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OSQAR Experiment
Optical Search for QED vacuum magnetic birefringence, Axions and photon Regeneration

Axion Search by Laser-based Experiment OSQAR

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on behalf of OSQAR collaboration

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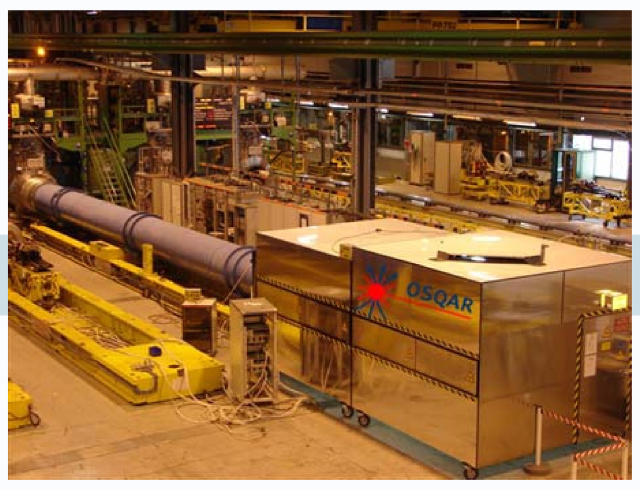
The **OSQAR** experiment

Optical **S**earch for **Q**ED vacuum magnetic birefringence, **A**xions and photon **R**egeneration

- purely laboratory laser-based experiment for search of axions and axion-like particles
- it focuses on precision measurements of the magnetic properties of the quantum vacuum using state-of-the-art superconducting decommissioned two LHC magnets at CERN
- it combines the simultaneous use of high magnetic field with laser beams in two distinct experiments
- the first one, the photon regeneration PR effect is looked as a “light shining through the wall”
- the second one, ultra-fine magnetic birefringence of the vacuum is aimed to be measured
- both experiments gives negative response till now but it can help to extend the exclusion region for axion mass

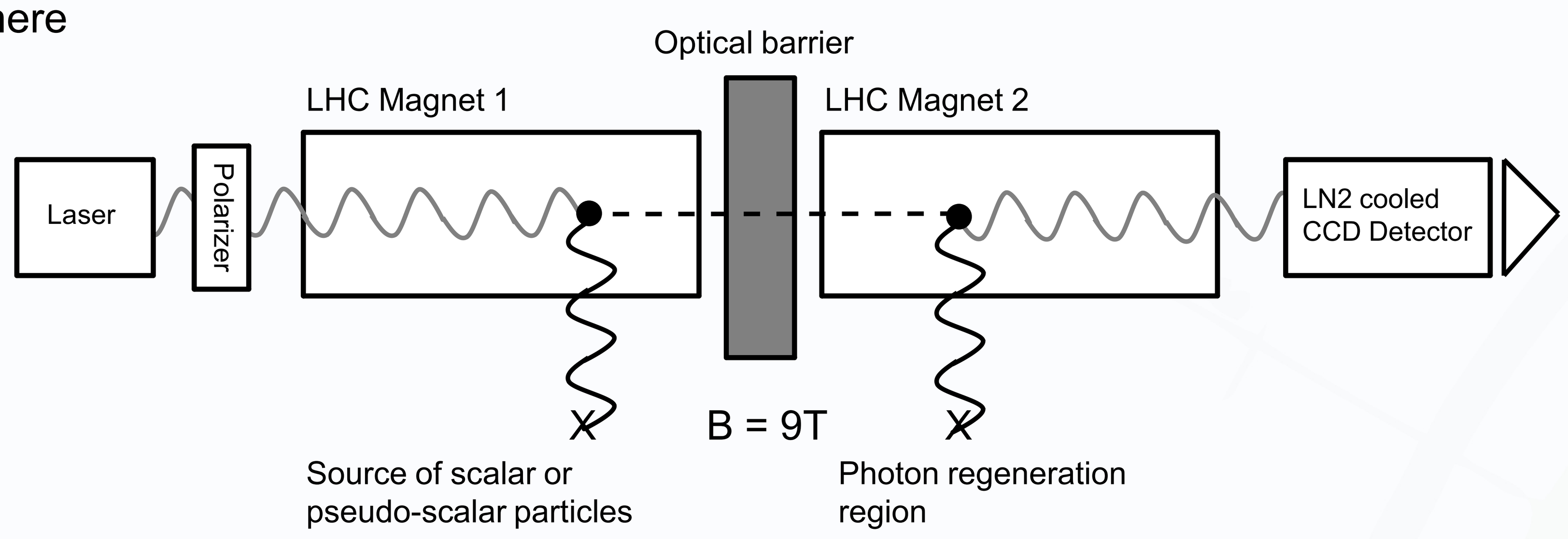


Photon Regeneration Experiment

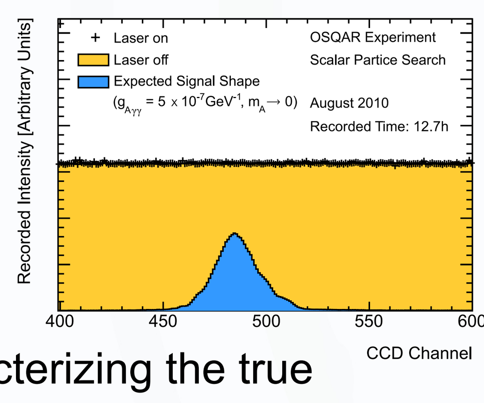
Probability of conversion of photon to weakly interacting axion is given by

$$P_{\gamma\leftrightarrow A} = \frac{1}{4\beta_A}(g_{A\gamma\gamma}BL)^2\left(\frac{2}{qL}\sin\frac{qL}{2}\right)^2$$

This axion can pass thru optical barrier and can convert to detectable photon at second magnet
The configuration with the simultaneous use of two aligned LHC dipoles providing a magnetic field of 9 T over 2 x 14.3 m, with an optical barrier at the end of the first magnet is here



- an ionized Ar+ laser, able to deliver in multi-line mode up to 7 W of optical power is used as light source
- the CCD detector, cooled by liquid nitrogen, Princeton Instruments LN/CCD-1024E/1, with controller ST-130) measures the laser beam profile by photon counting method. It is based on a 2D CCD chip (EEV 256×1024 pixels) and displays a low noise
- the laser beam was focused to small region of CCD, optical barrier was inserted, and spectra were measured
  data from CCD was taken at intervals 15-40 minutes to enable filtering of cosmic noise, resulting data were cumulated and statistic method was used for noise filtering.
- data was taken for 25 (21) hours for axion (for pseudo-scalar particles)
- expected spectra spectrum of CCD were compared with taken spectra - presented at Figure
- the laser beam had a well defined linear polarization parallel to the magnetic field, so this configuration was suitable for the search of both pseudoscalar and axion particles
- for scalarparticle, a half-wave plate oriented at 45° was inserted at the laser exit to align the polarization perpendicular to the magnetic field

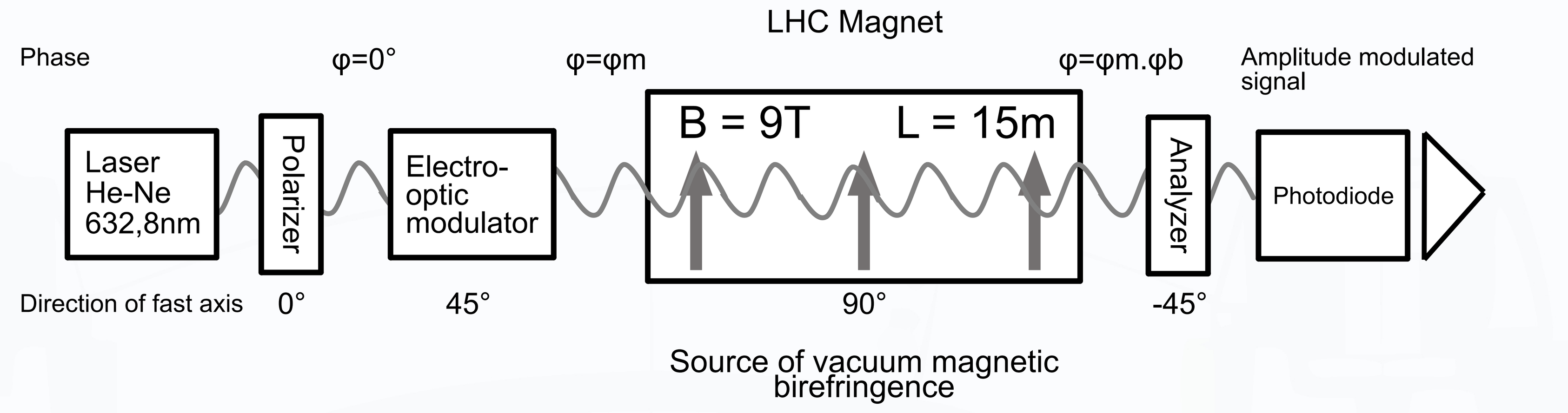


- the state without optical power nor magnetic field allows characterizing the true background signal
- no excess of events above the background was detected at this arrangement

Vacuum Magnetic Birefringence

This method want to measure the ultrafine Vacuum Magnetic Birefringence, predicted by the QED, for the first time.
VMB is caused by the presence of the static magnetic field, produced by LHC magnet perpendicular to the direction of the propagating beam.

- expected value by QED is $\Delta n \approx 3.6\ 10^{-22}$ in 9.5 T field and with high finesse cavity with optical path inside magnetic field l= 250 km
- axion presence can partially modify this birefringence
- an optical scheme has been proposed, validated and subsequently improved
- integration of the newly developed ultra-fine ellipsometry to OSQAR LHC magnets was done
- the predicted VMB effect is very weak so subsequent steps must be done
- VMB experiment starts from measurement magnetic-field-induced birefringence at gases, also known as a Cotton-Mouton, in air, in nitrogen, helium and finely in vacuum
- the first experiment was made with 80 Hz rotating half-wave plate. Now plate was replaced by 50 MHz electro-optical modulator



- Sinusoidal voltage of frequency ω is applied to electro-optical modulator
- if the induced birefringence T_m by optical modulator is not small and condition Tm<<1rad is not valid, intensity I variation can be detected with amplitude equal to birefringence of sample δ

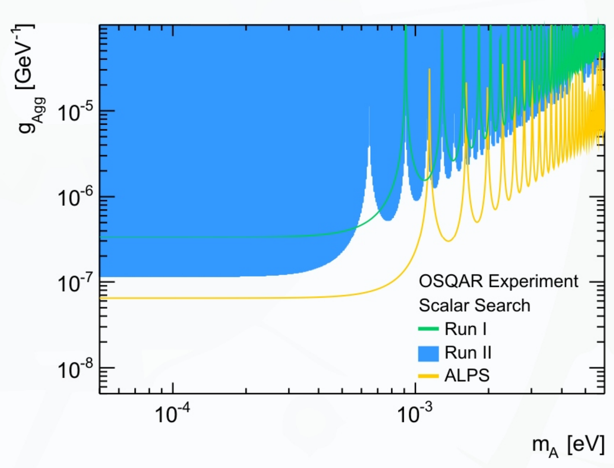
$$I = I_o/2(1 + \delta T_m \sin[\omega t])$$

- The value of Cotton- Mouton constant for air (RT, standard pressure) was measured by this technique - $1.12\cdot10^{-6}\ m^{-1}T^{-2}$

Results

Photon regeneration experiment

- flux detection threshold at 95% of confidence level is equal to 0.013 photon/s for the scalar particle search and 0.033 photons/s for the pseudo-scalar particle search (different data taking time)
- in the limit of masslessparticles the constraints obtained on di-photon coupling constants are $g_{A\gamma\gamma} < 1.15\cdot10^{7}$ GeV^{-1} for scalar and $g_{A\gamma\gamma} < 1.15\cdot10^{-7}$ GeV^{-1} for pseudo-scalar particles
- It extends the exclusion region For axion mass see Figure



Vacuum Magnetic Birefringence experiments

- the results of VMB are in the exclusion region of PR and are relatively far from the edge of this region
- the progress in ellipsometry technique can increase the sensitivity of this method Sensitivity of both methods can be significantly increased by using of high finesse cavities for prolongation of optical path inside magnetic field
- The R&D on construction of 15 meters long high finesse cavities had been started Physicists at all the word try to find proof of axion existence but any experiment (including OSQAR) or observation didn't confirm it till now. But the work on this field is in dynamic progress

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