Geophysics Interferometer (GIF)

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Mission & Status of GIF Subgroup

Definition and scope

1.Construction of ~~two~~ fixed-mirror interferometer~~s~~ (1.5km ~~x 2~~) along KAGRA, for both geophysical observation and KAGRA baseline monitor.

2.Arrangement of sensors and benchmarks for monitoring environment parameters of the tunnel, rooms, and instruments

Current status

1. Documents of retro-reflectors and vacuum chambers are being prepared for bids.

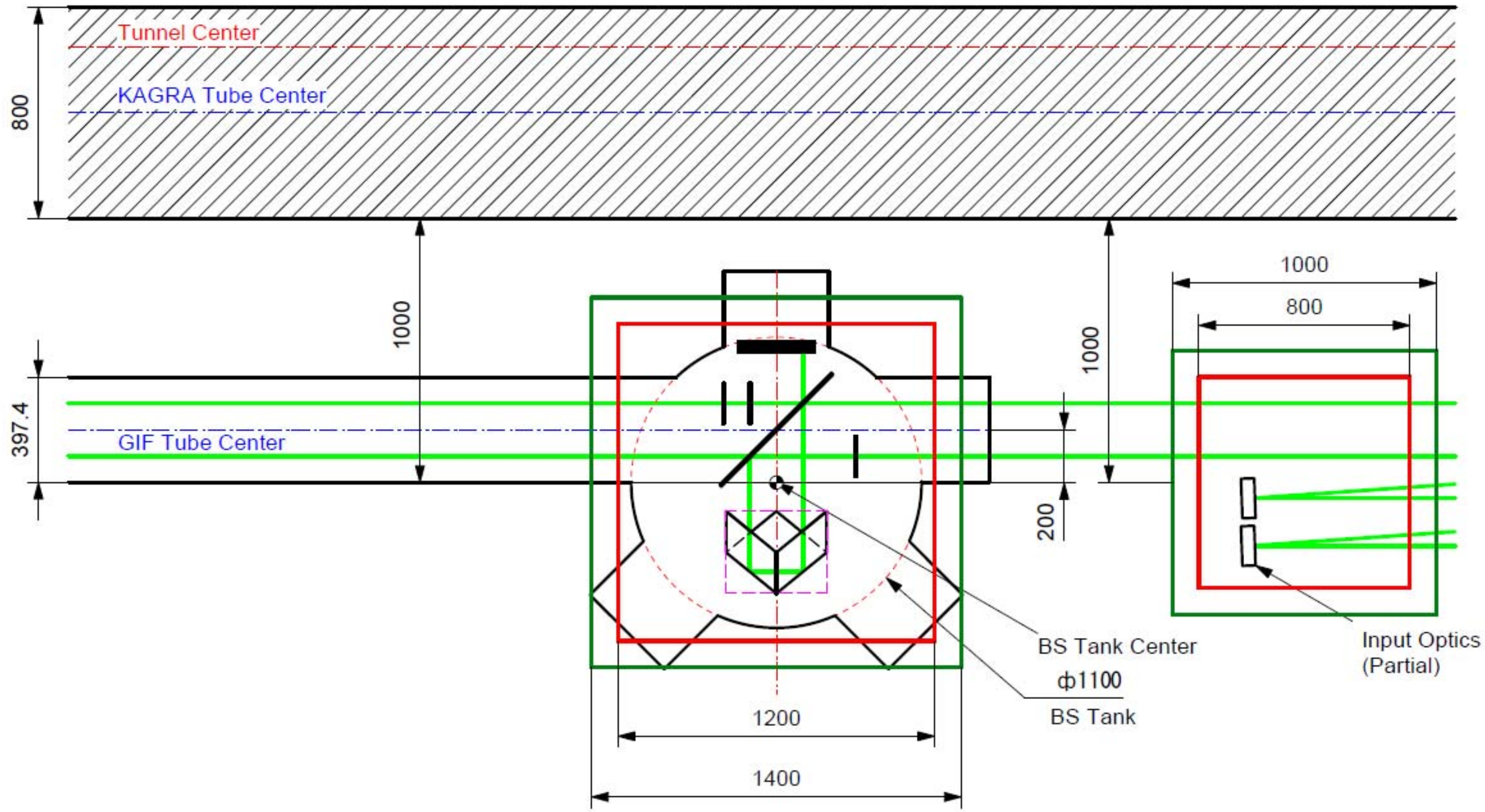
2. Layout around a vacuum chamber is shown below.

3. Sample environment sensors (thermometer, hygrometer, and barometer) are being tested in the CLIO site.

Layout

Optical layout and vacuum chamber

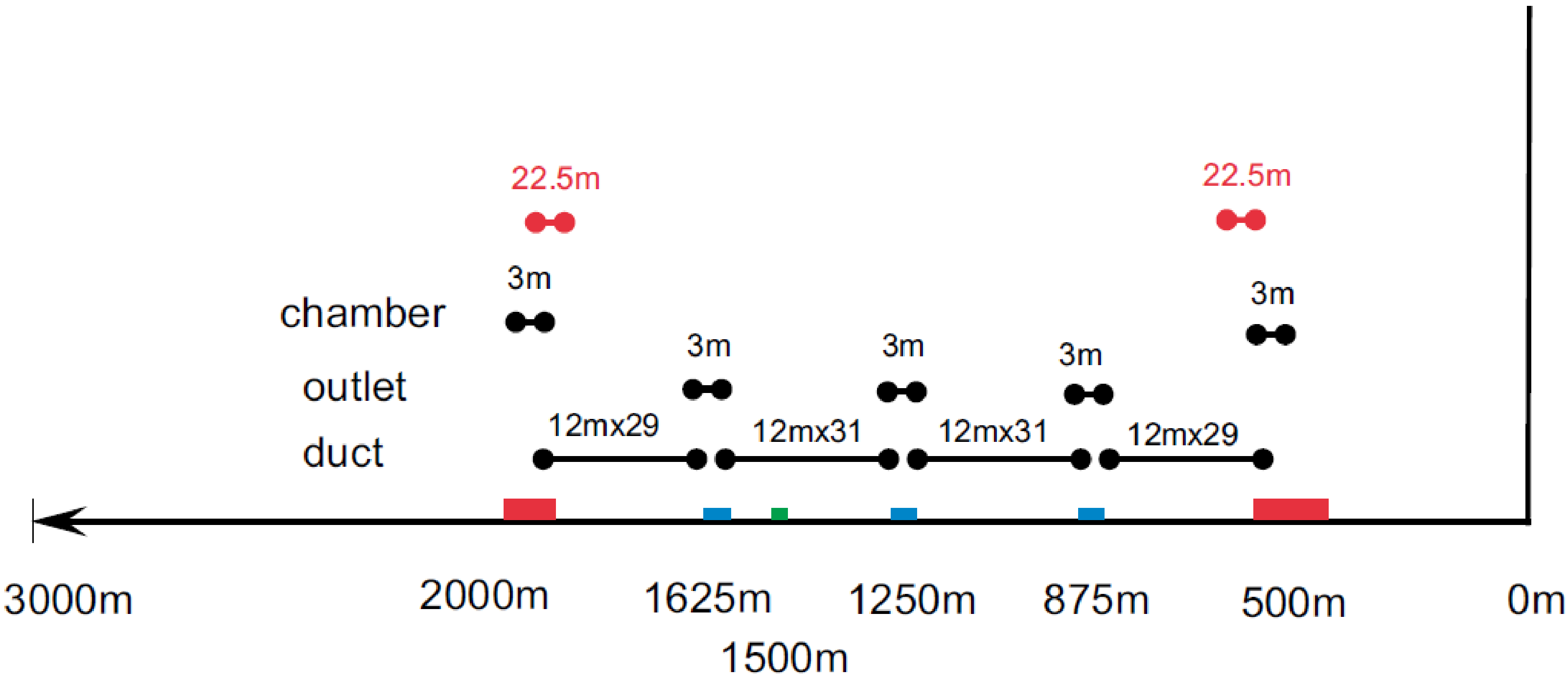
Vacuum chamber (inner dimension): diameter 1100mm, height 1000mm



Vacuum System

Arrangement of vacuum ducts

Missing 22.5m x 2 to complete 1500m



Environment Monitor (EM)

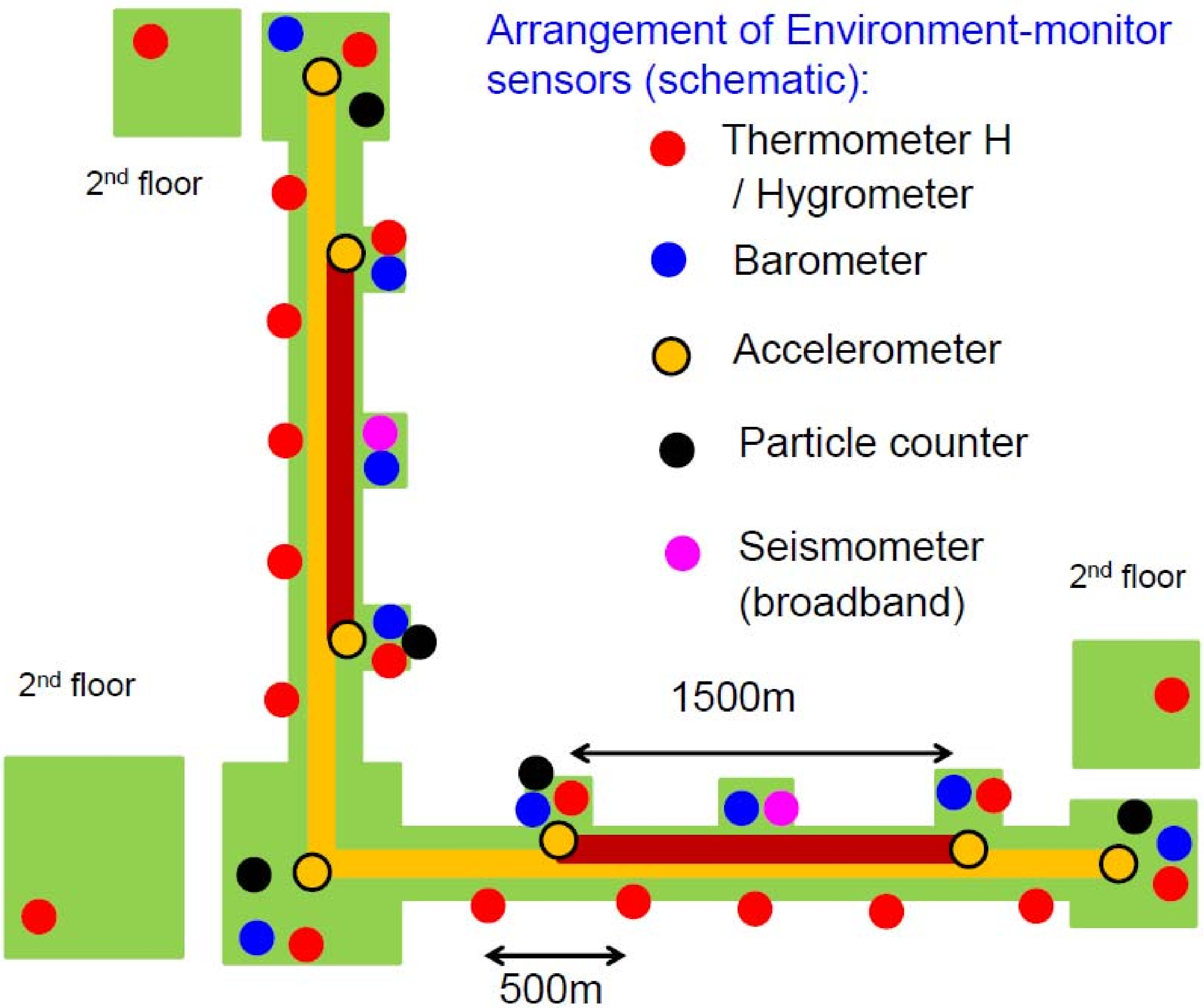
Definition & Scopes

Environment condition of the tunnel, rooms, and instruments need to be monitored for ensuring stable operation of detectors, correction of data analyses, and detection of anomalous operation.

Some sensors are directly attached to instruments for monitoring any noises applied to the instruments to assess validity of the data, such as veto analyses.

The sensors are characterized by physical quantity, relative / absolute, dimension, measurement range, resolution, and frequency response.

Sensor Locations



EM Sensors

already tested — to be tested

Group	Sensor	Rank	Dimension	Symbol	Range	Resolution	Response	Vendor	Room	Floor	Table	TR.y	ETM.y	etm.y	DAQ
									Y end Y3000m						
									1st floor						
COMMON	Thermo	abs.	300x300x120	TH_A_1	-50–50deg	0.15deg	DC-0.1Hz	Yokogawa							
	+Hygro	abs.		TH_A_1	0-100%	3%	DC-0.1Hz	Yokogawa							
	Thermo	rel.	20x20x300	T_R_1	-50-200deg	0.0001deg	DC-1Hz	Tokyo Dempa							
	Thermo	rel.	5x5x5	T_R_2	-55-150deg	0.5deg	DC-0.3Hz	Texas Inst.				3	1	1	1
	Baro.	abs.	180x180x65	B_A_1	850-1050hPa	0.15hPa	DC-0.1Hz	Yokogawa							
	Accel.	abs.	80x80x80	Acc_A_1	20m/s^2	1.e-5m/s^2	DC-500Hz	Japan Avl. Ele.			1				
	Accel.	rel.	15x15x15	Acc_R_1	50m/s^2	1.e-2m/s^2	1-5kHz	Kistler				3	1	1	1
	Velocity	rel.	250x250x250	Sei_R_1	1.3e-2m/s	3e-10m/s^2/rHz	8.3m-50Hz	Streckeisen							
	Velocity	rel.	250x250x300	Sei_R_2	1.5e-2m/s	1e-10m/s^2/rHz	4m-200Hz	Nanometrics							
	Velocity	rel.	200x200x300	Sei_R_3	1.3e-2m/s	3e-10m/s^2/rHz	3m-50Hz	Guralp							
	Acoustic	rel.	15x15x20	Mic_R_1	146dB	14.6dB	6.3-20kHz	Bruel and Kjaer		1					
	Acoustic	rel.	15x15x15	Mic_R_2	140dB	19dB	20-20kHz	Ono Sokki							
	Mag.	rel.	25x25x200	Mag_R_1	70-1000uT	6pT/rHz	DC-3kHz	Bartington		1					
	Mag.	rel.	100x100x100	Mag_R_1	50uT	0.1nT	DC-5Hz	Shimadzu							
	Particle	abs.	150x100x100	Par_A_1	0.2-5um	0.2um	NA	MetOne		1					
	Particle	abs.	150x300x300	Par_A_2	0.3-5um		10s-2h	RION							
VAC	Baro.	abs.	180x180x65	B_A_1	850-1050hPa	0.15hPa	DC-0.1Hz	Yokogawa							
	Particle	abs.	150x100x100	Par_A_1	0.2-5um	0.2um	NA	MetOne							
GIF	Thermo	abs.	300x300x120	TH_A_1	-50–50deg	0.15deg	DC-0.1Hz	Yokogawa		1					
	+Hygro	abs.		TH_A_1	0-100%	3%	DC-0.1Hz	Yokogawa		1					
	Thermo	rel.	20x20x300	T_R_1	-50-200deg	0.0001deg	DC-1Hz	Tokyo Dempa							
	Thermo	rel.	5x5x5	T_R_2	-55-150deg	0.5deg	DC-0.3Hz	Texas Inst.							
	Baro.	abs.	180x180x65	B_A_1	850-1050hPa	0.15hPa	DC-0.1Hz	Yokogawa		1					
	Accel.	abs.	80x80x80	Acc_A_1	20m/s^2	1.e-5m/s^2	DC-500Hz	Japan Avl. Ele.							
	Accel.	rel.	15x15x15	Acc_R_1	50m/s^2	1.e-2m/s^2	1-5kHz	Kistler							
	Velocity	rel.	250x250x250	Sei_R_1	1.3e-2m/s	3e-10m/s^2/rHz	8.3m-50Hz	Streckeisen							
	Velocity	rel.	250x250x300	Sei_R_2	1.5e-2m/s	1e-10m/s^2/rHz	4m-200Hz	Nanometrics							
	Velocity	rel.	200x200x300	Sei_R_3	1.3e-2m/s	3e-10m/s^2/rHz	3m-50Hz	Guralp							
	Acoustic	rel.	15x15x20	Mic_R_1	146dB	14.6dB	6.3-20kHz	Bruel and Kjaer							
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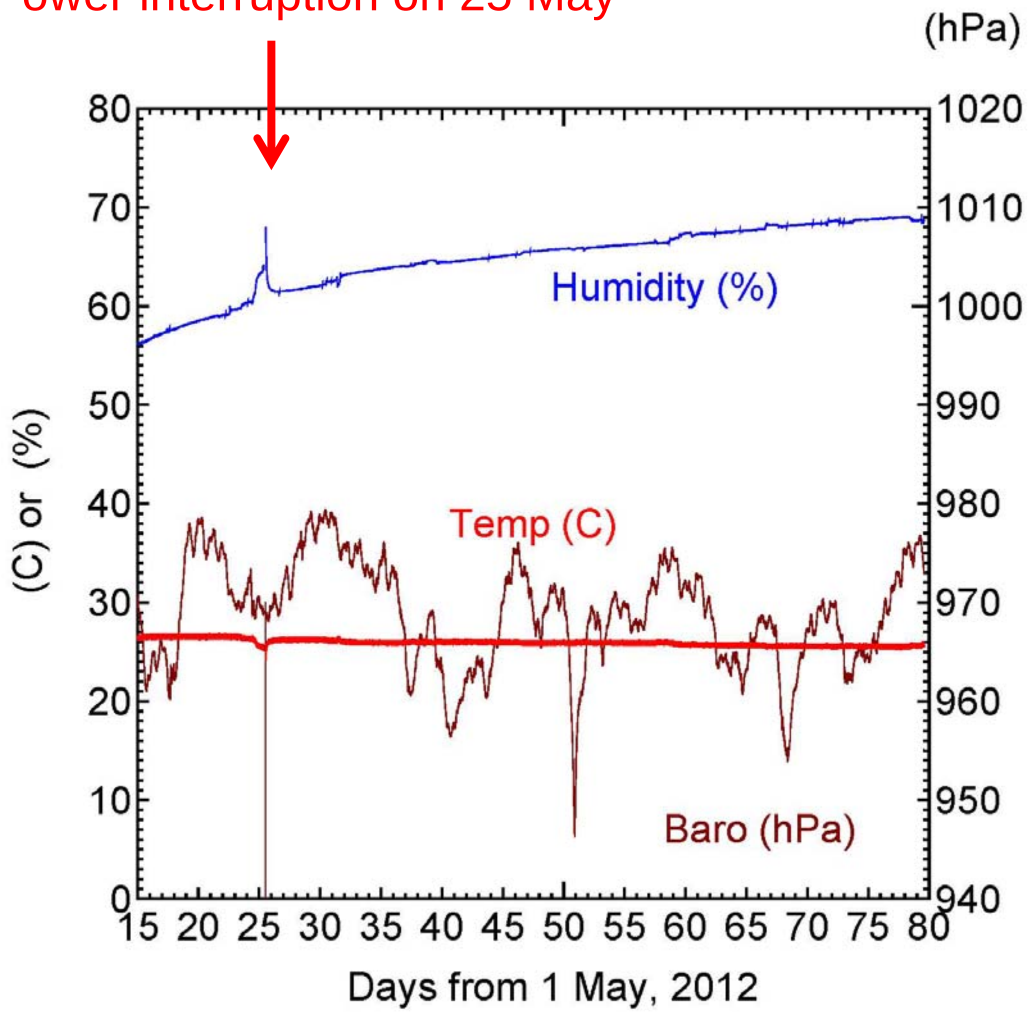
	Mag.	rel.	25x25x200	Mag_R_1	70-1000uT	6pT/rHz	DC-3kHz	Bartington							
	Mag.	rel.	100x100x100	Mag_R_1	50uT	0.1nT	DC-5Hz	Shimadzu							
	Particle	abs.	150x100x100	Par_A_1	0.2-5um	0.2um	NA	MetOne							
	Particle	abs.	150x300x300	Par_A_2	0.3-5um		10s-2h	RION							

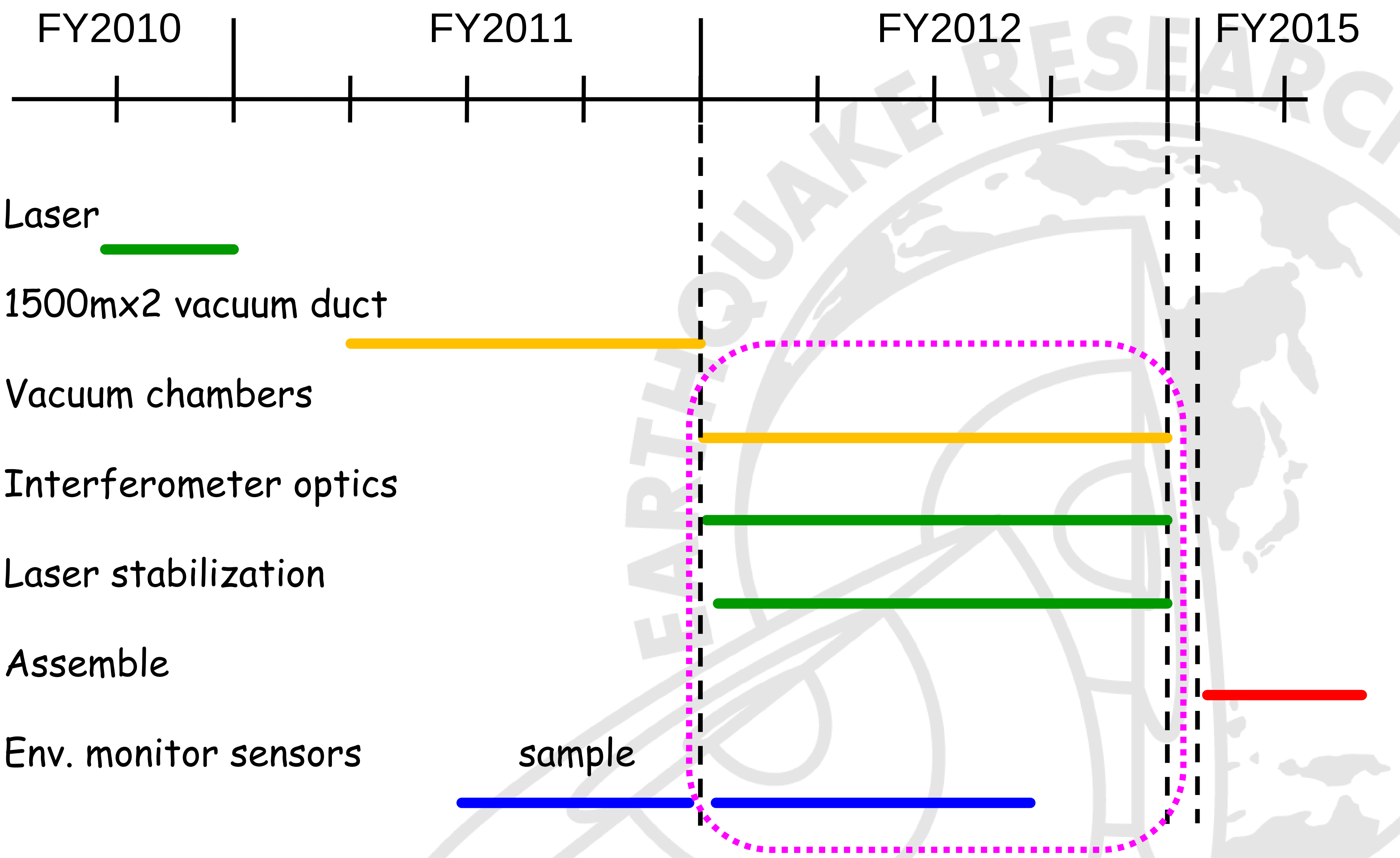
EM Example

Temperature, humidity, and barometric pressure at CLIO

Power interruption on 25 May



Schedule



FY2010
FY2011
FY2012
FY2015
Laser
1500mx2 vacuum duct
Vacuum chambers
Interferometer optics
Laser stabilization
Assemble
Env. monitor sensors
sample

GIF Milestones

		related sub-groups
2012.3	vacuum pipes delivery	Vacuum
	optics final design	Tunnel
	EM sensor determination	Det Char
2012.9	vacuum valves / pumps delivery	Vacuum
	infra specification (clean booth, LAN)	Fac. Sup.
2013.3	optical components delivery	
	vacuum components delivery	Vacuum
	EM sensors delivery	Det Char
(2014.3)	tunnel excavated	Tunnel
2014.6	vacuum & granite base installation	Vacuum/ Fac. Sup.
2014.12	vacuum installation	Vacuum
2015.3	optics installation	
	EM-DAQ operation	Det Char
2015.6	test observation start	
	safety management	Fac. Sup.
2015.9	observation & maintenance	
(2018.3)	bKAGRA	

GIF Optics Main Features

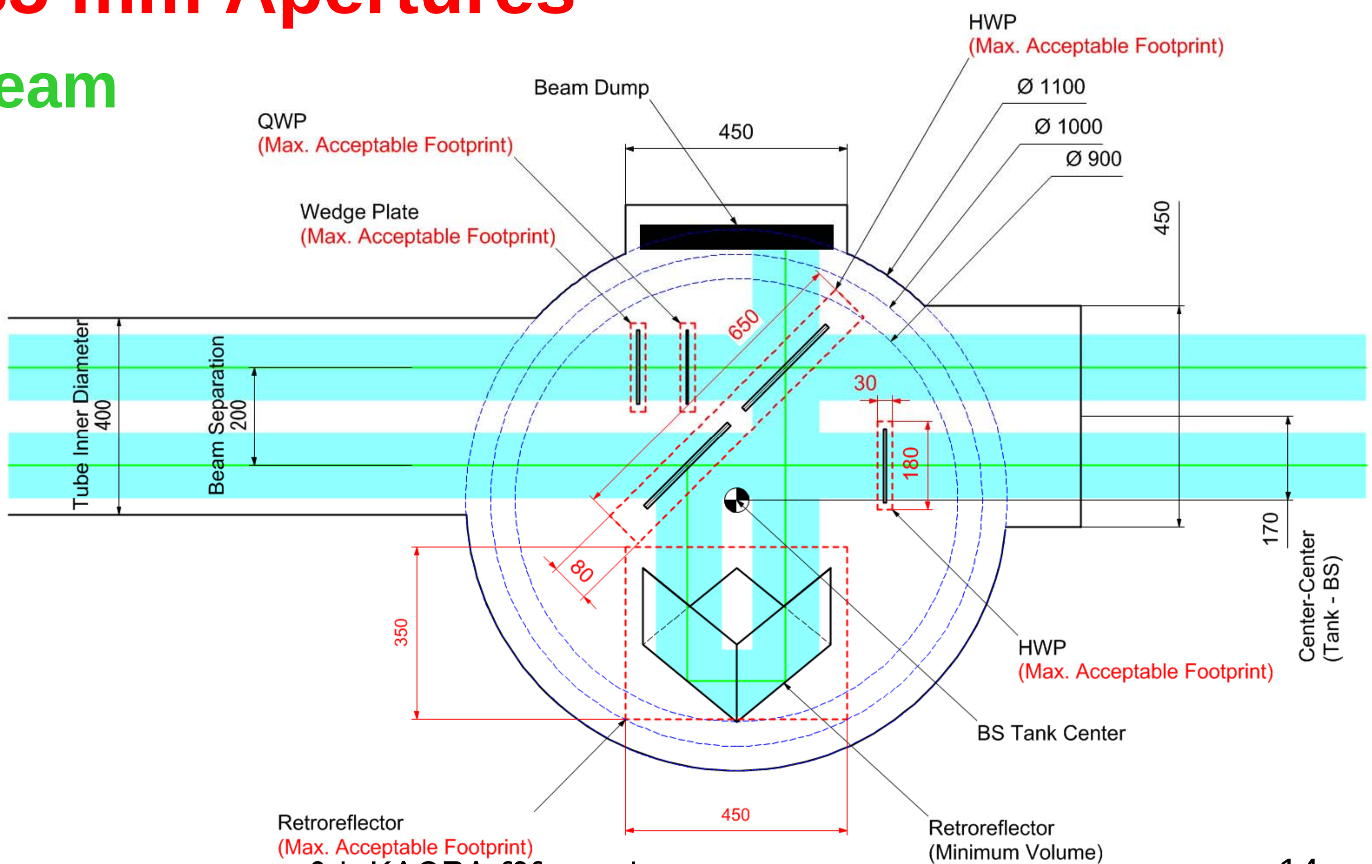
- **Asymmetric Michelson Laser Interferometer**
  - **1.5 km vs. 50 cm**
  - **Optics Attached to Bedrock**
- **Iodine-stabilized Nd:YAG Laser**
  - **λ = 532 nm**
  - **Stability (Ultimate Resolution): 10^{-13}**
- **Quadrature Detection**
  - **Bi-directional Output**
  - **Wave Plates Inserted as Retarders**
- **Retroreflectors as End Mirrors**
  - **No Alignment/Length Control**

Beam Layout

- **200 mm Separation**
  - **To Fit into 400 mm Vacuum Tube**
- **Beam Waist at Arm End**
  - **Minimizes Retroreflector**
  - **For Better Symmetry (of input & return beams)**
  - **Minimum Spot Size at BS**
    - **Waist Size: 15.9 mm**
    - **Spot Size at BS: 2.25 mm**
- **Required Minimum Apertures**
  - **Retroreflector: 295.7 mm (12 inches)**
  - **BS: 237 mm per Spot**

Optics in Main Tank

- 15” Hollow Retroreflector
- BS Separated to 2 pcs.
- WP w/ 85 mm Apertures
  - Clip Beam



Visibility

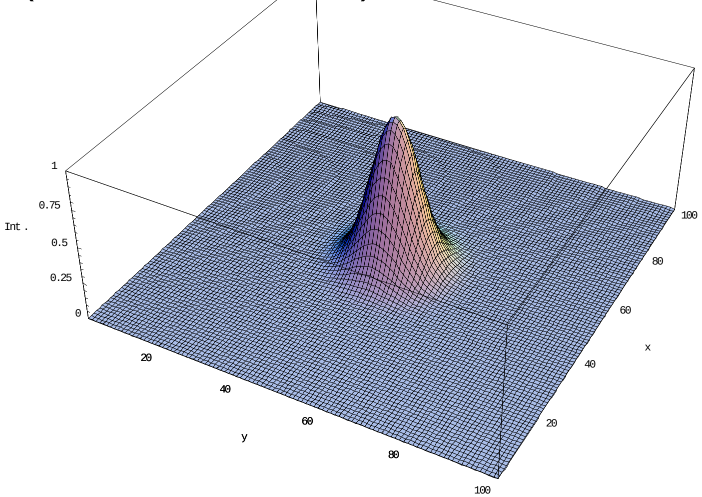
- Limited due to IFO Asymmetry
  - Vis = 0.707 (Best w/ Ideal Optics)
- Causes of Visibility Degradations
  - Wavefront Distortion
    - Irregular Surface of Retroreflectors
    - Non-Parallelism of BS & Wave Plates
  - Power Loss
    - Contamination (Low Reflectivity, Transmissitivity)
    - Clipping at Wave Plates
  - Other Causes
    - Scattering etc.

Surface Accuracy of Retroreflectors

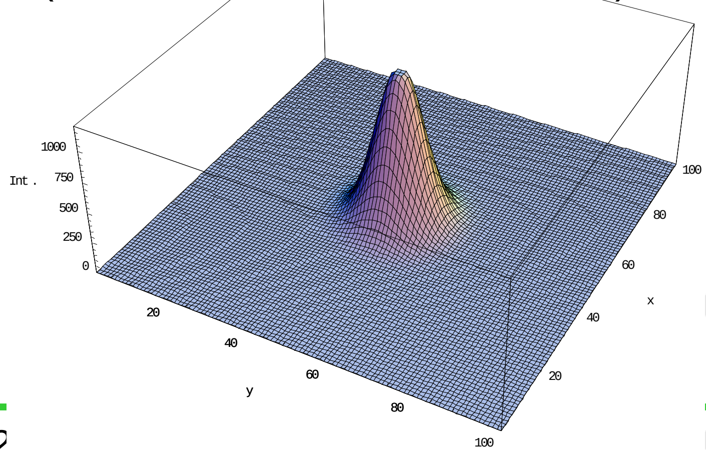
- **Realistic Numbers**
  - **A Manufacturer Specification (PLX)**
    - **0.3 λ Guaranteed**
    - **0.1 λ may be Possible (Best Effort)**
- **Estimating Visibility Degradation**
  - **Simple FE Model**
    - **Meshing over +/- 100 mm Wavefront**
      - 50 x 50, 100 x 100, 200 x 200, 500 x 500 Meshing Tested
    - **Random & Independent Surface Displacement**
      - follows Normal Distribution
        - Average: 0
        - STD: R x λ (Roughness Factor R = 0.1, 0.2, 0.3, …)

Model Example

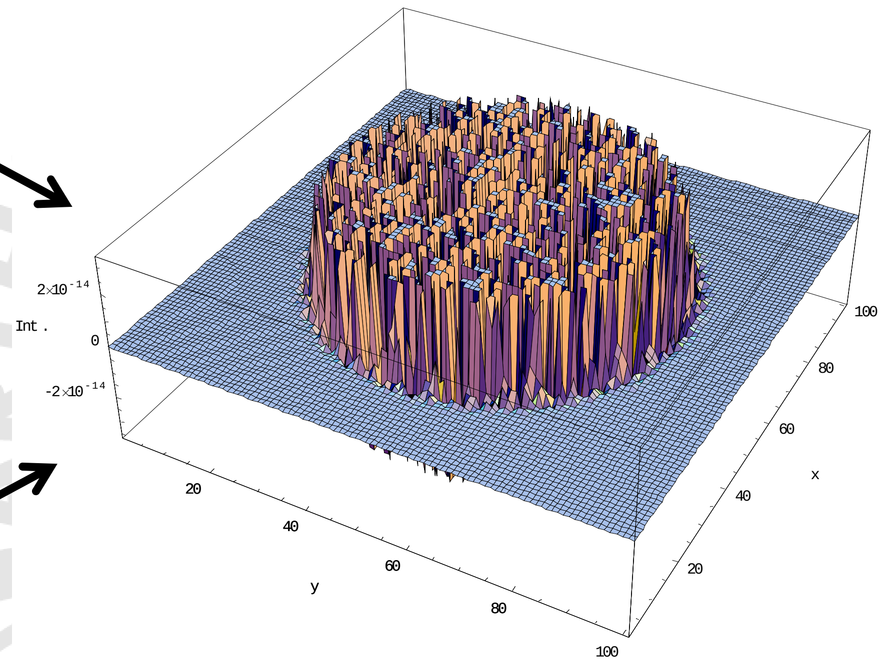
Output Beam Power
(Ideal Mirror Surface)



Output Beam Power
(Inaccurate Mirror Surface, R = 0.1)



Difference



Results

Visibility vs. Surface Inaccuracy

- Appropriate Mesh Number: 100 x 100
- Rapid Degradation Observed
  - Up to R~0.3
- Expected Visibilities
  - 0.53 +/- 0.02 (R=0.1)
  - 0.21 +/- 0.03 (R=0.2)
  - 0.05 +/- 0.03 (R=0.3)
  - cf. 0.71 (R=0)
- Beam Clipping
  - No Significant Impact