

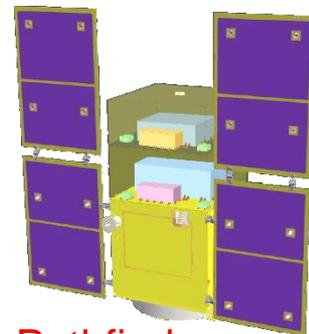
Testing Lorentz Invariance with an Optical Cavity

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Self Introduction

- Assistant Professor(助教), Ando Group from July 2014



DECIGO Pathfinder

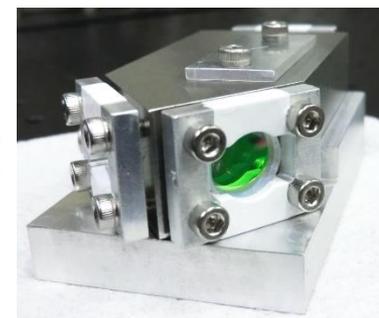
- Gravitational Waves
 - DECIGO Pathfinder prototype experiment
 - KAGRA



KAGRA

main interferometer design & development

- Test of Lorentz Invariance
 - anisotropy search in the speed of light
 - asymmetric optical ring cavity



optical ring cavity

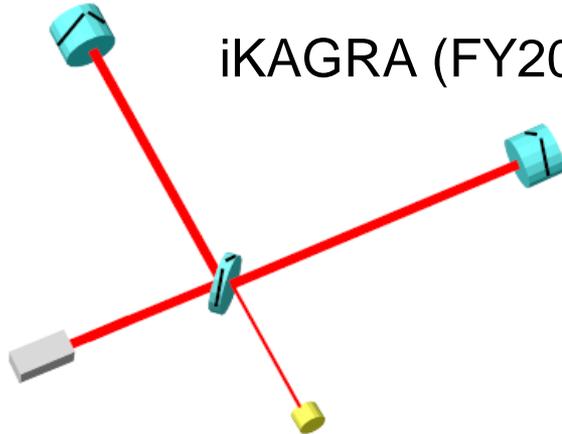
- “interferometry for fundamental physics”
macroscopic quantum mechanics, test of gravitational inverse square law, dark matter search etc.....

KAGRA

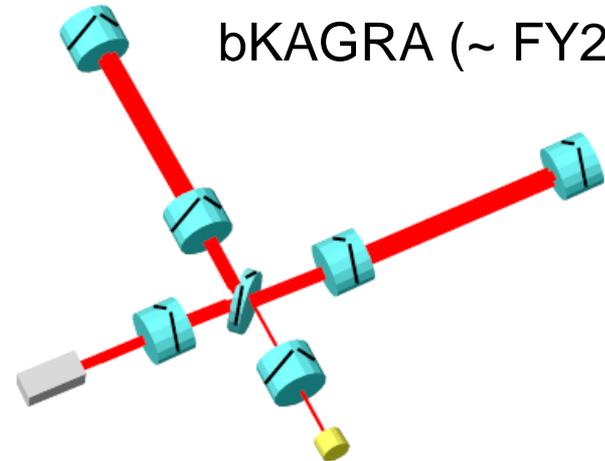
- Large-scale Cryogenic Gravitational wave Telescope being built in Kamioka mine, Gifu
- initial phase observation run in FY2015
 - room temperature
 - 3km Michelson
- final phase observation run in ~ FY2017
 - cryogenic temperature (20K)
 - 3km RSE



iKAGRA (FY2015)



bKAGRA (~ FY2017)



Recent KAGRA News

- inauguration of initial stage facility
- mirror installation ongoing
- very exciting stage!

2015年11月6日
朝日新聞



The screenshot shows a news article from the Asahi Shimbun Digital website. The article title is 「時空のひずみ」捉えるか 観測装置「KAGRA」公開 (Can we capture the distortion of spacetime? KAGRA observation device public). The article is dated 2015年11月6日 21時09分. The article content is partially visible, showing the beginning of the text. The article is categorized under 社会 (Society) and includes social media sharing options for Facebook (998 shares), Twitter (list), and a bookmark icon (11). The article is also available in a print-friendly version (紙面にプラス).

朝日新聞 DIGITAL

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トップニュース スポーツ カルチャー 特集・連載 オピニオン 写真

新着 社会 政治 経済・マネー 国際 テック&サイエンス 教育 環境・エネルギー 医療・健康

トピックス パリ同時テロ 「イスラム国」 大阪ダブル選 待ジャパン 児童虐待の現場から どすこいタイムズ

朝日新聞デジタル > 記事

社会 その他・話題 サイエンス 宇宙・天文 ノーベル賞

「時空のひずみ」捉えるか 観測装置「KAGRA」公開

2015年11月6日 21時09分

シェア 998 ツイート list ブックマーク 11 メール 印刷

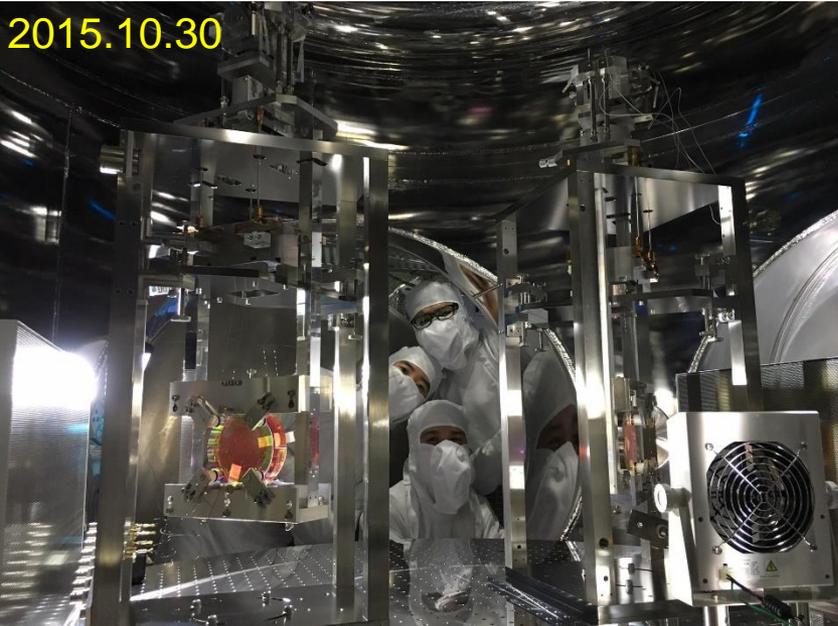
紙面にプラス

重力波観測装置「KAGRA」報道公開 東大宇宙線研

00:00 00:35

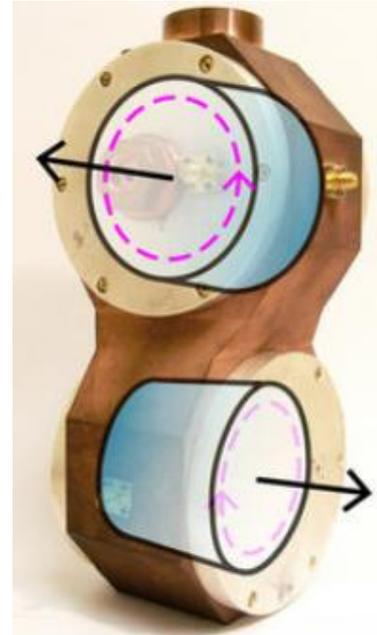
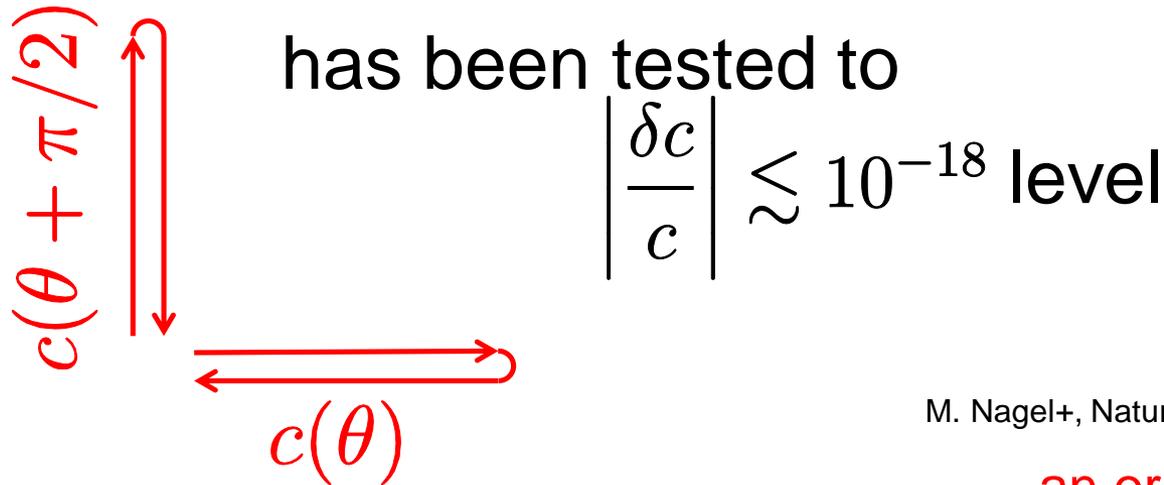
【動画】報道公開された重力波観測装置「KAGRA」=川村直子撮影

2015.10.30



Test of Lorentz Invariance

- LI could only be an approximate
- test isotropy of the speed of light
 - two-way test (Michelson-Morley type)



M. Nagel+, Nature Communications 6,8174 (2015)

- one-way test (our type)



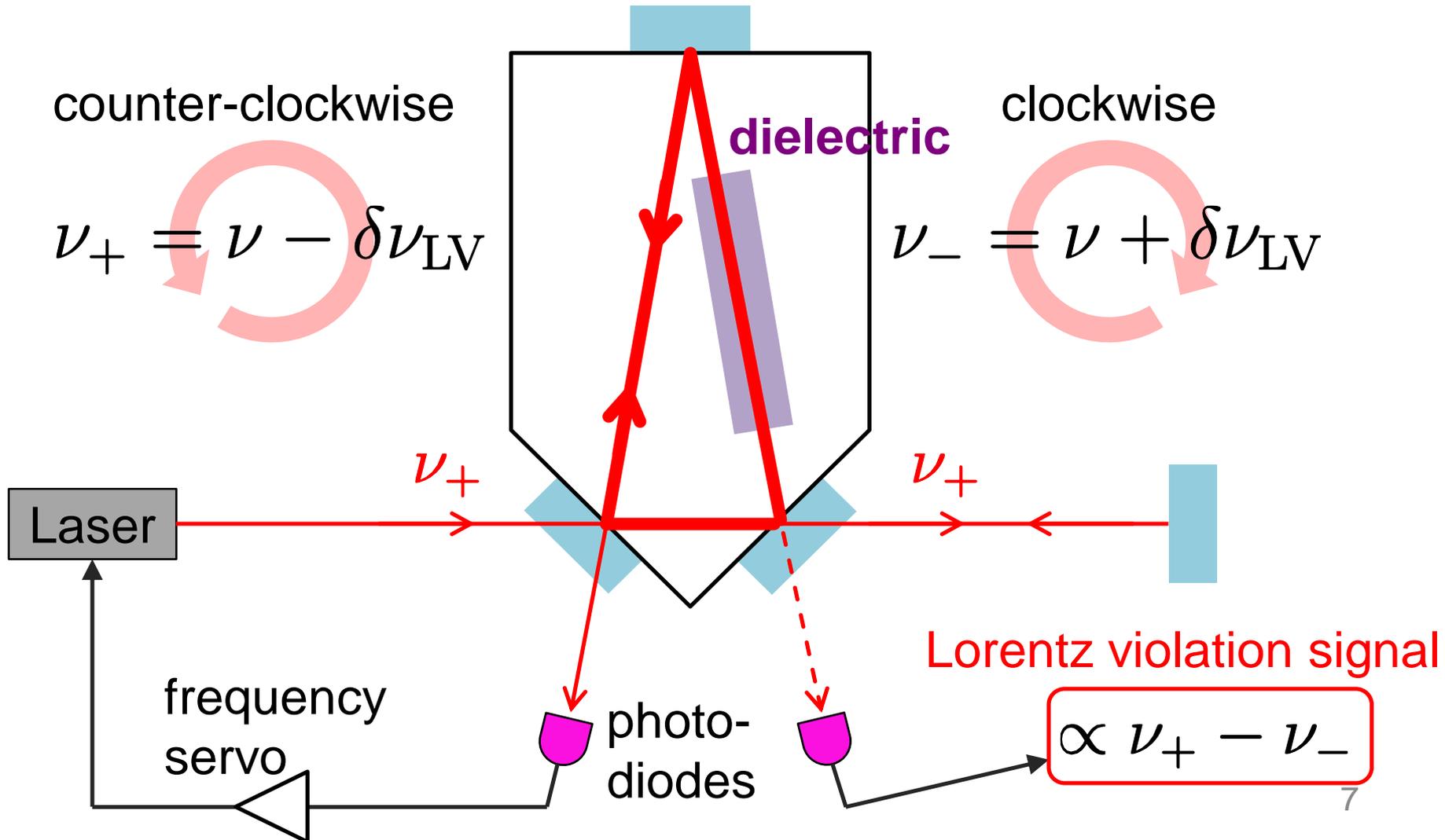
Asymmetric Optical Ring Cavity

- compare resonant frequencies of counter-propagating modes of asymmetric optical ring cavity

	<p>no dielectric</p> <p>ν_+ CCW</p> <p>ν_- CW</p>	<p>dielectric</p>	
no violation	$\nu_+ = \nu_0$ $\nu_- = \nu_0$	$\nu_+ = \nu$ $\nu_- = \nu$	<div style="border: 1px solid red; padding: 5px; color: red;"> resonant freq. shift $\propto LV$ </div>
Lorentz violation	$\nu_+ = \nu_0$ $\nu_- = \nu_0$	$\nu_+ = \nu - \delta\nu_{LV}$ $\nu_- = \nu + \delta\nu_{LV}$	

Method for Frequency Comparison

- double-pass configuration for null measurement



Experimental Setup

- frequency comparison using double-pass setup
- rotate and modulate LV signal

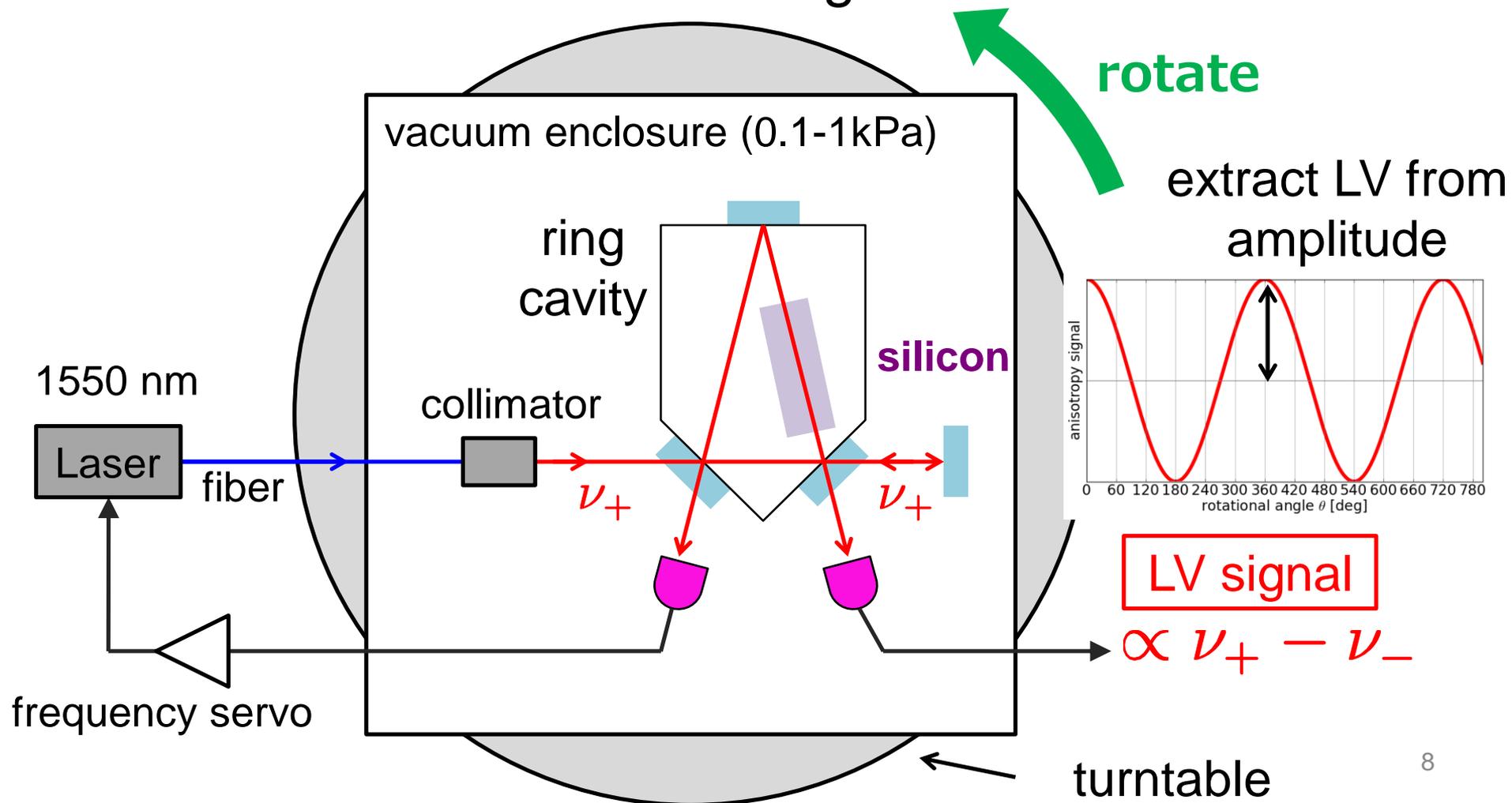


Photo of the Optics

Inside vacuum enclosure
(30cm × 30cm × 17cm)

ring
cavity

collimator

PDs1

PDp1

PDp2

PDs2

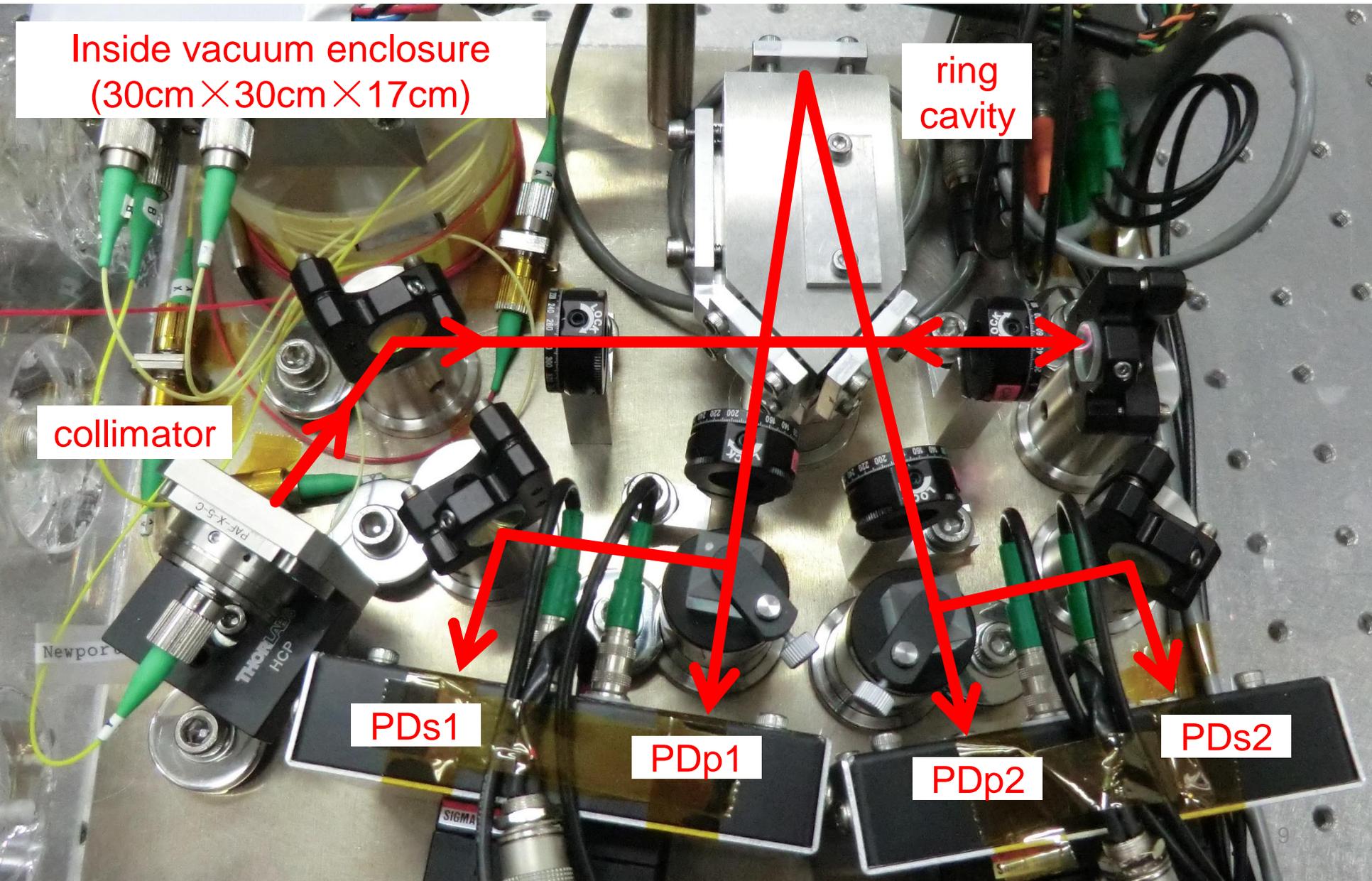


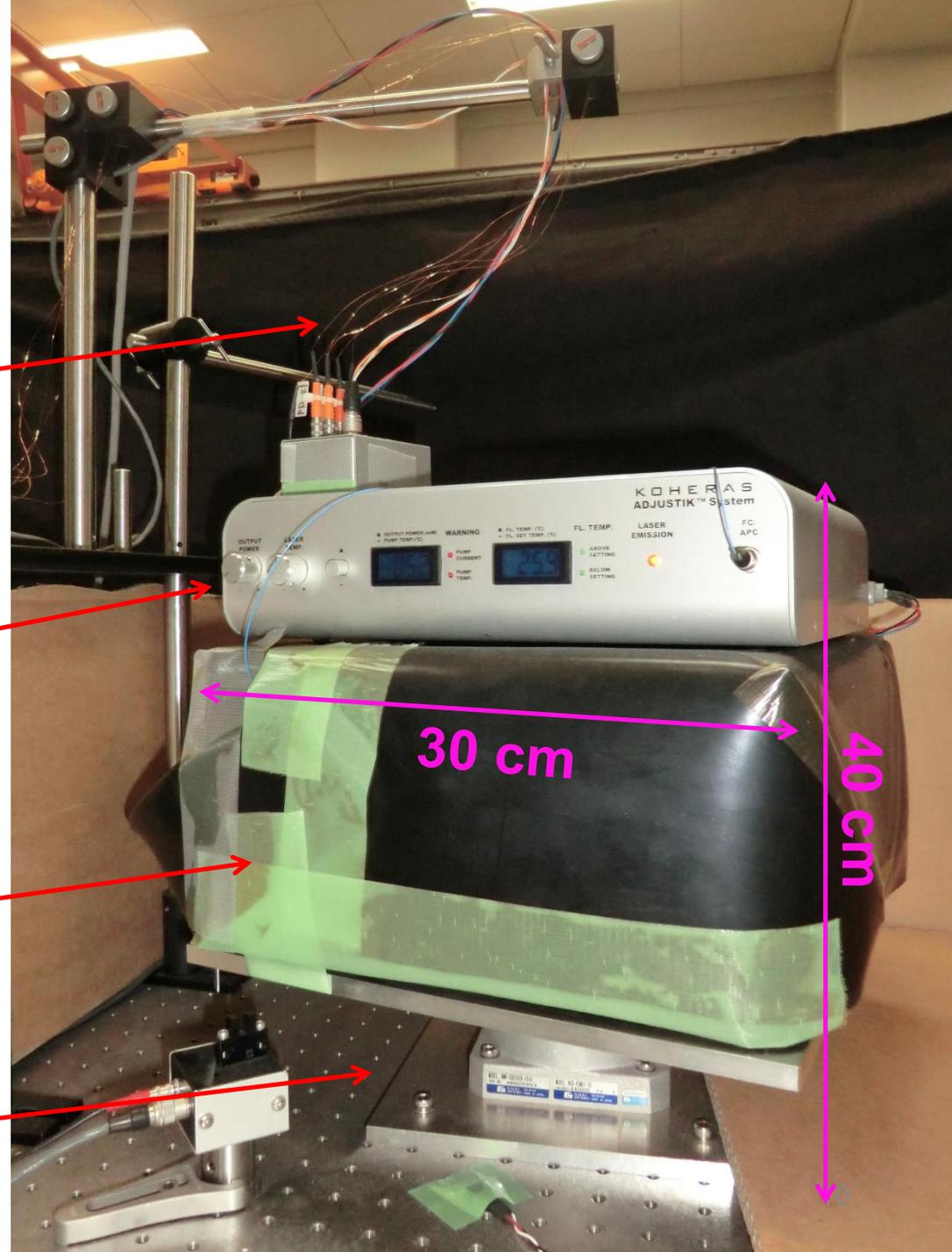
Photo of the Whole Setup

electrical cables

laser source

vacuum enclosure
+ shielding
(optics inside)

turntable



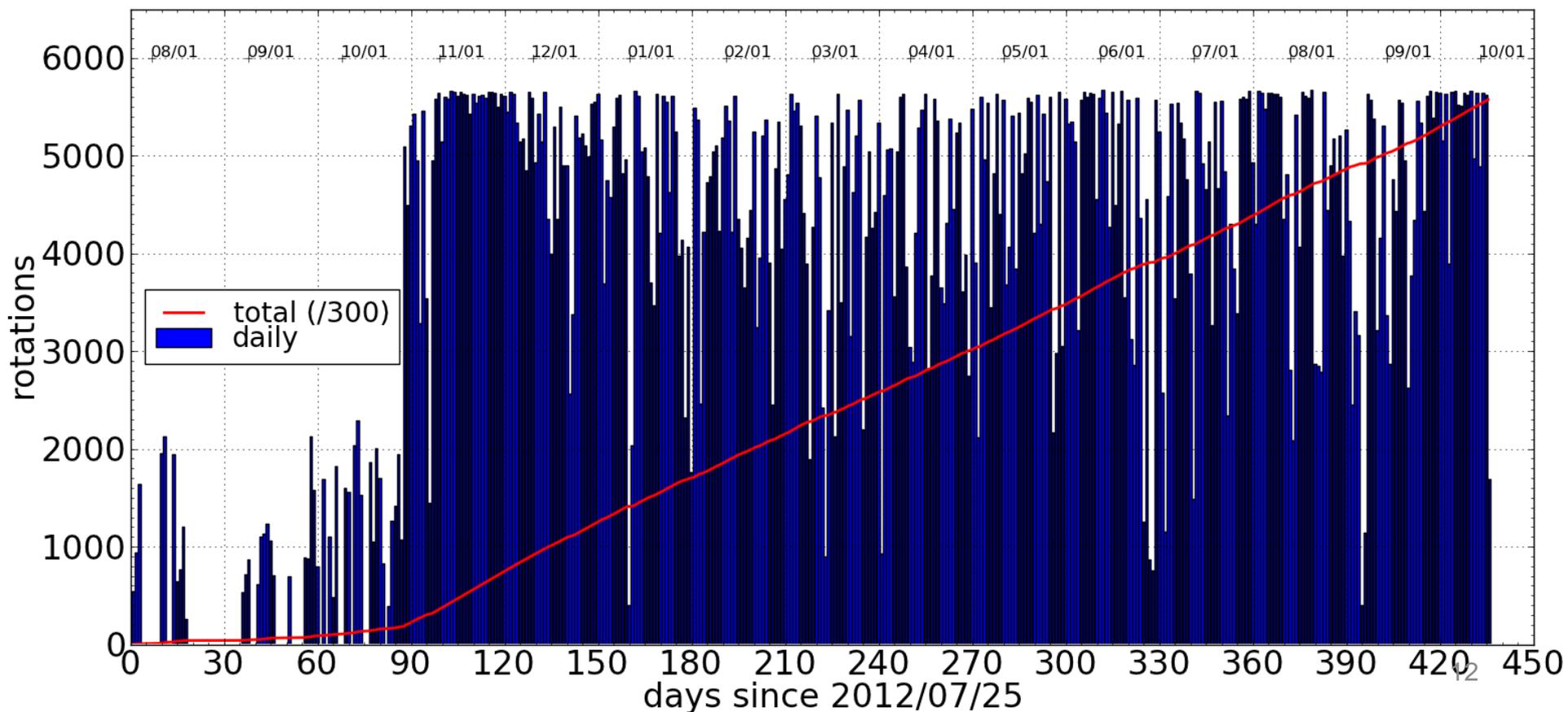
Rotation

- 12 sec / rotation, alternately



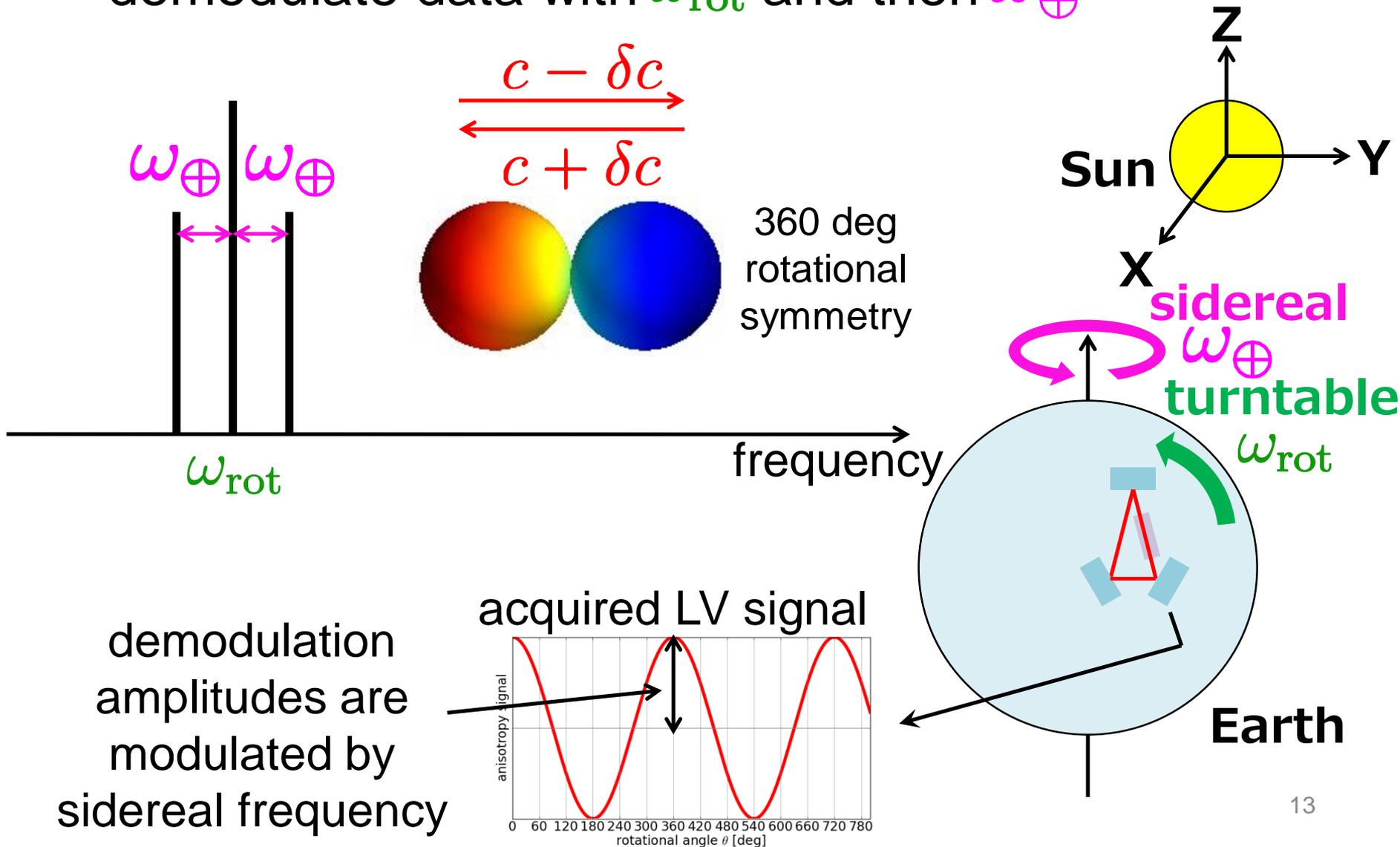
Observation Data

- from July 2012 to October 2013
- 393 days, 1.67 million rotations
- duty cycle: 53% (64% after Oct 2012)



Data Analysis

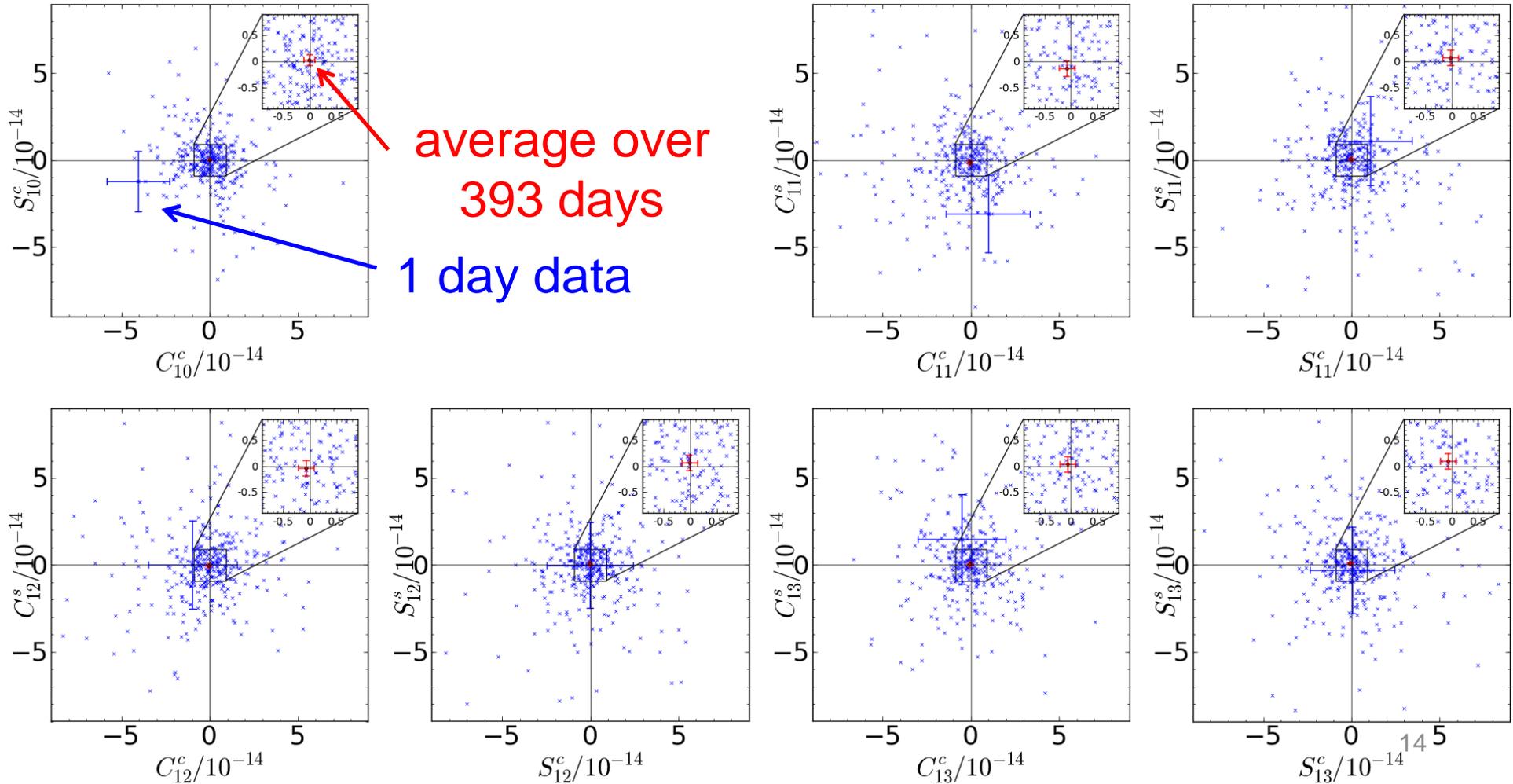
- demodulate data with ω_{rot} and then ω_{\oplus}



Demodulation Amps

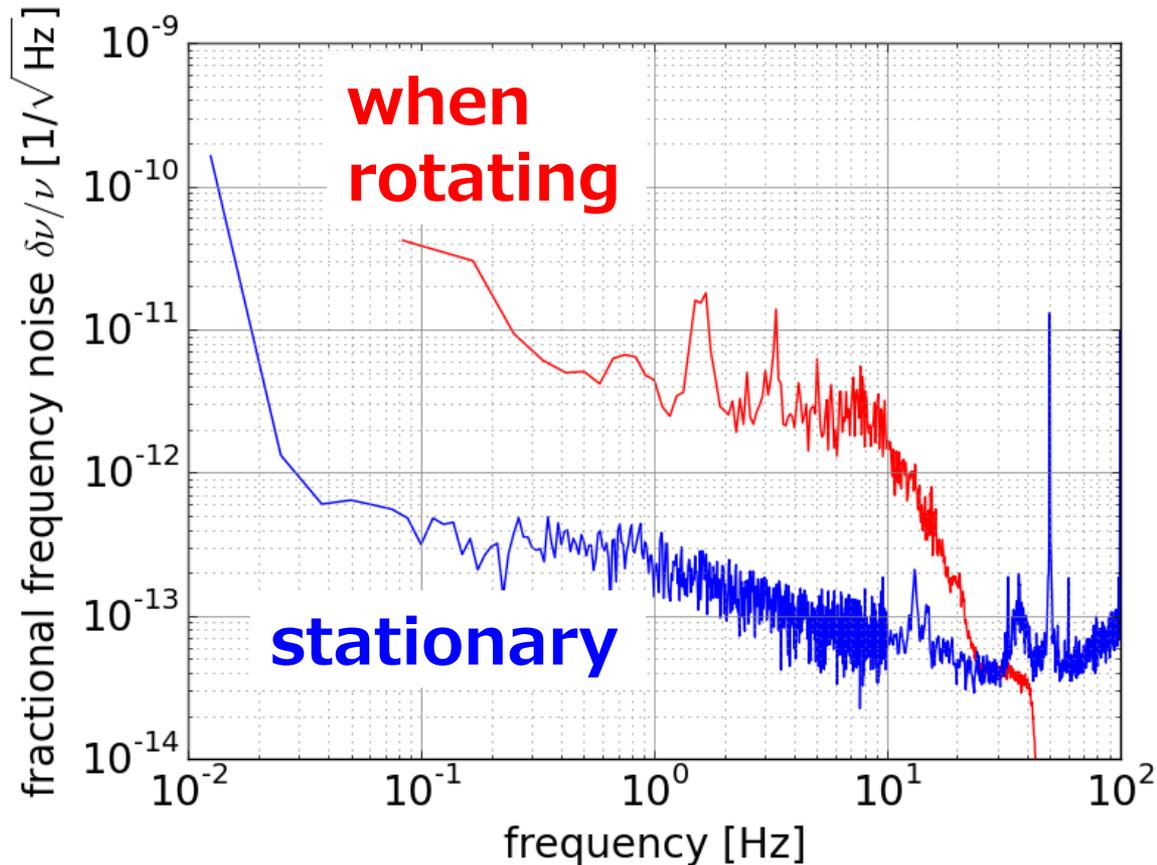
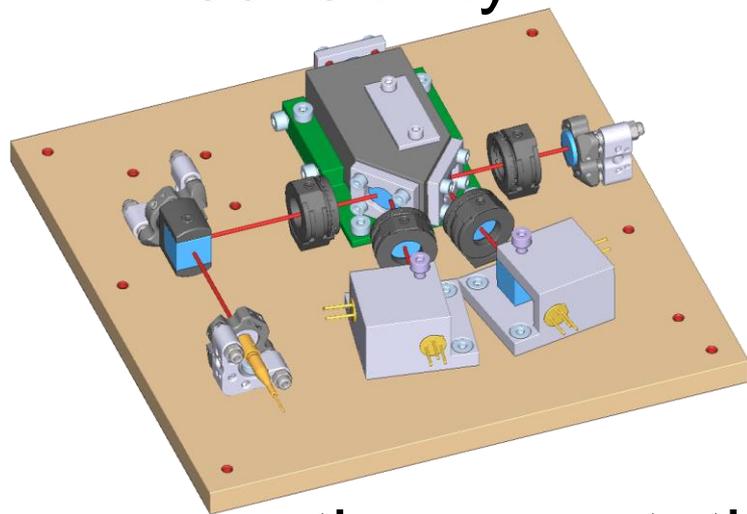
- zero consistent at 2σ

→ no significant LV can be claimed at $\left| \frac{\delta c}{c} \right| \lesssim 10^{-15}$



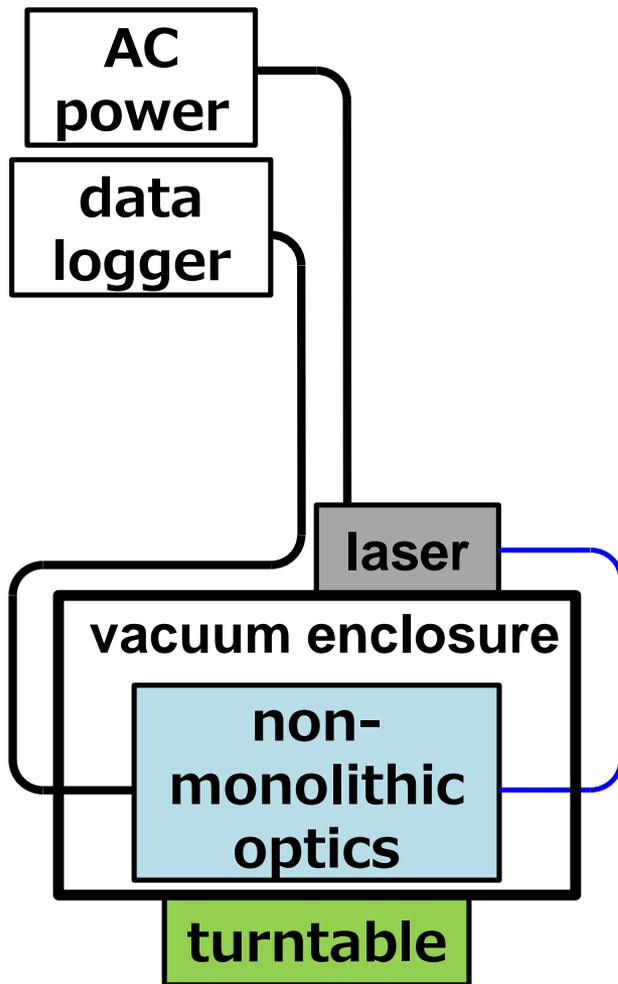
Upgrade of the Apparatus

- current noise level is limited by vibration noise from rotation
- semi-monolithic optical bench to reduce vibration sensitivity



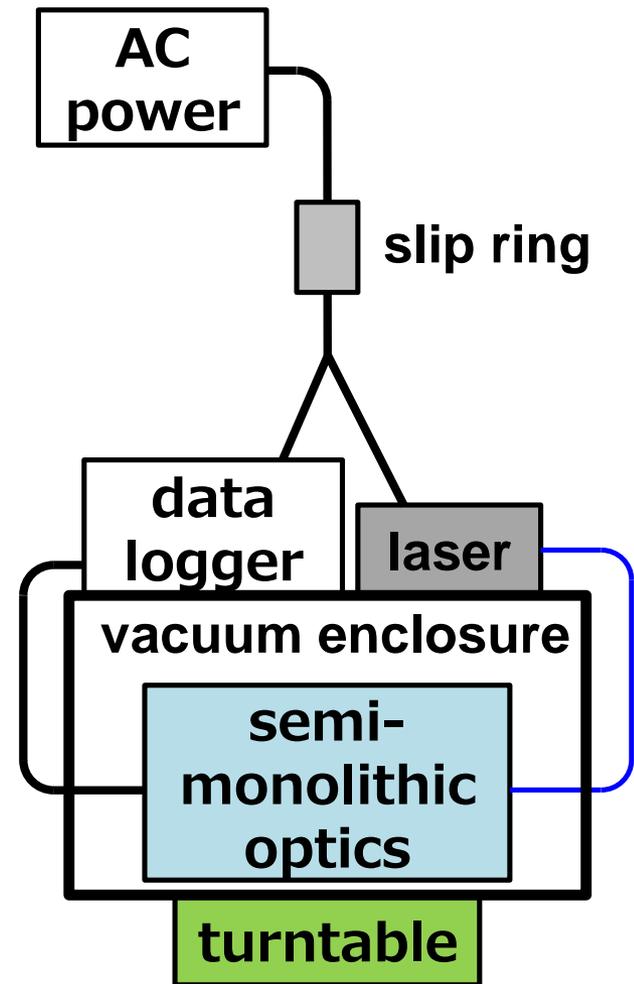
- continuous rotation for more stable operation
- aim to have reduced noise by $\sim 1/100$

Apparatus Comparison



2012 Model

- non-monolithic optics
- alternative rotation

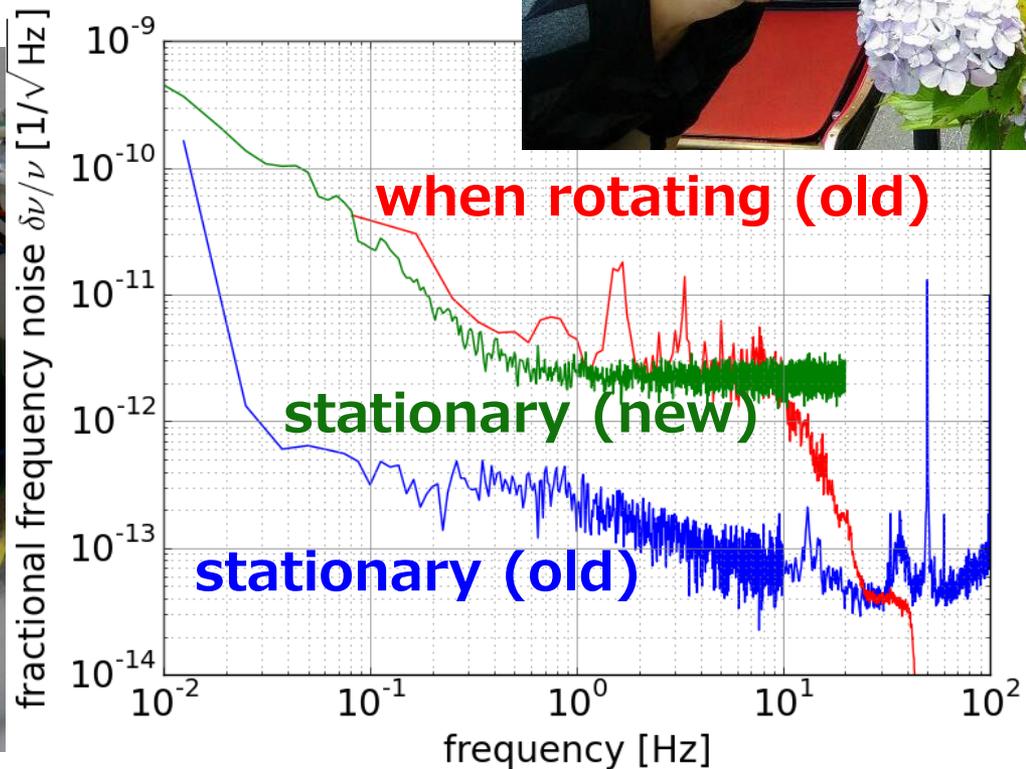
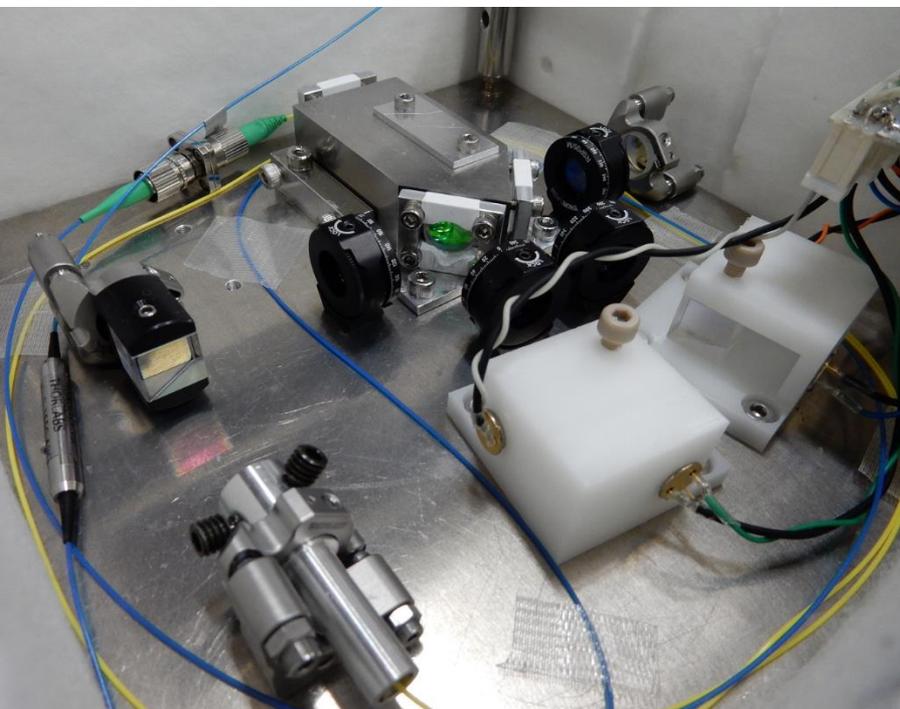
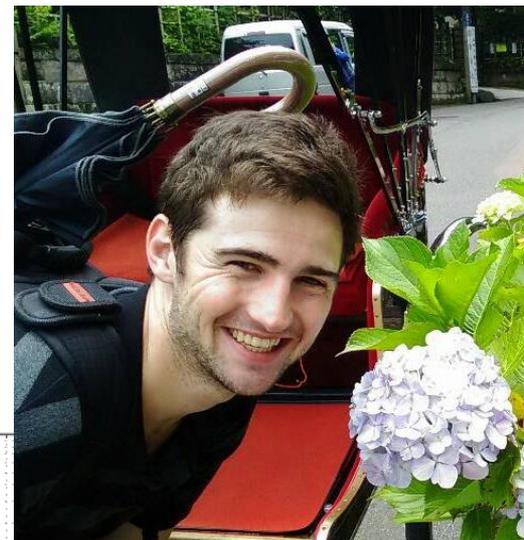


New Model

- semi-monolithic optics
- continuous rotation

Current Status of the New Model

- assembly mostly done
- stationary noise higher than before
- investigation ongoing (scattering?)



work done by Jake Guscott (undergrad from U of Adelaide)

Summary

- compared the speed of light propagating in opposite directions
- using a double-pass optical ring cavity
- put **new limits** on Lorentz violation in photons

$$\left| \frac{\delta c}{c} \right| \lesssim 10^{-15}$$

- currently developing an upgraded apparatus
- Y. Michimura+, [Phys. Rev. Lett. **110**, 200401 \(2013\)](#)
- Y. Michimura+, [Phys. Rev. D **88**, 111101\(R\) \(2013\)](#)
- supported by JSPS科研費 若手A 15H05445