Method of synthesized phase objects: rotation invariant optical recognition

[1]**Yezhov P.V.**, [2]Ostroukh A.P., [3]Kim Jin-Tae, [2]Kuzmenko A.V.

[1]Institute of Physics of NAS of Ukraine
[2] IC ”Institute of Applied Optics” of NAS of Ukraine
[3]Chosun University, Korea

Department of coherent and quantum optics

Outline

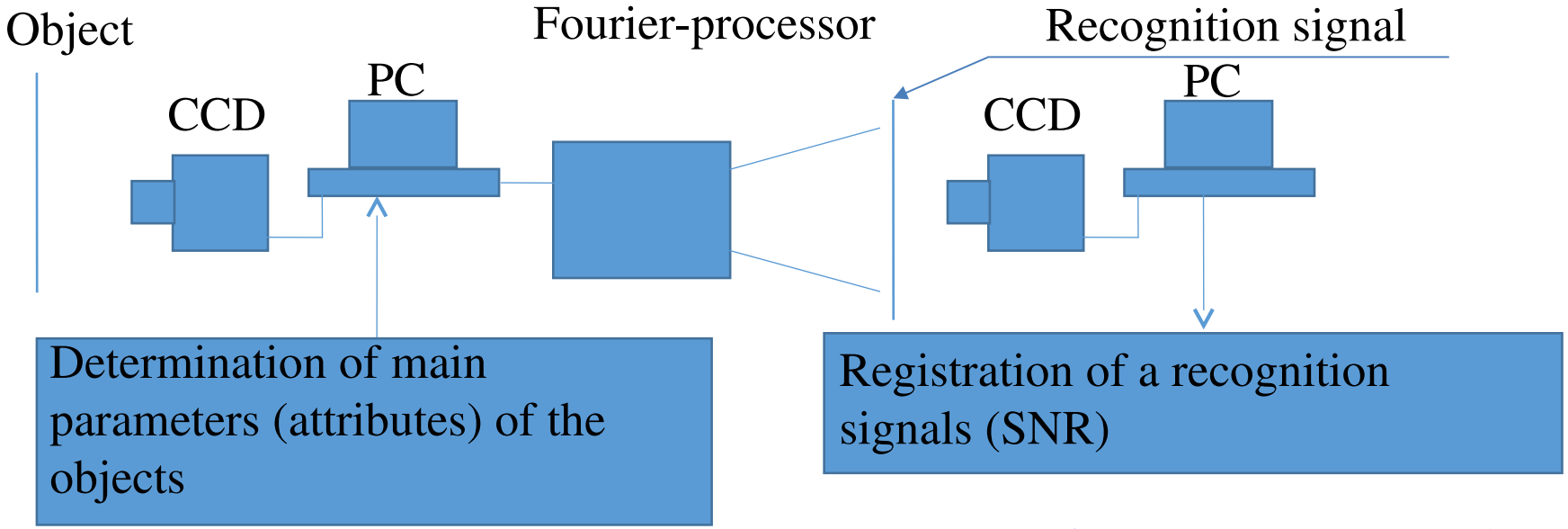
- Pattern recognition problem
- Method of synthesized phase objects
- Calculation experiment
- Optical experiment
- Conclusion

Image processing
(Pattern recognition)

Some of realized solutions are:

Optical recognition

1) Medical applications: X-ray images analysis
2) Microbiology:
   i) identification of bacterial species
   ii) sorting of red blood cells
3) Military: targets tracking, recognition
4) Spacecraft “Viking”: task of orientation on Mars
5) Security: face recognition



Pattern recognition problem

$$A_{corr} = |f_n \otimes f_m| \Rightarrow |\Im^{-1}(F_n \bullet F^*_m)| \Rightarrow$$

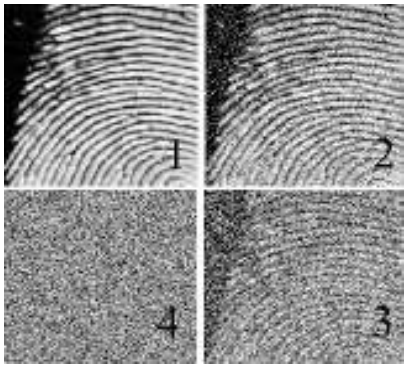
where $F_n = \Im^{+1}(f_n)$, $F_m = \Im^{+1}(f_m)$

Formulation of the problem

Determination of objects attributes

Number (k) of points rearrangements of the objects

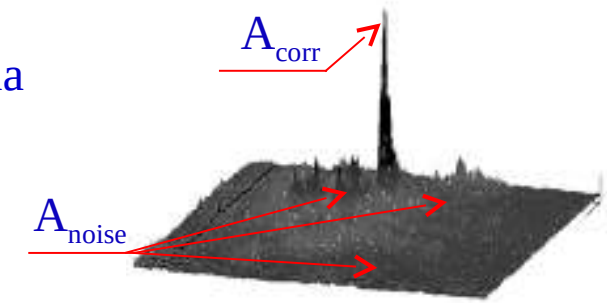
1. k=0
2. k=150
3. k=300
4. k=600

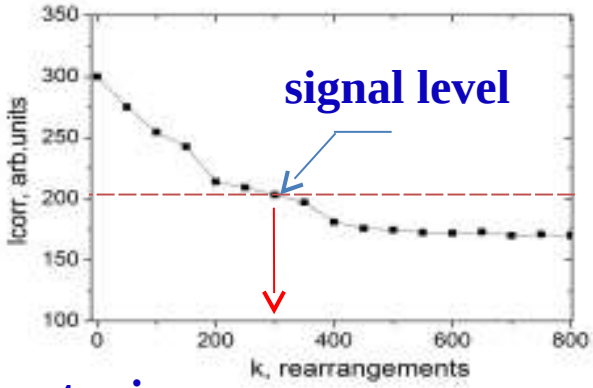


Fragments of the object

Solution

Determination of recognition criteria



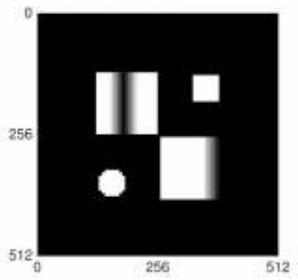


Typical parameter is

$SNR = 10 \bullet \log_{10}(A_{corr}/A_{noise})$, dB

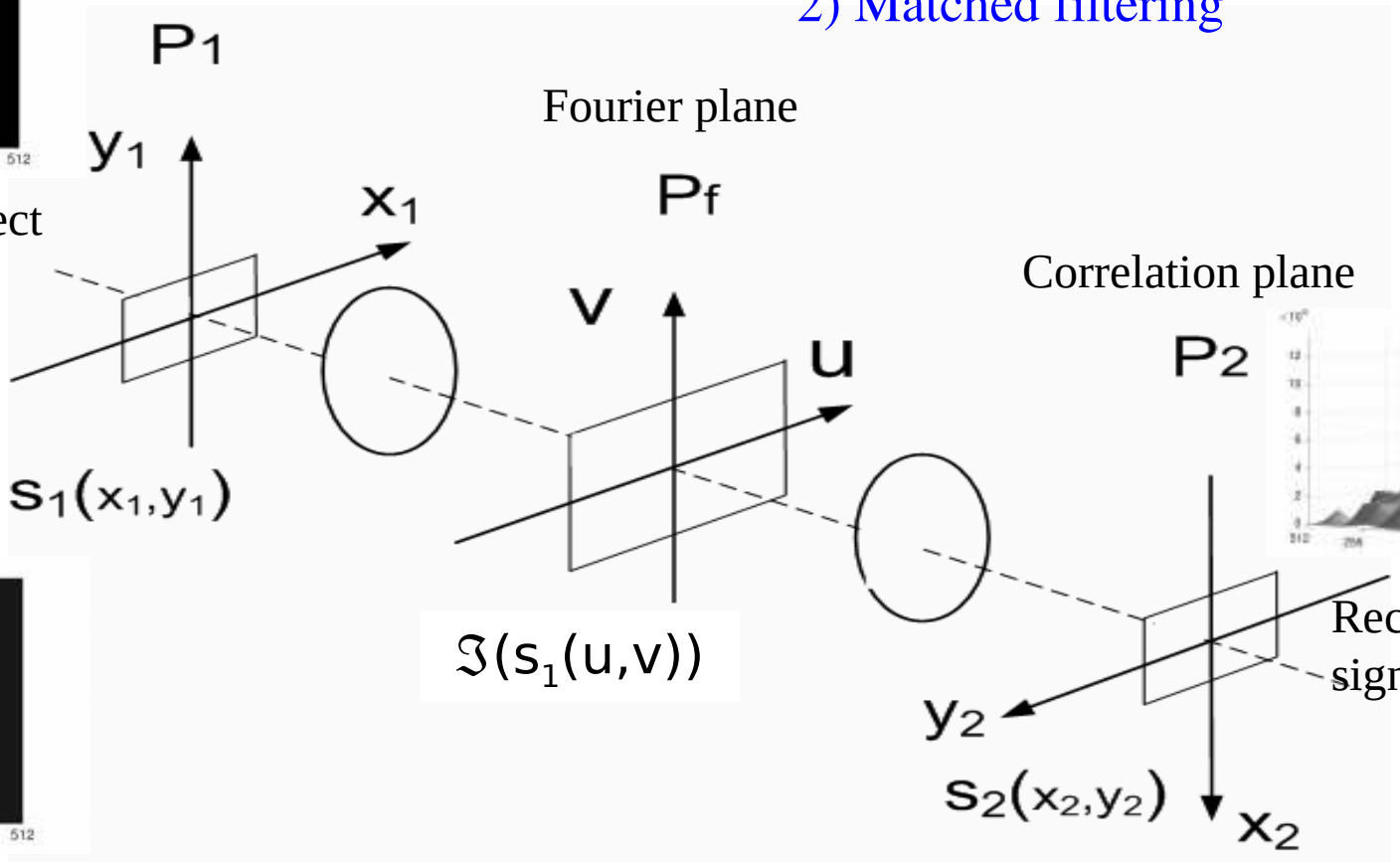
Problems

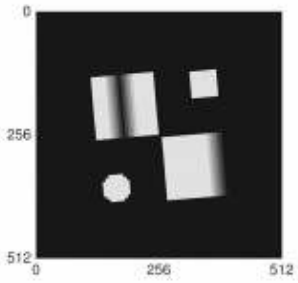
Procedure of optical recognition is
1) Fourier-filters formation
   for an reference object
2) Matched filtering



Object plane

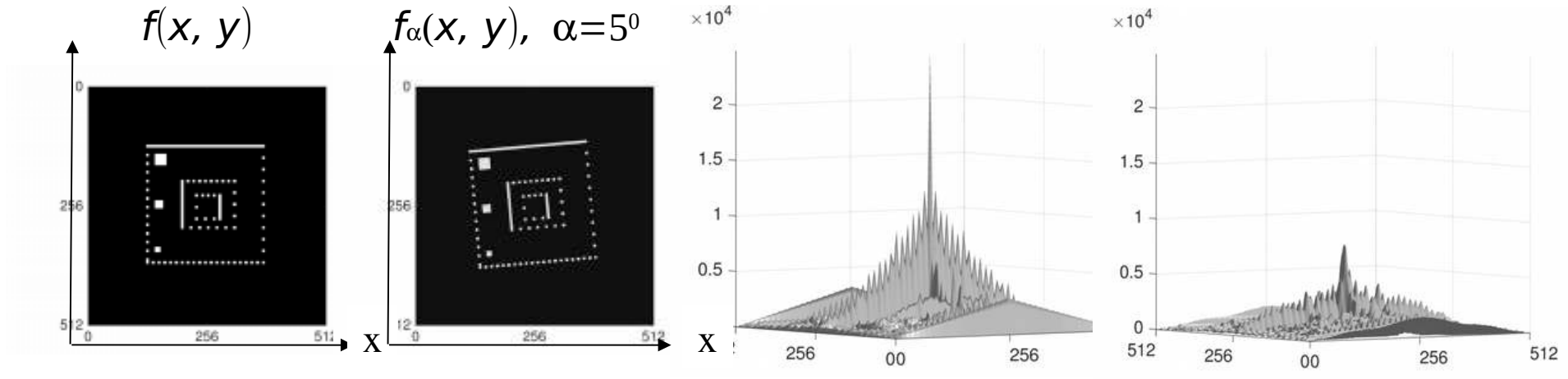
Reference object





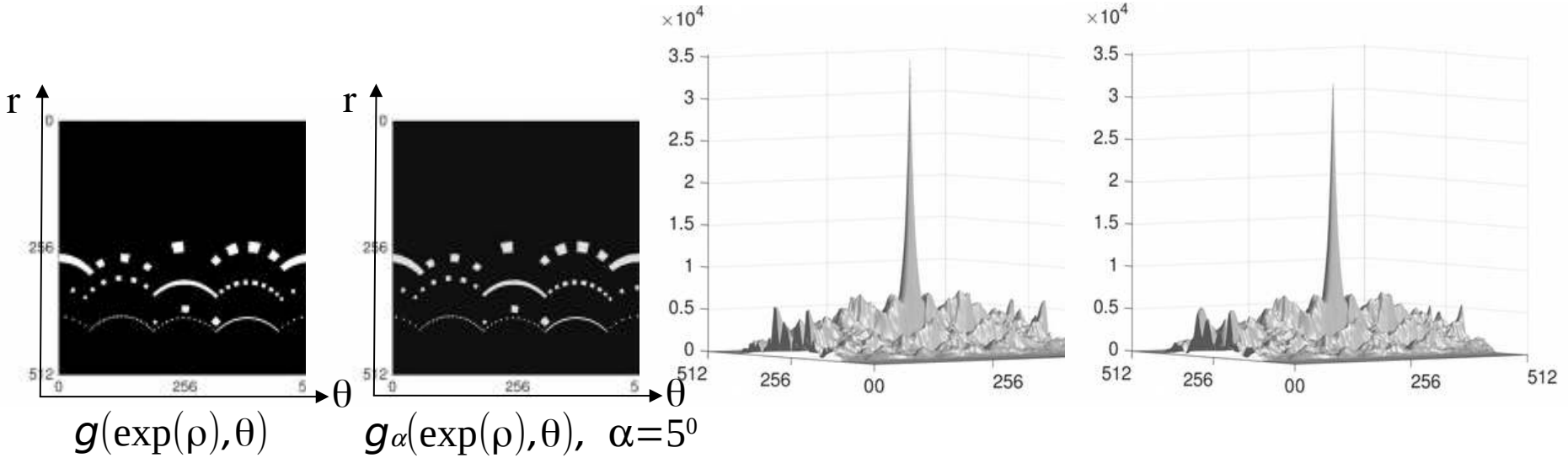
Objects

Rotation invariant correlation



Mellin transformation $M[f(s)] = \int x^{s-1} f(x)dx$

$f(x,y) \Rightarrow g(r,\theta) = g(\exp(\rho),\theta) \Rightarrow M[f(x,y)] = \Im[g(\exp(\rho),\theta)]$

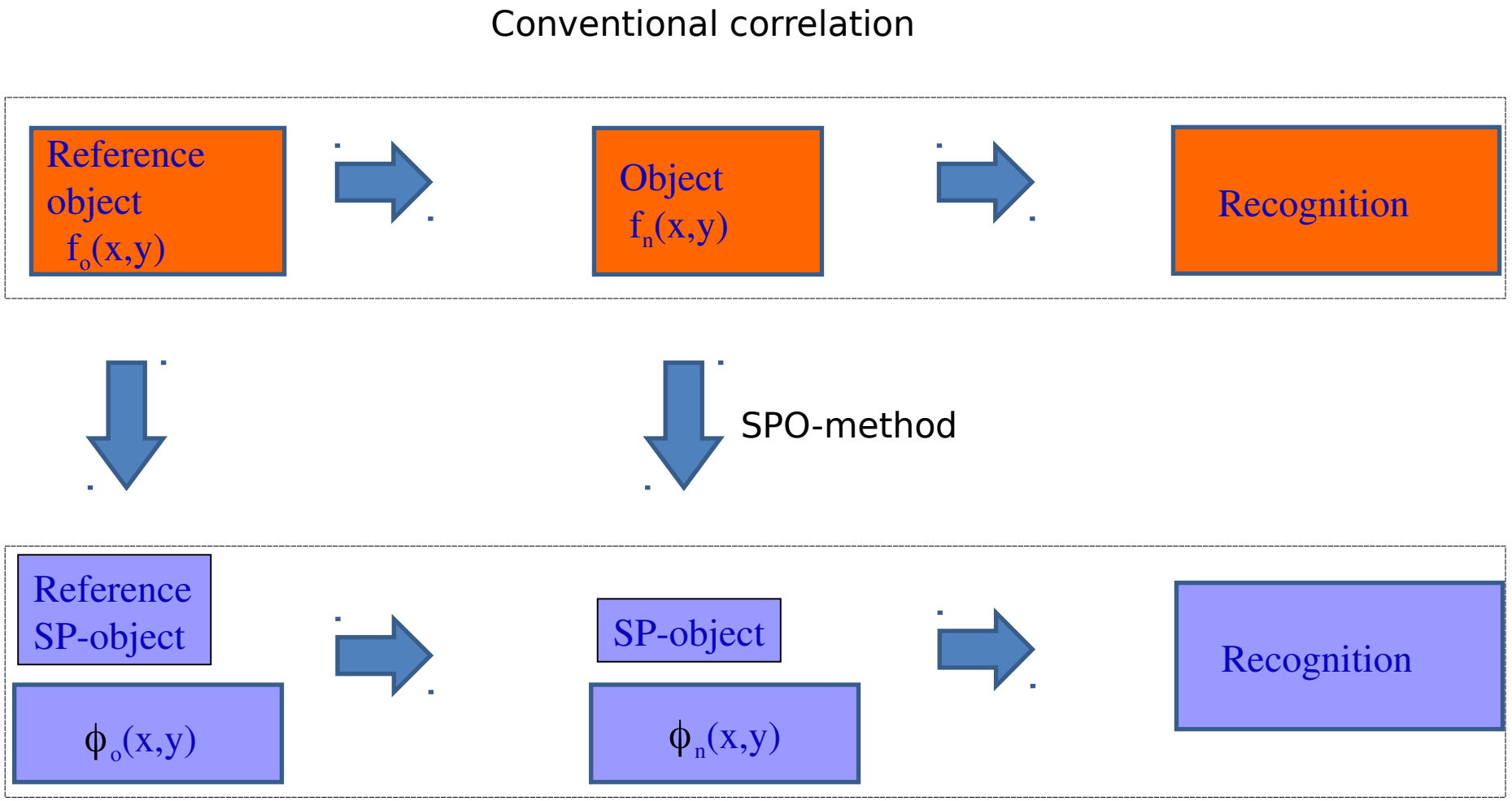


Method of synthesized phase objects:

I)
We propose a new approach to the recognition problem. The novelty of the suggested method that recognition comprises not the object itself, but some object-dependent synthesized phase object (diffuser) with a random phase distribution, which can be calculated using the known IFT algorithm

II)
The problem of recognition of amplitude objects of various types is reduced to that of phase objects of the same type

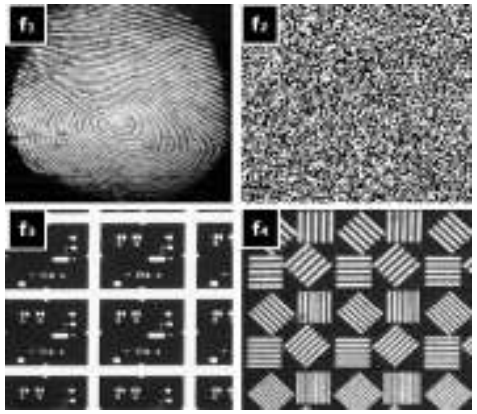
Recognition procedure
(SPO-method)



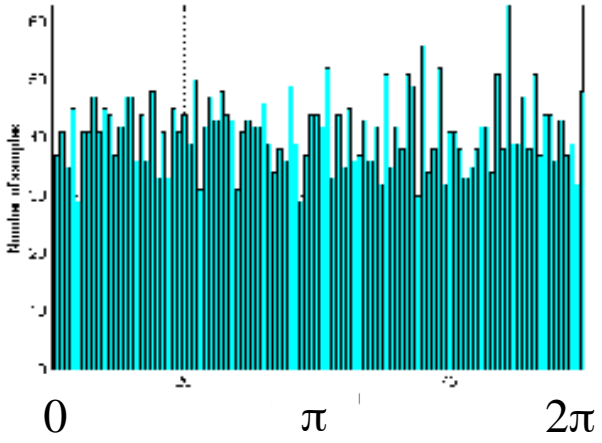
SPO-method

(advantages)

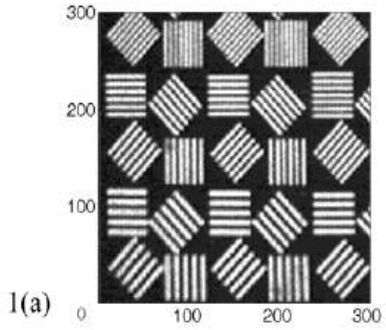
Objects



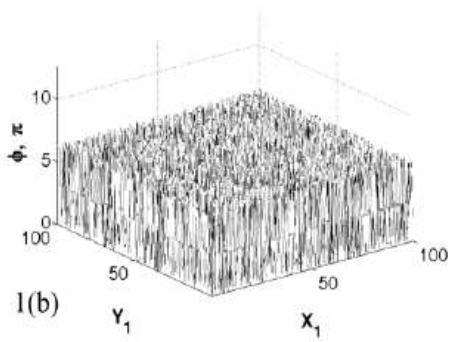
Phase distribution in a plane of typical SP-object



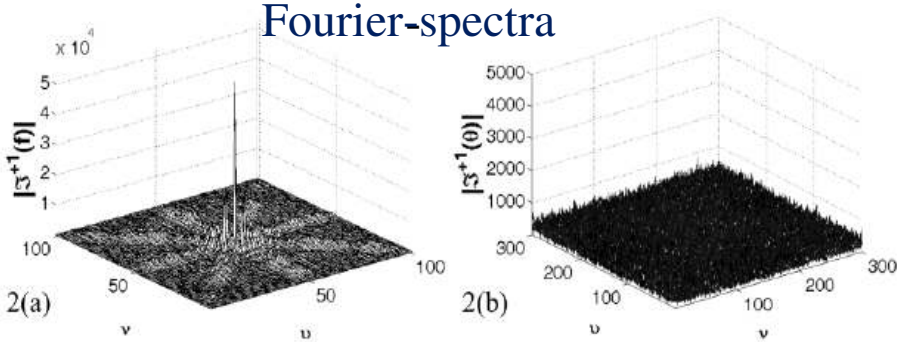
Object



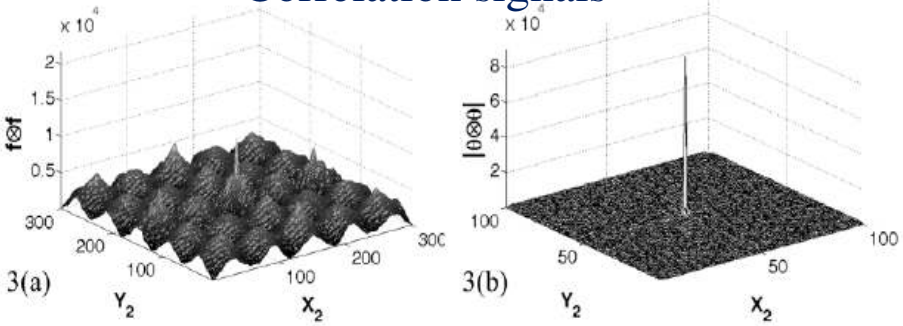
SP-object



Fourier-spectra



Correlation signals



SPO-method
(experiment)

For object f_1;

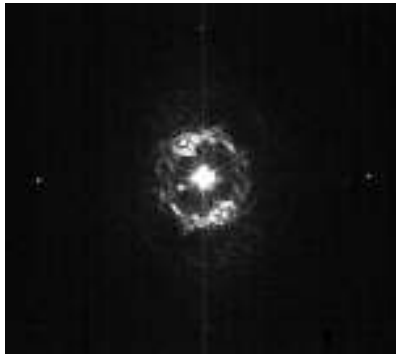
For SP-object

Object f_1;

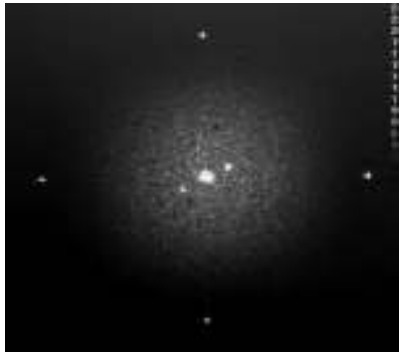
Object plane

Matrix size: 300x300

Fourier plane



$|\Im^{+1}(f_1)|$

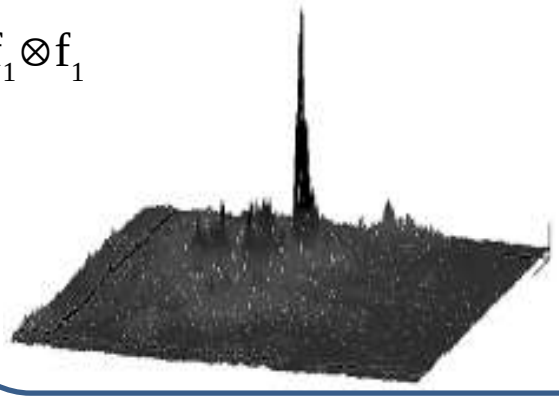


$|\Im^{+1}(\phi_1)|$

Correlation plane

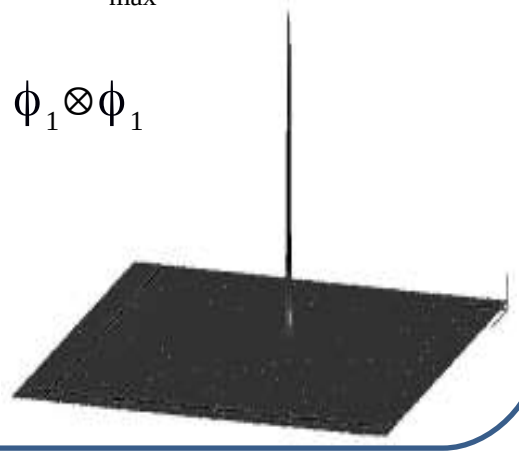
SNR_{max}=2.1 dB

$f_1 \otimes f_1$

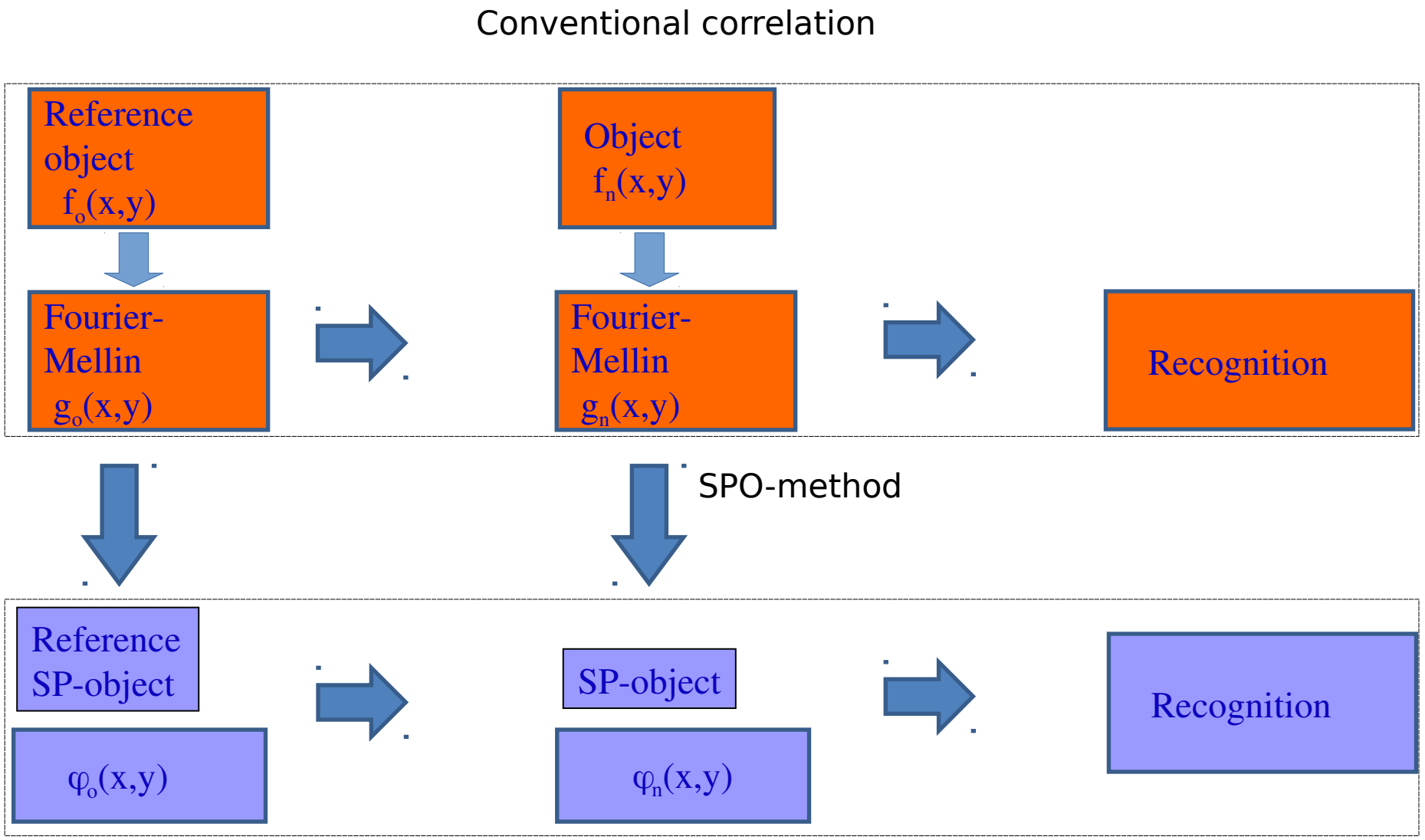


SNR_{max}=24 dB

$\phi_1 \otimes \phi_1$



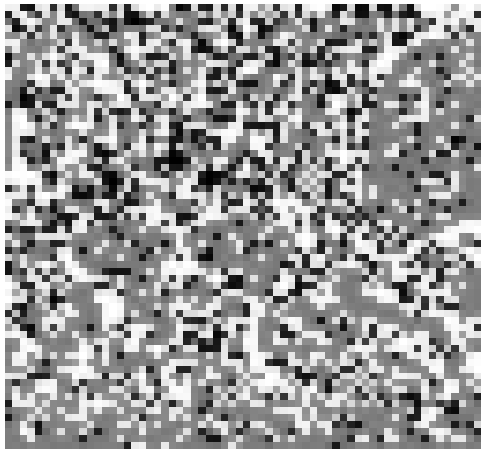
Recognition procedure with Fourier-Mellin transformation
(SPO-method)



SPO-method: rotation invariance correlation

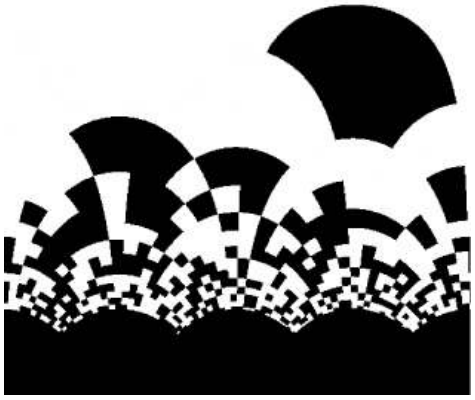
Objects **SP-objects**

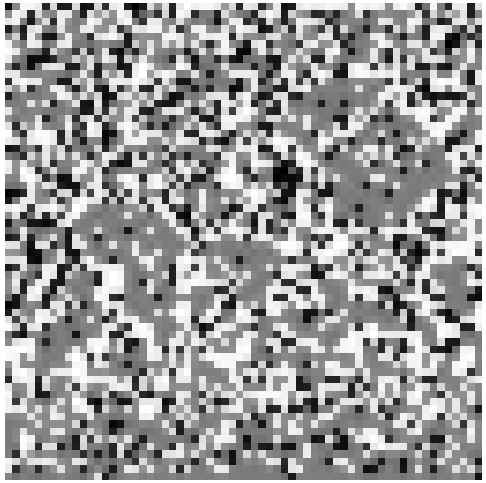
$f(x, y)$



$\phi(exp(\rho), \theta)$

$g(exp(\rho), \theta)$

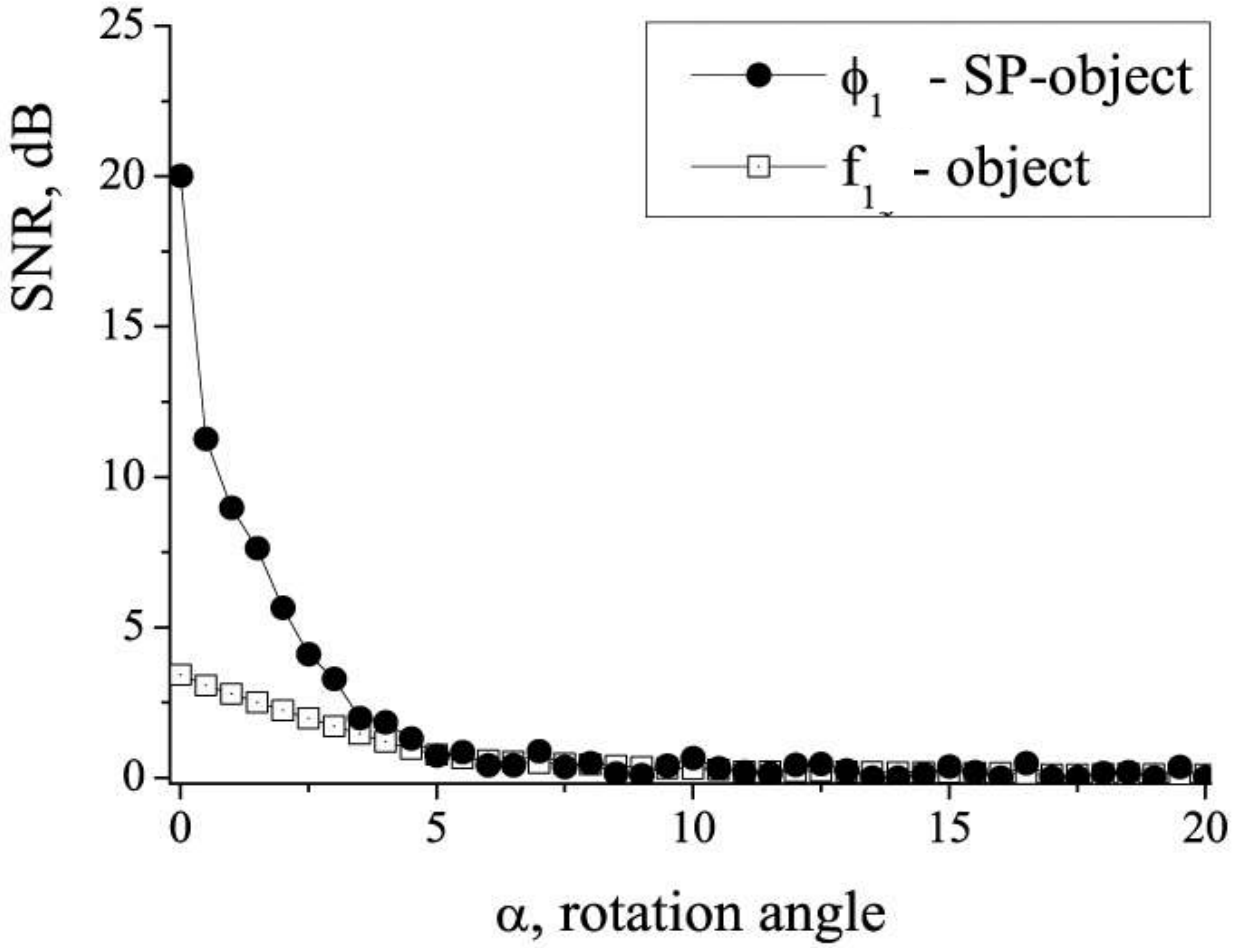




$\varphi(exp(\rho), \theta)$

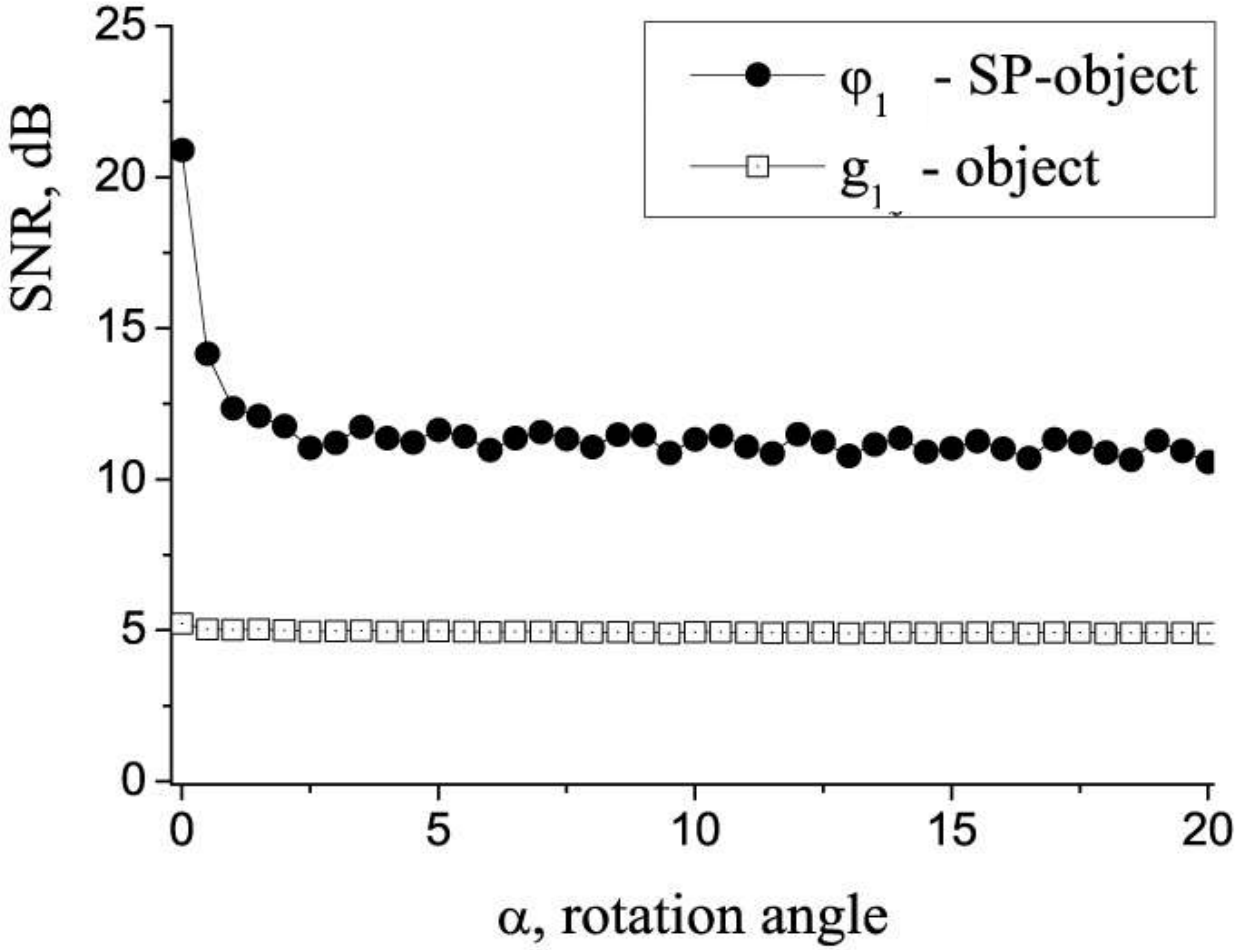
SPO and conventional correlation methods

(objects rotation)

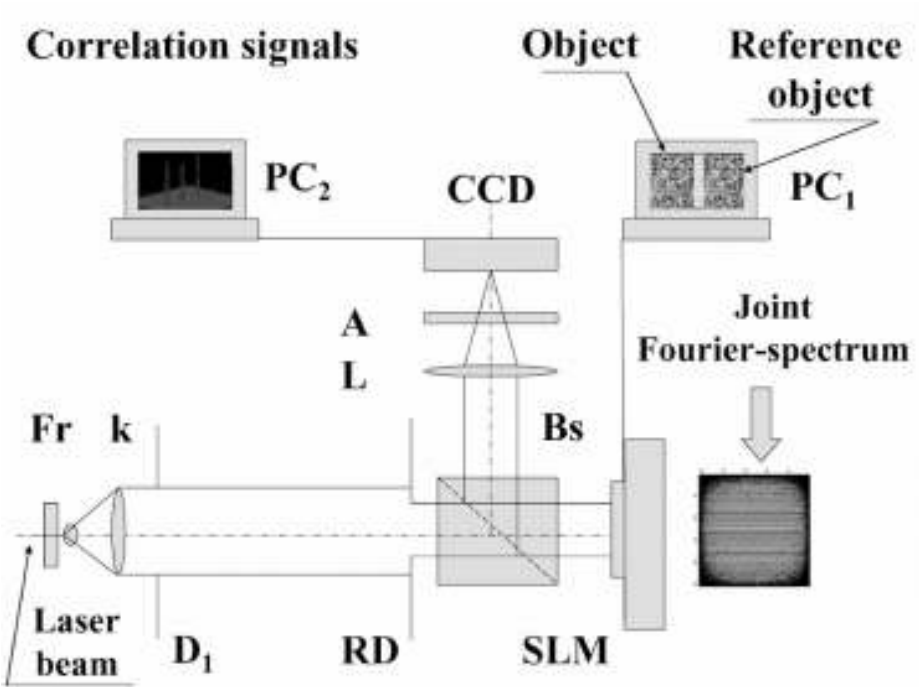


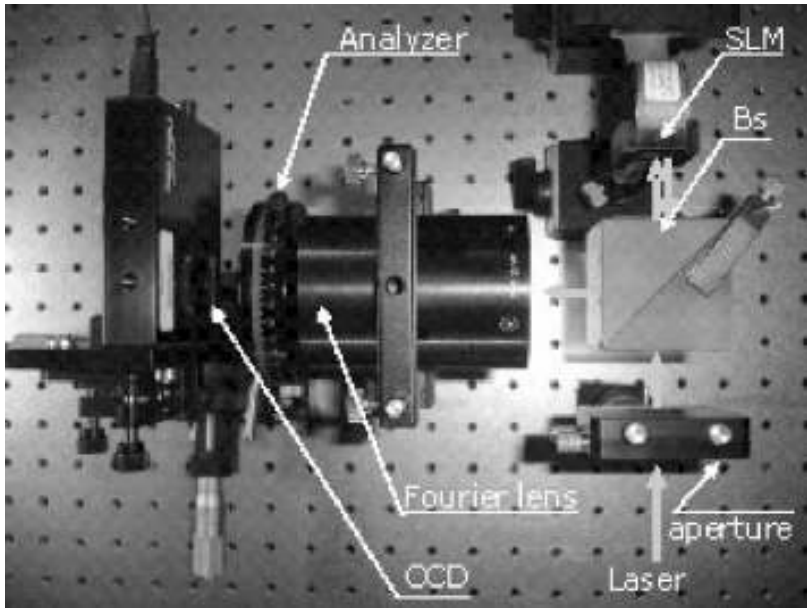
SPO and conventional correlation methods with Fourier-Mellin transformation

(objects rotation)



Joint Fourier-transform correlation

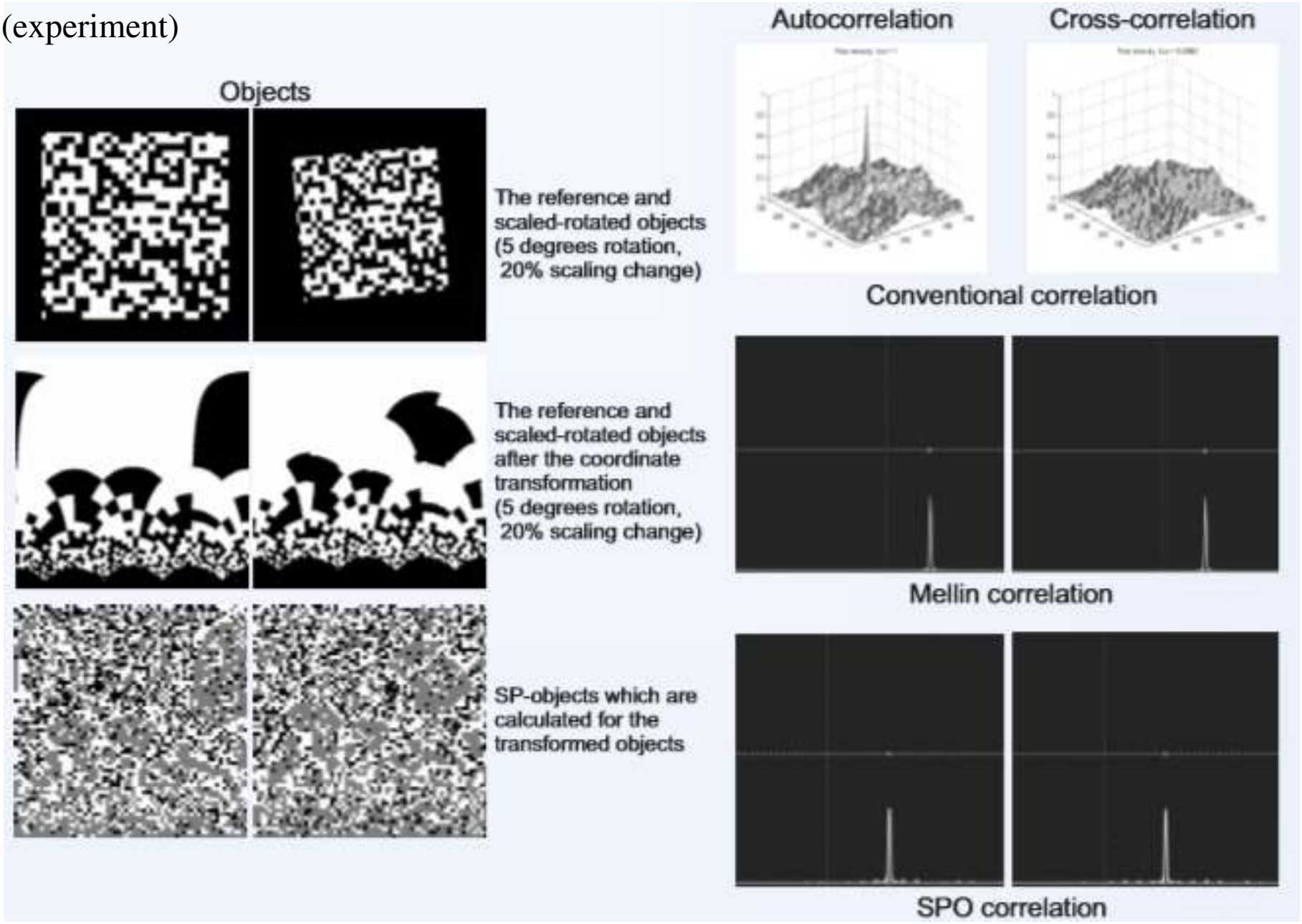




Laser, P,– He-Ne (543 nm) laser, polarizer;
Rh.F, k, D1– Fresnel rhomb, collimator, diaphragm; RD, Bs – aperture, beam splitter;
SLM – spatial light modulator HEO 1080 Pluto;
F, A – lens, analyzer ; CCD – SPU620 CCD with Beam Gage software.

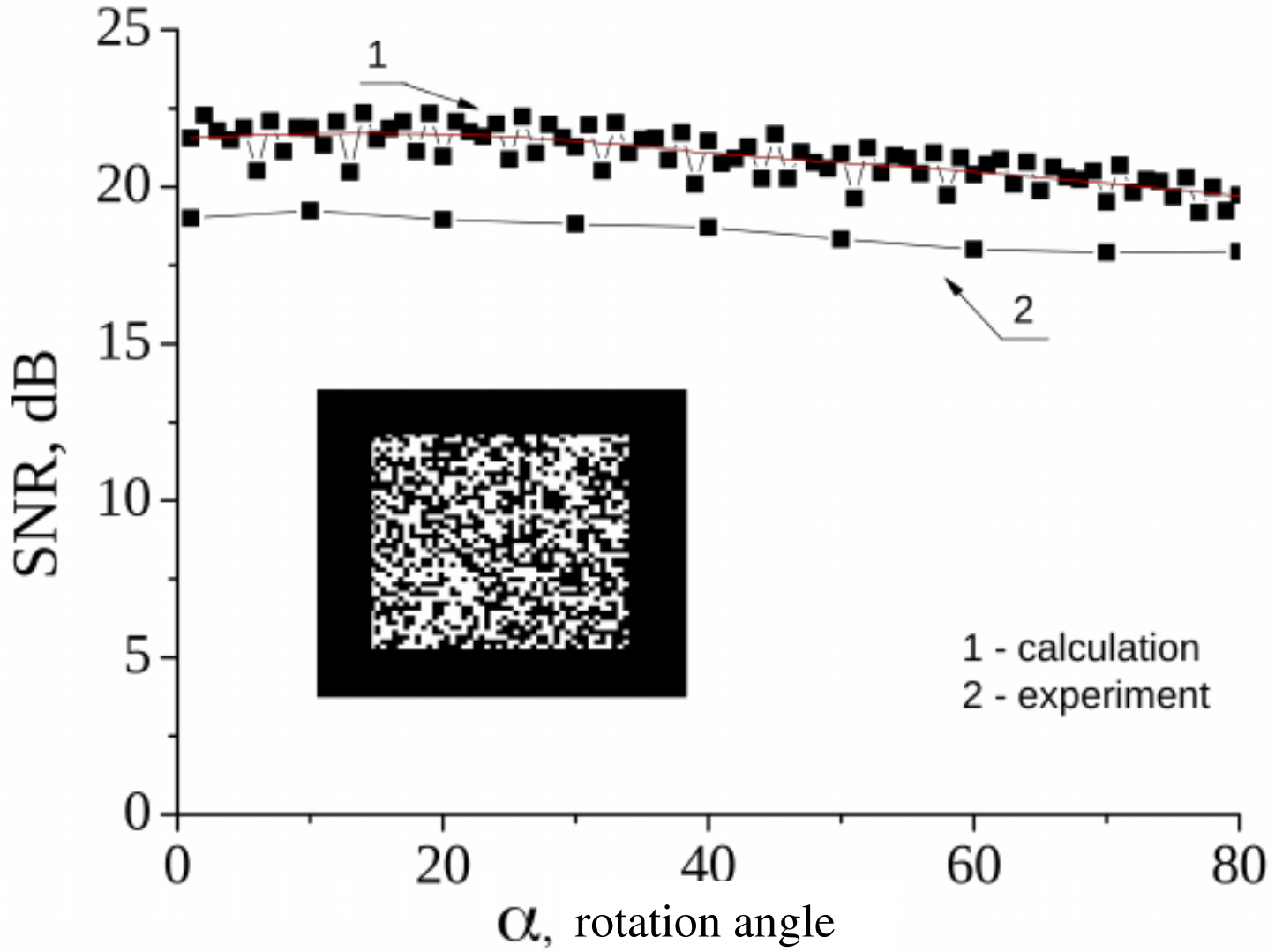
Rotation and scale invariant correlation

(experiment)



Rotation invariant correlation

(experiment)



Conclusions

Method of synthesized phase objects to solve the rotation invariant correlation for amplitude objects is proposed and experimentally investigated. It was shown that this method remains the basic advantages, namely:

i) It is shown that the solution of the problem for real objects belonging to various classes can be reduced under certain conditions to that of the problem of recognition of object-dependent SP-objects that belong to the same class of binary phase masks with random distribution of elements.

ii) Calculated and optical experiments in the joint Fourier-transform correlator indicated that this method allows to unify the shape of recognition signals by reducing it to the δ-like one and to improve SNR for correlation signals by 10-10^3 times.

iii) It was shown that the sensitivity of the proposed method to the distortions of the identified object structure is higher than that of the conventional method.

References

(2016 year only)

1.Yezhov, P. V., Ostroukh, A. P., Kim, J.-Tae. and Kuzmenko, A. V., “Method of synthesized phase objects in the optical pattern recognition problem” chapter in Book "Pattern Recognition", Book ed. by: Dr. S. Ramakrishnan: In Tech ISBN 978-953-51-4896-8, (2016).

2. P. Ostroukh, P.V. Yezhov, Jin-Tae Kim, and A.V. Kuzmenko, “ Method of synthesized phase objects for Fourier-Mellin invariant pattern recognition”, Proc. IEEE in the 7th International Conference on Advanced Optoelectronics and Lasers (*CAOL*2016*), Odessa, Ukraine, September 12 - 15, 2016.