Any Light Particle Search II - Status Overview

Noëmie Bastidon for the ALPS II collaboration
University of Hamburg, Hamburg, Germany

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The Any Light Particle Search II (ALPS II) experiment (DESY, Hamburg) searches for photon oscillations into Weakly Interacting Sub-eV Particles (WISPs). This second generation of the ALPS light-shining-through-a-wall (LSW) experiment approaches the finalization of the preparation phase before ALPS IIa (search for hidden photons). In the last years, efforts have been put for the setting up of two optical cavities as well as the characterization of a single-photon Transition-Edge Sensor (TES) detector. In the following, we put some emphasis on the detector development. In parallel, the setting up of ALPS IIc (search for axion-like particles), including the unbending of 20 HERA dipoles, has been pursued. The latest progress in these tasks will be discussed.

1 Introduction

The Any Light Particle Search II (ALPS II) experiment (DESY, Hamburg) searches for photon oscillations into light fundamental bosons (e.g., axion-like particles, hidden photons and other WISPs) by shining light through a wall [1]. The aimed sensitivity increase for the coupling strength of axion-like particles to photons of the experiment is of a factor of 3000 compared to ALPS I. Such an improvement is due to the increase of the magnets' length, to two optical cavities as well as to the replacement of the single-photon detector. Indeed, the ALPS experiment sensitivity to the conversion of photons into axion-like particles depends on various parameters and is expressed as

$$S(g_{a\mu}) \quad \propto \quad (\frac{1}{BL})(\frac{DC}{T})^{\frac{1}{8}}(\frac{1}{\eta \dot{N}_{\rm Pr}\beta_{\rm PC}\beta_{\rm RC}})^{\frac{1}{4}}$$

with a strong dependency on the magnetic length L and field B. The effect of the optical setup depends on $\dot{N}_{\rm Pr}$, the number of injected photons as well as on $\beta_{\rm PC}$ and $\beta_{\rm RC}$, the power build-ups of the production (PC) and regeneration cavities (RC). Finally, the reached sensitivity depends on the chosen detector's detection efficiency η and dark current (DC). The data-taking time is expressed as T. In the last years, preparation work has demonstrated the basics of the setup.

2 Optics

The ALPS IIa (search for hidden photons) optical setup includes two 10 m optical cavities separated by a ligth-tight barrier. A 30 W 1064 nm laser is injected inside the first cavity (Fig. 1). Such a system is technically challenging for two reasons: first, an alignment of both cavities

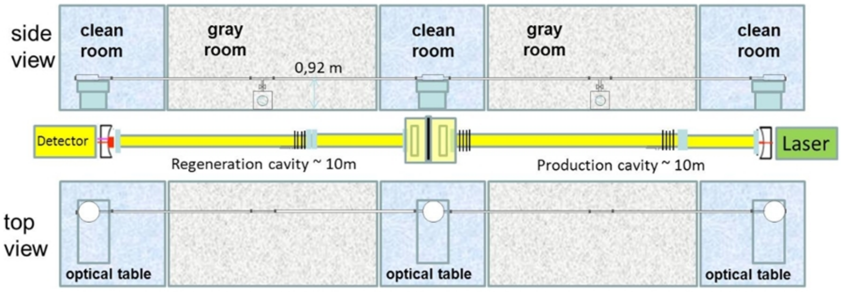

Figure 1: The ALPS IIa experiment.

towards each other is necessary to provide a larger spatial overlap of the modes resonating in both cavities. Second, high power buildups (PB) are required for both cavities in order to reach the ALPS IIa foreseen sensitivity. The aimed PB of the production cavity is of 5 000 and the regeneration cavity PB is of 40 000. In order to maximise this feature, the PC and RC need to be in the same modal phase with a mode-overlap of 95 %. The regeneration cavity is locked via an auxiliary green beam obtained via second harmonic generation (KTP crystal) of the PC infrared beam [2]. Latest tests showed a lower PB than required for the production cavity. Possible sources of such issues are the mirrors' coating, cleanliness of the mirrors, alignment of the cavity as well as a clipping in the beam pipes. Usage of a cavity ring-down technique demonstrated a good quality of the mirrors [3]. Measurements will be repeated with a larger beam radius in order to enlarge the tested region on the mirrors surface.

3 Coupling of the beam inside a fiber

The regeneration cavity will be connected via a fiber to a single-photon detector in order to detect possible regenerated photons. Efficient coupling of a 4.23 mm beam inside a 8.2 μm single-mode fiber is feasible but its stability over loner timescales still needs to be demonstrated.

The coupling of the beam inside a fiber setup includes two mirrors as well as an aspheric lens (Fig. 2). In the test setup, a class 1 $\lambda = 1064$ nm laser is shone to a mirror setup before being focused inside a standard single-mode fiber. It has been shown that the efficiency of the coupling depends highly on the alignement of the setup and on the focal length of the used lens (Fig. 2). During the preliminary tests, an efficiency higher than 80% was reached. The highest value for the final setup which has been currently obtained is of 53% for a focal length of 35 mm. This value is lower than what was expected for such a lens. In the near future, the beam quality will be studied with a knife-edge unit. Such a device allows the characterization and adjustement of the beam on micrometer-scale before it enters the fiber.

4 Detector

The detection of a low rate (one event every few hours) of low energetic (1.17 eV) photons requires both a high detection efficiency as well as a low dark count rate. Additionally, the ALPS II detection system is required to have a good energy and time resolution as well as a good long-term stability. To meet all of these criteria, the ALPS II setup includes a cryogenic

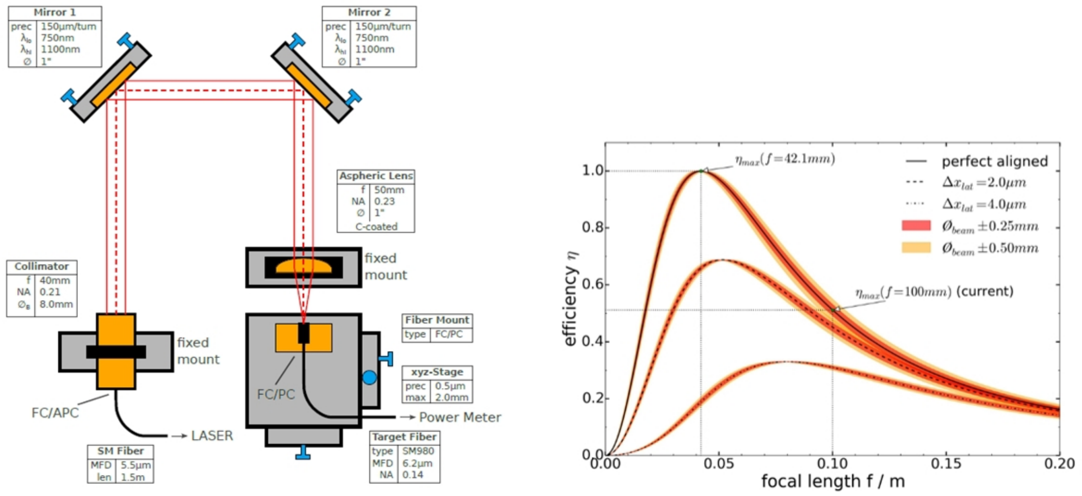

Figure 2: Coupling of the beam. On the left, a drawing of the coupling of the beam test setup. On the right, the theoretical efficiency of the coupling values η for different levels of alignment $\Delta\, x_{tot}$ and for different focal length f.

detector of the transition edge type (TES) developed by NIST (National Institute of Standard and Technology) [4].

Transition-Edge Sensors are superconductive microcalorimeters measuring the temperature difference ΔT induced by the absorption of a photon with R(T, I). The detector is positioned within its superconductive transition (TES set point corresponds to 30% of its normal resistance) through a thermal link to a heat bath at $T_b = 80mK$ and by applying a constant bias voltage accrss the TES. In order to obtain the cool-down of the detector, it is placed in an adiabatic demagnetization refrigerator (ADR) [5].

The ALPS detector module includes two TESs inductively coupled to a SQUID (Superconducting Quantum Interference Device). The ALPS detectors are optimized for 1064 nm photons. The sensitive area of each chip measures 25 x 25 μm^2 for a thickness of 20 nm. The substrate is surrounded by a standard fiber ceramic sleeve allowing connection of a single mode fiber ferrule [6].

NIST has demonstrated that such a detector can reach quantum efficiency higher than 95 % [7]. Latest measurements of the ALPS II detector efficiency led to a first approximation of 30 %. Optimization work is currently under progress.

5 ALPS IIc

The ALPS IIc experiment will allow the search for axion-like particles (ALPs). It is constituted in the same way as ALPS IIa with two 100 m cavities and the addition of 20 HERA (Hadron-Electron Ring Accelerator) dipoles [1] to allow the conversion of photons into ALPs and re-conversion. The HERA dipoles were all bent during their design, leading to a small aperture of 35 mm. It was foreseen to unbend all of the dipoles by applying a force in their middle (cold mass). The deformation of the first magnet was successful, yielding to an aperture of 50 mm allowing to set up the 100 m long cavities without any aperture limitations. The magnet is working according to its specifications with a slight increase of its quench current. Efforts to straighten further magnets are on-going.

6 Summary

The ALPS II experiment aims at an improvement of sensitivity by a factor of 3 000 compared to ALPS I for the coupling of axion-like particles to photons. This improvement is achieved mainly by implementing a regeneration cavity and a larger magnetic length. Basics of the optics setup have been demonstrated but not all of the specifications have been reached yet. A Tungsten Transition-Edge Sensor operated below 100 mK has been successfully used to detect single-photons in the near-infrared.

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References

[1] R. Bähre *et al.*, "Any light particle search II Technical Design Report," JINST **8** T09001 (2013) [arXiv:1302.5647v2 [hep-ex]].

[2] R. Hodajerdi, "Production Cavity and Central Optics for a Light Shining through a Wall Experiment," ISBN 1435-8085 (2015)

[3] T. Isogai *et al.*, "Loss in long-storage-time optical cavities," Optics Express **21**(24) 30114 (2013) [arXiv:1310.1820v2 [hep-ex]]

[4] N. Bastidon, D. Horns, A. Lindner, "Characterization of a Transition-Edge Sensor for the ALPS II Experiment," these proceedings (2015)

[5] G. K. White, P. J. Meeson, "Experimental techniques in low-temperature physics," Fourth Edition, Oxford University Press, (2002).

[6] J. Dreyling-Eschweiler *et al.*, "Characterization, 1064 nm photon signals and background events of a tungsten TES detector for the ALPS experiment," J. Mod. Opt. **62**, 14 (2005) [arXiv:1502.07878 [hep-ex]].

[7] A. E. Lita, A. J. Miller and S. W. Nam, "Counting near-infrared single-photons with 95% efficiency," Optics express **16**, 5 (2008).