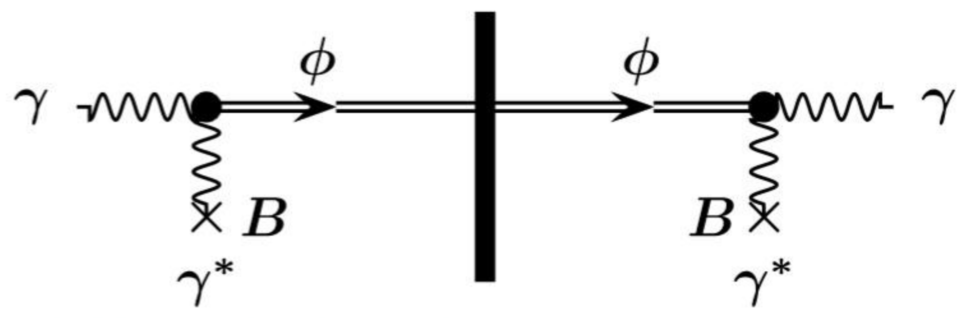
Any Light Particle Search II.

Todd Kozlowski, Rikhav Shah and Richard Smith
on behalf of the ALPS Collaboration

Light-Shining-Through-a-Wall (LSW) Experimental Concept

The Sikivie Process

Predictions from quantum chromodynamics (QCD), bolstered by astrophysical hints, suggest the existence of a class of axion-like particles (ALPs). These particles are able to convert to and from photons in an external magnetic field. This photon-ALP-photon conversion and reconversion, known as the Sikivie Process, allows us to search for ALPs in a laboratory setting.

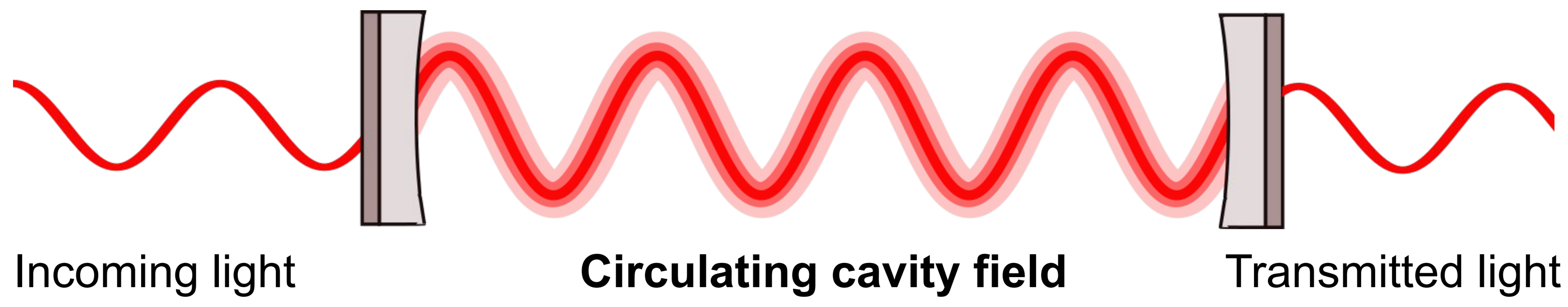


Producing Dark Matter in the Lab

In order to create a flux of axion-like particles to later detect, a large number of photons from a laser are subjected to a strong magnet field. Larger magnetic fields, as well as more laser light power, improve the ALP flux rate. Our newly-created ALPs are free to pass through even the most opaque barriers before being re-converted back into photons in order to be detected, effectively shining light through a wall!

Signal Enhancement with Resonant Cavities

The sensitivity of the ALPS IIc experiment is greatly improved by using optical cavities. Cavities are constructions of mirrors that exploit the principle of constructive interference to "store" light when the distance between the mirrors is an integer number of wavelengths of the incoming light. This technique is employed twice in ALPS IIc, both in generating and reconverting ALPs.



Feedback systems are used to maintain this condition by either adjusting the frequency of the incoming light, or making minute adjustments to the length of the cavity. The image on the right demonstrates how the power in a cavity is amplified near resonance.

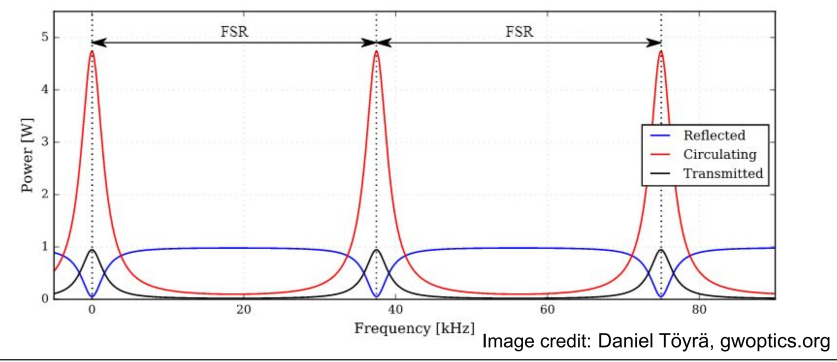


Image credit: Daniel Töyrä, gwoptics.org

ALPS IIc: the Next Generation of LSW Detector

Production Cavity

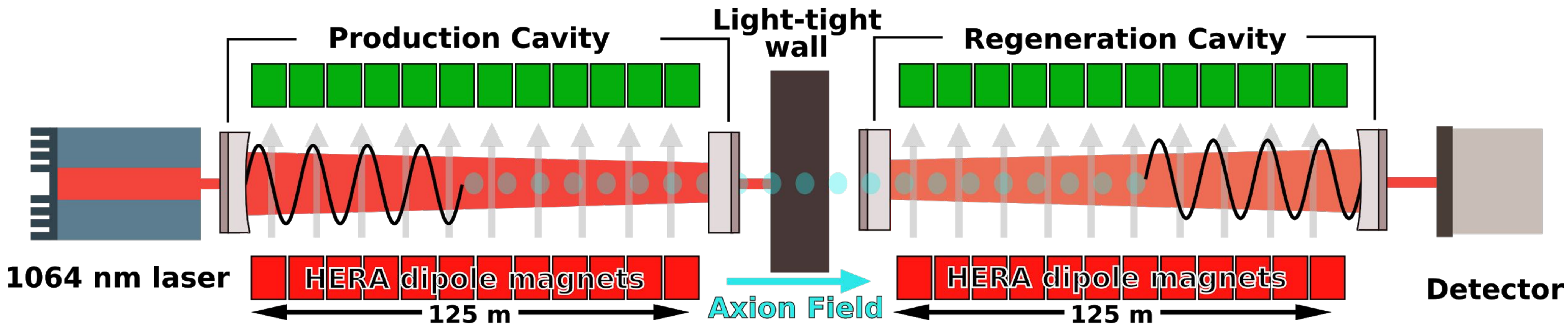
The production cavity (PC) is an optical resonator that builds up the 1064 nm laser source from 35 W of incoming power into 150 kW of circulating power in order to maximize the rate of axion-like particle generation. The cavity consists of two mirrors, spaced 125 meters apart on either end of a string of magnets.

Light-tight Wall

Any stray laser light passing from the production cavity into the regeneration cavity would be indistinguishable from a photon-ALP-photon reconversion signal. Therefore we require a barrier separating the two halves of the experiment which ALPs can freely pass through, but light cannot.

Regeneration Cavity

The regeneration cavity (RC) amplifies the signal of axion-like particles reconverting back into photons in the second magnet string. The power in this regenerated field is amplified by a factor of 40,000, improving detection probability over the 15-day measurement runs.



Dual Resonance Condition

In order for the regeneration cavity to maximally amplify the signal of reconverted photons, it must stay aligned and resonant to the light inside the production cavity. This condition sets some of the experiment's strictest requirements, including sub-picometer relative length stability and cavity mirror alignment to within microradians.

Superconducting Magnets

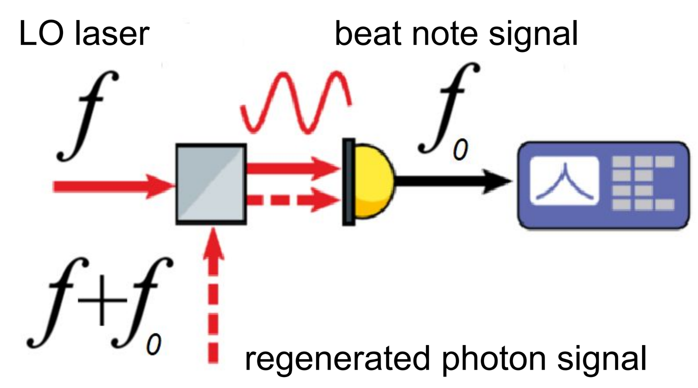
The magnetic field required to turn photons into ALPs and back again is provided by a string of re-purposed 5.3 T HERA dipole magnets. These magnets, formerly curved in order to serve the HERA ring accelerator, had to be physically un-bent. In total, ALPS IIc will use 24 of these up-cycled cryogenic magnets.

Detector

ALPS IIc has two different methods of detection at its disposal, both being developed in parallel. These options, a heterodyne interferometer and a cryogenic photon counter, use quite different experimental designs. This is ideal for signal confirmation by removing potential systematic errors.

Detection Methods

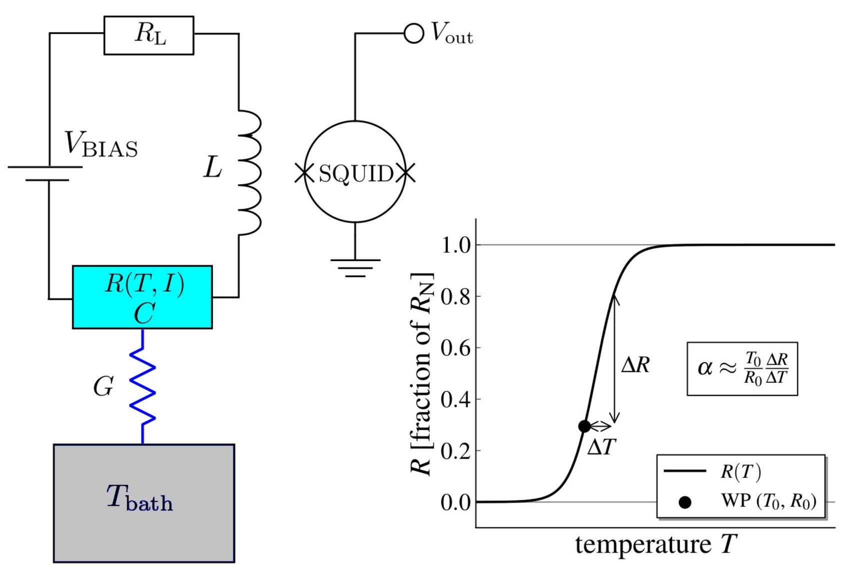
Heterodyne Interferometry



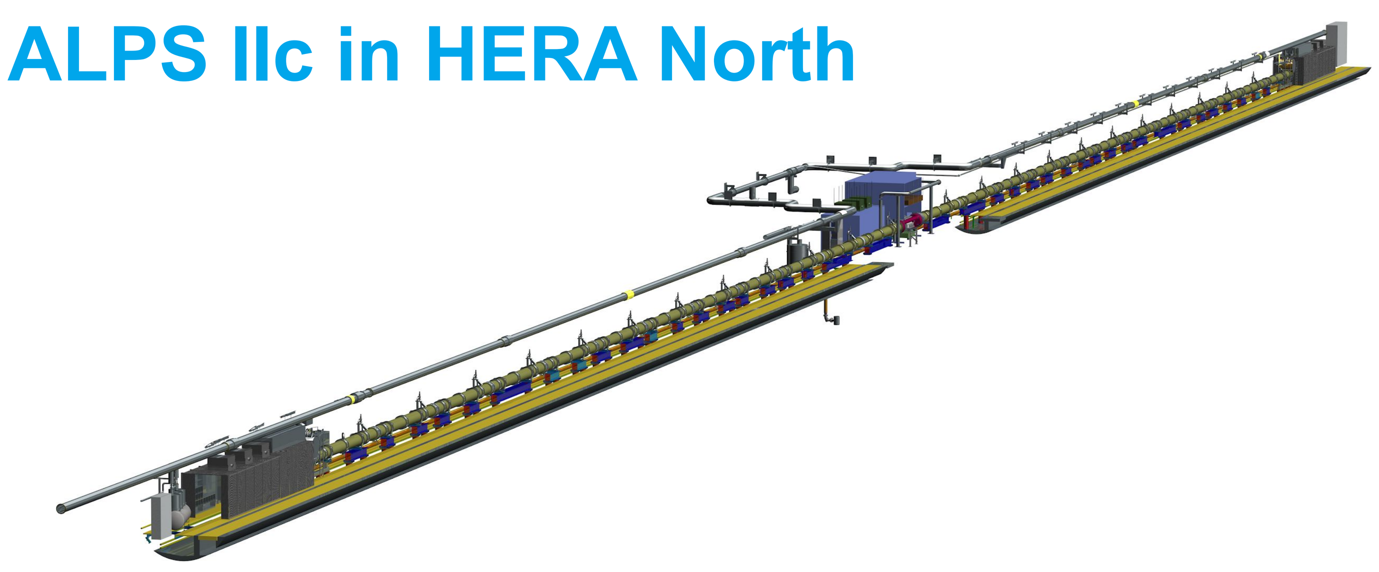
Heterodyne interferometry measures the interference between strong local oscillator and weak signal fields. By operating an additional laser at a slightly different frequency than our regenerated light, a coherent signal at the difference frequency will sum up while noise averages away.

Transition Edge Sensor

The Transition Edge Sensor (TES) is a cryogenic thermometer used as a photon counter. The sensor is held at the superconducting edge, where the change in temperature from absorbing even a single photon produces a large change in resistivity, resulting in a signal large enough to be read out.



ALPS IIc in HERA North



ALPS IIc is currently under construction in a 250 meter-long straight portion of the HERA accelerator tunnel. A central cleanroom will be located in the North Hall, and two additional structures will be built 125 meters in either direction down the tunnel to serve as end stations. The site is ideal for it existing infrastructure and quiet seismic conditions. The site construction and magnet installation will be completed by mid-2020, with installation and commissioning of the optical cavities to follow.

UF UNIVERSITY of FLORIDA · DESY. · JG|U · CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD · NSF · HEISING-SIMONS FOUNDATION · DFG · HELMHOLTZ RESEARCH FOR GRAND CHALLENGES