KAGRA, Large-scale Cryogenic Gravitational-wave Telescope of Japan

Name of member: NIPPON STEEL Stainless Steel Corporation

Owner: Inter-University Research Institute Corporation High Energy Accelerator Research Organization/KEK; and Institute for Cosmic Ray Research, The University of Tokyo/ICRR

Field: scientific observation facility

Location: Kamioka Town Hida City Gifu Pref. Japan

Environment: indoor; ultra high vacuum cryogenic

Grade and surface:

1. Hot forged stainless steel round shape for "Recoil Mass"
Recoil Mass is attached to the controlling device to hold the sapphire mirrors, which are one of the most important parts of the laser interferometer to detect a space-time distortion. Grade: NSSC 130S (18Cr-6Ni-11Mn-0.3N, similar to ASTM A666 XM-11)
Weight: 200kg x 4 pieces
2. Cold rolled stainless steel sheet for welded pipes
Grade: SUS304, No. 2B finish, 4.5mm thickness
Weight: Approx. 130 tons
3. Stainless steel plate for welded pipes

1) Welded stainless steel pipes for ultra-high vacuum duct
Grade: SUS304L, #150 electro-polishing for inner surface
Weight: Approx. 600 tons
Grade: SUS304, #150 electro-polishing for inner surface
Weight: Approx. 20 tons
2) Welded stainless steel pipes for the Cryostat (a vessel whose inside is cryogenic and highly evacuated)
Grade: SUS304, #150 electro-polishing for inner surface
Weight: Approx. 60tons
Total amount of stainless steel from NIPPON STEEL Stainless Steel Corporation Approx. 800 tons.
Advantage point of using stainless steel:
←NSSC130S for "Recoil Mass"→
Stable and low magnetic permeability (even after machining) in a cryogenic condition (-253°C)
Excellent manufacturability of round shape (340 mm ø x 270 mm L).
←SUS304L and SUS304 for the duct and "Cryostat"→
Excellent polishability by reducing inclusions, and rigorous surface inspection

"KAGRA" is the large-scale cryogenic gravitational-wave telescope in Japan, which will start up its observation in 2019 as the third gravitational-wave detector in the world, following LIGO in the United States and Virgo in Italy.
Approximately 800 tons of NSSC's high-performance austenitic stainless steel is applied to the laser interferometer which is the vital part of KAGRA

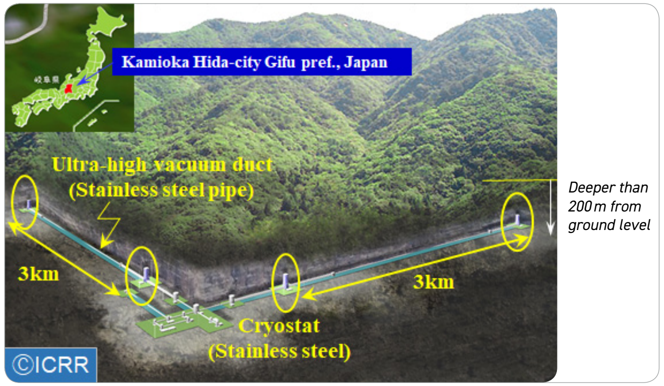

Photo 1: Schematic underground viewof KAGRA facility

to detect extremely small space-time distortion occurred by gravitational waves.
The laser interferometer is to measure the difference of length of two split laser beams passing the same distance after generated from one source.
The two 3,000 meters-long ducts where the two laser beams pass through orthogonally are welded pipes made of SUS304L. It is an ultra-high vacuum condition inside and the air pressure is just

Photo 2: Ultra-high vacuum stainless steel duct of 3,000 m in length, as the laser path in the interferometer

1/100,000,000,000 of the atmosphere.
The distortion occurred by gravitational waves can be measured as the difference of the total distance of the two laser beams. The beams are reciprocated for 500 times between the sapphire mirrors installed in cryogenic ultra-high vacuum vessels called "Cryostat" which are located at each end of two ultra-high vacuum ducts. The laser beams run 3,000 kilometers respectively and the difference of the total distance of them is just 10^{-19} m, or 0.0000000000000000001 meters.
NSSC130S* is used for "Recoil Mass" which holds sapphire mirrors and is attached to the control device in the extremely cold condition, -253°C.
Several measures have been implemented to eliminate all possible noise which might disturb the detection, because the distortion caused by gravitational waves is just 10^{-19} m when it reaches the earth. KAGRA was installed at least 200 m below the ground surface to avoid the influence of noise from the ground. Moreover, it has adopted cutting-edge technology to cool down the sapphire mirrors to cryogenic temperatures (-253°C) to reduce thermal noise at the molecular level.
NSSC's stainless steel used in this project has met the tough requirements to support these advanced technologies, including non-magnetic stability in cryogenic temperature.
After the test observation, it is expected that all installation work will be finished soon and KAGRA will start the first scientific observation in late 2019.
It has been proved that stainless steel can contribute to the development of the Gravitational-wave astronomy, which was just started to be studied.
*NSSC130S (YUS130S) was also applied to the collars for dipole magnets of Large Hadron Collider (LHC) of the European Organization for Nuclear Research (CERN), which helped to discover Higgs boson. The discoverers, Prof. François Englert and Prof. Peter W. Higgs, were awarded Nobel Prize in physics in 2013.

Photo 3: Cryostat (as a container for high purity crystal sapphire mirror, and so on

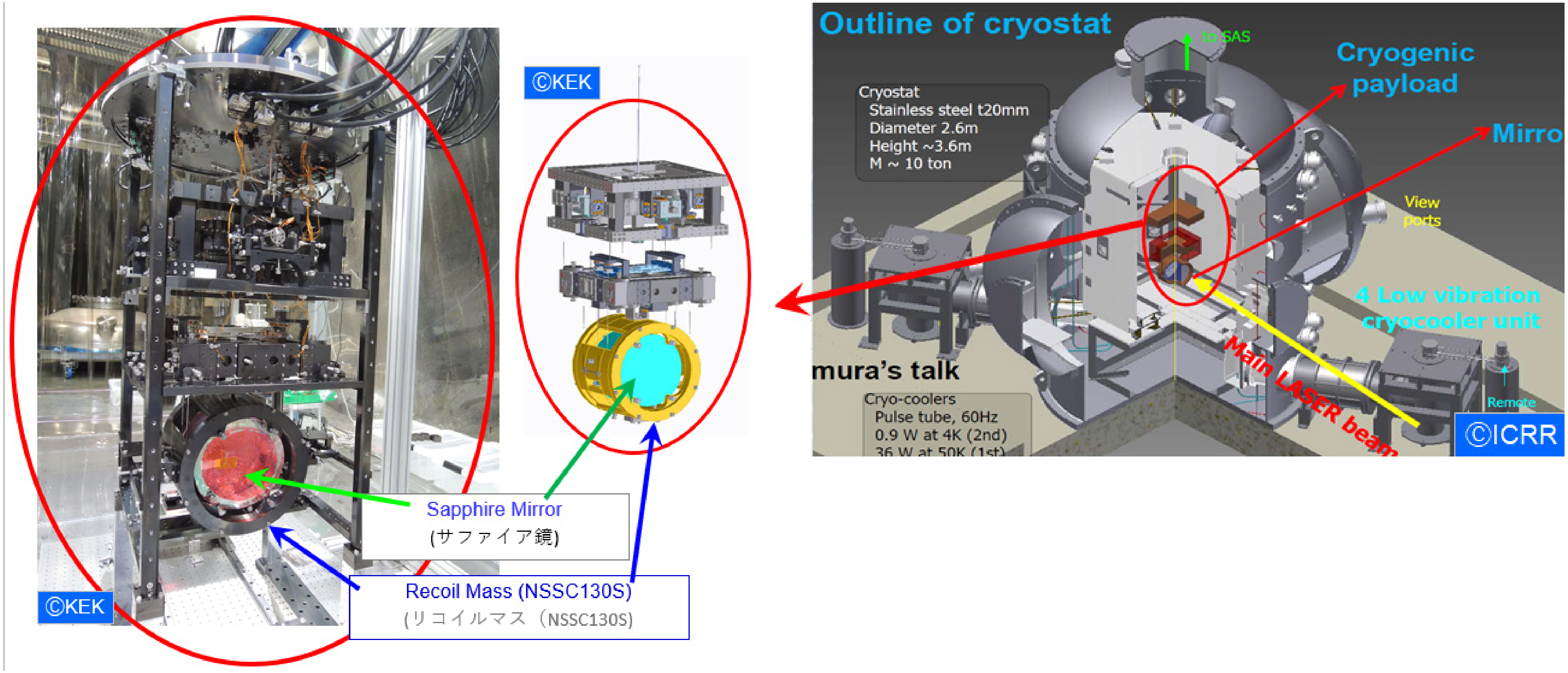

Figure1: Schematic illustration of Cryostat, Sapphire mirror, and its recoil mass made of NSSC®130S.