PASSION FOR LIGHT

JOINT EPS-SIF INTERNATIONAL WORKSHOP

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VILLA MONASTERO
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Passion for precision

Theodor W. Hänsch
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The simple Balmer spectrum of atomic hydrogen has provided the Rosetta stone for deciphering the strange laws of quantum physics during the early 20th century. Four decades ago, Doppler-free laser spectroscopy opened a new chapter in the exploration of hydrogen. The pursuit of ever higher resolution and measurement accuracy has inspired many experimental advances, from laser cooling of atomic gases to the laser frequency comb technique for measuring the frequency of light. Today, precision spectroscopy of hydrogen is reaching a precision of 15 decimal digits. However, the determination of fundamental constants and experimental tests of fundamental physics laws are now hindered by our insufficient knowledge of the rms charge radius of the proton. Recently, a laser measurement of the 2S-2P Lamb shift of muonic hydrogen has yielded an independent precise new value of the proton radius which differs by five old standard deviations from the official CODATA value. This discrepancy is subject of intense current discussions. It may be caused by a mistake, or it may indicate a dent in the armor of quantum electrodynamic theory.

From 1885 to 2011 and beyond: the story of the X-ray vision

Francesco Sette
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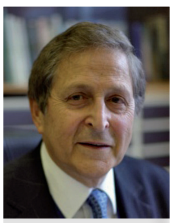
The discovery of X-rays in 1885 by Wilhelm Conrad Röntgen on 8 of November 1885 has added a new dimension to image our world. Since then, a tremendous scientific and technological progress took place, which allowed X-rays to let us understand where atoms are and how they move in condensed matter, materials and living matter. The observation of synchrotron radiation, and its use since the 1970s as the prime source of intense, collimated, polarized, highly monochromatic, tunable X-ray radiation created from accelerated relativistic charged particles, has again revolutionized our ability to picture the architecture of our everyday world at the level of the single atom properties. Today a new revolution is taking place with the production of laser-like X-ray radiation with pulse-lengths comparable to inter-atomic motion times, and X-ray images of atoms will soon become X-ray movies.



Manipulating atoms with light

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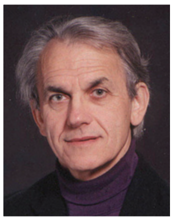
Understanding the nature of light and its interactions with matter has always been a challenge for physics. New concepts have emerged from these investigations, such as the quantum nature of the microscopic world and the wave-particle duality. The light emitted or absorbed by atoms is not only a valuable source of information on the structure of the world which surrounds us. It is also a powerful tool for acting on atoms, for manipulating them, for controlling their various degrees of freedom. It will be shown how it is possible to use the basic conservation laws in atom-photon interactions for polarizing atoms, for cooling them to very low temperatures, in the microkelvin, and even in the nanokelvin range. A review will be given of recent developments in this field, including ultra-precise atomic clocks, with errors less than one second in one billion years, the realization of new states of matter such as Bose-Einstein condensates, matter waves and atom lasers. New perspectives opened by these results will be briefly discussed.



Extreme light: testing the primordial imponderable matter, the vacuum

Gérard Mourou
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Fifty years, ago Peter Franken showed for the first time that the laser field was capable to distort the atomic potential by producing the laser second harmonic. This demonstration heralded the field of bound electron nonlinear optics. Twenty years ago the laser field became strong enough to accelerate electrons to the speed of light during one period of light, opening the field of relativistic nonlinear optics, the lynch pin of important potential applications in high energy radiation and particle sources. Today the laser achievable intensity and field are such that we are ready to go to the next step in our journey through laser–matter interaction. Several extreme light lasers in the exawatt regime are in the planning stage, namely the European Infrastructure, ELI and the Russian Exawatt. Their predicted intensity is such, they will enable to fulfill a long standing dream formulated since the early sixties, only few years after the first laser demonstration namely: the study of laser interaction with the vacuum, our primordial imponderable material.

Symmetries, simplicity and fundamental laws

Luciano Maiani
Università di Roma La Sapienza, Italy

The complexity of macroscopic phenomena finds its explanation in the laws obeyed by the elementary constituents, the "seeds of things" first guessed by the Greek natural philosophers, 500 years b.C.. It is at this level that the imperfections of the objects of our everyday life is resolved by simple laws and a surprisingly high degree of symmetry. Exploration of the structure of subnuclear matter has indeed revealed a remarkably simple structure of particles and forces known as the "Standard Theory", experimentally tested in depth at the end of the Century. Simplicity is also reached in another limit, that of the critical cooperative phenomena, where "more" rather than "smaller" makes the difference. Finally, a most surprising development of our times is the connection of small-scale phenomena to the large-scale structure of the Universe, a trace of the primordial Big Bang. Thus, present physics can be said to be the search of three related infinities: small, large and many. I shall review the path which led to the Standard Theory, the open problems being tackled with the Large Hadron Collider and the, admittedly less familiar to me, relations with the other two infinities.

Light: wave particle duality from Newton to quantum optics

Peter Knight
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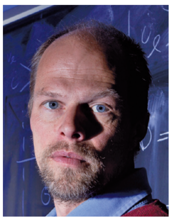
Attempts to understand the nature of light have been central to the historical development of physics. Although understanding the duality of wave and particle challenges our classical intuition, one cannot escape asking hard questions on this issue, and indeed this subject was at the heart of Bohr-Einstein debate in the early years of the 20th century. The emergence of quantum optics and especially studies of the nature of nonclassical light and its exploitation in quantum computing and quantum cryptography have put this back at the heart of current physics. This talk will review the historical development of wave particle duality, discuss its central place in the modern theory of quantum optics, and consider implications of the subject for current and future research in quantum information science.

Nanoscopium nominare libuit: microscopy towards optical nanoscopy

Alberto Diaspro
Università di Genova & IIT, Italy

Since the early years of the Galileo Galilei's "Occhialino" - " un occhialino per veder da vicino le cose minime" - brillantly renamed "Microscopium" by Johannes Faber (1574-1629), it was evident the potential of such an optical investigative tool. Even if the resolution of the optical microscope is limited by the wave nature of light, a new race for super resolution started 20 years ago with different approaches. Today, the modern viewpoint for super resolution moved from optical or computational solutions to the side of the object. Beam (targeted readout and point spread function shaping) and probe (stochastic readout and sparse sampling of single molecules) based approaches were developed allowing to reach an effective optical resolution of 7 nm and a precision localization of less than 5 nm. This authorizes the term Nanoscopy as demonstrated in this lecture that links the Galilei's invention with the Feynman's nanotechnolgical predictions. The lecture is dedicated to the memory of Giuliano Toraldo di Francia (1916-2011), developing pioneering concepts in the super resolution framework.



Trapping light fantastic

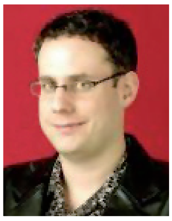
Diederik Wiersma
LENS and INO-CNR, Firenze, Italy

Sun light contains an enormous amount of energy and is provided to us freely every day. One square meter illuminated by the sun corresponds to about a kilowatt of energy. To harness this energy, at current state-of-the-art efficiencies, would already allow to supply the entire world with all its energy need, using a total surface equal to only one fourth of the size of the Sahara. Several strategies are being followed to improve the efficiency and reduce the cost of solar cells, applying sometimes surprisingly deep physical concepts like that of Anderson localization of light and trapping in plasmonic nano structures. I will give an overview of the current state-of-the-art, and discuss recent developments in this exciting field of research.

Cherenkov light: key to multi-messenger astronomy

Werner Hofmann
MPI für Kernphysik, Heidelberg, Germany

Modern multi-messenger astronomy - the observation in particular of high-energy phenomena in the Universe using a variety of messenger particles - has made rapid strides in the last decade, with detectors "imaging" very high energy gamma rays, neutrinos, and cosmic rays from cosmic sources. In many of the detection techniques, particle tracks are imaged using their Cherenkov light emission, providing large detection areas at (relatively) modest cost. The talk will address the history, the highlights, and the future challenges of this field.



The once and future Cosmic Microwave Background

Andrew Jaffe
Imperial College, London, UK

Measurements of the Cosmic Microwave Background (CMB) have proven to be the best way of determining cosmological parameters from observations combined with simple physical principles. I will discuss the formation of the CMB, the oldest light we observe, and how the pattern of its fluctuations is determined by those cosmological parameters. The Planck Surveyor has, for the past two years, been measuring the CMB over the whole sky with the highest sensitivity and the widest frequency coverage yet achieved. Although the Planck team will not be releasing its cosmological results until early 2013, the Planck data have already provided a wealth of information about the microwave sky, from observations of the structure of our galaxy to the properties of dusty galaxies in the nearby Universe, as well as the discovery of some of the most massive galaxy clusters yet observed. I will discuss these results and prospects for Planck's cosmological measurements as well as planned and proposed observations at still higher sensitivity from the ground, balloons and satellites.

Light and art: an indivisible relationship

Alessandro Farini
INO-CNR, Firenze, Italy

This talk is devoted to the close relationship between light and art. It is actually impossible to separate light from art and especially from painting and sculpture. First of all, light is intrinsic to a painting: one can think for example of Caravaggio's works of art, where light creates the scene also when it is painted in a non-realistic way, as in "The Calling of St Matthew". But light is also the instrument that permits to us to see artworks. Colors, but also volumes and spaces depend on the lighting degree. The recent introduction of Light Emitting Diodes (LEDs) in the lighting market is an important step forward, because it offers the opportunity to obtain different color temperatures and to change the dominant color in a very short amount of time. Some examples, using real contemporary artworks, are shown during the talk. Speaking about light and art offers also the opportunity to address a major topic: the relationship among light, an object and a human being seeing the object: this interrelation reveals the subjectivity and objectivity of our perception of light and colors.