Dwójłomność próżni
i techniki laserowe jej pomiaru

Uwagi na marginesie seminarium

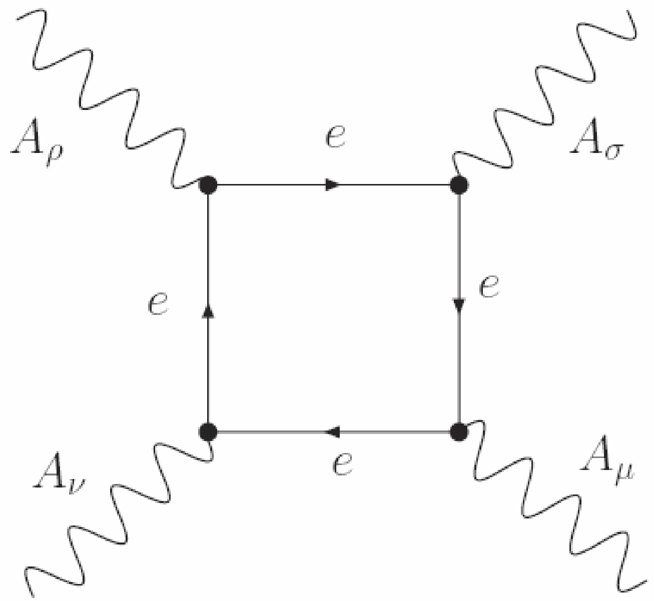
dot. dwójłomności i zastosowań laserów wysokiej mocy w badaniach podstawowych

Zbigniew Motyka

Lagrangian pola EM w EFT

Effective Field Theory – nieliniowe poprawki do r. Maxwella dla próżni

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{\alpha^2}{90m_e^4}\left[\left(F_{\mu\nu}F^{\mu\nu}\right)^2 + \frac{7}{4}\left(F_{\mu\nu}\tilde{F}^{\mu\nu}\right)^2\right]$$



Lagrangian Eulera-Heisenberga
(zewnętrzne pole magnetyczne)

diagram Feynmana
oddziaływań foton-foton
przez pętlę elektronową

$$\alpha = \frac{e^2}{\hbar c} \simeq 1/137$$

stała struktury subtelnej

Dwójłomność próżni

$$n_\perp = 1 + \frac{4}{2} \cdot \eta$$

$$\eta = \frac{\alpha}{45\pi} \frac{B^2}{B_{kr}^2} \sin^2 \theta$$

$$n_{||} = 1 + \frac{7}{2} \cdot \eta$$

$\theta = \sphericalangle (\underline{B} , \underline{k})$

$B_{kr} = m_e^2 / e$

OSQAR

2007 Optical Search for QED vacuum birefringence

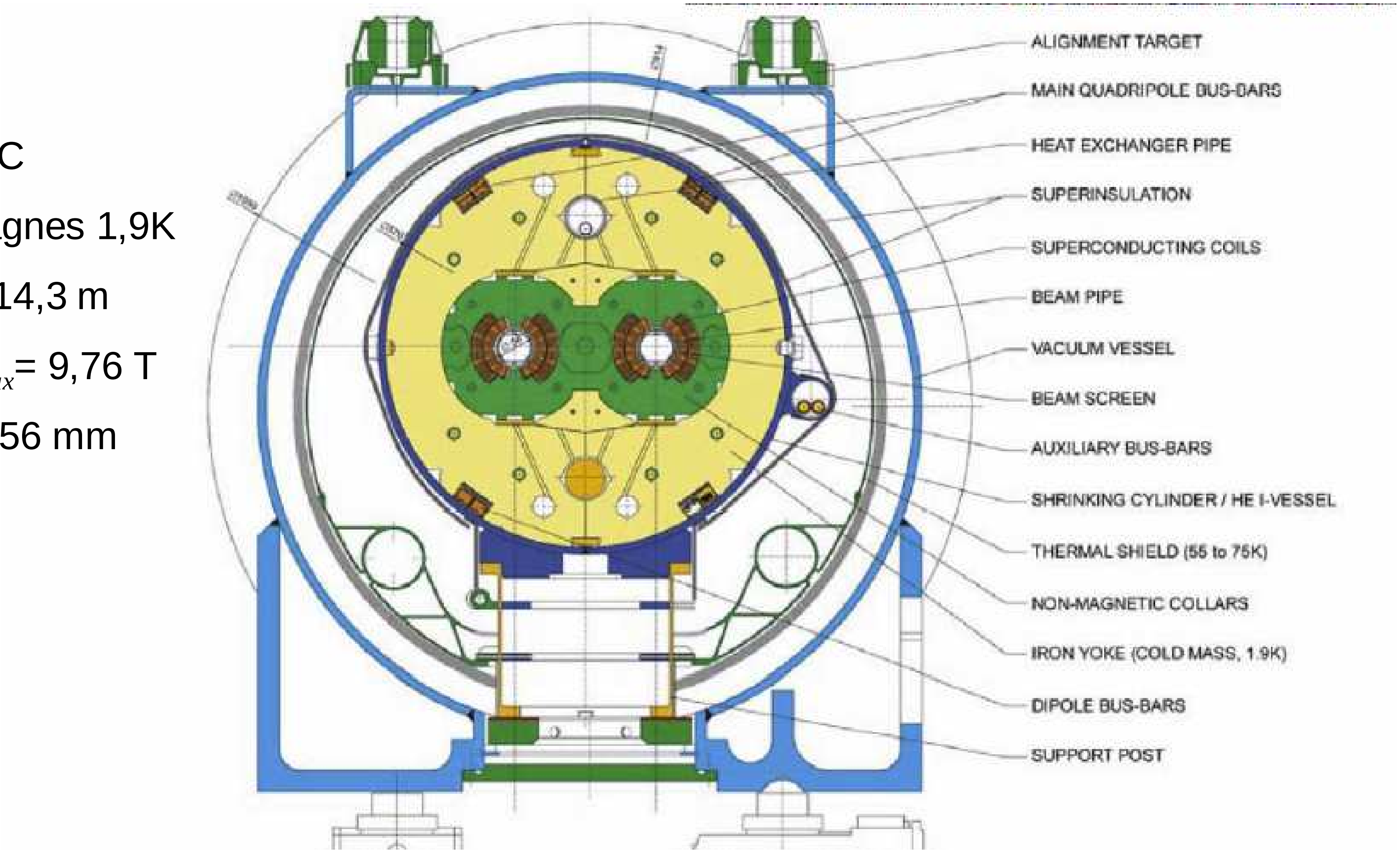
LHC

magnes 1,9K

L=14,3 m

B_{max}= 9,76 T

ϕ=56 mm



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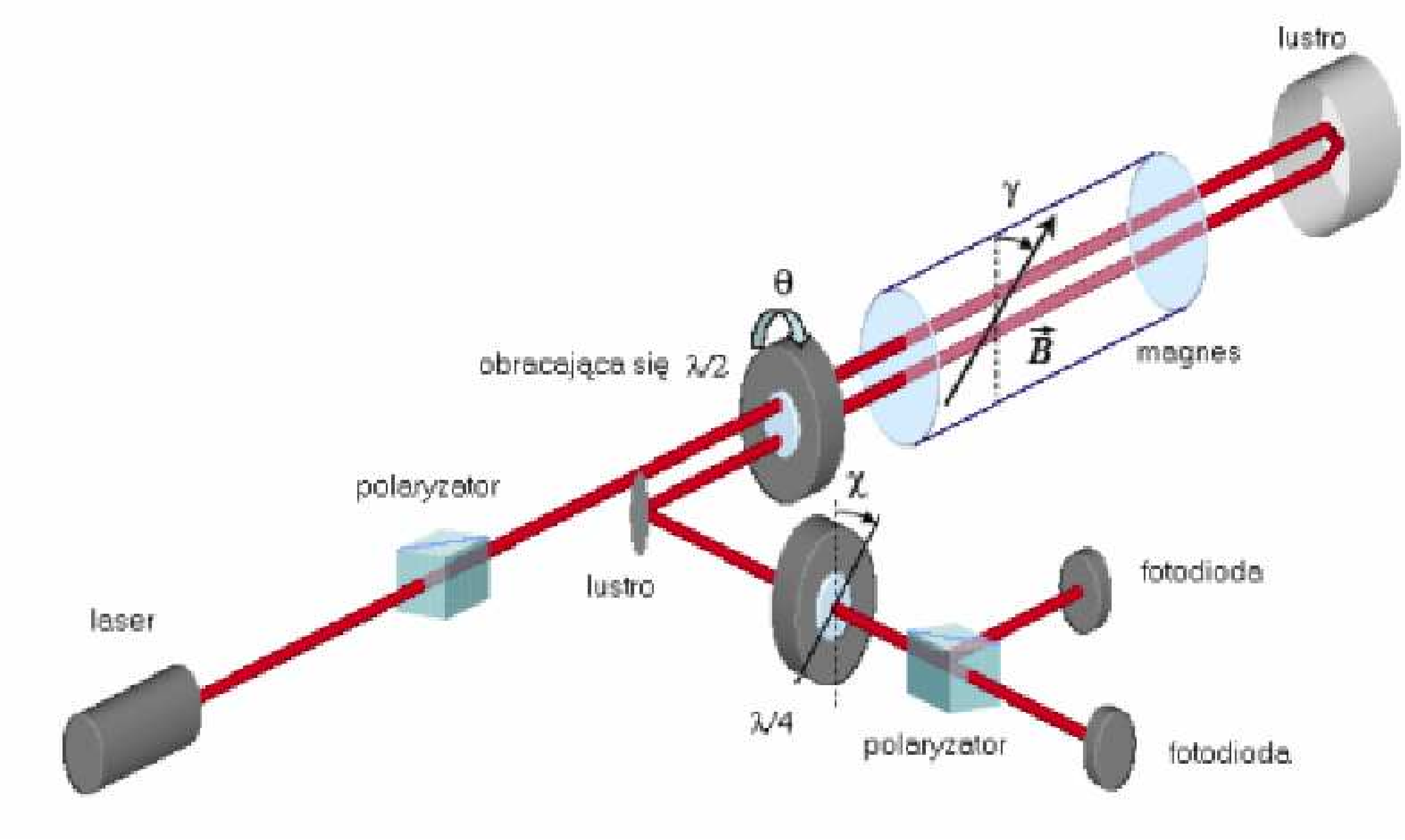
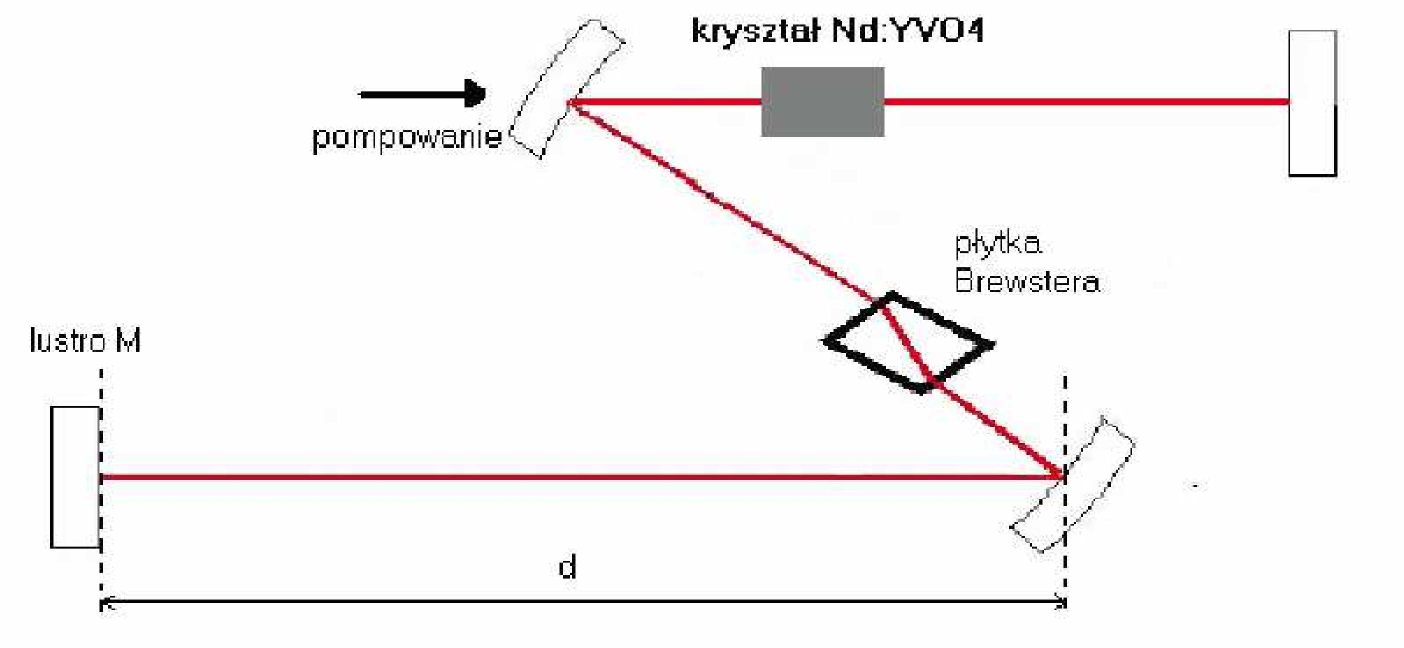

lustro
γ
θ
$\vec{B}$
obracająca się λ/2
magnes
polaryzator
χ
lustro
fotodioda
laser
λ/4
polaryzator
fotodioda

OSQAR



Laser Nd:YVO4 - Uniwersytet w Grenoble d=3m

Max. 10 kW λ = 1064 nm

Moc stabilna 150 W

OSQAR

Laser neodymowy itrowo-ortowanadowy $Nd:YVO_4$

Neodymium Doped Yttrium Orthvanadate(Nd:YVO4) Crystal

Compared with Nd:YAG and Nd:YLF for diode laser pumping, Nd:YVO4 lasers possess the advantages:

• lower dependency on pump wavelength and temperature control of a diode laser

• wide absorption band

• linearly polarized emission

• single-mode output.

Laser Nd:YVO4 - Uniwersytet w Grenoble

Max. 10 kW λ = 1064 nm
Moc stabilna 150 W

OSQAR

Laser Nd:YVO4

Lasing Wavelengths: 914nm, 1064 nm, 1342 nm

positive uniaxial, $n_o=n_a=n_b$, $n_e=n_c$,
$n_o=1.9573$, $n_e=2.1652$, @ 1064nm
$n_o=1.9721$, $n_e=2.1858$, @ 808nm
$n_o=2.0210$, $n_e=2.2560$, @ 532nm

Sellmeier Equation (for pure YVO4 crystals):

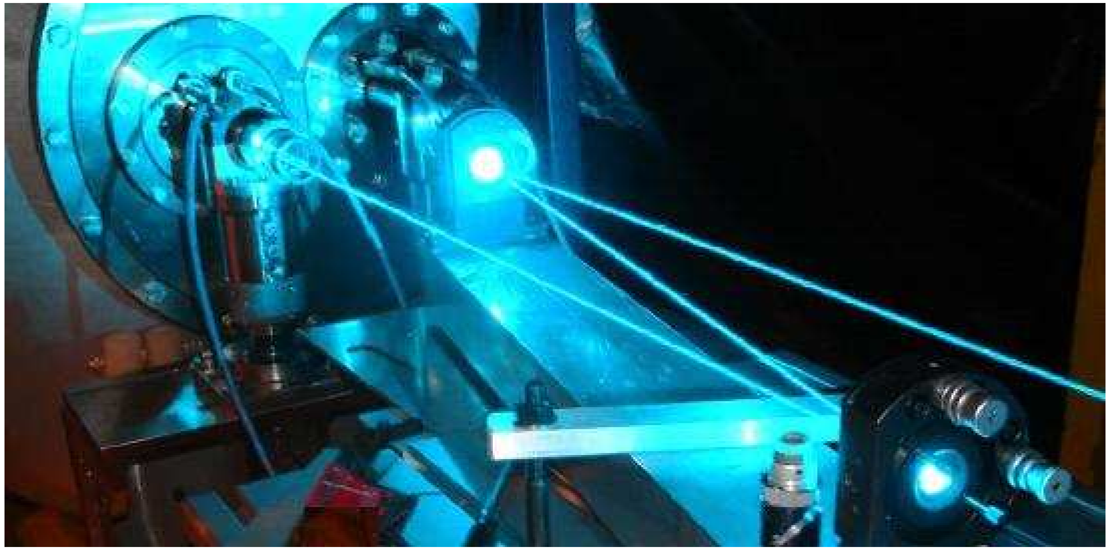
$$n_o^2=3.77834+0.069736/(\lambda^2 - 0.04724) - 0.0108133\lambda^2$$

$$n_e^2=4.59905+0.110534/(\lambda^2 - 0.04813) - 0.0122676\lambda^2$$

Polarized Laser Emission π polarization; parallel to optic axis (c-axis)

OSQAR

Wybrano alternatywny: (Ar+) 1 kW λ = 540 nm
Uzyskane początkowo: 18 W (2007)
W kolejnych próbach: kilkaset W (2007)



OSQAR 2007

niebieska	436-470
niebieskozielona	470-500
zielona	500-530

The light source used is an ionized argon (Ar+) laser which can deliver in multi-line mode up to 18 W of optical power. The optical beam is linearly polarized with a vertical orientation. To align the polarization of the light in the horizontal direction, a $\lambda/2$ wave-plate is inserted between the laser and the LHC dipole. It introduces an optical power loss of 20% at the laser wavelengths i.e. in the range 458-514 nm. The Ar+ laser was operated in multi-line mode with approximately 2/3 of the optical power at 514 nm (2.41 eV) and 1/3 at 488 nm (2.54 eV). Each of these atomic lines is made of about 50 equidistant longitudinal modes.

OSQAR


PR752
OSQAR
► Use of Class-4 laser
⇒ High risk to eyes and skin
⇒ Protection against direct beam, specular and diffuse reflections

OSQAR 2008

- OSQAR 2008 run was approved by the Research Board on 28 May 2008
  - Constraints:
    - Shutdown of the SM18 cryogenic infrastructure from July (lasted till end of September - longer than anticipated)
    - Test co-activities of LHC magnets & RF cavities
  - 2 spare LHC dipoles were connected to the OSQAR test benches & aligned; optimal configuration for the photon regeneration experiment was implemented
    - ► Laser beam was successfully aligned within apertures of both aligned LHC dipoles i.e. over 53 m long
    - ► No planned cold runs were performed in 2008
- Incident in the LHC tunnel in September 2008 has stopped the OSQAR experiments, in practice until June 2009
- The 2008 run is postponed till end of 2009
  - VMB: Ar+ Laser within 20-meter long extended cavity (in preparation)
  - Photon regeneration runs with two dipoles (in preparation)

OSQAR

MEMORANDUM 18-01-2010:

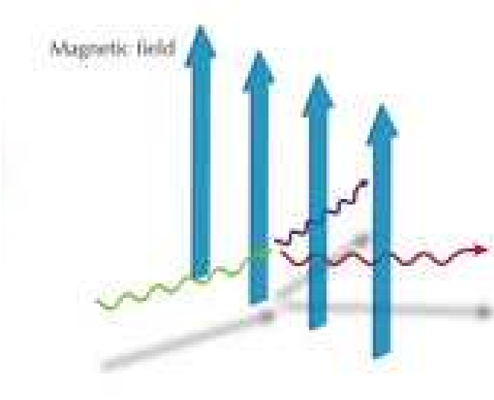
. Sensitivity approaching cosmological constraints

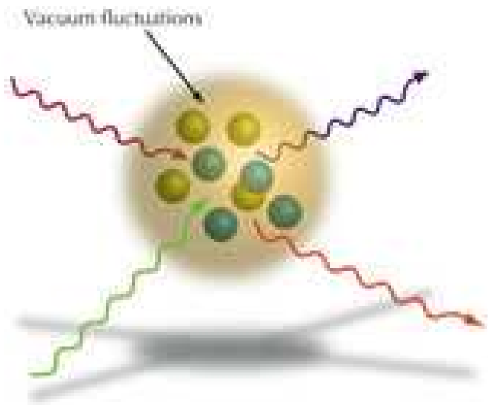
► 4th milestone - end of 2013 at the earliest

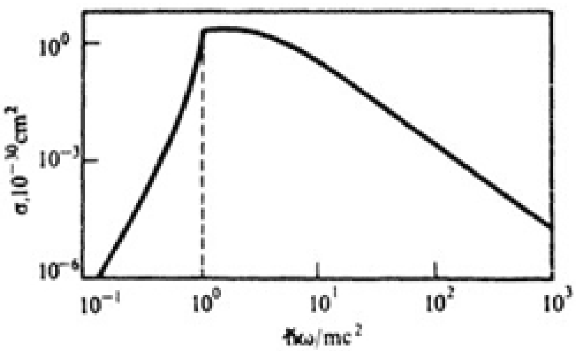
the revised program of OSQAR experiments.

ELI

Extreme Light Infrastructure European Project







cross-section for
photon-photon scattering
as a function of photon frequency

E. M. Lifshitz, L. P. Pitaevskii, and V. B. Berestetskii, Quantum Electrodynamics (Butterworth-Heinemann, 1982).

ELI

pan-European Laser facility

The facility, based on four sites, will be the first large scale infrastructure based on the Eastern part of the European Community and has obtained a **financial committment exceeding 700 M€.** The European Commission has recently signed the approval for funding the first ELI-pillar, located in the Czech Republic, with a budget of nearly 290 M€.

The first three sites will be situated in Prague (Czech Republic),
Szeged (Hungary) and Magurele (Romania)
and should be operational in 2015.

The fourth site will be selected in 2012 and is scheduled for commissioning in 2017.

ELI is a European Project, involving nearly 40 research and academic institutions from 13 EU Members Countries:

ELI

ELI's participation is managed by **Patrizio Antici**
ELI Coordinator: **Gérard Mourou**

Involved institutions:

Bulgaria
Sofia University, Sofia
Czech Republic
PALS, Praha
France
CEA-DRECAM-SPAM, Saclay
CPHT Centre de Physique Théorique de l'École Polytechnique, Palaiseau
Laboratoire d'Optique et Biosciences, Palaiseau
Laboratoire d'Utilisation des Lasers Intenses, Palaiseau
Laboratoire Leprince-Ringuet, Palaiseau
Laboratoire Charles Fabry de l'Institut d'Optique, Orsay
LIXAM Laboratoire d'Interation du rayonnement X Avec la Matière, Orsay
LOA Laboratoire d'Optique Appliquée, Palaiseau
Laboratoire des gaz et plasmas, Orsay
SOLEIL, Saclay

ELI

Germany

Friedrich Schiller Universität, Jena

Gesellschaft für Schwerionenforschung mbH, Darmstadt

Heinrich Heine Universitaet, Düsseldorf

LMU, Munich

MBI Max Born Institute, Berlin

Max Planck Institut für Quantenoptik, Garching

Greece

FORTH-IESL, Heraklion

Technical university of Crete

Hungary

University of Pécs, Pécs

Department of Optics, University of Szeged, Szeged

Research Institute for Solid State Physics and Optics, Budapest

KFKI Research Institute For Particle And Nuclear Physics

DDKKK

Italy

Istituto Nazionale di Fisica Nucleare - Sezione di Roma "La Sapienza", Roma
Politecnico di Milano, Milano
Universita di Pisa, Pisa

Lithuania

Laser Research Center, Vilnius

Poland

Instytut Optoelektroniki, Warszawa

Portugal

Instituto Superior Técnico, Lisbon

Romania

National Institute for Laser, Plasma and Radiation Physics, Bucharest

Spain

ICFO - Institute of Photonic Sciences, Barcelona
Universidad Complutense de Madrid, Madrid
University of Salamanca, Salamanca
Unversidad Politecnica de Madrid, Madrid

United Kingdom

Central Laser Facility, Didcot
Department of Physics, University of Strathclyde, Glasgow
Imperial College, London
Queen's University, Belfast

Literatura:

K. Homma i in. - *Probing vacuum birefringence by phase-contrast Fourier imaging under fields of high-intensity lasers*, arXiv 1104.0994 v.1, 06.04.2011

Andrzej Hryczuk – *Aksjony w teorii cząstek elem. i kosmologii* – praca mgr pod kier. prof. dr hab. Krzysztofa A. Meissnera, Inst. Fiz.Teor. UW

Pierre Pugnat (…) Krzysztof A. Meissner i in. *First results from the OSQAR photon regeneration experiment: No light shining through a wall*, arXiv:0712.3362 (2007)

The Extreme Light Infrastructure (ELI) European Project
The Quantum Vacuum and Quantum Dynamics
http://www.extreme-light-infrastructure.eu/High-field_5_2.php