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Changes in effective points of reflection in the ALPS II regeneration cavity

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ALPS II

The Any Light Particle Search (ALPS) II is a Light-Shining-Through-a-Wall type experiment which will consist of two optical resonators to enhance the rates of 1064 nm photons oscillating into Axion-like-particles (ALPs) and vice-versa. [1]

Dichroic locking scheme

Both cavities have to be resonant for the same spatial mode and their lengths need to be controlled so that photons of the same frequency are resonant in both cavities. Frequency locking of the regeneration cavity will be done with a second laser of different wavelength to easily seperate this control beam from regenerated photon signals. For this purpose, ALPS II will use the frequency double of the ALPs producing beam, a 532 nm control beam. [1]

Effective points of reflection

To make two different wavelengths resonant at the same time in the regeneration cavity, the involved mirror coatings have to be specified for both wavelengths accordingly. This is typically done by adding two different coating stacks on top of each other, thus, the two different wavelengths have different penetration depths into the coatings and see different optical lengths of the cavity. [2] The differential frequency shift between the two beams can be anywhere between zero and one full free spectral range of the cavity. In ALPS II, this shift, once it is known, can be easily compensated by the control electronics of the frequency stabilization. [3]

Change of effective points of reflection over time

A challenge for ALPS II is the possibility of a temperature-induced change of the difference in the effective points of reflection over time. The control electronics can only compensate for constant frequency differences between the two beams. If there is a drift in the effective points of reflection on the mirror coatings it will translate into a frequency mismatch between the control beam and the signal beam in the regeneration cavity, spoiling the enhancement factor of photon regeneration and thus, limiting the overall sensitivity of ALPS II.

Mirror-coating test bed at AEI in Hannover

To minimize the change in effective points of reflection specific coatings were designed, fabricated and need to be tested. For this purpose, a test experiment is set-up at AEI in Hannover to monitor the difference frequencies in a high finesse Fabry-Pérot cavity over different temperatures. The objective is to find mirror coatings with small enough temperature dependence of the effective point of reflection not to limit the ALPS II sensitivity.

References

[1] R. Bähre et al., Any light particle search II –Technical Design Report, IOP Publishing, 2013

[2] R. Bähre, Design and setup of an optical experiment for searching for weakly interacting sub-eV particles (WISPs) that couple to an electro-and/or magnetic field, Dissertation, Leibniz Universität Hannover, 2016

[3] A. D. Spector, J. H. Pöldet al., Characterization of optical systems for the ALPS II experiment, arXiv:1609.08985v2, Nov. 2016

Summary

In the ALPS II Light-Shining-Through-a-Wall type experiment the photon regeneration cavity is frequency stabilized with a laser beam of different wavelength than the signal beam. Thus, the mirror coatings need to be specified for both wavelengths which leads to different penetration depth for both wavelength in the mirror coatings. This difference in effective points of reflection can be compensated by control electronics, but a temperature-driven change of this frequency offset would be a problem in ALPS II. Thus, specific mirror coatings were designed and will be tested in an experimental set-up at the AEI in Hannover to find coatings which minimize this effect so that the design performance of the final experiment can be achieved.

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