

# First Results of Axion Dark Matter Search with DANCE

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Yuka Oshima

Department of Physics, University of Tokyo

Hiroki Fujimoto, Masaki Ando, Tomohiro Fujita,  
Jun'ya Kume, Yuta Michimura, Soichiro Morisaki,  
Koji Nagano, Atsushi Nishizawa, Ippei Obata

# Overview

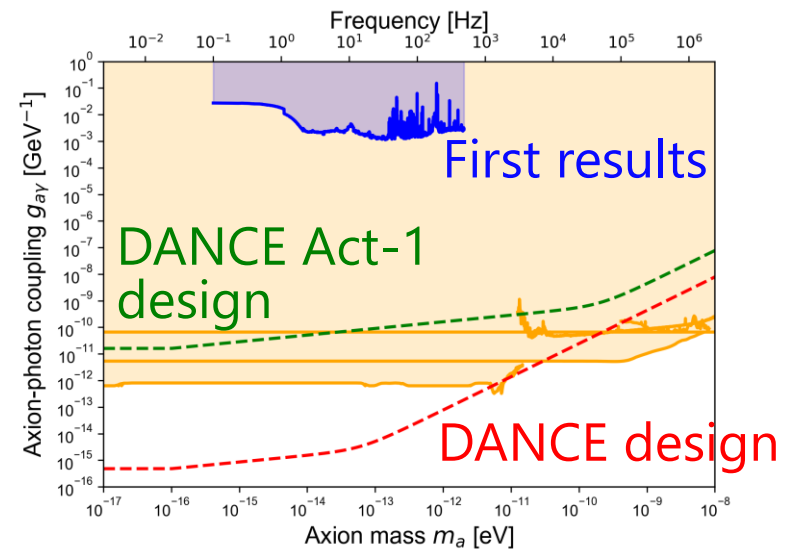
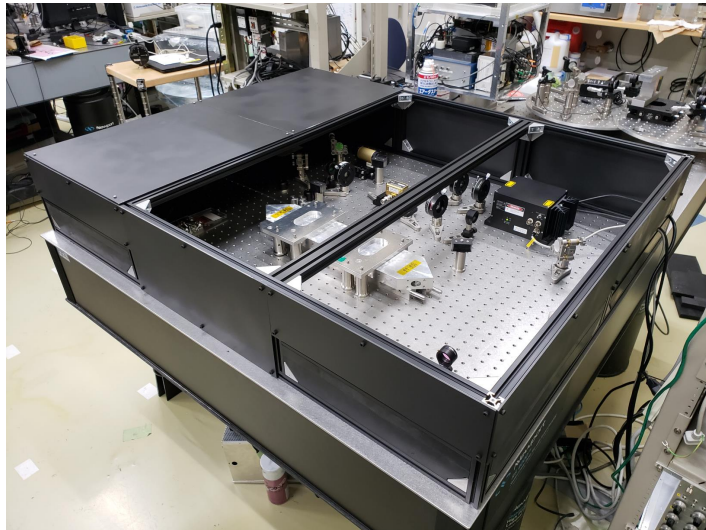
- New experimental project to search for axion DM with an optical cavity

I. Obata, T. Fujita, Y. Michimura  
[PRL 121, 161301 \(2018\)](#)

**DANCE: D**ark matter **A**xion search  
with ri**N**g **C**avity **E**xperiment

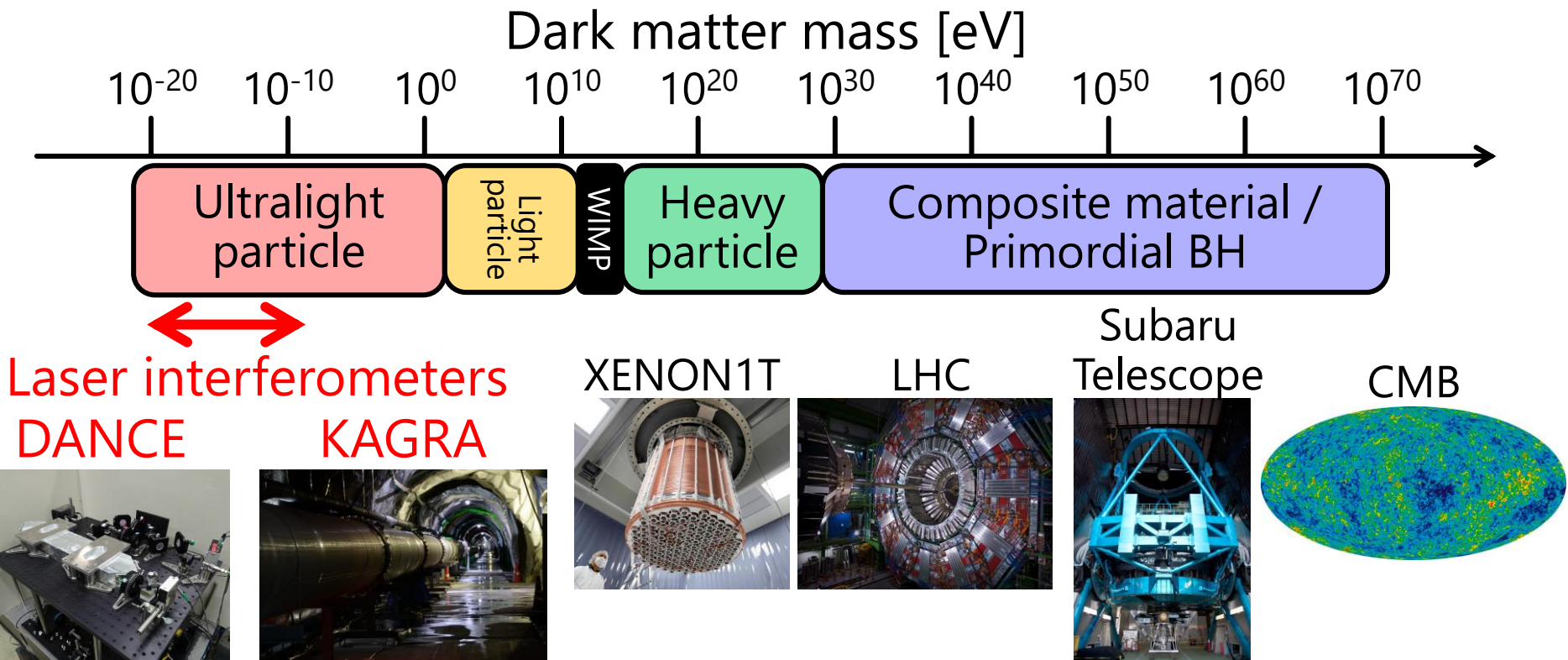
- First results of prototype experiment **DANCE Act-1** from long-term observation

YO, H. Fujimoto+, [arXiv:2303.03594](#)



# Axion search with laser interferometers

- We need to search for DM in a wider mass range
- Laser interferometers are useful to search for ultralight DM
- DANCE focuses on axion DM



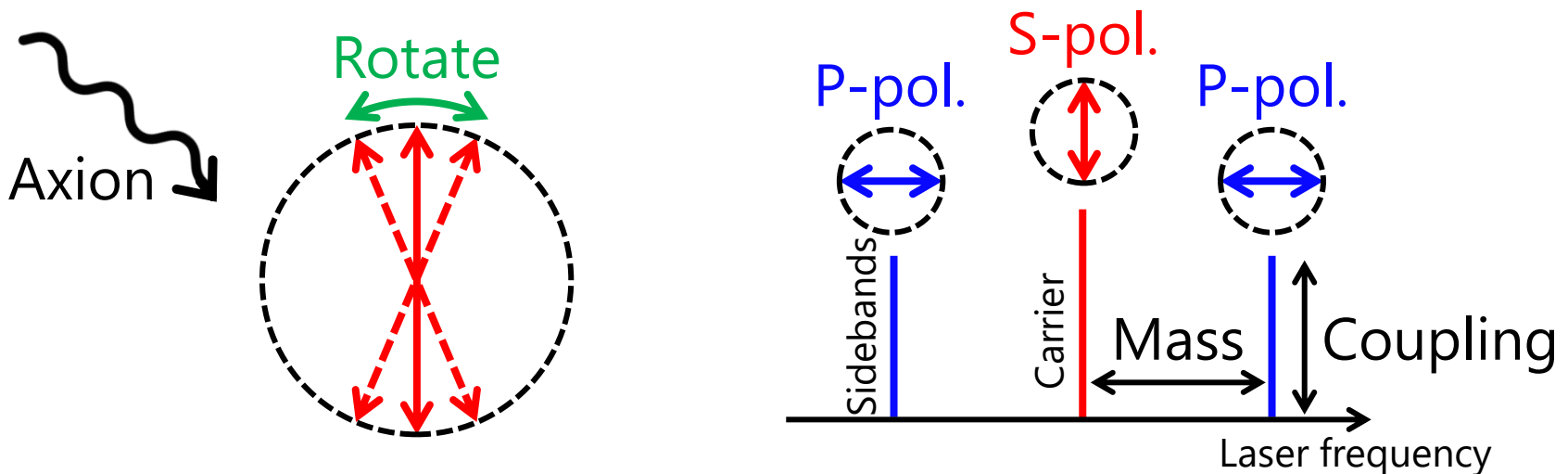
# Polarization rotation from axions

- Axion-photon coupling causes phase velocity difference between left- and right-handed photons

$$c_{L/R} = \sqrt{1 \pm \frac{g_{a\gamma} a_0 m_a}{k} \sin(m_a t + \delta_\tau)}$$

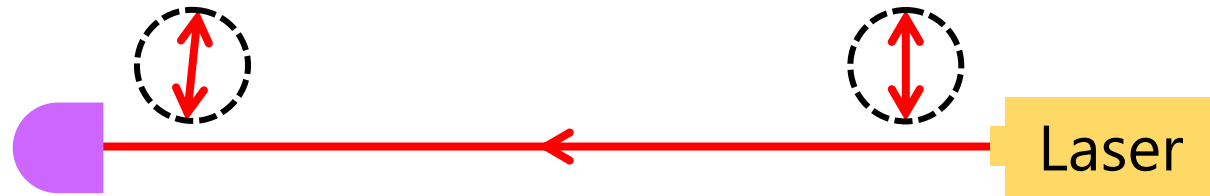
Coupling constant      Axion field      Axion mass

- Phase velocity difference of circular polarizations makes linear polarization rotate and oscillate

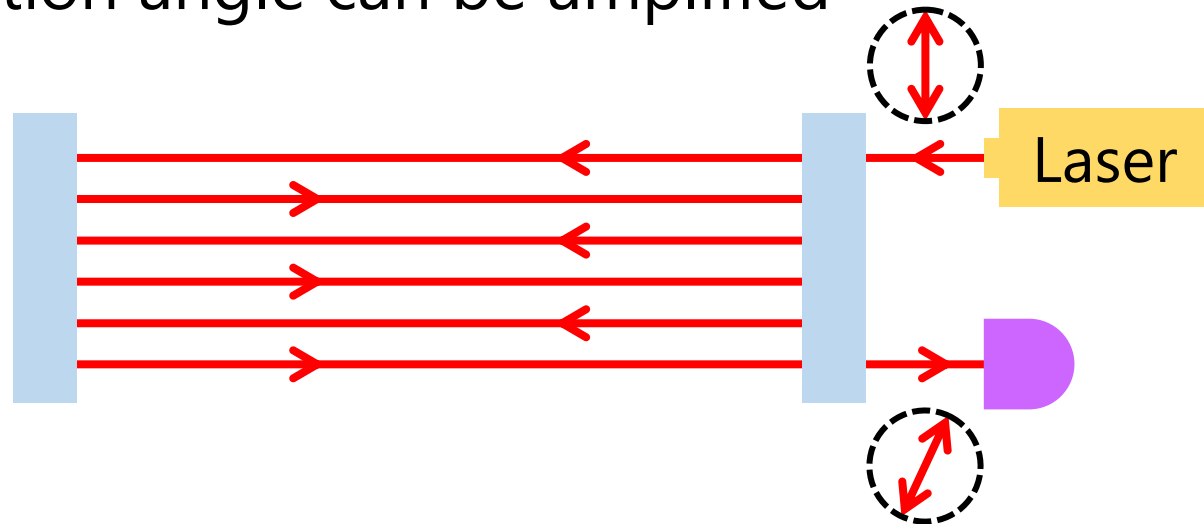


# Signal amplification with cavities

- Rotation angle is too small to be observed without a cavity

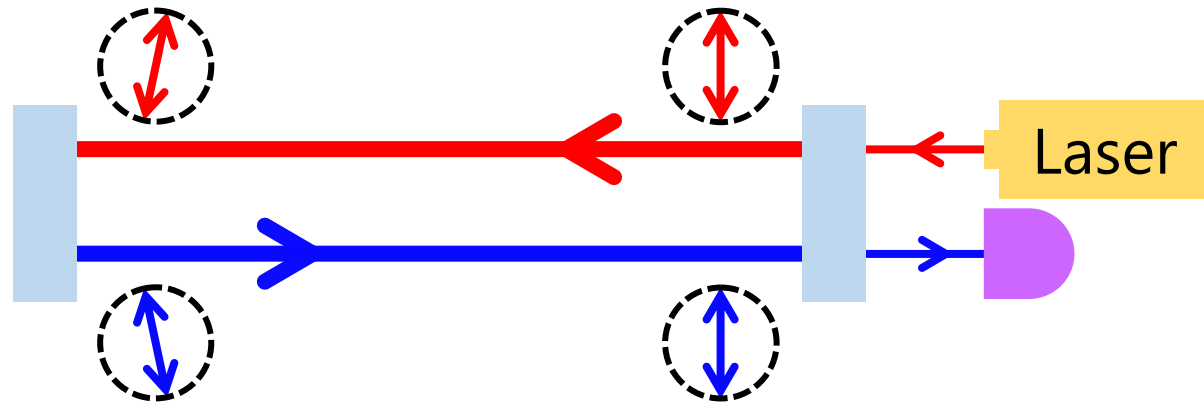


- Laser light runs many times between mirrors in an optical cavity  
→ Rotation angle can be amplified

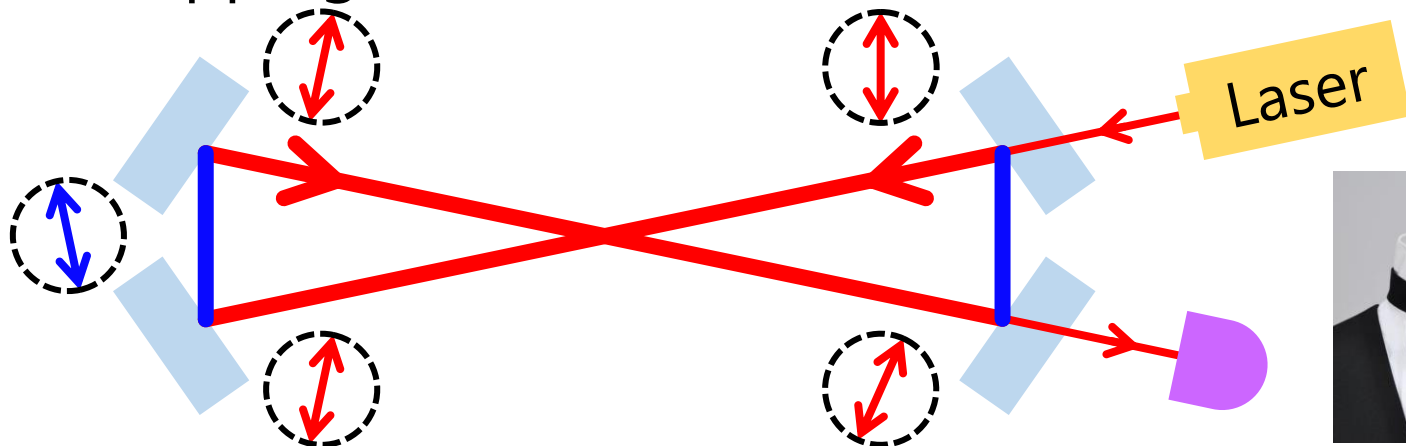


# Bow-tie ring cavity

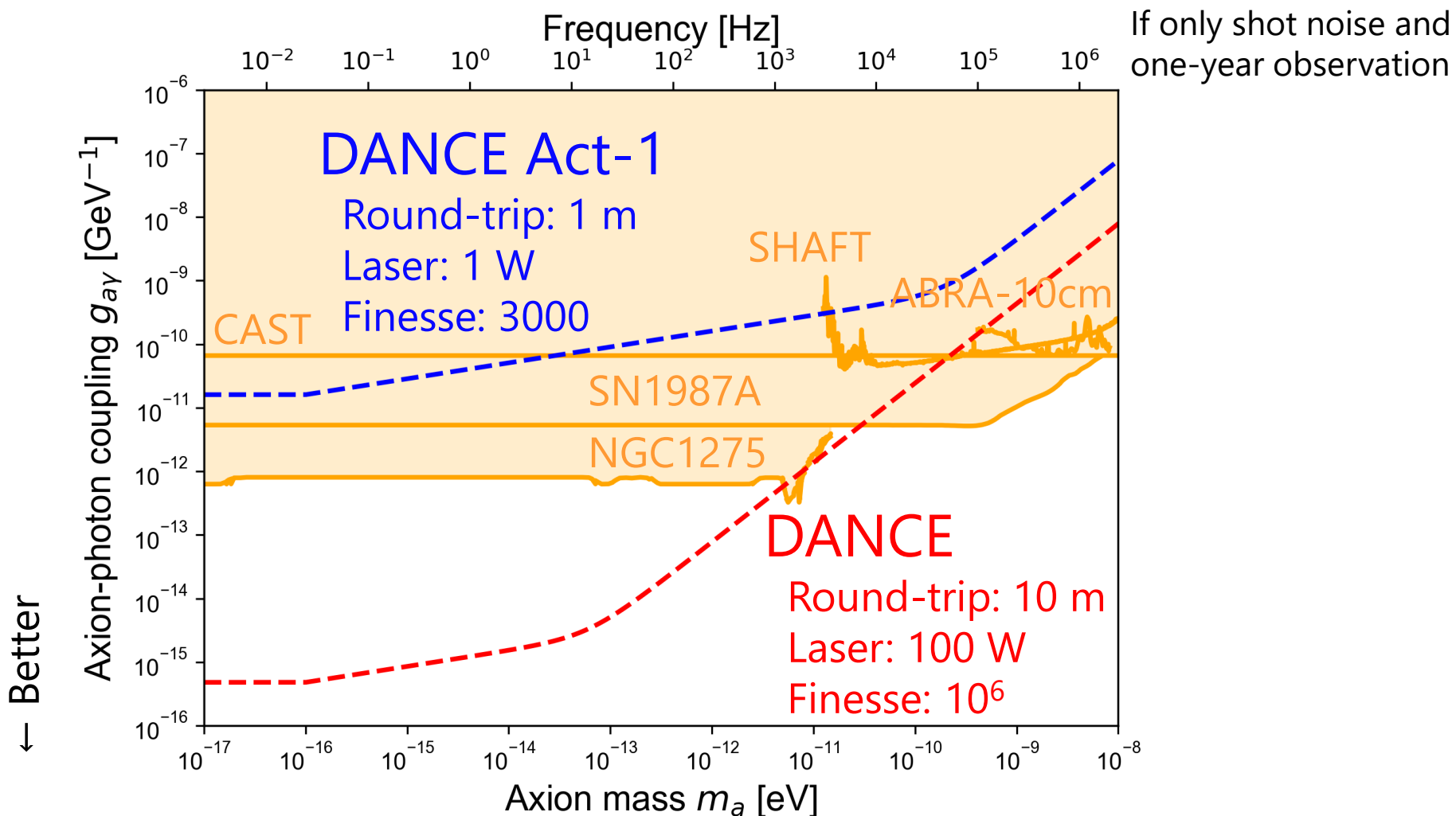
- Rotated direction is inverted by reflection on mirrors  
→ Rotation effect is canceled out



- A bow-tie ring cavity prevents linear polarization from flipping

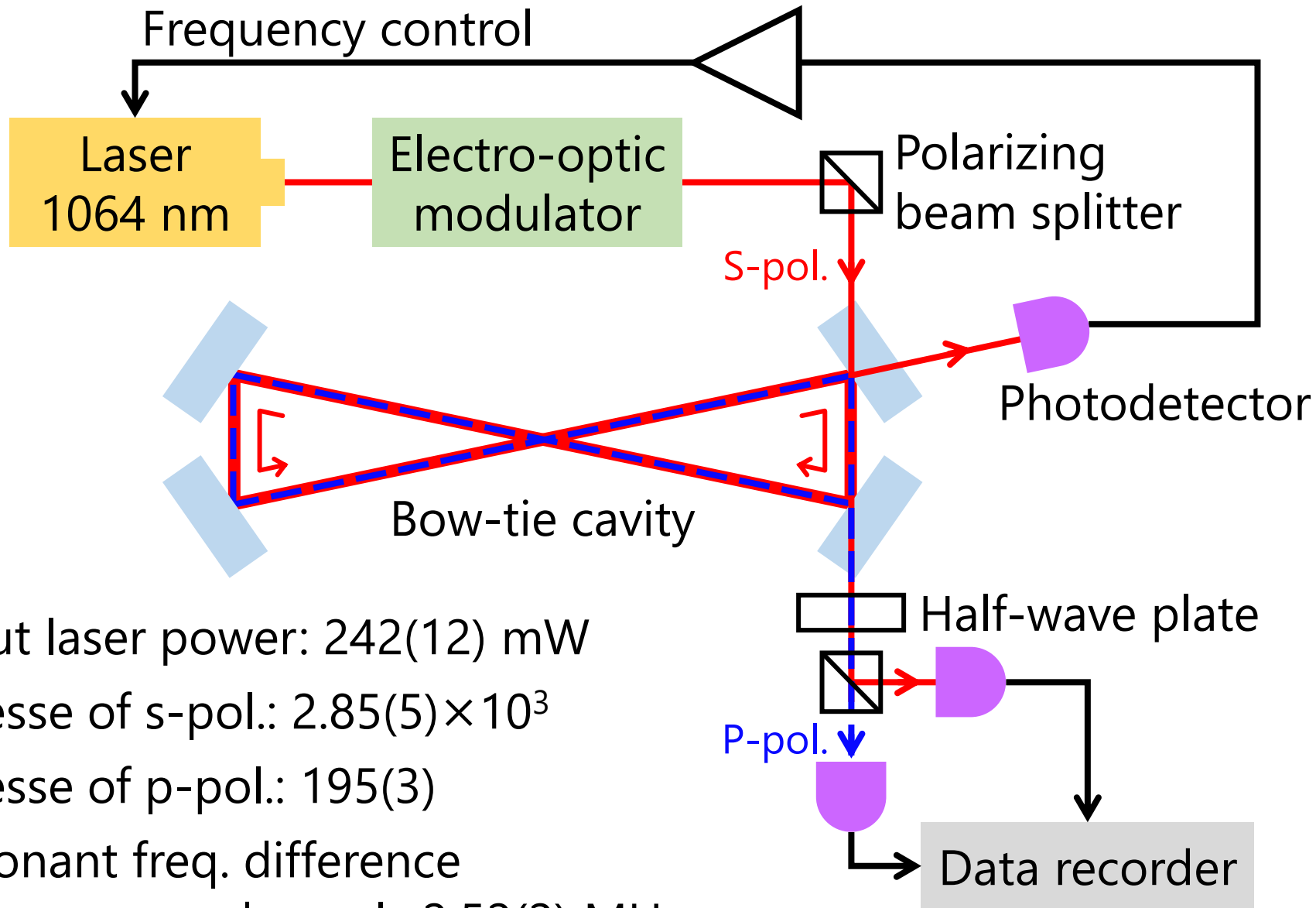


# Design sensitivity of DANCE



- Shot noise is caused by fluctuations in photons' number
- Need to minimize the other noise sources

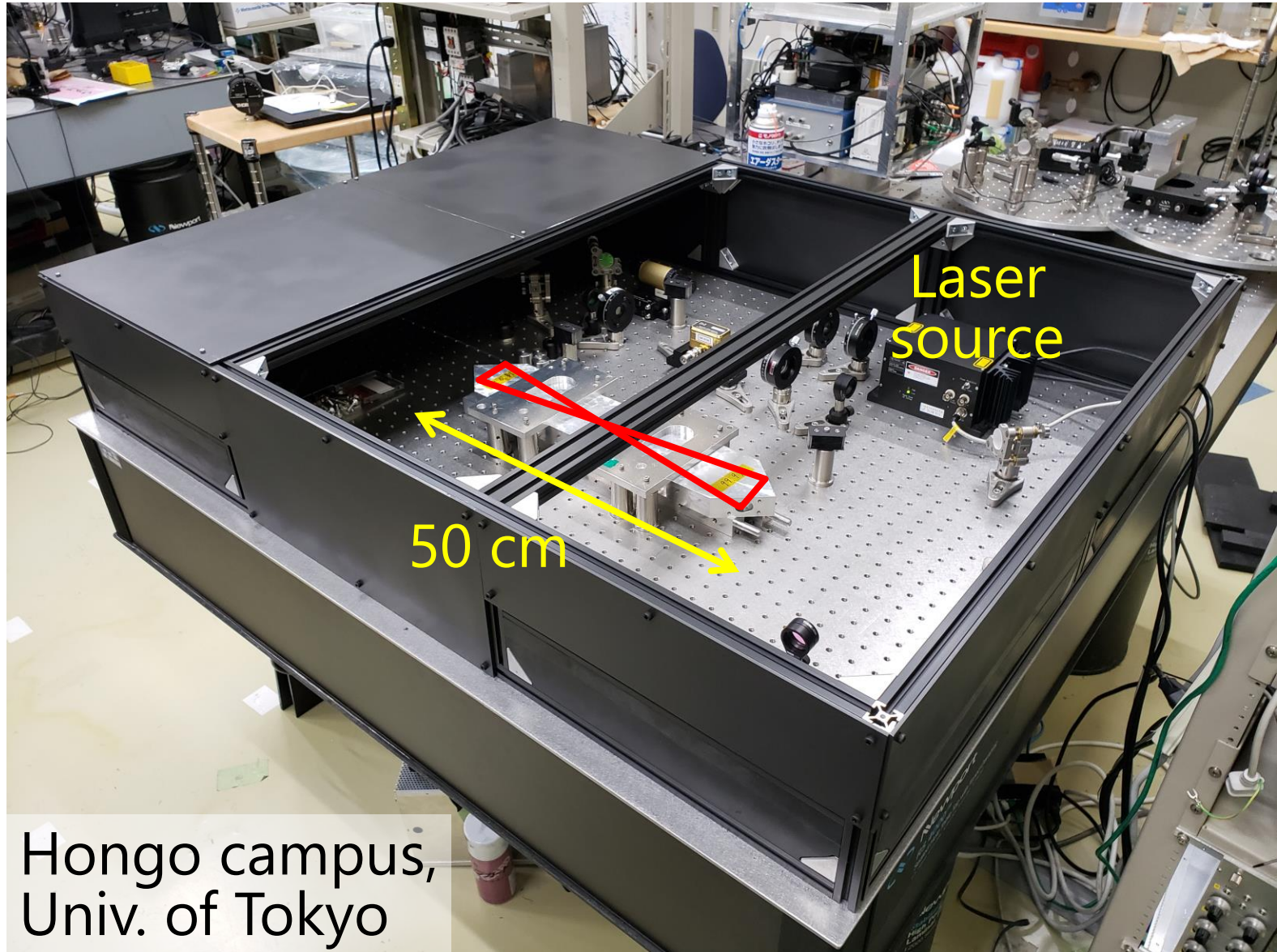
# Setup of DANCE Act-1



- Input laser power: 242(12) mW
- Finesse of s-pol.:  $2.85(5) \times 10^3$
- Finesse of p-pol.: 195(3)
- Resonant freq. difference between s- and p-pol.: 2.52(2) MHz



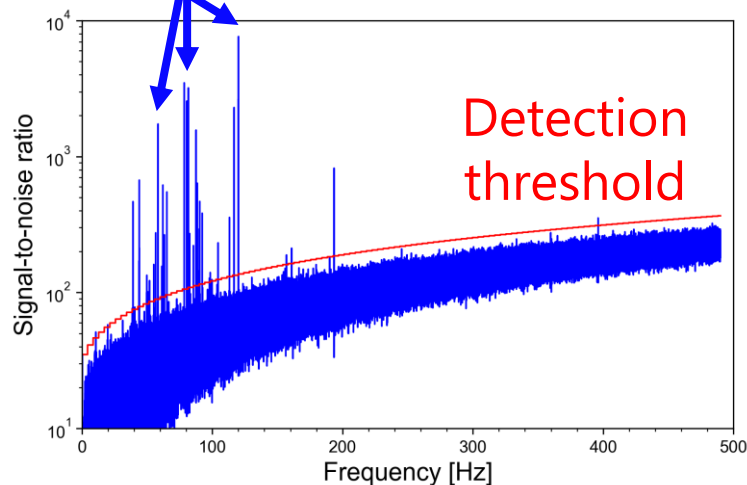
# Picture of DANCE Act-1



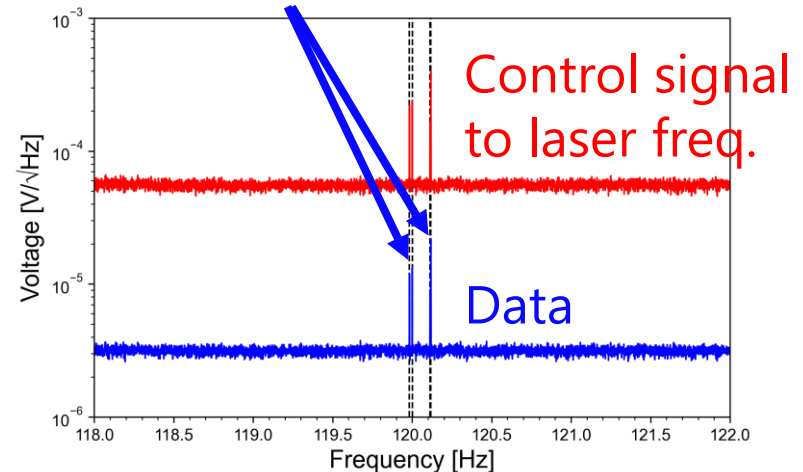
# Data acquisition and analysis

- Recorded the data in May 18-30, 2021
- The first 86,400-second (24-hour) data was selected
- After passing the data through the analysis pipeline, 551 points exceeded the threshold
- All candidate peaks were rejected by 3 veto procedures
  - Consistency veto: 551  $\rightarrow$  271
  - Linewidth veto: 271  $\rightarrow$  7
  - Control signal veto: 7  $\rightarrow$  0

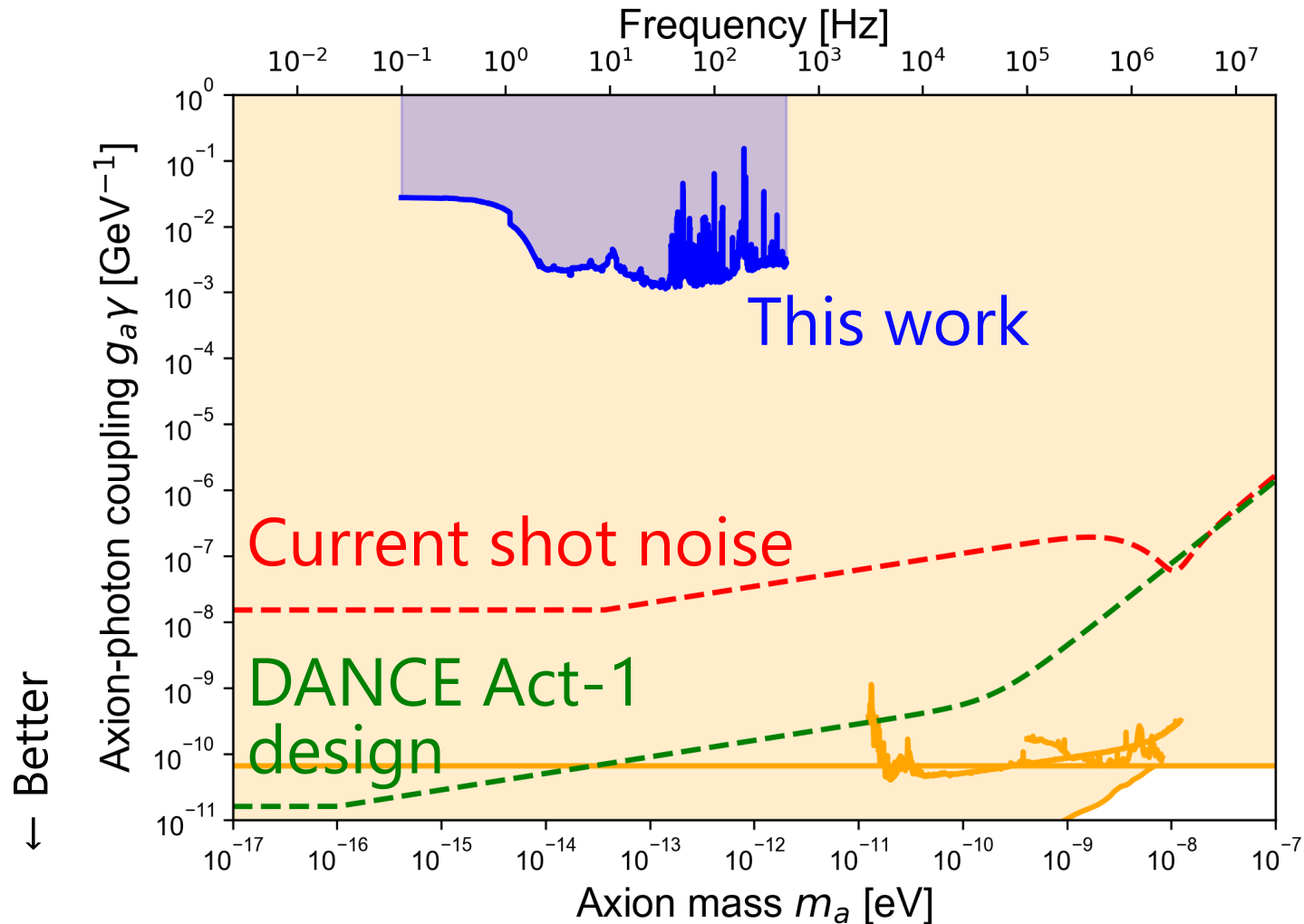
Candidate peaks



Probably due to mechanical resonance

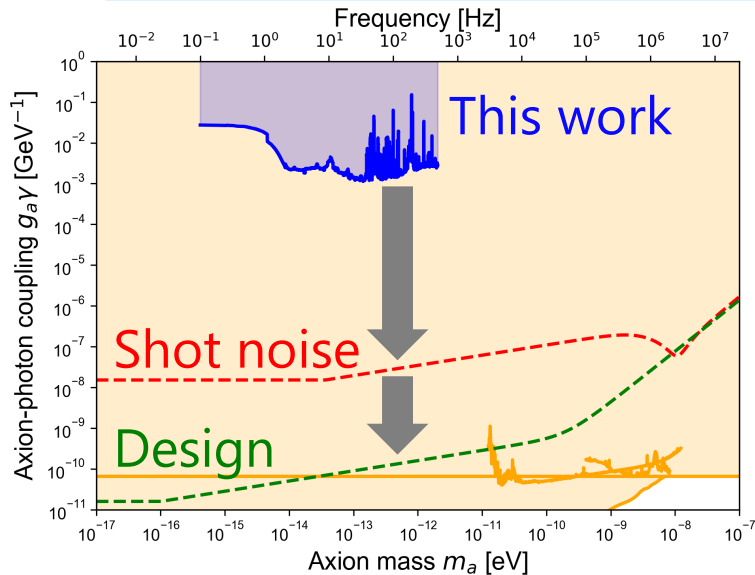


# Results



- Worse than design sensitivity by 7 orders of magnitude
- First results of axion DM search with an optical cavity

# Discussion to improve the sensitivity



## 1. This work to shot noise

- We need to reduce classical noises
  - Laser intensity noise
  - Laser frequency noise
  - Mechanical vibration

## 2. Shot noise to design sensitivity

- We need to improve the parameters
  - Input laser power: 0.2 W  $\rightarrow$  1 W
  - Observation time: 24 hours  $\rightarrow$  1 year
  - Resonant freq. difference between s- and p-pol.: 3 MHz  $\rightarrow$  0 Hz (simultaneous resonance)

We are installing an auxiliary cavity (Hiroki's talk)

# Summary

- New experimental project to search for axion DM with a bow-tie cavity: **DANCE**

I. Obata, T. Fujita, Y. Michimura  
[PRL 121, 161301 \(2018\)](#)

- Prototype experiment **DANCE Act-1** is ongoing
  - Long-term observation in May 2021
  - **The first upper bounds on  $g_{a\gamma}$  with an optical cavity**
  - We continue to improve the sensitivity

YO, H. Fujimoto+, [arXiv:2303.03594](#)

H. Fujimoto, YO+, [JPCS 2156, 012182 \(2021\)](#)

