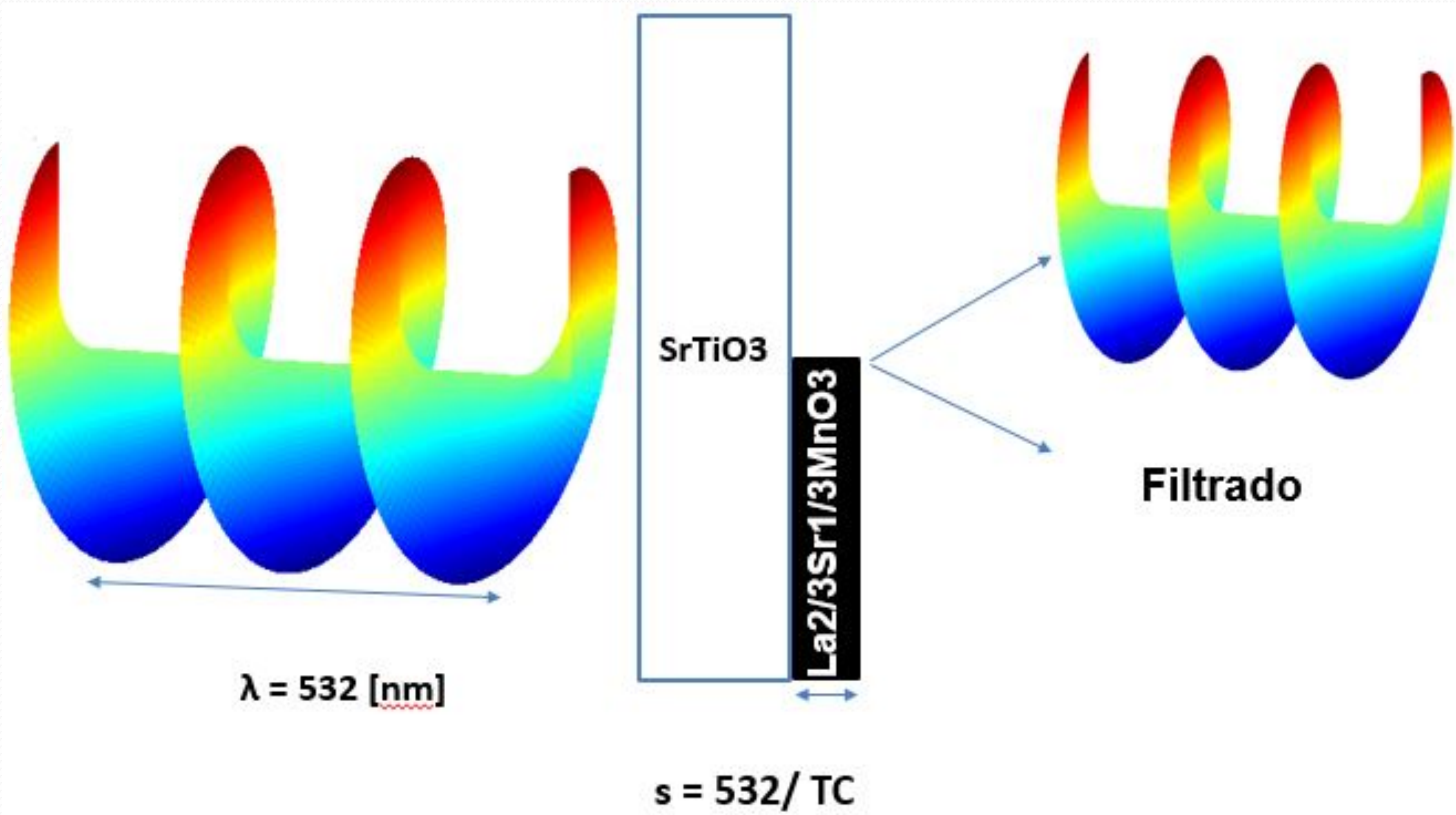
- Compuerta lógica sobre un cristal fotorrefractivo



Recording a Beam with Integer Angular Orbital Momentum into a Photorefractive Crystal BGO

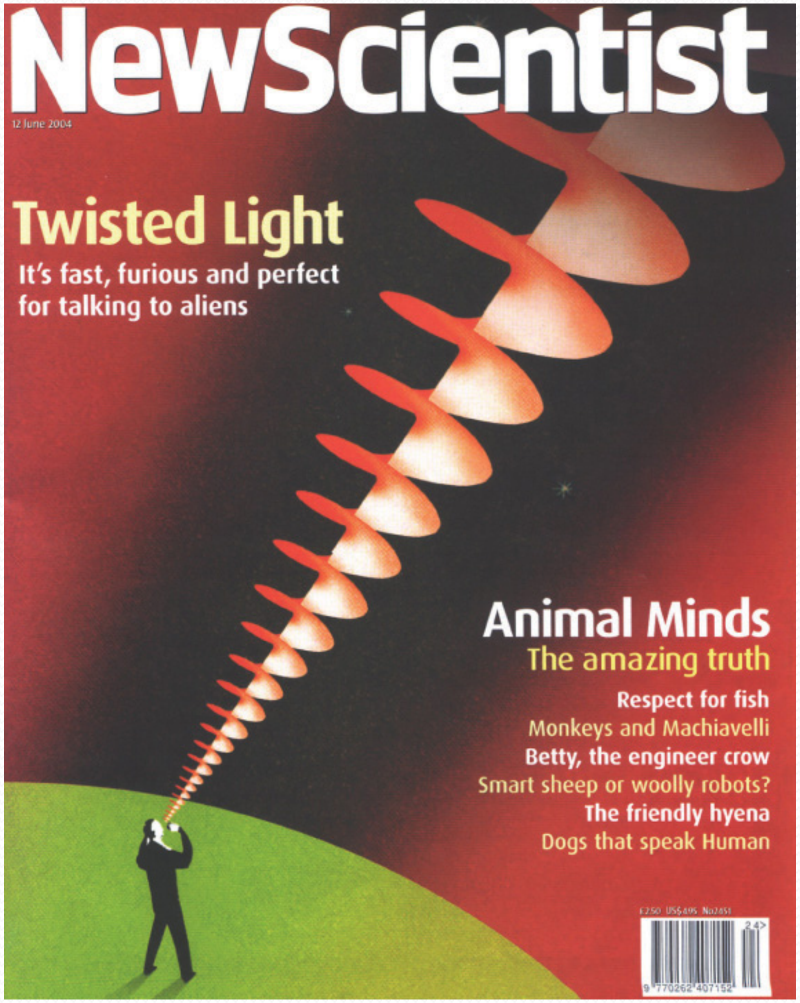
Cristian H. Acevedo[1], Vladimir A. Jérez[1], Carlos F. Díaz[1], Yezid Torres[1] and Ángela M. Guzmán[2]

- Decodificador usando películas delgadas



Gracias!

PREGUNTAS?



Unidades Financiadoras

Universidad Industrial de Santander

COLCIENCIAS
COLOMBIA