A study of contamination in gravitational wave detectors

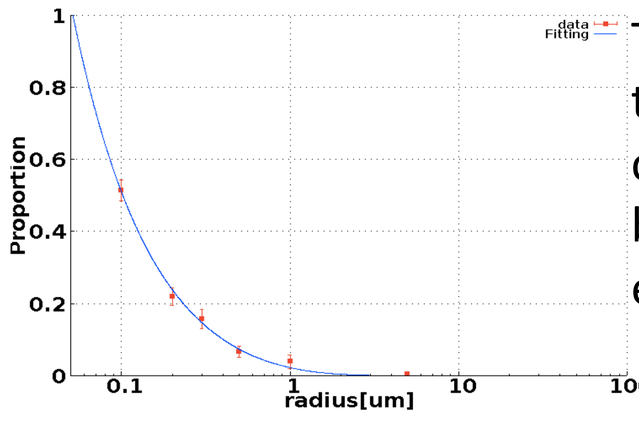
Kunihiko Hasegawa*1*2 Eiichi Hirose*2 Shinji Miyoki*2
1:Department of Physics, The University of Tokyo 2:Institute for Cosmic Ray Research, The University of Tokyo
Email:knhkhsgw@icrr.u-tokyo.ac.jp

Abstract:
The cryogenic sapphire mirrors in KAGRA are expected to suffer from many contaminations due to dust and gas molecules adhesion. The contamination due to dust particles is occurred during their installation process. The cryogenic contamination effect has not been studied correctly in the actual KAGRA cryostat system. Especially, the cryogenic contamination continue during cryogenic operation might require to stop observation for several months per every year to warm and clean up the sapphire mirrors. To minimize observation dead time due to the cryogenic contamination, a partial heat up method will be tested. As a first step, we are now trying to know the relation between the optical loss of a mirror and dust particle diameter and its distribution.

1.Contamination due to dust particles

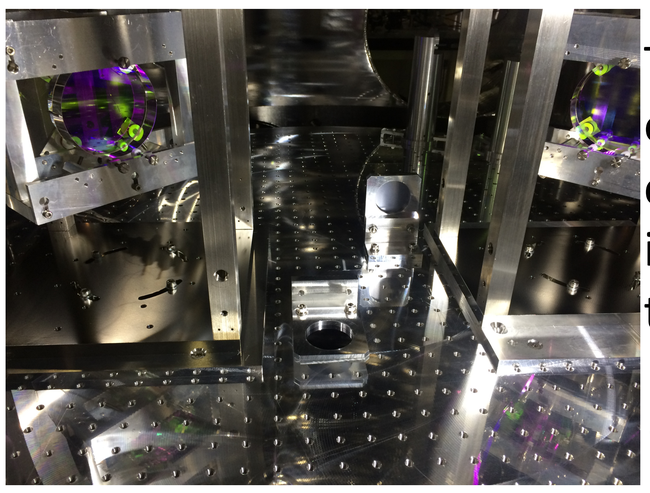
Dust particles adhere to mirror surface. Because some dust particles have size similar to laser wave length (1064nm), it may be strongly scattered. At first, we will check how much optical loss will be occurred in a Fabry-Perot cavity due to this contamination.

2.Size distribution of dust Particle



The particle size distribution in the KAGRA several vacuum chambers. The curve was fitted by power low and scaling exponent was-1.27 +/- 0.05

Fig[1]: Dust particle size distribution in KAGRA vacuum chamber

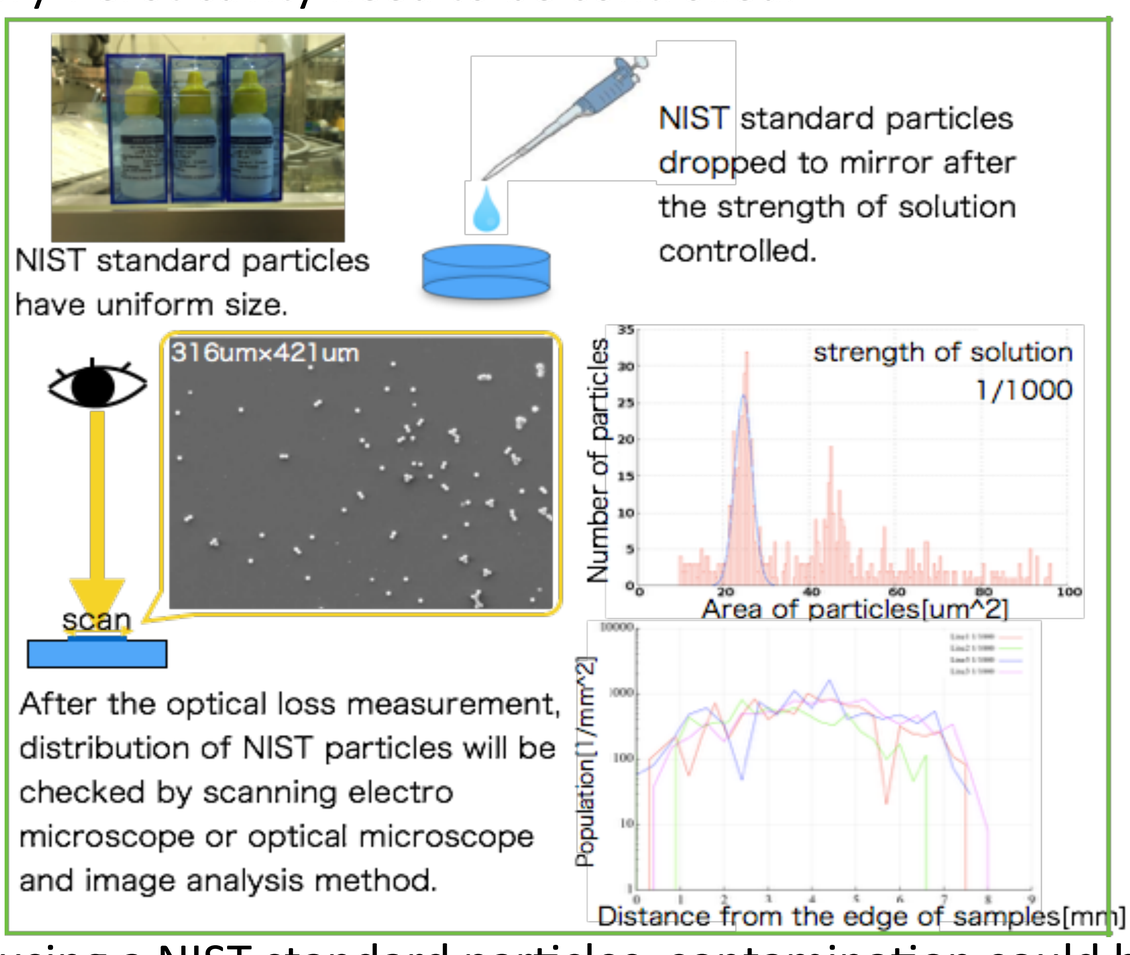


To know the absolute number of dust particles, silicon wafers called witness samples were installed in KAGRA vacuum tanks.

Fig[2]: Witness samples for MCI chamber

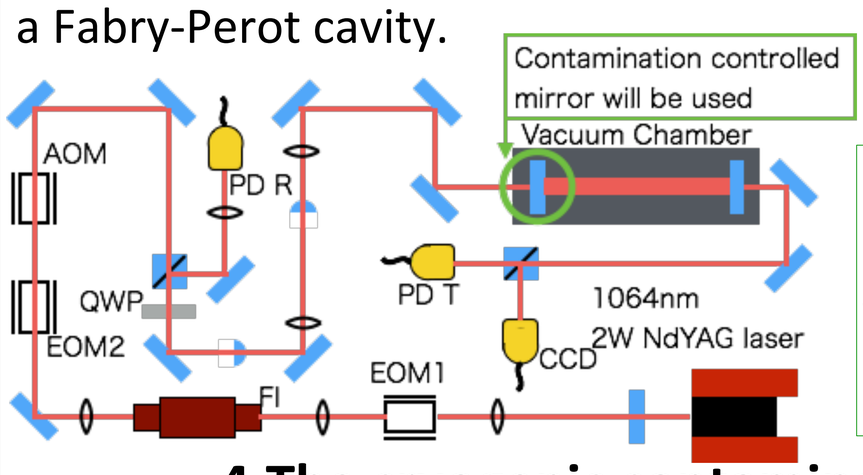
3.Experiment

To measure the dependence of optical loss on the number and size of particles, contamination on the mirror for a Fabry-Perot cavity need to be controlled.



By using a NIST standard particles, contamination could be controlled to some extent.

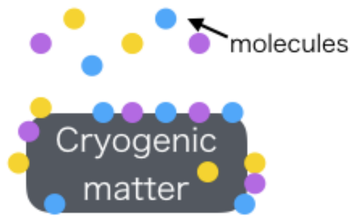
Optical loss due to contamination controlled mirror will be checked by the storage time and transfer function of a Fabry-Perot cavity.



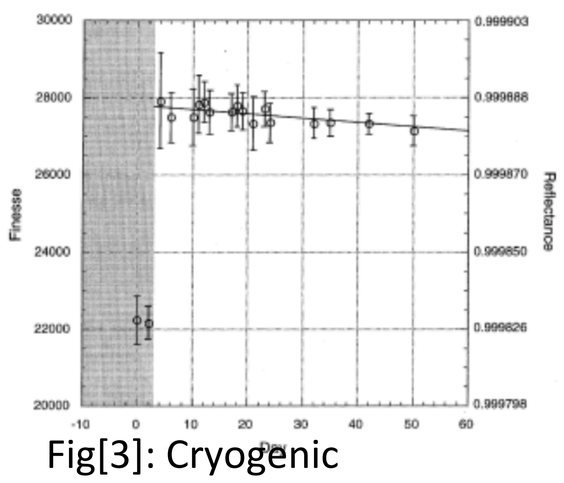
FP Cavity
(w/o contamination)
R~99.995%
T~20ppm F~66000
L=0.25m τ=200us
fc=5kHz

4.The cryogenic contamination

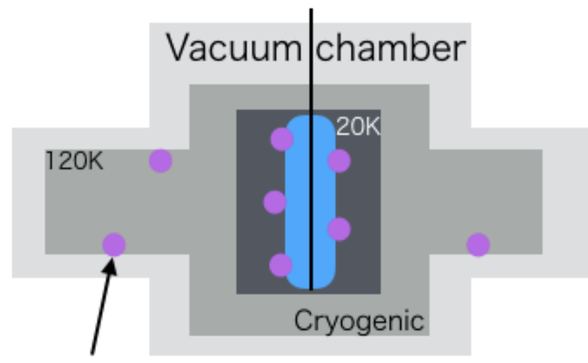
When gas molecules hit the cryogenic matter (temperature about 20K or below), they condense on its surface. This is called cryogenic pumping.



In the case of cryogenic mirror, like sapphire mirror of KAGRA, this cryogenic pump effect makes contamination on mirror surface and refractivity decreased.[1,2]



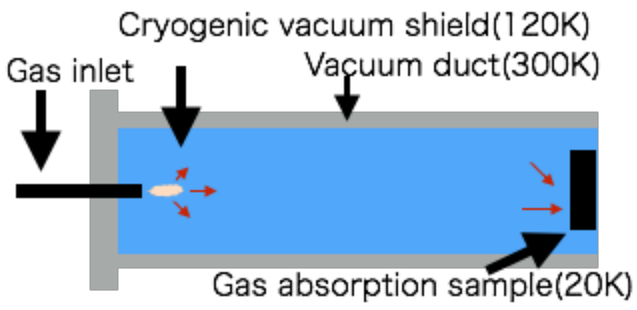
Fig[3]: Cryogenic contamination speed. (From Ref[2])



Fig[4]: KAGRA situation

5.Future Plan

To measure the dumping effect of KAGRA cryogenic shield, we need to know the conductance of cryogenic vacuum duct because conductance of a vacuum duct for molecular flow is proportional to the speed of gas molecule.



Cryogenic contamination speed will be also measured in this equipment with a Fabry-Perot cavity .

6.References

[1] S.Miyoki et al., Cryogenics, 40, pp61-66(2000)
[2] S.Miyoki et al., Cryogenics, 41, pp415-420 (2001)