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WISPFI-E:

WISP searches on a Fiber Interferometer under the application of an Electric field

Working Group: J. M. Batllori, Y. Gu, D. Horns, M. Maroudas, J. Ulrichs

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

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Background & Motivation

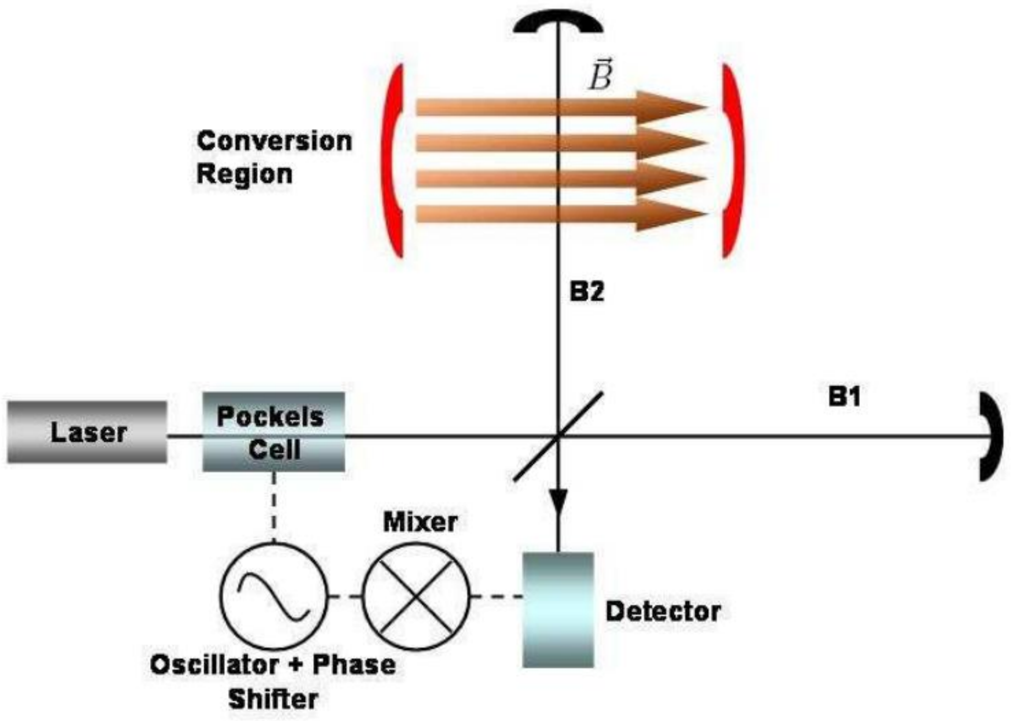
- Interferometric detection principle has been introduced by [1] for a Michelson-type interferometer.

- Novel table-top experiment focusing on **photon-axion conversion** in a waveguide by measuring **photon disappearance** in the presence of a strong external B field.

- **Mach-Zehnder interferometer** with the sensing arm inside the magnetic field. Expected signal: amplitude reduction & phase shift.

- Light guiding **over long distances & resonant detection** at a specially-confined region inside the bore of a strong magnet.

- No dependence on the local DM density.



Axion conversion probability scales with:

$$P_{\gamma\to a} \propto g^2_{a\gamma\gamma}(BL)^2 \text{ for } P_{\gamma\to a} \ll 1$$

Axion-Photon conversion probability

- The photon-to-axion conversion probability from the linearization of the Klein-Gordon Eqn. [2] is:

$$P_{\gamma\to a} = \sin^2(2\theta)\sin^2(\pi L/L_{osc}) \;\; where \;\; Tan(2\theta) = 2\omega\frac{g_{a\gamma\gamma}B}{k_\gamma^2 - k_a^2}$$

- Maximum conversion occurs to **large energy $\boldsymbol{\omega}$** or resonance conversion when $\boldsymbol{k_\gamma = k_a}$. The expected mixing angle is $\boldsymbol{\theta = 45°}$. The axion mass in resonance corresponding to a mode propagating in a medium with n_{eff} is:

$$m_a = \omega\sqrt{1 - n_{eff}^2}. \qquad n_{eff} < 1 \; needed!$$

- Focusing then on at or close to the **resonant conversion** and under the assumption of $\boldsymbol{P_{\gamma\to a} \ll 1}$ the resulting probability in terms of B-field and fiber length is:

$$P_{\gamma\to a} \approx 10^{-18}\left(\frac{g_{a\gamma\gamma}}{10^{-12}GeV^{-1}}\right)^2\left(\frac{B}{10\,T}\right)^2\left(\frac{L}{200m}\right)^2 \qquad \text{Energy } (\omega) \text{ independent}$$

Hollow-Core Photonic Crystal Fibers (HC-PCF)

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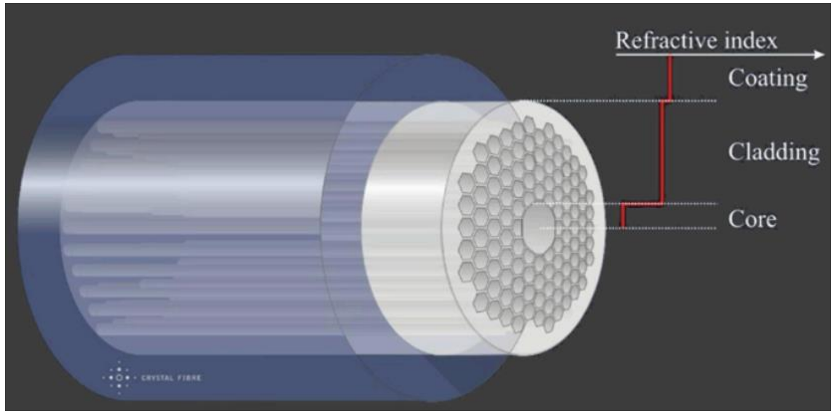
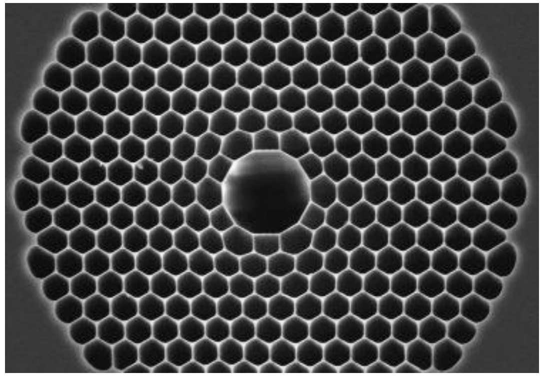


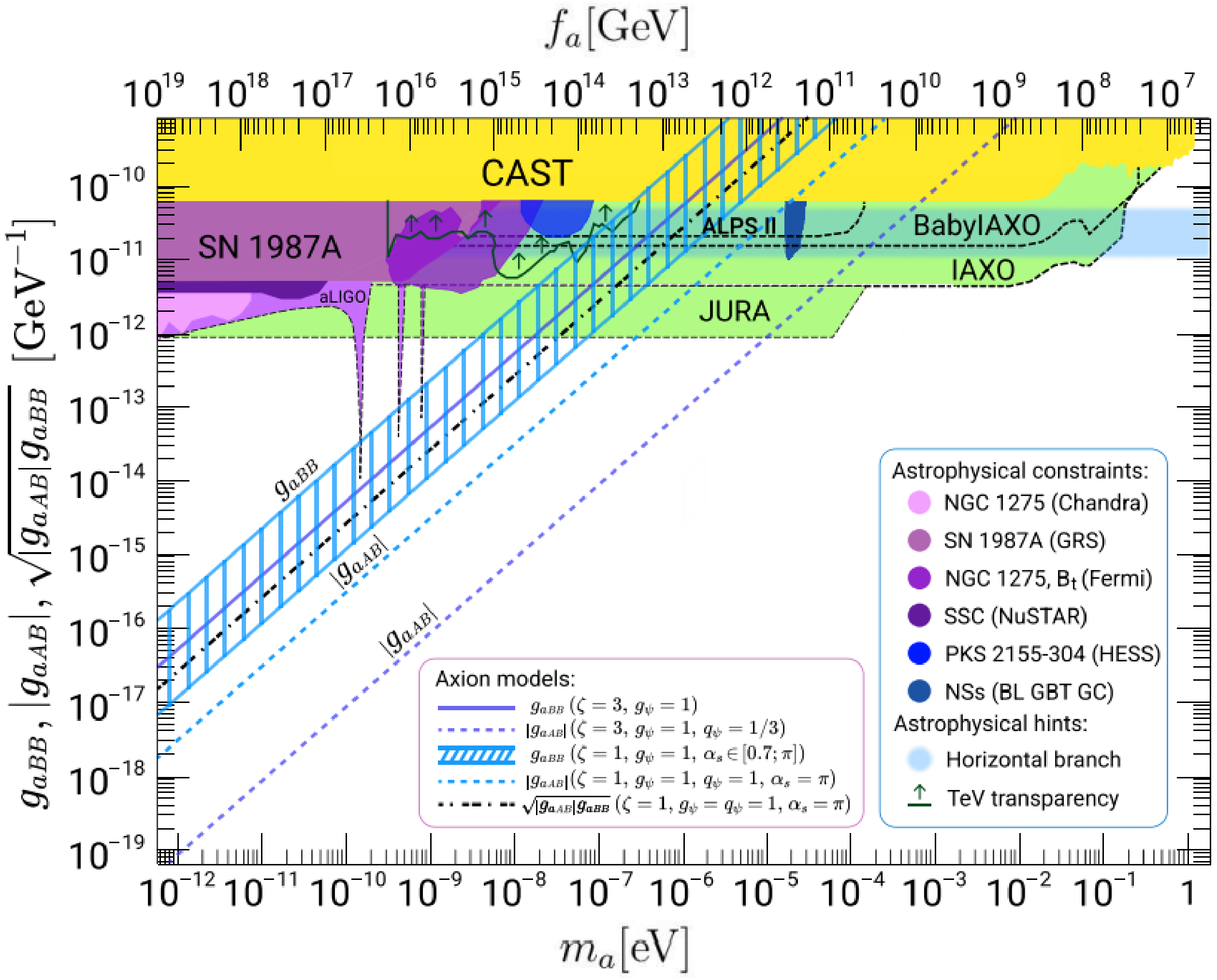


Images of HC-PCF (HC-1550) taken from NKT Photonics

- **Definition:** Fibers with a characteristic structure of a hollow-core surrounded by a periodic array of air-holes that to creation of a photonic-bandgaps and allows for confinement of light in the hollow core.
- **Effective mode index:** The creation of a photonic-bandgap makes light to be guided through the hollow core by an air-guiding mechanism. Therefore, n_{eff} **can be** $\mathrm{n_{eff}} \leq 1$ (direct relation to the phase velocity of the guided mode).
- **Applications:** Optical communications, gas sensing,…

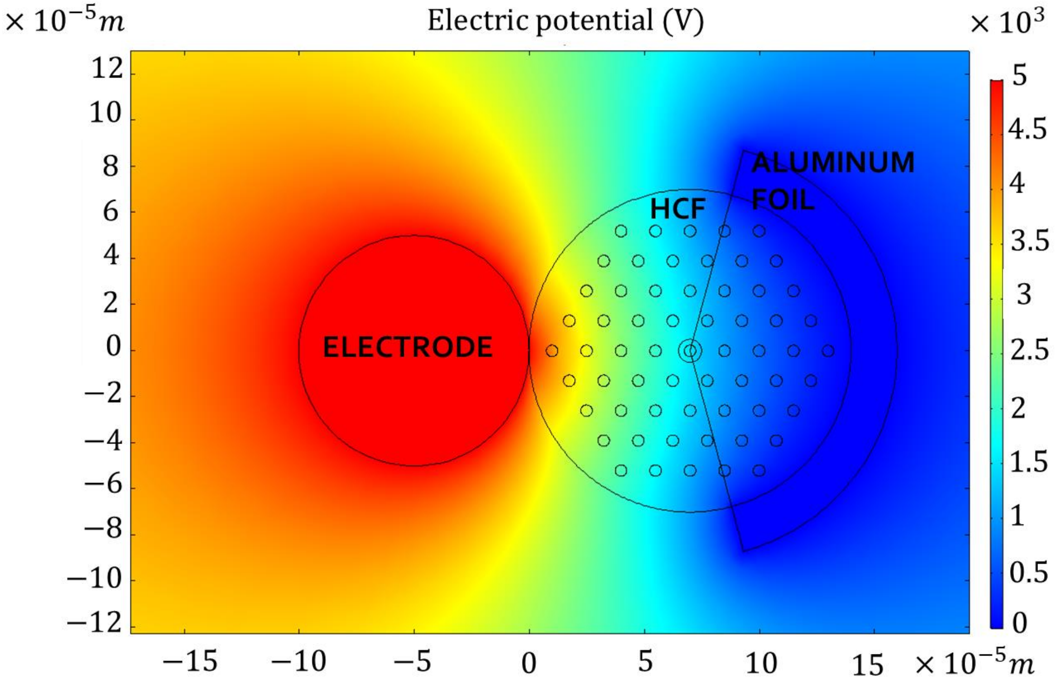
QMED: Photon-axion mixing

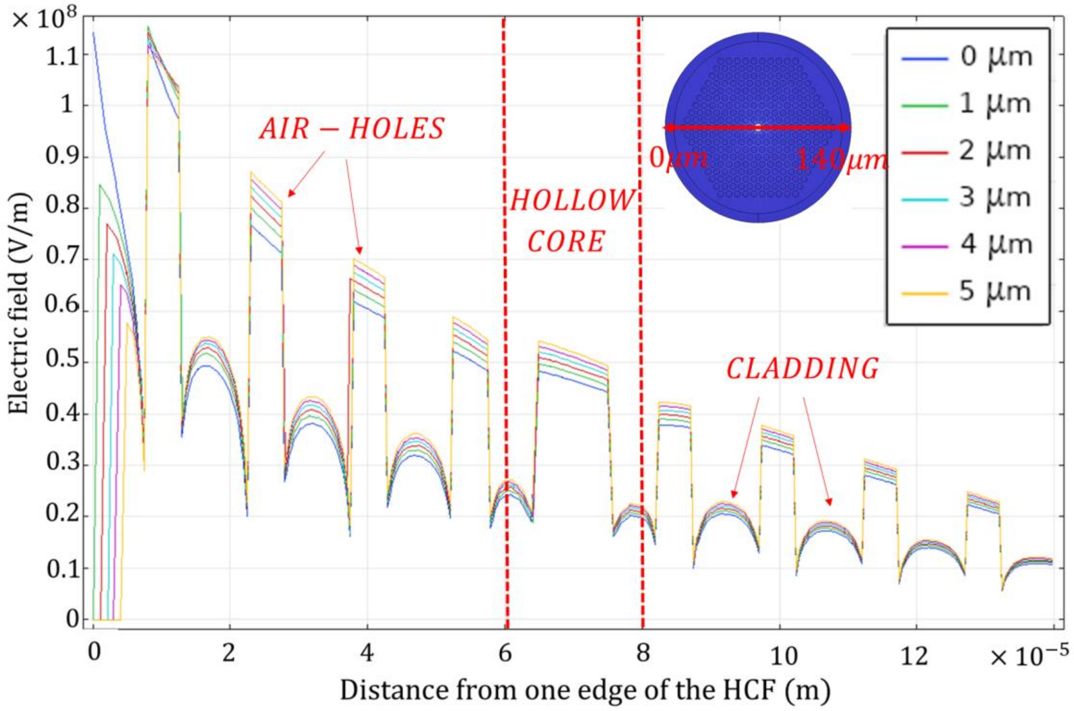
The axion-photon couplings g_{aAB} and g_{aBB} predicted in scenarios based upon modified Quantum-Electromagnetodynamics (QEMD) have not been exploited so far (Sokolov, 2022). By attaching electrode strips to the HC-PCF, it is possible to probe the photon-axion conversion under the application and modulation of strong electric fields.



Simulation of the E-field

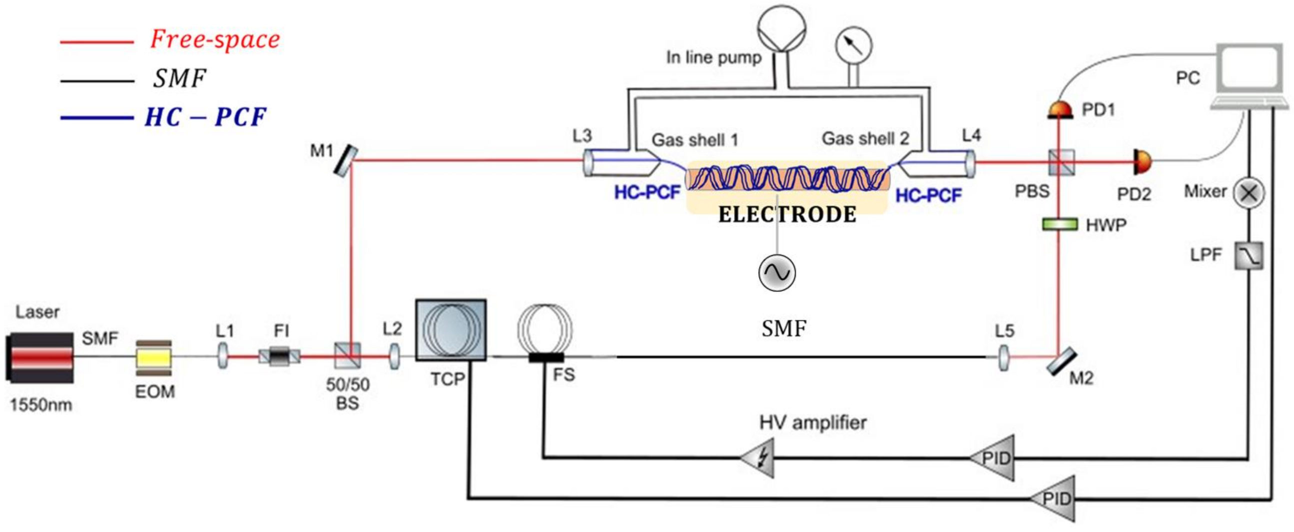
The application of an E-field of $\sim 5\ \mathrm{MV/m}$ will allow to achieve sensitivity levels comparable to those of conventional searches conducted with external magnetic fields of the order of $\sim 14\mathrm{T}$. The maximum estimated electric field at the center of the hollow-core ($5\ \mu m$) is E ~ $50\ MV/m$, equivalent to a B $\sim$ 140 T!

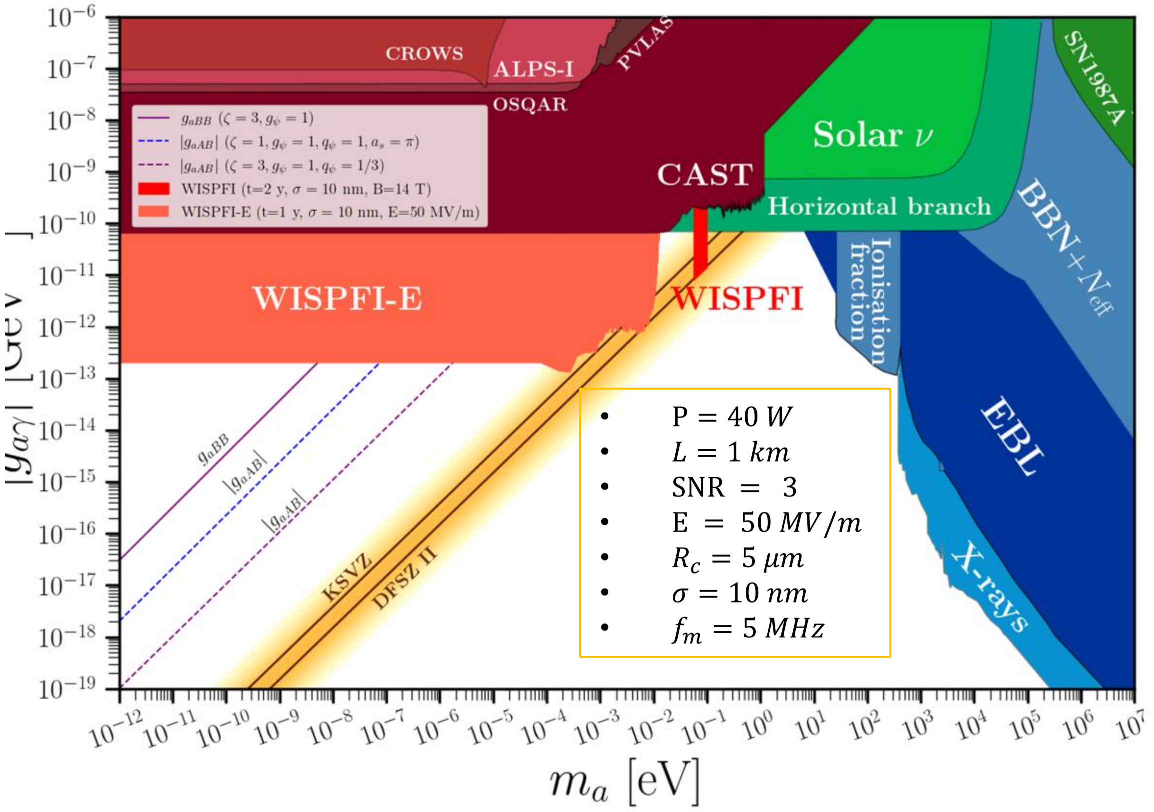




Preliminary sensitivity

The WISPFI-E’s experimental setup is based on a partial free-space MZI with the sensing arms implemented by waveguides that can be easily coiled around an electrode. The electric field is modulated at a fixed frequency (~kHz-MHz).





Check Talk by M. Maroudas on 06. 07 at 15. 35