

# Dark matter Axion search with riNg Cavity Experiment

## DANCE: Current sensitivity

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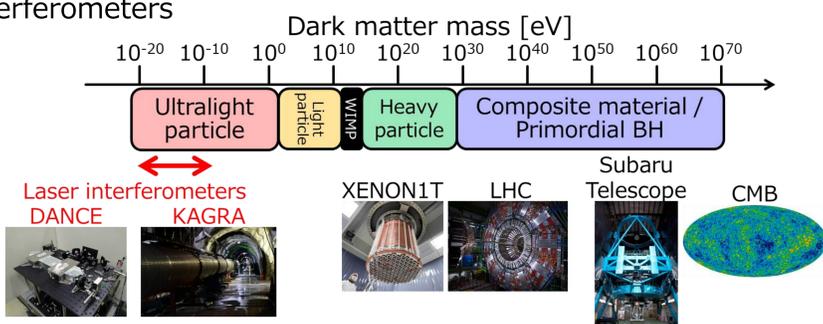
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### Abstract

We proposed Dark matter Axion search with riNg Cavity Experiment: DANCE. To search for axion-like particles (ALPs), we aim to detect the rotation and oscillation of optical linear polarization caused by axion-photon coupling with a bow-tie cavity. DANCE will improve the sensitivity to axion-photon coupling for axion mass  $<10^{-10}$  eV by several orders of magnitude compared to the best upper limits at present. A prototype experiment DANCE Act-1 is in progress to demonstrate the feasibility of the method and to investigate technical noises. We assembled the optics, evaluated the performance of the cavity, and estimated the current sensitivity. If we observe for a year, we can reach  $9 \times 10^{-7}$  GeV<sup>-1</sup> at  $10^{-13}$  eV. The current sensitivity is suggested to be limited by the laser intensity noise at low frequency and by external noises at high frequency.

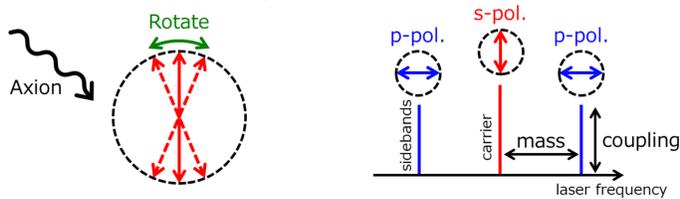
### 1. Motivation

- Dark matter is searched in wider mass range
- We will search for ALPs, a kind of ultralight particles, with laser interferometers

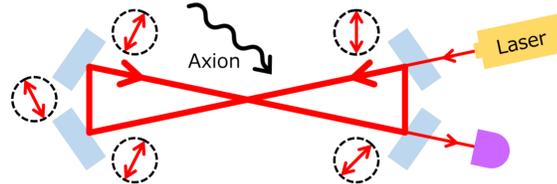


### 2. Principle of DANCE

- Axion-photon coupling makes modulation of linear polarization [1]
  - P-pol. sidebands will be generated from s-pol.



- Polarization rotation can be amplified with a cavity [2]
- A bow-tie cavity prevents rotated direction from inverting [3]

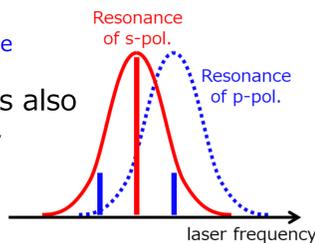


- Input laser power, round-trip length, and finesse are important parameters for DANCE to achieve good sensitivity

$$\sqrt{S_{\text{shot}}} = \sqrt{\frac{\lambda}{4\pi P} \left( \frac{\pi^2}{L^2 \mathcal{F}^2} + m_a^2 \right)}$$

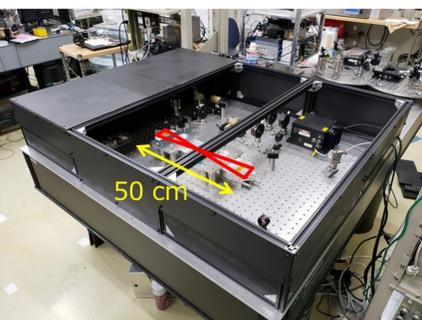
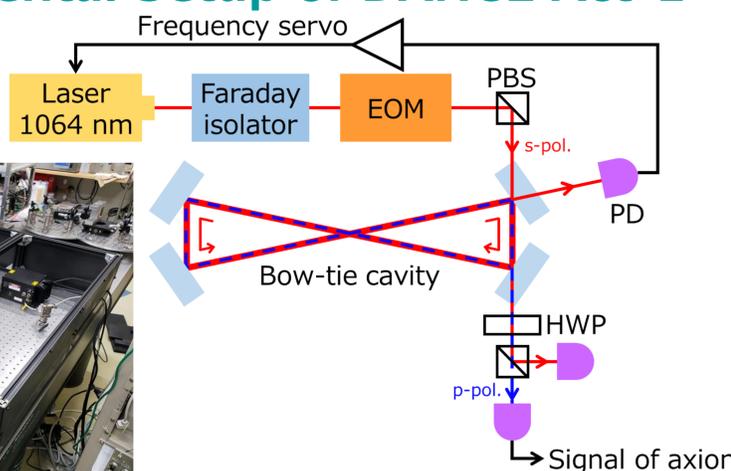
Shot noise (blue arrow) is related to Input laser power (blue arrow), Round-trip length (blue arrow), Finesse (blue arrow), and Axion mass (blue arrow).

- Simultaneous resonance of both polarizations is also important for good sensitivity at low frequency



[1] Carroll, Phys. Rev. Lett. **81**, 3067 (1998)  
[2] W. DeRocco, A. Hook, Phys. Rev. D **98**, 035021 (2018)  
[3] I. Obata, T. Fujita, Y. Michimura, Phys. Rev. Lett. **121**, 161301 (2018)

### 3. Experimental Setup of DANCE Act-1



### 4. Results & Discussion of DANCE Act-1

Table 1: Performance evaluation of the cavity

	Design values	Measured values
Round-trip length	1 m	1 m
Input laser power	1 W	274(1) mW
Output laser power	1 W	158(1) mW
Finesse for s-pol.	$3 \times 10^3$	$2.80(34) \times 10^3$
Finesse for p-pol.	$3 \times 10^3$	193(10)
Resonant frequency difference between polarizations	0 Hz	3.92(16) MHz (From non-zero phase shift difference by mirror reflections)

- Measured amount of p-pol. for 50 min
- Normalized with total amount of transmitted light
- The current sensitivity is  $3 \times 10^{-7}$  rad/ $\sqrt{\text{Hz}}$  at 50 Hz
- Sensitivity is suggested to be limited
  - by laser intensity noise at low frequency
  - by external noises at high frequency

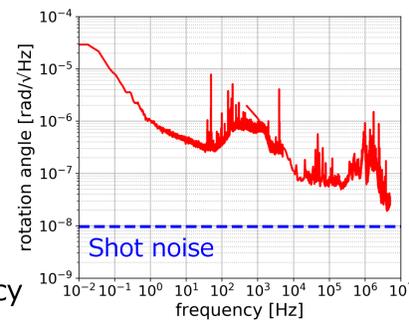


Fig. 1: Spectrum of rotation angle of linear pol.

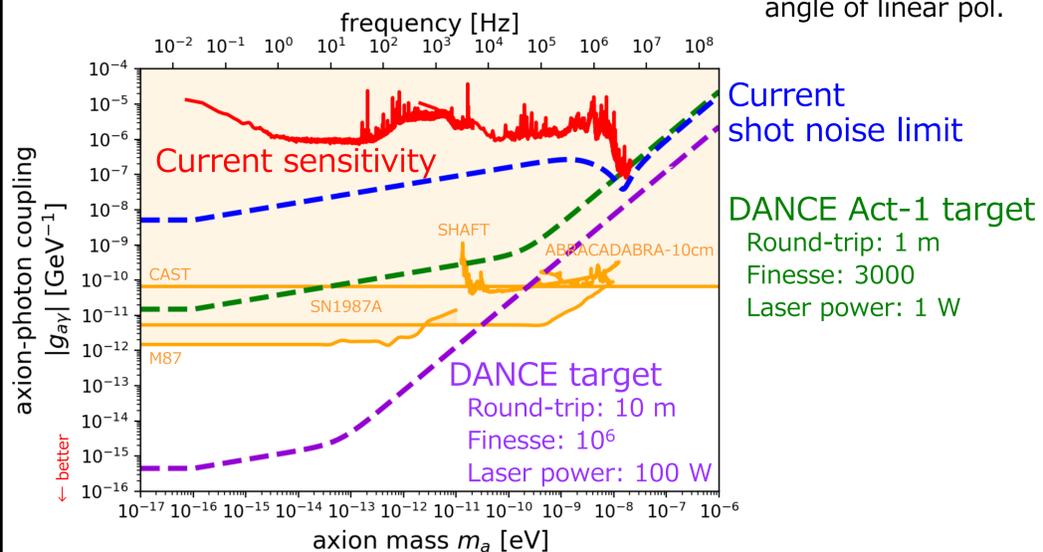


Fig. 2: Current estimated sensitivity (if observe for a year)

- Worse than target sensitivity by 5 orders of magnitude
- Need to improve output laser power and resonant frequency difference between polarizations to reach target sensitivity

### 5. Summary & Future Plans

- We proposed a new table-top experiment to search for ALPs
- DANCE observes rotation of linear polarization in a bow-tie cavity
- Prototype experiment DANCE Act-1 is ongoing
  - Assembled the optics and evaluated the performance of the cavity
  - If we observe for a year, we can reach  $9 \times 10^{-7}$  GeV<sup>-1</sup> at  $10^{-13}$  eV
- Plan to observe for a week and analyze the data
- Plan to build a new setup to improve the sensitivity
  - Inject higher laser input power
  - Cancel out resonant frequency difference between polarizations [4]

[4] D. Martynov, H. Miao, Phys. Rev. D **101**, 095034 (2020)