Geophysics interferometer (GIF) A. Araya, A. Takamori

Definition and scope

1. Construction of two fixed-mirror interferometers (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. One interferometer abandoned due to limited budget. Two vacuum systems will be constructed.

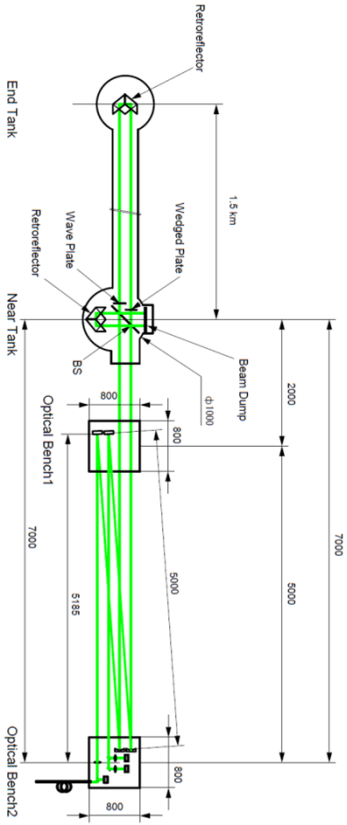
2. Retro reflectors and end chambers in production.

3. One laser stabilization system is being tested.

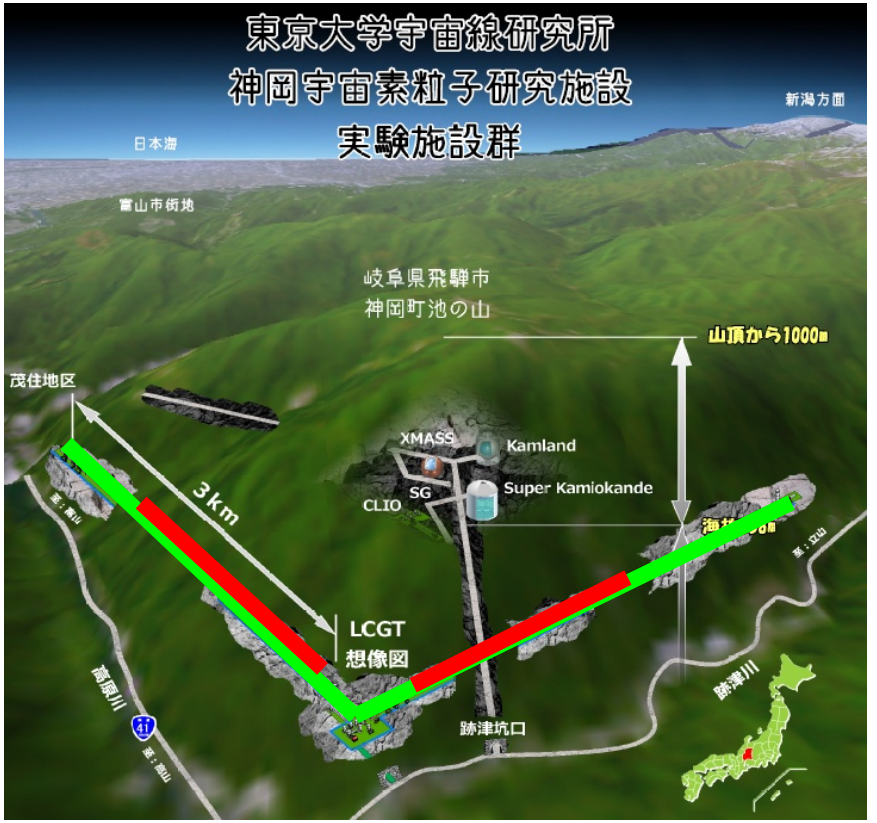
3. Sample environment sensors (thermometer, hygrometer, and barometer) have been tested in the CLIO site.

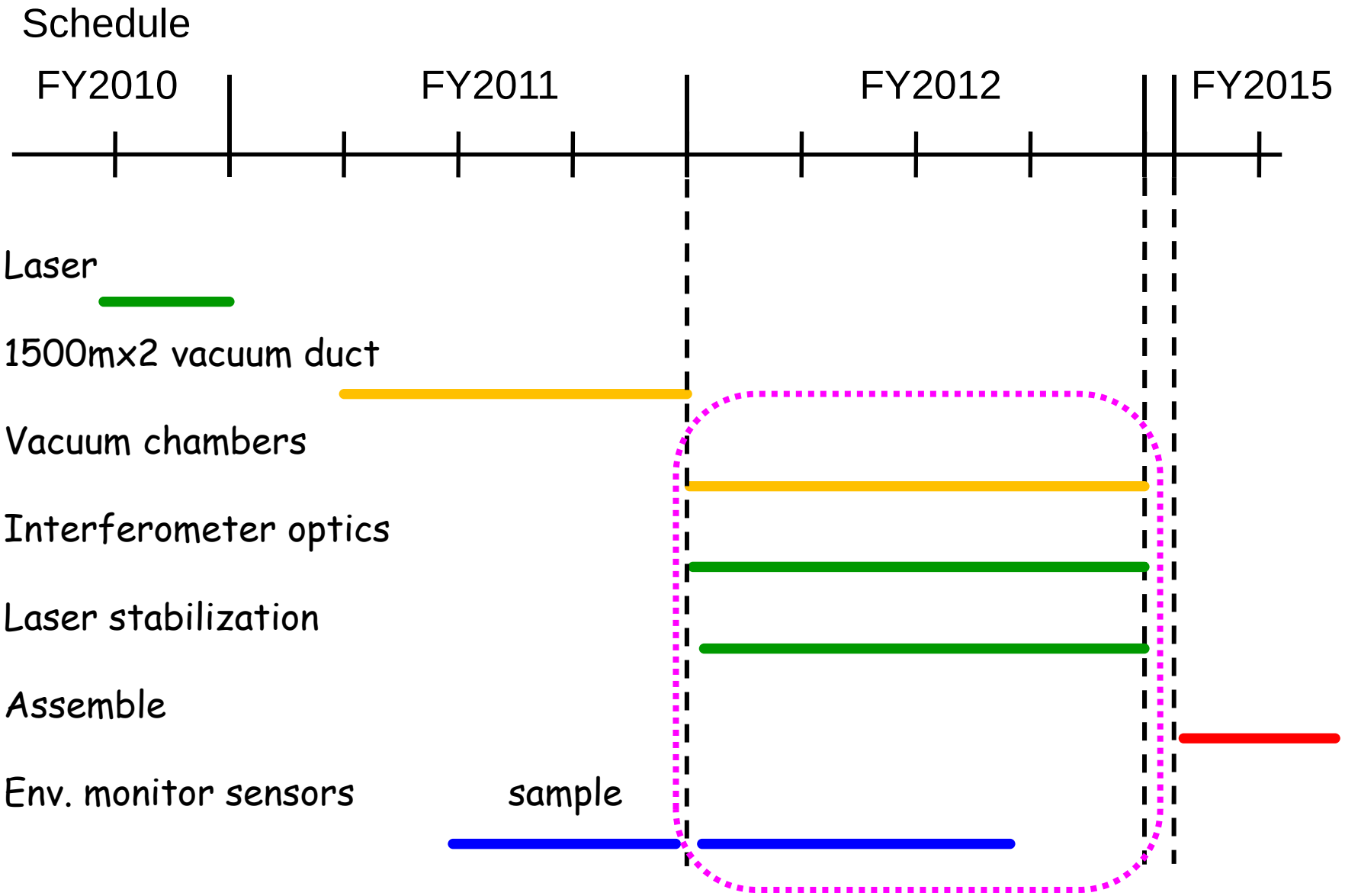
Geophysics interferometer

Strain sensitivity	3×10^{-13}
Baseline length	1500m
Vacuum pressure	1×10^{-4}Pa
The number of GIF	2->2(vacuum), 1(interferometer)

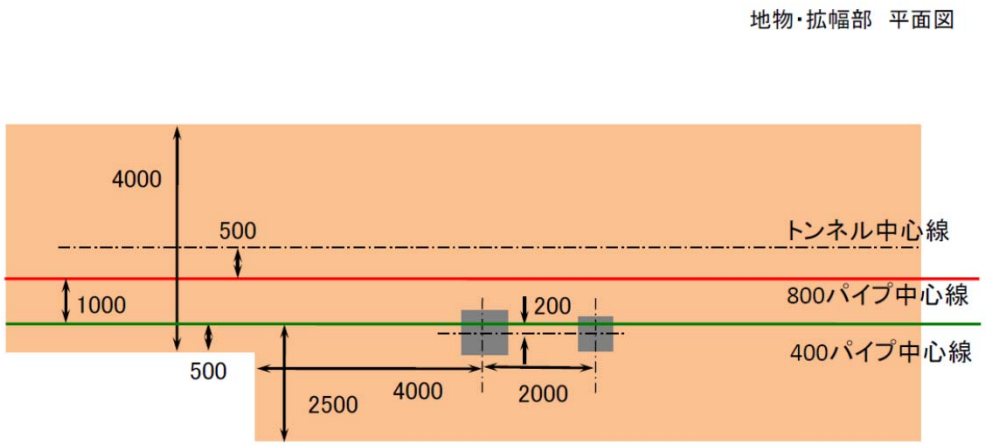


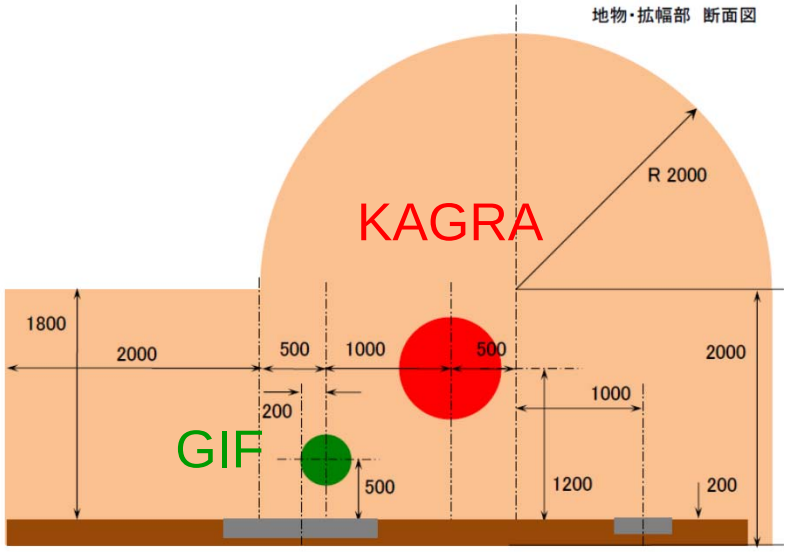
Geophysics Interferometers along KAGRA




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

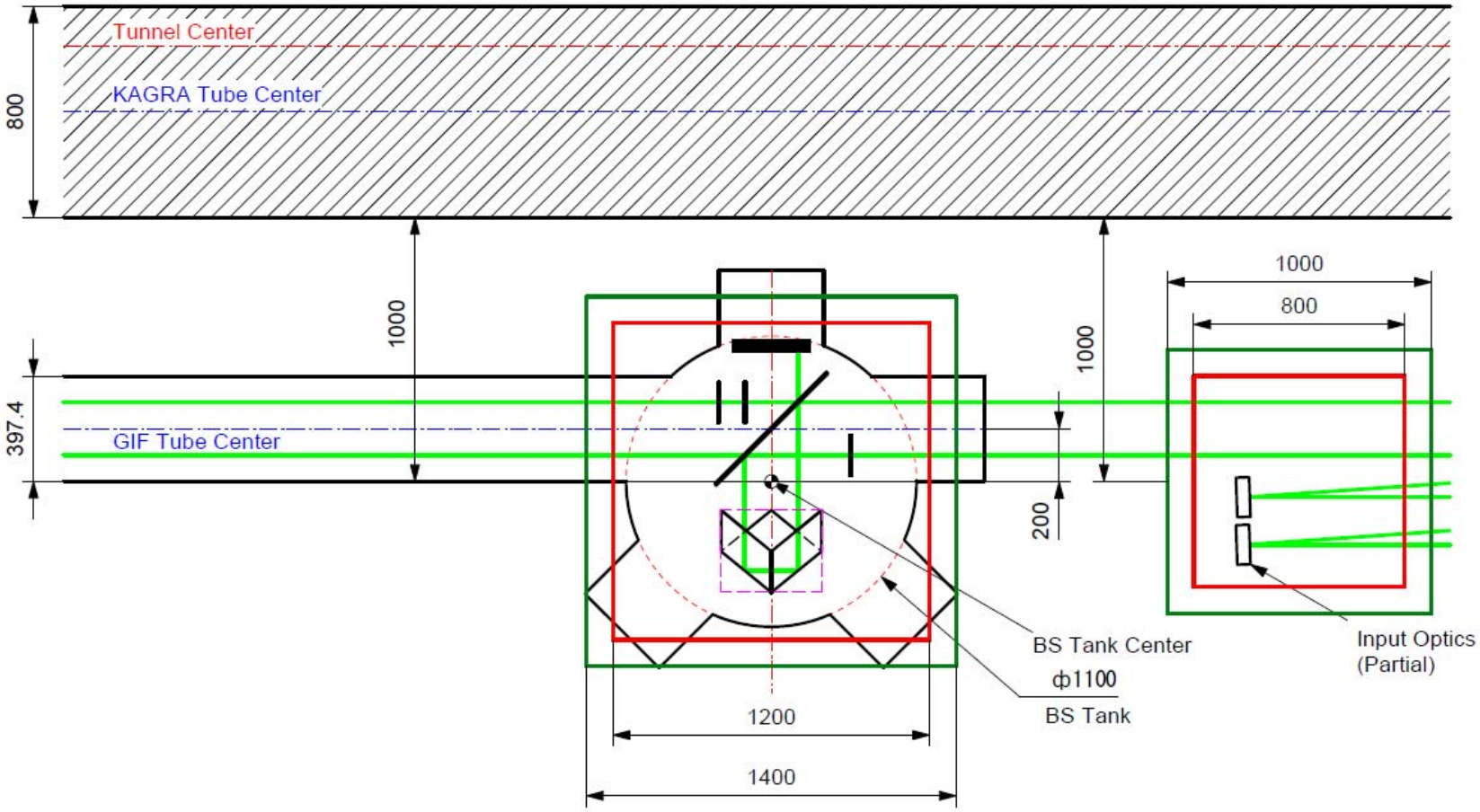
Layout around a vacuum chamber





Optical layout and vacuum chamber

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



Layout around a vacuum chamber

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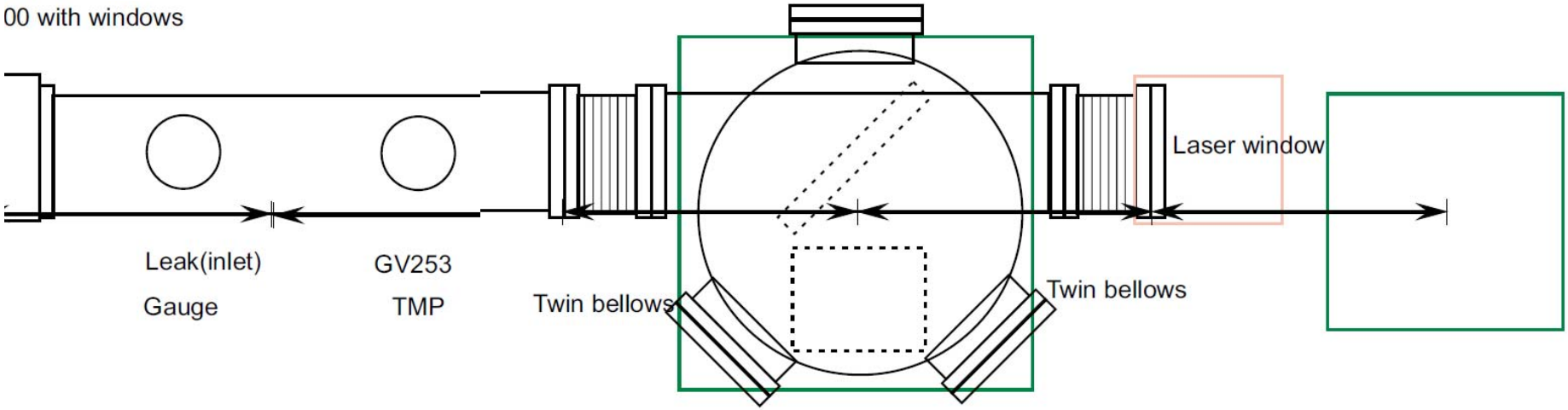
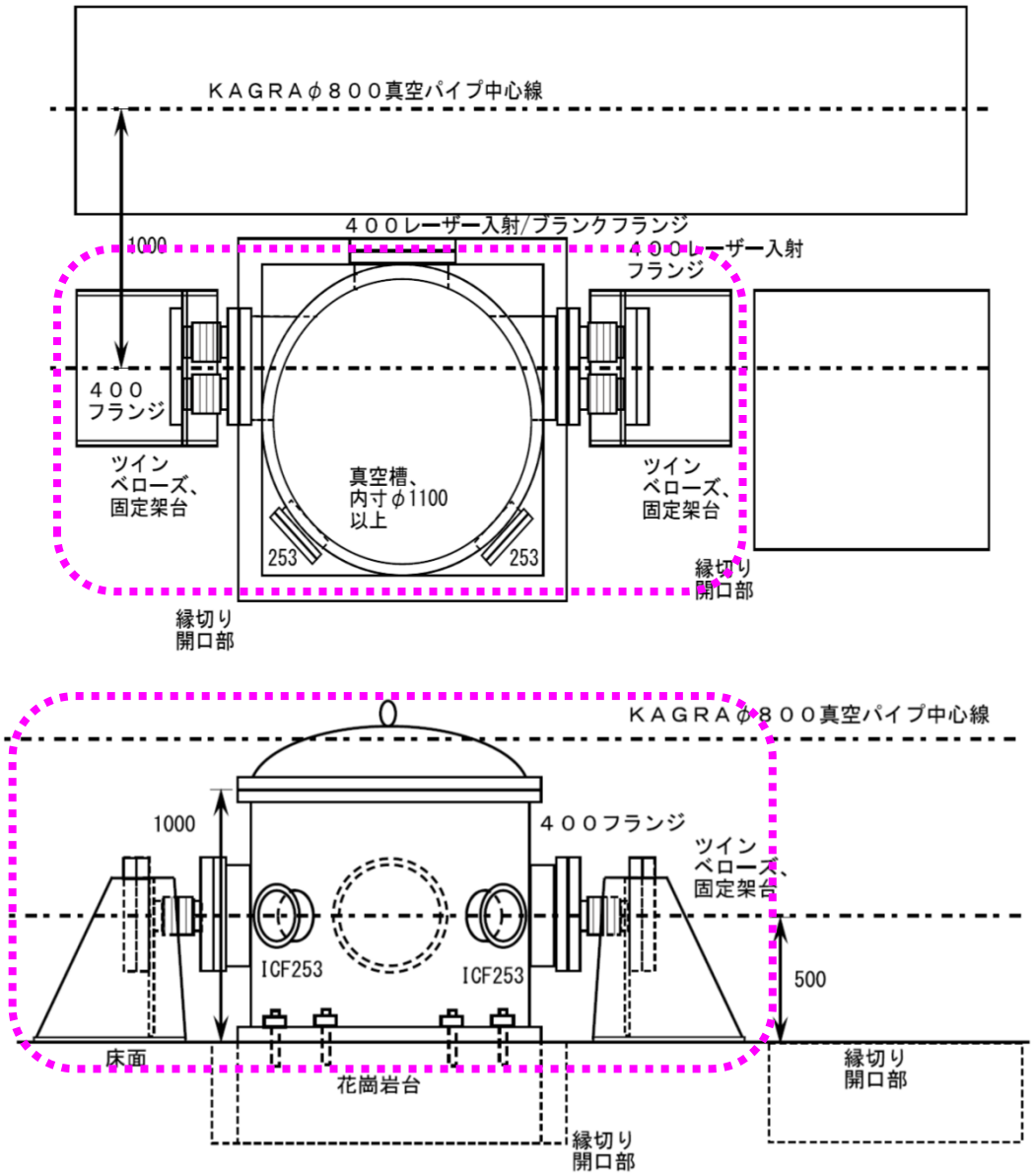


One arrow indicates 1 meter.

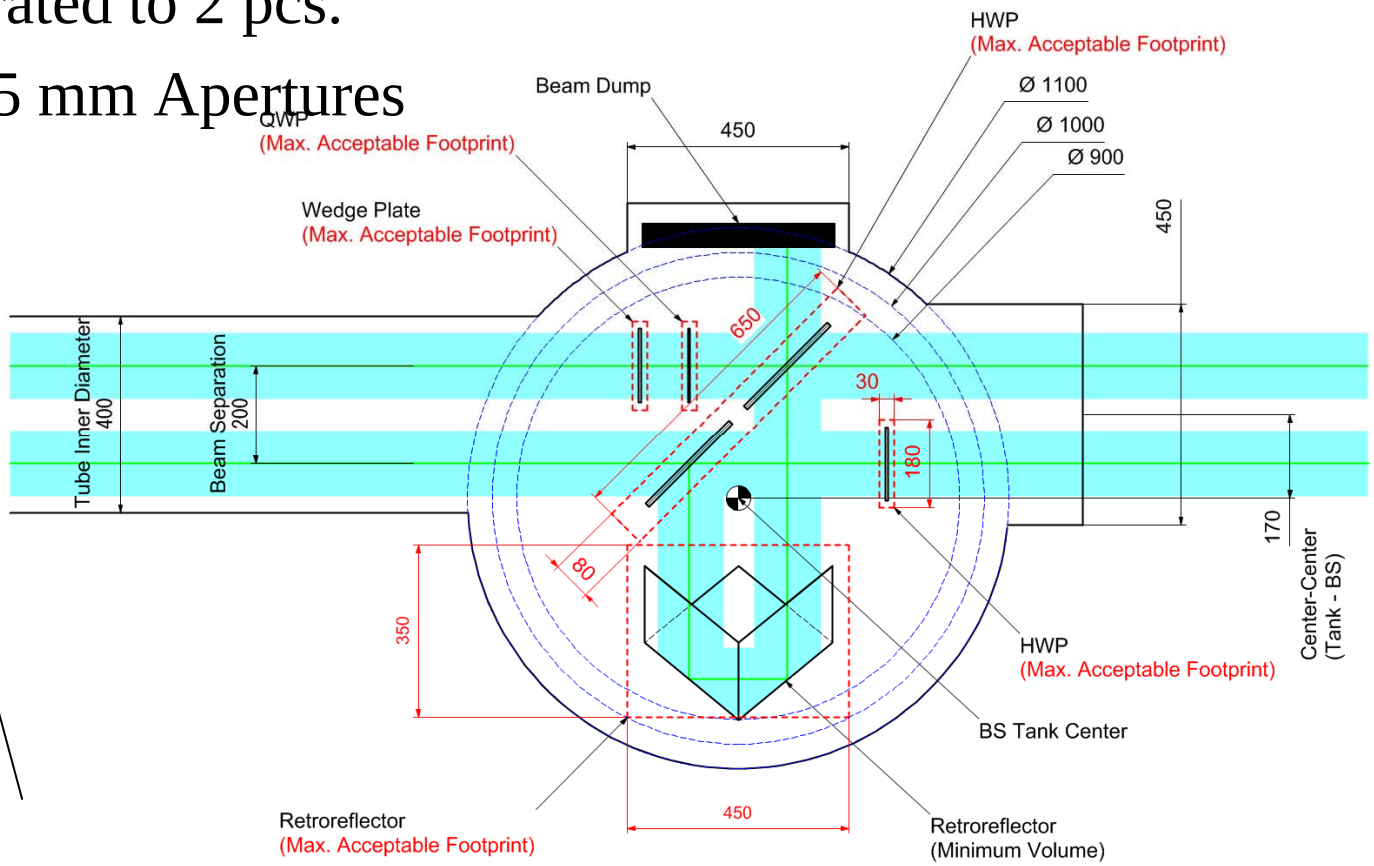
Vacuum system including bellows supports is now in production



Optics in Main Tank

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

Hollow Retroreflector



Surface Accuracy of Retroreflectors

– A Manufacturer Specification (PLX)

- 0.3 λ Guaranteed
- 0.1 λ Best effort

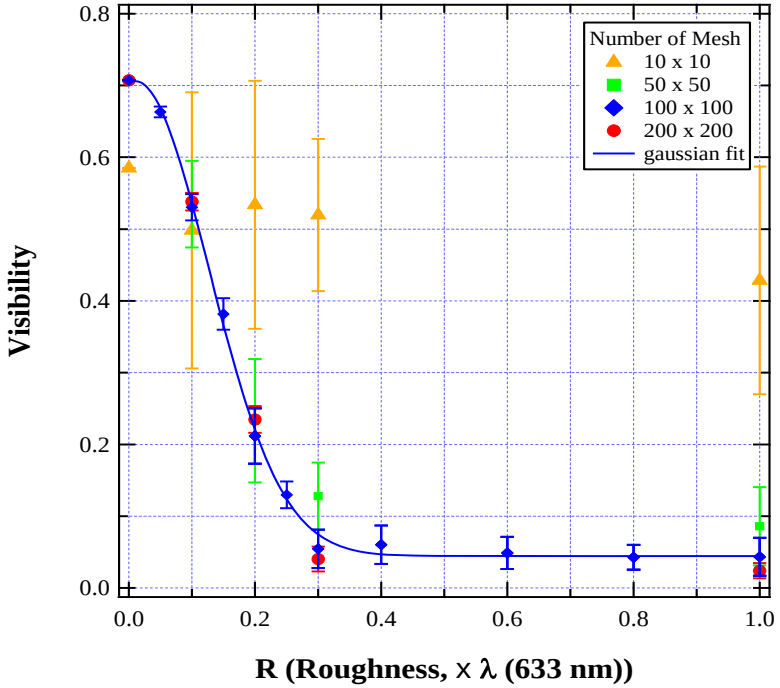
- Estimated Visibility Degradation

Visibilities

0.05 +/- 0.03 (0.3 λ)

0.21 +/- 0.03 (0.2 λ)

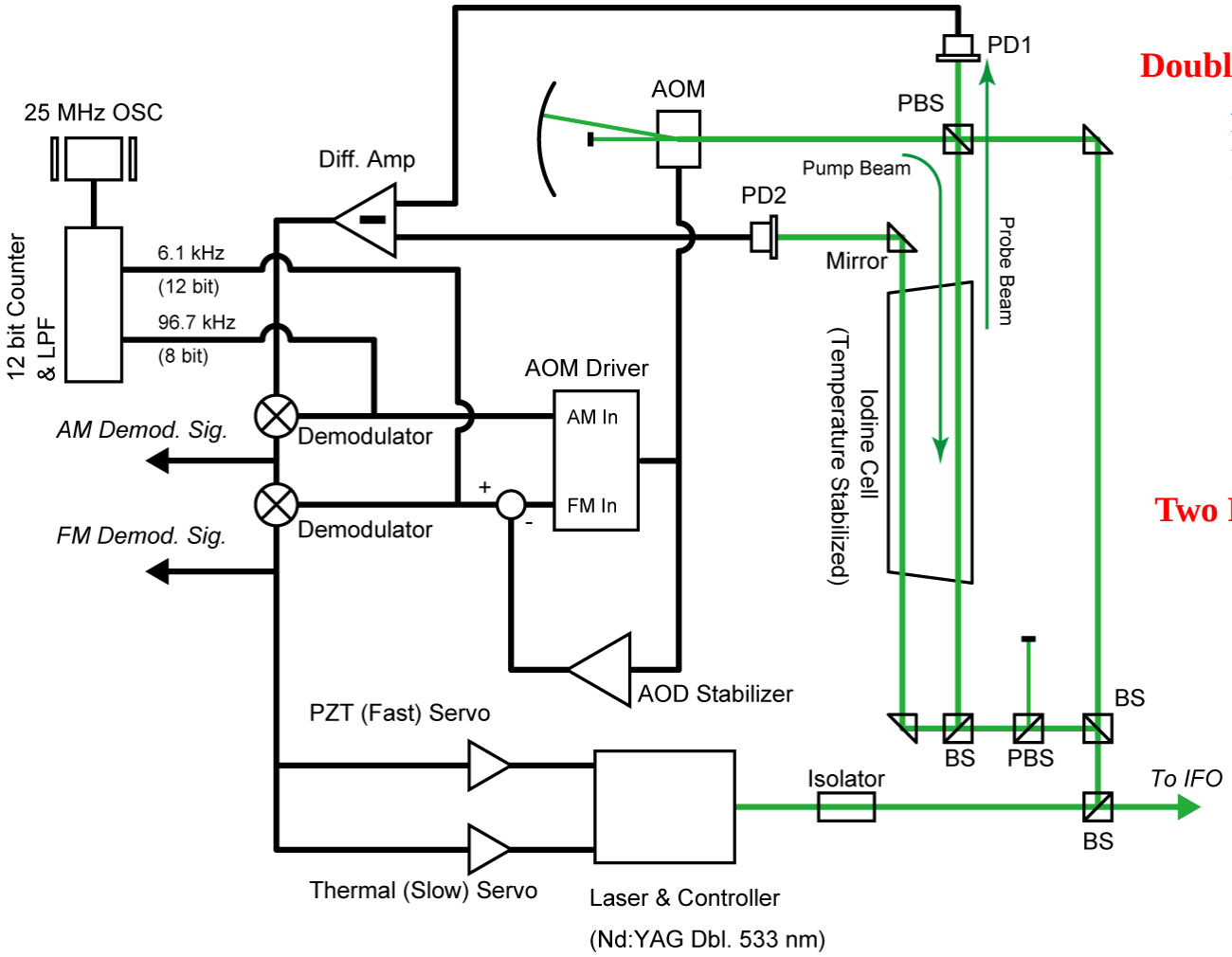
0.53 +/- 0.02 (0.1 λ)



GIF Laser

- Design & Implementation
  - Lock Laser Frequency to an I_2 Absorption Line
    - Highly Stable Quantum Standard
    - Frequency-Doubled Nd: YAG Laser (532 nm)
  - Modulation Transfer Technique
    - Doppler-free detection of the absorption line
  - Double Modulation
    - AM and FM applied to pump beam
      - to resolve absorption lines (AM) and its derivative (FM)
    - AOM used to apply both modulations

GIF Laser



Double Modulation

AM Freq: 96.7 kHz

FM Freq: 6.1 kHz

(generated from the same OSC)

Two Feedback Loops

Fast Loop:

Fed back to PZT

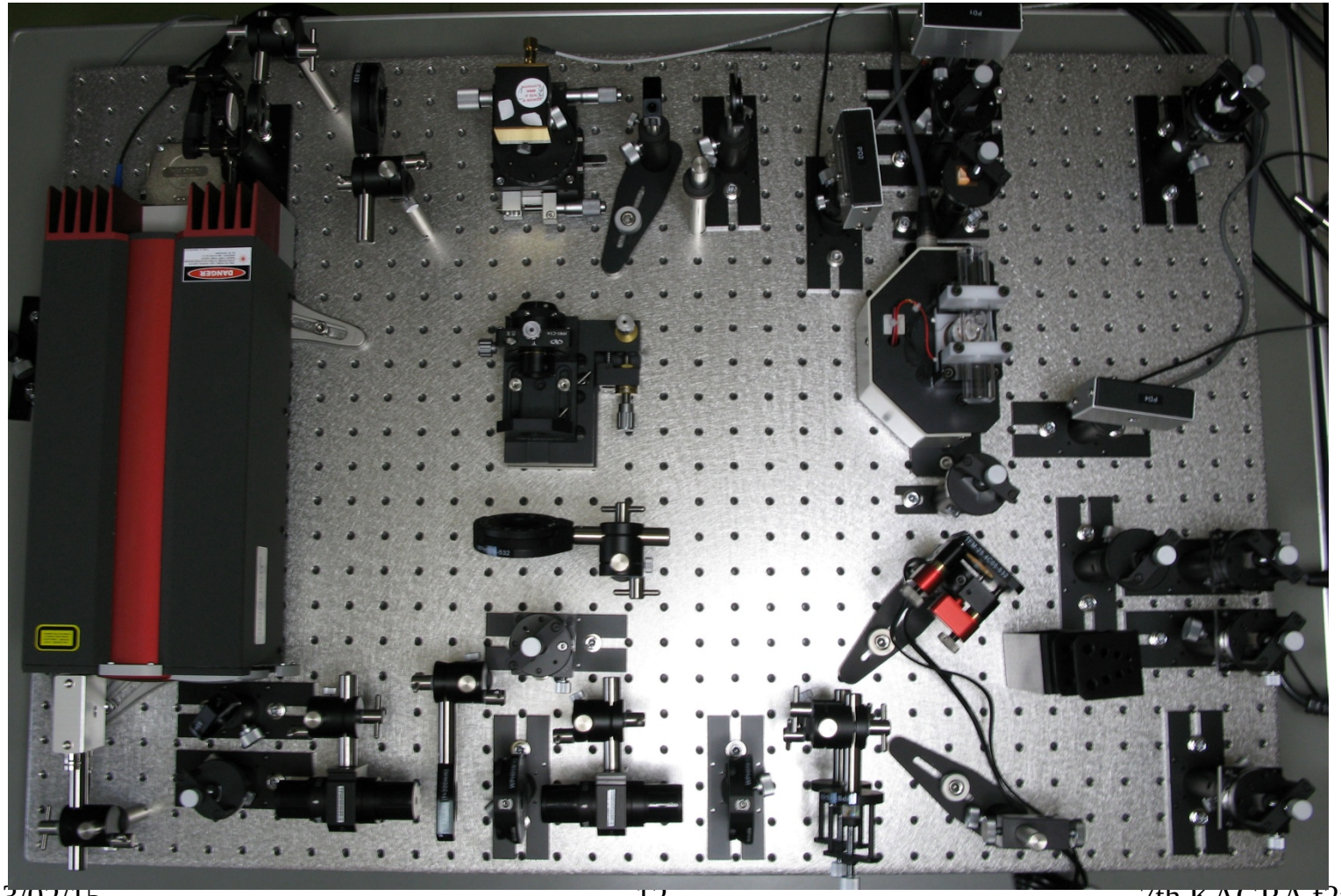
Lock Acquisition

Slow Loop:

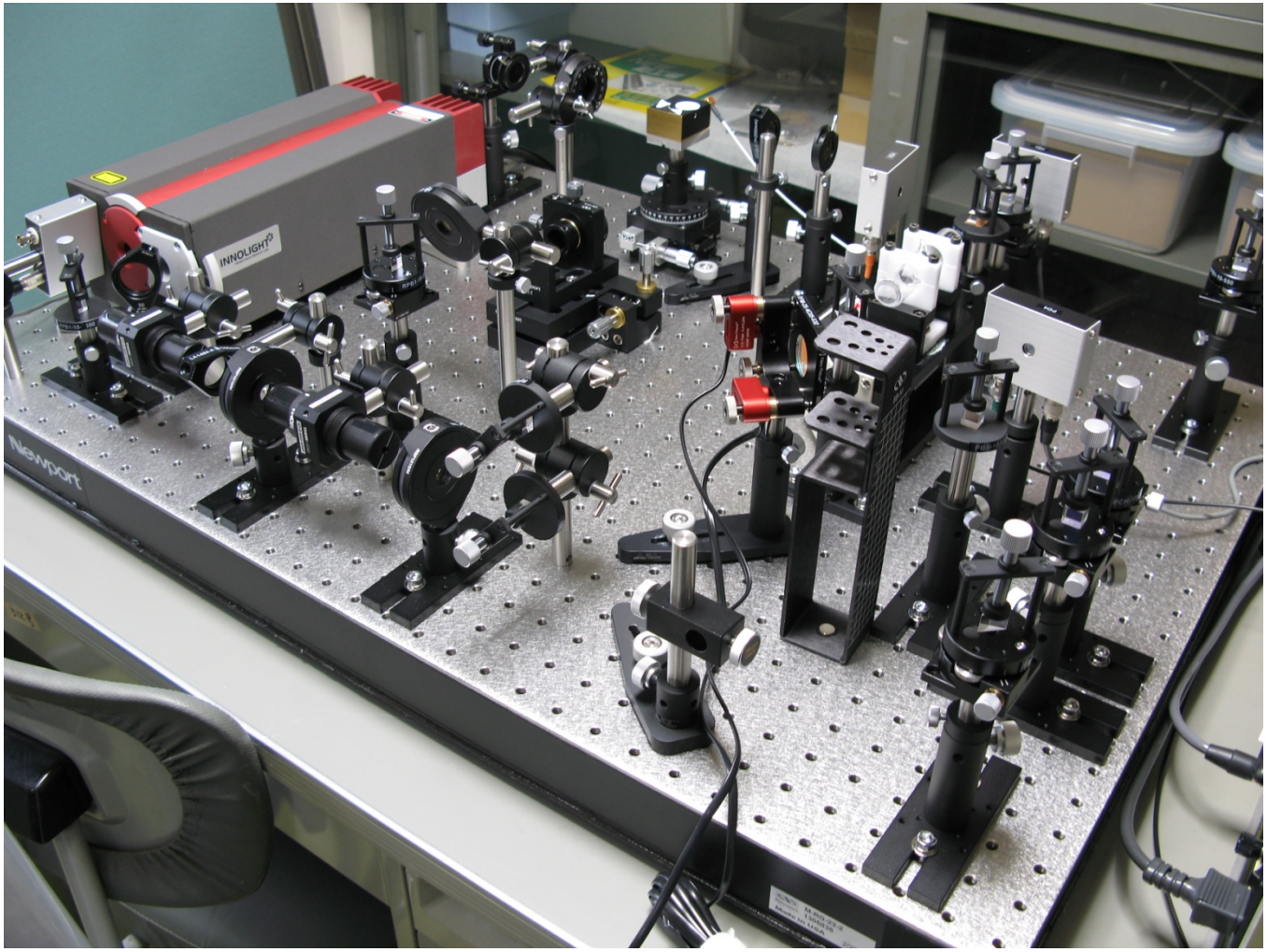
Fed back to YAG Temp.

Long-Term Stabilization

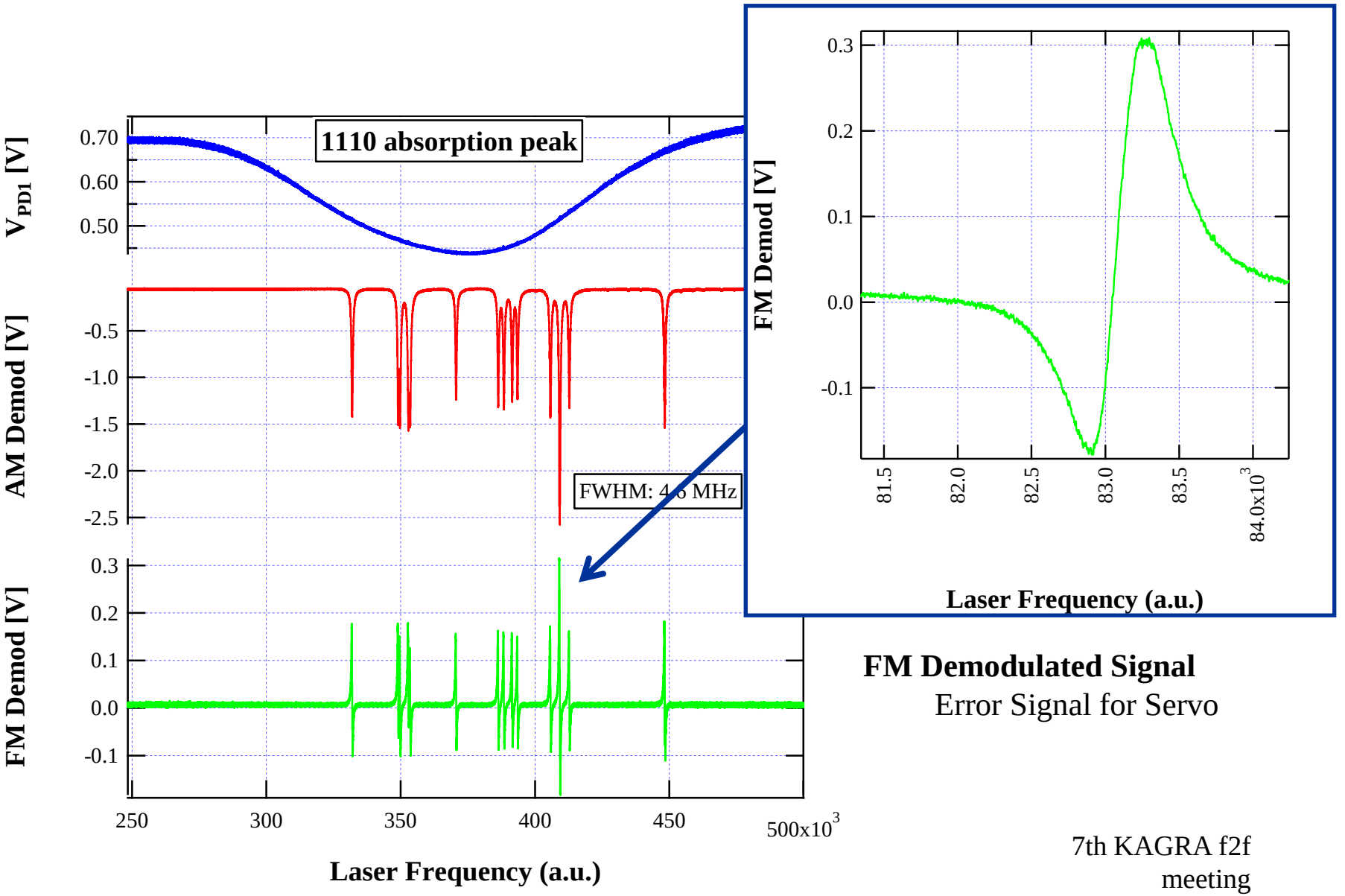
GIF Laser



GIF Laser

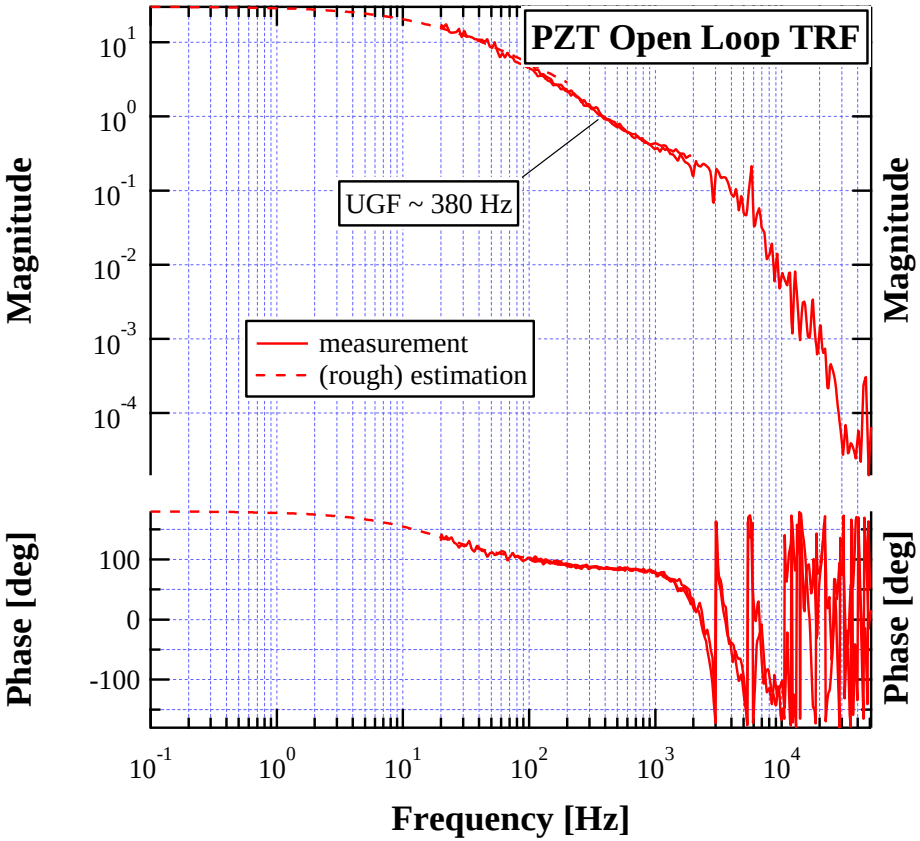


GIF Laser

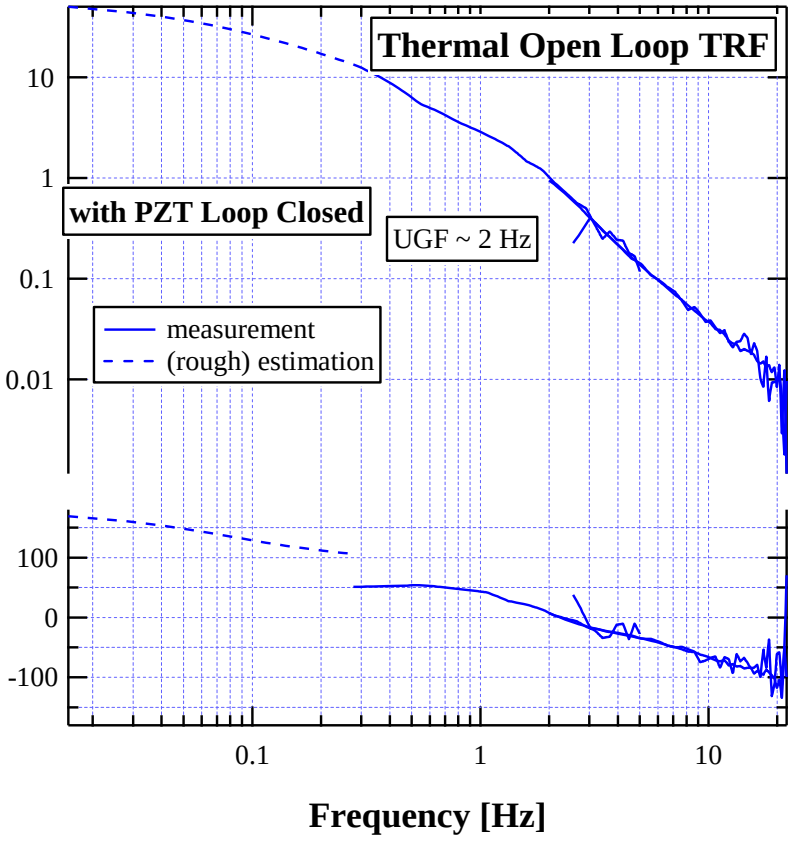


FM Demodulated Signal
Error Signal for Servo

GIF Laser
Wider feedback bandwidth attained (50Hz->380Hz)



PZT (Fast) Loop Trf.
UGF ~ 380 Hz



Thermal (Slow) Loop Trf.
UGF ~ 2 Hz, DC Gain ~ 50

GIF Laser

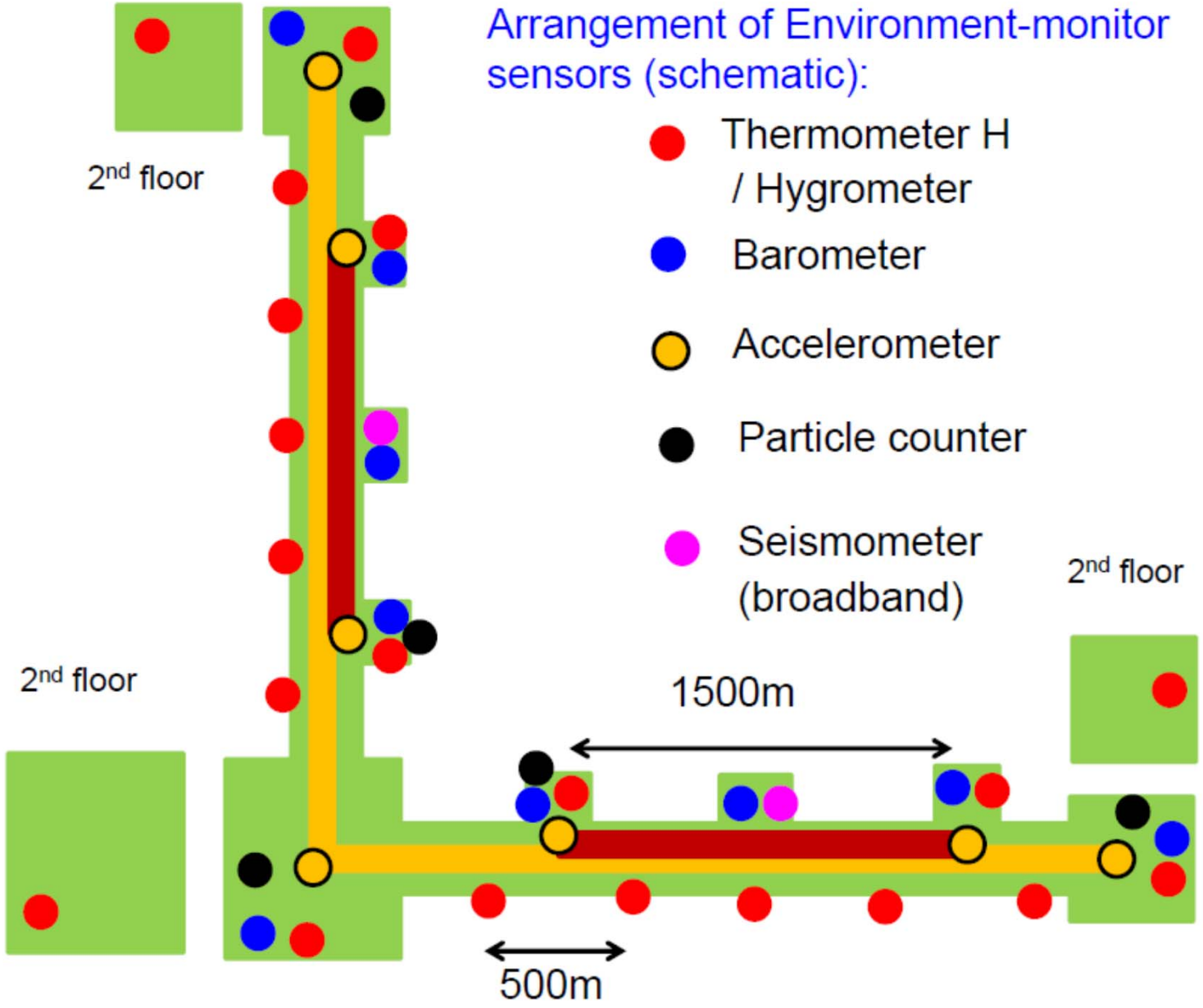
- Status & Plan
    - achieved long-term stable operation
  - Final Implementation Being Commissioned
    - revising and optimizing optics and electronics
  - Delivery of Second System (not yet scheduled)
    - as a backup
    - used for performance evaluation
      - beat measurement to estimate frequency stability

Environment monitor (EM)

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.


Arrangement of Environment-monitor sensors (schematic):
Thermometer H / Hygrometer
Barometer
Accelerometer
Particle counter
Seismometer (broadband)
2nd floor
2nd floor
2nd floor
1500m
500m

● already tested ● to be tested

									1st floor				
Group	Sensor	Rank	Dimension	Symbol	Range	Resolution	Response	Vendor	Room	Floor	Table	TR.y	ETM.:
COMMO	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
	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 Avi. Ele.			1		
	Accel.	rel.	15x15x15	Acc_R_1	50m/s^2	1.e-2m/s^2	1-5kHz	Kistler				3	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 Avi. 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					
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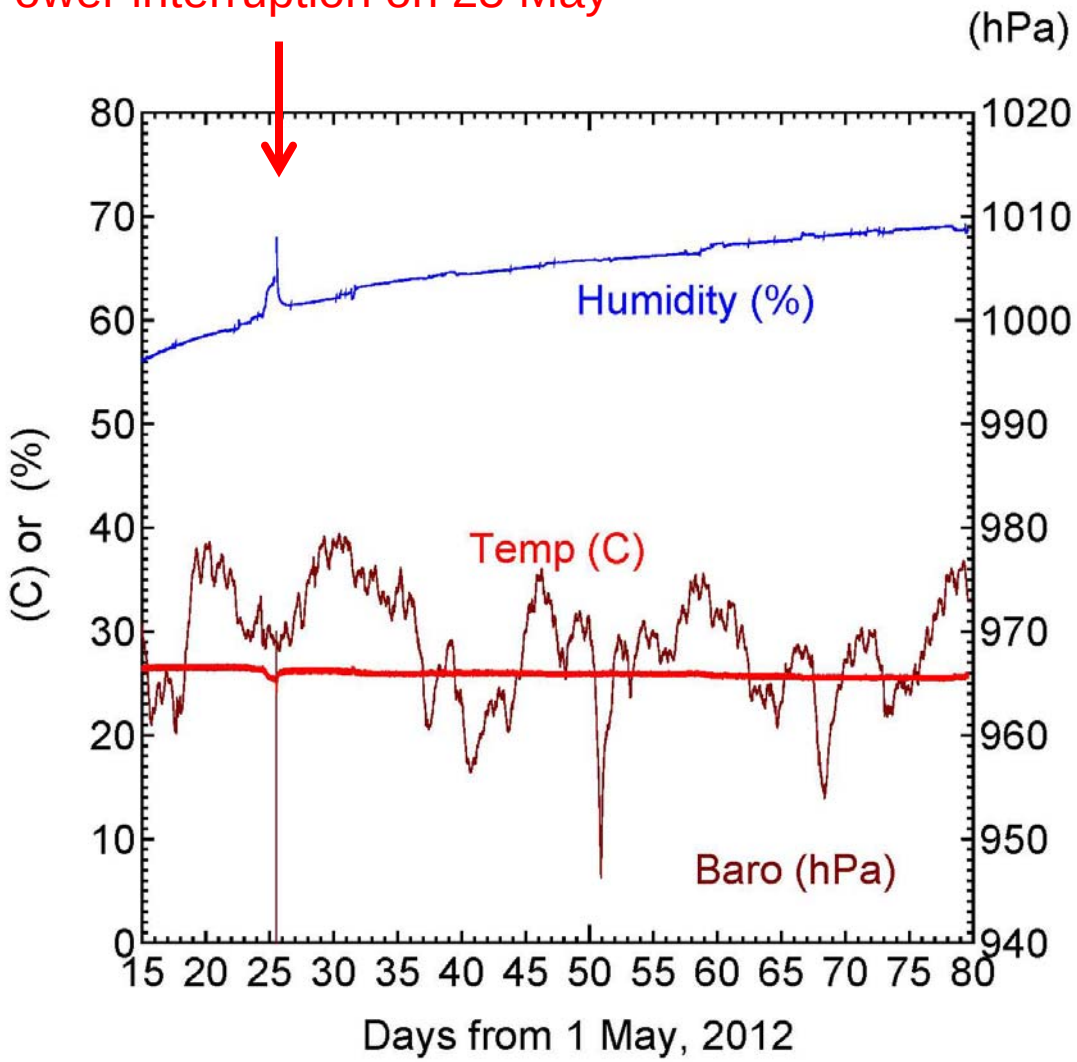
	Mag.	rel.	25x25x200	Mag_R_1	70-1000uT	6pT/rHz	DC-3kHz	Bartington					
	Mag.	rel.	100x100x100	Mag_R_1	50uT	0.1nT	DC-5Hz	Shimadzu					
	Particle	abs.	150x100x100	Par_A_1	0.2-5um	0.2um	NA	MetOne					
	Particle	abs.	150x300x300	Par_A_2	0.3-5um		10s-2h	RION					

Temperature, humidity, and barometric pressure at CLIO

Power interruption on 25 May



Milestones (Geophysics interferometer)

		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	

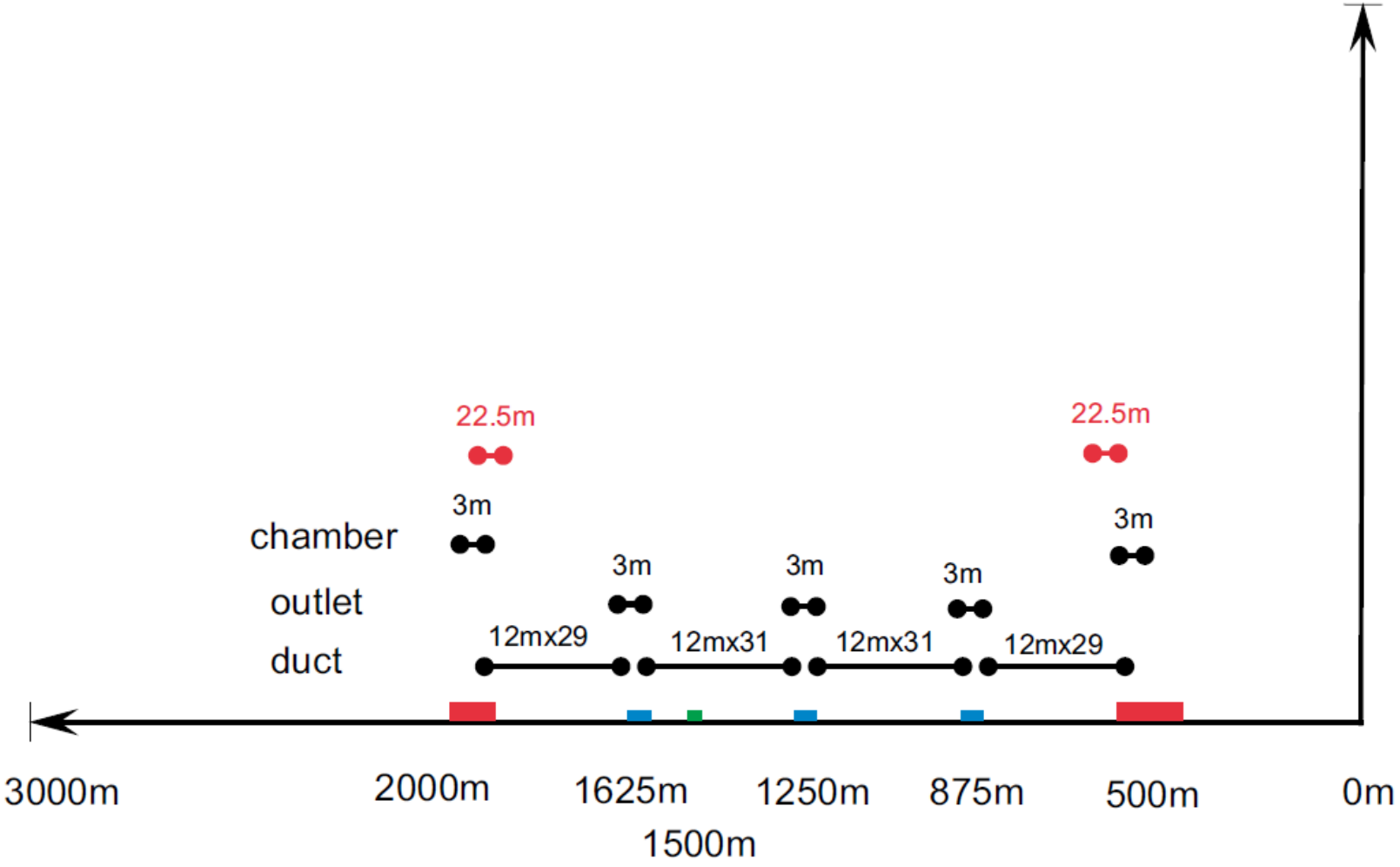
Items to be purchased in FY2013

Optics mounts and breadboards

Vacuum pipes, valves, gauges, pumps

Environment sensors

Arrangement of vacuum pipes …. 22.5m x 2 are lacking for 1500m x 2 baseline



● already tested ● to be tested

									1st floor				
Group	Sensor	Rank	Dimension	Symbol	Range	Resolution	Response	Vendor	Room	Floor	Table	TR.y	ETM.:
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	+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
	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 Avi. Ele.			1		
	Accel.	rel.	15x15x15	Acc_R_1	50m/s^2	1.e-2m/s^2	1-5kHz	Kistler				3	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					
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	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 Avi. 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					
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	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					