The Development of Alignment Monitor for J-PARC Muon g-2/EDM Experiment

H. YASUDA
T. KUME*, T. MIBE*, S. NISHIMURA
N. SAITO*, Y. SATO*, (University of Tokyo, KEK*)
for the J-PARC muon g-2/EDM Collaboration

ABSTRACT

We intend to measure muon g-2 and EDM at J-PARC. The decay positron detector must be aligned precisely for better sensitivity to the EDM. An interferometer with an optical frequency comb laser is considered for this purpose. In this poster, partial results from a proof of principle tests are reported.

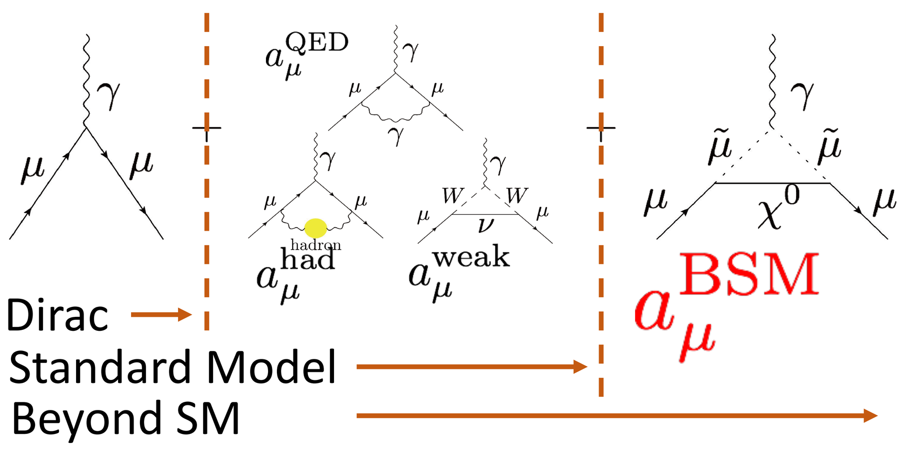
1. INTRODUCTION

MUON G-2/EDM EXPERIMENT @ J-PARC

Anomalous Magnetic Moment (g-2)

$$g = 2(1 + a_\mu)$$

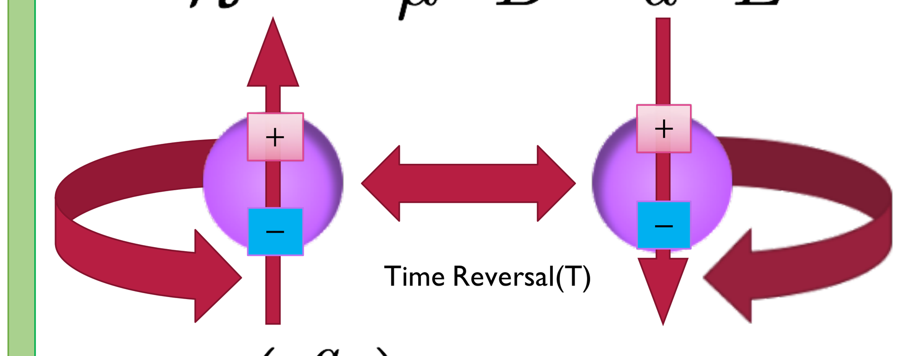
$$a_\mu = a_\mu^{\mathrm{QED}} + a_\mu^{\mathrm{had}} + a_\mu^{\mathrm{weak}} + a_\mu^{\mathrm{BSM}}$$



BNL measured the g-2 precisely and reported the discrepancy between the SM and experiment is 3.3 σ. This would indicate that Beyond the SM particle exists.

Electric Dipole Moment (EDM)

$$\mathcal{H} = -\vec{\mu} \cdot \vec{B} - \vec{d} \cdot \vec{E}$$



$$\vec{\mu} = g\left(\frac{q}{2m}\right)\vec{s} \qquad \vec{d} = \eta\left(\frac{q}{2mc}\right)\vec{s}$$

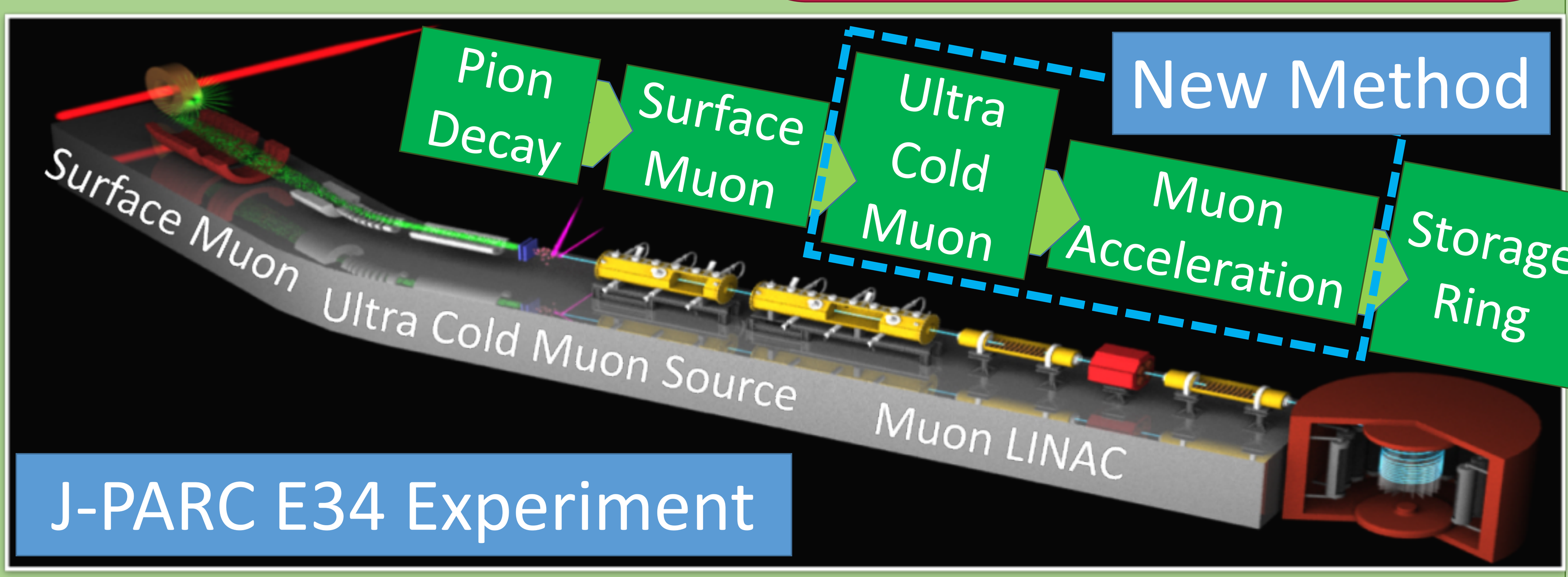
C even / P even / T even — P odd / T odd

EDM is T odd. If we observe lepton sector EDM, this is related to lepton sector CP violation. This is the crew to solve Matter-Antimatter problem.

New Experiment at J-PARC

BNL E821
g-2 : Precision 0.54 ppm
EDM : Sensitivity 10^{-19} e · cm

GOAL @ J-PARC/FNAL
g-2 : Precision 0.1 ppm
EDM : Sensitivity 10^{-21} e · cm



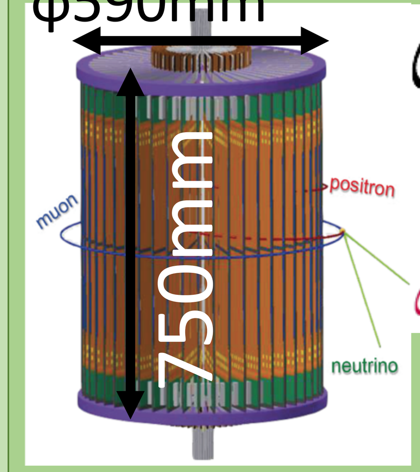
J-PARC E34 experiment is different way by the BNL experiment.
The most different point is "Ultra Cold Muon". Usually, we use surface muon (decayed muon). But we will stop this muon and accelerate ultra cold muon. By this process, we can use low emittance muon beam.

Anomalous Precession of Spin & Detector Sensitivity for EDM

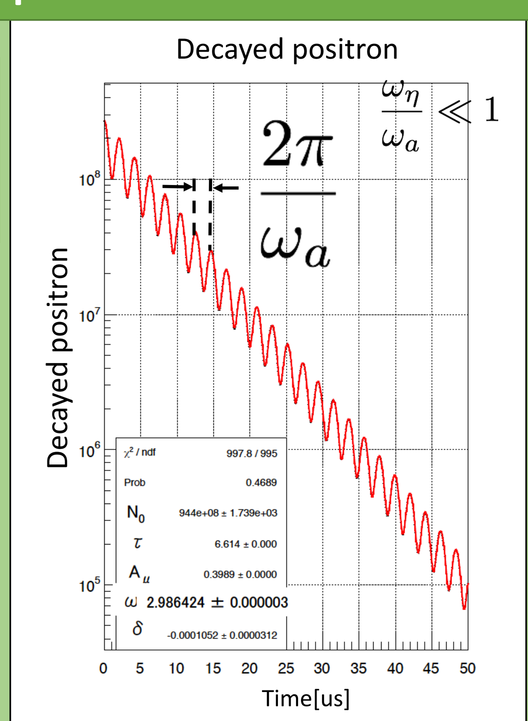
Spin Anomalous Precession

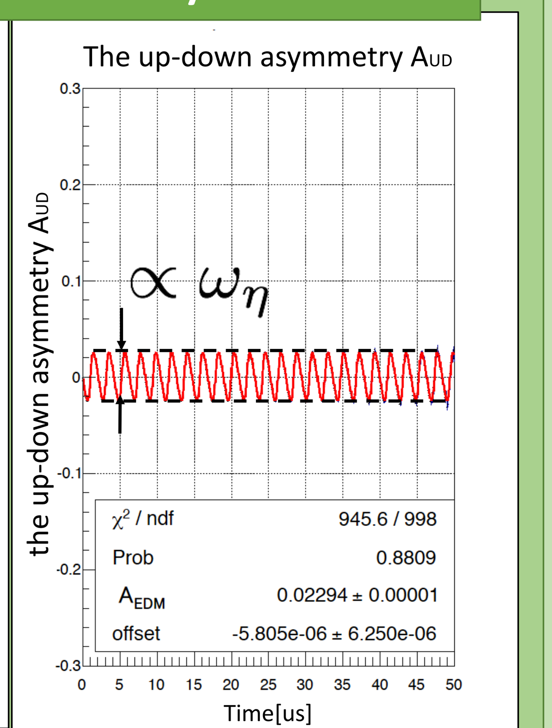
$$\vec{\omega} = -\frac{e}{m}\left[a_\mu \vec{B} + \frac{\eta}{2}\vec{\beta} \times \vec{B}\right]$$

$\vec{\omega}_a$: g-2 $\quad \vec{\omega}_\eta$: EDM



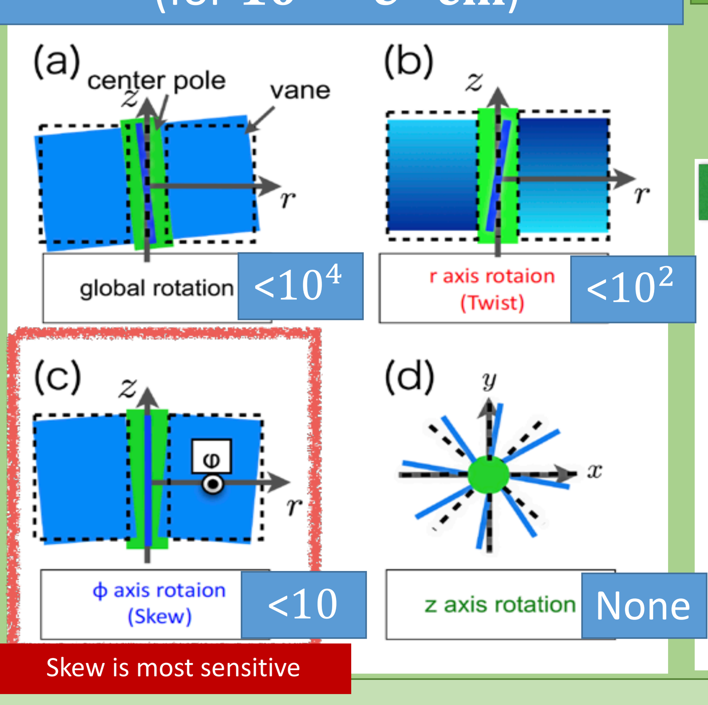
Detector Image





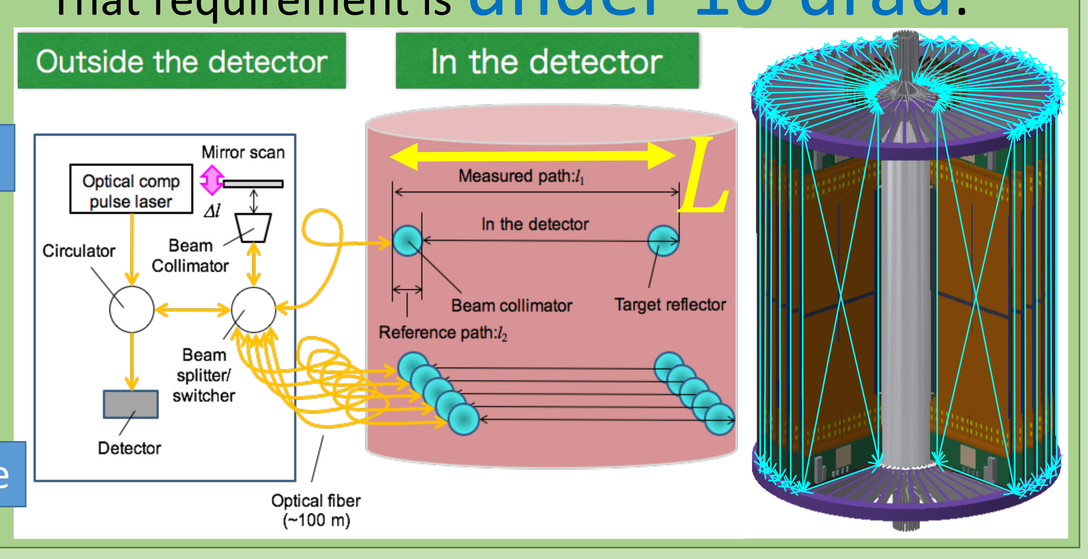
We will measure muon g-2 and EDM by spin anomalous precession.
ω_a is related to decayed positron number oscillation (wiggle plot) in left plot.
ω_η is related to up-down symmetry of detected position in right plot.

Alignment Requirement[urad] (for 10^{-21} e · cm)



Detector Misalignment

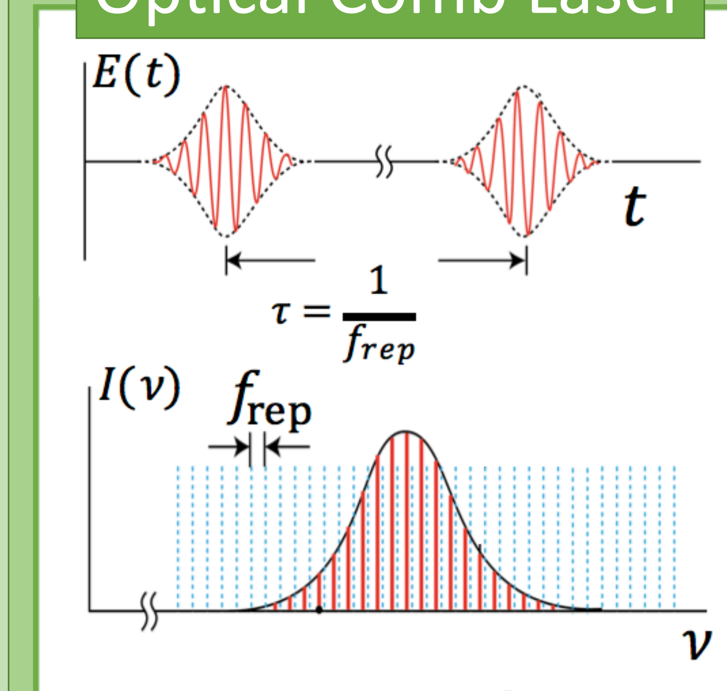
The misalignment is sensitive for EDM search.
That requirement is under 10 urad.



2. ALIGNMENT MONITOR

OPTICAL COMB LASER INTERFEROMETER

Optical Comb Laser

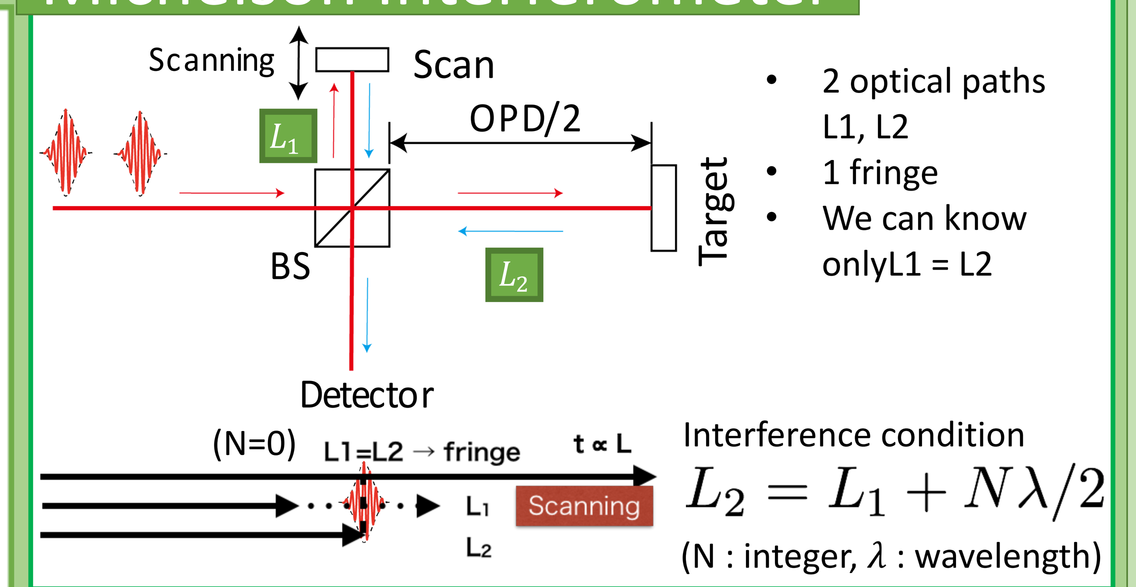


Pulse Laser
This is used as the scaler on a ruler. And this is strong for the noise.

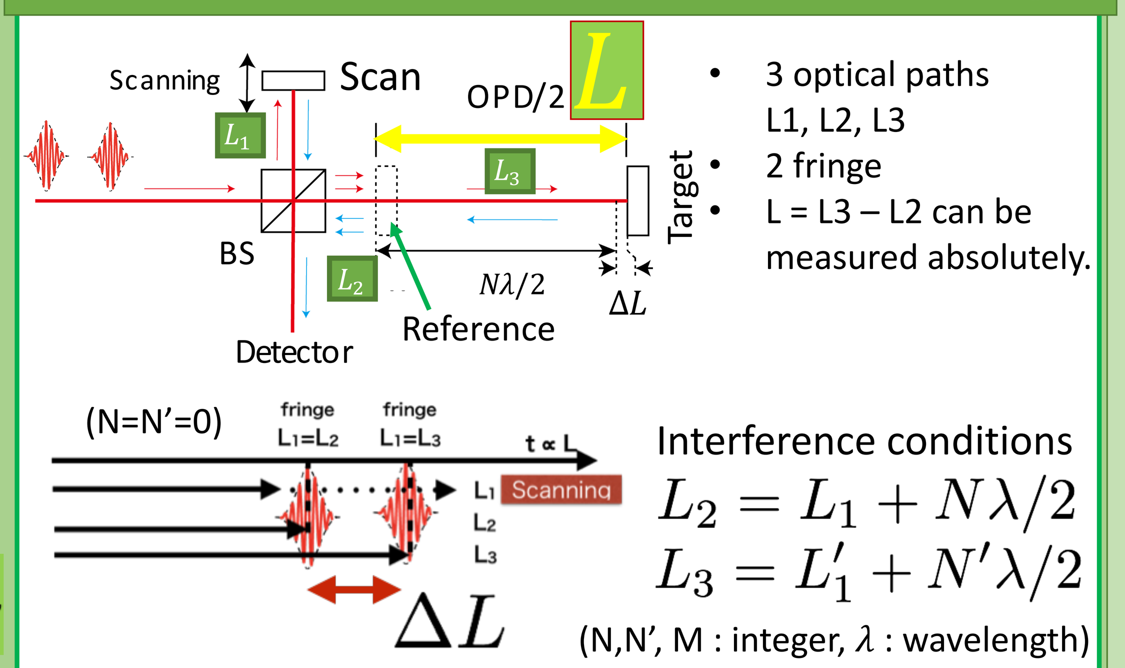
Repetition Frequency f_{rep}
Repetition frequency is much stable. This means the scaler is much accurate.

$$L = M\lambda/2 + \Delta L$$

Michelson Interferometer



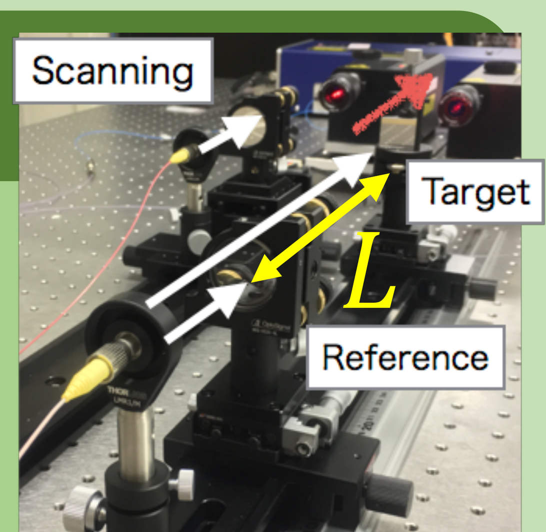
Interferometer to measure the absolute length

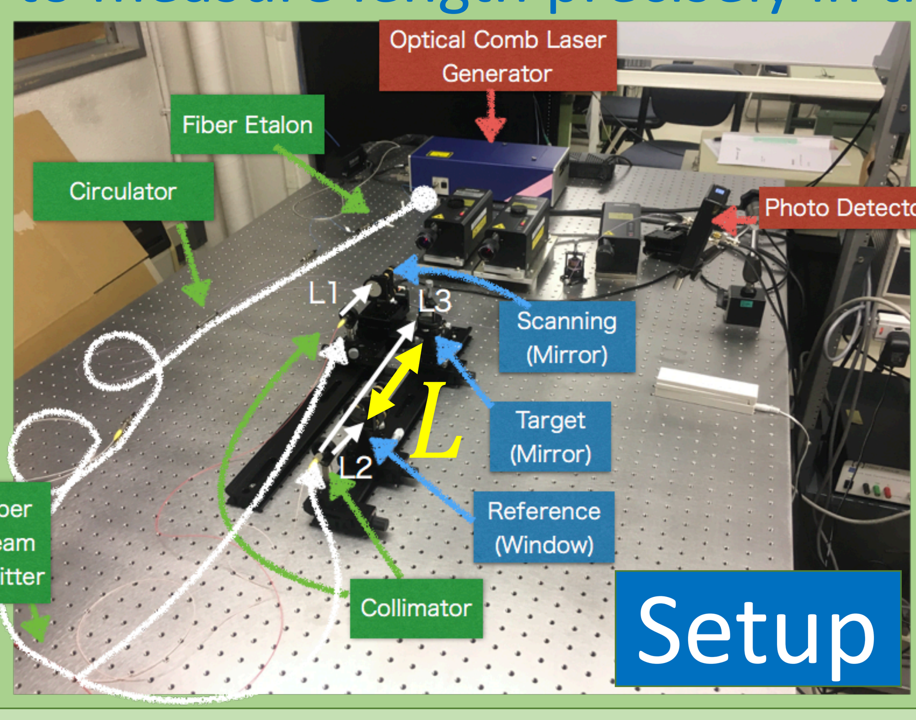


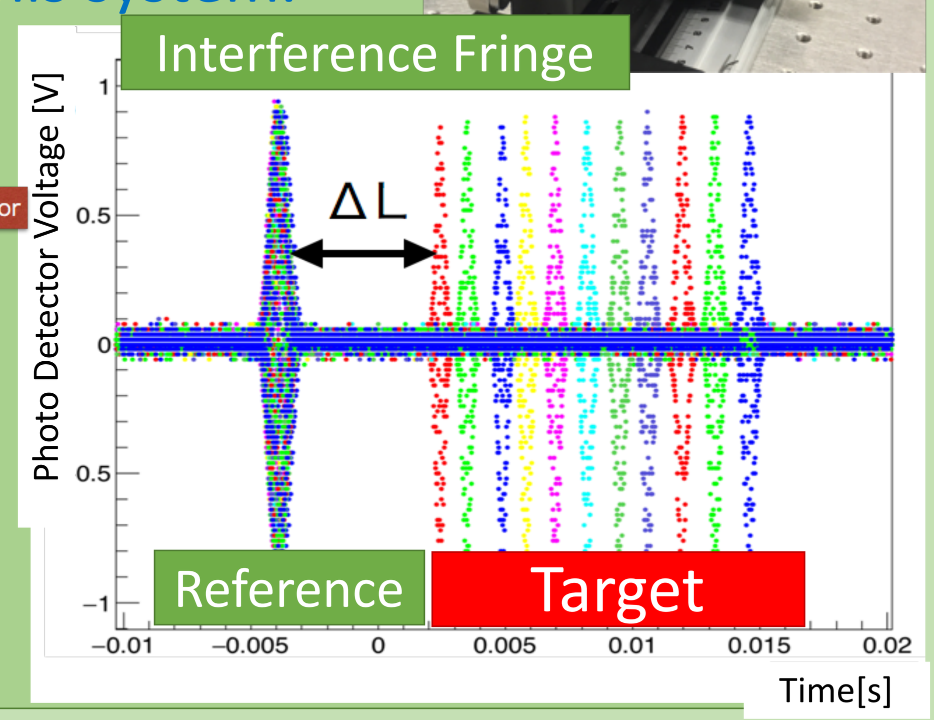
This laser can measure length precisely and easily.

3. DEMONSTRATION

We set up the above interferometer and tested it. We observed interference fringe in our system. And when the target mirror was moving every 100 um step, the ΔL become larger almost equivalent as shown in right-bottom plot. We can expect to measure length precisely in this system.







4. CONCLUSION & PROSPECTS

- The detector alignment is important for EDM search.
- We observed interference fringe in this system.
- We are developing analysis and error estimation.
- In future, we will use this system to determine the 3D coordinate of detector.

Reference
[1] G.W. Bennett et al., Phys Rev D 73 (2006) 072003
[2]] J-PARC muon g-2/EDM collaboration (2016) TDR
[3] S. Wiroj, at el.(2016)Pre.Engineering 43 486-492
[4] T. Kume, et al., IWAA 2016, 32, Grenoble, 3-7th, Oct