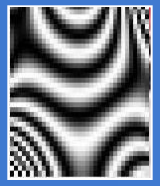
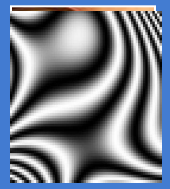




HAIS 2010

A Parametric Method Applied to Phase Recovery from a Fringe Pattern Based on a Particle Swarm Optimization

Julio Fernando Jiménez Vielma
Juan Humberto Sossa Azuela
Francisco Javier Cuevas de la Rosa
Laura Elena Gómez Sánchez

CENTRO DE INVESTIGACIONES EN OPTICA, A.C.

Relevance

The fringes patterns processing is of great importance in the recovery of the form (or strain) of 3D objects and to obtain physical variables such as pressure, volume, vibration analysis, temperature, etc..

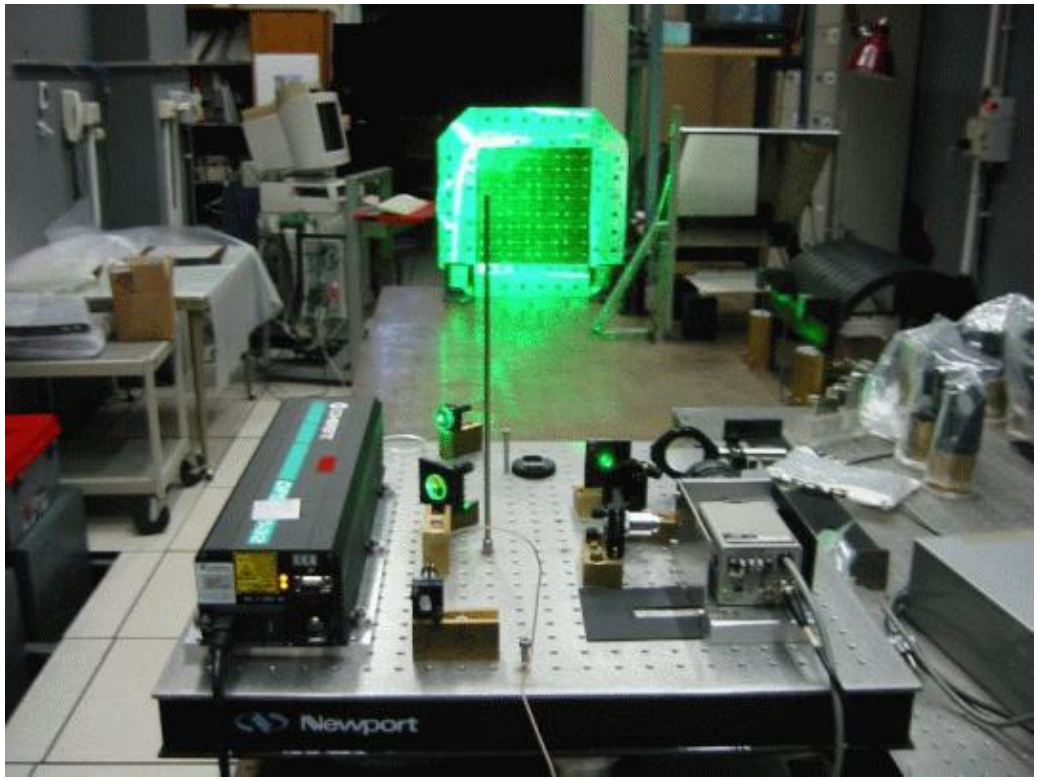
Physics of images formation

- Understanding the physics of imaging formation, we realize that different objects can produce the same two-dimensional images, creating a ill-posed problem that is, those where there are multiple solutions.

[Thikonov, 1963; Marroquin et. al, 1987; Bertero et al., 1988].

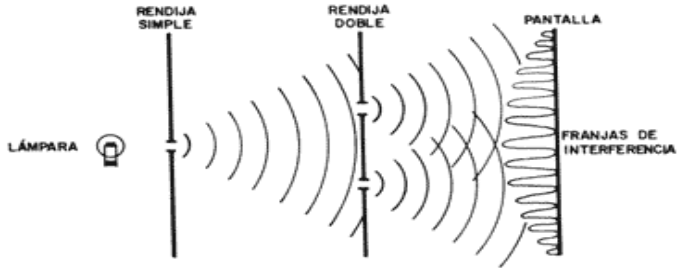
Interferometry

It is an optical technique which combines the light from different issuers

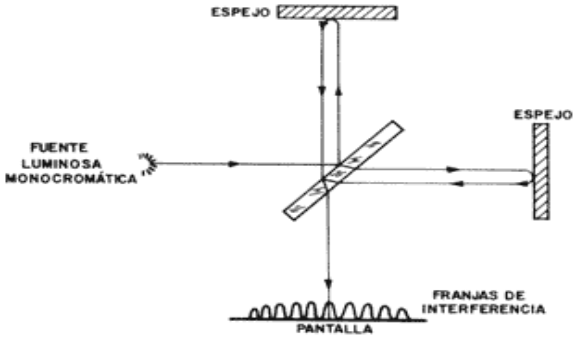


Interferometer

It is an instrument that employs the interference of light's waves to measure accurately the wavelengths of light itself



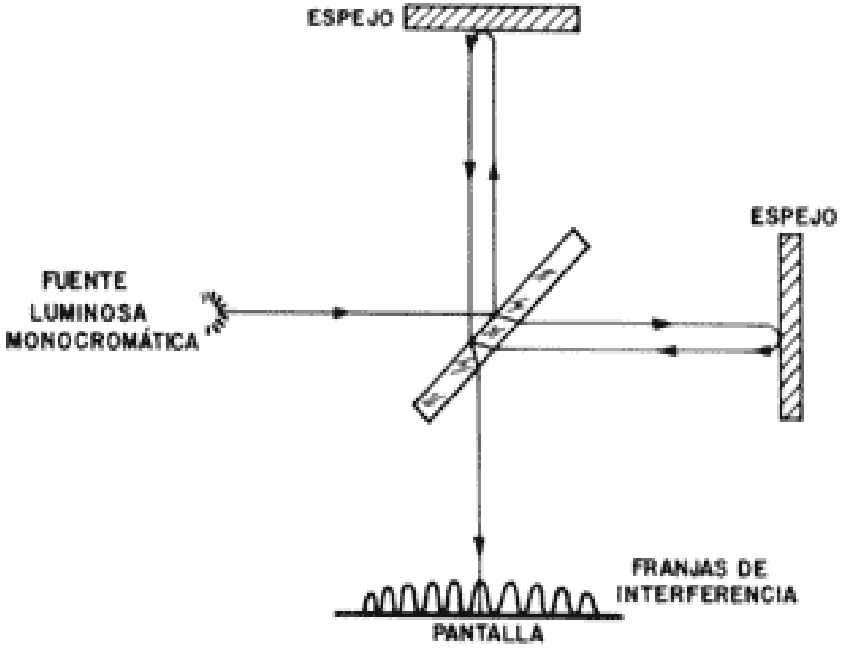
a) INTERFERÓMETRO DE YOUNG



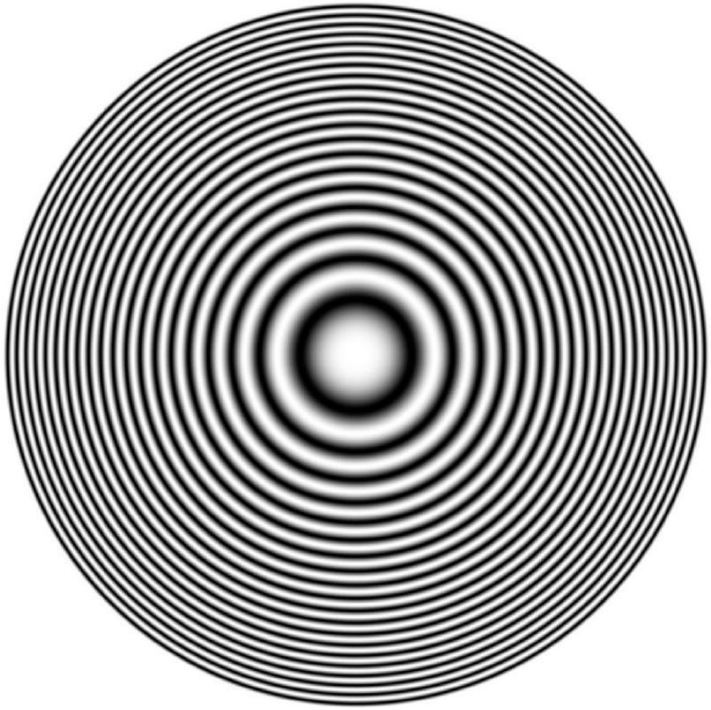
b) INTERFERÓMETRO DE MICHELSON

Michelson's Interferometer

- Closed-fringes(cosine profile)

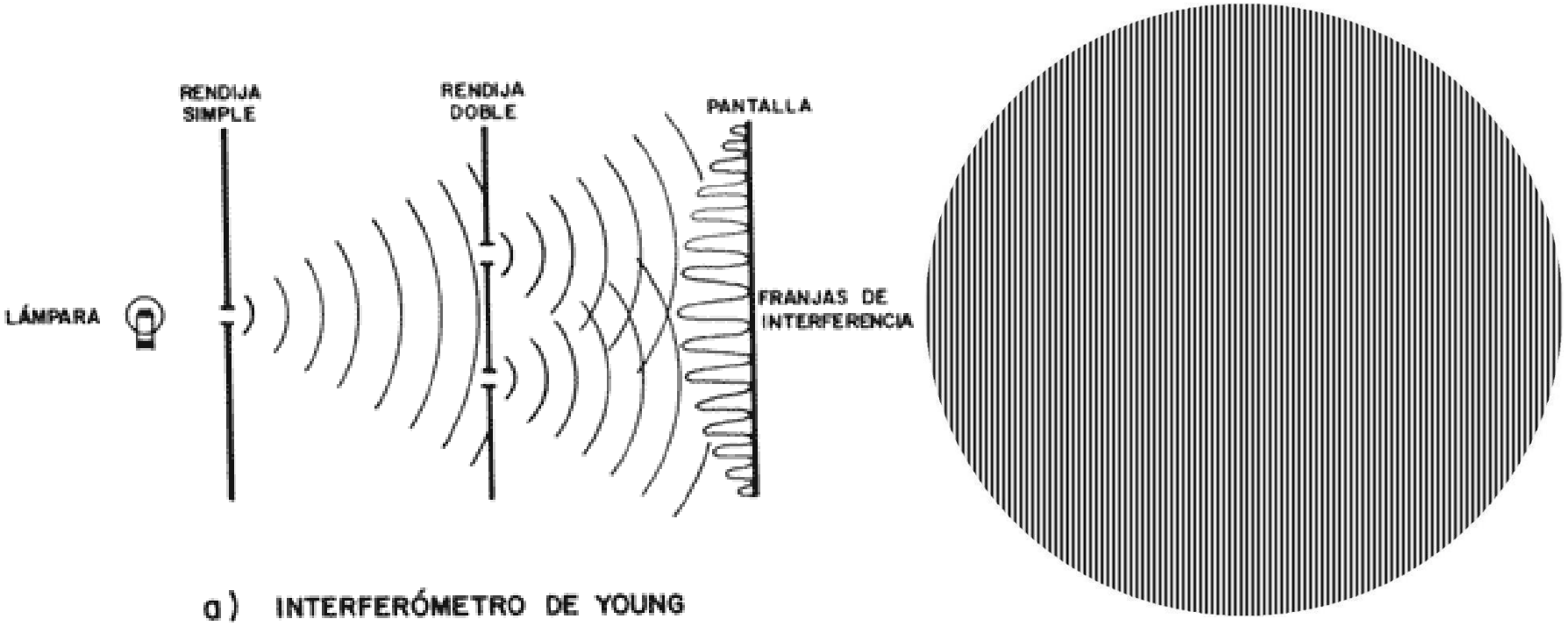


b) INTERFERÓMETRO DE MICHELSON



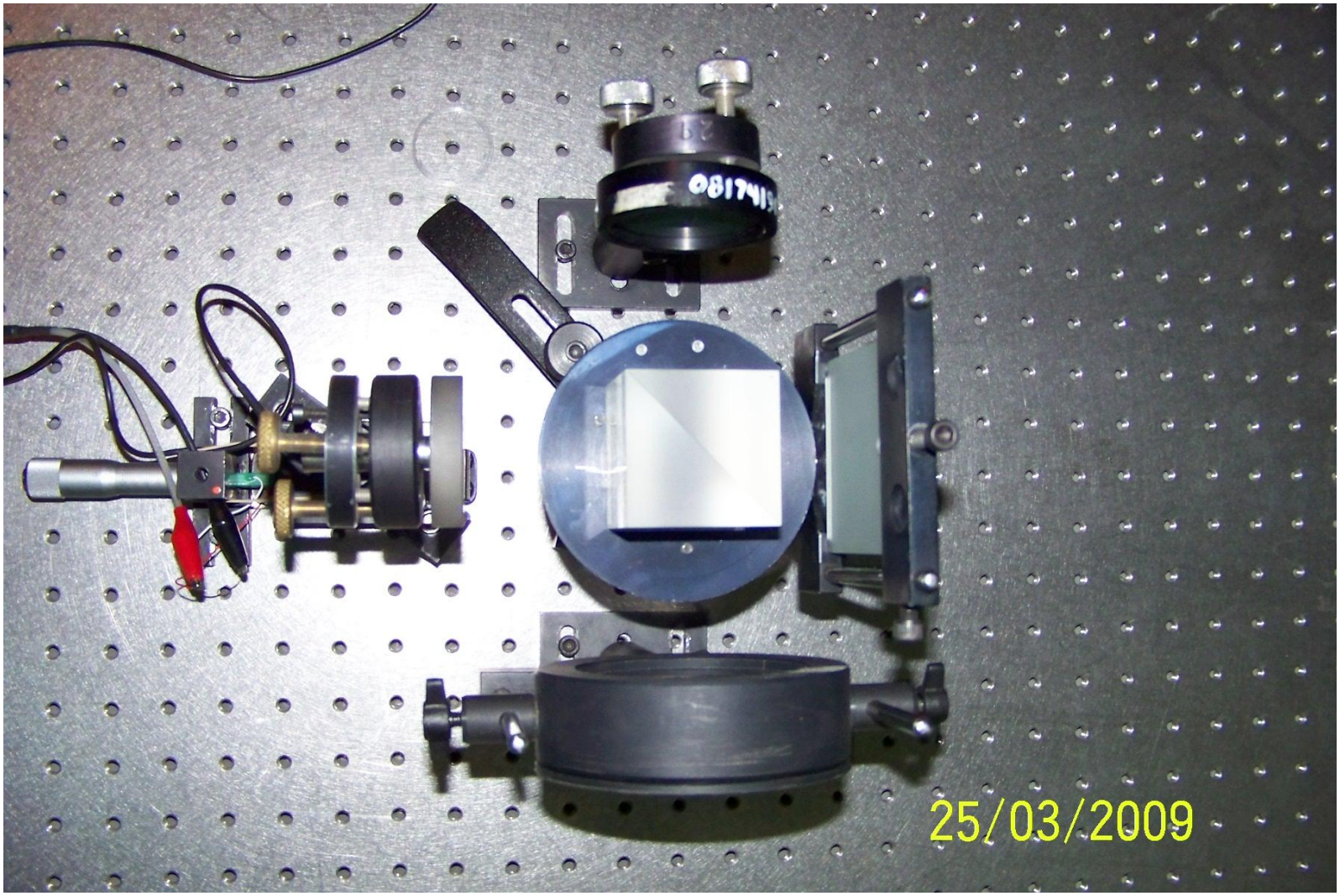
Young's Interferometer

- Open-Fringes.



a) INTERFERÓMETRO DE YOUNG

Interferometer



Interferometry

Fringes projection

Fringes pattern (interferogram) can be represented using the following mathematical expression:

$$I(x,y) = a(x,y) + b(x,y)\cos(w_x x + w_y y + \varphi(x,y) + \eta(x,y))$$

$a(x,y)$ = background illumination

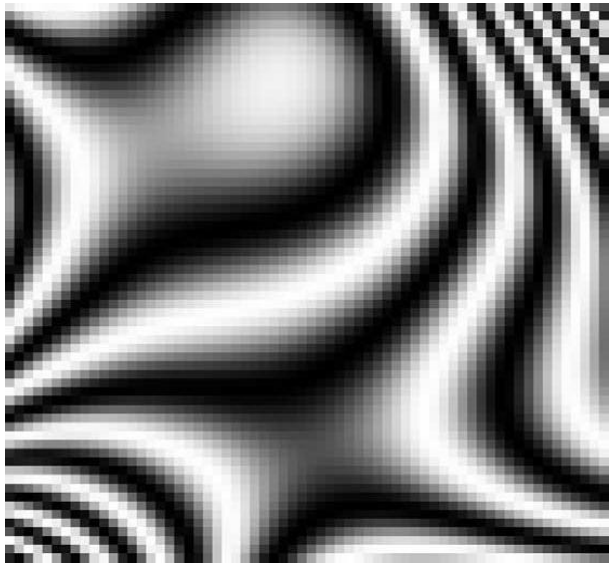
$b(x,y)$ = modulation amplitude

$w_x x, w_y y$ = carrier frequency in directions x and y

$\varphi(x,y)$ = related term to the physical quantity being measured

$\eta(x,y)$ = noise additive to the phase

Example of phase

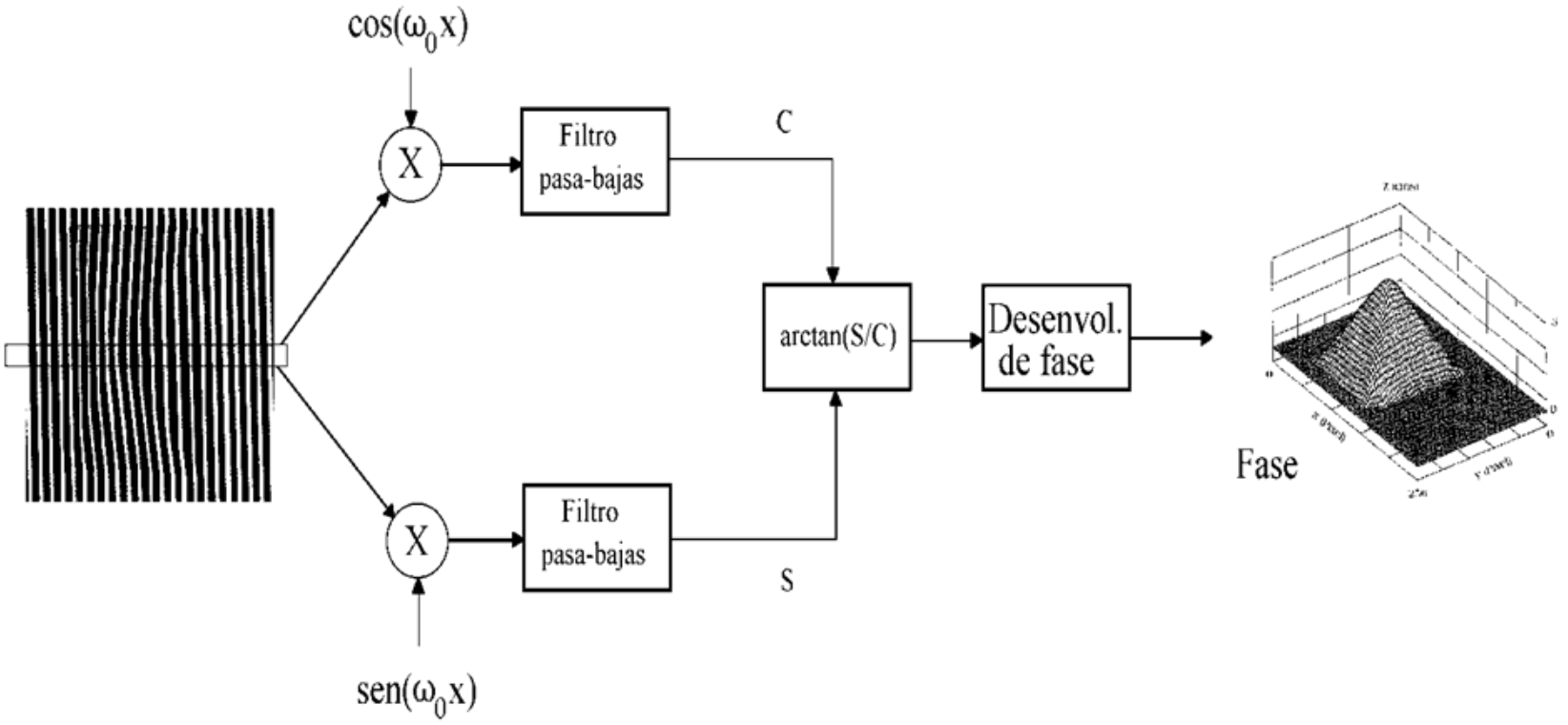


$$\begin{aligned}\phi(x,y) = &-0.7316x - .2801y + 0.00065x^2 \\ &+ 0.00036xy - 0.0372y^2 \\ &+ 0.000212x^3 + 0.00272x^2y \\ &+ 0.001xy^2 - 0.002y^3 \\ &+ 0.000012x^4 + 0.00015x^3y \\ &- 0.00023x^2y^2 + 0.00011xy^3 \\ &+ 0.000086y^4\end{aligned}$$

Techniques for recovering phase

- Direct Phase
- Fourier method
- Phase-locked-loop

Direct Phase

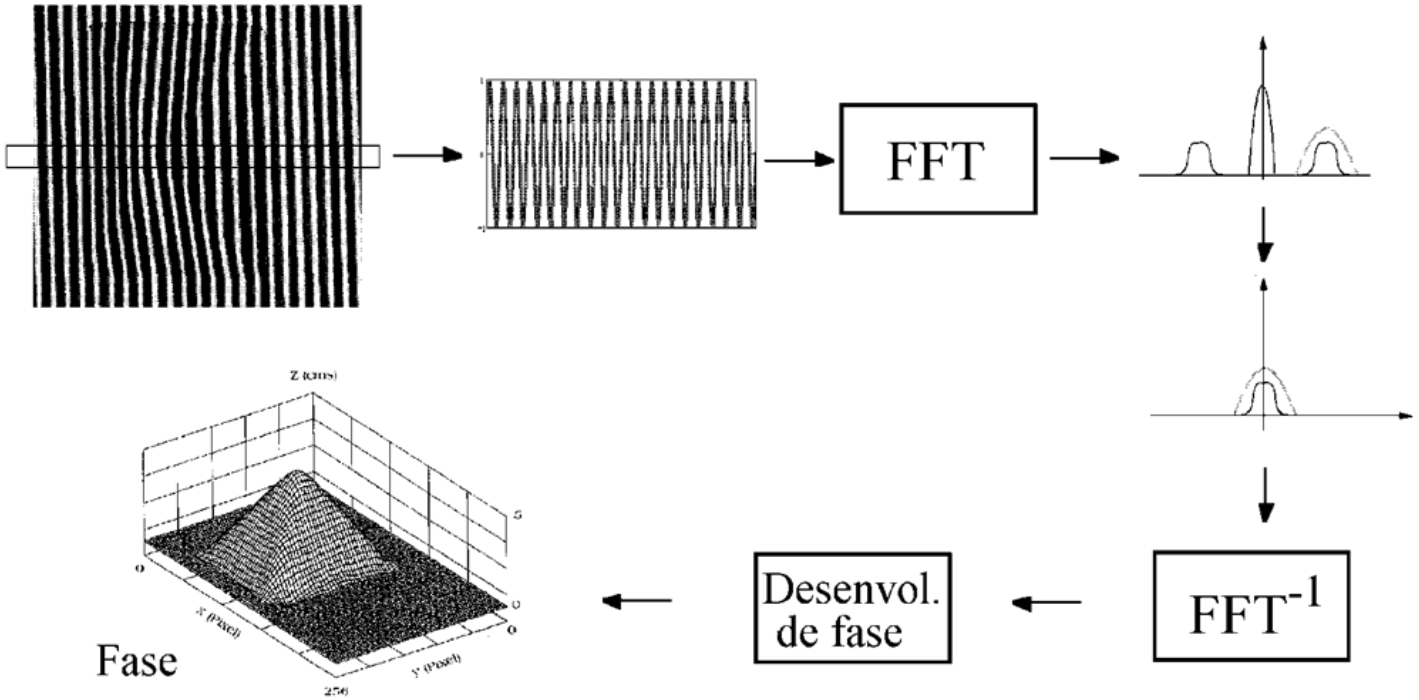


$$I_s(x,y) = a(x,y)\,sen(\omega_0 x) + b(x,y)sen(\phi(x,y)) + b(x,y)sen(2\,\omega_0 x + \phi(x,y)) \quad ,$$

$$I_c(x,y) = a(x,y)\,cos(\omega_0 x) + b(x,y)cos(\phi(x,y)) + b(x,y)cos(2\,\omega_0 x + \phi(x,y)) \quad ,$$

$$\Rightarrow \quad \phi(x,y) = \tan^{-1}\left(\frac{H[I_s(x,y)]}{H[I_c(x,y)]}\right)$$

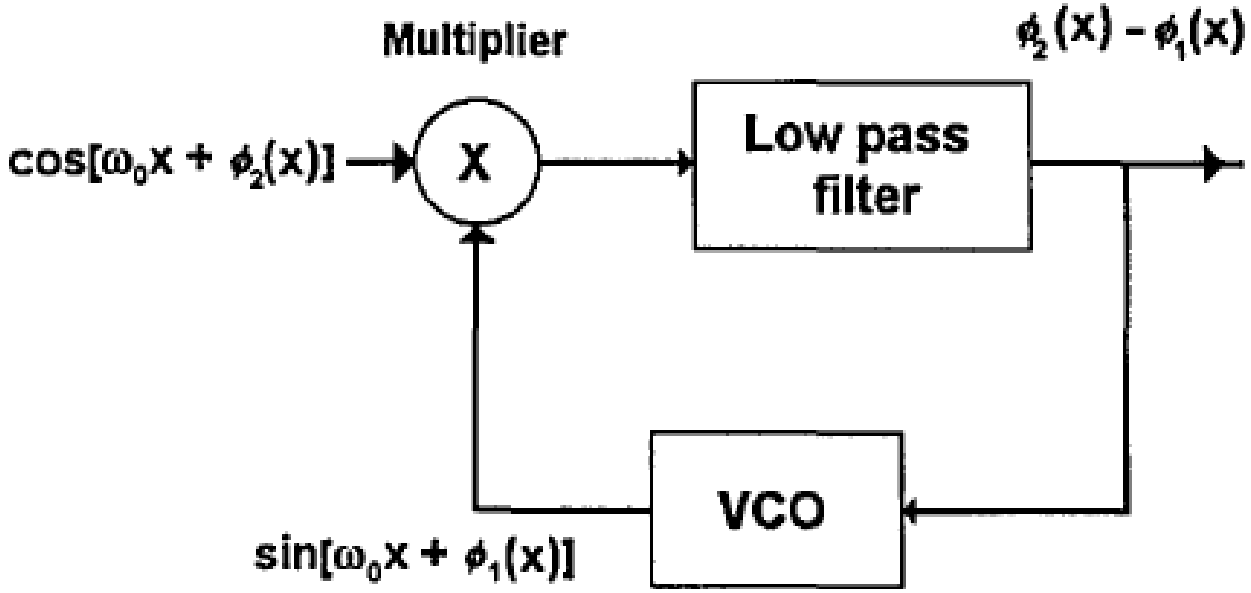
Fourier method



$$I(f,y) = A(f,y) + C(f - f_0 y) + C^*(f + f_0, y) \quad ,$$

$$c(x,y) = \frac{1}{2} b(x,y)\, e^{i\phi(x,y)} \quad ,$$

Phase-locked-loop



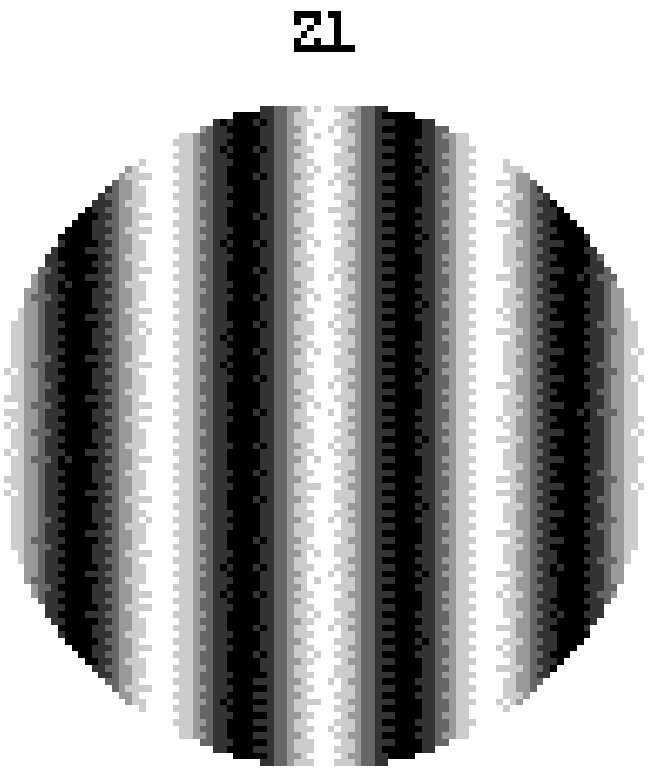
$$\phi(x+1,y) = \phi(x,y) - \tau\left[I(x+1,y) - I(x,y)\right] \times \sin\left[2\ \pi\ f_0 x\ +\ \phi(x,\ y)\right] \quad ,$$
$$(x = 1, 2, \ldots, N-1)$$

Particle Swarm Optimization

Particle swarm optimization (PSO) is a population based stochastic optimization technique, inspired by social behavior of bird flocking or fish schooling.

PSO shares many similarities with evolutionary computation techniques such as Genetic Algorithms (GA). The system is initialized with a population of random solutions and searches for optima by updating generations. However, unlike GA, PSO has no evolution operators such as crossover and mutation. In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles.

Function fitness



Function fitness

- Function to optimize

$$f_{fitness}(\mathbf{z}^k) = \alpha - \sum_{y=1}^{R} \sum_{x=1}^{C} (I(x,y) - \cos(w_x x + w_y y + f_{ajuste}(\mathbf{z},x,y))^2 +$$

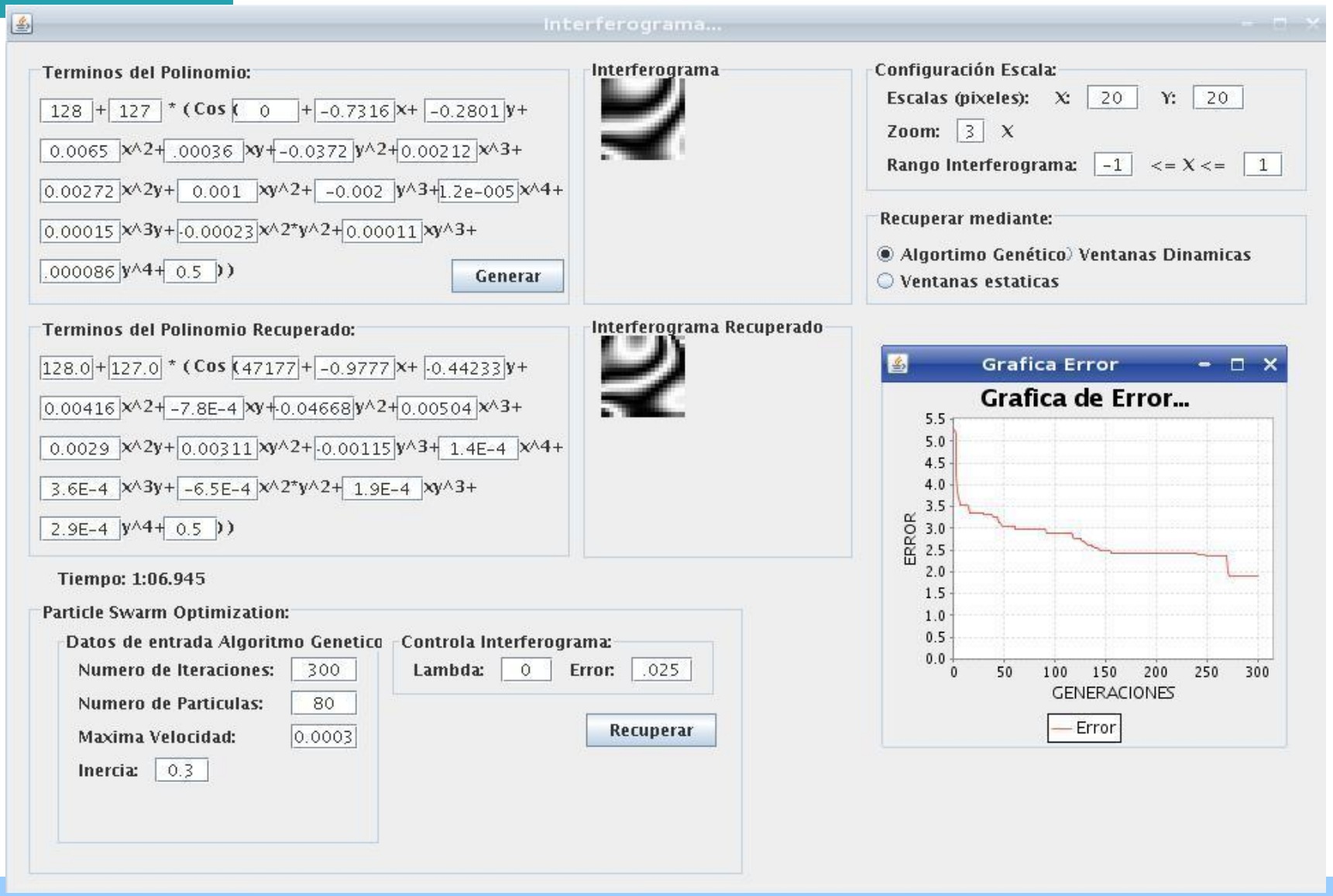
$$\lambda[\, f_{ajuste}(\mathbf{z},x,y) - f_{ajuste}(\mathbf{z},x-1,y))^2 +$$

$$(\, f_{ajuste}(\mathbf{z},x,y) - f_{ajuste}(\mathbf{z},x,y-1))^2\,]m(x,y).$$

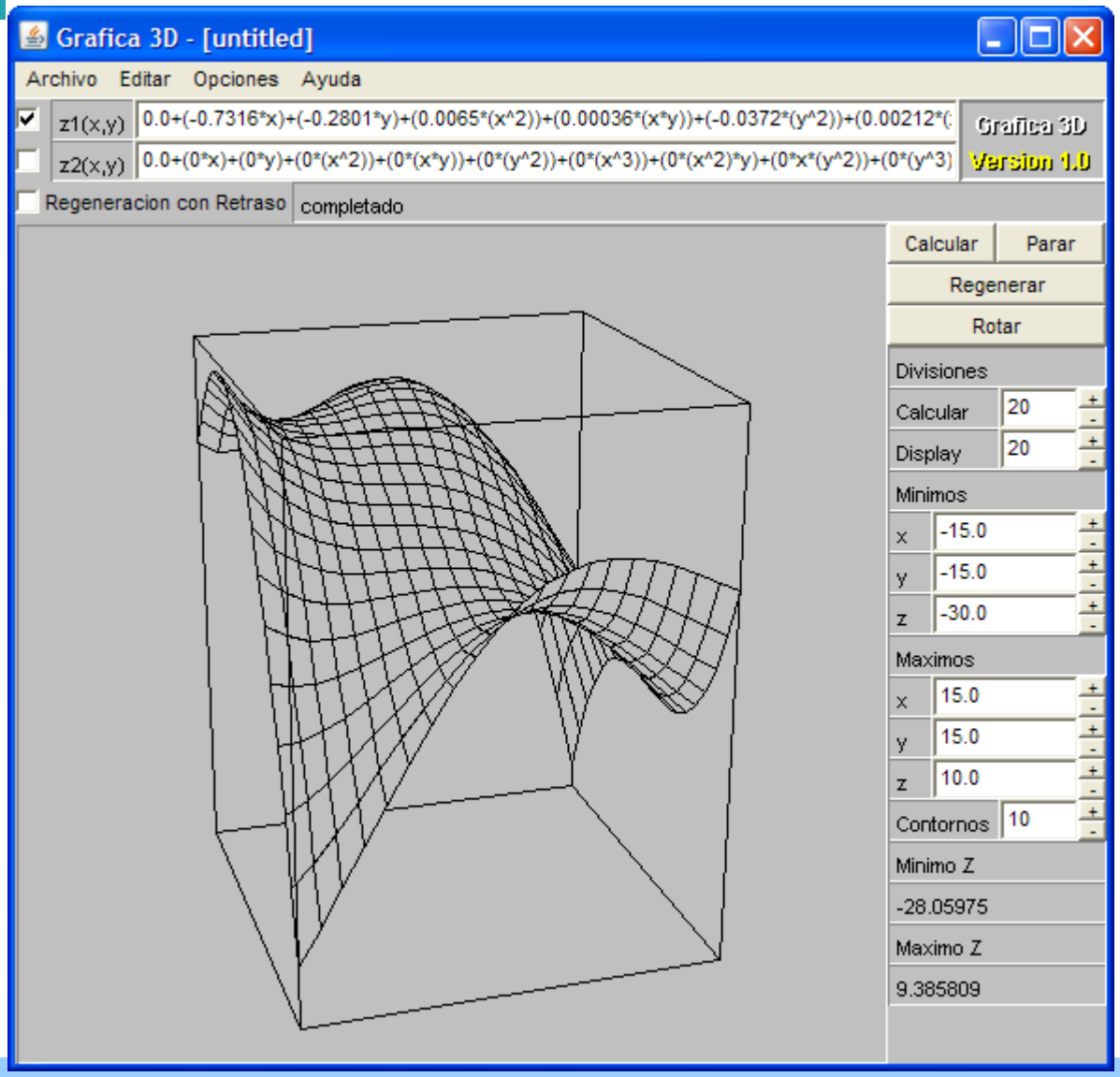
$$f_{ajuste}(\mathbf{z},x,y) = \mathbf{z}_0 + \mathbf{z}_1 x + \mathbf{z}_2 y + \mathbf{z}_3 x^2 + \mathbf{z}_4 xy + \mathbf{z}_5 y^2 + \mathbf{z}_6 x^3 + \mathbf{z}_7 x^2 y + \mathbf{z}_8 xy^2 +$$

$$\mathbf{z}_9 y^3 + \mathbf{z}_{10} x^3 y + \mathbf{z}_{11} x^2 y^2 + \mathbf{z}_{12} xy^3 + \mathbf{z}_{13} x^4 + \mathbf{z}_{14} y^4$$

Differential evolution

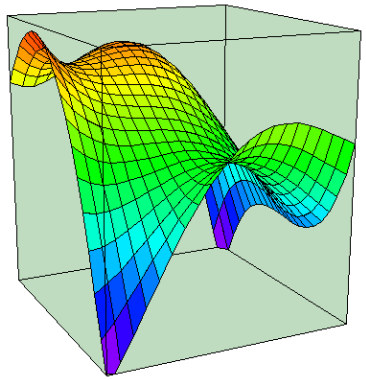


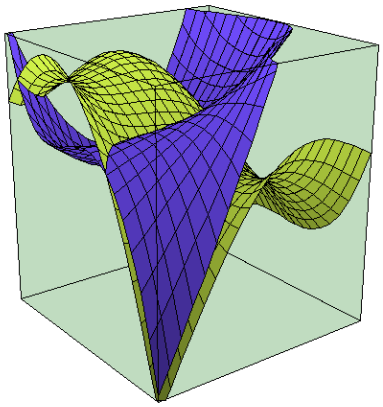
Phase 3D


Grafica 3D - [untitled]
Archivo Editar Opciones Ayuda
z1(x,y)
0.0+(-0.7316*x)+(-0.2801*y)+(0.0065*(x^2))+(0.00036*(x*y))+(-0.0372*(y^2))+(0.00212*(
z2(x,y)
0.0+(0*x)+(0*y)+(0*(x^2))+(0*(x*y))+(0*(y^2))+(0*(x^3))+(0*(x^2)*y)+(0*x*(y^2))+(0*(y^3)
Grafica 3D
Version 1.0
Regeneracion con Retraso
completado
Calcular
Parar
Regenerar
Rotar
Divisiones
Calcular 20
Display 20
Minimos
x -15.0
y -15.0
z -30.0
Maximos
x 15.0
y 15.0
z 10.0
Contornos 10
Minimo Z
-28.05975
Maximo Z
9.385809

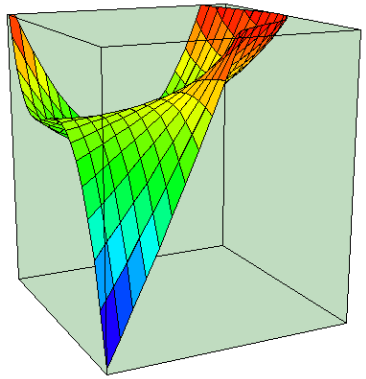
Recovery phase

Observed fringes





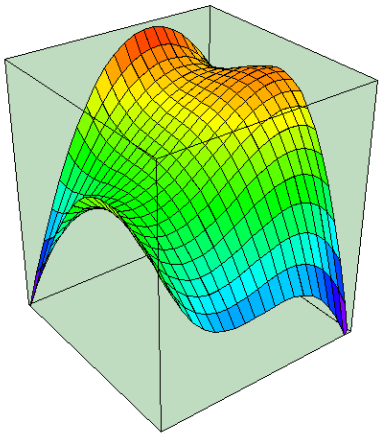
Recovered fringes

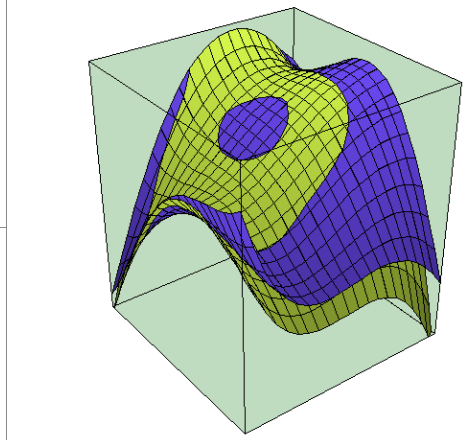


Error: 2.3058

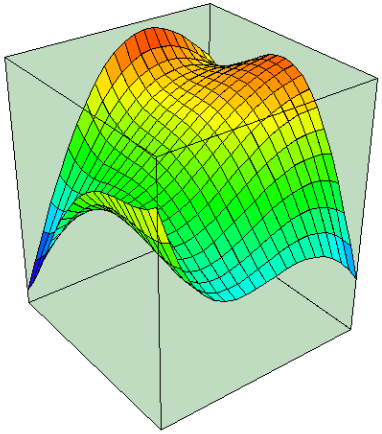
Recovery phase

Observed fringes





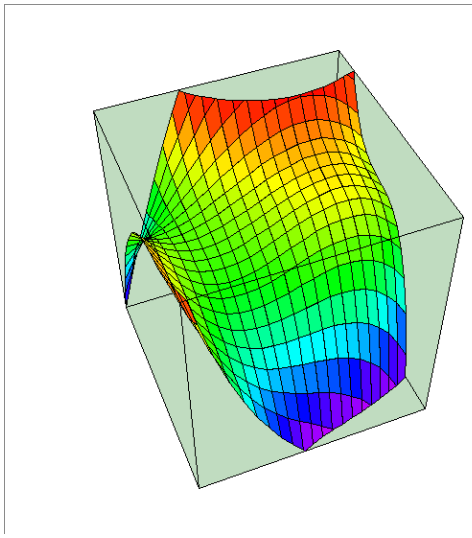
Recovered fringes

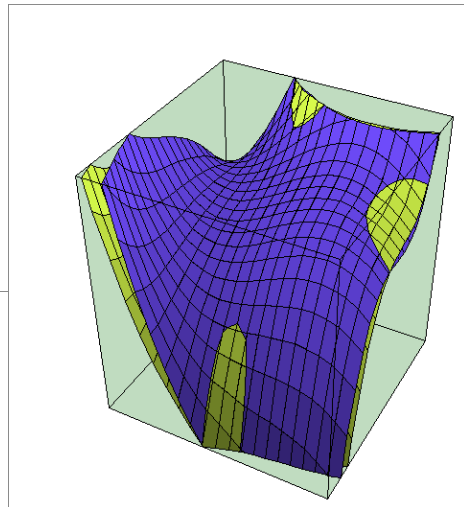


Error: 0.1928

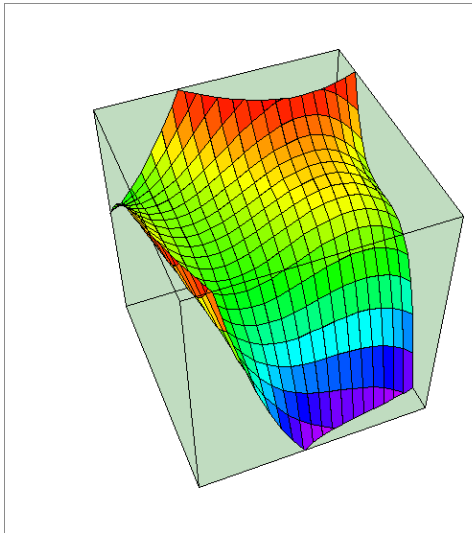
Recovery phase

Observed fringes





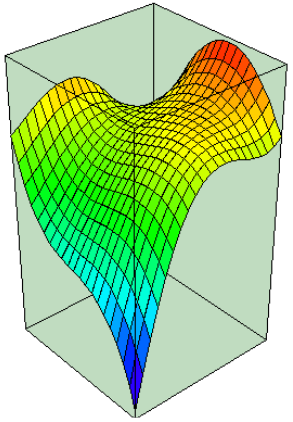
Recovered fringes



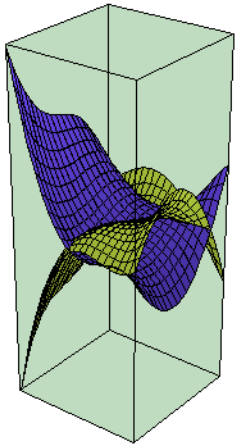
Error: 0.9212

Recovery phase

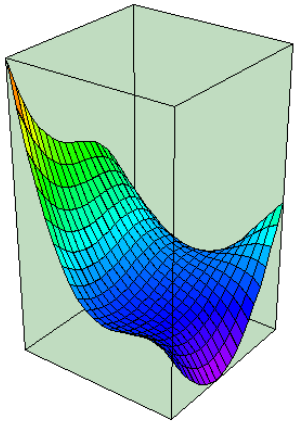
Observed fringes



3D

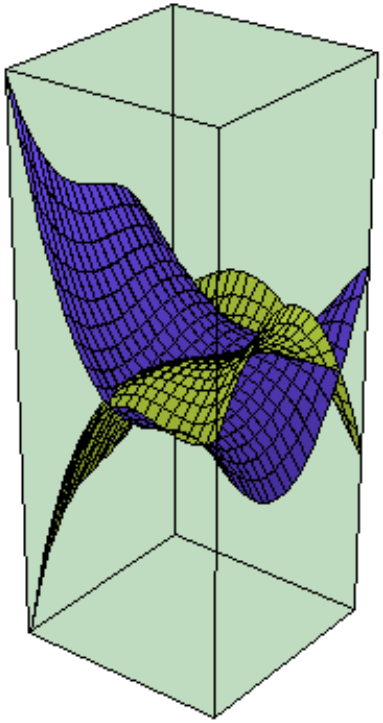


Recovered fringes

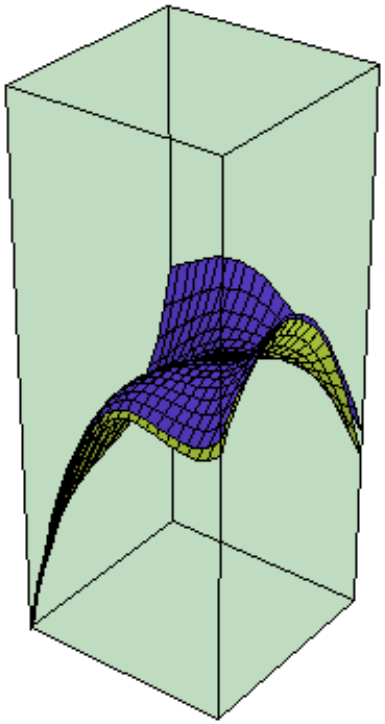


Error: 0.04187

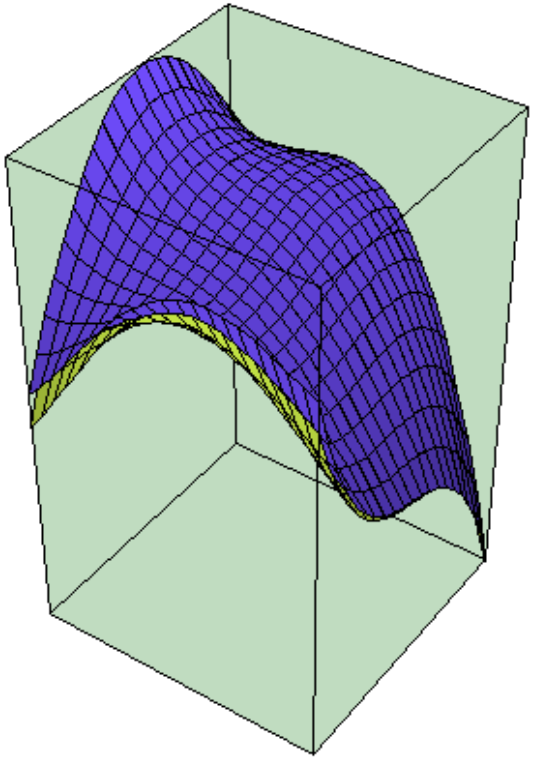
Phase coupling



phase coupling

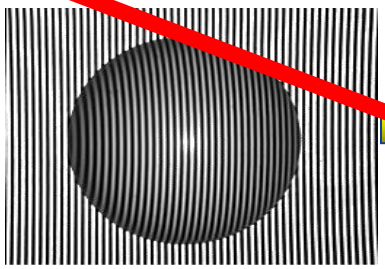


Coupling correction

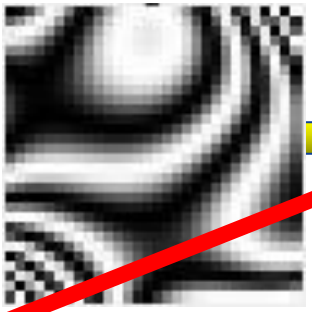


Phases:
Fixed and coupled

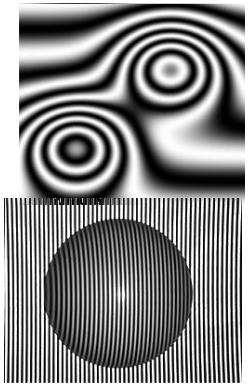
Conclusion



Direct Phase Fourier → unwrapping → Object 3D



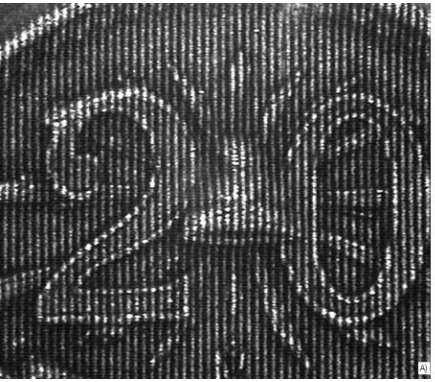
Phase-locked-loop and unwrapping → 3D

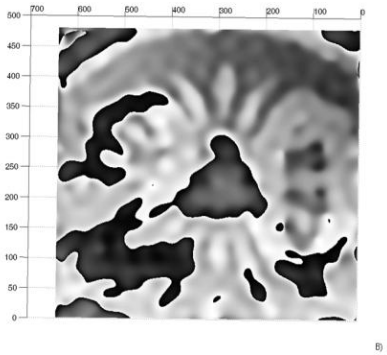


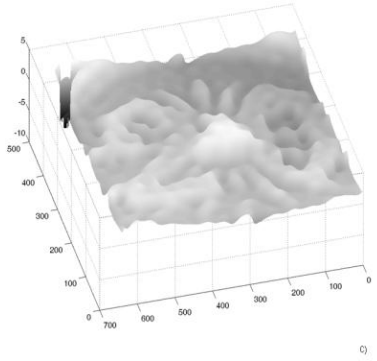
PSO → Object 3D

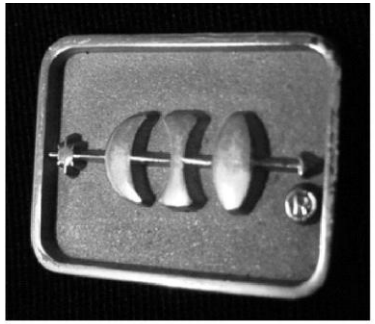
Applications

- Face recognition in 3-D.
- Quality control.
- Design and manufacturing by computer.
- Industrial inspection.
- Biomedicine and Robotic.
- Objects measurement .
- 3-D reconstruction









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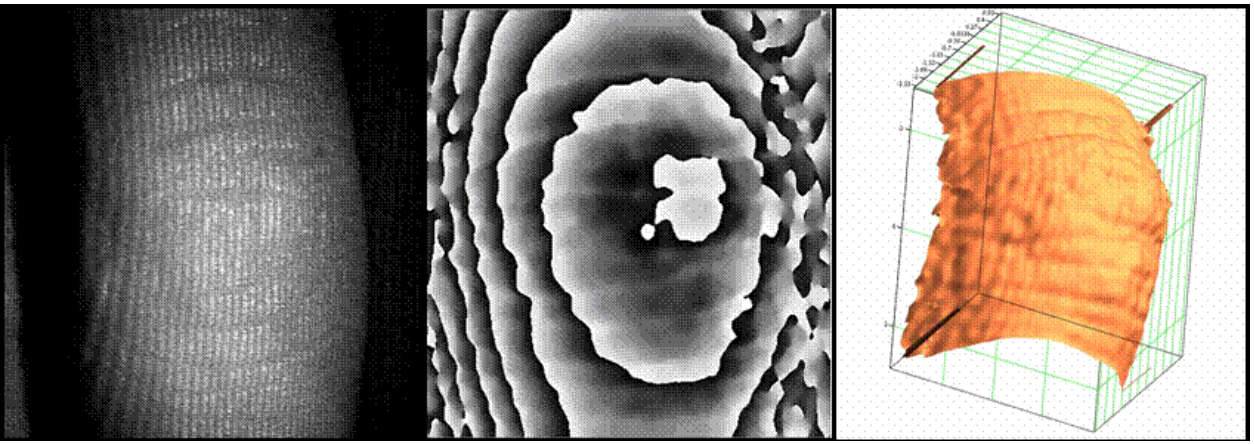
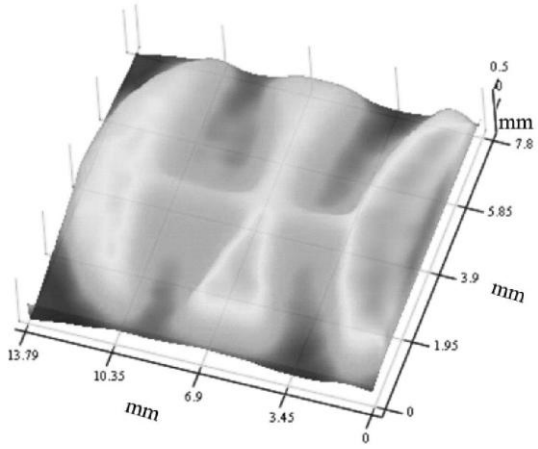




b)

Authors thank the COTEPABE-IPN, European Union, the European Commission and CONACYT for the economical support. This paper has been prepared by economical support of the European Commission under grant FONCICYT 93829. The content of this paper is an exclusive responsibility of the CIC-IPN and it cannot be considered that it reflects the position of the European Union.

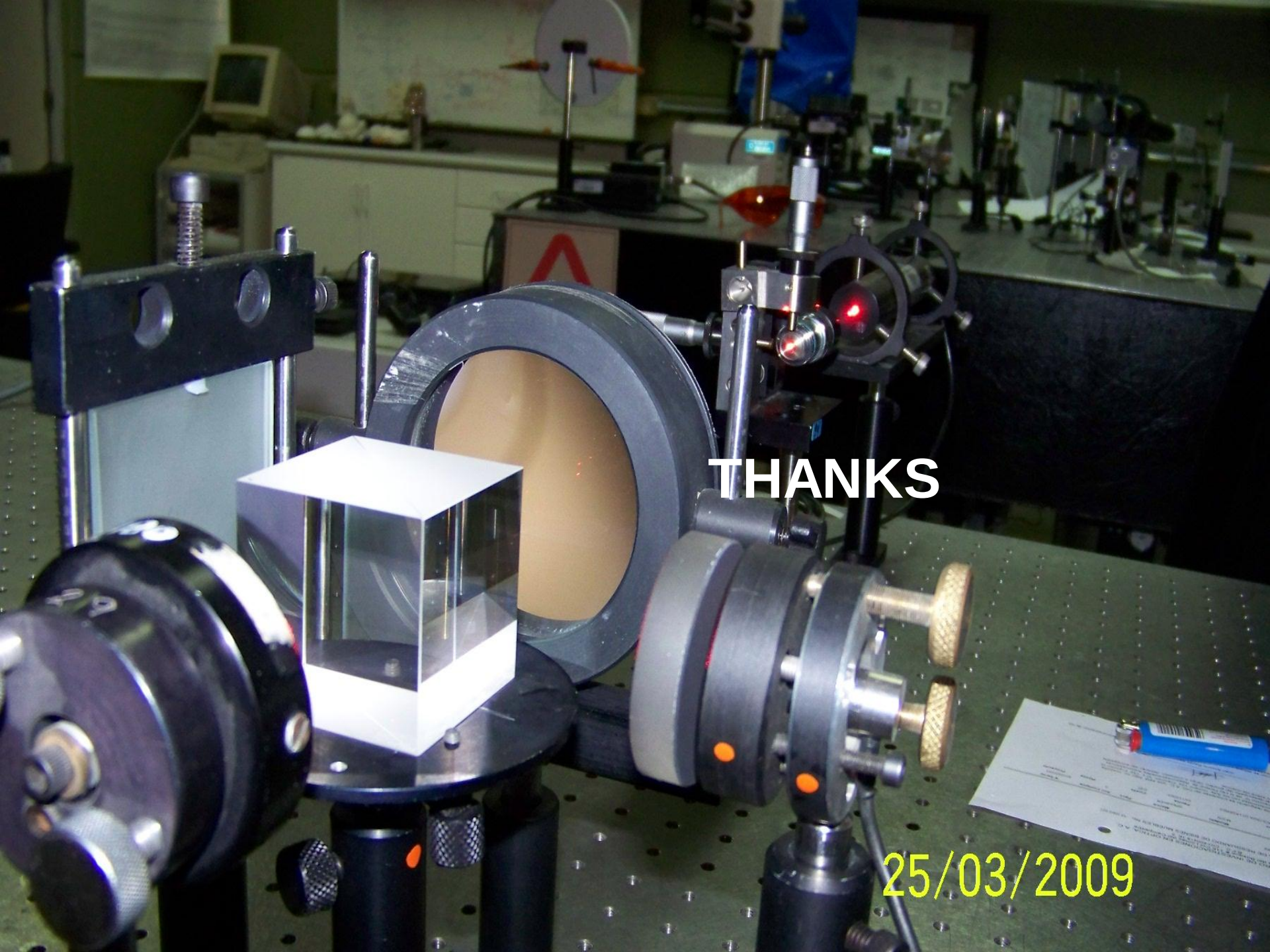
¡ THANKS !

Julio Fernando Jiménez Vielma

E-mail: jfvielma@cio.mx and humbertososa@gmail.com

Center for Computing Research – National Polytechnic Institute

Tel. 55 (55) 5729 6000


THANKS
25/03/2009