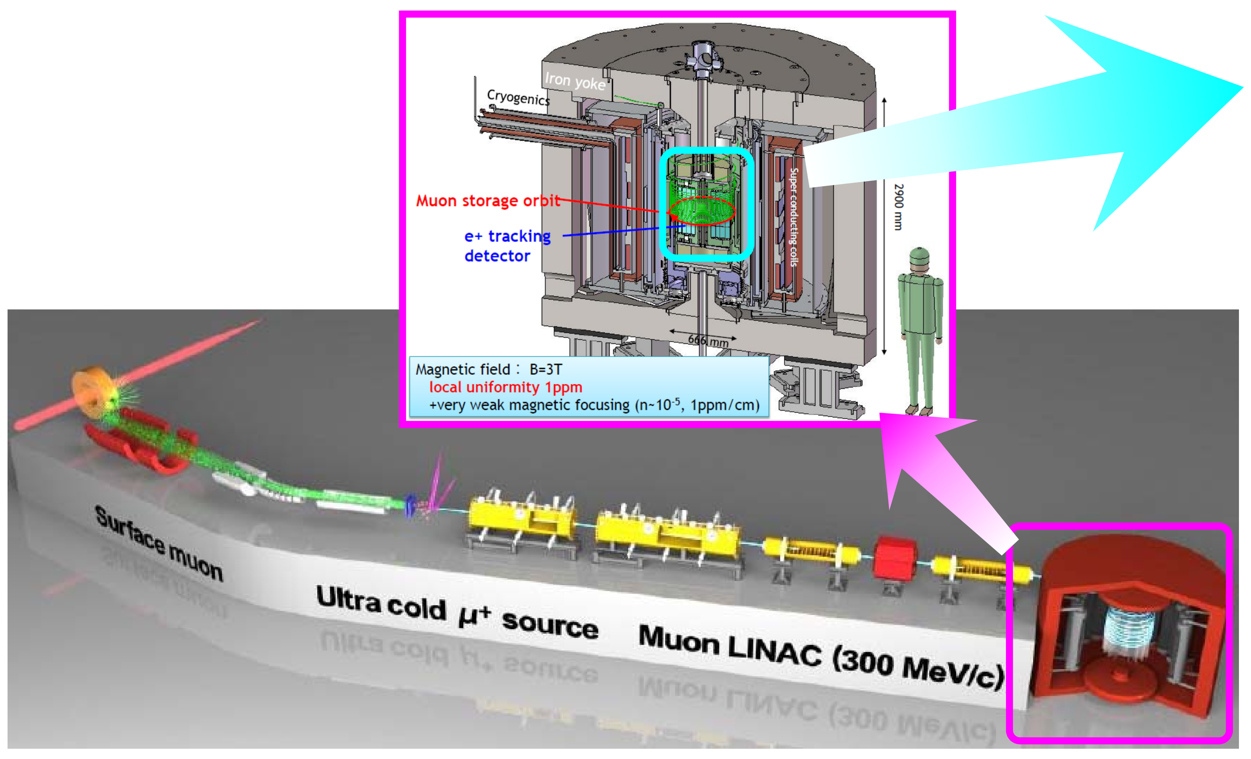
tatsuya.kume@kek.jp

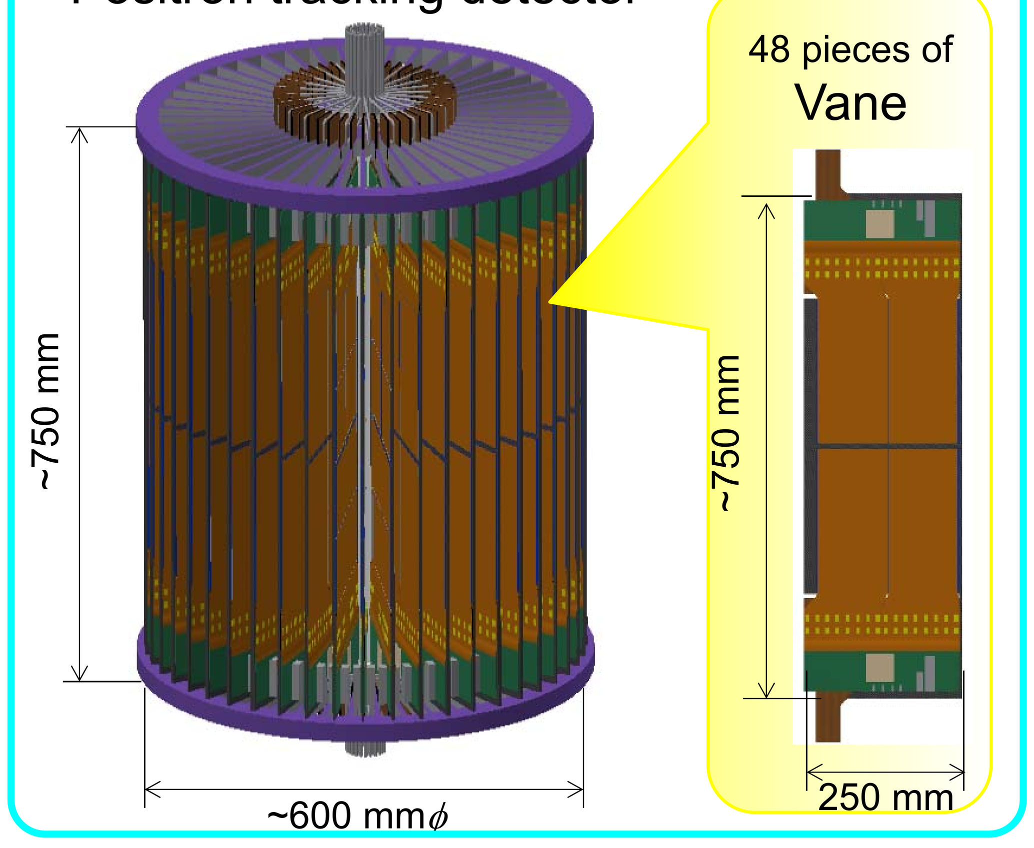
Precise alignment monitor by using optical frequency comb for the muon g-2/EDM experiment at J-PARC

Tatsuya KUME[1#], Tsutomu MIBE[2], Shoichiro NISHIMURA[3], Mikio SAKURAI[2], Yutaro SATOH[2], Wiroj SUDATHAM[4], Kiyoshi TAKAMASU[4], Hiromasa YASUDA[3] , and J-PARC muon g-2/EDM collaboration
1: Mechanical Engineering Center, High Energy Accelerator Research Organization (KEK),
2: Institute of Particle and Nuclear Studies, High Energy Accelerator Research Organization (KEK),
3: Department of Physics, The University of Tokyo,
4: Department of Precision Engineering, The University of Tokyo

Background : The muon g-2/EDM experiment at J-PARC and the positron tracking detector



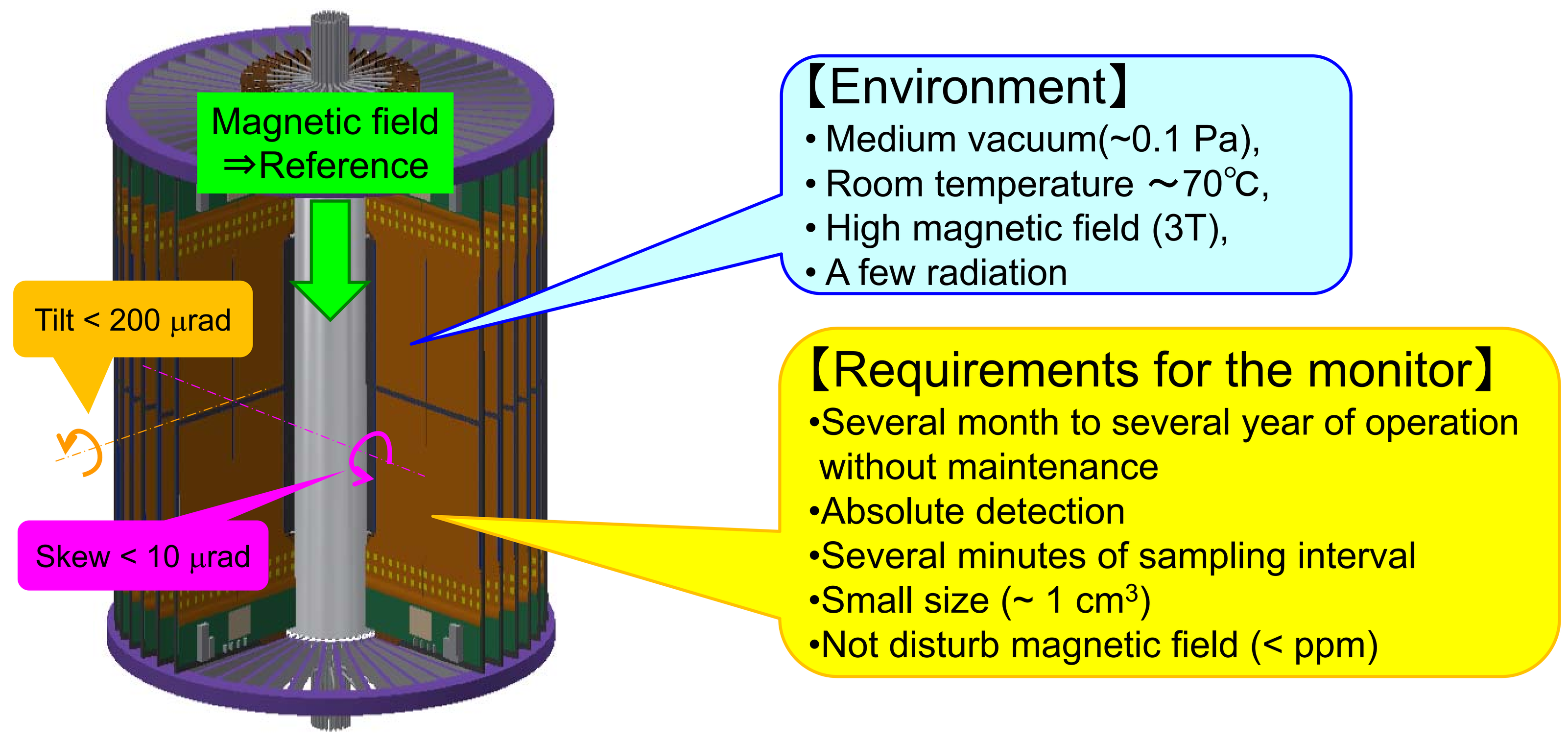
Experimental system and the positron tracking detector



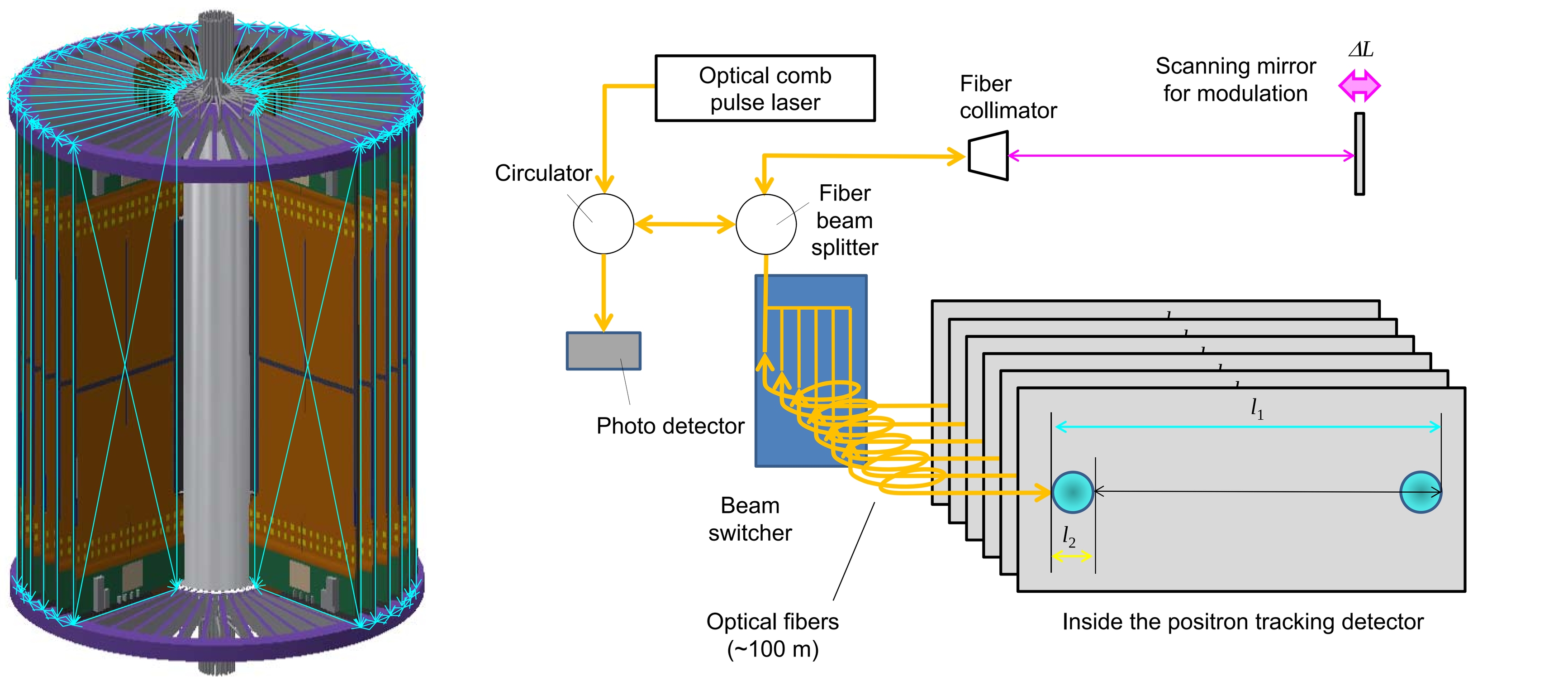
The muon *g*-2/EDM experiment at J-PARC aims to measure muon's anomalous magnetic moment, *g*-2 with an precision of 0.1 ppm; and to search for electric dipole moment, EDM with a sensitivity of 10^{-21} *e*·cm.

In the experiment, tracks of decay positrons in a storage ring with a 3 T of uniform magnetic field are to be measured by a **positron tracking detector**. It consists of 48 rectangular platy parts called a **vane**. They are aligned radially in the storage ring and form a cylindrical array.

Purpose & Concept : To ensure the alignment accuracy by using a length measurement grid



In order to measure the positron track enough accurately, alignment accuracy for each vane was estimated to be better than **10 μrad** for the skew and **200 μrad** for the tilt. We consider adopting an **alignment monitor** for ensuring the alignment accuracy **during the operation**.



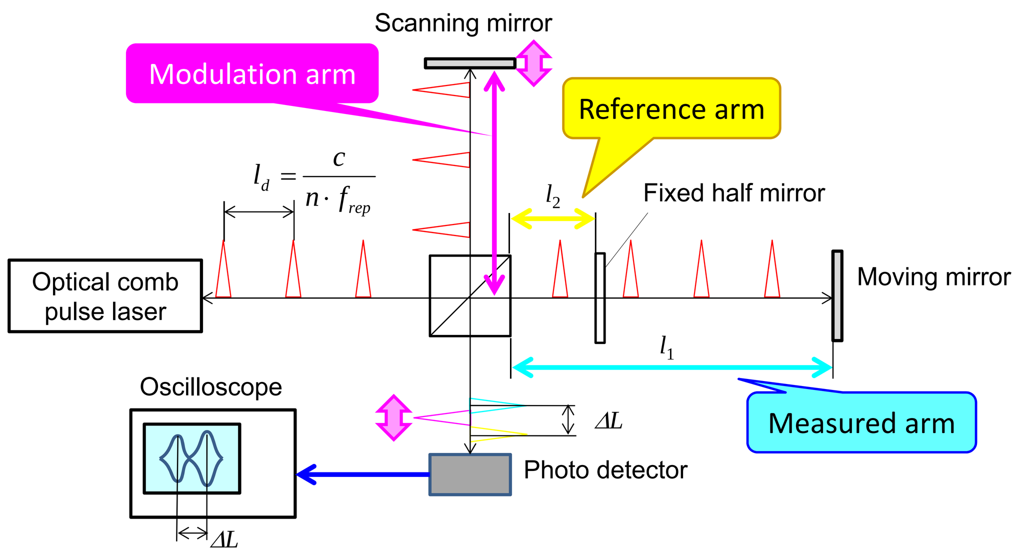
A **length measurement grid** stretched around the detector is adopted. It consists of **absolute distance interferometers** whose measurement beams are **introduced by using optical fibers** for preventing its sensitive core components from being affected by the harsh environment.

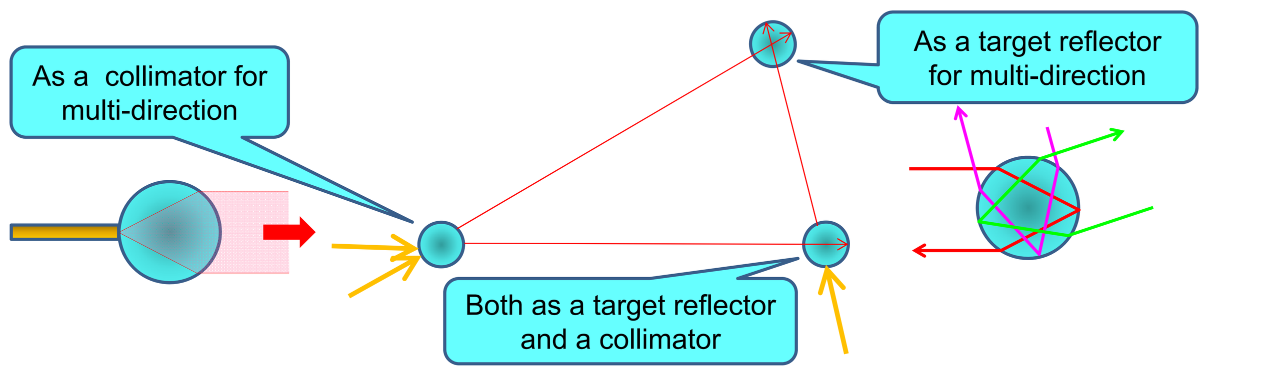
Technical features : Absolute distance interferometer by using an optical frequency comb and ball lenses

An **optical frequency comb** is an optical short pulse train with an extremely accurate and stable interval. The **distance, l_1-l_2 can be derived absolutely** by using a relation

$$l_2 - l_1 = a \cdot \frac{c}{2n \cdot f_{rep}} + \Delta L,$$

where *c*: light speed in vacuum, *n*: refractive index of the air, f_{rep}: repetition frequency of the comb, *a*: an integer (*a* = 0, 1, 2, …), and *ΔL*: optical path difference within the pulse interval. *ΔL* is derived by monitoring position of the scanning mirror.

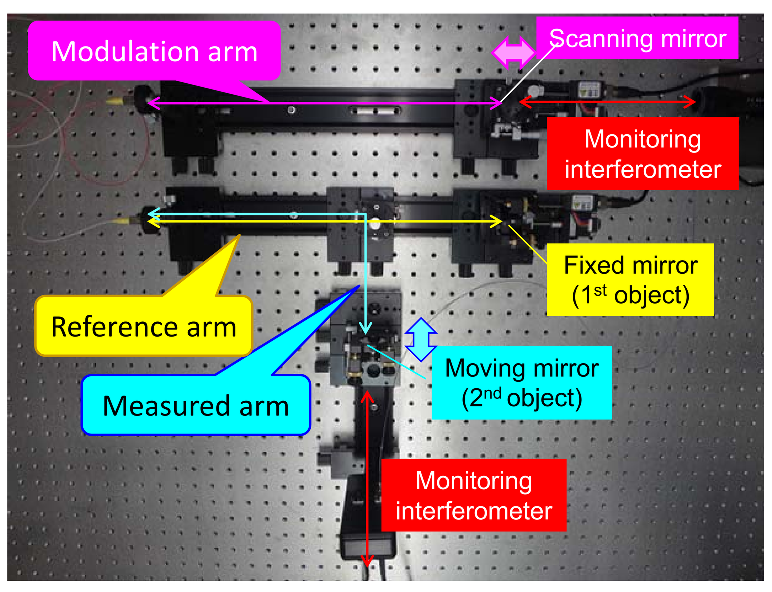


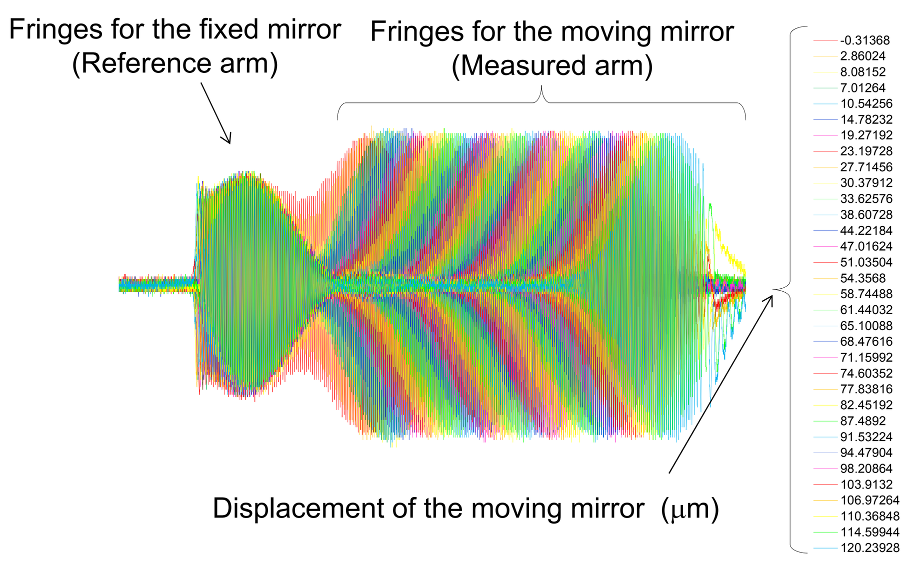


A ball lens with its refractive index, *n* of 2 can be adopted **both as a collimator and as a target reflector for multi-direction**. It is effective for reducing volume for the monitor and also effective for improving the accuracy.

Current status : Preliminary confirmations for the idea

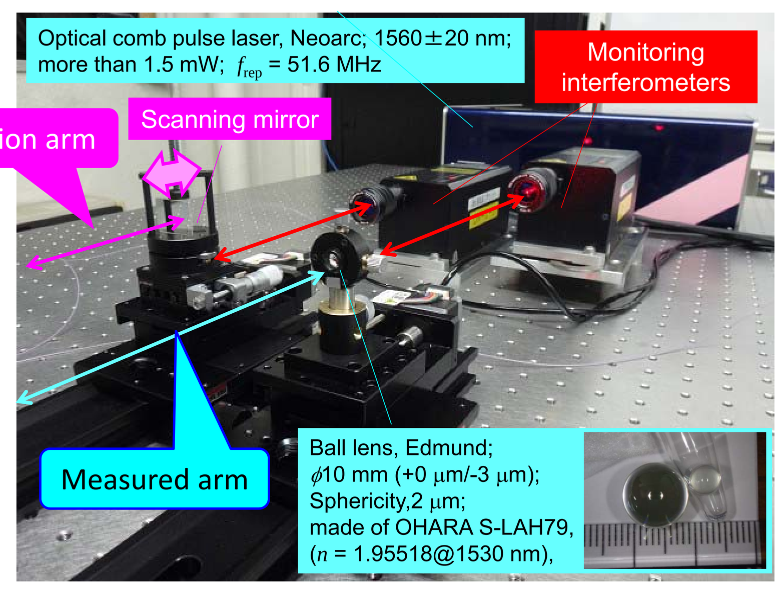
1. Derivation for the distance, l_1-l_2 from the two fringe peaks

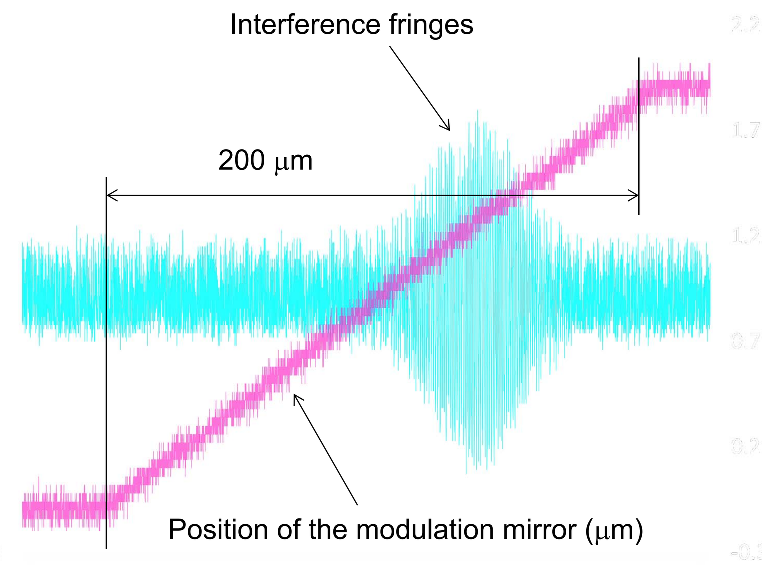




Two peaks of the interference fringes for each light from the fixed mirror and the moving mirror can be observed. The distance between the **two fringe peaks changes with the position** of the moving mirror. It follows that the distance between the two mirrors can be derived from the distance between the two fringe peaks.

2. Detection of interference fringes for the light from a ball lens





Interference fringes between the lights reflected by **the ball lens and the scanning mirror can be observed.** Low S/N for the fringes is caused by low intensity of light from the ball lens. This is because the refractive index of the ball lens is not the ideal value of 2 for infrared. It can be improved by tuning glass material.

Outlook : We are going to realize multiple length measurement paths for constructing preliminary 3D-length measurement grid, and demonstrate deriving 3D-coordinate of each node for the grid.

Acknowledgements : This work is supported by JSPS KAKENHI grant number 26287053. The authors thank N. Kimura and K. Sasaki of cryogenics science center in KEK for providing the monitoring interferometers. The authors also thank NEOARC co. ltd. for providing the optical comb pulse laser.