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Search for axion-like particles and hidden-sector photons in the resonant regeneration experiment SOLA

Introduction

- ALPs(axion-like particles) are predicted by some SM extensions.
- Photon mixing with new pseudoscalar and scalar particles(ALPs) can explain a set of astrophysical problems.
- Astrophysically motivated parameter region for ALPs includes masses $m < 10^{-6}\,eV$ and coupling with photons constant $\chi \sim 10^{-10} \ldots 10^{-11}\,GeV^{-1}$.
- The project is aimed at search of ALPs with help of a new kind of laboratory experiment, which realises a new idea of resonant regeneration.

Plan

- Motivation and description of the experiment.
- Method of resonant regeneration.
- Additions: search for hidden sector photons.
- Conclusion.

Description of the experiment

- Project corresponds to classic "light shining through wall"experiment supplemented with two synchronized cavities and optical barrier in between.
- Consists of 2 Fabry-Perot cavities with length $50\,cm$ inserted in magnet field about $2,2\,T$.
- Limit on reverse coupling constant $\sim 0,6 \cdot 10^8\,GeV$ with ALPs mass $m < 10^{-4}\,eV$ for cavity finesse about 10^5.
- Gives us advance in sensitivity of $2,5-3$ orders compared with existing setups with the same parameters.
- Methods and engineering results can be used for full-scale experiment with a potential of discovery of ALPs.

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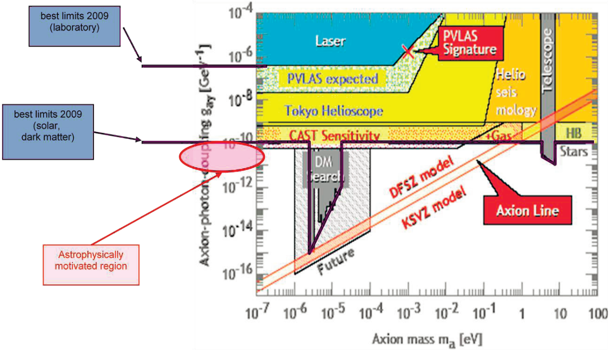

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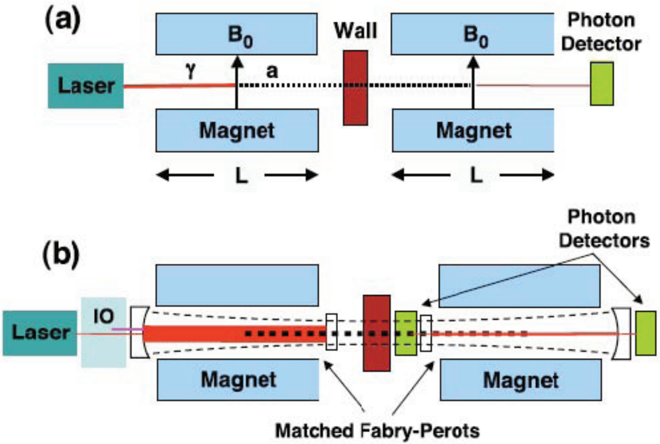
Motivation of the experiment

In region of ultrahigh energies we have a set of unsolved problems connected with unexplained photon radiation and propagation:

- observation of photons with energies $> 100\,GeV$ from distant blazars
- suggestion of presence of neutral particles with energies $> 10^{18}\,eV$ from distant sources
- luminosity function of active galaxies
- luminosity function of white drafts
- large-scale correlations in orientation of planes of polarization of kvazar radiation
- excess in X-ray solar radiation compared with theoretical models

Method of resonant regeneration

- Light from high power laser passes through strong magnetic field in which part of photons converts into ALPs.
- Wall between cavities lets only axions to pass through.
- Axions pass in second cavity and convert into photons in strong magnetic field after the wall.
- This photons are registered with photon detectors.


(a)
B0
Wall
B0
Photon Detector
Laser
γ
a
Magnet
Magnet
L
L
(b)
Photon Detectors
IO
Laser
Magnet
Magnet
Matched Fabry-Perots

Method of resonant regeneration

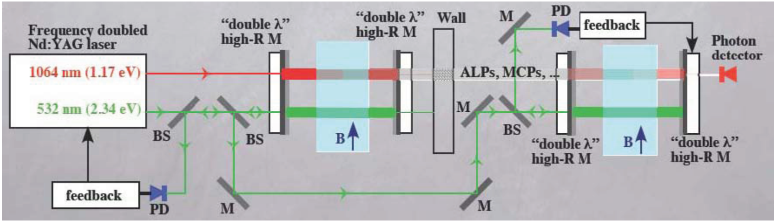
- Possibility of conversion is very small (for ALPs with mass m and reverse coupling constant $M = \frac{1}{\chi}$, L-length of region occupied with magnetic field, ω-laser frequency):

$$P_0 = [\frac{2\omega B_0}{M_a m_a^2} \sin \frac{m_a^2 L}{4\omega}]^4 \quad (1)$$

- The idea of resonant regeneration is based on installing the second cavity after the wall and synchronize both of the cavities. Thus, accordingly to $Sikivie, Tanner, vanBibber(2007)$ the possibility will be:

$$P = 2(F/\pi)^2 [\frac{2\omega B_0}{M_a m_a^2} \sin \frac{m_a^2 L}{4\omega}]^4 \quad (2)$$

Synchronization of two cavities is rather difficult. The group from INFN(Trieste) solved this problem. For synchronization they use laser beam with doubled frequency(green) and for search for axions - main beam(red). Detector for registration of regenerated photons is sensitive only to main frequency.



Search for hidden-sector photons

- Let us consider the simplest model with two U(1) gauge groups, one being our electromagnetic $U(1)_{QED}$, the other a hidden-sector $U(1)_h$, corresponding to paraphoton.
- Using the same theoretical approach as for axion-like particles (only without magnetic field), we will achieve the possibility of photon-paraphoton oscillations in experiment with two Fabry-Perot cavities (Q_1, Q_2-finesses of the cavities):

$$P_{trans}^{max} \approx \chi^4 Q_1 Q_2 \tag{3}$$

Search for hidden-sector photons

The power output P_{out} of the detector cavity will be:

$$P_{out} = P_{trans} P_{in} \tag{4}$$

Let us calculate the amount of photons we can detect after the second Fabry-Perot in case of different P_{in}, maximal $\chi = 10^{-7}$ and $Q_{1,2} = 10^5$, $\lambda = 1064\,nm$. We calculate possibility of oscillations in case of maximal mixing, when $m^2_{\gamma'} = 2\omega\pi/L$.

P_{in}	P_{trans}	P_{out}	Detected photons
$1W$	10^{-18}	$10^{-18}W$	5
$10W$	10^{-18}	$10^{-17}W$	52
$100W$	10^{-18}	$10^{-16}W$	529

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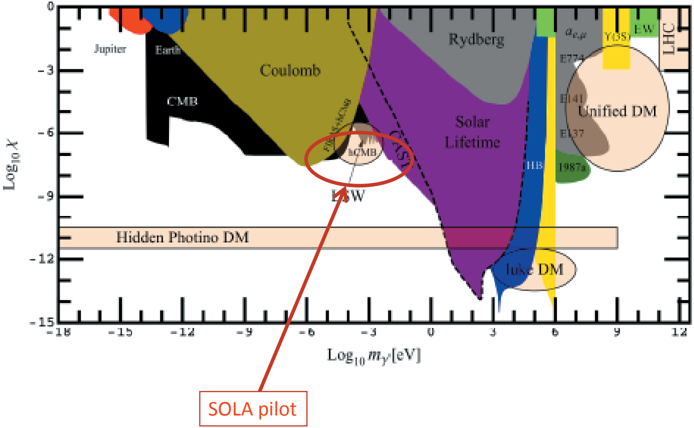

Conclusion

- With help of the method of resonant regeneration we can also search for photon-paraphoton oscillations.
- It is supposed that developed in this project methods and its results can be used for a full-scale experiment using magnet from solar axion telescope from CAST ($9\,T$). Such an experiment will allow us to search for ALPs with reverse coupling constant $3 \cdot 10^{10}\,GeV$, thus will give us sensitivity exceeding astrophysical limits and we will have a potential discovery of ALPs in astronomically motivated field of parameters.