European Science Foundation

Standing committee for Physical and Engineering Sciences (PESC)

ESF PESC Exploratory Workshop

IMAGING AT THE LIMITS

Scientific Report

Cargèse, Corsica, France

5-11 September 2004

Convened by

Claude Fabre[1], Alessandra Gatti[2], Agnès Maître[1], Alexander Sergienko[3]

[1] Laboratoire Kastler Brossel, Ecole Normale et Université Pierre et Marie Curie, France

[2]INFM, Dipartimento di Scienze Chimiche, Fisiche e Matematiche, Como, Italy

[3] Department of Electrical & Computer Engineering and Department of Physics, Boston University, USA

Executive summary

The event was financially supported by the European Physical Society (QEOD division), the European Research Office of the U.S. Army Research Laboratory, and the European Science Foundation. The conference organisation could benefit of one EPS "young physicist grant". The workshop got the EPS label and was recognized by the Société Française d'Optique. It was organized in the Institut d'Etudes Scientifiques de Cargèse, the French CNRS conference center in Corsica.

The conference was convened by Claude Fabre (Laboratoire Kastler Brossel, Université Pierre et Marie Curie, Paris, France), Alessandra Gatti (INFM, Como, Italy), Alexander Sergienko (Department of Electrical & Computer Engineering and Department of Physics, Boston University, USA), Agnès Maître (Laboratoire Kastler Brossel, Université Paris VII Denis Diderot, Paris, France).
The international scientific committee included the following members: H. Bachor (Canberra), R. Boyd (Rochester), C. Fabre (Paris), R. Frey (Orsay), A. Gatti (Como), M. Kolobov (Lille), E. Lantz (Besançon), L. Lugiato (Como), A. Maître (Paris), G-L. Oppo (Strathclyde), A.V. Sergienko (Boston), J.P. Torres (Barcelona), R. Frey (Orsay)

The workshop focused on quantum imaging and transverse high resolution measurement in optics. Quantum imaging is a novel area of research at the border of quantum mechanics and optics focusing on spatial aspects of quantum fluctuations of light. It brings the conceptual, theoretical, and experimental arsenal of quantum optics tools into the domain of image processing. It is benefiting from intrinsic parallelism of quantum entanglement to transport information on multiple channels below the quantum noise level. In addition to fundamental applications in the field of quantum information, the reduction of the transverse noise in a beam of light opens the way to high-precision transverse measurements.

The aim of the workshop was to present an overview on the emerging field of quantum imaging and to reflect its close connection with the best techniques developed in classical optics for high-precision and high-resolution spatial measurements, encryption, and optical duplication. The main workshop objective was to bring together experts in quantum optics of noise and entanglement and the classical optics specialists pushing the limits of high precision and sensitivity optical measurements using "classical light". The objective was the appearance of novel ideas in the field of spatial optical measurements and quantum information at the frontier between the classical and quantum optics.

The program sessions were divided in tutorials (usually 50 minutes), invited talks (35 minutes) and contributed talks (25 minutes). Two poster sessions were organized. The tutorial speakers were encouraged to have very pedagogical talks in order to introduce the subject for non-specialist people and to encourage the discussions between the two scientific communities. The conference counted 15 tutorials, corresponding to the "classical" contributions (9) or introducing all the subjects in the quantum feature(6). Those tutorials speakers were invited at the all beginning of the conference organization process.

The program covered 13 different topics. The longest session included one tutorial, three invited talks and three contributed. The smallest session just consisted in one tutorial. When it was possible, tutorials on the quantum field were associated with tutorials on the corresponding classical subject.
The different sessions pertained to noise, spatial squeezing and correlation, spatial entanglement, quantum information, solitons and vortex, optical storage, image amplification, high resolution imaging, superresolution, orbital angular momentum, adaptive optics, microscopy and optical coherence tomography, lithography.

The program included large lunch breaks which were very fruitful for discussion.
After request of the participants, all the presentations have been put on our website
http://quantim.dipscfm.uninsubria.it/quantim/cargese/

Scientific content

Most of the scientific information can be found in the one page summaries which are attached to this document. The following lines, just present the mains topics and the highlights of each session

Session 1: Noise
This first session comprised two tutorials. Claude Fabre, the first speaker of the workshop introduced the general concept of noise in quantum optics. As a coordinator of the European Quantim network devoted to the study of quantum images, he presented a general overview of the topic and the state of art. Finally he exposed the historical background of the workshop: dissemination of knowledge and the organisation of a conference belonged to the Quantim network objective. In the second tutorial (wednesday morning), Philippe Refregier explained how information can be classically extracted from a noisy image.

Session 2: Spatial squeezing and correlations
Luigi Lugiato opened this session with a tutorial including an historical introduction : the pioneering studies on quantum images (15 years ago) pertained to spatial squeezing and spatial correlations. He introduced not only this session but also the "spatial entanglement and entangled imaging" session (Tuesday, session 5).
The following talk was an invited one given by Ottavia Jedrkiewicz, on the first experimental observation of quantum correlation in parametric down conversion. The authors of the three contributed talks of the session, explained how noise reduction can be obtained by using diode laser or by parametric down conversion with application to contour recognition (Pere Colet)

Session 3: High resolution imaging
The authors of this session have exposed how ultrahigh resolution imaging can be performed by using classical or quantum means. The session was divided in two parts: in the first part (Monday) Gerd Leuchs explained that a subwavelength focal point can be obtained

using classical polarized light. In the second part (thursday), Hans Bachor and Nicolas Treps showed that a non classical light beam can be used to perform to beam displacement measurement with a sensitivity non limited by shot noise.

Session 4: Super resolution

Super resolution is an important topic in conventional imaging. The two tutorials of the session (monday) presented two complementary approaches, one classical and one quantum. When an object is imaged on a plane, due to the finite size and the quality of the imaging elements, diffraction blurs the image. The quality of the image is thus limited. Resolution in the image plane can be improved either by classical means (Peter Török) or by quantum means (Mikhail Kolobov).

Session 5: quantum imaging and quantum entanglement

The so called « Ghost Imaging » belongs to the first item studied by the "quantum imaging" pioneering groups in the mid ninethies. They used parametric down conversion in the counting regime to generate entangled pairs of photons (signal and idler). They used to put in the signal beam an object and to detect its transmitted intensity with a bucket detector, which didn't have any spatial resolution and could only measure the whole transmitted intensity of the signal. In the idler arm, they put just a multipixel detector having spatial resolution but no object. The setup didn't give access to the direct detection of the object by using just an arm (signal or idler): there wasn't any object in the idler arm and in the signal arm the detector didn't have any spatial resolution. Surprisingly, the coincidence (detection at the same time of one photon in the signal and one photon in the idler arm) permitted the retrieving of the object. This striking result was understood as a consequence of the entanglement between signal and idler.

In the last two years, Ghost imaging was largely discussed again. It has been showed that experiments similar to "ghost imaging" in the photon counting regime, could also been performed in the continuous wave regime (large number of photons). Recently, Robert Boyd performed an experiment showing the "ghost imaging experiment" could be micmic with classical light ginving the same results with two classically correlated beams. The assertion that "ghost imaging " didn't rely on entanglement and didn't express any quantum manifestation was largely discussed lately and during the workshop. The theoretical proof of the non-classicity of ghost imaging has been given by the group of Luigi Lugiato and Alessandra Gatti in Como.

The session reflected these various discussions; first a tutorial given by B.E. Saleh one of the father of the "ghost imaging" 10 years ago exposed the former and present context of those experiments. Then Bod Boyd presented an invited paper on experimental "ghost imaging" with classical light. Finally some contributed papers discussed experimental quantum entanglement in imaging. The group of Como presented a theoretical paper on a"ghost imaging experiment" using classical thermal light.

Large discussions have occurred during the workshop. A large part of the community has finally been convinced that "ghost imaging" was not a manifestation of quantum entanglement.

Session 6 : Adaptive optics

In the tutorial of this session, Carl Paterson exposed the striking resolution in imaging that can be achieved using classical adaptive optics. Those techniques received a large interest in the quantum community. Some of the groups are considering to apply some of the tools used in transverse quantum optics to push the extreme resolution obtained in adaptive to its ultimate limits.

Session 7 : Lithography

This short session counted two tutorials. In the first one, Mark Levenson explained the state of art in lithography and the objectives of such technologies for the next years. In the second one, Jonathan Dowlings explained how quantum optics can be used to improve the performance of lithography. In particular, he raised the possibility to use entangled beams generated by parametric interactions to decrease the minimum etching size.

Session 8 : Quantum information

Most of the protocols in quantum information can be extended to the multimode case and in particular to the transverse multimode operation. Ivan Sokolov in its invited talk presented a scheme for teleportation of images. Andrew White explained how spatial modes (Gaussian modes) can be used as qudits for quantum information. the motivations of his work was that entangled qudits provide more security than qubits (Qubits in a two dimensional space are equivalent to qudits in a higher dimensional space).

Session 9 : Solitons, Vortex

Solitons and vortex are in quantum optics directly connected to quantum information topics: they can be used as transverse bits of information, as expressed in the conclusion of the tutorial in the introduction devoted to vortex and solitons in classical optics. In the tutorial Gabriel Molina-Terriza explained then how solitons and vortex can be used as quantum information vectors. In the first contributed paper, vortex as tools for quantum information were further explored. The second contributed paper exposed the quantum features of domain walls and cavity solitons.

Session 10 : Orbital angular momentum

The whole Thursday morning was devoted to orbital angular momentum (one tutorial, three invited papers and two contributed). Orbital angular momentum is a quantum invariant in parametric down conversion. For a few years, it has benefited from a very large interest in the transverse quantum optics community. In quantum information, the two components of polarization, or of the coupled variables of phase and intensity are usually used. The associated Hilbert space dimension is limited to two, which limits the number of quantum information which can be expressed. With orbital angular momentum, carried by Laguerre-Gaussian beams, the dimension of the associated Hilbert space is infinite. Orbital angular momentum may open to new roads for high density coding of quantum information.

Steve Barnett in its tutorial introduced the orbital angular momentum for light which is associated with its phase spatial structure (polarisation of light can be expressed as its spin angular momentum). He explained how in non linear interaction orbital angular momentums can be entangled and use as qudits. He developed an uncertainty relation between orbital angular momentum and angle observables leading to new quantum communication devices.

Most of the following talks exposed experimental realisations of orbital angular momentum conservation in parametric conversion. The two last talks (group of H. Woerdman) extended these concepts to the definition of non integer orbital angular momentum states and to its realisation in a quantum "ghost" imaging experiment (session 5).

Session 11 : Optical storage

High density data storage represents a major challenge for opticians. Nowadays the diffraction limit for the size of the focal point is about to be reached and other strategies for maximizing the number of stored information have to be found.

In its tutorial, Joseph Braat made an overview of the state of the art in data storage. He presented the techniques developed for increasing the density like using UV light or by immersion of the media. In the best systems, some source of noise are very close to become the limit to their performances. He finally introduced the work of the SLAM European network (IST) on density increase in optical recording that was carried during the years 2001-2004.

In the contributed paper of the session, orbital angular momentum was presented as a way to encode multiple information in a single location and thus to increase the density of information stored in a media

Session 12 : Image amplification

This session was constituted with one tutorial and three contributed talks.

Classically an amplifier adds noise during the amplification process. From a quantum point of view, parametric interaction allows amplification without adding noise. Noiseless amplification has already been achieved in the single mode configuration. Amplification of images especially in the noiseless configuration has been much less studied. In its tutorial Eric Lantz explained the basis of parametric amplification of images. He first focussed on the classical amplification and explained then how noiseless amplification of images can be achieved.

The first contributed paper reports the experimental observation of noiseless amplification of images in a travelling wave configuration (optical parametric amplifier). The second paper reported amplification of images and quantum correlation in the optical parametric oscillator below threshold (cavity configuration). The last paper of the session presented the limits for which optical amplification of weak images is obtainable.

Session 13 : Microscopy and optical coherence tomography

The last session was dedicated to the best techniques in microscopy and optical coherence microscopy. It counted two tutorials and one contributed paper.

The first tutorial was presented by Olivier Haeberle who discussed the resolution limits in 3D fluorescence microscopy. For the moment the resolution is closed to 100nm. He showed that the ultimate resolution of the most advanced techniques (STED) should be a few nanometers in the far field.

In the second tutorial, Claude Boccara pesented different near field microscopy techniques (AFM, STM, SNOM, …). He showed that the best achievable resolution at the moment is about 10nm. He explained how these techniques could be extended to 3D imaging. Finally he presented the experimental setup and the performance of the 3D imaging system.

The last talk was the only quantum one in the session. Alexander Sergienko conclude this conference demonstrating that quantum optical tomography could be axially enhanced by usng a properly designed quasiphase matched material.

Assessments of the results, contribution to the future direction of the field

The audience in the workshop was broader than the usual quantum imaging community. More than one half of the participants were not completely implied in quantum imaging but were at that moment shifting to this topic, intending to do so or were just for the moment interested in it. One of the objectives of the meeting was to give the opportunity to scientists not involved yet in quantum imaging to get a better insight of this emerging field. The numerous tutorials were good introductions to the main sessions, making the more specialized invited or contributed talks accessible for all participants. Lot of fruitful discussions between people directly involved and people out of the field have occurred.
Another objective was to bring together experts in transverse quantum optics and experts in ultrahigh sensibility in classical spatial optics. The mixing between tutorials from the classical community and from the quantum one was very positive in this sense. Several collaborations between both communities have been discussed during the workshop. One is going to be put in concrete form with a European project proposal.
Inside the quantum community, new collaborations between overseas and European groups have been discussed. Inside Europe, groups outside the network Quantim, have expressed their interest for spatial studies. New alleys of research have been discussed. In particular the use of orbital angular momentum has been analysed as very promising as it opens the way to multidimensional quantum information.
In conclusion, the workshop has reached his main objectives: raising of new interests, initiating and committing new collaborations inside the quantum community and between the quantum and the classical ones, opening new roads of research in quantum imaging.

During the workshop several proposals for networks have been discussed
-The study of quantum entanglement in large parameter spaces appeared to be promising. The so called "quantum complexity" is one of the emerging projects in discussion. Its scientific area is quite broad: highly multimode quantum optics, hyperentanglement, optical angular momentum, quantum multimode adaptive optics, multivariate entanglement… This project may be submitted in the frame of the European FP6.
-Collaborations overseas have also been discussed; the US MURI project proposed "quantum imaging : new methods and applications". It involves US groups and three European groups, all of them attending the workshop.
-In the framework of the FP6 proposals, the "QUAESTUS" STREP FET open (QUantum Entanglement and non-classical States of photons for Ultra –Sensitive measurements involving several European and some American groups has been discussed
-the STREP project on optical data storage (Quantum optical retrieval of binary information contained in a wave length size media) is a good example of the collaborations starting

between groups from the classical community (Braat, Pereira, university of Delft) and groups from quantum community (Kolobov (Lille) or Fabre, Maître, Treps (Paris))

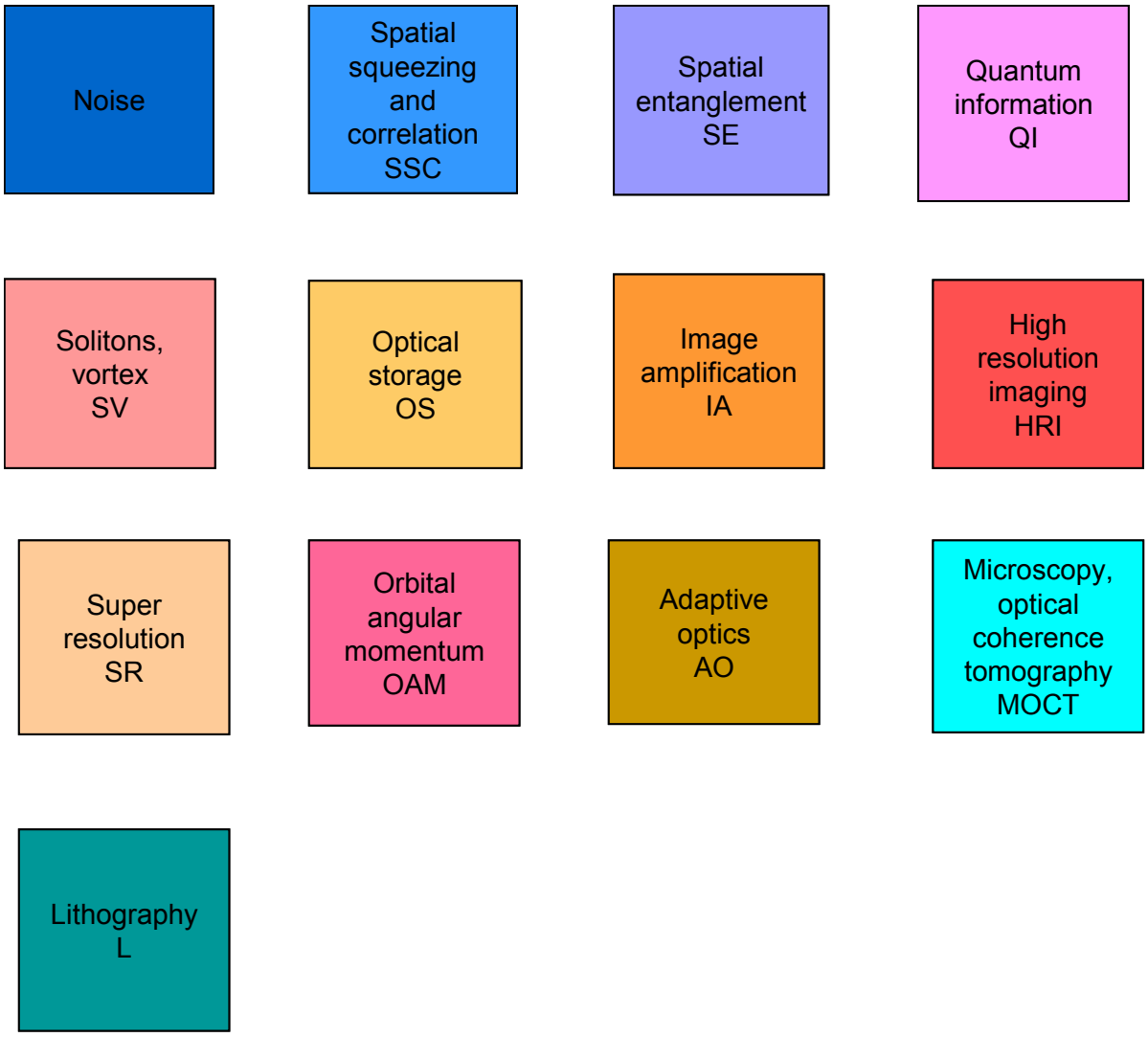
Statistical information on the participants

The total number of participants was 57. Just a third of those people was involved the European network Quantim, which initiated the conference. Apart of the 9 tutorials speakers on classical subjects and of the dozen persons involved for the long time in the subject but outside the Quantim community, the other people were either quite new in the field or were thinking in the future to focus on quantum imaging.
Three fourth of the participants were originated from Europe. Only 10% of the participants were women…

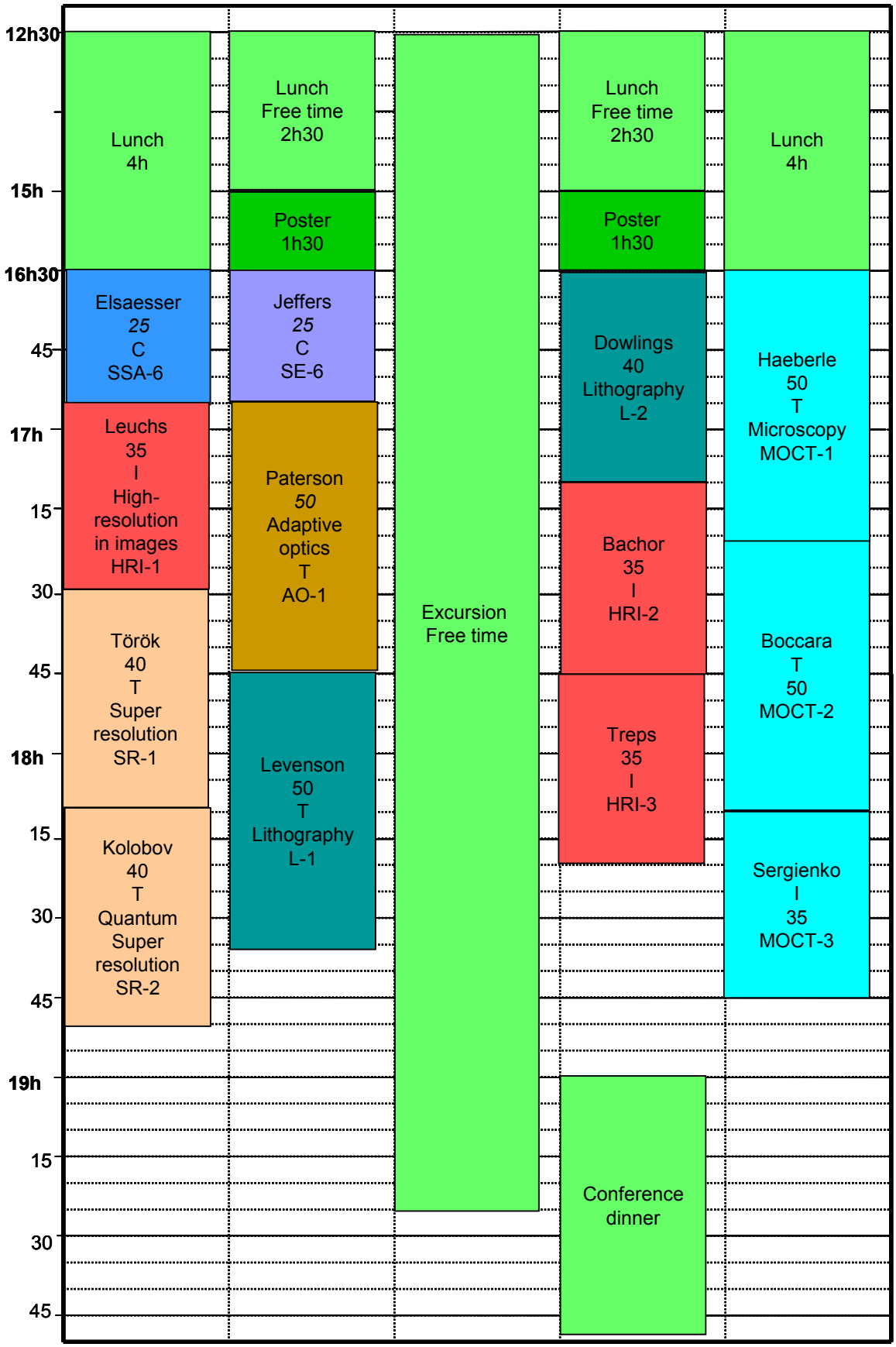
Origin of the participants

Country	N Attendees
AU	2
BR	4
BY	1
CZ	5
DE	4
DK	1
ES	3
FR	13
IT	4
JP	3
NL	4
RU	2
SE	1
UK	4
US	6
Total	57

Ratio Male/Female	
M	F
52	5


Noise
Spatial squeezing and correlation SSC
Spatial entanglement SE
Quantum information QI
Solitons, vortex SV
Optical storage OS
Image amplification IA
High resolution imaging HRI
Super resolution SR
Orbital angular momentum OAM
Adaptive optics AO
Microscopy, optical coherence tomography MOCT
Lithography L


8h30
45
9h
15
30
45
10h
15
30
45
11h
15
30
45
12h
15
30
Welcome
ESF
Fabre
35
Quantum
Noise
T
Noise-1
Lugiato
50
Spatial
Squeezing
And
correlations
T
SSC-1
Coffee break
30
Jedrkiewicz
35
I
SSC-2
Colet
25
C
SSC-3
Lassen
25
C
SSC-4
Saleh
50
Spatial
entanglement
and
entangled
imaging
T
SE-1
Boyd
35
I
SE-2
Coffee break
35
Souto
25
C
SE-3
Bache
25
C
SE-4
Padua
35
I
SE-5
Réfrégier
60
Noise and
information in
images
T
Noise-2
Ivan Sokolov
35
I
Quantum
information
QI-1
White
25
C
QI-2
Coffee break
25
Molina
Terriza
45
Solitons,
vortex
T
SV-1
Rehacek
25
C
SV-2
Jeffers
25
C
SV-3
Barnett 50
T
Orbital
angular
momentum
OAM-1
Barbosa
35
I
OAM-2
Khoury
35
I
OAM-3
Coffee break
30
Monken
25
C
OAM-4
Woerdman
35
I
OAM-5
Voigt
25
C
OAM-6
Braat
50
Optical
storage
T
OS-1
Van de Nes
25
C
OS-2
Lantz
50
T
Image
amplification
IA-1
Coffee break
30
Mosset
35
I
IA-2
Gigan
25
C
IA-3
Brustlein
25
C
IA-4


12h30
15h
16h30
17h
18h
19h
Lunch
4h
Lunch
Free time
2h30
Poster
1h30
Lunch
Free time
2h30
Poster
1h30
Lunch
4h
Elsaesser
25
C
SSA-6
Jeffers
25
C
SE-6
Dowlings
40
Lithography
L-2
Haeberle
50
T
Microscopy
MOCT-1
Leuchs
35
I
High-
resolution
in images
HRI-1
Paterson
50
Adaptive
optics
T
AO-1
Bachor
35
I
HRI-2
Boccara
T
50
MOCT-2
Török
40
T
Super
resolution
SR-1
Levenson
50
T
Lithography
L-1
Excursion
Free time
Treps
35
I
HRI-3
Kolobov
40
T
Quantum
Super
resolution
SR-2
Sergienko
I
35
MOCT-3
Conference
dinner

Participants

Igor Babushkin
:Institute of Physics, Academy of Sciences,
Skaryna ave. 70, 220072, Minsk, Belarus.
i.babushkin@dragon.bas-net.by
ibabushkin@mail.ru

Morten Bache
INFM, Dipartimento di Scienze Chimiche,
Fisiche e Matematiche,
Via Valleggio 11, 22100 Como, Italy.
morten.bache@uninsubria.it

Hans Bachor
ARC Centre of Excellence for Quantum-Atom Optics, Building 38
The Australian National University, Canberra ACT 0200
AUSTRALIA
hans.bachor@anu.edu.au

Gerardo Barbosa
Technological Institute Building, Northwestern University
2145 N. Sheridan Road, Evanston, IL 60208-3118, USA.
g-barbosa@northwestern.edu

Steve Barnett
Department of Physics, University of Strathclyde
107 Rottenrow, Glasgow, G4 0NG, Scotland, U.K.
steve@phys.strath.ac.uk

Claude Boccara
ESPCI
10 rue Vauquelin
75005 Paris, France
boccara@optique.espci.fr

Jan Bogdanski
Royal Institute of Technology (KTH) Stockholm
Electrum 229, SE-164 40 Kista
Sweden.
janbog@imit.kth.se

Zdenek Bouchal
Department of Optics
Palacky University
17. listopadu 50
772 00 Olomouc
Czech Republic
Bouchal@optnw.upol.cz

Robert Boyd
The Institute of Optics, University of Rochester,
Rochester, NY 14627 USA
boyd@optics.rochester.edu

Joseph Braat
Optics Research Group, Department Imaging Science & Technology
Faculty of Applied Sciences, Delft University of Technology
PO Box 5046, 2600 GA Delft
The Netherlands
j.j.m.braat@TNW.tudelft.nl

Sophie Brustlein
Laboratoire d'Optique P.M. Duffieux Institut Femto ST
Université de Franche comté, route de Gray
25030 Besançon Cedex (France)
sophie.brustlein@univ-fcomte.fr

Anatoly S. Chirkin
Department of General Physics and Wave Processes
Lomonosov Moscow State University
Moscow 119992, Russia
aschirkin@pisem.net

Pere Colet
Instituto Mediterraneo de Estudios Avanzados (IMEDEA)
CSIC-UIB
Campus Universitat Illes Balears
E-07122 Palma de Mallorca, SPAIN
pere@imedea.uib.es

Fabrice Devaux
Laboratoire d'Optique P.M. Duffieux Institut Femto ST
Université de Franche comté
route de Gray
25030 Besançon Cedex (France)
fdevaux@univ-fcomte.fr

Jonathan Dowling
NASA JET PROPULSION LABORATORY,
California Institute of Technology
4800 Oak Grove Drive, Mail Stop 126-347
Pasadena, California 91109-8099
USA
Jonathan.P.Dowling@jpl.nasa.gov

Wolfgang Elsäßer
Institut of applied physics, Darmstadt University of technology
Schlossgartenstrasse 7, 64289 Darmstadt, Germany
elsaesser@physik.tu-darmstadt.de

Claude Fabre
Laboratoire Kastler Brossel
UPMC, case 74, 4 place Jussieu
75252 Paris cedex 05
France
fabre@spectro.jussieu.fr

Gil Fanjoux
Laboratoire d'Optique P.M. Duffieux Institut Femto ST
Université de Franche comté
route de Gray
25030 Besançon Cedex (France)
gil.fanjoux@univ-fcomte.fr

Naoki Fukutake
Nikon Corporation,
Japan
fukutake.naoki@nikon.co.jp

Alessandra Gatti
INFM, Dipartimento di Scienze Chimiche,
Fisiche e Matematiche,
Via Valleggio 11, 22100 Como, Italy.
Alessandra.Gatti@mi.infn.it

Sylvain Gigan
Laboratoire Kastler Brossel
UPMC, case 74, 4 place Jussieu
75252 Paris cedex 05
France
sylvain.gigan@spectro.jussieu.fr

Olivier Haeberlé
Groupe LabEI - Laboratoire MIPS
Universite de Haute-Alsace
IUT de Mulhouse, 61 rue Albert Camus
68093 Mulhouse Cedex
France
o.haeberle@uha.fr

Zdenek Hradil
Department of Optics
Palacky University
17. listopadu 50
772 00 Olomouc
Czech Republic
hradil@optics.upol.cz

Ottavia Jedrkiewicz
INFM, Dipartimento di Scienze Chimiche, Fisiche e Matematiche,
Via Valleggio 11, 22100 Como, Italy.
ottavia.jedrkiewicz@uninsubria.it

John Jeffers
Department of Physics, University of Strathclyde
107 Rottenrow, Glasgow, G4 0NG,
Scotland, U.K.
john@phys.strath.ac.uk

Miroslav Jezek
Department of Optics
Palacky University
17. listopadu 50
772 00 Olomouc
Czech Republic
jezek@optics.upol.cz

Yoshio Kawabe
Research Institute for Electronic Science
Hokkaido University, Sapporo, Japan 060-0812
kawabe@es.hokudai.ac.jp

Mikhail Kolobov
Laboratoire PhLAM
Université de Lille 1
Cité Scientifique, Bât P5
F-59655 Villeneuve d'Ascq Cedex
FRANCE
mikhail.kolobov@univ-lille1.fr

Eric Lantz
Laboratoire d'Optique P.M. Duffieux Institut Femto ST
U.M.R. 6174 CNRS/Université de Franche comté
route de Gray
25030 Besançon Cedex (France)
elantz@univ-fcomte.fr

Mikael Lassen
Department of Physics, DTU
Building 309
2800 Lyngby, DK
mlassen@fysik.dtu.dk

Gerd Leuchs
Lehrstuhl für Optik
Institut für Optik, Information und Photonik
Staudtstr. 7 / B2
D-91058 Erlangen, Germany
leuchs@physik.uni-erlangen.de

Marc Levenson
MD Levenson Consulting
Saratoga, CA 95070
USA
MUDDLE@aol.com

Luigi Lugiato
INFM, Dipartimento di Scienze Chimiche,
Fisiche e Matematiche,
Via Valleggio 11, 22100 Como, Italy
luigi.lugiato@uninsubria.it

Agnès Maître
Laboratoire Kastler Brossel
UPMC, case 74, 4 place Jussieu
75252 Paris cedex 05
France
maitre@spectro.jussieu.fr

Yevhen Miroshnychenko
Institut fuer Angewandte Physik
Universitaet Bonn
Wegelerstrasse 8
53115 Bonn
Germany
miroshny@iap.uni-bonn.de

Gabriel Molina Terriza
Institut de Ciencies Fotoniques
Nexus-II Building
C/Jordi Girona, 29-1D
08034 - Barcelona
Spain
gabriel.molina@upc.es

Carlos Monken
Departamento de Fisica, Universidade
Federal de Minas Gerais, Caixa Postal 702,
30123-970 Belo Horizonte-MG, Brazil.
monken@fisica.ufmg.br

Alexis MOSSET
Laboratoire d'Optique P.M. Duffieux Institut Femto ST
U.M.R. 6174 CNRS/Université de Franche comté
route de Gray
25030 Besançon Cedex (France)
alexis.mosset@univ-fcomte.fr

Arthur van de Nes
Optics Research Group
Delft University of Technology
Lorentzweg 1, 2628 CJ, Delft
The Netherlands
A.vandeNes@tnw.tudelft.nl

Sebastiao Padua
Departamento de Fisica, Universidade
Federal de Minas Gerais, Caixa Postal 702,
30123-970 Belo Horizonte-MG, Brazil.
spadua@fisica.ufmg.br

Carl Paterson
Physics Department (Blackett Laboratory)
Imperial College, London SW7 2BZ
UK
carl@imperial.ac.uk

Vlasta Perinova
Department of Optics
Palacky University
17. listopadu 50
772 00 Olomouc
Czech Republic
perinova@optnw.upol.cz

Philippe Réfrégier
Institut Fresnel
EGIM NORD
Dom Univ. de St. Jérôme
13397 Marseille Cedex 20
philippe.refregier@fresnel.fr

Jaroslav Rehacek
Department of Optics
Palacky University
17. listopadu 50
772 00 Olomouc
Czech Republic
rehacek@phoenix.inf.upol.cz

B.E. Saleh
Quantum Imaging Laboratory
Department of Electrical & Computer Engineering and Department of Physics
8 Saint Mary's street,
Boston University, Boston,
02215 Massachusetts, USA
besaleh@bu.edu

Alexander Sergienko
Quantum Imaging Laboratory
Department of Electrical & Computer Engineering and Department of Physics
Boston University, Boston, 02215 Massachusetts, USA
carrasco@bu.edu

Ivan V. Sokolov
V.A.Fock Physics Institute,
St. Petersburg State University,
Russia
sokolov@is2968.spb.edu

Paulo Souto Ribeiro
Laboratório de Óptica Quântica
Instituto de Física
Universidade Federale de Rio de Janeiro
Rio de Janeiro
CP 68528 - CEP 21941-972
Brasil
phsr@pop.if.ufrj.br

Peter Török
Physics Department (Blackett Laboratory)
Imperial College, London SW7 2BZ
UK
peter.torok at imperial.ac.uk

Nicolas Treps
Laboratoire Kastler Brossel
UPMC, case 74, 4 place Jussieu
75252 Paris cedex 05
France
nicolas.treps@spectro.jussieu.fr

German J de Valcarcel
Departament d'Optica
Universitat de Valencia
Dr. Moliner 50
46100-Burjassot
Spain
German.Valcarcel@uv.es

Dirk Voigt
Leiden Institute of Physics
Leiden University
P.O. Box 9504
2300 RA Leiden
The Netherlands
dirk@molphys.leidenuniv.nl

Andreas Volkmer,
3. Institute of Physics, University of Stuttgart
Pfaffenwaldring 57
70550 Stuttgart
Germany
a.volkmer@physik.uni-stuttgart.de

Andrew White
Department of Physics,
University of Queensland,
Brisbane, QLD, 4072, Australia
andrew@mail.physics.uq.edu.au

J.P. Woerdman
Leiden Institute of Physics
Leiden University
P.O. Box 9504
2300 RA Leiden
The Netherlands
woerdman@molphys.leidenuniv.nl (qo@molphys.leidenuniv.nl)

Antonio Zelaquett Khoury
Instituto de Fisica - Universidade Federal Fluminense
Av. Gal. Milton Tavares de Souza S/N
Niteroi - RJ - 24210-340 - BRAZIL
khoury@if.uff.br

Haizhen Zhao
The university of Electro-Communications
1-5-1 Chofugaoka, Chofu, Tokyo 182-8585
Japan
haizhen@almas.co.jp