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WISPFI: Searching for ALPs-Photon conversion on fiber interferometer

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The Weak Interacting Slim Particles detection through a Fiber Interferometer (WISPFI) is conceived as a new experimental setup to search for light pseudo-scalars that couple to photons. The search for a light mass range is motivated by recent astrophysical observations [Majumdar, Calore, and Horns, 2018]. In that study, it was showed that gamma-ray observations of Galactic pulsars favor a mass range of $(3.6 \pm 0.2)\, neV$ and an estimated di-photon coupling of $g_{a\gamma\gamma} = (2.3 \pm 0.4) \times 10^{-10}\ GeV^{-1}$. The strongest constraint is from the OSQAR experiment [Ballou et al., 2015], which excludes $g_{a\gamma\gamma} > 3.5 \times 10^{-8}\ GeV^{-1}$ at 95 % confidence level.

Since these ranges have so far not yet probed in laboratory, this leads to the idea of performing this project. The WISPFI experiment has the potential to improve the sensitivity for laboratory-based searches considerably by using an innovative fiber-interferometric approach. WISPFI is based on a compact all-fiber Mach-Zehnder-type interferometer with the aim of using hollow-core photonic-crystal (HC-PC) fiber. This way, a compact design with a coiled-up fiber can be fit inside the warm-bore of a solenoid superconducting magnet of 14T field. The study addresses the search for weak-interacting slim particles (WISPs) by the use of experimental techniques used in the field of gravitational wave detection. This method allows to straightforwardly measure both the phase and amplitude changes in the presence of a non-vanishing $g_{a\gamma\gamma}$ and check for a possible signal. The main idea is based on the proposal of Tam and Yang (2012).

The sensitivity of an interferometer to detect and measure the effect of the photon-mixing in a straight fiber relies on the conversion probability $p_{a\to\gamma} \propto g^2_{a\gamma\gamma}(BL)^2 << 1$, where BL is the product of the transversal magnetic field B and the length L over which the photon beam is passing through the magnetic field. That is although considering a proper media in which the effective mass of photons is comparable to the axion mass. However, providing the sufficiently large values of BL to compensate the coupling factor can be challenging. In the light-shining-through-wall (LSW) experiments, the detection rate depends on the combined probability $p_{a\to\gamma} \propto g^4_{a\gamma\gamma}(BL)^4 << 1.$\\

The shot noise for a laser source of N photons is expected to scale with $\sqrt{N}$ following Poisson statistics.The sensitivity of the setup can be efficiently improved by increasing the power of the laser, P_{laser} and implementing a squeezed light source with a squeezed factor S. The minimal coupling detectable is constrained by $g_{a\gamma\gamma} \propto S^{-\frac{1}{2}} P_{laser}^{-\frac{1}{2}}$. In conventional LSW-experiments the axion-photon coupling has a magnitude proportional to $g_{a\gamma\gamma} \propto P_{laser}^{-\frac{1}{4}}$. Regarding that, we estimate the sensitivity of the experiment for a resonant axion mass of 62meV using a hollow-core fiber to reach a detectable axion-photon coupling of $g_{a\gamma\gamma} < 10^{-10}$ GeV^{-1}, with still marge of improvement with the implementation of squeezed light.

The development of a squeezed-light fiber interferometer is then necessary and is one of the objectives that are aimed to be fulfilled soon. This kind of interferometer is potentially interesting for its implementation in high-precision metrology applications.

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