

Dark matter Axion search with ring Cavity Experiment DANCE: Signal calibration and sensitivity evaluation

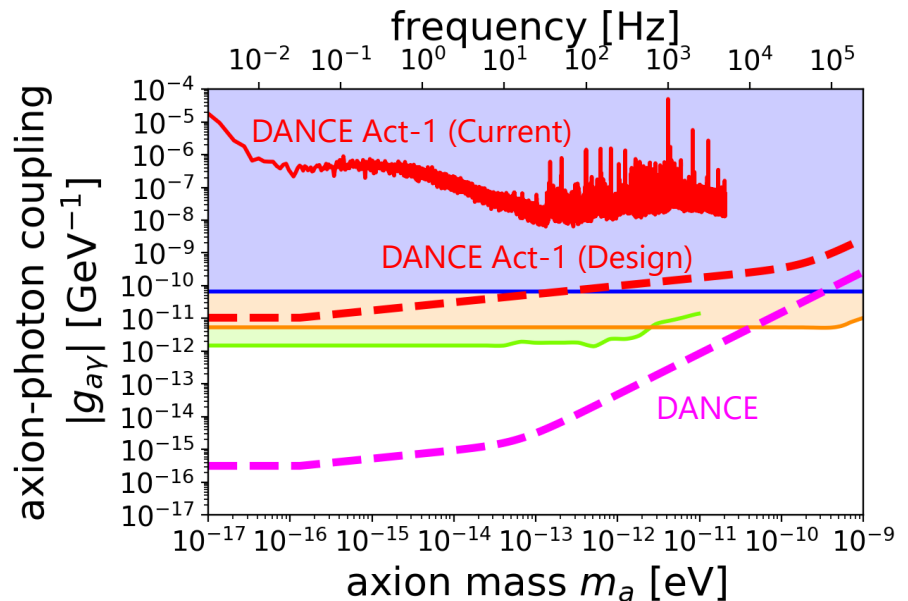
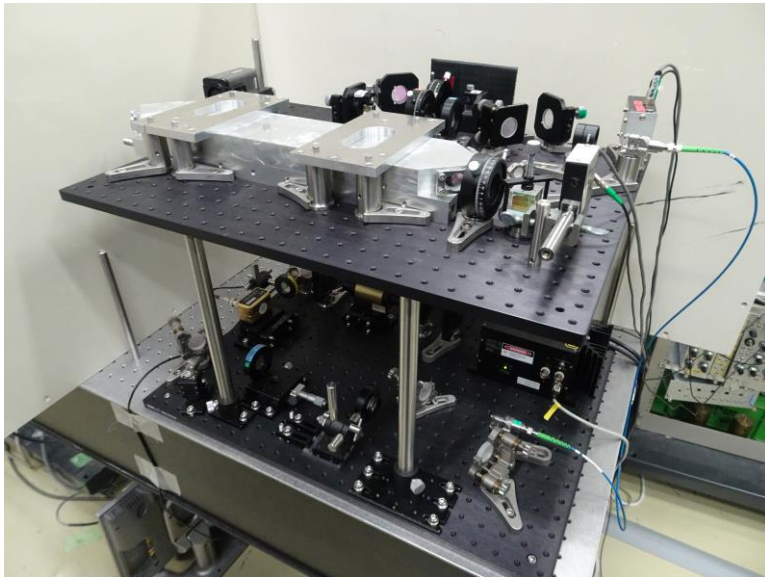
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Overview

- A new method to search for axion-like particles with a table-top experiment
I. Obata, T. Fujita, Y. Michimura, [PRL 121, 161301 \(2018\)](#)
- **DANCE**: **D**ark matter **A**xion search with **r**ing **C**avity **E**xperiment
- Prototype experiment **DANCE Act-1** is ongoing



DM search with laser interferometers

- Dark matter has not been detected yet
- Need to search in wider mass range
- **Ultralight dark matter search with laser interferometers** is attracting attention

Dark matter mass [GeV]

10^{-30} 10^{-20} 10^{-10} 10^0 10^{10} 10^{20} 10^{30} 10^{40} 10^{50} 10^{60}



QCD axion

XENON1T

LHC

Subaru Telescope

CMB

2.4 Hz - 2.4 kHz
(10^{-14} eV - 10^{-11} eV)

KAGRA



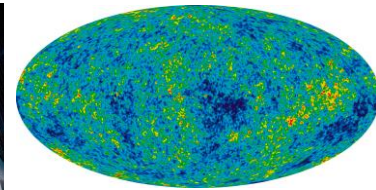
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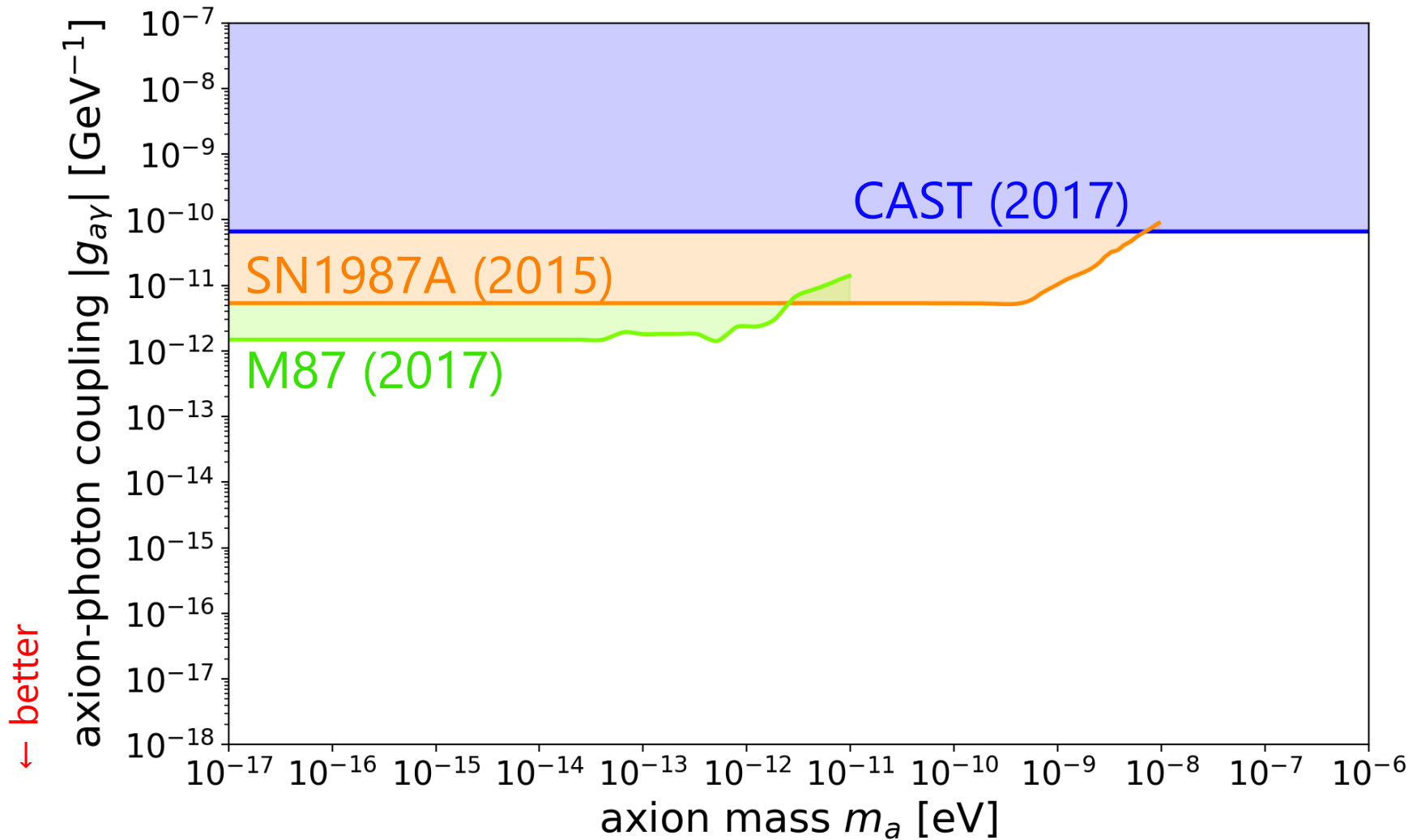


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Upper limits from previous researches

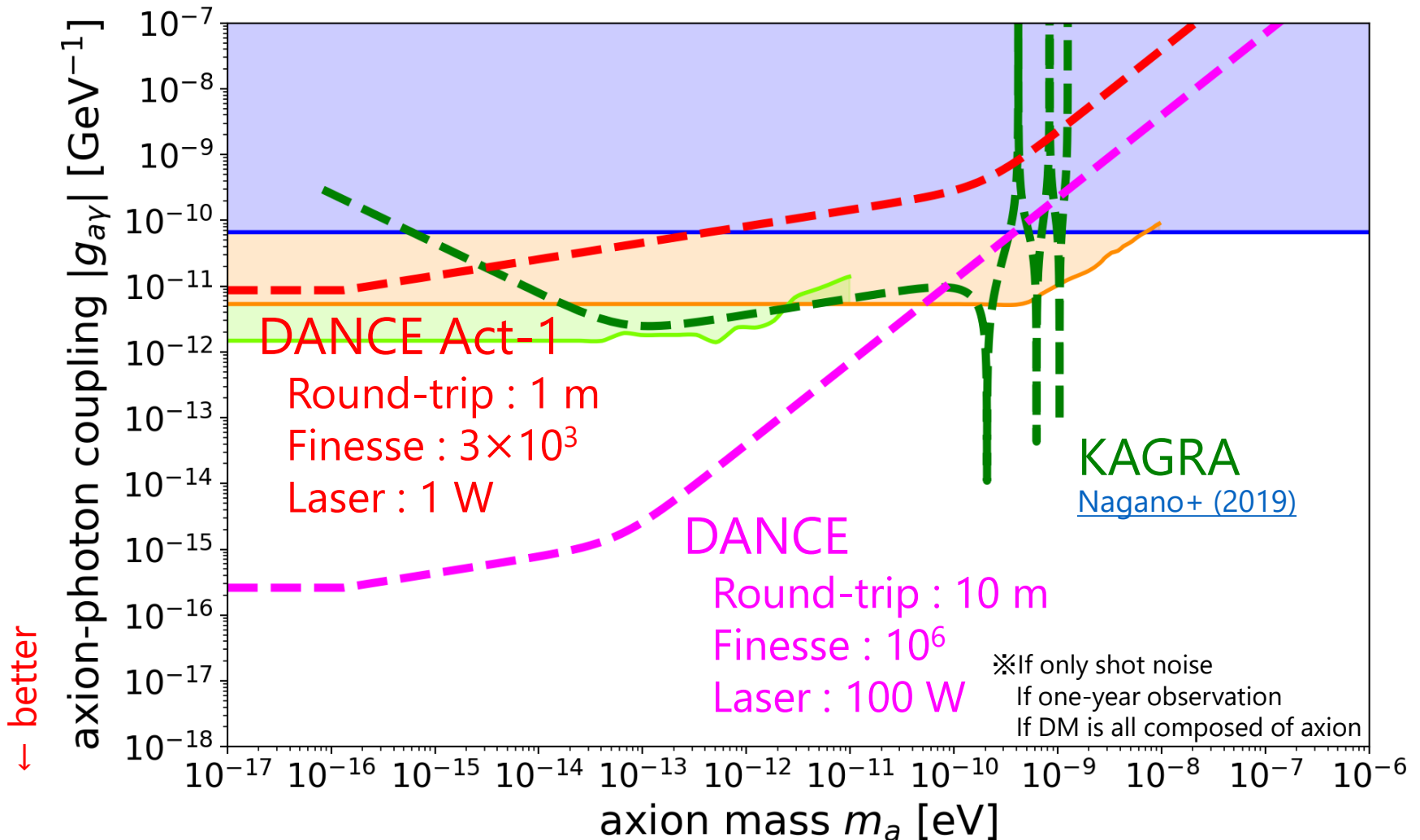


[Anastassopoulos+ \(2017\)](#)

[Payez+ \(2015\)](#)

[Marsh+ \(2017\)](#)

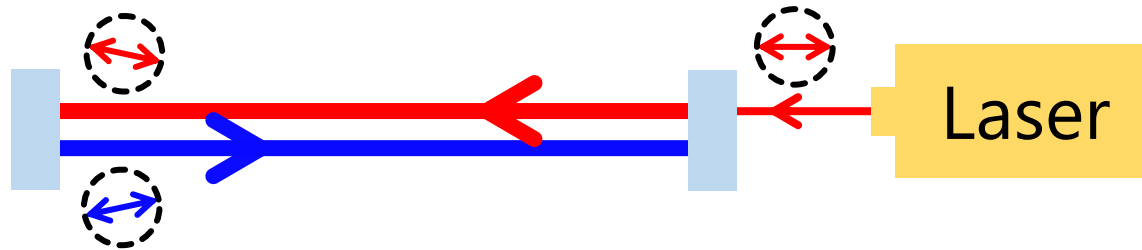
Sensitivity of DANCE



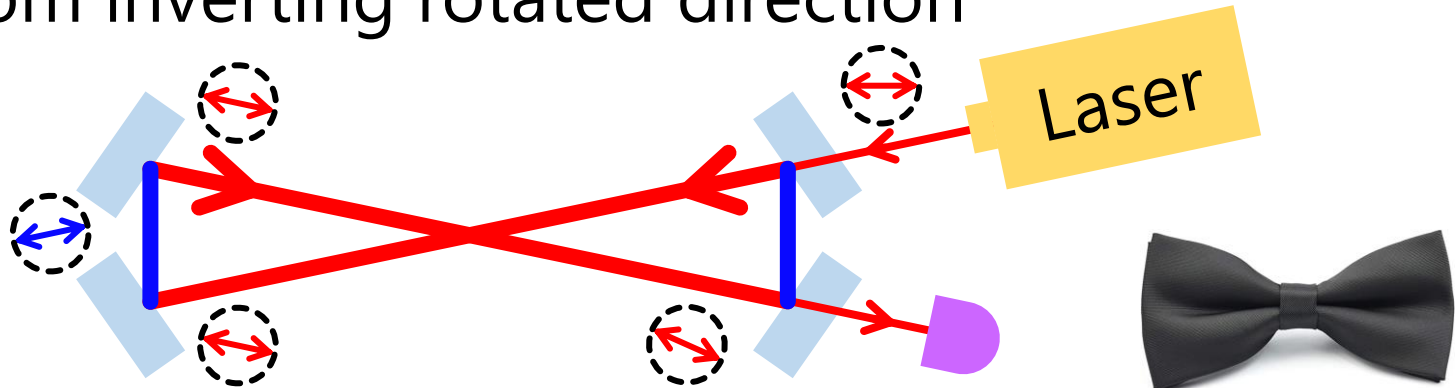
- DANCE will improve limits by several orders of magnitude
- Mass band of DANCE is complementary to that of KAGRA

Bow-tie ring cavity

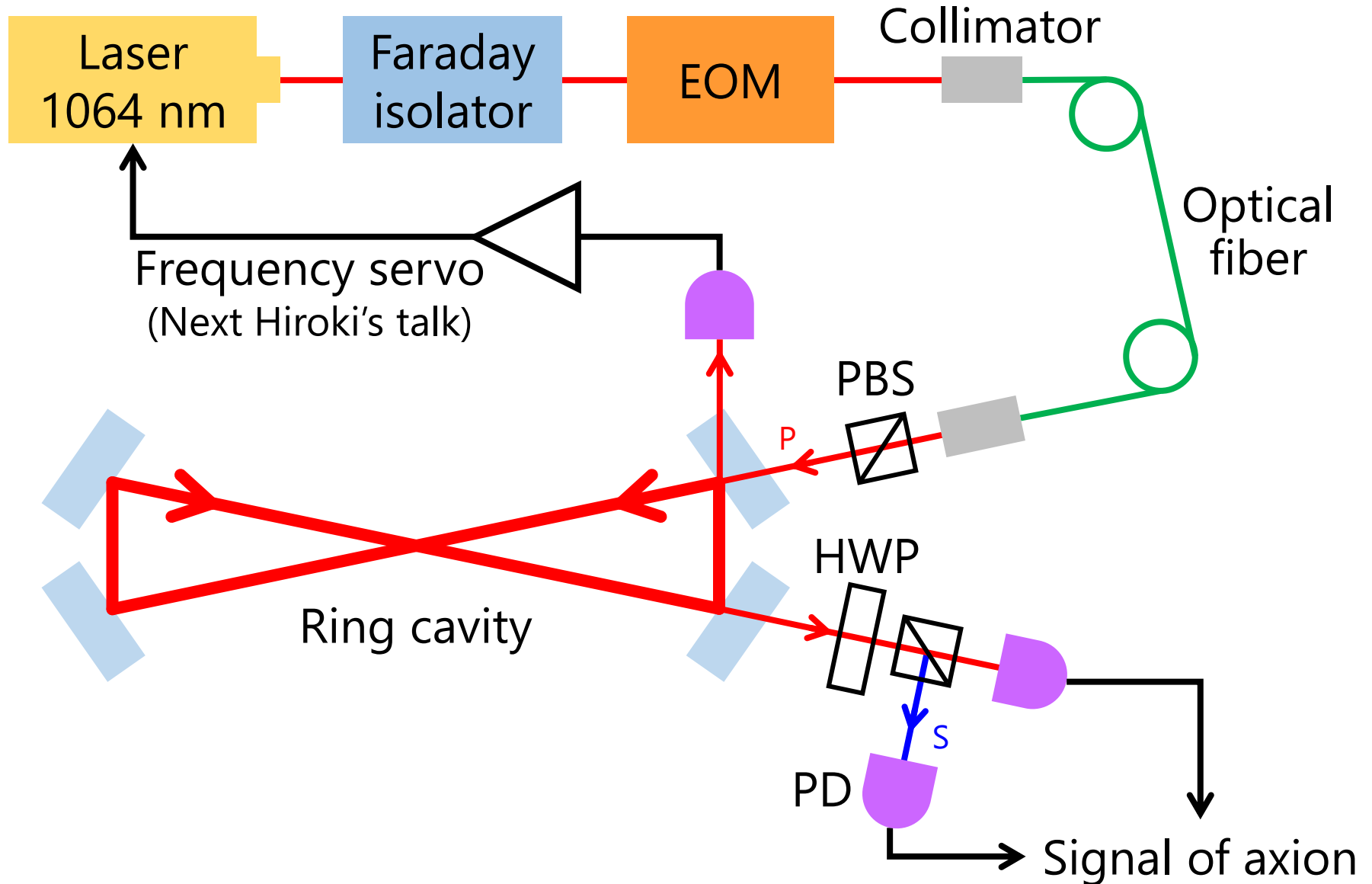
- DANCE observes rotation angle of linear polarization caused by axion (if axion is DM)
- Rotated direction is inverted in a linear cavity
→ Rotation effect is cancelled out



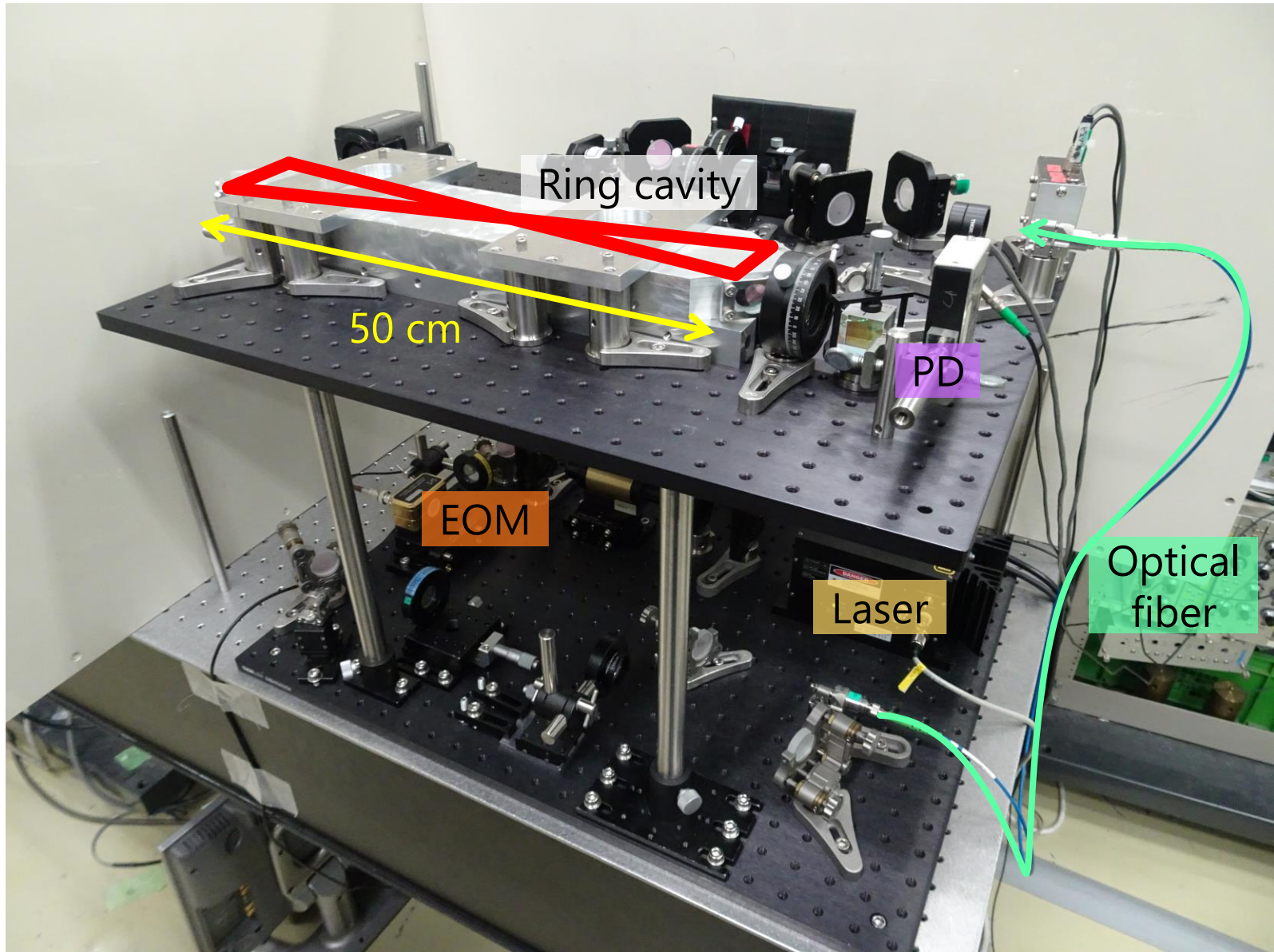
- A **bow-tie ring cavity** prevents linear polarization from inverting rotated direction



Experimental setups of DANCE



Picture of the setups



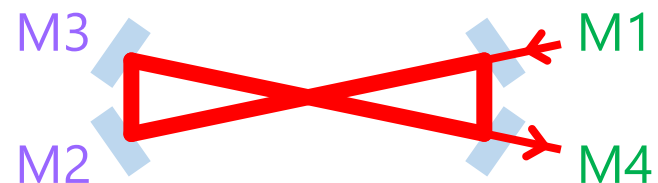
Performance evaluation of a cavity

	Design value	Measured value (P polarization)
Reflectance of mirrors	M1, M4: 99.9 % M2, M3: 100 %	M1, M4: 99.9 % M2, M3: 99.95 %
Finesse	3140	525 ± 19 (S pol. : 527 ± 29)
Round-trip length	99.4 cm	102 ± 4 cm
Radius of curvature of mirrors	100 cm (all)	102 ± 2 cm
Incident angle	42 deg	41.9 ± 1.7 deg
Mode matching ratio	99.9987 %	83.03 ± 0.09 %
Input power	~ 1 W	~ 40 mW

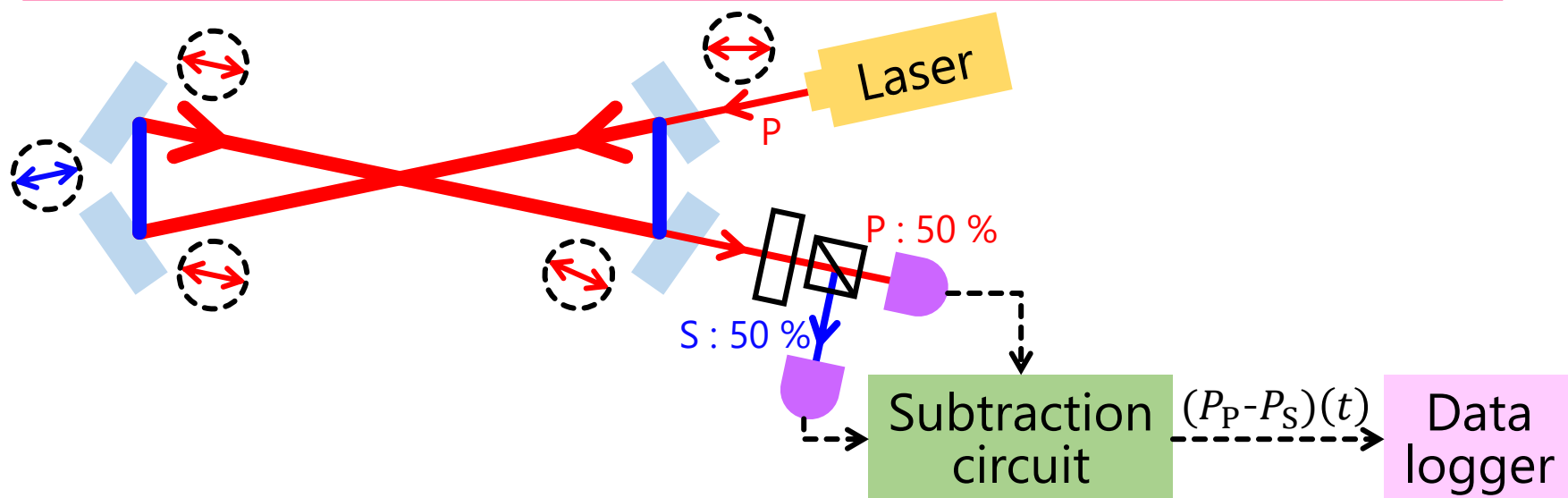
→ Finesse
2100

→ Loss of light
0.91 %

→ Misalignment
0.9 deg

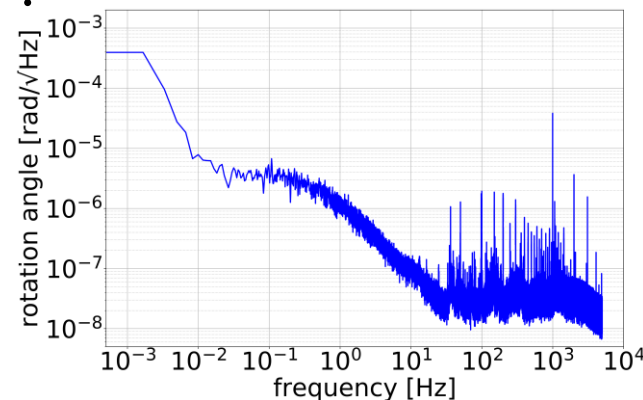


Data acquisition & Data analysis

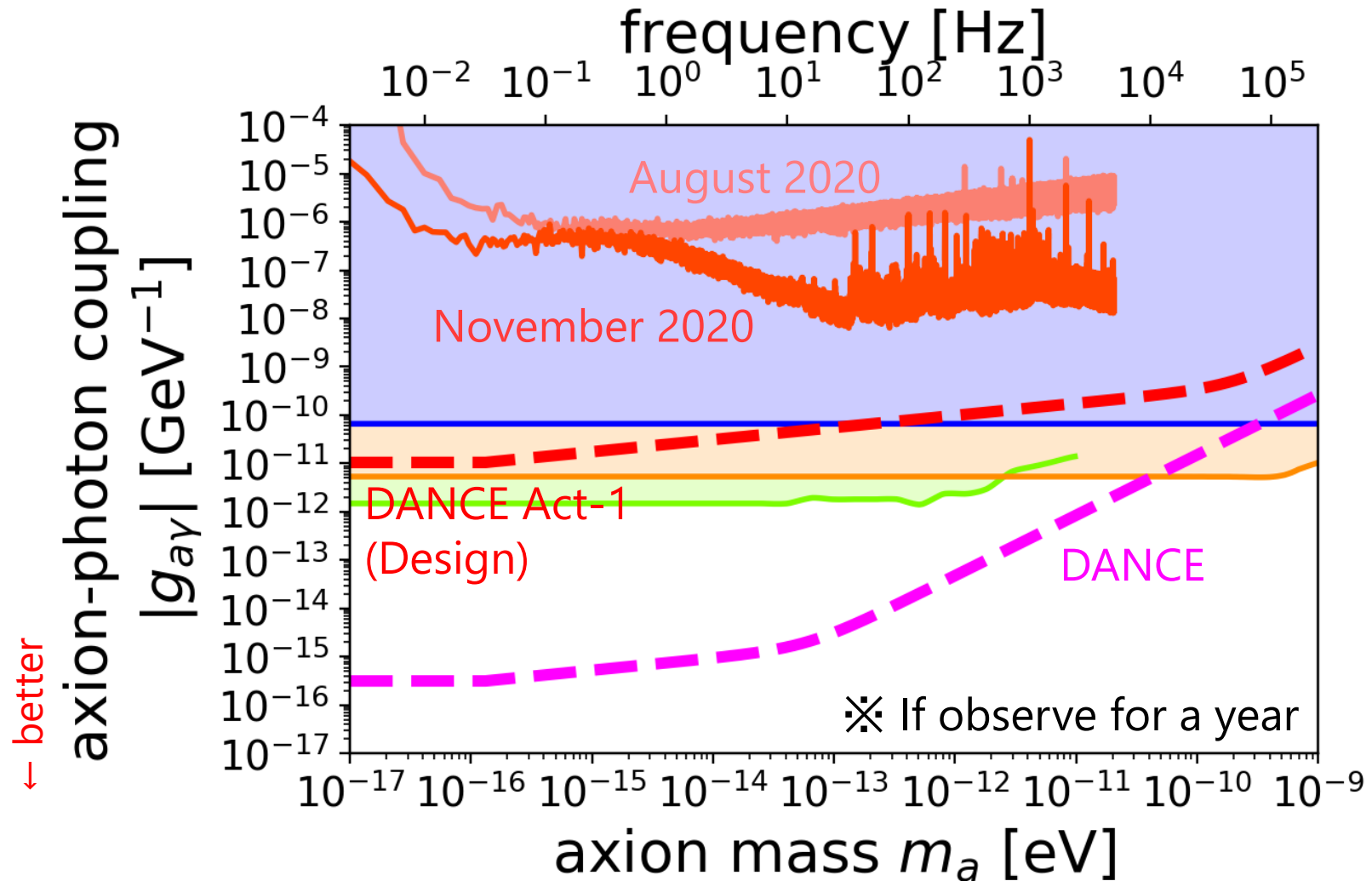


- HWP is fixed to make equal amount of P and S polarization
- Record a differential power $(P_P - P_S)(t)$, P_P and P_S
- Rotation angle of linear polarization :

$$\phi(t) = \frac{(P_P - P_S)(t)}{2(P_P + P_S)}$$

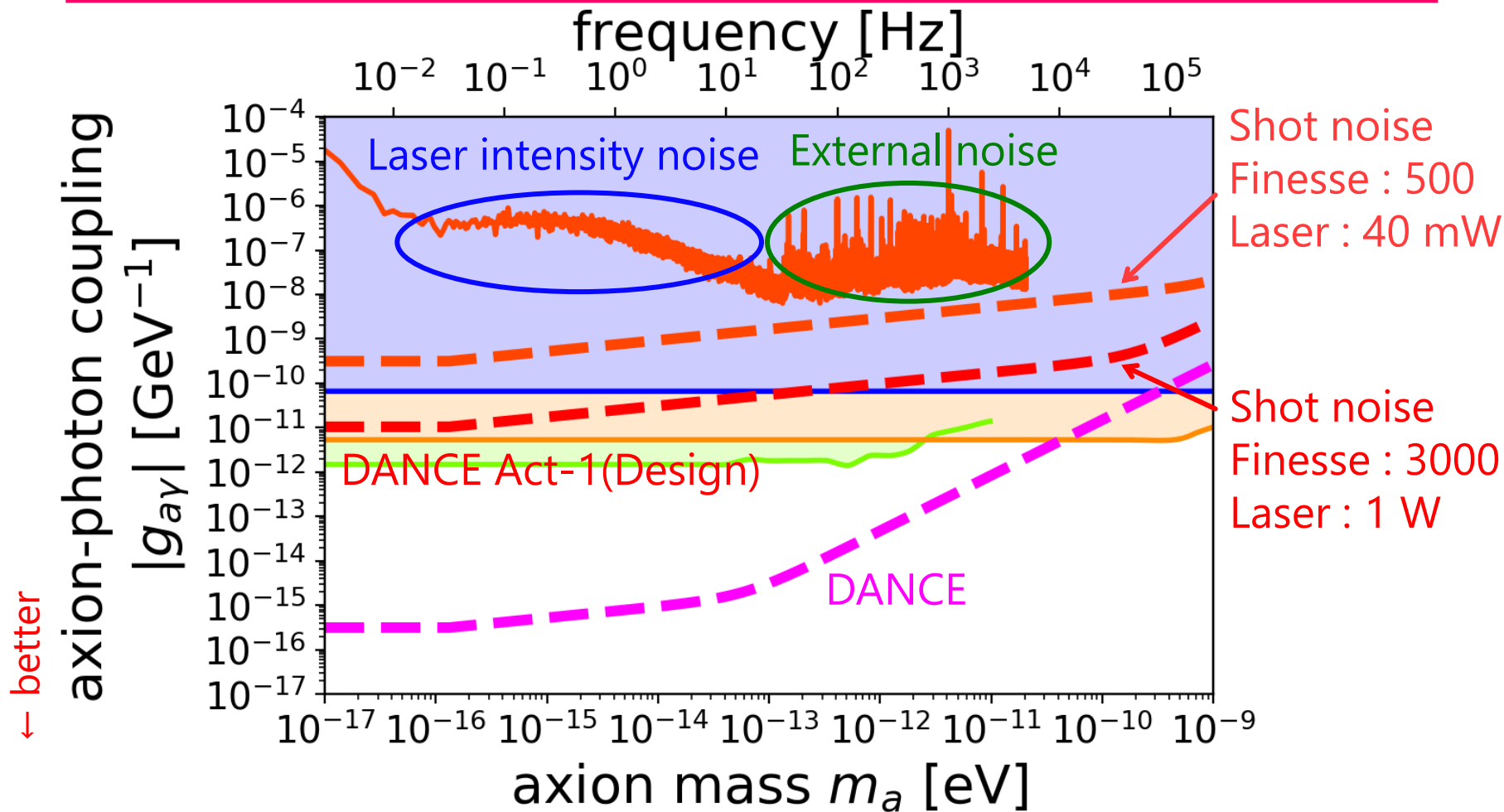


Current estimated sensitivity



- We have to improve the current sensitivity by 10^3 - 10^5 times to reach the design sensitivity

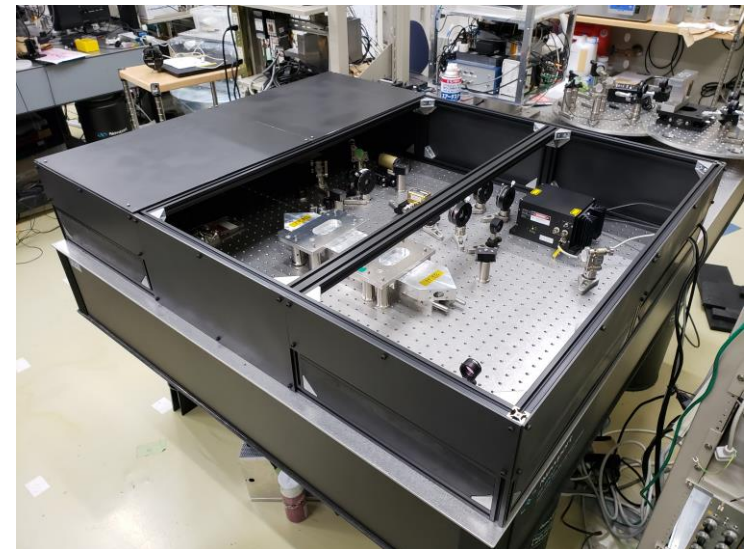
Estimation of sensitivity improvement



- Shot noise limited : + 10^1 - 10^3 times
- Finesse (500 \rightarrow 3000) : + 10 times
- Laser (40 mW \rightarrow 1 W) : + 10 times

New setups & Future plans

- Improve finesse → ~ 2300
 - Change to high quality mirrors
 - Improve alignment of mirrors
- Reduce noises → one order of magnitude
 - Construct setups only on the 1st floor
 - Surround an optical table with plates
- Higher laser input power
→ ~ 500 mW
- Plan to take data for a week during New Year holidays



Summary

- A new table-top experiment searches for ALPs with a ring cavity
DANCE: Dark matter Axion search with riNg Cavity Experiment
- DANCE observes rotation of linear polarization in a bow-tie cavity
- Prototype experiment **DANCE Act-1** is ongoing
 - Now improving finesse and reducing noises to achieve the design sensitivity