

# Search for Anisotropy in the One-way Speed of Light Using an Optical Ring Cavity

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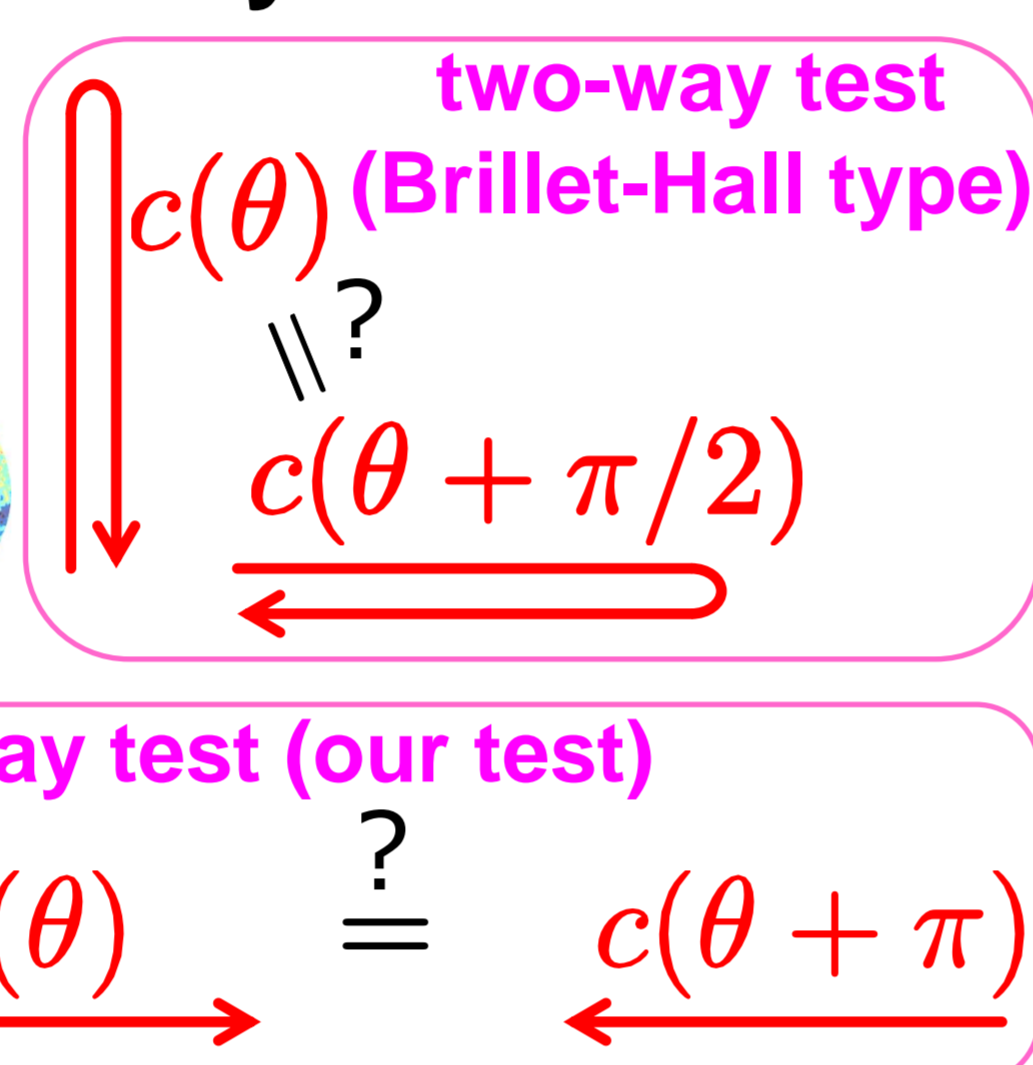
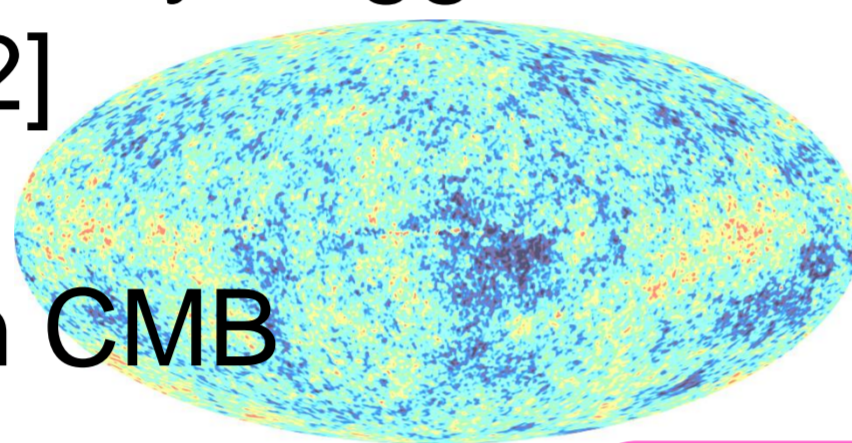
## Abstract:

A search for anisotropy in the one-way speed of light was performed by measuring resonant frequency difference between clockwise and counterclockwise mode of an optical ring cavity. Our cavity contains a piece of silicon, which is transparent to 1550 nm light. The laser frequency is stabilized using counterclockwise mode of the cavity, and transmitted light is reflected back into the cavity for resonant frequency comparison with clockwise mode. This double-pass configuration gives a high common mode rejection of environmental disturbances. By rotating the apparatus, our result set an upper limit on anisotropy in the one-way speed of light to a level of  $\delta c/c \lesssim 10^{-14}$ . Within Mansouri-Sexl test theory[1], our result implies an isotropy violation parameter  $\alpha + 1/2 = (-1.1 \pm 4.2) \times 10^{-12}$ , which is more than an order of magnitude better than the previous best limit.

## 1. Motivation

### Test of SR, Lorentz Invariance in electrodynamics

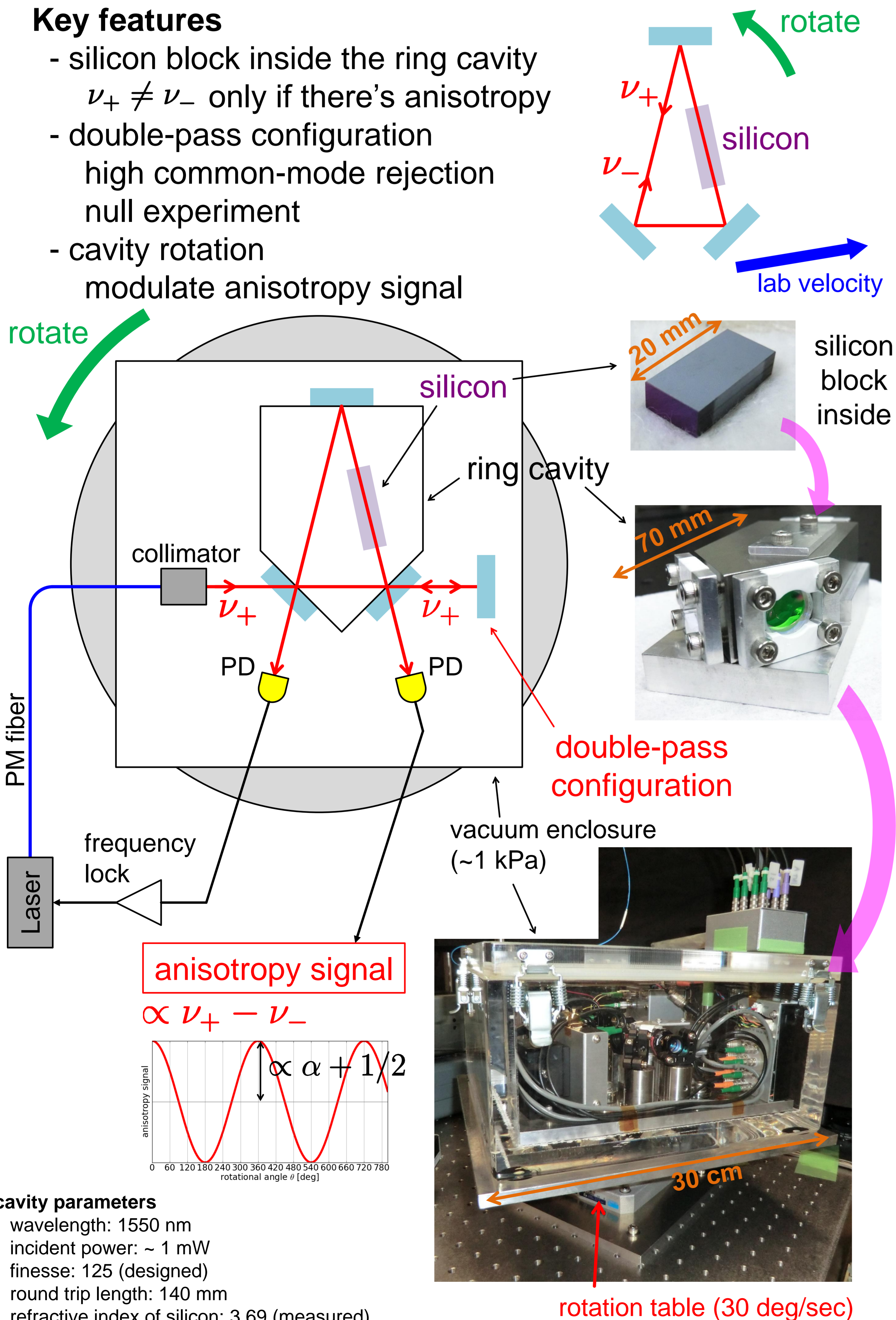
- no violation found so far
- quantum gravity theory suggests possible violation[2]  
 $\delta c/c \lesssim 10^{-17}$  ?
- slight anisotropy in CMB  
CMB rest frame
- weak upper limit on one-way light speed anisotropy



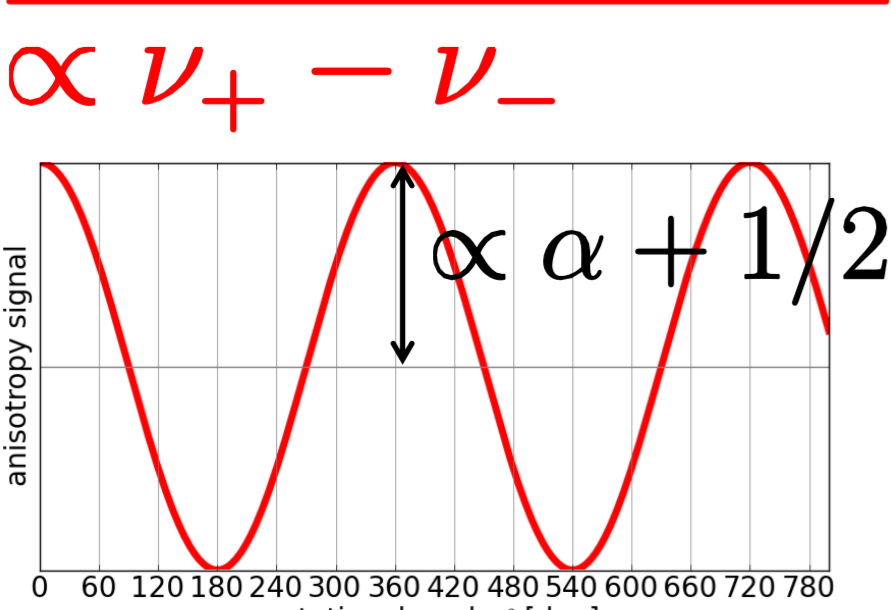
## 2. Experimental Setup

### Key features

- silicon block inside the ring cavity  
 $\nu_+ \neq \nu_-$  only if there's anisotropy
- double-pass configuration  
high common-mode rejection  
null experiment
- cavity rotation  
modulate anisotropy signal



anisotropy signal

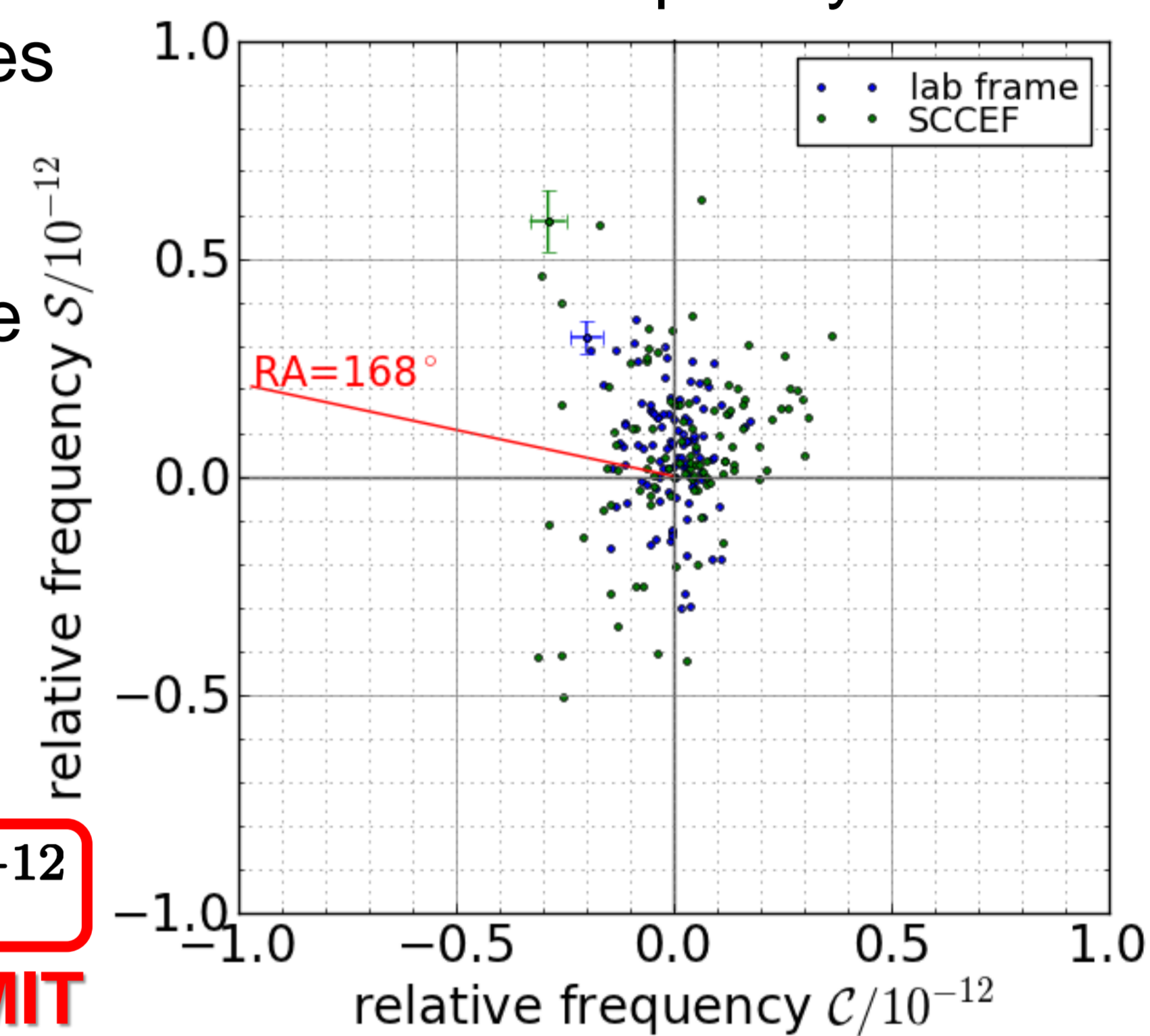


**cavity parameters**  
wavelength: 1550 nm  
incident power: ~ 1 mW  
finesse: 125 (designed)  
round trip length: 140 mm  
refractive index of silicon: 3.69 (measured)

## 3. Result

### Data analysis

- data taken during ~3800 rotation in Sep. 2012
- data selection by monitoring the noise level
- demodulate anisotropy signal with rotational frequency  
amplitude and phase gives lab velocity with respect to a preferred frame
- convert it into the Sun frame

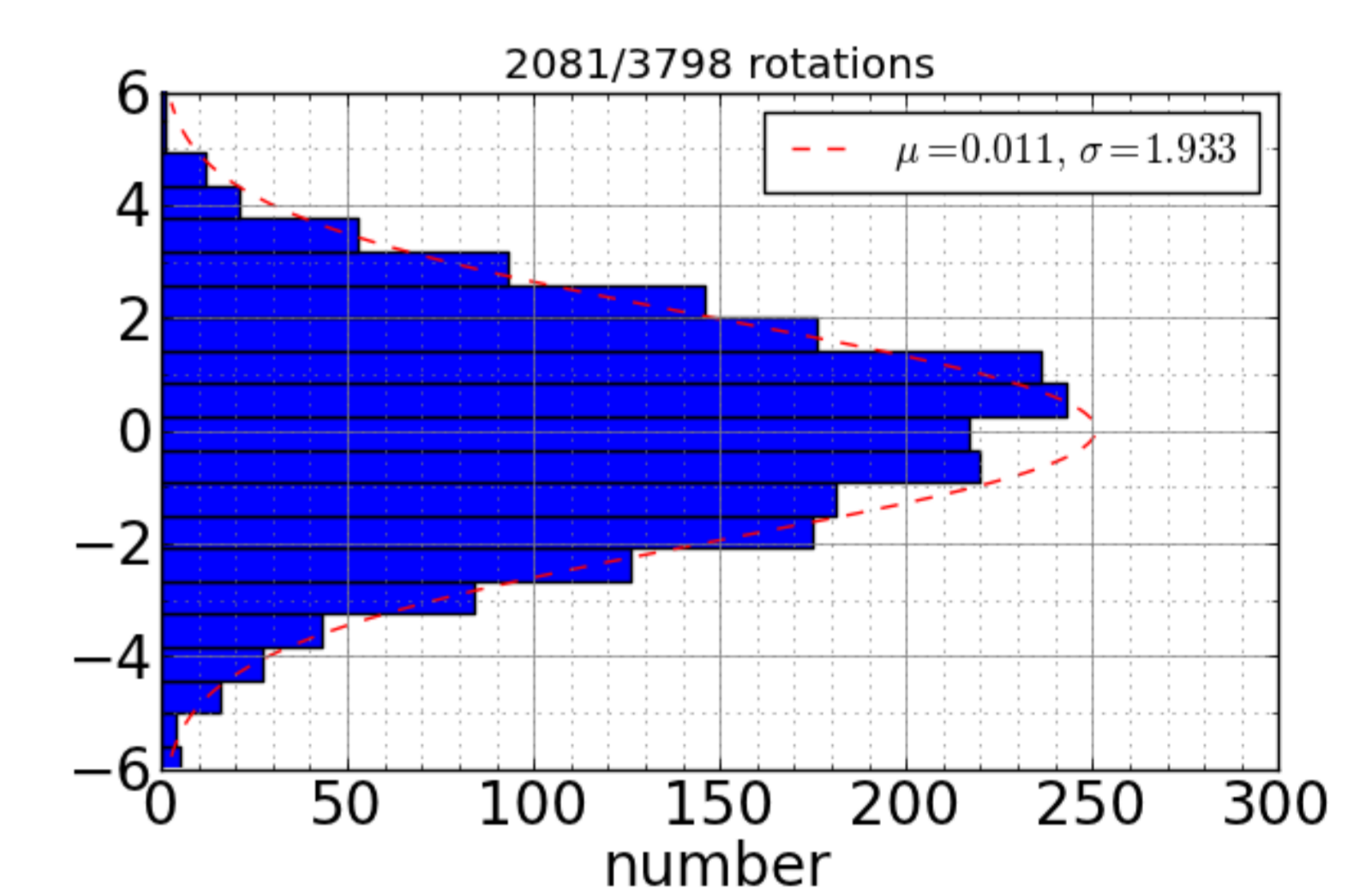
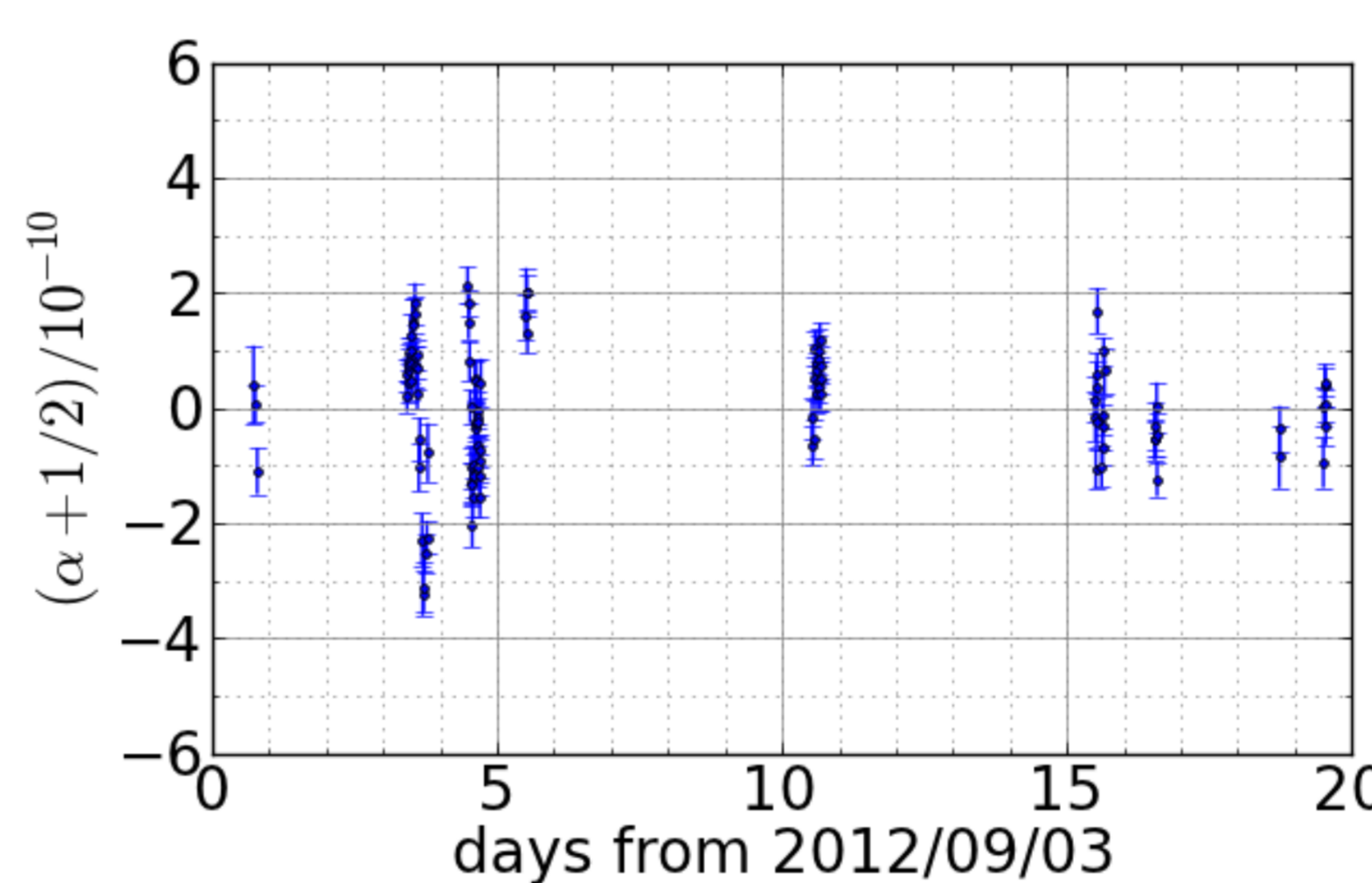


### Current result

- no deviation found in the phase space
- upper limit on anisotropy

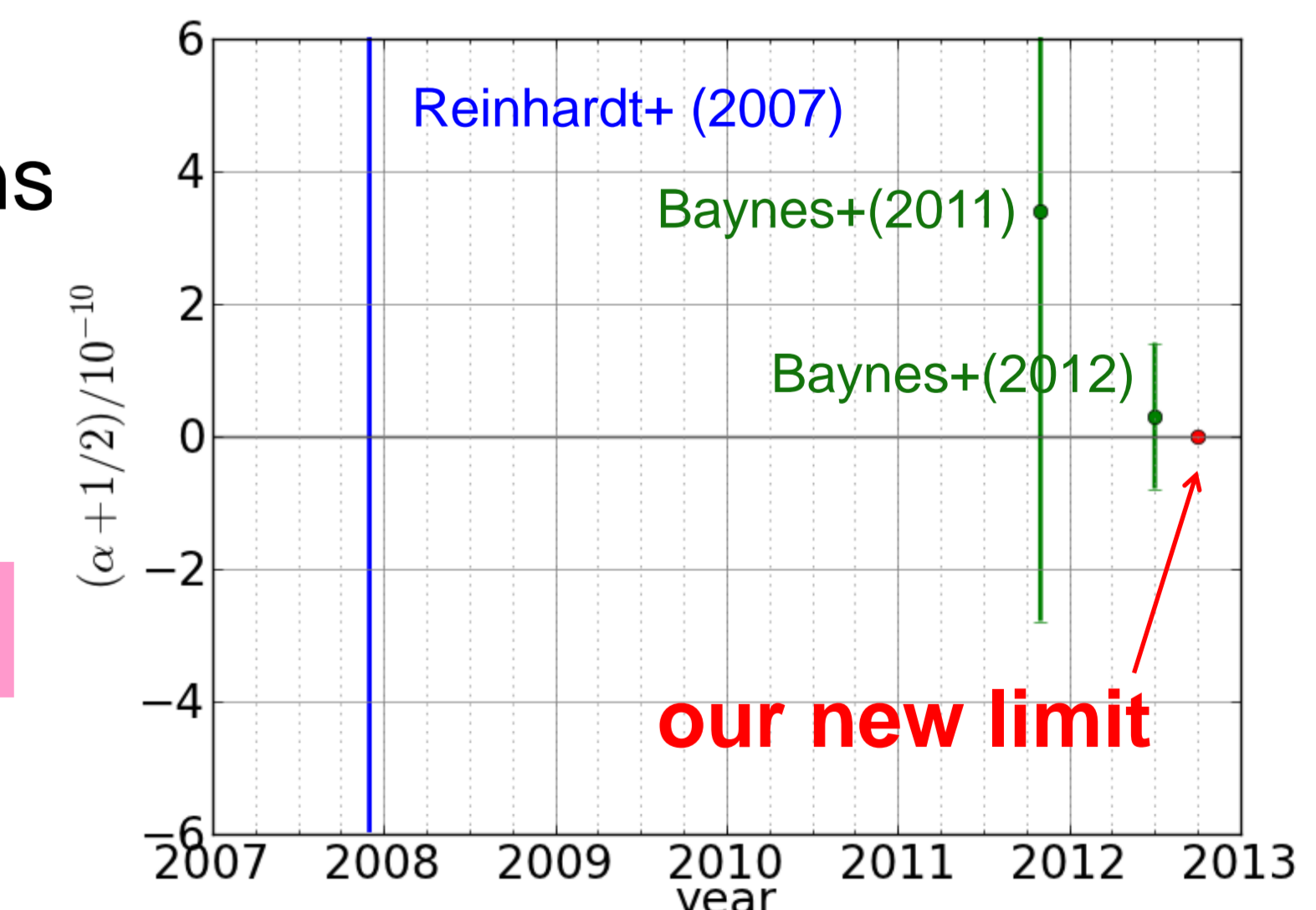
$$\alpha + 1/2 = (-1.1 \pm 4.2) \times 10^{-12}$$

**WORLD BEST LIMIT**



### Comparison with other experiments

- Reinhardt+ (2007) [3]  
Doppler experiment using ions
- Baynes+ (2011, 2012) [4]  
single-pass ring cavity



### References

- [1] R. Mansouri and R. U. Sexl: Gen. Relativ. Grav. 8 (1977) 497, 515, 809.
- [2] D. Colladay and V. Alan Kostelecký: Phys. Rev. D 58 (1998) 116002.
- [3] S. Reinhardt *et al.*: Nat. Phys. 3 (2007) 861.
- [4] F. N. Baynes *et al.*: Phys. Rev. Lett. 108 (2012) 260801.

## 4. Summary

### Summary

- new type of apparatus for one-way anisotropy search
- **set the world best limit (more than a tenfold improvement)**

### What limits current sensitivity?

- slight drift in the tilt of the optical table
- noise is limited by vibration mainly from the cables